NEW ADVANCED SECONDARY SCHOOL CURRICULLUM

SCENARIO BASED ITEMS

FOR PHYSICS, CHEMISTRY & MATHEMATICS

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By

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PHYSICS SCENARIO BASED ITEMS

Topic 1: MEASUREMENT AND DIMENSIONS OF PHYSICAL QUANTITIES

Sub-topic 1.1: Dimensional Analysis

Scenario 1

During a university engineering competition,a student proposed a new equation for calculating the power output of a small hydroelectric turbine they had designed. The equation combined variables like water density, flow rate, gravitational acceleration, and turbine radius. Before building a prototype, the team's physics advisor suggested they check the dimensional consistency of the proposed equation to avoid fundamental flaws in their design logic. This step would save them considerable time and resources by ensuring the mathematical relationship between the physical quantities made sense before moving to the experimental phase.

Task:

As a learner of physics;

(a)State the fundamental reason why checking dimensional consistency is a crucial step in formulating physical equations.

(b)The proposed equation for power is $P = k\rho Av^3$, where ρ is density, A is area, and v is velocity. Determine the dimensions of the constant k.

(c)Explain what the result of your dimensional analysis implies about the physical validity of the student's equation.

Scenario 2

A research and development team in a renewable energy company is modeling the energy, E , captured by a new wind turbine design. They suspect it depends on the air density (ρ), the swept area of the blades (A), and the wind velocity (v). They propose a relationship of the form $E = k\rho^a A^b V^c$, where k is a dimensionless constant. Before running costly computational fluid dynamics simulations, they use dimensional analysis to find the values of the exponents a, b, and c to ensure their model is physically plausible.

Task:

As a learner of physics;

(a)Write down the dimensional formula for energy.

(b)By applying the principle of dimensional homogeneity, derive the values of the exponents a , b , and c in the proposed equation.

(c)The final derived equation for the power of a wind turbine is $P = \frac{1}{2} C_b \rho A v^3$. Relate this to your findings and state what the dimensionless constant C_b represents.

Scenario 3

In a physics laboratory,a student derives an expression for the period T of a simple pendulum. From their observations, they suggest that the period might be related to the mass of the bob (m), the length of the string (l), and the acceleration due to gravity (g) by the equation $T = 2\pi m^a l^b g^c$. Their teacher informs them that one of these variables does not actually affect the period and that dimensional analysis can help identify which one and verify the correct relationship.

Task:

As a learner of physics;

(a)Using dimensional analysis, show that the period T cannot depend on the mass m of the bob.

(b)Using the dimensions of l and g , determine the values of exponents b and c that make the equation $T = 2\pi m^a l^b g^c$ dimensionally consistent.

(c)Compare your derived relationship with the standard formula for the period of a simple pendulum.

Scenario 4

A pharmaceutical company is developing a new drug delivery system where the rate of flow, Q , of a liquid medicine through a thin capillary is thought to depend on the pressure difference (Δ P), the radius of the capillary (r), its length (l), and the viscosity of the liquid ($\acute{\eta}$). A new intern proposes a formula without considering dimensions. The lead scientist, recalling the Hagen-Poiseuille equation, uses dimensional analysis to quickly check the intern's proposal for basic validity before proceeding with complex experiments.

Task:

As a learner of physics;

(a)List the fundamental dimensions for the viscosity of a liquid ($\acute{\eta}$).

(b)Assume the relationship is $Q = k (\Delta P)^a r^b l^c \acute{\eta}^d$. Use dimensional analysis to find the values of the exponents a , b, c, and d.

Scenario 5

While studying for his advanced level exams, a student encounters a complex formula in his textbook for the force, F , exerted by a flowing fluid on a spherical object. The formula involves the fluid's density (ρ), its velocity (v), the sphere's radius (r), and the fluid's viscosity ($\acute{\eta}$). To remember the formula better, he decides to use dimensional analysis to see if he can derive a possible combination of these variables that would result in the dimensions of force, thus understanding the relationship more deeply.

Task:

As a learner of physics;

(a)Write down the dimensional formula for force.

(b)Using the method of dimensional analysis, determine if the force F could be proportional to ρ , v , and r alone, i.e., $F \propto \rho^a v^b r^c$. Find a , b , and c .

(c)The actual force (Stokes' law) is $F = 6\pi \acute{\eta} rv$. Explain why your analysis in (b) could not yield this exact formula and what this reveals about the limitations of dimensional analysis.

Topic 2: STATICS

Sub-topic 2.1: Resultant Force

Scenario 6

A community in eastern Uganda is building a footbridge across a small river using locally sourced materials.The bridge design involves multiple ropes and wooden planks, creating a complex system of forces. During construction, the engineers need to ensure the resultant force on the central support remains within safe limits. They've measured tensions of 300N at 30° and 400N at 120° from the horizontal acting on the same point. The village engineer must calculate whether these forces will compromise the bridge's stability during use.

Task:

As a learner of physics;

(a)Sketch a vector diagram representing the two forces acting on the central support.

(b)Calculate the magnitude of the resultant force using the component method.

(c)Determine the direction of the resultant force relative to the horizontal.

(d)Suggest one modification to the bridge design that could help reduce the resultant force on the central support.

Scenario 7

During a physics practical session,students are investigating vector addition using three spring balances attached to a single ring. The balances show readings of 4N, 5N, and 6N respectively, with angles of 0°,

120°, and 240° from the positive x-axis. The students need to verify if the system is in equilibrium and understand why the ring remains stationary despite the multiple forces acting on it.

Task:

As a learner of physics;

(a)Resolve each force into its x and y components.

(b)Calculate the net force in both x and y directions.

(c)Explain why the ring remains stationary based on your calculations.

(d)Propose what would happen if one of the spring balances was removed suddenly.

Scenario 8

A team of agricultural extension workers is installing a new irrigation system that requires pulling a heavy water tank across a field.Three workers pull with forces of 200N east, 150N northeast, and 100N north. The team leader needs to determine the most efficient pulling direction and whether the combined effort will be sufficient to move the 400kg tank, considering the frictional force is 350N.

Task:

As a learner of physics;

(a)Represent all forces graphically using an appropriate scale.

(b)Calculate the resultant force using both graphical and analytical methods.

(c)Determine if the workers can move the tank and justify your answer.

(d)Suggest the optimal pulling direction that would require minimum force to move the tank.

Scenario 9

In a mechanics workshop,technicians are designing a new lifting mechanism that uses multiple cables to hoist heavy engine blocks. The system must lift loads of up to 1000N safely, with three cables making angles of 0°, 45°, and 90° to the vertical. The maximum tension each cable can withstand is 500N. The workshop supervisor needs to verify if this configuration can safely lift the maximum load.

Task:

As a learner of physics;

(a)Draw a free-body diagram showing all forces acting on the engine block.

(b)Calculate the tension in each cable when lifting the maximum load.

(c)Assess whether any cable is likely to break under this loading condition.

(d)Recommend an improved angular configuration that would distribute the load more evenly.

Scenario 10

A group of students is designing a model suspension bridge for a science competition.The main cable must support multiple vertical loads representing vehicles. The loads are 50N, 75N, and 100N at intervals of 20cm along the cable. The students need to calculate the resultant force and determine the required cable strength to ensure the bridge model doesn't collapse during judging.

Task:

As a learner of physics;

(a)Calculate the total vertical force acting on the main cable.

(b)Determine the horizontal tension in the cable if the end supports are 10m high and 20m apart.

(c)Calculate the maximum tension in the cable.

(d)Propose one design feature that could help reduce the maximum cable tension.

Sub-topic 2.2: Moments and Couples

Scenario 11

A local furniture workshop is designing a new type of seesaw for a community playground.The design must accommodate children of different weights sitting at various positions. The 4m long plank has a pivot at its center, and children of mass 25kg and 35kg want to play together. The workshop needs to

determine the exact positions where each child should sit to maintain balance, considering the plank itself has a mass of 15kg.

Task:

As a learner of physics;

(a)Define the term 'moment of a force' as applied to this situation.

(b)Calculate where the 35kg child should sit if the 25kg child is 1.5m from the pivot.

(c)Explain how the mass of the plank affects the balance condition.

(d)Suggest one safety consideration in the seesaw design.

Scenario 12

A mechanic in a rural automotive workshop needs to loosen a tight bolt using a 50cm long spanner.The bolt requires a turning force of 100Nm to loosen, but the mechanic can only apply a maximum force of 300N with one hand. The workshop manager suggests using a pipe extension to increase the spanner's length, but they need to calculate the exact length required and consider any potential risks of this modification.

Task:

As a learner of physics;

(a)Calculate the minimum spanner length needed to loosen the bolt.

(b)Explain why applying force perpendicular to the spanner gives maximum moment.

(c)Describe what is meant by a 'couple' and give an example from automotive practice.

(d)Identify one potential risk of using an over-length spanner.

Scenario 13

A construction company is installing a new signboard weighing 200N outside their office.The 2m wide sign will be supported by two brackets 1.5m apart. The engineers need to calculate the forces on each bracket and ensure the wall mounting can withstand these forces. They're particularly concerned about the turning effect on the wall fittings during windy conditions.

Task:

As a learner of physics;

(a)Calculate the force on each bracket when there's no wind.

(b)Determine the additional moment created by a 50N wind force acting at the sign's center.

(c)Suggest how the bracket positions could be optimized to reduce the moment on the wall.

(d)Explain why understanding moments is crucial in this engineering application.

Scenario 14

In a physics laboratory experiment,students are investigating the principle of moments using a uniform meter rule, several 100g masses, and a knife-edge pivot. They need to verify the rule's mass by finding balancing positions with known masses. The students notice that the rule doesn't balance exactly at the 50cm mark when no masses are added, suggesting the pivot point might not be at the center of mass.

Task:

As a learner of physics;

(a)Describe a procedure to determine the mass of the meter rule using the principle of moments.

(b)Calculate the mass of the rule if it balances at the 48cm mark when a 50g mass is placed at the 10cm mark.

(c)Explain why the concept of 'center of mass' is important in this experiment.

(d)Discuss one source of error in this experiment and how to minimize it.

Scenario 15

A team of engineers is designing a new type of bottle opener that uses the principle of moments for maximum mechanical advantage.The design must be easy for elderly people to use while requiring minimal force. The opener has a 15cm handle and applies force 2cm from the pivot point. The team needs

to calculate the mechanical advantage and determine if the design meets their requirement of requiring less than 30N force to remove a bottle cap that needs 150N to open.

Task:

As a learner of physics;

(a)Calculate the mechanical advantage of the bottle opener design.

(b)Determine the actual force required to open the bottle.

(c)Explain how the concept of moments makes this tool effective.

(d)Propose one design improvement that could further reduce the required force.

Topic 3: LINEAR MOTION

Sub-topic 3.1: Equations of Linear Motion

Scenario 16

A public transportation company is analyzing the safety of its boda-boda(motorcycle taxi) operations on a busy urban route. One of their riders was observed accelerating uniformly from rest at a traffic light to reach a speed of 36 kmh^{-1} over a distance of 50 meters. The company's safety officer needs to analyze this motion to determine if the rider was within the recommended acceleration limits for urban areas and to calculate the time taken to cover this distance, as part of a broader review of driver training protocols and operational safety standards.

Task:

As a learner of physics;

(a)Convert the final speed from kmh^{-1} to ms^{-1}.

(b)Calculate the acceleration of the boda-boda.

(c)Determine the time taken to cover the 50-meter distance.

(d)Analyze whether this acceleration rate is reasonable for safe urban transportation.

Scenario 17

During the construction of a new market complex in Lira Municipality,a crane operator needs to lift construction materials to the top of the building. A concrete block accidentally falls from the crane platform 80 meters above the ground. The site safety officer must calculate how long it takes for the block to reach the ground and its velocity upon impact to assess potential danger zones and improve safety protocols for future operations.

Task:

As a learner of physics;

(a)Identify which equation of motion applies to this situation.

(b)Calculate the time taken for the concrete block to hit the ground.

(c)Determine the velocity of the block just before impact.

(d)Recommend two safety measures to prevent such accidents on construction sites.

Scenario 18

A long-distance bus company operating the Kampala-Gulu route is testing a new braking system for its fleet.During a test run, a bus traveling at 90 kmh^{-1} applies emergency brakes and comes to a complete stop over a distance of 100 meters. The engineers need to analyze the braking performance to ensure it meets national transportation safety standards and to provide data for driver training programs.

Task:

As a learner of physics;

(a)Calculate the deceleration of the bus during braking.

(b)Determine the time taken for the bus to come to a complete stop.

(c)Compare the calculated deceleration with the minimum safety standard of 4 ms^{-2}.

(d)Explain how road conditions might affect the actual braking distance.

Scenario 19

A student athlete training for the Uganda Secondary Schools Sports Association championships is practicing sprint starts.From a stationary position, she achieves a speed of 8 ms^{-1} in 3 seconds. Her coach wants to analyze her performance to identify areas for improvement and compare her acceleration with national-level sprinters.

Task:

As a learner of physics;

(a)Calculate the athlete's acceleration during the first 3 seconds.

(b)Determine the distance covered during this acceleration phase.

(c)Plot a velocity-time graph for the first 5 seconds of her motion.

(d)Suggest two training methods that could improve her initial acceleration.

Scenario 20

A truck carrying agricultural produce from Mbale to Kampala maintains a constant acceleration of 2 ms^{-2} for 15 seconds after leaving a toll station.The transport company needs to calculate the final velocity and distance covered during this acceleration phase to optimize fuel consumption and schedule accurate delivery times.

Task:

As a learner of physics;

(a)Calculate the final velocity after 15 seconds of acceleration.

(b)Determine the distance covered during the acceleration period.

(c)If the truck then maintains this final velocity for 30 seconds, calculate the total distance traveled.

(d)Explain why understanding acceleration is important for fuel efficiency in transportation.

Sub-topic 3.2: Relative Motion

Scenario 21

A ferry boat operating on Lake Victoria needs to cross directly from Entebbe to Lukaya,a distance of 8 km. The ferry can maintain a speed of 15 kmh^{-1} in still water, but today there's a current flowing at 5 kmh^{-1} perpendicular to its intended path. The captain needs to determine the correct heading and the actual time it will take to complete the crossing to maintain the ferry schedule.

Task:

As a learner of physics;

(a)Calculate the direction the captain should steer the ferry.

(b)Determine the resultant speed of the ferry relative to the shore.

(c)Calculate the actual time required to cross the lake.

(d)Explain how the current affects the ferry's actual path.

Scenario 22

Two buses depart from the same Kampala taxi park at the same time.One travels to Jinja at 80 kmh^{-1} while the other heads to Masaka at 70 kmh^{-1} on roads that diverge at an angle of 120°. A transportation company analyst needs to calculate how fast the distance between them is increasing after 30 minutes to optimize dispatch operations.

Task:

As a learner of physics;

(a)Calculate the distance each bus travels in 30 minutes.

(b)Determine the relative velocity between the two buses.

(c)Calculate the rate at which the distance between them is increasing.
(d)Suggest how this analysis could help in emergency response planning.

Scenario 23

An airplane flying from Entebbe International Airport to Kidepo National Park must maintain a ground speed of 500 kmh^{-1} on a bearing of 045°.If there's a wind blowing from the north at 60 kmh^{-1}, the pilot needs to calculate the required airspeed and heading to reach the destination on time and with minimum fuel consumption.

Task:

As a learner of physics;
(a)Determine the required airspeed of the airplane.
(b)Calculate the heading the pilot should maintain.
(c)Explain why the actual path differs from the intended bearing.
(d)Discuss how wind affects flight duration and fuel requirements.

Scenario 24

During a military training exercise in Karamoja,two armored vehicles are moving toward each other on a straight road. Vehicle A approaches from the east at 60 kmh^{-1} while Vehicle B approaches from the west at 80 kmh^{-1}. When they are 10 km apart, both drivers spot each other and need to calculate their relative approach speed for emergency maneuvering decisions.

Task:

As a learner of physics;
(a)Calculate their relative speed of approach.
(b)Determine the time until they meet if they continue at their current speeds.
(c)If Vehicle A decelerates at 2 ms^{-2}, calculate the new meeting time.
(d)Explain the importance of understanding relative motion in military operations.

Scenario 25

A student waiting to cross a busy street in Kampala observes two cars approaching.Car A is 200 meters away moving at 50 kmh^{-1}, while Car B is 150 meters away moving at 60 kmh^{-1} in the same direction. The student needs to determine if it's safe to cross between them and calculate the time available for crossing.

Task:

As a learner of physics;
(a)Calculate the relative speed between the two cars.
(b)Determine the time gap between the cars passing the crossing point.
(c)Assess if a 10-second crossing time is safe.
(d)Recommend a safe procedure for crossing busy roads.

Sub-topic 3.3: Momentum

Scenario 26

A traffic police investigation team is analyzing a road accident on the Kampala-Masaka highway where a car of mass 1200 kg moving at 80 kmh^{-1} collided with a stationary truck of mass 5000 kg.After the collision, the two vehicles moved together. The investigators need to calculate their common velocity after impact to determine if speed was a major factor in the accident severity.

Task:

As a learner of physics;
(a)Calculate the initial momentum of the car before collision.
(b)Determine the common velocity of the vehicles after collision.
(c)Calculate the kinetic energy lost during the collision.

(d)Explain how this analysis helps in accident reconstruction.

Scenario 27

At a construction site in Hoima,a pile driver of mass 800 kg falls freely from a height of 5 meters onto a concrete pile of mass 200 kg. The site engineer needs to calculate the velocity just before impact and the momentum transferred to the pile to ensure the equipment operates within design specifications.

Task:

As a learner of physics;

(a)Calculate the velocity of the pile driver before impact.

(b)Determine the momentum transferred to the pile.

(c)If the pile penetrates 0.2 m into the ground, calculate the average force of resistance.

(d)Explain why momentum conservation is important in pile driving operations.

Scenario 28

During a physics demonstration at a science fair,students set up two identical trolleys on a track. One trolley moving at 2 m/s collides elastically with a stationary trolley. The students need to predict and verify the final velocities of both trolleys to demonstrate momentum conservation principles to the audience.

Task:

As a learner of physics;

(a)State the principle of conservation of momentum.

(b)Calculate the final velocities of both trolleys after collision.

(c)Verify that kinetic energy is conserved in this collision.

(d)Design a simple experiment to demonstrate inelastic collision.

Scenario 29

A rocket launched from a testing facility in Nakasongala has a mass of 5000 kg and ejects gases at a rate of 100 kg/s with a velocity of 500 ms^{-1} relative to the rocket.The engineers need to calculate the initial acceleration and how it changes as fuel is consumed to optimize the launch trajectory.

Task:

As a learner of physics;

(a)Calculate the thrust force produced by the rocket engine.

(b)Determine the initial acceleration of the rocket.

(c)Explain why the acceleration increases as fuel is consumed.

(d)Discuss the importance of momentum conservation in rocket propulsion.

Scenario 30

In a supermarket warehouse in Kampala,workers are loading goods using a conveyor system. Packages of mass 5 kg each are dropped onto the conveyor at a rate of 2 packages per second. The conveyor moves at 1 m/s, and the operations manager needs to calculate the additional force required to maintain this speed during loading.

Task:

As a learner of physics;

(a)Calculate the momentum transferred to the conveyor per second.

(b)Determine the additional force required to maintain constant speed.

(c)Explain how this relates to Newton's second law.

(d)Suggest how to minimize the force required during loading operations.

Sub-topic 3.4: Newton's Laws of Motion

Scenario 31

An elevator in a new office building in Kampala's central business district has a maximum load capacity of 1500 kg.When fully loaded, it accelerates upward at 2 ms^{-2}. The building engineers need to calculate the tension in the cable during acceleration to ensure it meets safety factors and to design appropriate maintenance schedules.

Task:

As a learner of physics;

(a)Draw a free-body diagram for the elevator.

(b)Calculate the tension in the cable during upward acceleration.

(c)Determine the apparent weight felt by passengers during this motion.

(d)Explain how Newton's first law applies when the elevator moves at constant velocity.

Scenario 32

A fisherman on Lake Albert pulls a fishing net with a force of 300 N at an angle of 30°to the horizontal. The net has a mass of 50 kg and experiences a water resistance of 100 N. The fisherman needs to calculate the acceleration of the net and whether he can lift it into the boat without assistance.

Task:

As a learner of physics;

(a)Resolve the pulling force into horizontal and vertical components.

(b)Calculate the net force acting on the fishing net.

(c)Determine the acceleration of the net.

(d)Apply Newton's third law to describe the force pairs involved.

Scenario 33

During the construction of a bridge across the Nile River, workers are sliding a 500 kg steel beam up a 30° incline with a coefficient of kinetic friction of 0.3. They apply a force parallel to the incline and need to calculate the minimum force required to keep the beam moving at constant velocity.

Task:

As a learner of physics;

(a)Calculate the component of gravity parallel to the incline.

(b)Determine the frictional force acting on the beam.

(c)Calculate the minimum force required for constant velocity motion.

(d)Explain how Newton's first law applies to this situation.

Scenario 34

A student performing a physics experiment connects two blocks of mass 3 kg and 5 kg with a light string on a frictionless surface.She applies a force of 16 N to the larger block and needs to calculate the acceleration of the system and the tension in the connecting string.

Task:

As a learner of physics;

(a)Calculate the acceleration of the system.

(b)Determine the tension in the string connecting the blocks.

(c)Draw free-body diagrams for both blocks.

(d)Verify that your solution satisfies Newton's third law.

Scenario 35

A car of mass 1200 kg towing a trailer of mass 800 kg accelerates at 1.5 m/s^2 on a level road.The driver needs to calculate the driving force required and the tension in the tow bar, considering a constant resistance force of 400 N acting on the entire system.

Task:
As a learner of physics;
(a)Calculate the total driving force required.
(b)Determine the tension in the tow bar.
(c)Explain how Newton's second law applies to this connected system.
(d)Discuss what happens to the tension if the trailer's brakes are applied.

Topic 4: MOTION UNDER GRAVITY
Sub Topic 4.1: Free Fall
Scenario 36
During a drought in Kiko Village,young David was tasked with assessing the water level in an old, uncovered well. To gauge its depth, he dropped a heavy stone from rest directly above the opening and started his stopwatch. He heard the distinct sound of the stone striking the water 2.8 seconds later. Intrigued by his physics lessons, David wanted to calculate the depth before using a measuring rope. He knew that the speed of sound was very fast and that for a first calculation, its travel time could be ignored, meaning the entire time was for the stone's fall. He used the standard acceleration due to gravity, g = 9.81 m/s^2, for his calculations, aiming to understand the motion of the object from the moment of release to the moment just before it hit the water.
Task:
a)Define the term free fall.
b)Calculate the depth of the well, ignoring the time for sound to travel.
c)Determine the velocity of the stone just before it hits the water.
d)In reality, the time for sound to travel upwards affects the measurement. Would ignoring this make the calculated depth an overestimate or an underestimate? Explain.
e)Sketch a velocity-time graph for the stone's motion from release until it hits the water.
Scenario 37
At Sagee Senior Secondary School,the compound has several tall coconut trees. During a windy day, a ripe coconut became dislodged and fell from the top of a tree. The school gardener, Mr. Omondi, witnessed the event and estimated that the coconut took approximately 2.5 seconds to hit the soft ground, leaving a slight impression. The school's physics club, led by a student named Annette, decided to use this real-life event to verify a physics principle. They assumed the coconut started from rest and fell freely under gravity, which they took as 9.81 m/s^2 for simplicity. They wanted to find the height of the tree and also understand how the coconut's speed changed at different points in its journey downwards.
Task:
a)State the initial velocity of the coconut.
b)Calculate the height of the coconut tree.
c)What was the velocity of the coconut 2 seconds after it started falling?
d)Calculate the distance the coconut fell during the final second of its motion (between t=1.5s and t=2.5s).
e)Explain why a feather falling from the same height would not be a good example of free fall.
Scenario 38
A Uganda Red Cross Society helicopter was on a mission to deliver emergency food supplies to a remote,flood-stricken village in Kiko sub-county. The pilot had to make an airdrop because there was no clear landing zone. Flying steadily and horizontally at a constant altitude of 125 meters, a paramedic pushed a sealed food package out of the side door. The package, designed to be aerodynamic and sturdy, was initially at rest relative to the helicopter. From the perspective of the people on the ground, the package followed a characteristic curved path as it descended. The pilot needed to release the package

before reaching the drop zone to ensure it landed accurately, requiring an understanding of its free-fall motion.

Task:

a)Calculate the time taken for the package to hit the ground.

b)What is the vertical component of the package's velocity just before impact?

c)If the helicopter was moving at a horizontal speed of 40 m/s, calculate the horizontal distance the package travels from the point of release.

d)Describe the energy transformation of the package during its fall.

e)State the path followed by the package as seen by an observer in the helicopter. Explain.

Scenario 39

As part of a physics practical at school,a group of students was investigating energy loss in a bouncing ball. They dropped a basketball from a height of 20.0 meters above the concrete floor of the courtyard and used a high-frame-rate camera to record its motion. The ball was released from rest, and the students were particularly interested in its motion before the first bounce. They observed the ball falling freely, accelerating until it made contact with the ground. The data from this first, purely free-fall phase was crucial for establishing a baseline to compare against the subsequent, lower bounces where energy was lost as sound and heat.

Task:

a)Calculate the time taken for the ball to hit the ground for the first time.

b)Find the velocity with which the ball hits the ground.

c)On its first bounce, the ball rebounds with an upward velocity of 15 ms^{-1}. Calculate the maximum height it reaches after this bounce.

d)How long does the ball take to reach this maximum height after the bounce?

e)Sketch a velocity-time graph for the ball's motion from the moment it is dropped until the moment it reaches the maximum height after the first bounce.

Scenario 40

The Advanced-Level Physics students at Kibinge High School were conducting a classic experiment to determine the acceleration due to gravity,g. They used an electromagnet to hold a small steel ball at the top of a tall, transparent vertical tube. The tube had markings to measure the falling distance. When the circuit to the electromagnet was broken, the ball was released and fell freely. A digital timer, connected to the circuit and a trapdoor at the bottom, automatically measured the time of fall for a known vertical distance, s. In one of their trials, the height was set at 1.50 meters and the timer recorded a fall time of 0.553 seconds.

Task:

a)State one precaution the students must take to ensure accurate results.

b)Using the data from the trial (s = 1.50 m, t = 0.553 s), calculate the experimental value of the acceleration due to gravity, g.

c) Calculate the percentage error in this experiment, given that the accepted value of g is 9.81 ms^{-2}.

d)Suggest one source of error that could account for the difference.

e)If this experiment were performed on the Moon, where the gravitational acceleration is 1.63 m/s^2, what would be the new time of fall for the same height?

Sub topic 4.2: Projectiles

Scenario 41

During the district athletics competition at Kibinge High School,an athlete named John prepared for his long jump. He sprinted down the track and launched himself from the edge of the take-off board with an initial velocity of 9.5 m/s at an angle of 22° above the horizontal. His center of mass was 1.0 meter above

the ground at the point of launch. The physics teacher, Mr. Mugisha, used this event to demonstrate the principles of projectile motion to his students. He explained that John's path through the air was a perfect example of a projectile, and his jump distance could be calculated by analyzing the horizontal and vertical components of his motion independently, ignoring air resistance.

Task:

As a learner of physics:

a)(i) Define a projectile.

(ii) Calculate the initial horizontal component of John's velocity.

b)Calculate the maximum height John's center of mass reaches above the ground.

c)Determine the total horizontal distance (the range) John jumps before landing in the sand pit.

d)What is the magnitude and direction of John's velocity just before he lands?

e)Explain one reason why the actual jump distance might be less than your calculated value.

Scenario 42

In a thrilling football match between Kiko Village and neighboring Mpenja,the score was tied 1-1. In the last minute, Kiko was awarded a free-kick just outside the penalty area, 20 meters from the goal. The star player, Musa, kicked the ball with an initial velocity of 18 m/s. To get the ball over the defensive wall, he launched it at an angle of 35° above the horizontal. The crossbar of the goal is 2.4 meters high. The fans watched anxiously as the ball followed a high, arcing path, its fate determined by the laws of physics.

Task:

As a learner of physics:

a)Calculate the time taken for the ball to reach the goal line horizontally.

b)Determine the height of the ball when it reaches the goal line.

c)State, with a reason, whether the ball will go into the goal (under the crossbar) or over it.

d)Calculate the maximum height reached by the ball during its flight.

e)What initial kick speed would be needed for the ball to just barely skim under the crossbar at the goal line, assuming the same launch angle?

Scenario 43

A fire broke out at the Kiko Village trading centre.The village fire brigade arrived and set up their water pump. To reach the roof of a burning building 15 meters away horizontally, the firefighter adjusted the nozzle to eject water at 20 m/s. The nozzle was held 1.5 meters above the ground. The firefighter needed to calculate the correct angle to hit the base of the fire on the roof, which was at a height of 6.0 meters. The water jet, acting as a projectile, needed to be precisely aimed to be effective.

Task:

a)Show that the two possible angles of projection, θ, to hit the target are given by the solution to the equation: $15\tan\Theta - g(15)^2 / 2(20)^2\cos^2\Theta = 4.5$

b)(i) Calculate the two possible angles that satisfy the condition.

(ii) Which angle would the firefighter choose and why?

c)For the smaller angle, calculate the time of flight of the water.

d)What is the velocity of the water (magnitude and direction) just as it hits the roof?

e)State one factor, other than air resistance, that could cause the water to miss its target.

Scenario 44

A technician was installing a satellite dish on the roof of a house in Kiko.He accidentally dropped his metal spanner. The spanner slid off the roof, which was 8.0 meters high, with a horizontal velocity of 3.0 m/s. Concerned about where it would land, the technician quickly tried to calculate its landing spot relative to the base of the house. A flower bed was located 2.5 meters from the wall, and he needed to know if the spanner would land in it. The motion of the spanner, from the moment it left the roof, was a classic case of horizontal projectile motion.

Task:

a)Calculate the time taken for the spanner to hit the ground.

b)Determine the horizontal distance from the base of the house where the spanner lands.

c)State, with a reason, whether the spanner will land in the flower bed (2.5m from the wall).

d)Calculate the magnitude of the spanner's velocity just before it hits the ground.

e)Sketch the path of the spanner as seen by an observer on the ground.

Scenario 45

The Uganda People's Defence Forces(UPDF) were conducting a training exercise near Lake Victoria. An artillery gun was placed on a cliff 80 meters above the lake's surface. The gun was fired horizontally, launching a shell with a muzzle velocity of 150 m/s towards a practice target floating on the water. The soldiers needed to predict the point of impact to assess their accuracy. The shell's trajectory was a projectile motion, with its horizontal motion at constant velocity and its vertical motion under constant acceleration due to gravity.

Task:

a)Calculate the time of flight for the shell before it hits the water.

b)Determine the horizontal range (the distance from the base of the cliff) where the shell lands.

c)Find the magnitude and direction of the shell's velocity just before it strikes the water.

d)What would be the effect on the time of flight if the shell was fired with a higher horizontal velocity? Explain.

e)If the gun was now aimed at 30° above the horizontal with the same initial speed, calculate the new maximum height reached by the shell above the lake level.

Topic 5: WORK, ENERGY AND POWER

Sub topic 5.1: Work

Scenario 46

A 14-seater minibus(Taxi) has stalled on a flat, level road in Nakawa trading centre. The conductor and three passengers attempt to push it to the side of the road. Together, they exert a combined, constant force of 800 N in the direction of the road. They successfully push the minibus a distance of 25 meters over a period of one minute. The local mechanic, who is also a physics enthusiast, uses this situation to explain the concept of work to his apprentice.

Task:

As a learner of physics:

a)Define the term work and state its SI unit.

b)Calculate the total work done by the conductor and passengers in pushing the minibus.

c)If one passenger pushed at an angle of 30° to the horizontal with a force of 200 N, calculate the work done by this specific passenger over the 25-meter distance.

d)Explain why a traffic officer who directs traffic but does not push the bus does no work on it.

e)If the same amount of work was used to lift the minibus vertically upwards, calculate the height it would be raised. (Mass of minibus = 1500 kg)

Scenario 47

During the construction of a new granary inBudaka Village, a worker lifts 50 concrete blocks, each of mass 10 kg, from the ground up to the building platform which is 3 meters high. He completes this task steadily over 30 minutes. Another worker drags a sack of sand weighing 60 kg along a rough horizontal surface for a distance of 10 meters using a rope that makes an angle of 60° to the horizontal with a force of 150 N.

Task:

As a learner of physics:

a)Calculate the total work done by the first worker in lifting all the concrete blocks.
b)Calculate the work done by the second worker in dragging the sack of sand.
c)State the angle between force and displacement for which the work done is maximum.
d)Explain why the work done by the second worker is less than if he had pulled the sack horizontally with the same force.
e)If the sack was pulled at constant speed, what can you deduce about the net work done on the sack? Explain.

Scenario 48

In Rubirizi District, a farmer uses a pair of oxen to plough his field. The oxen exert a steady force of 1200 N on the plough at an angle of 20° to the horizontal ground as they move forward. During one session, the farmer ploughs a furrow that is 100 meters long. The farmer's son, who is learning physics, calculates the work done to understand the energy requirements of their traditional farming method.

Task:

As a learner of physics:
a)Calculate the work done by the oxen in ploughing the 100-meter furrow.
b)What component of the oxen's force is actually doing the work to pull the plough forward? Calculate its magnitude.
c)If the oxen took 5 minutes to complete this furrow, what was their average power output?
d)Suggest one reason why the actual useful work done on the soil is less than the value calculated in (a).
e)If the plough is lifted to turn the soil, what type of work is being done against?

Scenario 49

The students ofKibuli Secondary School are helping to relocate their school library. A student carries a stack of 20 books, with a total mass of 15 kg, along a horizontal corridor for a distance of 30 meters to the new library room. She then lifts the entire stack onto a new bookshelf 1.5 meters high.

Task:

As a learner of physics:
a)Calculate the work done by the student while carrying the books along the horizontal corridor. Explain your answer.
b)Calculate the work done by the student in lifting the books onto the shelf.
c)If she took 10 seconds to lift the books, what was her power output during the lifting process?
d)Another student uses a trolley to move the same stack of books along the corridor. How does the work done by this student compare to the work done by the first student? Explain.
e)Define one joule of work.

Scenario 50

At a fruit processing plant inJinja, a conveyor belt is used to lift mangoes from the washing station to the packing station. The belt is inclined at 30° to the horizontal and is 10 meters long. The motor driving the belt exerts a force of 500 N to move 20 kg of mangoes up the belt at a constant speed to a vertical height of 5 meters.

Task:

As a learner of physics:
a)Calculate the work done by the motor in moving the mangoes up the entire length of the conveyor belt.
b)Calculate the useful work done in lifting the mangoes against gravity to the new height.
c)Why is the work done by the motor greater than the useful work calculated in (b)?
d)Calculate the efficiency of the conveyor belt system.
e)Name the force that does negative work on the mangoes as they are moved up the conveyor belt.

Sub topic 5.2: Energy

Scenario 51

During a science club trip to Jinja,a student from Nile High School performs a bungee jump from a platform 50 meters above the Nile. The student, with a mass of 60 kg, jumps from rest. Ignoring air resistance and considering the bungee cord only after a fall of 20 meters, the club members analyze the energy transformations. At the lowest point of the jump, the student comes momentarily to rest just 5 meters above the water surface.

Task:

As a learner of physics:

a)Calculate the gravitational potential energy of the student relative to the water surface before the jump.

b)What is the student's kinetic energy after falling 20 meters (just before the bungee cord begins to stretch)?

c)State the principle of conservation of energy.

d)Calculate the energy stored in the bungee cord when the student is at the lowest point.

e)Describe the energy transformations from the moment the student jumps until reaching the lowest point.

Scenario 52

The Mwizi River in western Uganda has been dammed to create a hydroelectric power plant. Water from the reservoir falls through a height of 80 meters to drive the turbines. The engineer explains that the water flowing at a rate of 500 kg per second possesses energy that gets converted to electrical energy at the power station.

Task:

As a learner of physics:

a)Define gravitational potential energy.

b)Calculate the potential energy lost by each kilogram of water as it falls to the turbines.

c)Calculate the total power available from the falling water if 500 kg flows per second.

d)If the power station produces 300 kW of electrical power, calculate its efficiency.

e)State two places where energy is lost in this hydroelectric system.

Scenario 53

A traffic police officer in Mbale is investigating a road accident where a motorcycle of mass 200 kg skidded on a level road. The skid marks measure 20 meters long. From witness accounts, the motorcycle was moving at 54 km/h before braking. The officer uses physics principles to determine if the rider was speeding. The coefficient of friction between the tires and road is 0.6.

Task:

As a learner of physics:

a)Convert 54 kmh^{-1} to meters per second.

b)Calculate the initial kinetic energy of the motorcycle.

c)Using the work-energy theorem, calculate the work done by friction in stopping the motorcycle.

d)Calculate the frictional force that acted on the motorcycle.

e)Using your calculations, verify whether the motorcycle could have stopped within 20 meters if it was moving at 54 kmh^{-1}.

Scenario 54

A student athlete at Kawempe High School is practicing for the pole vault competition. The vaulter, with mass 70 kg, approaches the jump with a speed of 8 ms^{-1}. Using the flexible pole, the athlete converts kinetic energy into potential energy to clear the bar set at 4.5 meters above the ground.

Task:

As a learner of physics:

a)Calculate the initial kinetic energy of the vaulter before the jump.

b)Calculate the maximum theoretical height the vaulter could reach if all kinetic energy converted to potential energy.
c)Explain why the actual height cleared is less than your answer in (b).
d)What is the vaulter's speed when crossing the bar if 20% of the initial kinetic energy remains as kinetic energy at the highest point?
e)State the energy transformation that occurs during the descent after clearing the bar.

Scenario 55

Students at St. Joseph's Technical College are building a solar-powered car for a national competition. The car of mass 300 kg accelerates from rest to 36 kmh^{-1} using energy stored in its batteries, which originally stored 60,000 J of energy. On a test run, the car reaches its maximum speed on a level track.

Task:

As a learner of physics:
a)Convert 36 kmh^{-1} to meters per second.
b)Calculate the final kinetic energy of the car at its maximum speed.
c)Calculate the efficiency of the energy conversion from battery storage to kinetic energy.
d)Where is the rest of the energy lost?
e)The car now approaches a hill. If all its kinetic energy converts to potential energy, calculate the maximum height it could climb up the hill.

Sub topic 5.3: Power

Scenario 56

In Nakaseke village, a new electric water pump has been installed to serve the community. The pump lifts water from a depth of 15 meters below ground level and discharges it at a rate of 10 liters per second into an overhead tank. The electrical motor driving the pump has an input power rating of 2.5 kW. The village council wants to understand the pump's performance and running costs. (Density of water = 1000 kgm^{-3})

Task:

As a learner of physics:
a)Define power and state its SI unit.
b)Calculate the useful power output of the pump (power used in lifting the water).
c)Calculate the efficiency of the pump system.
d)If the pump runs for 6 hours daily, calculate the electrical energy consumed in kilowatt-hours (kWh).
e)Suggest two reasons why the pump's output power is less than its input power.

Scenario 57

A group of students fromMount Elgon High School are hiking up Mount Rwenzori. One student with a mass of 60 kg climbs vertically through a height of 800 meters in 45 minutes. Another student of the same mass takes 60 minutes for the same climb. The physical education teacher uses this situation to explain the concept of power to the students.

Task:

As a learner of physics:
a)Calculate the work done against gravity by each student.
b)Calculate the power developed by each student during their climb.
c)Explain why the student who climbed faster developed more power.
d)If a third student carried a 10 kg backpack while climbing in 45 minutes, what power would they develop?
e)State two factors that affect the power developed by a person climbing a mountain.

Scenario 58

At a construction site inKampala, a crane is used to lift heavy concrete blocks to the top of a building. The crane lifts a block of mass 200 kg vertically through 30 meters in 15 seconds. The crane's engine consumes fuel that provides energy at a rate of 10 kW during this operation.

Task:

As a learner of physics:

a)Calculate the useful power output of the crane during the lifting operation.

b)Calculate the efficiency of the crane.

c)If the crane lifts two blocks simultaneously in the same time, what would be its new power output?

d)The crane now lifts the same block at constant speed to the same height but takes 20 seconds. How does this affect the:

(i) Work done by the crane?

(ii) Power developed by the crane?

e)Suggest two ways to improve the efficiency of the crane.

Scenario 59

Aboda boda (motorcycle taxi) operator in Gulu town wants to check the performance of his motorcycle. The 150 kg motorcycle (including rider) accelerates from rest to 72 km/h on a level road in 10 seconds against a constant resistive force of 300 N. The mechanic needs to determine if the engine is delivering adequate power.

Task:

As a learner of physics:

a)Convert 72 kmh^{-1} to meters per second.

b)Calculate the final kinetic energy of the motorcycle.

c)Using the work-energy theorem, calculate the net work done on the motorcycle.

d)Calculate the average power developed by the engine during acceleration.

e)Why is the power calculated in (d) greater than the power needed to maintain a constant speed of 72 kmh^{-1}?

Scenario 60

St. Mary's Collegein Kisubi uses a standby generator during power outages. The generator's engine is rated at 25 kW. On a particular evening, the generator supplies electricity to lights, computers, and fans with a total power consumption of 18 kW. The generator runs for 4 hours, consuming 20 liters of diesel with an energy content of 36 MJ per liter.

Task:

As a learner of physics:

a)Calculate the total electrical energy supplied by the generator in kWh.

b)Calculate the total energy input from the diesel fuel.

c)Calculate the overall efficiency of the generator system.

d)If the generator could be made to work at its full rated capacity with the same efficiency, how long would 20 liters of diesel last?

e)State two reasons why the generator's efficiency is less than 100%.

Topic 6: SOLID FRICTION
Sub topic 6.1: static friction
Scenario 61
A heavily loaded lorry is parked on a steep incline along the Fort Portal-Kyenjojo road.The driver returns to find the lorry has not moved, despite the significant slope. The lorry has a mass of 5000 kg, and the incline makes an angle of 15° with the horizontal. The driver needs to know if the parking brake alone is sufficient or if static friction is also playing a crucial role in preventing the lorry from sliding down the hill.
Task:
As a learner of physics:
a)Define static friction.
b)Calculate the component of the lorry's weight acting parallel to the incline.
c)If the lorry is stationary, what is the relationship between the static frictional force and the parallel component of the weight?
d)Calculate the minimum coefficient of static friction between the tyres and the road required to prevent the lorry from sliding.
e)If rain reduces the coefficient of friction, explain what is likely to happen to the lorry.
Scenario 62
In the library of Kiira College Butiki, a librarian is trying to move a heavy metal cabinet weighing 200 kg across a level concrete floor. She gradually increases her push until the cabinet just begins to move. She finds that she must apply a horizontal force of 800 N to initiate movement. Once moving, a smaller force is needed to keep it sliding.
Task:
As a learner of physics:
a)What is the name given to the value of the frictional force just before the cabinet begins to move?
b)Calculate the normal reaction force on the cabinet.
c)Determine the coefficient of static friction between the cabinet and the concrete floor.
d)If a student helps by lifting upwards on the cabinet with a force of 200 N while the librarian pushes with the same 800 N force, will the cabinet be easier to start moving? Show calculations to support your answer.
e)State the law of static friction related to the area of contact.
Scenario 63
A painter is using a uniform ladder of length 5 meters and mass 20 kg to paint a wall inMbale. The ladder rests against a smooth vertical wall at a point 4 meters above the ground, with its base on rough horizontal ground. The painter, who has a mass of 70 kg, stands three-quarters of the way up the ladder. The ladder is on the verge of slipping.
Task:
As a learner of physics:
a)Explain why static friction is essential for the ladder to remain in equilibrium.
b)Calculate the normal reaction at the wall.
c)Determine the force of static friction at the base of the ladder.
d)Calculate the minimum coefficient of static friction required at the ground to prevent the ladder from slipping.
e)If the painter moves higher up the ladder, what happens to the required coefficient of static friction? Explain.

Scenario 64

A physics student at Mbarara High School investigates circular motion by whirling a small rubber bung of mass 0.2 kg attached to a string in a horizontal circle. The string makes an angle with the vertical, and the bung moves on a rough horizontal surface. The student finds that for a given speed, the bung maintains a constant radius because static friction provides the necessary centripetal force alongside the horizontal component of the tension.

Task:

As a learner of physics:

a)Besides tension, what force provides the centripetal force for the bung's circular motion?

b)If the coefficient of static friction is 0.5 and the normal reaction is 2 N, calculate the maximum static frictional force available.

c)If the centripetal force required is 1.2 N, will the bung slip? Justify your answer.

d)How would increasing the angular speed affect the frictional force required?

e)State limiting friction.

Scenario 65

At a mining site inKilembe, an elevator cage of mass 1200 kg is held stationary by a steel cable in a vertical shaft. The cage is resting on a ledge, and the cable is slack. The miners need to hoist it upwards. The coefficient of static friction between the cage and the vertical guide rails is 0.3. A horizontal hydraulic jack is used to push the cage away from the rails to reduce friction before lifting.

Task:

As a learner of physics:

a)Identify the two forces that oppose the initial upward motion of the cage.

b)Calculate the maximum static frictional force if the normal reaction from the guide rails is 2000 N.

c)The jack applies a horizontal force to reduce the normal reaction. Calculate the new normal reaction needed to reduce the static friction to 300 N.

d)Why is it easier to keep the cage moving than to start it moving?

e)Name the type of friction that acts once the cage is moving.

Sub topic 6.2: Dynamic friction

Scenario 66

A lorry with a total mass of 8000 kg is traveling at 72 kmh^{-1} along the Kampala-Masaka highway when the driver suddenly applies the brakes,causing the wheels to lock and skid. The lorry skids in a straight line for 50 meters before coming to a stop. The police use the skid marks to investigate if the lorry was speeding.

Task:

As a learner of physics:

a)Define dynamic (kinetic) friction.

b)Convert 72 kmh^{-1} to meters per second.

c)Using the work-energy theorem, calculate the work done by kinetic friction in stopping the lorry.

d)Calculate the coefficient of kinetic friction between the tyres and the road surface.

e)If the road was wet, reducing the coefficient of kinetic friction by half, what would be the new stopping distance from the same speed?

Scenario 67

In a factory in Namanve Industrial Park, a conveyor belt is used to transport packages. The belt is inclined at 15° to the horizontal and moves at a constant speed. A 10 kg package is placed on the belt and is observed to slide relative to the belt for a short distance before coming to rest relative to the moving belt. The coefficient of kinetic friction between the package and the belt is 0.25.

Task:
As a learner of physics:
a)Calculate the component of the package's weight acting parallel to the incline.
b)Calculate the kinetic frictional force acting on the package as it slides.
c)Determine the net force acting on the package while it is sliding.
d)Calculate the acceleration of the package relative to the ground while it is sliding.
e)Explain why the package eventually stops sliding relative to the moving belt.

Scenario 68
During a physics club trip to Mount Rwenzori,students are sliding down a snowy slope on a sled. The slope is inclined at 20° to the horizontal, and the coefficient of kinetic friction between the sled and the snow is 0.1. The sled with a student has a total mass of 80 kg and starts from rest.
Task:
As a learner of physics:
a)Draw a diagram showing the forces acting on the sled as it moves down the slope.
b)Calculate the net force acting on the sled parallel to the incline.
c)Calculate the acceleration of the sled down the slope.
d)If the slope is 100 meters long, calculate the speed of the sled at the bottom of the slope.
e)How would the acceleration change if a heavier student used the same sled? Explain.
Scenario 69
A car of mass 1200 kg is traveling at a constant speed of 90 kmh^{-1} on a level road.The engine is providing power to overcome various resistive forces, with kinetic friction being a significant component. The total resistive force acting on the car is 600 N.
Task:
As a learner of physics:
a)State the relationship between the engine's driving force and the total resistive force when the car moves at constant speed.
b)Calculate the power developed by the engine to maintain this speed.
c)If 40% of the total resistive force is due to kinetic friction, calculate the coefficient of kinetic friction between the tyres and the road.
d)When the driver takes her foot off the accelerator, the car slows down. Explain why this happens.
e)Convert 90 kmh^{-1} to meters per second.
Scenario 70
Students at Kings College Budo are determining the coefficient of kinetic friction using a weighted block on a horizontal wooden track. They pull a 2 kg block with a spring balance, and when the block is moving at constant speed, the spring balance reads 5 N. They then repeat the experiment by adding a 1 kg mass on top of the block, and the spring balance now reads 7.5 N when the block moves at constant speed.
Task:
As a learner of physics:
a)Why must the block be moving at constant speed when taking the spring balance reading?
b)Calculate the coefficient of kinetic friction between the block and the wooden track.
c)Using the same setup, what would the spring balance read if they used a 4 kg block?
d)State one precaution the students should take to ensure accurate results.
e)Name the law that relates the normal reaction and the kinetic frictional force.

Topic 7: FLUID MECHANICS
Sub-topic 7.1: Molecular Forces in Fluids
Scenario 71

In a rural Ugandan community near Lake Victoria,local fishermen have observed an interesting phenomenon where some insects can walk on water surfaces without sinking. The village science teacher decides to use this observation to teach students about surface tension and molecular forces in fluids. During a practical lesson, they measure the force required to lift a thin wire ring from the water surface and calculate the surface tension coefficient. The students discover that contaminated water from nearby agricultural runoff shows significantly different surface tension properties compared to clean lake water, which could affect aquatic life and water purification processes in their community.

Task:

As a learner of physics;

(a)Explain the molecular mechanism that creates surface tension in liquids.

(b)Describe an experiment to measure the surface tension of water using a wire ring and a precision balance.

(c)Calculate the surface tension coefficient if a force of 0.045 N is required to lift a wire ring of circumference 0.15 m from the water surface.

(d)Discuss two real-world implications of changing surface tension in natural water bodies.

Scenario 72

A team of agricultural researchers in the Nakasongola district is investigating why water rises to different heights in various types of soil.They set up capillary tubes of different diameters to simulate soil pores and measure how water climbs through them. The researchers need to understand how capillary action affects water distribution in arid regions and how this knowledge can improve irrigation systems for local farmers who depend on seasonal rainfall for their crops.

Task:

As a learner of physics;

(a)Define capillary action and explain its molecular basis.

(b)Derive the relationship between capillary rise, tube diameter, and liquid density.

(c)Calculate the height water will rise in a glass tube of diameter 0.4 mm, given the surface tension of water is 0.072 N/m and the contact angle is 0°.

(d)Suggest how understanding capillary action can help in designing more efficient irrigation systems.

Scenario 73

At a soap manufacturing plant in Kampala,quality control technicians are testing new detergent formulations. They observe that adding certain chemicals significantly reduces water's surface tension, improving cleaning efficiency. The plant manager needs to quantify this effect and understand the molecular interactions involved to optimize their product while ensuring environmental safety for wastewater discharged into the Nakivubo Channel.

Task:

As a learner of physics;

(a)Explain how detergent molecules reduce surface tension at the molecular level.

(b)Describe how the angle of contact changes when a surface becomes more wettable.

(c)A detergent reduces surface tension from 0.072 Nm^{-1} to 0.035 Nm^{-1}. Calculate the percentage decrease in surface tension.

(d)Analyze one environmental concern related to reduced surface tension in natural water bodies.

Scenario 74

During a physics field trip to a water treatment plant in Jinja,students observe air bubbles rising through sedimentation tanks. The plant engineer explains that bubble formation and stability depend on excess

pressure and surface tension. The students decide to investigate how bubble size affects internal pressure and how this principle applies to water purification processes that remove impurities through aeration.

Task:

As a learner of physics;

(a)Derive the expression for excess pressure inside a spherical bubble.

(b)Calculate the excess pressure inside a soap bubble of radius 2 cm if the surface tension of soap solution is 0.025 Nm^{-1}.

(c)Explain why smaller bubbles have higher internal pressure than larger ones.

(d)Discuss the importance of bubble formation in water treatment processes.

Scenario 75

In a university materials science laboratory,researchers are developing new waterproof fabrics for use in Uganda's rainy season. They test different textile treatments by measuring the contact angle of water droplets on fabric surfaces. The research team needs to understand how surface energy and molecular forces affect waterproofing to create affordable rain protection for farmers and outdoor workers.

Task:

As a learner of physics;

(a)Define angle of contact and explain its significance in waterproofing.

(b)Calculate the surface energy if the surface tension is 0.028 Nm^{-1} and a water droplet forms a contact angle of 120° on a treated fabric.

(c)Explain why some fabrics are "waterproof" while others are "water-resistant" based on molecular forces.

(d)Suggest how this research could benefit agricultural workers in rural Uganda.

Sub-topic 7.2: Pressure and Density of Liquids

Scenario 76

The National Water and Sewerage Corporation is designing a new water tower for the growing town of Mbarara.Engineers need to calculate the pressure at the base of the proposed 25-meter high tank to ensure the pipeline system can handle the static pressure and deliver water effectively to elevated areas of the town. The design must account for seasonal temperature variations that affect water density and consequently the pressure distribution throughout the distribution network.

Task:

As a learner of physics;

(a)State the relationship between liquid pressure, depth, and density.

(b)Calculate the pressure at the base of the water tower if the height is 25 m and water density is 1000 kgm^{-3}.

(c)Determine how the pressure would change if the tower contained diesel (density 850 kgm^{-3}) instead of water.

(d)Explain why water towers are effective for maintaining consistent water pressure in municipal systems.

Scenario 77

During the construction of the Karuma Hydropower Dam,engineers observed that water pressure increased significantly with depth during the reservoir filling process. Safety inspectors need to verify that the dam structure can withstand the maximum pressure at its base and design appropriate spillways and outlet works. The engineering team must also consider how sediment accumulation at the reservoir bottom might affect long-term pressure distribution.

Task:

As a learner of physics;

(a)Calculate the pressure at a depth of 80 meters in the reservoir.
(b)Explain why pressure increases with depth in fluids.
(c)If the reservoir has a surface area of 50 km², estimate the total force on the dam face.
(d)Discuss one engineering challenge related to fluid pressure in large dam projects.

Scenario 78

A scuba diving instructor operating in Lake Bunyonyi needs to educate new divers about pressure changes underwater.The instructor demonstrates how pressure affects air spaces in the body and diving equipment. Students measure pressure at different depths using specialized gauges and learn to calculate decompression schedules to prevent diving-related health issues in Uganda's deepest lake.

Task:

As a learner of physics;
(a)Calculate the total pressure experienced by a diver at 20 meters depth in the lake.
(b)Explain how pressure changes affect the volume of air in a diver's lungs.
(c)A diver's air tank contains 2000 liters of air at surface pressure. Calculate the volume this air would occupy at 20 meters depth.
(d)Why is understanding pressure crucial for scuba diving safety?

Scenario 79

In a Kampala hospital,medical staff need to administer intravenous (IV) fluids to patients. The nurses must hang IV bags at correct heights to ensure proper fluid flow rates based on hydrostatic pressure principles. The hospital is reviewing its procedures after an incident where an IV bag was placed too low, causing inadequate fluid delivery to a critical patient.

Task:

As a learner of physics;
(a)Calculate the minimum height an IV bag must be placed to generate sufficient pressure for flow.
(b)Explain how blood pressure measurements relate to fluid pressure principles.
(c)A saline solution (density 1020 kgm^{-3}) IV bag is placed 1.2 meters above the patient's arm. Calculate the pressure difference.
(d)Suggest two factors that could affect IV fluid flow rates in clinical settings.

Scenario 80

A meteorological station in Moroto is measuring atmospheric pressure variations to improve weather forecasting in the Karamoja region.Technicians use mercury barometers and need to understand how temperature affects density and pressure measurements. The data collected helps predict seasonal rainfall patterns crucial for pastoral communities in this drought-prone area.

Task:

As a learner of physics;
(a)Explain how a mercury barometer measures atmospheric pressure.
(b)Calculate the height of mercury column when atmospheric pressure is 1.01×10^5 Pa (density of mercury = 13600 kgm^{-3}).
(c)Discuss how temperature variations might affect barometer readings.
(d)Explain why accurate atmospheric pressure measurement is important for agricultural planning.

Sub-topic 7.3: Fluid Flow

Scenario 81

The Ministry of Water and Environment is rehabilitating the old water pipeline network in Gulu Municipality. Engineers are analyzing flow rates through pipes of different diameters to optimize water distribution. They observe that narrower pipes show significantly reduced flow rates despite higher pump

pressure, leading to investigations into flow resistance and energy losses that affect water supply reliability in growing urban areas.

Task:

As a learner of physics;

(a)State the equation of continuity for incompressible fluid flow.

(b)Water flows through a pipe that narrows from 0.2 m to 0.1 m diameter. If the speed in the wider section is 2 ms^{-1}, calculate the speed in the narrower section.

(c)Explain why the flow speed changes at the constriction.

(d)Discuss one implication of the continuity equation for urban water supply systems.

Scenario 82

A sugarcane processing plant in Busoga region uses large pipelines to transport juice between processing stages.Plant engineers notice that juice viscosity changes with temperature, affecting flow rates and production efficiency. The quality control team needs to establish optimal temperature ranges that maintain desired flow characteristics while preserving juice quality throughout the processing chain.

Task:

As a learner of physics;

(a)Define viscosity and explain how it affects fluid flow.

(b)Describe an experiment to compare the viscosity of different liquids.

(c)A fluid with viscosity 0.01 Pa·s flows through a 10 m long pipe of radius 0.05 m under a pressure difference of 1000 Pa. Calculate the flow rate.

(d)Explain how temperature affects viscosity and why this matters in food processing.

Scenario 83

Aircraft maintenance engineers at Entebbe International Airport are studying air flow over wing surfaces to optimize fuel efficiency for Uganda Airlines'new fleet. They use wind tunnels to simulate different flight conditions and measure how air speed affects lift forces. The research aims to reduce operational costs while maintaining safety standards for flights across East Africa.

Task:

As a learner of physics;

(a)State Bernoulli's principle and write the corresponding equation.

(b)Explain how wing shape creates lift force during flight.

(c)If air speeds above and below a wing are 80 ms^{-1} and 70 ms^{-1} respectively, calculate the pressure difference (air density = 1.2 kgm^{-3}).

(d)Discuss two applications of Bernoulli's principle in aviation.

Scenario 84

A micro-hydro power project on River Mpanga in Fort Portal is designing its turbine system.Engineers need to calculate the maximum power available from water flowing through a channel of specific dimensions. The community-based project aims to provide electricity to remote villages, and accurate flow measurements are essential for determining the project's feasibility and economic viability.

Task:

As a learner of physics;

(a)Calculate the volume flow rate of water through a channel of cross-sectional area 2 m^2 with flow velocity 3 ms^{-1}.

(b)Determine the kinetic energy available per second from this flow.

(c)If the turbine efficiency is 70%, calculate the useful power output.

(d)Explain how such micro-hydro projects contribute to rural development.

Scenario 85
Medical researchers at Mulago Hospital are studying blood flow through partially blocked arteries.Using principles of fluid dynamics, they analyze how plaque buildup affects blood pressure and flow rates. This research helps in understanding cardiovascular diseases that are increasingly prevalent in Uganda's aging population and developing better treatment protocols.
Task:
(a)Explain how arterial narrowing affects blood flow using fluid dynamics principles.
(b)If an artery narrows to half its original radius, calculate how the flow rate changes (assuming constant pressure difference).
(c)Discuss why blood pressure typically increases when arteries are constricted.
(d)Suggest how understanding fluid flow can help in designing medical interventions.

Topic 8: MECHANICAL PROPERTIES OF MATTER
Sub-topic 8.1: Loading Wires; Hooke's Law
Scenario 86
A construction materials testing laboratory in Kampala is evaluating the quality of steel wires supplied for a new bridge project.Technicians suspend various lengths of wire and add weights in increments, carefully measuring the extension produced. They plot graphs of load against extension to determine if the wires behave elastically under expected working loads and to identify the maximum load before permanent deformation occurs, ensuring the bridge's safety for public use. The tests are crucial as the bridge will serve a rapidly growing community and must withstand heavy traffic and environmental stresses over its planned lifespan, making material reliability a top priority for the engineering team.
Task:
As a learner of physics;
(a)State Hooke's Law and identify the point on a load-extension graph where this law ceases to apply.
(b)A wire stretches by 2 mm under a load of 50 N. Calculate the extension when the load is 125 N, assuming Hooke's Law is obeyed.
(c)The wire breaks when the load reaches 800 N. Suggest why it is important for engineers to know this value.
(d)Sketch a typical load-extension graph for a ductile metal wire and label the elastic limit.
Scenario 87
In a vocational school workshop in Jinja, students are learning to make traditional stringed musical instruments. They test different types of strings by applying tensions and measuring the resulting extensions to find strings that return to their original length when tension is released. This ensures the instruments will maintain their tuning during performances. The students discover that natural fibers behave differently from modern synthetic materials, leading to a discussion about elastic limits and material choices in instrument design.
Task:
As a learner of physics;
(a)Define the term 'elastic limit' in the context of the instrument strings.
(b)A string has an original length of 60 cm and stretches by 3 cm under a tension of 40 N. Calculate the extension under a tension of 100 N.
(c)Explain why a string that has been stretched beyond its elastic limit would be unsuitable for a musical instrument.
(d)Describe how the students could determine whether a string has been stretched beyond its elastic limit.

Scenario 88
A mining company in Kilembe is testing new safety harnesses for workers in the copper mines.The harnesses use specially designed elastic ropes that can arrest a fall gradually. Engineers drop known weights attached to the ropes and measure the maximum extension to ensure the ropes can stop a falling worker without exerting dangerous deceleration forces.
Task:
As a learner of physics;
(a)Explain how the elastic properties of the safety rope protect a falling worker.
(b)If a rope extends by 1.5 m when stopping a 80 kg worker, calculate the average force exerted by the rope.
(c)Suggest why the rope must not be stretched beyond its elastic limit during a fall.
(d)A rope is tested repeatedly with increasing weights. What observation would indicate that its elastic limit has been exceeded?

Scenario 89
A furniture manufacturer in Mbale is testing the springs for new sofa designs.Quality control technicians compress springs of different thicknesses and measure how much they shorten under various loads. They need to identify springs that provide comfortable support without permanently deforming when people sit on the furniture.
Task:
As a learner of physics;
(a)Describe how the technicians could verify that a spring obeys Hooke's Law.
(b)A spring shortens by 4 cm under a load of 60 N. Calculate the load required to shorten it by 7 cm.
(c)After testing, a spring does not return to its original length. Explain what has happened to the spring.
(d)The company wants to make a stiffer spring. Suggest how the spring could be modified.
Scenario 90
A physics class is investigating the effect of wire thickness on elasticity.Students suspend wires of the same material but different diameters and add identical weights, measuring the extension for each wire. They discover that thicker wires extend less than thinner ones, leading to discussions about cross-sectional area and stress in materials.
Task:
As a learner of physics;
(a)A force of 50 N is applied to a wire of diameter 0.5 mm. Calculate the stress in the wire.
(b)If the wire in (a) extends by 0.8 mm, and another wire of the same material but diameter 1.0 mm extends by 0.2 mm under the same force, explain why the extensions are different.
(c)Define the term 'strain' and calculate the strain for the first wire if its original length was 2.0 m.
(d)The students plot a graph of stress against strain. What does the gradient of the straight-line portion represent?

Sub-topic 8.2: Modulus of Elasticity
Scenario 91
An engineering firm is designing a new transmission line between Kampala and Entebbe that will use aluminum cables suspended between pylons.The engineers need to calculate how much the cables will stretch under their own weight and varying weather conditions to ensure they maintain proper clearance above the ground and other structures.
Task:
As a learner of physics;

(a)Define Young's Modulus and state its units.
(b)An aluminum wire of length 20 m and cross-sectional area 2.0×10^{-6} m² extends by 4.0 mm under a load of 200 N. Calculate Young's Modulus for aluminum.
(c)Explain why knowledge of Young's Modulus is important when designing overhead cables.
(d)The same load is applied to a steel wire of the same dimensions. Would you expect the extension to be greater or less than for aluminum? Justify your answer.

Scenario 92

A civil engineering company is evaluating different materials for columns in a multi-story building in Kampala's city center.They test concrete, steel, and composite samples by applying compressive forces and measuring how much they shorten. The results will determine which material provides the best combination of strength, cost-effectiveness, and safety for the project.

Task:

As a learner of physics;
(a)A concrete column of height 3.0 m and cross-sectional area 0.5 m² shortens by 0.15 mm when supporting a load of 2.0×10^5 N. Calculate Young's Modulus for the concrete.
(b)Explain why different materials have different values of Young's Modulus.
(c)Steel has a Young's Modulus of 2.0×10^{11} Pa. Calculate how much a steel column of the same dimensions would shorten under the same load.
(d)Suggest one advantage of using steel rather than concrete for building columns.

Scenario 93

A manufacturer of rock-climbing equipment in Uganda is testing new types of carabiners made from different aluminum alloys.They need to ensure the carabiners are strong enough to hold a falling climber yet light enough for practical use. Tests involve applying tensile forces to the carabiners and measuring extensions.

Task:

As a learner of physics;
(a)A carabiner made from alloy A extends by 0.5 mm under a load of 2.0 kN, while one made from alloy B extends by 0.3 mm under the same load. Which alloy has the greater Young's Modulus? Explain your answer.
(b)The carabiner from alloy A has a working length of 8 cm and cross-sectional area of 4.0×10^{-5} m². Calculate Young's Modulus for alloy A.
(c)Explain why a high Young's Modulus is desirable for climbing equipment.
(d)If a carabiner deforms permanently after a heavy load is removed, what does this indicate about the load applied?

Scenario 94

A university materials science department is researching new composite materials for use in prosthetic limbs.The materials need to mimic the flexibility and strength of natural bone while being lightweight and durable. Researchers apply forces to samples and measure extensions to calculate their elastic properties.

Task:

As a learner of physics;
(a)A sample of composite material is 15 cm long with cross-sectional area 3.0×10^{-5} m². It extends by 0.25 mm under a load of 600 N. Calculate Young's Modulus for the material.
(b)Natural bone has a Young's Modulus of about 2.0×10^{10} Pa. Compare this with your answer to (a) and comment on the suitability of the composite for prosthetic limbs.
(c)Explain why a prosthetic limb material should not have too high a value of Young's Modulus.
(d)During testing, the composite material breaks suddenly without significant extension. What property does this indicate?

Scenario 95

A team of engineers is investigating why a pedestrian bridge in a Kampala suburb developed unexpected sagging after only two years of use.They test samples of the steel cables used in the bridge construction to determine if the material properties have changed due to environmental factors or if the wrong grade of steel was used initially.

Task:

As a learner of physics;

(a)A sample from the bridge cable has length 2.0 m and diameter 1.0 cm. It extends by 1.2 mm under a load of 4.0 kN. Calculate Young's Modulus for the steel.

(b)The specification for the bridge required steel with Young's Modulus 2.1×10^{11} Pa. Determine if the sample meets this requirement.

(c)Suggest two reasons why the bridge cables might have stretched more than expected over time.

(d)Explain how regular measurement of bridge cable extension could help identify problems before they become dangerous.

Topic 9: THERMOMETRY

Sub-topic 9.1: Temperature Scales

Scenario 96

A meteorological research team stationed at the summit of Mount Elgon is conducting a long-term climate change study.They use specialized platinum resistance thermometers to record precise temperature variations at different altitudes. The team must frequently convert their readings between Celsius and Kelvin scales to align with international climate databases and to perform thermodynamic calculations. During data analysis, they notice a consistent warming trend that correlates with changing precipitation patterns, affecting local agriculture and water resources. The researchers are particularly interested in absolute zero concepts when modeling extreme weather scenarios and understanding the fundamental limits of temperature variations in their atmospheric studies. Their work contributes to Uganda's national climate adaptation strategy by providing critical data on temperature trends in vulnerable highland ecosystems.

Task:

As a learner of physics;

(a)Convert a temperature reading of 15°C to the Kelvin scale.

(b)Explain why the Kelvin scale is preferred over the Celsius scale for scientific climate models.

(c)If the temperature at the mountain summit drops from 5°C to -3°C, calculate the temperature difference in both Celsius and Kelvin scales.

(d)Discuss why understanding different temperature scales is crucial for accurate meteorological data interpretation.

Scenario 97

A food processing plant in Masaka that exports fruit concentrates to European markets must ensure their products meet strict international quality standards.The quality control laboratory uses calibrated liquid-in-glass thermometers alongside digital infrared thermometers to monitor temperatures during pasteurization and storage. Technicians regularly cross-reference Celsius and Fahrenheit readings since their export documentation requires both units. Recently, they encountered a shipment rejection due to temperature documentation errors, leading to financial losses and prompting a comprehensive review of their temperature monitoring protocols and staff training programs. The plant manager has organized special training sessions focusing on temperature scale conversions and measurement accuracy to prevent future incidents and maintain their export certification status.

Task:
As a learner of physics;
(a)Convert a pasteurization temperature of 72°C to the Fahrenheit scale.
(b)Derive the relationship between Celsius and Fahrenheit scales from their fixed points.
(c)A thermometer shows 104°F in the storage room. Convert this to Celsius and determine if it meets the required 40°C maximum storage temperature.
(d)Explain two consequences of temperature measurement errors in food processing industries.

Sub-topic 9.2: Types of Thermometers
Scenario 98
A regional hospital in Gulu is upgrading its medical equipment,including various types of thermometers for different departments. The procurement committee must choose between mercury-in-glass, clinical, digital, and infrared thermometers based on accuracy, safety, and specific use cases. The pediatric ward requires non-invasive options for children, while the intensive care unit needs highly precise and continuous monitoring capabilities. The hospital's chief medical officer has organized demonstration sessions from different suppliers, emphasizing the importance of understanding the working principles of each thermometer type to make informed purchasing decisions that will serve their diverse patient needs effectively while adhering to the national healthcare standards.
Task:
As a learner of physics;
(a)Describe the working principle of a liquid-in-glass thermometer.
(b)Explain two advantages of digital thermometers over mercury thermometers in clinical settings.
(c)A resistance thermometer has a resistance of 120Ω at 0°C and 165Ω at 100°C. Calculate the temperature when the resistance is 140Ω.
(d)Suggest why different departments in a hospital might require different types of thermometers.
Scenario 99
An industrial complex in Jinja that houses both a steel manufacturing plant and a pharmaceutical company requires diverse temperature monitoring systems.The steel plant needs thermometers that can measure extremely high temperatures in furnaces, while the pharmaceutical company requires precise temperature control for drug formulation processes. Engineers are evaluating thermocouples, resistance thermometers, and radiation pyrometers for different applications. The complex management has initiated a cross-departmental training program to educate technicians about the appropriate selection, installation, and maintenance of various thermometer types to optimize industrial processes and ensure workplace safety standards are consistently met.
Task:
As a learner of physics;
(a)Explain how a thermocouple thermometer generates an electromotive force (emf).
(b)Describe two situations where a radiation pyrometer would be preferred over other types of thermometers.
(c)A thermocouple produces an emf of 12mV at 200°C and 18mV at 300°C. Calculate the expected emf at 250°C, assuming a linear relationship.
(d)Discuss the importance of selecting appropriate thermometer types for different industrial applications.
Scenario 100
A agricultural research station in the drylands of Nakasongola is conducting experiments on crop resilience to temperature variations.Researchers use soil thermometers, maximum-minimum thermometers, and automated digital thermometers to monitor microclimate conditions across different experimental plots. The team needs to correlate soil temperature data with plant growth metrics to

develop better farming strategies for climate-vulnerable regions. The research coordinator has implemented a quality assurance protocol that includes regular calibration of all thermometers against standard references to ensure data reliability for their long-term agricultural adaptation studies, which are crucial for food security in the region.

Task:

As a learner of physics;

(a)Explain how a maximum-minimum thermometer records temperature extremes.

(b)Describe the construction and working principle of a bimetallic thermometer.

(c)A bimetallic strip is made of brass and invar. If brass has a higher coefficient of thermal expansion than invar, describe and explain what happens when the temperature increases.

(d)Suggest why regular calibration of thermometers is essential in scientific research.

TOPIC 10: HEAT QUANTITIES

Sub-topic 10.1: Heat Capacity

Scenario 101

A solar energy research center in Mbarara is testing different materials for thermal energy storage in solar cookers.Researchers measure how much heat various substances can absorb to identify materials that maintain cooking temperatures after sunset. The team uses samples of water, sand, and specially formulated phase-change materials, heating them equally while recording temperature changes. They discovered that water-based systems provide more consistent heating but require better insulation, while solid materials reach higher temperatures faster but cool more quickly. These findings are crucial for designing efficient solar cooking systems for rural households that lack consistent access to conventional cooking fuels. The research aims to reduce deforestation caused by firewood collection while providing sustainable cooking solutions.

Task:

As a learner of physics;

(a)Define specific heat capacity and state its SI units.

(b)Calculate the heat energy required to raise the temperature of 2kg of water from 20°C to 80°C.

(c)Explain why water has a higher specific heat capacity than most common materials.

(d)If equal masses of water and sand receive the same amount of heat, which will show a greater temperature increase? Explain your answer.

Scenario 102

An automotive engineering workshop in Kampala is testing different engine coolant mixtures for matatus(public transport vehicles). Mechanics compare how effectively various coolant solutions absorb heat from engines during operation. They test pure water, ethylene glycol mixtures, and commercial coolant products by circulating them through a test engine and measuring temperature changes. The research aims to identify coolants that prevent engine overheating in Uganda's tropical climate while being affordable for local vehicle owners. Preliminary results show that proper coolant selection can significantly extend engine life and reduce breakdowns on busy routes.

Task:

As a learner of physics;

(a)A coolant system contains 5kg of liquid. If the temperature rises from 25°C to 85°C, calculate the heat absorbed (specific heat capacity of coolant = 3800 $Jkg^{-1}°C$).

(b)Explain why different coolants have different specific heat capacities.

(c)Suggest two properties of an ideal engine coolant besides high specific heat capacity.

(d)The same engine is tested with water (c=4200 $Jkg^{-1}°C$) and with coolant (c=3800 $Jkg^{-1}°C$). Which will show a smaller temperature rise? Explain why.

Scenario 103

A ceramics factory in Iganga is optimizing their kiln firing process to reduce energy costs.Engineers investigate how different clay compositions absorb heat during firing by measuring temperature changes in sample pieces. They found that some clay mixtures require less fuel to reach the required temperature, leading to significant cost savings. The factory plans to use these findings to train kiln operators in energy-efficient firing techniques while maintaining product quality. This research aligns with Uganda's industrial energy conservation initiatives and helps small-scale potters reduce production costs.

Task:

As a learner of physics;

(a)A 0.5kg clay piece requires 45,000J of heat to raise its temperature from 30°C to 230°C. Calculate its specific heat capacity.

(b)Explain how knowledge of specific heat capacity helps in reducing industrial energy costs.

(c)Compare the heat capacities of equal masses of clay and copper, given their specific heat capacities are 900 $Jkg^{-1}°C$ and 385 $Jkg^{-1}°C$ respectively.

(d)Why do different materials have different specific heat capacities at the molecular level?

Scenario 104

A physics class in Fort Portal is investigating why coastal regions experience milder temperature variations than inland areas.Students set up experiments with water and soil samples, exposing them to equal heat sources and monitoring temperature changes over time. They discover that water heats up and cools down more slowly than soil, explaining the moderating effect of large water bodies on climate. The students present their findings to the district environmental office, suggesting that preserving water bodies could help mitigate extreme temperature fluctuations in urban areas.

Task:

As a learner of physics;

(a)2kg of water and 2kg of soil each receive 84,000J of heat. If water's temperature rises by 10°C, calculate the temperature rise of soil (c_{soil} = 800 $Jkg^{-1}°C$).

(b)Explain how specific heat capacity affects climate patterns in coastal regions.

(c)Design an experiment to compare the specific heat capacities of two different liquids.

(d)Why is water's high specific heat capacity important for aquatic life?

Scenario 105

A hospital in Jinja is evaluating different materials for hot water storage tanks.Engineers test stainless steel, copper, and plastic containers to determine which maintains water temperature longest while being cost-effective. They fill identical tanks with hot water and monitor cooling rates over 24 hours. The findings will inform the hospital's decision on replacement tanks for their hot water system, crucial for maintaining hygiene standards in surgical and maternity wards while controlling energy costs.

Task:

As a learner of physics;

(a)A hot water tank contains 100kg of water at 65°C. Calculate the heat lost when the water cools to 40°C.

(b)Explain how the specific heat capacity of the tank material affects heat retention.

(c)Suggest why hospitals might choose materials with lower specific heat capacities for hot water pipes.

(d)If two tanks of equal mass but different materials contain water at the same temperature, which will cool faster? Explain your reasoning

Sub-topic 10.2: Change of State; Latent Heat

Scenario 106

A fruit processing company in Masaka uses freezing technology to preserve mango pulp for export.Engineers monitor how much heat must be removed to freeze the pulp efficiently without damaging its quality. They discovered that understanding latent heat of fusion helps optimize freezer settings and reduce electricity costs. The company is training technicians in proper freezing techniques to maintain product quality while meeting European export standards. This knowledge has helped reduce energy consumption by 25% while improving the texture of thawed fruit products.

Task:

As a learner of physics;

(a)Define latent heat of fusion and state its units.

(b)Calculate the heat that must be removed to freeze 4kg of mango pulp at 0°C (latent heat of fusion = 250,000 Jkg^{-1}).

(c)Explain why temperature remains constant during phase change despite heat being removed.

(d)Suggest why different substances have different latent heats of fusion.

Scenario 107

A traditional distillery in Bushenyi producing waragi(local gin) uses heat to vaporize alcohol from fermented banana mash. The operators need to calculate how much heat is required to vaporize different quantities of alcohol to optimize fuel wood usage. Recently, they've been experimenting with improved still designs that recover latent heat from condensation to pre-heat the mash, significantly reducing production costs and environmental impact from wood burning.

Task:

As a learner of physics;

(a)Calculate the heat required to vaporize 2kg of ethanol already at its boiling point (latent heat of vaporization = 840,000 J/kg).

(b)Explain what happens to the heat energy during vaporization at the molecular level.

(c)Compare the latent heat of vaporization with the latent heat of fusion for the same substance.

(d)Why is the latent heat of vaporization usually higher than the latent heat of fusion?

Scenario 108

A meteorological research station on Lake Victoria studies how evaporation from the lake surface affects local weather patterns.Scientists measure how much solar energy is used to evaporate water rather than heat the lake. This research helps predict rainfall patterns and understand the lake's role in regulating regional climate. The data collected shows that evaporation rates have increased due to rising temperatures, affecting fishing communities and agricultural planning around the lake basin.

Task:

As a learner of physics;

(a)Calculate the heat energy required to evaporate 1kg of water from the lake surface (latent heat of vaporization of water = 2,260,000 Jkg^{-1}).

(b)Explain how evaporation acts as a cooling process.

(c)Describe the energy transformations during the water cycle.

(d)How does latent heat release during condensation affect weather patterns?

Scenario 109

A metal casting workshop in Kasese uses scrap aluminum to produce cooking pots.Workers need to calculate how much heat is required to melt different amounts of aluminum for efficient furnace operation. The workshop has recently introduced better insulation and heat recovery systems based on understanding latent heat principles, reducing charcoal consumption by 40% while maintaining production quality for local markets.

Task:
As a learner of physics;
(a)Calculate the heat required to melt 3kg of aluminum at its melting point (latent heat of fusion of aluminum = 397,000 Jkg^{-1}).
(b)Explain why the temperature of melting aluminum remains constant until all is liquid.
(c)A furnace supplies heat at 5000J per second. How long will it take to melt 2kg of aluminum?
(d)Suggest two ways to reduce heat loss during the melting process.

Scenario 110

A refugee settlement in northern Uganda uses solar stills to purify drinking water.The technology uses sunlight to evaporate contaminated water, which then condenses as pure water. Aid workers train residents to calculate how much heat is needed to produce their daily water requirements. Understanding latent heat helps optimize the still designs and predict daily water output based on solar intensity, crucial for maintaining adequate water supplies in the dry season.

Task:
As a learner of physics;
(a)Calculate the heat energy needed to produce 5kg of distilled water from contaminated water at 20°C (specific heat capacity of water = 4200 $Jkg^{-1}°C$, latent heat of vaporization = 2,260,000 Jkg^{-1}).
(b)Explain why the condensation stage is crucial in solar still operation.
(c)Design a simple solar still using locally available materials.
(d)How does understanding latent heat help in planning water purification systems?

Topic 11: TRANSFER OF HEAT

Sub-topic 11.1: Conduction

Scenario 111

A construction materials testing laboratory in Kampala is evaluating different roofing materials for affordable housing projects.Engineers test corrugated iron, clay tiles, and thatch samples to determine their thermal conductivity properties. They measure how quickly heat passes through each material when one side is heated to simulate sunlight exposure. The research aims to identify materials that keep houses cool in Uganda's tropical climate while remaining affordable for low-income families. Preliminary results show that traditional thatch provides better insulation than modern materials, leading to renewed interest in improved traditional building techniques that combine cultural heritage with thermal comfort. This research supports the government's affordable housing initiative by providing data on cost-effective cooling solutions.

Task:
As a learner of physics;
(a)Define thermal conductivity and state its SI units.
(b)A metal rod of length 0.5m and cross-sectional area 0.001m^2 has one end maintained at 100°C and the other at 20°C. If the thermal conductivity is 50 $Wm^{-1}°C$, calculate the heat current through the rod.
(c)Explain why metals are better conductors of heat than wood.
(d)Suggest two ways to reduce heat conduction through a roof.

Scenario 112

A cookware manufacturer in Jinja is developing new energy-efficient cooking pots for rural households.Engineers test aluminum, stainless steel, and copper pots to determine which material distributes heat most evenly while minimizing hot spots that can burn food. They use thermal imaging cameras to visualize heat distribution and measure how quickly each pot reaches cooking temperature. The research aims to reduce cooking time and fuel consumption for families using firewood or charcoal,

addressing both economic and environmental concerns associated with traditional cooking methods in Uganda.

Task:

As a learner of physics;

(a)Explain why copper pots heat up more quickly than aluminum pots of the same thickness.

(b)Calculate the rate of heat transfer through a pot bottom 0.5cm thick with area 0.02m², if the temperature difference is 150°C (k_{copper} = 400 $Wm^{-1}°C$).

(c)Suggest why handles of cooking pots are made of materials with low thermal conductivity.

(d)Design an experiment to compare the thermal conductivity of two different metals.

Scenario 113

A textile factory in Mbale is investigating heat loss through factory walls to reduce energy costs.Engineers measure how different insulation materials affect heat transfer through brick walls. They test conventional fiberglass insulation against locally available materials like cotton waste and papyrus reeds. The study aims to develop affordable insulation solutions that can be manufactured locally, creating jobs while reducing the factory's carbon footprint. Initial results show that properly processed agricultural waste can provide effective insulation at half the cost of imported materials.

Task:

As a learner of physics;

(a)A wall has area 20m² and thickness 0.2m. If the temperature difference is 15°C and thermal conductivity is 0.5 W/m°C, calculate the heat loss per hour.

(b)Explain how air pockets in insulation materials reduce heat conduction.

(c)Compare the thermal conductivity of metals, plastics, and gases.

(d)Why is understanding heat conduction important for energy conservation in industries?

Scenario 114

A hospital in Gulu is upgrading its neonatal unit to maintain stable temperatures for premature babies.Engineers are testing different materials for incubator walls to ensure minimal heat loss while allowing medical staff to observe the infants. They compare double-walled plastic, acrylic, and special composite materials, measuring heat retention under various room temperatures. The project aims to reduce electricity costs while providing optimal care for vulnerable newborns in a region with frequent power outages.

Task:

As a learner of physics;

(a)An incubator wall of area 1.5m² and thickness 0.02m has inner temperature 37°C and outer temperature 25°C. If thermal conductivity is 0.2 $Wm^{-1}°C$, calculate the heat loss rate.

(b)Explain why double-walled construction with air gaps reduces heat conduction.

(c)Suggest two properties besides low thermal conductivity that are important for incubator materials.

(d)How does understanding heat conduction help in designing medical equipment?

Scenario 115

A solar water heater manufacturer in Mbarara is optimizing heat exchanger designs to improve efficiency.Engineers test different pipe materials and configurations to maximize heat transfer from solar collectors to water while minimizing losses. They measure how copper, aluminum, and plastic pipes perform under various flow rates and temperature differences. The research aims to make solar water heating more accessible to Ugandan households, reducing reliance on electricity and wood fuel for water heating.

Task:

As a learner of physics;

(a)A copper pipe of length 2m and radius 0.01m carries hot water at 70°C through a room at 25°C. Calculate the heat loss per second (k_{copper} = 400 $Wm^{-1}°C$).
(b)Explain why copper is preferred over plastic for heat exchangers despite its higher cost.
(c)Describe how pipe insulation reduces heat conduction losses.
(d)Design a simple experiment to demonstrate heat conduction through different materials.

Sub-topic 11.2: Convection

Scenario 116

A weather research station on Lake Victoria is studying how convection currents over the lake affect local rainfall patterns.Meteorologists use weather balloons to measure temperature differences between the lake surface and higher altitudes, tracking how warm, moist air rises and cools to form clouds. This research helps predict the timing and intensity of thunderstorms that provide crucial rainfall for agriculture in surrounding regions. The data collected is shared with fishing communities to help them plan safe fishing times and with farmers for crop planning.

Task:

As a learner of physics;
(a)Explain how convection currents form over Lake Victoria.
(b)Describe the role of convection in the water cycle.
(c)Why does warm air rise while cool air sinks?
(d)How does convection affect weather patterns in Uganda?

Scenario 117

A factory in Entebbe manufacturing electronic equipment uses convection cooling to prevent overheating of circuit boards.Engineers design ventilation systems that use natural convection to remove heat from sensitive components without requiring energy-consuming fans. They test different cabinet designs and component layouts to optimize airflow, ensuring equipment reliability in Uganda's warm climate. This approach reduces manufacturing costs and makes the equipment more suitable for areas with unreliable electricity.

Task:

As a learner of physics;
(a)Explain how convection helps cool electronic equipment.
(b)Describe an experiment to demonstrate convection in liquids.
(c)Why are heat-producing components usually placed at the top of electronic cabinets?
(d)Suggest two design features that enhance convection cooling.

Scenario 118

A university agriculture department in Kabale is studying how convection currents in the atmosphere affect frost formation in highland areas.Researchers measure temperature profiles in valley areas where cold air drainage causes frost damage to crops. They experiment with different farming practices and windbreak designs to modify local convection patterns and protect valuable potato and pea crops from frost damage during cold seasons.

Task:

As a learner of physics;
(a)Explain how convection currents can cause frost in valleys.
(b)Describe how smoke or fog can affect convection processes.
(c)Why do farmers sometimes use smudge pots or wind machines to prevent frost damage?
(d)How does understanding convection help in agricultural planning?

Scenario 119
A domestic energy project in Lira promotes improved cooking stoves that use convection principles for better efficiency.Technicians demonstrate how properly designed stoves create strong convection currents that complete combustion and transfer heat to cooking pots more effectively. Women in rural households report using less firewood and experiencing less smoke exposure after adopting the new designs, leading to health and economic benefits for their families.
Task:
As a learner of physics;
(a)Explain how convection improves combustion in cooking stoves.
(b)Describe the convection currents in a typical cooking fire.
(c)Why do improved cooking stoves have chimneys or air vents?
(d)Design a simple experiment to show convection in gases.
Scenario 120
An architectural firm in Kampala is designing naturally ventilated buildings that use convection to maintain comfortable temperatures without air conditioning.Architects study how hot air rises through buildings and how to design windows, vents, and interior spaces to create effective convection currents. The designs incorporate traditional ventilation principles with modern materials, creating buildings that are comfortable, energy-efficient, and culturally appropriate for Uganda's climate.

Task:
As a learner of physics;
(a)Explain how convection can be used for natural building ventilation.
(b)Describe the convection process in a room with windows at different heights.
(c)Why are ventilation openings usually placed near the ceiling?
(d)How does building orientation affect convection ventilation?

Sub-topic 11.3: Radiation
Scenario 121
A solar energy company in Soroti is testing different surface coatings for solar water heaters to maximize heat absorption from sunlight.Engineers compare black chrome, matte black paint, and selective surfaces under Ugandan sunlight conditions. They measure how much heat each surface absorbs and how much infrared radiation it emits, seeking the optimal balance for all-day hot water supply. The research aims to make solar water heating more efficient and affordable for Ugandan households, particularly in rural areas with abundant sunshine but limited electricity access.
Task:
As a learner of physics;
(a)Explain why black surfaces are better absorbers of radiation than white surfaces.
(b)Describe the difference between good absorbers and good emitters of radiation.
(c)A solar collector surface of area $2m^2$ receives solar radiation at 800 W/m^2. If it absorbs 70% of this radiation, calculate the power absorbed.
(d)Why are vacuum tubes used in some solar collectors?
Scenario 122
A hospital in Mbale is upgrading its neonatal care unit with radiant warmers for premature babies.Medical physicists are testing different radiant heater designs to provide consistent warmth without dangerous hot spots. They measure infrared radiation levels at different distances and angles, ensuring the equipment meets safety standards while effectively maintaining babies' body temperature. The technology is

particularly important in a hospital with frequent power outages, as some radiant warmers can operate on battery backup.

Task:

As a learner of physics;

(a)Explain how radiant warmers transfer heat without physical contact.

(b)Describe the electromagnetic spectrum of thermal radiation.

(c)Why are special coatings used on radiant warmer reflectors?

(d)How does radiation differ from conduction and convection?

Scenario 123

A tea processing factory in Fort Portal uses radiation pyrometers to monitor temperatures during tea drying without contacting the delicate tea leaves.Quality control technicians compare pyrometer readings with traditional thermometer measurements to ensure accurate temperature control during critical processing stages. Proper temperature management affects the tea's flavor and shelf life, directly impacting the factory's export quality and profitability in international markets.

Task:

As a learner of physics;

(a)Explain how a radiation pyrometer measures temperature without contact.

(b)Describe the principle of black body radiation.

(c)Why are radiation pyrometers suitable for measuring high temperatures?

(d)Calculate the peak wavelength of radiation from a surface at 1000K

(Wien's constant = 2.9×10^{-3} mK).

Scenario 124

A building materials company in Hoima is developing reflective roof coatings to reduce heat gain in buildings.Researchers test how different pigments and surface textures affect the absorption and emission of thermal radiation. They use specialized equipment to measure the "albedo" (reflectivity) of various coatings under Ugandan sunlight conditions. The goal is to develop affordable coatings that can reduce indoor temperatures by 5-8°C, decreasing the need for energy-intensive cooling systems.

Task:

As a learner of physics;

(a)Explain how reflective roof coatings reduce heat gain.

(b)Describe the relationship between surface color and radiation absorption.

(c)A roof coating reflects 80% of incident radiation. If it receives 1000 Wm^{-1}, calculate the power reflected and absorbed.

(d)Why are some modern reflective coatings silver-colored rather than white?

Scenario 125

An astronomical observatory in Mbarara uses infrared telescopes to study celestial objects through Uganda's clear night skies.Physicists explain to visiting students how all objects emit thermal radiation and how telescopes detect this radiation from distant stars and galaxies. The educational program includes demonstrations of thermal imaging cameras that show how radiation principles apply both in astronomy and everyday life, inspiring students to pursue science careers.

Task:

(a)Explain why all objects emit thermal radiation.

(b)Describe how the temperature of a star affects its color.

(c)State Stefan-Boltzmann law and explain its significance.

(d)A star has surface temperature 6000K and radius 7×10^{8}m. Calculate the total power radiated

($\sigma = 5.67\times10^{-8}$ $Wm^{-2}K^{4}$).

Topic 12: BEHAVIOUR OF GASES

Sub-topic 12.1: The Behaviour of Ideal Gases

Scenario 126

A medical oxygen plant in Kampala is calibrating its compression systems to ensure accurate filling of oxygen cylinders for hospitals across Uganda.Engineers monitor how pressure, volume, and temperature interact during the compression process using the ideal gas law. They need to calculate the exact amount of oxygen that can be safely stored in each cylinder under different environmental conditions, particularly considering temperature variations between air-conditioned storage rooms and hot transportation vehicles. This precision is crucial for ensuring that medical facilities in remote areas receive cylinders with consistent oxygen content, which can be life-saving for patients with respiratory conditions in regions with limited healthcare infrastructure.

Task:

As a learner of physics;

(a)State the ideal gas equation and identify all its variables.

(b)A gas occupies 2.5 m^3 at 300K and 100 kPa. Calculate its volume at 350K and 150 kPa.

(c)Explain why real gases deviate from ideal behavior at high pressures.

(d)A medical cylinder contains 0.5 m^3 of oxygen at 200 kPa and 25°C. Calculate the number of moles of oxygen.

Scenario 127

A meteorology department at Makerere University is studying atmospheric pressure variations across different altitudes in Uganda's mountainous regions.Researchers release weather balloons equipped with sensors that measure how air pressure decreases with altitude, applying gas laws to understand atmospheric behavior. The data helps predict weather patterns and is particularly valuable for aviation safety, especially for small aircraft flying between airstrips in mountainous areas like Kasese and Kabale where rapid weather changes can create dangerous flying conditions.

Task:

As a learner of physics;

(a)A weather balloon has volume 5.0 m^3 at ground level where pressure is 101 kPa. Calculate its volume at 10 km altitude where pressure is 26 kPa (assume constant temperature).

(b)Explain why atmospheric pressure decreases with altitude.

(c)If the temperature also decreases with altitude, how would this affect the balloon's volume?

(d)Describe one application of gas laws in weather prediction.

Scenario 128

A soft drink manufacturing plant in Entebbe uses carbon dioxide gas to carbonate beverages.Quality control technicians must ensure consistent fizziness by maintaining exact pressure-temperature relationships during the carbonation process. They've noticed that production inconsistencies occur during different seasons due to factory temperature variations, leading to either flat or over-fizzy drinks. The company is implementing automated monitoring systems that adjust pressure based on real-time temperature readings to maintain product quality year-round.

Task:

As a learner of physics;

(a)Calculate the pressure needed to dissolve 2.5 moles of CO_2 in 0.5 m^3 of water at 25°C ($R = 8.31\ Jmol^{-1}\cdot K$).

(b)Explain why more gas dissolves in liquids at higher pressures.

(c)If the factory temperature rises from 20°C to 35°C, how should the pressure be adjusted to maintain the same gas concentration?

(d)Why do fizzy drinks sometimes spurt when opened on a hot day?

Scenario 129

A tire manufacturing company in Jinja is testing how air pressure in vehicle tires changes with temperature variations experienced on Ugandan roads.Engineers inflate tires to recommended pressures in a controlled environment, then measure pressure changes when tires are exposed to direct sunlight and during high-speed driving. The research aims to develop better tire pressure recommendations for Uganda's diverse climate conditions, from the hot Karamoja region to the cooler highland areas, improving vehicle safety and fuel efficiency.

Task:

As a learner of physics;

(a)A car tire has volume 0.025 m^3 and contains air at 220 kPa and 20°C. Calculate the pressure when the temperature rises to 45°C (volume remains constant).

(b)Explain why tire manufacturers recommend checking pressure when tires are cold.

(c)Calculate the number of air molecules in the tire at 20°C.

(d)How does proper tire pressure affect vehicle fuel efficiency?

Scenario 130

A biogas project in rural Masaka uses animal waste to produce methane for cooking.Engineers monitor how gas pressure in storage tanks changes with temperature throughout the day, affecting gas flow to cooking stoves. Farmers using the system report inconsistent flame quality, especially during early mornings and evenings when temperatures change rapidly. The project team is designing simple insulation methods for storage tanks to maintain more consistent pressure and improve cooking efficiency for the farming families.

Task:

As a learner of physics;

(a)A biogas tank contains 2.0 m^3 of methane at 28°C and 120 kPa. Calculate the volume this gas would occupy at STP (0°C and 101 kPa).

(b)Explain why gas pressure decreases when temperature drops.

(c)If the temperature drops from 30°C to 15°C overnight, calculate the percentage decrease in pressure (volume constant).

(d)Suggest two simple methods to maintain consistent biogas pressure in rural settings.

Sub-topic 12.2: The Kinetic Theory of Gases

Scenario 131

A university physics department in Mbarara is using computer simulations to demonstrate how gas pressure arises from molecular collisions. Students observe virtual particles moving randomly and colliding with container walls, calculating how factors like particle speed and density affect pressure. The visualization helps bridge the gap between abstract theory and observable phenomena, particularly helping students understand why gases exert pressure even though individual molecules are invisible. This approach has improved student performance in thermodynamics examinations and sparked interest in molecular physics research.

Task:

As a learner of physics;

(a)State the basic assumptions of the kinetic theory of gases.

(b)Explain how gas pressure arises from molecular motion.

(c)If the speed of gas molecules doubles while density remains constant, how does pressure change?

(d)Why does the kinetic theory assume molecules have negligible volume?

Scenario 132

An industrial safety company in Kampala is investigating a compressed air tank explosion that occurred at a manufacturing plant.Engineers use kinetic theory to analyze how increased molecular motion at high temperatures and pressures led to the tank failure. The investigation focuses on whether safety valves were properly calibrated and if workers followed temperature monitoring protocols. The findings will inform new safety guidelines for industries using compressed gases across Uganda.

Task:

As a learner of physics;

(a)Derive the expression for pressure exerted by a gas using kinetic theory.

(b)Explain why temperature is a measure of the average kinetic energy of molecules.

(c)Calculate the root mean square speed of oxygen molecules at 27°C (molar mass of O_2 = 0.032kgmol^{-1}).

(d)How does kinetic theory explain the increase in pressure with temperature?

Scenario 133

A research team studying air quality in Kampala's central business district uses kinetic theory to model how pollutants disperse in the atmosphere.Scientists track how vehicle emissions move and mix with air, considering factors like molecular speeds and collision frequencies. The research helps predict pollution hotspots and informs urban planning decisions, particularly important as Kampala experiences rapid urbanization and increasing vehicular traffic affecting air quality and public health.

Task:

As a learner of physics;

(a)Explain why gases mix rapidly despite gravity.

(b)Describe how temperature affects diffusion rates in gases.

(c)If the temperature increases from 20°C to 40°C, how does this affect the average speed of air molecules?

(d)How does kinetic theory explain Graham's law of diffusion?

Scenario 134

A food processing company in Jinja uses nitrogen gas for packaging potato chips to extend shelf life.Quality control technicians apply kinetic theory to understand how oxygen molecules might penetrate packaging materials over time. They test different packaging films and gas mixtures to find the optimal combination that minimizes oxygen entry while keeping production costs affordable for the local market.

Task:

As a learner of physics;

(a)Explain why lighter gases diffuse faster than heavier gases.

(b)Calculate the ratio of diffusion rates between hydrogen and oxygen gases at the same temperature.

(c)How does kinetic theory explain why gases fill their containers?

(d)Why is nitrogen used in food packaging instead of air?

Scenario 135

A renewable energy company is developing advanced solar collectors that use kinetic theory principles to minimize heat loss.Engineers design vacuum-insulated panels where the space between surfaces contains very few gas molecules, reducing conductive heat transfer. The technology could significantly improve solar water heater efficiency, making them more effective during Uganda's cloudy seasons and early morning hours when traditional collectors lose substantial heat.

Task:

As a learner of physics;

(a)Explain how a vacuum reduces heat transfer using kinetic theory.

(b)Describe what happens to gas pressure as molecules are removed from a container.

(c)If 99% of molecules are removed from a container, how does this affect the pressure?

(d)Why is understanding molecular speeds important in vacuum technology?

Sub-topic 12.3: The Behaviour of Real Gases

Scenario 136

A natural gas company developing Uganda's oil and gas resources in the Albertine Graben is studying how real gas behavior differs from ideal gases under high extraction pressures.Engineers use the van der Waals equation to model how intermolecular forces and molecular volume affect gas compressibility at the high pressures found in underground reservoirs. This accurate modeling is essential for estimating recoverable reserves and designing efficient extraction systems that maximize resource utilization while minimizing environmental impact in the ecologically sensitive region.

Task:

As a learner of physics;

(a)State two factors that cause real gases to deviate from ideal behavior.

(b)Write the van der Waals equation and explain the correction terms.

(c)Explain why real gases are more compressible than ideal gases at low temperatures.

(d)Under what conditions do real gases approximate ideal gas behavior?

Scenario 137

A chemical plant in Tororo that produces industrial gases must liquefy nitrogen and oxygen for storage and transport.Engineers carefully control temperature and pressure to achieve liquefaction, considering the real gas behavior through critical constants. The plant supplies medical oxygen to hospitals and nitrogen to food processing companies across eastern Uganda, requiring precise handling to ensure product quality and safety during the liquefaction and storage processes.

Task:

As a learner of physics;

(a)Define critical temperature and explain its significance in gas liquefaction.

(b)Describe what happens to a gas when it is compressed at temperatures above and below its critical temperature.

(c)Why can't a gas be liquefied by pressure alone if the temperature is above critical temperature?

(d)The critical temperature of CO_2 is 31°C. Explain why CO_2 can exist as liquid in fire extinguishers.

Scenario 138

A university chemistry laboratory in Gulu is studying carbon dioxide behavior for environmental science research.Students measure P-V isotherms for CO_2 at different temperatures, observing the liquid-vapor coexistence region and critical point. The experiments help students understand phase diagrams and the conditions under which CO_2 can be stored as liquid or supercritical fluid, knowledge applicable to carbon capture technologies being considered for Uganda's industrial emissions reduction strategies.

Task:

As a learner of physics;

(a)Sketch a typical P-V diagram for a real gas and label the critical point.

(b)Explain what happens in the liquid-vapor coexistence region.

(c)Why does the van der Waals equation give a more accurate description of real gases than the ideal gas equation?

(d)Describe the behavior of a gas at its critical point.

Scenario 139

A refrigeration company in Kampala is designing new cooling systems using alternative refrigerants with minimal environmental impact.Engineers compare real gas properties of different compounds to identify those with suitable critical temperatures and pressures for efficient refrigeration cycles. The research aims to replace older refrigerants that contribute to ozone depletion or global warming, aligning with Uganda's

commitments to international environmental agreements while developing affordable cooling solutions for homes and businesses.

Task:

As a learner of physics;

(a)Explain why intermolecular forces affect real gas behavior.

(b)Describe how real gas behavior influences refrigerator design.

(c)Why do real gases have lower pressures than ideal gases at high densities?

(d)Calculate the van der Waals constants if a gas has critical temperature 150K and critical pressure 50 atm.

Scenario 140

A scuba diving company operating on Lake Victoria must carefully manage air compression for diving tanks,considering real gas effects at high pressures. Dive instructors teach students about how compressed air behaves differently from ideal gas predictions, particularly regarding decompression schedules and safety limits. Understanding these principles is crucial for preventing decompression sickness among recreational and professional divers exploring Uganda's freshwater ecosystems and underwater attractions.

Task:

As a learner of physics;

(a)Explain why real gas corrections are important in scuba diving calculations.

(b)Describe how molecular volume affects gas compressibility at high pressures.

(c)Why do real gases have higher pressures than ideal gases at very high pressures?

(d)How does understanding real gas behavior enhance diving safety?

Topic 13: THERMODYNAMICS

Sub-topic 13.1: Internal Energy of Gas Systems

Scenario 154

A power generation company operating thermal plants along Lake Victoria shoreline is optimizing their energy conversion efficiency.Engineers analyze how the internal energy of steam changes throughout the power generation cycle, from boiler to turbine to condenser. They discovered that better management of internal energy transitions could improve overall plant efficiency by 8%, significantly reducing fuel costs and environmental impact. The company implements new monitoring systems that track internal energy changes in real-time, allowing operators to make adjustments that maximize electricity output while using less fossil fuel, contributing to Uganda's energy sustainability goals.

Task:

As a learner of physics;

(a)Define internal energy and state its components in a gas system.

(b)Explain how the internal energy of an ideal gas differs from that of a real gas.

(c)Calculate the change in internal energy when 2 moles of monatomic ideal gas are heated from 20°C to 80°C.

(d)Why is understanding internal energy important in thermal power generation?

Scenario 142

A university physics department in Mbarara conducts experiments with different gases to demonstrate internal energy concepts.Students use pressurized cylinders of helium, nitrogen, and carbon dioxide, measuring temperature changes during rapid expansion. The experiments show how internal energy depends on molecular structure and temperature, with monatomic gases behaving differently from polyatomic gases. These practical demonstrations help students grasp abstract thermodynamic concepts

and understand why different gases have different applications in industrial and scientific contexts across Uganda.

Task:

As a learner of physics;

(a)Explain why the internal energy of an ideal gas depends only on temperature.

(b)Describe the difference in internal energy between monatomic and diatomic gases at the same temperature.

(c)If the temperature of a gas doubles, what happens to its internal energy?

(d)How does molecular structure affect the internal energy of a gas?

Scenario 143

A manufacturer of compressed gas cylinders in Jinja conducts safety tests to understand how internal energy changes during compression and storage.Quality control technicians measure temperature rises during the filling process and monitor how internal energy dissipates during storage. This research has led to improved filling protocols that prevent overheating and potential cylinder failures, enhancing safety for industries that use compressed gases throughout Uganda, from healthcare to manufacturing sectors.

Task:

As a learner of physics;

(a)Explain why temperature increases when a gas is compressed rapidly.

(b)Describe what happens to the internal energy of a gas during adiabatic compression.

(c)A gas is compressed to half its volume without heat exchange. Does its internal energy increase or decrease? Explain.

(d)Why is understanding internal energy changes important for gas cylinder safety?

Scenario 144

A research institute studying Uganda's geothermal potential in the Albertine Graben monitors how internal energy transforms as hot water and steam move from underground reservoirs to the surface.Scientists analyze how internal energy converts to kinetic energy and eventually to electrical energy in power plants. This research supports the development of Uganda's geothermal energy resources, providing data crucial for designing efficient extraction systems that can supplement hydroelectric power, especially during drought seasons when water levels in dams are low.

Task:

As a learner of physics;

(a)Explain how internal energy is converted to other forms in geothermal power generation.

(b)Describe the relationship between internal energy and enthalpy.

(c)Calculate the internal energy change when 1 kg of water at 100°C vaporizes completely (latent heat of vaporization = 2260 kJ/kg).

(d)How does understanding internal energy contribute to renewable energy development?

Scenario 145

A automotive engineering workshop in Kampala studies how internal energy changes in vehicle engines affect performance and emissions.Mechanics analyze the combustion process where chemical energy converts to internal energy of gases, which then performs work on pistons. The workshop uses this understanding to tune engines for better fuel efficiency and lower emissions, particularly important as Uganda implements stricter vehicle emission standards to address urban air quality issues in rapidly growing cities.

Task:

As a learner of physics;

(a)Explain how internal energy changes during the combustion process in an engine.

(b)Describe the connection between internal energy and engine efficiency.

(c)Why does only part of the internal energy created during combustion become useful work?
(d)How can understanding internal energy help reduce vehicle emissions?

Sub-topic 13.2: The First Law of Thermodynamics

Scenario 146

An industrial plant in Tororo manufacturing ceramic products uses large kilns where precise temperature control is essential for product quality.Engineers apply the first law of thermodynamics to optimize fuel usage while maintaining required temperature profiles throughout the firing process. By carefully tracking heat input, work done, and internal energy changes, they've reduced energy consumption by 20% while improving product consistency. This approach has significant economic benefits for Uganda's growing ceramics industry, making their products more competitive in regional markets while reducing environmental impact through lower fuel consumption.

Task:

As a learner of physics;
(a)State the first law of thermodynamics and write its mathematical expression.
(b)In a kiln firing process, 500 kJ of heat is supplied to clay, and it does 150 kJ of work in expanding. Calculate the change in internal energy.
(c)Explain how the first law applies to energy conservation in industrial processes.
(d)Why is the first law considered a statement of energy conservation?

Scenario 147

A hospital in Gulu uses oxygen concentrators that operate on thermodynamic principles to provide medical oxygen for patients with respiratory conditions.Technicians maintain these machines by understanding how gas compression and expansion cycles follow the first law of thermodynamics. The reliable operation of this equipment is crucial for patient care, especially in remote regions where cylinder oxygen supply is unpredictable. Hospital engineers have trained local technicians in basic maintenance using thermodynamic principles, ensuring equipment availability when needed most.

Task:

As a learner of physics;
(a)In an oxygen concentrator, 300 J of work is done on the gas, and it releases 100 J of heat to the surroundings. What is the change in its internal energy?
(b)Explain the sign convention for heat and work in the first law equation.
(c)Describe a real-world application of the first law in medical equipment.
(d)How does understanding the first law help in maintaining medical devices?

Scenario 148

A research project at Makerere University studies traditional cooking methods used in rural Uganda from a thermodynamics perspective. Students analyze how much of the heat energy from firewood actually transfers to cooking pots versus being lost to the environment. The research has led to designs for improved cookstoves that better apply the first law of thermodynamics, significantly reducing fuelwood consumption and indoor air pollution in households across Uganda, particularly benefiting women and children who spend most time near cooking areas.

Task:

As a learner of physics;
(a)In a cooking process, 2000 J of heat is supplied to a pot, and the food's internal energy increases by 1500 J. Calculate the work done.
(b)Explain how the first law applies to everyday activities like cooking.
(c)Why are improved cookstoves more efficient than traditional three-stone fires?
(d)How can understanding the first law address energy poverty in rural areas?

Scenario 149

A automotive engineering company in Kampala uses the first law of thermodynamics to analyze and improve engine performance in vehicles adapted for Ugandan road conditions.Engineers measure how efficiently internal combustion engines convert fuel energy into useful work versus losses to cooling systems and exhaust. This analysis has led to modifications that improve fuel economy by 15% in vehicles operating in Uganda's diverse terrain, from mountainous regions to urban stop-start traffic conditions, reducing transportation costs for businesses and individuals.

Task:

As a learner of physics;

(a)In a car engine, the fuel releases 1000 J of energy, the engine does 350 J of useful work, and 600 J is lost as heat. Account for the remaining 50 J using the first law.

(b)Explain why no heat engine can be 100% efficient.

(c)Calculate the efficiency of the engine described in part (a).

(d)How does the first law help in improving vehicle fuel efficiency?

Scenario 150

A renewable energy company installs solar water heaters across Uganda and uses thermodynamic principles to optimize their performance.Technicians analyze how solar energy input relates to water temperature increases and system losses. By applying the first law to balance energy gains and losses, they've improved system designs to provide reliable hot water even during cloudy periods, making solar technology more practical for Ugandan households and reducing reliance on electricity and wood fuel for water heating needs.

Task:

As a learner of physics;

(a)A solar water heater absorbs 5000 J of solar energy, and the water's internal energy increases by 4200 J. Calculate the heat loss to the surroundings.

(b)Explain how insulation affects the application of the first law in solar heaters.

(c)Describe how the first law applies to renewable energy systems.

(d)Why is understanding thermodynamics important for sustainable development?

Topic 14: REFLECTION OF LIGHT

Sub-topic 14.1: Reflection at Plane Surfaces

Scenario 151

A regional hospital in Fort Portal is redesigning its outpatient examination rooms to improve natural lighting and patient comfort.Architects are using principles of reflection at plane surfaces to position large mirrors that can redirect sunlight into darker areas of the room without causing glare. They need to calculate precise angles of incidence and reflection to ensure optimal illumination throughout the day as the sun's position changes. The design must also consider seasonal variations in sun path and the specific architectural constraints of the existing hospital building. This innovative approach aims to reduce electricity consumption for lighting while creating a more healing environment for patients, particularly in the pediatric and recovery wards where natural light has been shown to improve patient outcomes and reduce hospital stay duration.

Task:

As a learner of physics;

(a)State the two laws of reflection at plane surfaces.

(b)A light ray strikes a plane mirror at an angle of 30° to the normal. Calculate the angle between the incident and reflected rays.

(c)Explain why multiple images are formed when two plane mirrors are placed at an angle to each other.

(d)Describe one practical application of plane mirrors in medical facilities.

Scenario 152

A security company in Kampala is installing surveillance systems in shopping malls using multiple plane mirrors to eliminate blind spots in corridors and parking areas. Engineers must calculate the exact placement of mirrors to ensure complete coverage while maintaining clear images. The system design must account for the minimum mirror size needed to view entire areas and the optimal angles to prevent image distortion. This comprehensive approach has significantly improved security in public spaces, reducing incidents of theft and providing clearer evidence for investigations when needed.

Task:

As a learner of physics;

(a)Explain why the image formed by a plane mirror is always virtual and erect.

(b)A person 1.8 m tall stands 2 m from a plane mirror. Calculate the minimum height of mirror required for the person to see their full image.

(c)Describe the characteristics of images formed by plane mirrors.

(d)Why are plane mirrors preferred over curved mirrors for security surveillance in some applications?

Scenario 153

A traditional dance troupe in Busoga region uses strategically placed plane mirrors during rehearsals to help dancers monitor their formations and synchronize their movements.The choreographer positions mirrors at specific angles to allow dancers to see both their own reflections and those of other performers without turning their heads. This technique has improved the precision of traditional dances performed during cultural festivals and tourist events, preserving Uganda's cultural heritage while enhancing performance quality.

Task:

As a learner of physics;

(a)Two plane mirrors are inclined at 60° to each other. Calculate the number of images formed of an object placed between them.

(b)Explain the concept of lateral inversion in plane mirrors.

(c)A dancer moves towards a plane mirror at 2 ms^{-1}. Calculate the speed at which their image approaches them.

(d)How does understanding reflection help in performing arts?

Scenario 154

An automotive repair workshop in Mbale uses plane mirrors mounted on extendable poles to inspect hard-to-reach areas of vehicle undersides.Mechanics must understand reflection principles to interpret the mirrored images accurately when diagnosing exhaust system problems, brake line issues, or structural damage. This method has reduced inspection time by 40% and improved diagnostic accuracy, particularly for complex repairs on public service vehicles that operate on Uganda's rough rural roads.

Task:

As a learner of physics;

(a)Explain why the image in a plane mirror appears to be as far behind the mirror as the object is in front.

(b)A mechanic uses a mirror to read a serial number that is 50 cm from the mirror. How far from the mirror does the image appear to be?

(c)Describe how mirrors help in inspecting inaccessible areas.

(d)Why is understanding image formation important in automotive repair?

Scenario 155

A physics teacher in Gulu demonstrates the principle of periscopes using simple plane mirrors to students interested in optical instruments.Students construct basic periscopes from cardboard tubes and mirrors to understand how reflection enables seeing over obstacles. This hands-on activity helps students grasp

practical applications of reflection principles while developing skills that could be useful in fields like construction, wildlife observation, and security services in Uganda's diverse environments.

Task:

As a learner of physics;

(a)Describe the arrangement of mirrors in a simple periscope.

(b)Explain how a periscope uses the laws of reflection to enable viewing over obstacles.

(c)Calculate the minimum length of a periscope needed to see over a 1.5 m wall if the observer's eye is 1.2 m above ground.

(d)Design a simple periscope using locally available materials.

Sub-topic 14.2: Reflection at Curved Surfaces

Scenario 156

A solar energy company in Soroti is developing parabolic solar cookers that use curved reflective surfaces to concentrate sunlight onto cooking pots.Engineers must calculate the focal lengths of different parabolic designs to achieve optimal temperature for cooking while ensuring safety. The research aims to create affordable solar cooking solutions for rural households, reducing dependence on firewood and addressing deforestation issues in Uganda's dry regions. Field tests show that properly designed parabolic cookers can reach temperatures sufficient for boiling water and cooking staple foods within minutes during sunny days.

Task:

As a learner of physics;

(a)Define the principal focus and focal length of a concave mirror.

(b)A concave mirror has a radius of curvature of 40 cm. Calculate its focal length.

(c)Explain why parabolic mirrors are used in solar concentrators rather than spherical mirrors.

(d)Describe one safety precaution needed when using curved mirrors for solar cooking.

Scenario 157

An optometry clinic in Kampala uses concave mirrors in ophthalmoscopes to examine the interior of patients'eyes. Optometrists must understand how curved mirrors form images to correctly interpret what they see during retinal examinations. The precise use of these instruments helps in early detection of eye diseases like glaucoma and diabetic retinopathy, which are becoming more prevalent in Uganda's aging population and among people with changing lifestyle diseases.

Task:

As a learner of physics;

(a)An object is placed 30 cm from a concave mirror of focal length 15 cm. Calculate the image position.

(b)Describe the nature of the image formed in part (a).

(c)Explain why concave mirrors are used in medical instruments for examining body cavities.

(d)What would be the effect on the image if the object is moved closer to the mirror than the focal point?

Scenario 158

A vehicle manufacturing plant in Jinja uses convex mirrors as side-view mirrors in their buses and trucks.Engineers must determine the appropriate curvature to provide the widest possible field of view while maintaining usable image size. This design consideration is particularly important for public service vehicles operating on Uganda's busy roads, where improved visibility can prevent accidents and enhance road safety for all users.

Task:

As a learner of physics;

(a)Explain why convex mirrors are used as rear-view mirrors in vehicles.

(b)A convex mirror has a focal length of 20 cm. An object is placed 30 cm from the mirror. Calculate the image position.
(c)Compare the images formed by concave and convex mirrors.
(d)Why do convex mirrors show a wider field of view than plane mirrors of the same size?

Scenario 159

A beauty salon in Entebbe uses concave mirrors for precise facial treatments and makeup application.Stylists need to understand how image magnification works at different distances to provide the best service to clients. The salon has trained its staff in basic optics to help them choose the right mirror positions for different beauty procedures, enhancing customer satisfaction and service quality in Uganda's growing beauty industry.

Task:

As a learner of physics;
(a)An object is placed 10 cm from a concave mirror of focal length 15 cm. Calculate the magnification.
(b)Explain what happens to the image when an object is placed between the focus and pole of a concave mirror.
(c)Describe one practical use of concave mirrors in daily life.
(d)Why are concave mirrors sometimes called "converging mirrors"?

Scenario 160

A physics laboratory at Makerere University is studying image formation using curved mirrors of different radii.Students investigate how object position affects image characteristics in both concave and convex mirrors. The experiments help students understand real-world applications of curved mirrors, from astronomical telescopes to security systems, preparing them for careers in Uganda's developing technology sector where optical principles are increasingly important.

Task:

As a learner of physics;
(a)Derive the mirror formula for curved mirrors.
(b)An object 4 cm tall is placed 20 cm from a concave mirror of focal length 12 cm. Calculate the image height.
(c)Explain the difference between real and virtual images with reference to curved mirrors.
(d)Design an experiment to determine the focal length of a concave mirror.

Topic 15: REFRACTION OF LIGHT

Sub-topic 15.1: Refraction at Plane Surfaces

Scenario 161

The National Water and Sewerage Corporation is investigating apparent depth phenomena in Uganda's water bodies to improve safety measures around lakes and rivers.Engineers are studying how refraction at the air-water interface makes objects in water appear closer than they actually are, which has contributed to several drowning incidents where rescuers misjudged distances. The research team uses precise angle measurements and refractive indices to calculate actual depths versus apparent depths, developing educational materials for communities living near water bodies. This initiative aims to reduce water-related accidents, particularly in fishing communities around Lake Victoria and the Nile River, by helping people better understand optical illusions created by light refraction.

Task:

As a learner of physics;
(a)State Snell's Law of refraction and define refractive index.
(b)Calculate the angle of refraction when light enters water from air at an angle of incidence of 40° (refractive index of water = 1.33).

(c)Explain why a swimming pool appears shallower than it actually is.
(d)A fish is 2 meters below the water surface. Calculate its apparent depth as viewed from directly above.

Scenario 162

A gemstone mining company in Karamoja is training geologists to identify different minerals using refraction principles.Technicians measure how light bends when passing through various gemstones to determine their refractive indices, which serves as a key identification property. This non-destructive testing method helps distinguish between similar-looking stones like quartz, tourmaline, and sapphire, ensuring proper valuation of Uganda's mineral resources. The company has developed a mobile refraction testing kit that field geologists can use at mining sites, improving the efficiency of gemstone identification and reducing misidentification errors that previously led to significant financial losses.

Task:

As a learner of physics;
(a)Define critical angle and calculate it for the water-air boundary (n_water = 1.33).
(b)Explain why different materials have different refractive indices.
(c)A light ray passes from glass (n=1.5) to water (n=1.33). Calculate the angle of refraction if the angle of incidence is 30°.
(d)How does understanding refraction help in mineral identification?

Scenario 163

An optical fiber installation company in Kampala is deploying internet infrastructure using principles of refraction and total internal reflection.Engineers must calculate the minimum angle for light to remain trapped within the fiber cores, ensuring efficient data transmission over long distances. This technology is crucial for expanding Uganda's digital infrastructure to rural areas, where traditional copper cables are impractical. The proper understanding of refraction has enabled the company to design networks that minimize signal loss, bringing reliable internet access to schools, hospitals, and businesses across previously underserved regions.

Task:

As a learner of physics;
(a)Explain the conditions necessary for total internal reflection to occur.
(b)An optical fiber has a core refractive index of 1.48 and cladding index of 1.46. Calculate the critical angle for light guidance.
(c)Describe how total internal reflection is utilized in optical fibers.
(d)Why is refraction important in telecommunications technology?

Scenario 164

A wildlife conservation organization in Queen Elizabeth National Park uses underwater cameras to study aquatic life.Researchers must account for refraction effects when estimating the positions and sizes of fish and other aquatic organisms. The team has developed correction algorithms based on refraction principles to accurately interpret their footage, leading to more reliable population estimates and better understanding of underwater ecosystems. This approach has improved the management of Uganda's aquatic resources and helped protect endangered species in their natural habitats.

Task:

As a learner of physics;
(a)A light ray passes from water to air. If the angle of incidence is 30°, calculate the angle of refraction.
(b)Explain why objects underwater appear larger than they actually are.
(c)Describe how a prism disperses white light into its constituent colors.
(d)How does understanding refraction improve biological research?

Scenario 165

A traditional fishing community on Lake Kyoga uses their understanding of refraction to improve fishing techniques.Elder fishermen teach younger generations how to account for the apparent position of fish when spearfishing, demonstrating how to aim slightly below where the fish appears to be. This traditional knowledge, now explained through refraction principles, has maintained its relevance alongside modern fishing technologies. The community has collaborated with local schools to integrate this practical physics application into science education, bridging indigenous knowledge with formal learning.

Task:

As a learner of physics;

(a)Derive the relationship between real depth, apparent depth, and refractive index.

(b)A fisherman sees a fish that appears to be 1 meter below the water surface. If the refractive index of water is 1.33, calculate the actual depth of the fish.

(c)Explain why the fisherman must aim below the apparent position of the fish to spear it successfully.

(d)How can traditional knowledge enhance the understanding of scientific principles?

Sub-topic 15.2: Critical Angle and Total Internal Reflection

Scenario 166

A medical equipment company in Kampala is developing endoscopic instruments for minimally invasive surgeries using total internal reflection principles.Engineers design fiber optic bundles that allow surgeons to see and operate inside the human body through small incisions. The precise calculation of critical angles ensures that light travels efficiently through the fibers, providing clear illumination and visualization during procedures. This technology has revolutionized surgical practices in Ugandan hospitals, reducing recovery times and improving patient outcomes, particularly in gastrointestinal and orthopedic surgeries where traditional open procedures carried higher risks.

Task:

As a learner of physics;

(a)Define critical angle and state the conditions for total internal reflection.

(b)Calculate the critical angle for a glass-air interface ($n_g = 1.5$).

(c)Explain why total internal reflection is preferred over mirrored surfaces in medical endoscopes.

(d)Describe one medical application of total internal reflection.

Scenario 167

A telecommunications company is installing undersea fiber optic cables along Lake Victoria to connect island communities to the mainland internet infrastructure.Engineers must ensure that the cables maintain total internal reflection despite temperature variations and pressure changes at different depths. The project aims to bridge the digital divide for fishing communities on islands like Buvuma and Ssese, where reliable internet access can transform education, healthcare, and economic opportunities. Proper understanding of critical angles has enabled the design of cables that minimize signal loss across these underwater routes.

Task:

As a learner of physics;

(a)A fiber optic cable has a core refractive index of 1.62 and cladding index of 1.52. Calculate the numerical aperture.

(b)Explain how temperature changes might affect total internal reflection in optical fibers.

(c)Describe the advantages of fiber optic communication over traditional copper wires.

(d)Why is understanding critical angle important in telecommunications?

Scenario 168

A physics education project in rural schools uses simple experiments with water tanks and lasers to demonstrate total internal reflection.Students observe how light can be "piped" through streams of water, understanding the principle behind fiber optics. This hands-on approach makes abstract concepts tangible for students in areas with limited laboratory equipment, inspiring interest in physics and potential careers in Uganda's growing technology sector. The project has successfully increased physics enrollment in participating schools by demonstrating practical applications of classroom theory.

Task:

As a learner of physics;

(a)Describe an experiment to demonstrate total internal reflection using a semi-circular glass block.

(b)Explain why light undergoes total internal reflection in a water stream.

(c)Calculate the critical angle for a diamond-air interface ($n_d = 2.42$).

(d)How does understanding total internal reflection benefit technology education?

Scenario 169

A automotive company manufacturing vehicles for Ugandan roads uses prisms in periscopes and optical instruments based on total internal reflection.Engineers design these components to provide clear vision in various lighting conditions encountered across Uganda's diverse geography, from bright sunny days in Karamoja to misty conditions in the Rwenzori Mountains. The precise understanding of critical angles ensures these optical systems perform reliably, enhancing safety for drivers operating in challenging environments.

Task:

As a learner of physics;

(a)Explain how a right-angled prism can act as a perfect reflector.

(b)Calculate the critical angle for an interface between glass (n =1.5) and water (n =1.33).

(c)Describe the use of prisms in binoculars and periscopes.

(d)Why are prisms sometimes preferred over mirrors in optical instruments?

Scenario 170

A jewelry designer in Kampala creates pieces that use total internal reflection to enhance the brilliance of gemstones.By cutting facets at precise angles relative to the critical angle, the designer maximizes light reflection within stones, making them appear more sparkling and valuable. This application of physics principles has elevated the quality of Ugandan gemstone jewelry, increasing its appeal in both local and international markets and supporting the growth of Uganda's creative industry.

Task:

As a learner of physics;

(a)Explain how the critical angle affects the brilliance of a gemstone.

(b)A gemstone has refractive index 1.77. Calculate its critical angle with air.

(c)Describe how jewelers use physics principles to enhance gemstone appearance.

(d)Why does a properly cut diamond appear more brilliant than a glass imitation?

Sub-topic 15.3: Refraction Through Lenses

Scenario 171

An eye clinic in Kampala conducts vision screening camps across Uganda,using lenses of different powers to correct various refractive errors. Optometrists apply lens formula principles to determine the appropriate spectacles for patients with myopia, hypermetropia, and presbyopia. The mobile clinics have significantly improved access to vision care in rural areas, where untreated vision problems often limit educational and economic opportunities. By training local health workers in basic refraction techniques,

the program has created sustainable vision care services in communities previously lacking optical services.

Task:

As a learner of physics;

(a)State the lens maker's formula and define each term.

(b)A converging lens has a focal length of 20 cm. An object is placed 30 cm from the lens. Calculate the image position.

(c)Explain how converging lenses correct hypermetropia (long-sightedness).

(d)Describe the nature of the image formed by a simple magnifying glass.

Scenario 172

A photography company specializing in Ugandan wildlife uses various lenses to capture animals in their natural habitats.Photographers must understand how lens properties affect image characteristics when shooting in challenging conditions like dense forests or open savannas. The company trains guides in basic optics to help clients choose appropriate lenses for different photographic situations, enhancing Uganda's growing wildlife tourism industry. This knowledge has resulted in better wildlife documentation and more satisfied tourists, supporting conservation efforts through photography.

Task:

As a learner of physics;

(a)Explain the difference between convex and concave lenses.

(b)A concave lens has a focal length of 15 cm. An object is placed 30 cm from the lens. Calculate the image position.

(c)Describe how lens power is related to focal length.

(d)Why do photographers use different lenses for different types of photography?

Scenario 173

A university physics department studies lens aberrations to improve optical instruments used in Ugandan research facilities.Students investigate spherical and chromatic aberrations in simple lenses and learn correction methods using lens combinations. This research supports the development of better microscopes for medical laboratories and telescopes for astronomical observation, enhancing Uganda's scientific capabilities. Understanding these principles has enabled local technicians to maintain and repair optical equipment that would otherwise require expensive international expertise.

Task:

As a learner of physics;

(a)Define spherical aberration and chromatic aberration in lenses.

(b)Explain how combining lenses of different materials reduces chromatic aberration.

(c)Calculate the power of a lens with focal length 25 cm.

(d)Why is understanding lens aberrations important in scientific research?

Scenario 174

A renewable energy project uses Fresnel lenses to concentrate sunlight for solar cooking and water purification in refugee settlements.Engineers design these large, thin lenses that apply refraction principles to focus solar energy efficiently. The technology provides sustainable energy solutions in areas with limited infrastructure, reducing dependence on firewood and improving living conditions. The project has trained refugees in lens maintenance and basic optics, creating skills that can be utilized beyond their current situation.

Task:

As a learner of physics;

(a)Explain how a converging lens focuses parallel light rays to a point.

(b)Describe the principle behind Fresnel lenses.

(c)A lens forms an image twice the size of the object. If the object is 15 cm from the lens, calculate the focal length.
(d)How can lens technology address energy challenges in humanitarian settings?

Scenario 175

A traditional craftsman in Buganda creates optical devices using locally available materials,applying principles of refraction through lenses. He makes simple telescopes and microscopes that demonstrate optical principles while serving practical purposes in communities with limited access to commercial scientific equipment. This initiative preserves indigenous knowledge while promoting scientific literacy, showing how traditional craftsmanship can interface with modern physics understanding to create educational tools relevant to Ugandan contexts.

Task:

As a learner of physics;
(a)Derive the thin lens formula for a converging lens.
(b)An object 2 cm tall is placed 20 cm from a converging lens of focal length 15 cm. Calculate the image height.
(c)Describe how a simple microscope works using a single converging lens.
(d)How can local craftsmanship contribute to science education in resource-limited settings?

Topic 16: OPTICAL INSTRUMENTS

Sub-topic 16.1: Microscopes

Scenario 176

A medical research laboratory in Kampala is studying malaria parasites using compound microscopes.The laboratory technicians need to understand the principles of microscope operation to accurately identify different Plasmodium species in blood samples. They work with lenses of various focal lengths to achieve the necessary magnification for detecting early-stage parasites. The laboratory serves as a reference center for malaria diagnosis in Uganda, supporting health centers across the country. Their accurate microscopy work directly impacts treatment decisions for thousands of malaria patients annually, making the understanding of optical principles crucial for proper diagnosis and effective disease management in Uganda's ongoing fight against malaria.

Task:

As a learner of physics;
(a)Explain the principle of operation of a compound microscope.
(b)A compound microscope has an objective lens of focal length 2 cm and an eyepiece of focal length 5 cm. The tubes length is 20 cm. Calculate the magnifying power when the final image is at infinity.
(c)Describe the function of the objective lens and eyepiece in a compound microscope.
(d)Why is proper illumination important in microscopy?

Scenario 177

A university biology department in Mbarara is conducting research on soil microorganisms using advanced microscopy techniques.Students learn to calculate resolving power and understand how it affects their ability to distinguish between different bacterial species. The research focuses on identifying beneficial microorganisms that could improve agricultural productivity in Uganda's farming regions. By applying principles of wave optics to microscope design, students gain insights into the limitations and capabilities of their instruments, leading to more accurate scientific observations and conclusions in their agricultural microbiology research.

Task:

As a learner of physics;
(a)Define the terms 'magnification' and 'resolving power' in microscopy.

(b)Explain how oil immersion objectives improve the resolution of microscopes.
(c)Calculate the magnifying power of a simple microscope with focal length 5 cm when the image is at the near point (25 cm).
(d)How does understanding microscope optics contribute to biological research?

Scenario 178

A mobile medical clinic operating in rural Uganda uses portable microscopes for field diagnosis of various diseases.Health workers need to maintain and calibrate these instruments under challenging field conditions. Understanding the optical principles allows them to troubleshoot common problems like fogged lenses, misalignment, and illumination issues. This knowledge has significantly improved the reliability of field diagnostics in remote areas, enabling timely treatment of diseases like tuberculosis, malaria, and various parasitic infections that affect rural communities with limited access to healthcare facilities.

Task:

As a learner of physics;
(a)Describe the optical arrangement in a compound microscope with a ray diagram.
(b)Explain why the objective lens of a microscope has a very short focal length.
(c)A microscope produces a final image 30 cm from the eyepiece. If the eyepiece has focal length 2.5 cm, calculate its magnification.
(d)Why is portability an important consideration for medical equipment in rural areas?

Scenario 179

A quality control laboratory in a Jinja-based pharmaceutical company uses microscopes to inspect drug formulations and check for contaminants.Technicians apply their understanding of depth of field and focus to examine particles in suspension and identify impurities in medications. This careful optical inspection complements chemical analysis in ensuring that drugs manufactured in Uganda meet international quality standards. The company's commitment to quality control has enabled it to export medications to other East African countries, contributing to Uganda's pharmaceutical industry development.

Task:

As a learner of physics;
(a)Explain how adjusting the microscope's condenser affects image quality.
(b)Describe what is meant by 'empty magnification' in microscopy.
(c)A microscope objective has a numerical aperture of 0.65. Calculate its resolving power for green light of wavelength 550 nm.
(d)How does microscopy contribute to pharmaceutical quality control?

Scenario 180

A traditional medicine research center in Uganda is documenting medicinal plants using microscopic analysis of plant tissues.Researchers combine indigenous knowledge with modern optical techniques to study the cellular structures of plants used in traditional healing. This interdisciplinary approach has led to the scientific validation of several traditional remedies while maintaining respect for cultural heritage. The center trains traditional healers in basic microscopy, creating bridges between different knowledge systems and promoting the sustainable use of Uganda's rich biodiversity.

Task:

As a learner of physics;
(a)Derive the expression for the magnifying power of a compound microscope.
(b)Explain how the numerical aperture affects the performance of a microscope.
(c)Design a simple microscope using easily available materials.
(d)How can traditional knowledge and modern optical technology work together?

Sub-topic 16.2: Telescopes

Scenario 181

The Uganda Astronomical Society is establishing a public observatory near Entebbe to promote interest in space science.The facility uses refracting telescopes that apply principles of geometrical optics to observe celestial objects. Volunteers learn to calculate magnification and light-gathering power to optimize observations of planets, stars, and deep-sky objects visible from Uganda's equatorial location. The observatory serves as an educational resource for schools and universities, inspiring the next generation of Ugandan astronomers and physicists while providing a unique recreational activity for the public.

Task:

As a learner of physics;

(a)Explain the principle of operation of an astronomical refracting telescope.

(b)A telescope has an objective of focal length 100 cm and an eyepiece of focal length 5 cm. Calculate the magnifying power when the final image is at infinity.

(c)Describe the difference between an astronomical telescope and a terrestrial telescope.

(d)Why are large aperture objectives preferred in astronomical telescopes?

Scenario 182

A wildlife conservation organization in Queen Elizabeth National Park uses spotting telescopes for animal monitoring and anti-poaching activities.Rangers apply their understanding of telescope optics to identify animals at long distances and observe their behavior without disturbance. The proper use of optical instruments has enhanced conservation efforts by enabling more accurate population counts and quicker response to potential threats. This application of physics supports Uganda's successful wildlife management programs that balance conservation with tourism development.

Task:

As a learner of physics;

(a)Explain why the objective lens of a telescope has a long focal length.

(b)A telescope has magnifying power 20x. If the focal length of the eyepiece is 2 cm, calculate the focal length of the objective.

(c)Describe how image brightness is related to telescope aperture.

(d)How does optical technology support wildlife conservation efforts?

Scenario 183

A maritime safety agency on Lake Victoria uses telescopic instruments for navigation and search-and-rescue operations.Officers need to understand the optical principles behind their equipment to maximize effectiveness during emergencies. The agency has implemented training programs that combine theoretical optics with practical exercises, improving response times and success rates in water rescues. This application of telescope technology has saved numerous lives on East Africa's largest lake, where changing weather conditions can quickly create dangerous situations for boat operators.

Task:

As a learner of physics;

(a)Draw a ray diagram for an astronomical telescope in normal adjustment.

(b)Explain what is meant by 'normal adjustment' of a telescope.

(c)Calculate the length of a telescope in normal adjustment if the objective and eyepiece have focal lengths 50 cm and 5 cm respectively.

(d)Why is understanding telescope optics important for maritime safety?

Scenario 184

An education project in rural Uganda uses simple telescope-making kits to teach optics principles.Students build basic refracting telescopes from cardboard tubes and inexpensive lenses,

learning about focal lengths and magnification through hands-on experience. This practical approach has increased student engagement with physics in areas with limited educational resources, demonstrating that complex optical principles can be understood and applied with locally available materials. Several participants have pursued further studies in optics and technology fields as a result of this early exposure.

Task:

As a learner of physics;

(a)Describe the two main functions of a telescope objective.

(b)Explain why chromatic aberration is a problem in refracting telescopes.

(c)Design a simple refracting telescope using specified lenses.

(d)How can hands-on projects enhance science education in resource-limited settings?

Scenario 185

A survey company working on Uganda's infrastructure projects uses telescopic instruments for precise measurement and alignment.Engineers apply their knowledge of telescope optics to ensure accuracy in construction projects ranging from road building to dam construction. The company has developed specialized training that combines optical theory with practical surveying techniques, creating skilled technicians who can work on Uganda's major development projects. This expertise supports the country's infrastructure development while providing employment opportunities for technically skilled workers.

Task:

(a)Derive the expression for the magnifying power of a telescope.

(b)Explain how telescopic sights are used in surveying instruments.

(c)A telescope objective has diameter 10 cm. Calculate its light-gathering power relative to the human eye (pupil diameter 0.5 cm).

(d)How does optical technology contribute to national development projects?

Topic 17: ELECTROSTATICS

Sub-topic 17.1: Production of Charge

Scenario 186

A printing press in Kampala specializes in high-quality magazine production but faces persistent problems with paper jams and ink smudging during the dry season.The technicians trace the issue to static electricity, as paper sheets moving rapidly through rollers acquire significant electrostatic charges. This causes them to cling to machinery or to each other, disrupting the automated process. The company consults a physics expert who explains the triboelectric effect and recommends installing ionizing bars and maintaining higher humidity in the press room. Implementing these changes based on electrostatic principles has reduced downtime by 30% and improved print quality, demonstrating the importance of understanding charge production in industrial applications.

Task:

As a learner of physics;

(a)Explain the triboelectric effect and how it causes paper to become charged in a printing press.

(b)Describe two methods by which static charge can be produced.

(c)If a polythene rod becomes negatively charged after being rubbed with wool, what charge does the wool acquire? Explain using the law of charge conservation.

(d)Suggest two practical ways to dissipate unwanted static charge in an industrial setting.

Scenario 187

A petrochemical storage facility in the Lake Albert region has implemented strict electrostatic safety protocols after a near-miss incident during fuel transfer.Engineers explain that as hydrocarbon fuels flow through pipes, they can generate static electricity through friction, creating a spark hazard that could ignite flammable vapors. All personnel are now trained in proper grounding and bonding procedures

before any transfer operation. The facility has also installed static dissipaters in storage tanks and requires special footwear and clothing for workers. This comprehensive approach has significantly enhanced operational safety at the facility, protecting both workers and Uganda's valuable petroleum resources.

Task:

As a learner of physics;

(a)Explain how flowing liquids can generate static electricity.

(b)Describe the principle of electrostatic induction.

(c)Why is it dangerous to pump flammable liquids without proper grounding?

(d)A worker wears shoes with insulating soles while handling fuel containers. What risk does this create and how can it be mitigated?

Scenario 188

A physics teacher at a secondary school in Gulu uses simple experiments to demonstrate electrostatic principles.Students rub various materials like glass rods with silk and plastic rods with fur, then use a gold-leaf electroscope to detect and characterize the charges produced. Through these activities, students learn about charge conservation, conduction, and induction. The teacher emphasizes real-world applications, from photocopiers to electrostatic precipitators in industrial smoke stacks, showing how foundational electrostatic concepts underpin important technologies used in Uganda's development.

Task:

As a learner of physics;

(a)Describe how a gold-leaf electroscope works to detect charge.

(b)Explain the difference between charging by conduction and charging by induction.

(c)A charged rod is brought near the cap of an uncharged electroscope and the leaves diverge. What can you conclude about the charge on the rod?

(d)Design a simple experiment to show that there are two types of electric charge.

Scenario 189

A textile factory in Jinja experiences problems with cloth fibers repelling each other during weaving, causing production defects. The issue is particularly severe during Uganda's dry seasons when humidity is low. Factory engineers install static elimination equipment that uses radioactive sources or electrical ionizers to neutralize charges on synthetic fabrics. They also implement humidity control measures in the production areas. Understanding electrostatic principles has enabled the factory to maintain consistent product quality throughout the year, supporting Uganda's growing textile industry and its export markets.

Task:

As a learner of physics;

(a)Explain why synthetic materials are particularly prone to developing static charges.

(b)Describe how humidity affects static electricity accumulation.

(c)Why do like charges repel and unlike charges attract?

(d)Suggest two methods to reduce static electricity problems in a textile factory.

Scenario 190

A meteorological research station on Mount Elgon studies atmospheric electricity, particularly during thunderstorms common in the region. Scientists use specialized equipment to measure electrostatic fields in the atmosphere and correlate them with weather patterns. Their research helps improve lightning prediction models, which is valuable for aviation safety and for protecting isolated communities in mountainous areas. The station also educates local communities about lightning safety, using principles of electrostatics to explain why certain locations and activities are particularly dangerous during thunderstorms.

Task:

As a learner of physics;

(a)Explain how thunderclouds become electrically charged.
(b)Describe the process by which lightning occurs between a cloud and the ground.
(c)Why are tall objects and open areas particularly vulnerable to lightning strikes?
(d)What safety precautions should people take during a thunderstorm based on electrostatic principles?

Sub-topic 17.2: Electrostatic Force
Scenario 191
A research laboratory at Makerere University is using an updated version of Coulomb's torsion balance experiment to precisely measure electrostatic forces.Physics students set up the apparatus with small charged spheres and measure the force between them at varying distances. Their careful measurements verify the inverse-square law relationship that Coulomb first established. This hands-on experience helps students appreciate the foundational nature of Coulomb's work, which underpins much of modern electrical science and technology. The laboratory exercise also highlights the challenges of making precise physical measurements and the importance of controlling variables in experimental physics.
Task:
As a learner of physics;
(a)State Coulomb's Law in both words and mathematical form.
(b)Two point charges of +2 μC and +3 μC are placed 0.1 m apart in air. Calculate the electrostatic force between them.
(c)If the distance between the two charges in part (b) is doubled, what happens to the force between them?
(d)Explain why Coulomb's Law is described as an inverse-square law.
Scenario 192
An industrial process at a cement factory in Tororo uses electrostatic forces to remove dust particles from exhaust gases.Engineers design plates with high voltage differences that create strong electric fields, causing dust particles to become charged and migrate toward collection plates. This electrostatic precipitation technology helps the factory meet Uganda's environmental standards by significantly reducing particulate emissions. The plant technicians must regularly maintain the system and understand the relationship between voltage, plate separation, and the resulting electrostatic forces to ensure optimal performance of the pollution control equipment.
Task:
As a learner of physics;
(a)Explain how an electrostatic precipitator uses Coulomb forces to remove dust from air.
(b)Two parallel plates have a potential difference of 10 kV and are separated by 5 cm. Calculate the electric field strength between them.
(c)How does the electrostatic force on a charged particle depend on the electric field strength?
(d)Why is electrostatic precipitation an effective method for controlling industrial air pollution?
Scenario 193
A technology company in Kampala is developing an electrostatic sorting system for separating different types of plastic waste for recycling.The system uses the fact that different plastics acquire different charges when rubbed, allowing them to be separated by electrostatic forces. This technology could significantly improve Uganda's waste management capabilities, particularly for dealing with the growing problem of plastic pollution. Understanding the relationship between material properties and electrostatic behavior is crucial for optimizing the sorting process and making plastic recycling more economically viable in the Ugandan context.
Task:
As a learner of physics;

(a)Explain how electrostatic forces can be used to separate different materials.
(b)Two identical spheres with charges +5 μC and -3 μC are brought into contact and then separated. What is the final charge on each sphere?
(c)Calculate the force between two charges of +4 μC and -6 μC placed 15 cm apart in air.
(d)Why is electrostatic separation particularly useful for recycling certain materials?

Scenario 194

A physics education initiative uses simple experiments to help students visualize electrostatic forces.Students charge small suspended pith balls and observe how the distance between them affects the repulsive force. They also explore how introducing different materials between charged objects affects the force. These experiments make abstract concepts tangible and help students understand the fundamental nature of electrostatic interactions. The program has been particularly successful in rural schools, where teachers have developed low-cost apparatus from locally available materials to demonstrate these important physical principles.

Task:

As a learner of physics;
(a)Describe an experiment to demonstrate that electrostatic force depends on the distance between charges.
(b)How does the medium between charges affect the electrostatic force between them?
(c)Two charges experience a force F when placed a distance d apart in air. What would be the force if they were placed the same distance apart in a medium with dielectric constant 4?
(d)Why is it important for students to perform experiments with electrostatic forces?

Scenario 195

An inkjet printer manufacturer establishing a plant in the Namanve Industrial Park must carefully control electrostatic forces to ensure precise droplet placement.The printing technology uses electrostatic fields to deflect charged ink droplets onto specific positions on paper. Engineers must calculate the exact field strengths needed for different printing resolutions and ink properties. This application of Coulomb's Law is essential for producing high-quality printed materials, supporting Uganda's growing publishing and packaging industries. The technology represents a sophisticated industrial application of fundamental electrostatic principles.

Task:

As a learner of physics;
(a)Explain how electrostatic forces are used in inkjet printing technology.
(b)A charge of 1.6×10^{-13} C experiences a force of 8×10^{-9} N in an electric field. Calculate the electric field strength.
(c)How would the deflection of an ink droplet change if its charge were doubled while the electric field remained constant?
(d)Why is precise control of electrostatic forces important in modern printing technology?

Topic 18: CAPACITORS

Sub-topic 18.1: Parallel Plate Capacitors

Scenario 196

A radio repair workshop in Kampala frequently deals with faulty tuning capacitors in older radio models.The technicians need to understand how parallel plate capacitors work to diagnose and fix issues with station selection. They explain to apprentices that by changing the overlap area of the plates, the capacitance changes, allowing the radio to select different frequencies. The workshop has become a training ground for young electronics enthusiasts, many of whom go on to pursue careers in Uganda's

growing electronics industry. The practical understanding of capacitors has helped preserve older radio technology while teaching fundamental principles that apply to modern communication devices.

Task:

As a learner of physics;

(a)Define capacitance and state its SI units.

(b)Calculate the capacitance of a parallel plate capacitor with plates of area 0.2 m^2 separated by 0.5 mm of air.

(c)Explain how the capacitance changes if the distance between plates is doubled.

(d)Why are variable capacitors essential in radio tuning circuits?

Scenario 197

A physics teacher at a school in Jinja uses homemade parallel plate capacitors to demonstrate energy storage principles.Students construct simple capacitors using aluminum foil sheets separated by paper dielectric materials. They measure how different dielectrics affect capacitance using multimeters and simple circuits. This hands-on approach helps students grasp abstract concepts like permittivity and energy storage. The activity has sparked interest in practical physics, with several students developing projects for the annual Uganda Science and Innovation Competition based on capacitor applications.

Task:

As a learner of physics;

(a)Explain the function of a dielectric material in a capacitor.

(b)A parallel plate capacitor has a capacitance of 10 μF in air. Calculate its capacitance when filled with a dielectric of constant 5.

(c)Describe how the stored energy changes when a dielectric is inserted into a charged capacitor.

(d)Design an experiment to compare the dielectric constants of different materials.

Scenario 198

A solar energy company in Mbale uses large capacitor banks to smooth out power fluctuations in their solar installations.Engineers must calculate the required capacitance to maintain stable voltage outputs despite varying sunlight conditions. The capacitors store excess energy during peak production and release it during brief cloud cover, improving the reliability of solar power systems in rural health centers and schools. This application has made solar energy more practical for critical applications in Uganda's off-grid communities.

Task:

As a learner of physics;

(a)Derive the formula for the capacitance of a parallel plate capacitor.

(b)Calculate the area needed for a parallel plate capacitor with air dielectric to have a capacitance of 1μF if the plates are 1 mm apart.

(c)Explain how capacitors help stabilize power supply in renewable energy systems.

(d)Why are capacitor banks important in modern energy systems?

Scenario 199

A medical equipment maintenance team at a regional hospital in Gulu troubleshoots defibrillator machines that use capacitor banks to store the energy needed for heart resuscitation.Technicians must understand capacitor charging and discharging principles to ensure these life-saving devices function reliably. They perform regular tests to verify that the capacitors can store and deliver the precise energy levels required for effective defibrillation. This knowledge has helped maintain critical medical equipment in regions with limited technical support resources.

Task:

As a learner of physics;

(a)Explain how capacitors store energy in a defibrillator.

(b)A defibrillator capacitor is charged to 5000 V and has a capacitance of 100 μF. Calculate the energy stored.
(c)Describe what happens to the stored energy when the capacitor is discharged through a patient's chest.
(d)Why is precise energy control important in medical devices like defibrillators?

Scenario 200

An automotive electronics workshop in Kampala specializes in repairing car audio systems where capacitors are used extensively in crossover networks and power supply filters.Technicians measure capacitor values and test their performance in different circuit configurations. Understanding how parallel plate capacitors work helps them diagnose issues with sound quality and power delivery in vehicle entertainment systems. This expertise supports Uganda's growing automotive services industry, particularly as more sophisticated electronic systems become common in imported vehicles.

Task:

As a learner of physics;
(a)Explain how capacitors are used in audio system crossover networks.
(b)Calculate the charge stored on a 1000 μF capacitor when connected to a 12 V car battery.
(c)Describe what happens to a capacitor's ability to store charge if the plate area is increased.
(d)Why are capacitors important in automotive electronics?

Sub-topic 18.2: Charging and Discharging Capacitors

Scenario 201

A photography studio in Entebbe uses professional flash units that rely on capacitor charging and discharging principles.The photographers need to understand the timing involved in charging the capacitors to ensure ready availability for rapid-sequence shooting. They've learned that the RC time constant determines how quickly the flash units recycle between shots. This understanding has improved their efficiency during important events like weddings and corporate functions, enhancing the quality of professional photography services in Uganda's growing creative industry.

Task:

As a learner of physics;
(a)Define the time constant in an RC circuit.
(b)A 100 μF capacitor is charged through a 10 kΩ resistor. Calculate the time constant.
(c)Explain what percentage of the full charge the capacitor reaches after one time constant.
(d)Why is understanding charging times important in photographic flash equipment?

Scenario 202

A university electronics laboratory in Mbarara studies capacitor discharging through various resistive loads.Students use oscilloscopes to visualize the exponential decay of voltage during discharge and verify the theoretical time constants. These experiments help bridge the gap between abstract mathematical models and observable circuit behavior. The skills developed in these labs prepare students for careers in Uganda's emerging electronics manufacturing sector, where timing circuits are essential for many applications.

Task:

As a learner of physics;
(a)Derive the expression for voltage during capacitor discharge.
(b)A capacitor is discharged through a resistor. If the initial voltage is 12 V, calculate the voltage after one time constant.
(c)Describe how the discharge curve would change if the resistance value were increased.
(d)Why is exponential decay characteristic of capacitor discharge?

Scenario 203

A traffic light control system in Kampala uses timing circuits based on capacitor charging to manage light sequences at intersections.Engineers must calculate precise RC values to ensure appropriate timing for different traffic conditions. The system's reliability depends on understanding how capacitors charge through resistors to trigger switching circuits at predetermined intervals. This application of capacitor charging principles has contributed to improved traffic flow and road safety in Uganda's capital city.

Task:

As a learner of physics;

(a)Explain how RC circuits can be used as timing devices.

(b)A timing circuit needs a delay of 5 seconds. If using a 100 μF capacitor, calculate the required resistance.

(c)Describe what happens in an RC circuit when the capacitor is fully charged.

(d)Why are timing circuits important in traffic control systems?

Scenario 204

A cardiac care unit at a hospital in Jinja uses heart rate monitors that employ capacitor charging circuits to measure pulse intervals.Medical technicians need to understand how these circuits work to properly calibrate and maintain the equipment. The capacitors charge at rates proportional to heart rate, providing visual and audible signals for medical staff. This application of capacitor charging principles supports critical healthcare services in Uganda's regional hospitals.

Task:

As a learner of physics;

(a)Explain how capacitor charging can be used to measure time intervals.

(b)Calculate how long it takes for a capacitor to charge to 95% of the supply voltage in terms of the time constant.

(c)Describe the factors that affect the charging rate of a capacitor.

(d)Why are reliable timing circuits important in medical monitoring equipment?

Scenario 205

A renewable energy research center in Uganda studies capacitor charging and discharging in the context of energy storage for small-scale solar systems.Researchers investigate how capacitors can provide brief bursts of power for starting motors or handling short-term load spikes in off-grid power systems. This research explores alternatives to batteries for certain applications, particularly in remote areas where battery maintenance and replacement present challenges.

Task:

As a learner of physics;

(a)Compare capacitor energy storage with battery energy storage.

(b)A capacitor is charged to 50 V and then discharged through a 100 Ω resistor. If the capacitance is 500 μF, calculate the initial discharge current.

(c)Explain why capacitors can deliver high power for short durations.

(d)How can capacitor energy storage complement battery systems in renewable energy applications?

Sub-topic 18.3: Energy Storage in Capacitors

Scenario 206

A physics demonstration at a Kampala science center uses a large capacitor bank to show dramatic energy discharge through a flash tube.Educators explain how the capacitors store electrical energy in an electric field and release it suddenly to create a brilliant flash of light. The demonstration helps visitors understand energy storage principles and their applications in technologies like camera flashes and strobe

lights. This public engagement activity has increased interest in physics among secondary school students visiting the center.

Task:

As a learner of physics;

(a)Derive the formula for energy stored in a capacitor.

(b)Calculate the energy stored in a 1000 μF capacitor charged to 400 V.

(c)Explain where the energy is physically stored in a capacitor.

(d)Why are capacitors able to release energy much faster than batteries?

Scenario 207

An industrial plant in Tororo uses capacitor banks to improve power factor in their electrical system,reducing energy costs. Engineers explain that the capacitors store and release energy to counteract the effects of inductive loads like electric motors. This application of capacitor energy storage principles has significantly reduced the plant's electricity bills while stabilizing the power quality. The success of this project has led other Ugandan industries to adopt similar power factor correction measures.

Task:

As a learner of physics;

(a)Explain how capacitors can improve power factor in AC systems.

(b)A capacitor stores 0.5 J of energy at 200 V. Calculate its capacitance.

(c)Describe why industrial facilities use capacitor banks for power factor correction.

(d)How does power factor correction benefit both the consumer and the power utility?

Scenario 208

A research project at Makerere University investigates using capacitors for energy storage in small-scale renewable systems. Students compare different capacitor technologies - electrolytic, ceramic, and super capacitors - for their energy density and discharge characteristics. The research aims to develop affordable energy storage solutions for rural applications where conventional batteries may be unsuitable. This work supports Uganda's goals of increasing renewable energy adoption, particularly in off-grid communities.

Task:

As a learner of physics;

(a)Explain the difference between conventional capacitors and super capacitors.

(b)A supe capacitor has a capacitance of 100 F and is charged to 2.5 V. Calculate the stored energy.

(c)Compare the energy density of capacitors with different dielectric materials.

(d)Why is research into capacitor energy storage important for renewable energy development?

Scenario 209

An electronics manufacturer in the Namanve Industrial Park produces power supply units that use capacitors to smooth DC output voltage.Quality control technicians test the capacitors' ability to store and release energy to maintain stable voltages under varying load conditions. Understanding energy storage principles helps them select appropriate capacitors for different applications, ensuring the reliability of electronic equipment produced for the Ugandan market and for export.

Task:

As a learner of physics;

(a)Explain how capacitors smooth DC power supply outputs.

(b)A power supply requires a capacitor to store 0.1 J of energy and operate at 25 V. Calculate the minimum capacitance needed.

(c)Describe what happens to the output voltage if the smoothing capacitor fails.

(d)Why are capacitors essential components in power supply circuits?

Scenario 210
A vocational training institute in Lira teaches automotive electronics,including the role of capacitors in vehicle ignition systems. Students learn how capacitors store energy that is suddenly discharged to create sparks in spark plugs. This practical understanding helps them diagnose and repair ignition problems in the many imported used vehicles on Uganda's roads. The skills developed through this training support Uganda's automotive repair industry and provide employment opportunities for technical graduates.
Task:
As a learner of physics;
(a)Explain how capacitors are used in automotive ignition systems.
(b)An ignition capacitor stores 0.05 J of energy at 300 V. Calculate its capacitance.
(c)Describe why rapid energy discharge is important in ignition systems.
(d)How does understanding capacitor energy storage help automotive technicians?

Topic 19: DIGITAL ELECTRONICS
Sub-topic 19.1: Junction Diodes
Scenario 211
A solar power installation company in Uganda uses junction diodes in their photovoltaic systems to prevent reverse current flow at night.Engineers explain to installation technicians how diodes act as one-way valves for electric current, ensuring that solar panels don't drain batteries when not generating power. This understanding has improved the reliability of solar installations across Uganda, particularly in rural areas where maintenance visits are infrequent. The company has developed training materials that use simple analogies to help technicians with varying educational backgrounds understand and apply diode principles in their work.
Task:
As a learner of physics;
(a)Explain the working principle of a p-n junction diode.
(b)Draw the circuit symbol for a diode and indicate the direction of conventional current flow.
(c)Describe how diodes are used in solar power systems.
(d)Why is reverse current protection important in solar energy systems?
Scenario 212
An electronics repair workshop in Kampala's downtown area specializes in fixing power supplies and battery charchers where diodes are commonly used in rectifier circuits.The technicians use multimeters to test diodes for proper operation, checking forward voltage drop and reverse leakage current. Their ability to diagnose diode-related issues has made the workshop a go-to resource for repairing electronic equipment in the community. This practical expertise supports the circular economy by extending the life of electronic devices in Uganda.
Task:
As a learner of physics;
(a)Describe how to test a diode using a multimeter.
(b)Explain what is meant by the "forward voltage drop" of a diode.
(c)A silicon diode has a forward voltage drop of 0.7 V. If it conducts 100 mA, calculate the power dissipated.
(d)Why are diodes essential components in power supply rectifier circuits
Scenario 213
A physics teacher at a school in Fort Portal uses simple experiments with diodes, batteries, and LEDs to demonstrate semiconductor principles. Students build basic circuits that show how diodes only conduct in one direction and learn to identify the anode and cathode terminals. These hands-on activities make

abstract semiconductor concepts tangible and help students understand the foundation of modern electronics. The school has incorporated these experiments into the physics curriculum, improving student engagement with the subject.

Task:

As a learner of physics;

(a)Draw and explain the I-V characteristic curve of a junction diode.

(b)Describe the difference between forward bias and reverse bias in a diode.

(c)Design a simple circuit to demonstrate the rectifying action of a diode.

(d)Why are hands-on experiments important for understanding electronic components?

Scenario 214

A telecommunications company in Uganda uses diodes in various protection circuits to safeguard sensitive equipment from voltage spikes and static electricity. Engineers design these circuits using Zener diodes for voltage regulation and other diodes for preventing reverse polarity connection. Understanding diode characteristics helps them create robust protection systems that maintain service reliability, particularly during Uganda's frequent thunderstorms that can induce power surges in communication infrastructure.

Task:

As a learner of physics;

(a)Explain how a Zener diode differs from a regular diode.

(b)Describe how diodes can protect electronic circuits from voltage spikes.

(c)A Zener diode is rated at 5.1 V. What is its function in a voltage regulation circuit?

(d)Why is circuit protection important in telecommunications equipment?

Scenario 215

A renewable energy project in rural Uganda uses diodes in simple charge controllers for solar home systems. Community technicians are trained to understand how diodes prevent battery overdischarge and manage power flow between solar panels, batteries, and loads. This knowledge empowers local communities to maintain their own energy systems, supporting sustainable development in off-grid areas. The project has successfully deployed hundreds of solar systems with local technicians providing ongoing support.

Task:

As a learner of physics;

(a)Explain how diodes are used in solar charge controllers.

(b)Describe what happens to a diode when it is reverse biased beyond its breakdown voltage.

(c)Why is it important for community technicians to understand basic electronic components?

(d)How can simple diode-based circuits support renewable energy adoption in rural areas?

Sub-topic 19.2: Transistors

Scenario 216

A radio station in Mbale uses transistor amplifiers in their broadcast equipment to boost audio signals before transmission.The technical team understands how transistors provide signal amplification through their ability to control large currents with small input signals. This knowledge helps them maintain clear broadcast quality despite varying signal conditions. The station has become a training ground for aspiring broadcast engineers in eastern Uganda, with many technicians learning transistor fundamentals through hands-on experience with the transmission equipment.

Task:

As a learner of physics;

(a)Explain the basic operation of a bipolar junction transistor as an amplifier.

(b)Draw the circuit symbols for NPN and PNP transistors.
(c)Describe how a transistor can control a large current with a small input current.
(d)Why are transistors essential in audio amplification systems?

Scenario 217

An agricultural research center in Kabale uses transistor-based temperature control systems in their seed storage facilities.Engineers design circuits that use transistors as switches to activate cooling systems when temperatures rise above predetermined levels. Understanding transistor switching characteristics helps them create reliable environmental control systems that preserve valuable seed varieties for Uganda's farming communities. This application of transistor technology supports food security by maintaining genetic diversity in crop species.

Task:

As a learner of physics;
(a)Explain how a transistor operates as a switch.
(b)Describe the cutoff and saturation regions of transistor operation.
(c)Design a simple transistor switch circuit to control a relay based on temperature input.
(d)Why are transistor switches preferred over mechanical switches in control systems?

Scenario 218

A vocational training institute in Kampala teaches transistor principles as part of their electronics technician program.Students learn to identify transistor terminals, test transistors using multimeters, and build simple amplifier and switch circuits. The practical skills developed in these courses prepare students for employment in Uganda's growing electronics sector, from equipment repair to industrial automation. Many graduates have found employment with telecommunications companies, broadcast stations, and manufacturing plants across Uganda.

Task:

As a learner of physics;
(a)Describe how to identify the base, collector, and emitter of a bipolar junction transistor.
(b)Explain the concept of current gain (β) in a transistor.
(c)A transistor has a base current of 20 μA and a collector current of 2 mA. Calculate the current gain.
(d)Why are practical skills in transistor circuits valuable for employment in the electronics industry?

Scenario 219

A solar lighting company in Uganda uses transistors in the control circuits of their advanced solar lanterns and home lighting systems.Engineers design circuits that use transistors for maximum power point tracking, battery charging control, and LED dimming functions. Understanding transistor characteristics helps them optimize the efficiency and functionality of their products, making solar lighting more affordable and effective for Ugandan households. The company's success has contributed to increased adoption of solar lighting in areas with limited grid electricity.

Task:

As a learner of physics;
(a)Explain how transistors can be used for power control in electronic devices.
(b)Describe the advantages of using transistors instead of mechanical switches in power control applications.
(c)Why are transistors important in maximizing the efficiency of solar-powered devices?
(d)How has transistor technology contributed to the adoption of renewable energy solutions

Scenario 220

A university engineering department in Mbarara studies transistor applications in simple computing circuits.Students build basic logic gates using transistors and learn how these form the foundation of digital computers. This fundamental understanding prepares students for advanced studies in computer

engineering and supports Uganda's goals of developing local expertise in information technology. The department has established partnerships with local tech companies to ensure the curriculum remains relevant to industry needs.

Task:

As a learner of physics;

(a)Explain how transistors can be used to create basic logic gates.

(b)Design a simple AND gate using transistors and diodes.

(c)Describe the significance of transistors in the development of modern computing.

(d)Why is understanding transistor fundamentals important for computer engineering?

Topic 20: CIRCULAR MOTION

Sub-topic 20.1: Centripetal Force

Scenario 221

The Uganda National Roads Authority is conducting safety audits on several roundabouts in Kampala that have experienced a high number of vehicle skidding incidents, especially during the rainy season. Engineers are analyzing the relationship between vehicle speed, road curvature, and friction to determine safe speed limits. They use centripetal force principles to calculate the maximum speeds at which vehicles can navigate these roundabouts without skidding outward. The study has led to new signage and road markings that have reduced accidents by 25% at the targeted intersections, demonstrating how physics principles directly impact public safety in Uganda's rapidly growing urban centers.

Task:

As a learner of physics;

(a)Define centripetal force and state the factors that affect it.

(b)Calculate the centripetal force required to keep a 1200 kg car moving at 40 kmh^{-1} around a roundabout of radius 25 m.

(c)Explain why vehicles are more likely to skid on wet roads than on dry roads when navigating curves.

(d)How does understanding centripetal force contribute to road safety engineering?

Scenario 222

A traditional pottery workshop in Mbale uses a motorized potter's wheel that operates on circular motion principles.The potter understands that the clay must experience sufficient centripetal force to maintain its circular path without flying off the wheel. By adjusting the wheel's rotational speed based on the amount and consistency of clay, the potter creates symmetrical pots efficiently. This application of physics principles has helped preserve Uganda's pottery traditions while increasing production efficiency for both functional pottery and artistic creations sold to tourists.

Task:

As a learner of physics;

(a)Derive the expression for centripetal acceleration in terms of angular velocity.

(b)A potter's wheel of diameter 40 cm rotates at 120 rpm. Calculate the centripetal acceleration at the rim.

(c)Explain what happens to clay on the wheel if the centripetal force is insufficient.

(d)Why is understanding circular motion important in traditional crafts?

Scenario 223

A water pumping station on the River Nile uses a centrifugal pump that applies circular motion principles to move water.Engineers must calculate the relationship between impeller diameter, rotational speed, and the pressure developed to ensure efficient operation. The proper understanding of centripetal forces in the rotating impeller has enabled the design of pumps that provide reliable water supply to communities along the river, supporting both domestic use and agricultural irrigation in Uganda's Nile basin region.

Task:

As a learner of physics;

(a)Explain how a centrifugal pump uses circular motion principles.

(b)Calculate the angular velocity of a pump impeller that rotates at 1500 rpm.

(c)Describe how centripetal force is related to the pressure developed in a centrifugal pump.

(d)Why are centrifugal pumps widely used in water supply systems?

Scenario 224

A sports science program at a Ugandan university studies the biomechanics of hammer throw athletes during training.Coaches analyze how athletes generate centripetal force through body rotation to accelerate the hammer before release. Understanding the physics of circular motion has helped optimize training techniques, leading to improved performance of Ugandan athletes in international competitions. The research has contributed to Uganda's growing reputation in field events, particularly in sports that involve rotational movements.

Task:

As a learner of physics;

(a)Explain the role of centripetal force in hammer throw.

(b)A 7.26 kg hammer is swung in a circle of radius 1.8 m with a speed of 25 ms^{-1}. Calculate the centripetal force.

(c)Describe how an athlete maintains the circular path of the hammer before release.

(d)How does understanding physics improve athletic performance?

Scenario 225

An amusement park near Kampala features a rotor ride where participants stand against a rotating cylindrical wall that drops away,leaving them pinned by centripetal force. The operators must calculate safe rotational speeds based on the coefficient of friction between clothing and the wall surface. Understanding these physics principles ensures rider safety while providing an exciting experience that demonstrates circular motion concepts vividly. The ride has become a popular educational tool for physics teachers bringing students for practical demonstrations.

Task:

As a learner of physics;

(a)Explain why riders don't fall when the floor drops away in a rotor ride.

(b)Calculate the minimum rotational speed required to keep a rider of mass 60 kg pressed against the wall if the radius is 4 m and the coefficient of friction is 0.4.

(c)Describe the forces acting on a rider in the rotor ride.

Sub-topic 20.2: Conical Pendulum

Scenario 226

A physics teacher at a school in Gulu demonstrates circular motion using a conical pendulum made from local materials.Students observe how the bob moves in a horizontal circle and learn to relate the angle of the string to the speed of rotation. Through measurements of period, string length, and angle, students verify theoretical predictions and understand how vertical and horizontal force components combine to produce circular motion. This practical approach has improved student comprehension of abstract dynamics concepts and sparked interest in experimental physics among learners in northern Uganda.

Task:

As a learner of physics;

(a)Describe the forces acting on the bob of a conical pendulum.

(b)Derive the expression for the period of a conical pendulum in terms of string length and angle.

(c)A conical pendulum of length 1.5 m makes an angle of 20° with the vertical. Calculate its period of revolution.
(d)Why is the conical pendulum a useful demonstration of circular motion principles?

Scenario 227

A construction company in Uganda uses a giant plumb bob based on conical pendulum principles to establish vertical alignment in tall structures.When wind causes the plumb bob to swing, it traces a conical path rather than a simple pendulum motion. Engineers must understand this behavior to accurately interpret the reference line for vertical alignment in skyscraper construction in Kampala's growing skyline. This application has improved construction accuracy in Uganda's major urban development projects.

Task:

As a learner of physics;
(a)Explain the difference between a simple pendulum and a conical pendulum.
(b)A plumb bob of mass 2 kg hangs from a 10 m string and makes a conical path of radius 0.5 m. Calculate the tension in the string.
(c)Describe how wind affects a plumb bob's motion and how this is accounted for in construction.
(d)Why is precise vertical alignment important in tall building construction?

Scenario 228

A cultural performance group in Ankole region incorporates traditional dances that involve spinning objects on strings,unconsciously applying conical pendulum principles. Physics students studying these cultural practices have documented how dancers intuitively adjust rotation speeds to maintain specific angles, demonstrating an empirical understanding of circular motion. This interdisciplinary study has helped preserve indigenous knowledge while connecting it to formal physics education in Ugandan schools.

Task:

As a learner of physics;
(a)Explain how the angle of a conical pendulum changes with rotational speed.
(b)A dancer spins a 0.5 kg object on a 1.2 m string so that it makes an angle of 30° with the vertical. Calculate the linear speed of the object.
(c)Describe the energy transformations in a conical pendulum.
(d)How can traditional cultural practices enhance the understanding of physics principles?

Scenario 229

An industrial screening plant in Kasese uses conical pendulum principles in vibrating screens that separate different sizes of mineral ores.The screens operate with a conical motion that optimizes material separation efficiency. Engineers must calculate the appropriate oscillation parameters to achieve the desired screening action for different materials. This application has improved the efficiency of Uganda's mining operations, particularly in the processing of copper and cobalt ores from the western region.

Task:

As a learner of physics;
(a)Explain how conical pendulum motion is applied in industrial screening equipment.
(b)Describe the relationship between the cone angle and the screening efficiency.
(c)Why is controlled circular motion important in material separation processes?
(d)How has physics understanding improved Uganda's mining industry?

Scenario 230

A university physics department studies the conical pendulum as a classic example of two-dimensional motion.Students use photogates and angle sensors to collect precise data on the relationship between rotational speed, string tension, and cone angle. The experiments help students develop skills in data

analysis and mathematical modeling while reinforcing their understanding of circular motion dynamics. This foundation prepares them for more advanced studies in mechanics and engineering.

Task:

As a learner of physics;

(a)Derive the expression for the tension in the string of a conical pendulum.

(b)A conical pendulum bob has a mass of 0.2 kg and rotates with a period of 1.5 s. If the string is 1 m long, calculate the angle it makes with the vertical.

(c)Design an experiment to verify the theoretical relationship for a conical pendulum's period.

(d)Why is experimental verification important in physics education?

Sub-topic 20.3: Motion on Circular Tracks

Scenario 231

The Uganda Railways Corporation is rehabilitating curved railway tracks between Kampala and Malaba,and engineers are calculating the optimal banking angles for these curves. Using principles of circular motion, they determine the banking angles that allow trains to navigate curves safely at designated speeds without excessive wear on the rails. This physics-based approach has improved both safety and efficiency on Uganda's revitalized railway system, which plays a crucial role in regional trade as a link to the Kenyan port of Mombasa.

Task:

As a learner of physics;

(a)Explain why railway tracks are banked on curves.

(b)Derive the expression for the ideal banking angle of a curved track.

(c)Calculate the banking angle required for a railway curve of radius 400 m designed for trains moving at 80 km/h.

(d)How does proper track banking contribute to transportation safety?

Scenario 232

A motorsports club organizing races at a track in Jinja must ensure that the circuit's curved sections are safely designed for the expected vehicle speeds.Race organizers work with physicists to calculate the minimum radius of curvature for different sections based on the friction available between tires and track surface. This application of circular motion principles has helped establish Uganda's first internationally recognized motorsports venue, promoting both recreational racing and driver training programs.

Task:

As a learner of physics;

(a)Explain how friction provides the necessary centripetal force on unbanked curved tracks.

(b)A car of mass 800 kg takes an unbanked curve of radius 50 m at 60 kmh^{-1}. Calculate the minimum coefficient of friction required to prevent skidding.

(c)Describe what happens to a vehicle on a curve if the centripetal force required exceeds the maximum frictional force available.

(d)Why is understanding circular motion important in motorsports?

Scenario 233

A cycling event around Lake Victoria involves riders navigating curved roads along the shoreline.Race organizers educate participants about the physics of leaning into curves to maintain stability and speed. Experienced cyclists intuitively understand how to adjust their lean angle based on their speed and the sharpness of the curve. This understanding has improved safety in Uganda's growing competitive cycling scene, which includes both local races and international events that showcase the country's scenic landscapes.

Task:
As a learner of physics;
(a)Explain why a cyclist must lean inward when negotiating a curve.
(b)A cyclist moving at 30 km/h goes around a curve of radius 20 m. Calculate the angle of lean required.
(c)Describe the forces acting on a cyclist moving on a curved path.
(d)How does understanding circular motion improve cycling performance and safety?

Scenario 234
An aviation training school in Entebbe teaches student pilots the physics of banking aircraft during turns.Instructors explain how the horizontal component of lift provides the centripetal force needed for circular motion, while the vertical component supports the aircraft's weight. This understanding is crucial for performing coordinated turns safely, especially during takeoff and landing patterns at Entebbe International Airport, which has complex airspace due to its location near Lake Victoria.

Task:
As a learner of physics;
(a)Explain how an aircraft executes a turn using banking.
(b)An aircraft flying at 200 m/s makes a turn with a radius of 1500 m. Calculate the banking angle required.
(c)Describe what is meant by a "coordinated turn" in aviation.
(d)Why understanding circular motion essential for is pilots?

Scenario 235
A civil engineering firm designing interchange ramps for the Kampala-Entebbe Expressway uses circular motion principles to determine appropriate curvature and banking. The engineers calculate the maximum safe speeds for different ramp designs to ensure vehicles can navigate them safely in various weather conditions. This physics-based approach has contributed to the safety of Uganda's modern highway system, reducing accidents on high-speed road networks that connect major economic centers.

Task:
As a learner of physics;
(a)Derive the expression for the maximum safe speed on a banked curved road.
(b)A highway curve of radius 200 m is banked at 15°. Calculate the maximum speed at which a vehicle can negotiate this curve without relying on friction.
(c)Explain how both banking and friction contribute to the safe negotiation of curves at high speeds.
(d)Why road design is based on physics principles important for public safety?

Topic 21: SIMPLE HARMONIC MOTION

Sub-topic 21.1: Displacement, Velocity, Acceleration and Energy for SHM

Scenario 236
A civil engineering firm in Kampala is designing earthquake-resistant buildings for Uganda's growing urban areas.Engineers use SHM principles to model how structures will respond to seismic vibrations, calculating displacement, velocity, and acceleration profiles for different oscillation modes. They analyze how energy transfers between potential and kinetic forms during building vibrations and design damping systems to dissipate this energy safely. This application of SHM theory has improved building safety standards in Uganda, particularly important as the country experiences occasional seismic activity from the East African Rift system. The engineering firm has developed specialized computer models that simulate SHM behavior under various earthquake scenarios.

Task:
As a learner of physics;
(a)Define simple harmonic motion and state the necessary conditions for it to occur.

(b)The displacement of an object in SHM is given by $x = 0.2 \sin(10t)$ meters. Calculate the maximum velocity and acceleration.
(c)Explain how the total mechanical energy remains constant during SHM and derive the expression for total energy.
(d)Why is understanding SHM important in earthquake-resistant building design?

Scenario 237

A physics education program in rural Uganda uses simple pendulum experiments to teach SHM concepts.Students measure how displacement, velocity, and acceleration vary throughout the oscillation cycle using basic timing methods and angle measurements. They verify that the restoring force is proportional to displacement and directed toward the equilibrium position. This hands-on approach has made abstract oscillation concepts more accessible to students in schools with limited laboratory equipment, improving physics comprehension across diverse learning environments in Uganda.

Task:

As a learner of physics;
(a)Derive the expression for the acceleration in SHM and show that it is proportional to displacement.
(b)A simple harmonic oscillator has amplitude 0.15 m and period 2.5 s. Calculate the maximum velocity and acceleration.
(c)Sketch graphs showing how displacement, velocity, and acceleration vary with time for one complete cycle of SHM.
(d)How do practical experiments enhance understanding of theoretical physics concepts?

Scenario 238

A biomedical engineering team at Mulago Hospital designs prosthetic limbs that incorporate SHM principles for more natural movement.The engineers analyze how human joints approximate SHM during walking and design artificial joints that replicate this motion. Understanding the relationship between displacement, velocity, and acceleration helps them create prosthetics that minimize energy expenditure for the user. This application has significantly improved mobility for amputees in Uganda, particularly those injured in accidents or conflicts.

Task:

As a learner of physics;
(a)Explain how human walking motion can be modeled using SHM principles.
(b)A prosthetic knee joint oscillates with amplitude 0.1 m and frequency 1 Hz. Calculate the maximum velocity and acceleration.
(c)Describe how energy transforms between kinetic and potential forms during the oscillation of a prosthetic limb.
(d)Why is replicating natural motion patterns important in prosthetic design?

Scenario 239

A precision instrument manufacturer in Jinja produces mechanical watches that use balance wheels operating on SHM principles. Watchmakers must understand how the displacement, velocity, and acceleration of the balance wheel affect timekeeping accuracy. The company has implemented quality control procedures based on precise measurements of oscillation parameters, ensuring their timepieces meet international standards. This expertise supports Uganda's growing light manufacturing sector and provides skilled employment opportunities.

Task:

As a learner of physics;
(a)Explain how a balance wheel in a mechanical watch exhibits SHM.
(b)A watch balance wheel has a moment of inertia of 2×10^{-7} kg·m² and a torsional constant of 3×10^{-5} $Nmrad^{-1}$. Calculate its period of oscillation.

(c)Describe how the amplitude of oscillation affects the timekeeping accuracy of a mechanical watch.
(d)Why is precise control of oscillation parameters important in timekeeping devices?

Scenario 240

A renewable energy research center in Uganda studies wave energy converters that operate on SHM principles.Researchers analyze how floating buoys move with ocean-like oscillations, calculating how displacement, velocity, and acceleration profiles affect energy capture efficiency. This research aims to develop wave energy technologies suitable for Lake Victoria and other Ugandan water bodies, providing another renewable energy option for communities without grid access.

Task:

As a learner of physics;
(a)Explain how a wave energy converter can utilize SHM principles.
(b)A buoy oscillates with SHM with amplitude 0.8 m and period 4 s. Calculate its velocity when it is 0.4 m from the equilibrium position.
(c)Derive the expression for the kinetic energy of an object in SHM in terms of displacement.
(d)How can SHM principles contribute to renewable energy development in Uganda?

Sub-topic 21.2: Oscillations

Scenario 241

A civil engineering team working on the new Kampala flyover designs expansion joints that accommodate thermal oscillations in the bridge structure.Engineers calculate how the bridge length oscillates with daily and seasonal temperature changes, ensuring the joints can handle these movements without structural damage. Understanding oscillation patterns has been crucial for designing durable infrastructure in Uganda's variable climate, where temperatures can fluctuate significantly between day and night, and between seasons.

Task:

As a learner of physics;
(a)Describe different types of oscillations observed in physical systems.
(b)A steel bridge is 200 m long at 20°C. If the temperature varies between 15°C and 35°C, calculate the range of length oscillation ($\alpha_{steel} = 1.2\times10^{-5}$).
(c)Explain how understanding oscillations helps in designing structures that experience thermal expansion.
(d)Why are expansion joints necessary in large structures like bridges?

Scenario 242

A physics teacher at a school in Mbale demonstrates different oscillation systems using locally available materials.Students build simple pendulums, mass-spring systems, and torsional pendulums, comparing their oscillation characteristics. Through these experiments, students learn how different physical parameters affect oscillation frequency and amplitude. This practical approach has improved student performance in national physics examinations and sparked interest in experimental science.

Task:

As a learner of physics;
(a)Compare the oscillations of a simple pendulum and a mass-spring system.
(b)A mass-spring system has a period of 1.5 s. When an additional mass of 0.2 kg is added, the period becomes 2.0 s. Calculate the original mass and the spring constant.
(c)Design an experiment to compare the periods of oscillation for different pendulum lengths.
(d)Why is it valuable to study different types of oscillation systems?

Scenario 243
A traditional music ensemble in Busoga region uses various percussion instruments that rely on oscillation principles.Drummers understand how different drum sizes and membrane tensions produce distinct oscillation patterns that create specific tones and rhythms. This indigenous knowledge of acoustics has been preserved through generations and is now being documented by ethnomusicologists working with physics students to analyze the scientific principles underlying traditional Ugandan music.
Task:
As a learner of physics;
(a)Explain how a drum membrane oscillates to produce sound.
(b)Describe how tension and size affect the oscillation frequency of a drum membrane.
(c)Why do different percussion instruments produce different sounds when struck?
(d)How can traditional knowledge enhance our understanding of oscillation physics?
Scenario 244
A medical research facility in Uganda studies physiological oscillations such as heartbeats and breathing patterns.Doctors analyze how these oscillations change under different health conditions, using the information for diagnostic purposes. Understanding normal oscillation patterns helps identify abnormalities that may indicate disease. This application of oscillation physics has improved healthcare delivery in Ugandan hospitals, particularly in cardiology and respiratory medicine departments.
Task:
As a learner of physics;
(a)Describe how the human heartbeat can be considered an oscillation.
(b)A normal resting heart rate is 72 beats per minute. Calculate the period and frequency of this oscillation.
(c)Explain why monitoring physiological oscillations is important in medicine.
(d)How has physics contributed to medical diagnostics through the study of oscillations?
Scenario 245
An automotive engineering workshop in Kampala specializes in diagnosing and fixing suspension oscillations in vehicles.Mechanics use their understanding of oscillation principles to identify problems like wheel wobble, body roll, and suspension bounce. They apply this knowledge to tune suspension systems for Uganda's varied road conditions, from smooth highways to rough rural tracks. This expertise has improved vehicle safety and comfort for Ugandan motorists.
Task:
As a learner of physics;
(a)Explain how a vehicle suspension system reduces oscillations from road irregularities.
(b)A car's suspension system causes it to oscillate with a frequency of 1.5 Hz after hitting a bump. If the amplitude decreases to half its initial value in 2 seconds, calculate the damping coefficient.
(c)Describe why proper suspension tuning is important for vehicle safety.
(d)How does understanding oscillations help automotive technicians?

Topic 22: GRAVITATION
Sub-topic 22.1: Laws of Gravitation
Scenario 246
The Uganda National Space Agency is planning its first satellite mission and needs to calculate orbital parameters using Newton's law of gravitation.Engineers must determine the gravitational forces between the satellite and Earth to ensure stable orbit insertion. They also analyze how the gravitational pull from the Moon and Sun affects the satellite's trajectory. This application of gravitation principles represents

Uganda's entry into space technology, with potential benefits for communication, weather monitoring, and agricultural planning across the country.

Task:

As a learner of physics;

(a)State Newton's law of universal gravitation and explain all terms in the equation.

(b)Calculate the gravitational force between Earth (mass = 6×10^{24} kg) and a 500 kg satellite at an altitude of 400 km (Earth radius = 6400 km).

(c)Explain why the gravitational force is considered universal.

(d)How does understanding gravitation contribute to space technology development?

Scenario 247

A geography and physics collaboration at Makerere University studies how gravitational variations affect Uganda's landscape.Researchers measure slight differences in gravitational acceleration across different regions, correlating them with geological features like mountain ranges and rift valleys. This interdisciplinary approach has improved understanding of Uganda's tectonic activity and mineral deposits, supporting sustainable resource management in the country.

Task:

As a learner of physics;

(a)Explain how gravitational acceleration varies with altitude and latitude.

(b)Calculate the value of g at the top of Mount Elgon (height 4300 m above sea level) compared to at sea level.

(c)Describe how gravitational measurements can reveal information about underground geological structures.

(d)Why is studying gravitational variations important for resource exploration?

Scenario 248

A science education program uses Cavendish experiment simulations to teach gravitation concepts in Ugandan schools where the actual apparatus is unavailable.Students work with virtual models that demonstrate how the gravitational constant G can be measured through delicate torsion balance experiments. This approach has made sophisticated physics concepts accessible to students across Uganda, including those in remote areas with limited laboratory facilities.

Task:

As a learner of physics;

(a)Describe the Cavendish experiment and explain how it measured the gravitational constant G.

(b)Two lead spheres of mass 50 kg each are placed with their centers 0.5 m apart. Calculate the gravitational force between them.

(c)Why was the measurement of G historically significant?

(d)How can virtual experiments enhance physics education in resource-limited settings?

Scenario 249

An astronomy club in Mbarara studies how gravitational forces govern the motion of celestial objects visible from Uganda's equatorial location.Members calculate gravitational interactions within our solar system and beyond, using telescopes to observe the results of these forces on planetary orbits and galaxy formations. The club has inspired many young Ugandans to pursue careers in astronomy and astrophysics.

Task:

As a learner of physics;

(a)Explain how Newton's law of gravitation accounts for planetary orbits.

(b)Calculate the gravitational force between the Sun (mass = 2×10^{30} kg) and Earth (mass = 6×10^{24} kg) given their average separation is 1.5×10^{11} m.

(c)Describe how gravitational forces shape the structure of galaxies.
(d)Why is Uganda's equatorial location advantageous for astronomical observation?

Scenario 250

A civil engineering project planning a tunnel through the Rwenzori Mountains must account for gravitational forces in their structural calculations.Engineers analyze how gravity affects rock stability and determines the optimal tunnel path through the mountainous terrain. Understanding gravitation has been essential for this challenging infrastructure project that will improve transportation links between western Uganda and the Democratic Republic of Congo.

Task:

As a learner of physics;
(a)Explain how gravitational forces influence rock stability in mountainous regions.
(b)A 1000 kg rock rests on a mountainside inclined at 30° to the horizontal. Calculate the component of gravitational force parallel to the slope.
(c)Describe why understanding gravitation is important in tunnel engineering.
(d)How does infrastructure development benefit from applying physics principles?

Sub-topic 22.2: Motion in Orbits

Scenario 251

Uganda's emerging space program is designing the orbit for its first Earth observation satellite.Engineers must calculate the orbital velocity and period for different altitudes to optimize the satellite's coverage of Ugandan territory. They apply principles of orbital motion to ensure the satellite passes over key agricultural and environmental monitoring areas with the required frequency. This project represents an important step in Uganda's technological development, with applications in food security, disaster management, and resource monitoring.

Task:

As a learner of physics;
(a)Derive the expression for orbital velocity of a satellite around Earth.
(b)Calculate the orbital velocity and period for a satellite at 700 km altitude above Earth's surface.
(c)Explain the difference between geostationary and low Earth orbits.
(d)Why are satellite orbits important for Earth observation applications?

Scenario 252

A physics teacher in Gulu uses simple demonstrations to explain orbital motion concepts to students.Using balls attached to strings, students experience how changing speed affects circular motion and relate this to planetary orbits. The teacher also uses computer simulations to show how different orbital parameters affect satellite trajectories. This multi-faceted approach has improved student understanding of celestial mechanics in a region where astronomy education was previously limited.

Task:

As a learner of physics;
(a)Explain why satellites remain in orbit around Earth without falling down or flying away.
(b)A satellite orbits Earth with orbital radius r and velocity v. If the radius is doubled, what happens to the orbital velocity?
(c)Describe how centripetal force is provided by gravity in orbital motion.
(d)Why is it helpful to use both physical demonstrations and computer simulations in teaching orbital motion?

Scenario 253

A telecommunications company in Uganda uses geostationary satellites to provide broadcast services across the country.Engineers must understand orbital mechanics to properly align satellite dishes and

ensure reliable signal reception. The company has developed training programs that teach technicians the physics behind satellite orbits, improving service quality for customers in both urban and rural areas of Uganda.

Task:

As a learner of physics;

(a)Explain what makes a geostationary orbit special and derive the altitude for such an orbit.

(b)Calculate the altitude of a geostationary satellite above Earth's surface.

(c)Describe why geostationary satellites are useful for communications.

Scenario 254

An environmental monitoring agency studies how orbital parameters affect satellite-based climate observation over Uganda.Scientists analyze how different orbits provide varying coverage patterns for monitoring Lake Victoria's water levels, deforestation in Uganda's forests, and agricultural patterns across the country. This understanding helps optimize the use of both Ugandan and international satellites for environmental protection and sustainable development planning.

Task:

As a learner of physics;

(a)Explain how orbital inclination affects a satellite's coverage of Earth's surface.

(b)Compare the coverage patterns of polar orbits versus equatorial orbits.

(c)Why are multiple satellites often needed for comprehensive Earth observation?

Scenario 255

A university astronomy department studies orbital resonances in our solar system, particularly how gravitational interactions between planets create stable orbital patterns. Students learn how these principles apply to everything from asteroid belts to exoplanet systems. This fundamental research enhances Uganda's growing capabilities in space science and provides valuable training for students interested in careers in astronomy and astrophysics.

Task:

As a learner of physics;

(a)Explain what is meant by orbital resonance and give an example from our solar system.

(b)Derive Kepler's third law for circular orbits and explain its significance.

(c)How do gravitational interactions between multiple bodies affect orbital stability?

Sub-topic 22.3: Satellites

Scenario 256

The Uganda Communications Commission regulates satellite services operating in Ugandan airspace.Officials must understand satellite technology to effectively manage frequency allocations and orbital slot assignments. The commission has developed expertise in satellite physics to ensure optimal use of this limited resource for telecommunications, broadcasting, and internet services across Uganda. This regulatory framework supports Uganda's digital transformation goals by facilitating reliable satellite connectivity.

Task:

As a learner of physics;

(a)Describe the basic components of an artificial satellite and their functions.

(b)Explain how satellites maintain their orientation and stability in space.

(c)What are the main sources of power for satellites and how do they work?

(d)Why is proper regulation important for satellite services in a country?

Scenario 257

A disaster management agency in Uganda uses satellite data for early warning systems and emergency response. Satellite imagery helps monitor flood risks in river basins, volcanic activity in the Virunga mountains, and drought conditions in Karamoja region. Understanding satellite capabilities and limitations allows the agency to make better decisions that save lives and reduce property damage during natural disasters in Uganda.

Task:

As a learner of physics;

(a)Explain how satellites can monitor natural disasters from space.

(b)Describe different types of remote sensing satellites and their applications.

(c)What are the advantages of using satellites for disaster management compared to ground-based systems?

(d)How has satellite technology improved emergency response in Uganda?

Scenario 258

An agricultural extension service in Uganda uses satellite data to support farmers across the country.Satellite imagery helps monitor crop health, soil moisture, and pest outbreaks, providing timely information to agricultural advisors. This application of satellite technology has improved food security in Uganda by enabling more precise farming practices and better resource management.

Task:

As a learner of physics;

(a)Explain how satellites can monitor vegetation health from space.

(b)Describe how satellite data can help farmers optimize irrigation and fertilizer use.

(c)What are the limitations of using satellites for agricultural monitoring?

(d)How can satellite technology contribute to food security in Uganda?

Scenario 259

A defense and security agency in Uganda uses satellite technology for border monitoring and peacekeeping operations.Satellites provide surveillance capabilities that help detect illegal activities and monitor remote border regions. Understanding satellite orbits and imaging technologies allows the agency to effectively utilize these assets for national security purposes while respecting privacy and international laws.

Task:

As a learner of physics;

(a)Explain how satellites can be used for surveillance and security purposes.

(b)Describe the factors that affect the resolution of satellite imagery.

(c)What are the ethical considerations in using satellites for surveillance?

(d)How does satellite technology enhance national security capabilities?

Scenario 260

A university in Uganda is developing its first CubeSat as an educational and technology demonstration project.Students and faculty work together to design, build, and test a small satellite that will carry experimental payloads into orbit. This hands-on project provides valuable experience in satellite technology and space systems engineering, building Uganda's capacity in the growing global space industry.

Task:

As a learner of physics;

(a)Explain what CubeSats are and why they have become popular in space education.

(b)Describe the process of designing and building a small satellite.

(c)What educational benefits come from hands-on satellite projects?

(d)How can university satellite projects contribute to a country's technological development?

Topic 23: PROGRESSIVE WAVES
Sub-topic 23.1: Basic Properties of Waves
Scenario 261
A telecommunications company is expanding its 4G network across rural Uganda,and engineers are studying how radio waves (a type of progressive wave) propagate through different terrains. They need to understand fundamental wave properties like wavelength, frequency, and speed to optimize tower placement for maximum coverage. In the hilly regions of Kigezi, signals are affected by diffraction and reflection, while in the flat Karamoja plains, signal range is much greater. The company uses this understanding of wave behavior to ensure that even remote communities can access mobile services, which is crucial for communication, mobile banking, and accessing market information.
Task:
As a learner of physics;
(a)Define the terms amplitude, wavelength, frequency, and period for a progressive wave.
(b)A radio station broadcasts at a frequency of 100 MHz. Given that the speed of light is 3×10^{8} m/s, calculate the wavelength of these radio waves.
(c)Explain the relationship between wave speed, frequency, and wavelength.
(d)Why is understanding wave propagation important for telecommunications planning in Uganda?
Scenario 262
Fishermen on Lake Victoria have observed that on windy days,the water waves have a direct impact on their fishing efficiency and safety. They note that waves transfer energy across the lake's surface, sometimes making it dangerous to navigate in small boats. By observing the time between successive wave crests (the period) and estimating the distance between them (the wavelength), experienced fishermen can estimate wave speed and decide whether it's safe to venture further onto the lake. This practical understanding of wave properties, passed down through generations, is now being complemented with formal physics education in lakeside schools.
Task:
As a learner of physics;
(a)A fisherman times 10 wave crests passing his boat in 25 seconds. Calculate the wave period and frequency.
(b)If the distance between successive wave crests is 3 meters, calculate the speed of the waves.
(c)Explain how water waves demonstrate that waves transfer energy without transferring matter.
(d)How can a formal understanding of wave properties improve the safety of traditional fishing practices?
Scenario 263
A music festival in Kampala features a diverse range of traditional and modern instruments,all of which produce sound waves. Sound engineers setting up the festival's audio system must understand wave properties to avoid destructive interference and ensure clear sound quality across the entire venue. They adjust speaker placement and sound levels based on the wavelength of different sound frequencies, ensuring that both high-pitched traditional flutes and low-pitched drums are heard clearly by the audience, preserving the richness of Uganda's musical heritage.
Task:
As a learner of physics;
(a)A drum produces a sound wave with a frequency of 150 Hz. If the speed of sound in air is 340 ms^{-1}, calculate its wavelength.
(b)Explain the difference between transverse and longitudinal waves, giving an example of each.
(c)Describe how the amplitude of a sound wave is related to its loudness.

(d)Why is understanding sound wave properties important for organizing large outdoor events?

Scenario 264

The Uganda National Meteorological Authority uses buoys on Lake Victoria to monitor water waves and provide weather warnings.The buoys measure the vertical displacement of the water surface over time, generating data on wave height (amplitude) and frequency. Meteorologists use this data to understand storm patterns and energy transfer over the lake, issuing timely warnings to fishermen and cargo ships. This application of wave physics is vital for the safety and economic activities of millions of people who depend on Lake Victoria.

Task:

As a learner of physics;

(a)A weather buoy records a water wave with an amplitude of 2 meters and a period of 8 seconds. Calculate the frequency of the wave.

(b)Write the general equation for a progressive wave and explain each term.

(c)Explain how wave energy is related to its amplitude and frequency.

(d)How does monitoring wave properties contribute to public safety and economic activities on Lake Victoria?

Scenario 265

A physics teacher in a rural school without sophisticated lab equipment uses a long slinky spring to demonstrate wave properties.Students create both transverse and longitudinal pulses by flicking the spring and observe how the wave speed changes when the spring's tension is altered. They measure wavelengths and frequencies using stopwatches and meter rules, calculating wave speeds and verifying the wave equation. This low-cost, hands-on approach has proven highly effective in making abstract wave concepts tangible for students across Uganda.

Task:

As a learner of physics;

(a)Describe how you would use a slinky spring to demonstrate transverse and longitudinal waves.

(b)In a slinky spring, a wave takes 0.5 seconds to travel 2 meters. Calculate the wave speed.

(c)If the frequency of the wave is 2 Hz, calculate the wavelength.

(d)Why are practical demonstrations important for understanding wave physics?

Sub-topic 23.2: Interference of Waves

Scenario 266

A noise control engineer is designing acoustic barriers for a new highway passing near a school in Wakiso District. The engineer uses principles of wave interference to design barrier structures that cause destructive interference of sound waves, reducing noise levels in classrooms. By calculating the wavelength of predominant traffic noises and designing barriers with specific shapes and materials, the engineer can create "quiet zones" through destructive interference. This application of physics helps protect the learning environment for thousands of students affected by Uganda's growing road infrastructure.

Task:

As a learner of physics;

(a)Explain the principle of superposition and how it leads to wave interference.

(b)Describe the conditions necessary for constructive and destructive interference.

(c)Two identical sound waves meet at a point. If the path difference between them is half a wavelength, what type of interference occurs and why?

(d)How can interference principles be used to reduce noise pollution in urban areas?

Scenario 267
A traditional xylophone maker in Buganda carefully tunes the instrument by adjusting the length of wooden bars to create specific musical intervals.The craftsman understands, through experience, that certain bar lengths produce sounds that interfere constructively to create pleasant harmonies, while others cause dissonance. Physics students studying this traditional craft have measured how the fundamental frequencies and overtones of different bars interact, explaining the acoustic principles behind the instrument's harmonious sound, thus bridging indigenous knowledge with modern science.
Task:
As a learner of physics;
(a)Explain how interference affects the sound quality of musical instruments.
(b)Two sound waves with frequencies 256 Hz and 260 Hz are produced simultaneously. Calculate the beat frequency heard.
(c)Describe how beats are formed and how they are used in tuning musical instruments.
(d)How can the study of wave interference help preserve and improve traditional musical instruments?
Scenario 268
An oil exploration company conducting seismic surveys in the Albertine Graben uses interference patterns to map underground rock structures.They generate shock waves at the surface and analyze how reflected waves from different geological layers interfere with each other. The resulting interference patterns reveal information about the depth and composition of underground formations, helping locate potential oil and gas reserves. This application of wave physics is crucial for Uganda's emerging petroleum industry.
Task:
As a learner of physics;
(a)Explain how interference patterns can provide information about underground structures.
(b)In a seismic survey, two reflected waves arrive at a detector with a path difference of 100 meters. If the wave speed is 2000 m/s and frequency is 20 Hz, determine whether constructive or destructive interference occurs.
(c)Describe how seismic interference patterns are used in oil exploration.
(d)Why is understanding wave interference important for natural resource exploration?

Scenario 269
A physics laboratory at Kyambogo University uses a ripple tank to demonstrate interference patterns of water waves.Students observe how two coherent sources create a characteristic pattern of nodes (points of destructive interference) and antinodes (points of constructive interference). They measure the distance between nodal lines and use this to calculate wavelengths, verifying theoretical predictions. These experiments help students visualize interference phenomena that are difficult to observe directly with light or sound waves.
Task:
As a learner of physics;
(a)Describe the interference pattern produced by two coherent wave sources in a ripple tank.
(b)In a ripple tank experiment, two sources 5 cm apart produce waves with wavelength 1 cm. Calculate the angle between the central maximum and the first nodal line.
(c)Explain why coherent sources are necessary to produce a stable interference pattern.
(d)How does the ripple tank experiment help in understanding wave interference?
Scenario 270
A fiber optics technician installing internet cables in Kampala must understand interference to minimize signal loss in optical fibers.When light waves travel through fibers, imperfections can cause multiple

reflections that interfere with the main signal. The technician uses this understanding to select appropriate fiber types and connection methods that minimize destructive interference, ensuring high-speed data transmission for Uganda's growing digital economy.

Task:

As a learner of physics;

(a)Explain how interference can affect signal quality in optical fibers.

(b)Light of wavelength 1500 nm travels through an optical fiber. Calculate the minimum path difference that would cause destructive interference.

(c)Describe how understanding interference helps in designing better communication systems.

(d)Why is reducing signal interference important for Uganda's digital development?

Sub-topic 23.3: Diffraction of Waves

Scenario 271

A marine navigation officer on Lake Victoria uses VHF radio to communicate with other vessels and shore stations.The officer understands that radio waves can diffract around islands and headlands, sometimes enabling communication even when there's no direct line of sight. This knowledge is crucial for planning communication strategies when navigating through the many islands of the Ssese archipelago, where direct radio paths are often obstructed. Understanding diffraction has improved maritime safety on Africa's largest lake.

Task:

As a learner of physics;

(a)Define diffraction and explain the conditions under which it is most noticeable.

(b)Radio waves with frequency 160 MHz are used for marine communication. Calculate their wavelength and explain why they can diffract around islands.

(c)How does the amount of diffraction change with the size of the obstacle relative to the wavelength?

(d)Why is understanding wave diffraction important for navigation and communication on Lake Victoria?

Scenario 272

A physics teacher uses laser pointers and various slits to demonstrate light diffraction patterns on a screen.Students observe how light spreads out after passing through narrow slits, creating characteristic patterns of bright and dark bands. They measure how the diffraction pattern changes with slit width, verifying that diffraction increases as the slit width approaches the wavelength of light. These experiments help students understand phenomena like the limitation of microscope resolution and the functioning of optical instruments.

Task:

As a learner of physics;

(a)Describe the diffraction pattern produced when light passes through a single narrow slit.

(b)A helium-neon laser (wavelength 633 nm) passes through a slit of width 0.1 mm. Calculate the angle to the first minimum in the diffraction pattern.

(c)Explain how diffraction limits the resolution of optical instruments.

(d)Design an experiment to study how diffraction depends on slit width.

Scenario 273

A traditional architect designing a new cultural center in Buganda incorporates ventilation openings that use sound diffraction principles. The openings are designed to allow air flow while diffracting street noises away from interior spaces, creating quieter indoor environments. This application of indigenous architectural knowledge, now explained through diffraction physics, demonstrates how traditional building designs often incorporated sophisticated understanding of wave behavior long before formal scientific study.

Task:
As a learner of physics;
(a)Explain how diffraction allows sound to enter rooms through open windows even when not in direct line with the sound source.
(b)Compare the diffraction of high-frequency and low-frequency sounds through the same opening.
(c)How can understanding sound diffraction improve architectural design?
(d)What can traditional architecture teach us about practical applications of physics principles?

Scenario 274
A medical ultrasound technician at a regional hospital in Uganda must understand diffraction to properly interpret ultrasound images.As ultrasound waves pass through body tissues, they diffract around structures, and the resulting diffraction patterns provide information about tissue composition and boundaries. The technician uses this understanding to distinguish between different types of tissues and identify potential abnormalities, contributing to diagnostic accuracy in healthcare facilities across Uganda.

Task:
As a learner of physics;
(a)Explain how diffraction affects ultrasound imaging.
(b)An ultrasound machine operates at 3.5 MHz. If the speed of sound in tissue is 1540 m/s, calculate the wavelength and discuss how this affects the resolution of the images.
(c)Describe how understanding wave diffraction helps in medical diagnostics.
(d)Why is ultrasound technology particularly valuable in resource-limited healthcare settings?

Scenario 275
A materials scientist at the Uganda Industrial Research Institute uses X-ray diffraction to analyze crystalline structures of local minerals.When X-rays pass through a crystal, they diffract in specific patterns that reveal the arrangement of atoms within the material. This technique helps identify mineral compositions and structures, supporting Uganda's mining sector and materials science research. The institute has trained local technicians in operating diffraction equipment, building national capacity in materials characterization.

Task:
As a learner of physics;
(a)Explain the principle of X-ray diffraction in crystal analysis.
(b)X-rays of wavelength 0.154 nm are diffracted from a crystal, producing a first-order maximum at 15°. Calculate the spacing between crystal planes.
(c)Describe how diffraction patterns provide information about crystal structures.
(d)How can materials characterization techniques like X-ray diffraction contribute to Uganda's industrial development?

Sub-topic 23.4: Polarisation of Waves

Scenario 276
A sunglasses manufacturer in Kampala produces polarized lenses that reduce glare for drivers,fishermen, and outdoor workers. The company's technicians understand how light reflected from horizontal surfaces becomes partially polarized and how polarizing filters can block this glare. This application of polarization physics has improved visual comfort and safety for many Ugandans, particularly those who work outdoors in bright conditions around water bodies or on paved surfaces.

Task:
As a learner of physics;
(a)Explain what is meant by polarization of transverse waves.

(b)Describe how reflection can polarize light waves.
(c)Explain how polarized sunglasses reduce glare from reflective surfaces.
(d)Why is reducing glare important for safety in activities like driving and fishing?

Scenario 277

A broadcast engineer at Uganda Broadcasting Corporation uses polarization in television transmission to increase channel capacity.By transmitting some signals with horizontal polarization and others with vertical polarization, the station can broadcast multiple channels on the same frequency without interference. This understanding of wave polarization helps optimize the use of limited broadcast spectrum, allowing more programming options for Ugandan viewers.

Task:

As a learner of physics;
(a)Explain the difference between polarized and unpolarized waves.
(b)Describe how polarization is used in communication systems to increase capacity.
(c)Why can't longitudinal waves be polarized?
(d)How does understanding polarization benefit broadcast technology in Uganda?

Scenario 278

A geology student on field study in the Karamoja region uses a polarizing microscope to identify mineral samples.The student observes how different minerals rotate the plane of polarized light in characteristic ways, helping identify mineral types even when they look similar to the naked eye. This application of polarization is valuable for geological mapping and mineral exploration in Uganda, supporting the sustainable development of the country's mineral resources.

Task:

As a learner of physics;
(a)Explain how a polarizing microscope works to identify minerals.
(b)Describe what is meant by optical activity and how it is used in mineral identification.
(c)Why is polarized light useful for studying crystalline structures?
(d)How can polarization techniques contribute to Uganda's mineral sector development?

Scenario 279

A physics teacher demonstrates polarization using simple materials available in Ugandan schools.Students use two polarizing filters and observe how rotating one filter relative to the other affects the transmitted light intensity. They also polarize radio waves using wire grid polarizers made from everyday materials. These low-cost experiments make the abstract concept of polarization tangible and help students understand applications ranging from 3D movies to liquid crystal displays (LCDs).

Task:

As a learner of physics;
(a)Describe a simple experiment to demonstrate polarization of light.
(b)Two polarizing filters are arranged with their transmission axes at 60° to each other. If unpolarized light of intensity I_0 is incident on the first filter, calculate the intensity transmitted through the second filter.
(c)Explain Malus's Law for the intensity of polarized light transmitted through a polarizer.
(d)Why are hands-on experiments valuable for understanding wave polarization?

Scenario 280

A research team at Makerere University studies seismic wave polarization to better understand Uganda's earthquake risks.By analyzing how seismic waves become polarized as they travel through different rock layers, the researchers can map subsurface structures and identify fault lines. This work contributes to Uganda's earthquake preparedness and helps in planning infrastructure that can withstand seismic events, particularly in regions near the Western Rift Valley.

Task:
As a learner of physics;
(a)Explain how seismic waves can become polarized.
(b)Describe how analyzing polarized seismic waves provides information about subsurface structures.
(c)Why is understanding seismic wave polarization important for earthquake risk assessment?
(d)How can physics research contribute to disaster preparedness in Uganda?

Topic 24: STATIONARY WAVES
Sub-topic 24.1: Formation of Stationary Waves
Scenario 281
A traditional music ensemble in the Busoga region uses string instruments like the"endingidi" (tube fiddle) that produce music through stationary waves. The players adjust the tension and length of the strings to create different notes, intuitively applying principles of stationary wave formation. A physics student studying these instruments measures how the fundamental frequency and harmonics relate to string length and tension, documenting how this indigenous knowledge aligns with acoustic physics. This research helps preserve Uganda's musical heritage while providing practical examples of stationary waves for physics education, creating a bridge between cultural traditions and scientific understanding in Ugandan schools.
Task:
As a learner of physics;
(a)Explain how stationary waves are formed on a stretched string.
(b)Describe the difference between nodes and antinodes in a stationary wave pattern.
(c)A string of length 0.6 m is fixed at both ends. Calculate the wavelength of the fundamental frequency.
(d)How does understanding stationary waves help in the study of traditional musical instruments?
Scenario 282
A telecommunications engineer working on Uganda's fiber optic network explains how stationary waves can cause signal degradation in poorly terminated cables.When signals reflect from the end of a cable, they interfere with incoming waves, creating stationary wave patterns that result in signal hotspots and dead spots. The engineer uses time-domain reflectometry to identify these points of impedance mismatch and ensures proper termination to prevent stationary wave formation. This application of wave physics has improved internet reliability across Uganda, supporting the country's digital transformation goals.
Task:
As a learner of physics;
(a)Explain how stationary waves can form in transmission lines.
(b)Describe what happens at points of impedance mismatch in a cable.
(c)Why are stationary waves undesirable in communication cables?
(d)How does understanding stationary waves improve telecommunications infrastructure?
Scenario 283
A physics teacher at a school near Lake Kyoga demonstrates stationary waves using a vibrator attached to a string with variable tension.Students observe how changing the frequency affects the number of nodes and antinodes, and they measure the relationship between frequency, tension, and the number of segments. This hands-on approach helps students visualize abstract wave concepts and understand the mathematical relationships governing stationary waves. The school has incorporated these demonstrations into their physics curriculum, improving student performance in national examinations.
Task:
As a learner of physics;
(a)Describe an experiment to demonstrate stationary waves on a string.

(b)A string under tension vibrates with three segments when driven at 120 Hz. Calculate the frequency needed to produce four segments.
(c)Explain how stationary waves differ from progressive waves.
(d)Why are practical demonstrations important for understanding wave phenomena?

Sub-topic 24.2: Stationary Waves in Pipes and Strings

Scenario 284

An organ builder in Kampala is constructing a pipe organ for a new cathedral,applying principles of stationary waves in pipes to create specific musical tones. The builder calculates the required pipe lengths for different notes, considering whether pipes are open at both ends or closed at one end. This application of acoustic physics ensures the organ produces harmonious sounds that enhance worship experiences. The project represents a fusion of traditional craftsmanship with scientific understanding, creating a musical instrument that will serve Uganda's growing Christian community for generations.

Task:

As a learner of physics;
(a)Compare stationary waves in open pipes and closed pipes.
(b)Calculate the fundamental frequency of an open pipe of length 0.5 m (speed of sound = 340 ms^{-1}).
(c)Explain why closed pipes produce only odd harmonics.
(d)How does understanding stationary waves in pipes help in musical instrument design?

Scenario 285

A noise control engineer designs acoustic resonators to reduce low-frequency noise from a generator at a rural health center in Nakaseke.The engineer creates Helmholtz resonators and quarter-wave tubes that form stationary waves at specific frequencies, effectively absorbing problematic noise. This application of stationary wave principles has made generator operations less disruptive to medical services, particularly important for health centers serving communities without grid electricity. The engineer has trained local technicians to maintain these acoustic treatments.

Task:

As a learner of physics;
(a)Explain how a quarter-wave tube can absorb sound of a specific frequency.
(b)Design a resonator to absorb 100 Hz noise, given the speed of sound is 340 ms^{-1}.
(c)Describe how stationary waves are used in noise control applications.
(d)Why is noise control important in healthcare settings?

Scenario 286

A university physics department studies the effect of temperature on stationary waves in organ pipes.Students measure how the pitch of pipes changes with temperature variations in the lecture hall, relating this to changes in the speed of sound. This research has practical implications for musical performance spaces in Uganda, where temperature can vary significantly between day and night. The findings help musicians and architects design spaces with stable acoustic properties.

Task:

As a learner of physics;
(a)Explain how temperature affects stationary waves in pipes.
(b)An organ pipe produces a frequency of 440 Hz at 20°C. Calculate the frequency at 30°C.
(c)Describe why musical instruments require tuning when temperature changes.
(d)How can understanding stationary waves improve architectural acoustics?

Topic 25: SOUND WAVES

Sub-topic 25.1: Production and Transmission of Sound

Scenario 287

A traditional storytelling group in northern Uganda uses various instruments and vocal techniques to produce sound waves that captivate audiences.The storytellers understand how to project their voices across open spaces and how different materials produce distinct sounds when struck. A physics student documenting these traditions explains the scientific principles behind sound production and transmission, showing how vocal cord vibrations create compression waves that travel through air to listeners' ears. This interdisciplinary study helps preserve oral traditions while demonstrating practical applications of sound physics in Ugandan cultural practices.

Task:

As a learner of physics;

(a)Explain how sound waves are produced and transmitted through a medium.

(b)Describe the factors that affect the speed of sound in air.

(c)Calculate the wavelength of a sound wave with frequency 1000 Hz (speed of sound = 340 ms^{-1}).

(d)How does understanding sound production and transmission enhance cultural performances?

Scenario 288

A wildlife conservation organization in Queen Elizabeth National Park uses acoustic monitoring to study animal populations.Researchers place recording devices throughout the park to capture sound waves produced by different species, from elephant rumbles to bird calls. Understanding how these sounds transmit through various environments helps researchers estimate animal numbers and monitor ecosystem health. This non-invasive monitoring technique has improved conservation efforts in Uganda's national parks, providing valuable data without disturbing wildlife.

Task:

As a learner of physics;

(a)Explain why sound cannot travel through a vacuum.

(b)Compare how sound travels through solids, liquids, and gases.

(c)A researcher times how long it takes for an elephant's call to travel 1 km. If the speed of sound is 340 m/s, calculate this time.

(d)How does acoustic monitoring support wildlife conservation in Uganda?

Sub-topic 25.2: Notes, Beats and Octaves

Scenario 289

A piano tuner servicing instruments in Kampala's music schools uses the phenomenon of beats to achieve perfect tuning.The tuner strikes two strings that should produce the same note and listens for beats, adjusting tension until the beats disappear. This application of sound wave interference ensures that pianos used in Uganda's growing music education sector are properly tuned. The tuner has developed a training program to teach apprentices this skilled trade, combining practical expertise with understanding of physics principles.

Task:

As a learner of physics;

(a)Explain how beats are produced when two sound waves of slightly different frequencies interfere.

(b)Two tuning forks of frequencies 256 Hz and 260 Hz are sounded together. Calculate the beat frequency.

(c)Describe how beats are used in tuning musical instruments.

(d)Why is proper instrument tuning important for music education?

Scenario 290
A traditional choir director in Buganda teaches singers about octaves and harmonic intervals,concepts that have deep roots in Ugandan musical traditions. The director explains how notes separated by an octave have frequencies in a 2:1 ratio, creating a pleasing harmonic relationship. This understanding helps choir members maintain proper pitch relationships and create the rich harmonies characteristic of Ugandan choral music. The director incorporates basic acoustics into rehearsals, enhancing both musical performance and scientific literacy.
Task:
As a learner of physics;
(a)Define the terms note, beat, and octave in the context of sound waves.
(b)If a note has frequency 440 Hz, calculate the frequency of the note one octave higher.
(c)Explain why notes separated by octaves sound harmonious when played together.
(d)How does understanding the physics of sound improve musical performance?

Sub-topic 25.3: Doppler Effect
Scenario 291
A traffic police unit in Kampala uses radar guns based on the Doppler effect to monitor vehicle speeds on busy roads.Officers understand that the frequency change between transmitted and reflected radio waves reveals a vehicle's speed. This application of physics helps enforce speed limits and improve road safety in Uganda's capital, where traffic accidents remain a significant concern. The police department has trained officers in the basic principles behind the technology to ensure proper use and accurate speed measurements.
Task:
As a learner of physics;
(a)Explain the Doppler effect and how it is used in speed measurement.
(b)A radar gun operating at 10 GHz measures a frequency increase of 1500 Hz for a approaching car. Calculate the car's speed (speed of light = 3×10^{8} ms^{-1}).
(c)Describe why the observed frequency changes when a source and observer are in relative motion.
(d)How does Doppler radar technology contribute to road safety in Uganda?
Scenario 292
A medical ultrasound technician at a hospital in Mbale uses Doppler ultrasound to monitor blood flow in patients.The technician understands how frequency changes in reflected ultrasound waves reveal the speed and direction of blood flow. This non-invasive technique helps diagnose conditions like deep vein thrombosis and monitor fetal heartbeat during pregnancy. Understanding the Doppler effect is essential for proper interpretation of these medical images, contributing to healthcare quality in Uganda's regional hospitals.
Task:
As a learner of physics;
(a)Explain how the Doppler effect is used in medical ultrasound.
(b)Describe how Doppler ultrasound provides information about blood flow.
(c)Why is Doppler ultrasound a valuable diagnostic tool in resource-limited settings?
(d)How has physics contributed to improvements in medical diagnostics in Uganda?

Topic 26: CURRENT ELECTRICITY
Sub-topic 26.1: Current, Resistance and Ohm's Law
Scenario 293
An electrical engineer working with Uganda's Rural Electrification Agency is designing appropriate electrical systems for villages newly connected to the grid.The engineer must calculate current flows and voltage drops in distribution lines to ensure all households receive adequate power. Understanding Ohm's Law and resistance principles helps design systems that minimize power loss over long distances, a critical consideration in Uganda's rural electrification efforts. This work supports the government's goal of increasing electricity access from the current 60% to 100% of the population.
Task:
As a learner of physics;
(a)State Ohm's Law and define electrical resistance.
(b)Calculate the current flowing through a 100 Ω resistor connected to a 240 V supply.
(c)Explain how resistance causes voltage drop in long distribution lines.
(d)Why is understanding current and resistance important for rural electrification projects?
Scenario 294
A vocational school in Lira teaches electrical installation skills to students seeking employment in Uganda's growing construction sector. Students learn to measure current, voltage, and resistance using multimeters and verify Ohm's Law through practical experiments. They also learn how different materials and wire thicknesses affect resistance, knowledge essential for safe and efficient electrical installations. This training provides valuable skills that support Uganda's infrastructure development while creating employment opportunities for technical graduates.
Task:
As a learner of physics;
(a)Describe an experiment to verify Ohm's Law.
(b)A copper wire of length 50 m and cross-sectional area 2.5 mm² has resistivity 1.7×10^{-8} Ωm. Calculate its resistance.
(c)Explain how resistance depends on the dimensions and material of a conductor.
(d)Why are practical electrical skills important for Uganda's development?

Topic 27: MAGNETISM IN MATTER
Sub-topic 27.1: Magnetic Fields
Scenario 295
A geology student at Mbarara University of Science and Technology studies Earth's magnetic field and its variations across Uganda.The student uses a magnetometer to measure field strength at different locations, noting how it changes from the volcanic regions in the west to the sedimentary basins in the east. This research contributes to understanding Uganda's geological history and has applications in navigation and mineral exploration. The student presents findings at a national science conference, highlighting how physics principles help interpret Uganda's geological features.
Task:
As a learner of physics;
(a)Describe Earth's magnetic field and its importance.
(b)Explain how a compass needle aligns with Earth's magnetic field.
(c)Calculate the force on a 2 m wire carrying 5 A current perpendicular to a 0.5 T magnetic field.
(d)How does studying magnetic fields contribute to geological understanding?

Sub-topic 27.2: Magnetisation and Demagnetisation

Scenario 296

A manufacturing company in Namanve Industrial Park produces magnetic components for various industries.Quality control technicians must understand magnetization processes to ensure components meet specifications. They also know how to safely demagnetize tools that become accidentally magnetized during manufacturing processes. This expertise supports Uganda's growing manufacturing sector, particularly in electronics and automotive components production.

Task:

(a)Explain the process of magnetizing a ferromagnetic material.

(b)Describe different methods of demagnetization.

(c)Why might accidental magnetization be problematic in certain tools?

(d)How does understanding magnetization processes support industrial development?

Topic 28: MAGNETIC EFFECT OF AN ELECTRIC CURRENT

Sub-topic 28.1: Force on a Current-Carrying Conductor

Scenario 297

An electric motor repair workshop in Kampala services motors used in various industries across Uganda.Technicians understand how the force on current-carrying conductors in magnetic fields creates the rotation in electric motors. This knowledge helps them diagnose motor problems and rewind coils correctly. The workshop has become a training center for electric motor technicians, supporting maintenance of industrial equipment and agricultural machinery throughout Uganda.

Task:

As a learner of physics;

(a)State Fleming's Left-Hand Rule for the force on a current-carrying conductor.

(b)Calculate the force on a 0.3 m conductor carrying 8 A current perpendicular to a 0.4 T magnetic field.

(c)Explain how this principle is applied in electric motors.

(d)Why are electric motor repair skills valuable in Uganda's industrial and agricultural sectors?

Topic 29: ELECTROMAGNETIC INDUCTION

Sub-topic 29.1: Laws of Electromagnetic Induction

Scenario 298

A technician at the Bujagali Hydropower Plant explains how electromagnetic induction principles generate electricity for Uganda's grid.The technician describes how rotating turbines spin magnets within coils, inducing current according to Faraday's Law. Understanding these principles helps in maintaining optimal generator performance and troubleshooting power generation issues. This knowledge is crucial for Uganda's energy sector, as hydropower provides the majority of the country's electricity.

Task:

As a learner of physics;

(a)State Faraday's Law of electromagnetic induction.

(b)Explain Lenz's Law and how it relates to Faraday's Law.

(c)Describe how a generator produces electricity using electromagnetic induction.

(d)Why is understanding electromagnetic induction important for Uganda's energy sector?

Topic 30: A.C CIRCUITS

Sub-topic 30.1: Measurement of A.C

Scenario 299

An electrical inspector with the Uganda Electricity Regulatory Authority conducts safety audits of commercial buildings in Kampala. The inspector uses instruments to measure AC parameters like RMS

voltage, frequency, and power factor to ensure compliance with national standards. Understanding AC measurement principles is essential for identifying potential safety hazards and ensuring efficient energy use in Uganda's growing commercial sector.

Task:

As a learner of physics;

(a)Explain the difference between peak voltage and RMS voltage in AC circuits.

(b)Calculate the RMS value of an AC voltage with peak value 340 V.

(c)Describe how an AC ammeter differs from a DC ammeter.

(d)Why is proper AC measurement important for electrical safety?

Topic 31: ATOMIC PARTICLES

Sub-topic 31.1: Rutherford's Atomic Model

Scenario 300

A physics teacher at a school in Gulu uses simple analogies to explain Rutherford's gold foil experiment and its implications for atomic structure.Students learn how this experiment revealed the nuclear model of the atom, with most of the atom's mass concentrated in a tiny nucleus. The teacher connects this historical experiment to modern applications like radiation therapy in cancer treatment, showing how fundamental physics research leads to practical technologies that benefit society.

Task:

As a learner of physics;

(a)Describe Rutherford's alpha particle scattering experiment.

(b)Explain how the results of this experiment led to the nuclear model of the atom.

(c)Why were most alpha particles undeflected in this experiment?

(d)How does understanding atomic structure contribute to modern technologies?

Topic 32: QUANTUM THEORY

Sub-topic 32.1: Photo Electric Effect

Scenario 301

A solar panel installer in Uganda explains how the photovoltaic effect—based on quantum principles—converts sunlight into electricity.The installer understands that photons with sufficient energy can eject electrons from semiconductor materials, creating current flow. This knowledge helps in selecting appropriate solar panels for different applications and optimizing their installation for maximum energy capture. As Uganda expands solar energy use, understanding these quantum principles becomes increasingly important for renewable energy technicians.

Task:

As a learner of physics;

(a)Explain the photoelectric effect and its significance in quantum theory.

(b)Describe how the photoelectric effect is utilized in solar panels.

(c)Why don't all photons cause electron emission in the photoelectric effect?

(d)How has quantum physics contributed to renewable energy development in Uganda?

Topic 33: NUCLEAR PROCESSES

Sub-topic 33.1: Nuclear Stability

Scenario 302

A medical physicist at the Uganda Cancer Institute explains how radioactive isotopes are used in cancer diagnosis and treatment.The physicist understands which isotopes are stable enough for medical use and how unstable isotopes decay in predictable ways. This knowledge ensures safe and effective use of

nuclear medicine in Uganda's healthcare system, particularly important as cancer incidence rises nationwide.

Task:

As a learner of physics;

(a)Explain what makes a nucleus stable or unstable.

(b)Describe the concept of half-life in radioactive decay.

(c)How are radioactive isotopes used in medicine?

(d)Why is understanding nuclear processes important for healthcare in Uganda?

Scenario 303

The Uganda Energy Board is conducting a preliminary feasibility study on the potential for nuclear power as a long-term,low-carbon energy source to complement hydropower. Engineers are analyzing different fissionable isotopes, such as Uranium-235 and Thorium-232, comparing their natural abundance, half-lives, and the energy released per fission reaction. A key part of the study involves understanding the "band of stability" on the N-Z graph to explain why some nuclei are stable while others undergo radioactive decay. This foundational research is crucial for informing a national debate on energy security and diversification.

Task:

As a learner of physics;

(a)Explain what is meant by the "band of nuclear stability" on a plot of neutrons (N) versus protons (Z).

(b)State two factors that contribute to the stability of a nucleus.

(c)Uranium-235 (^{235}U) has 92 protons. Calculate the number of neutrons it contains and use the concept of the band of stability to suggest why it is fissionable.

(d)Why is understanding nuclear stability a necessary first step for any country considering nuclear energy?

Scenario 304

A researcher at the Uganda Industrial Research Institute is using a gamma irradiation chamber to sterilize medical equipment and preserve agricultural seeds.The Cobalt-60 source in the chamber decays into Nickel-60. The researcher must understand why Co-60 is unstable and the nature of its decay to ensure the chamber operates safely and effectively. She explains to interns that the decay process moves the nucleus closer to the band of stability.

Task:

As a learner of physics;

(a)Cobalt-60 decays to Nickel-60 via beta decay. Write the balanced nuclear equation for this process.

(b)Explain, in terms of the composition of the nucleus, why Cobalt-60 undergoes beta decay to achieve greater stability.

(c)Calculate the energy equivalent (in Joules) of the mass defect for this decay if the total mass of the products is 0.001 u less than the mass of Cobalt-60 (1 u = 931.5 MeV/c^2).

(d)Why are radioactive isotopes like Cobalt-60 suitable for sterilization despite being unstable?

Scenario 305

In a physics laboratory at Makerere University, students are analyzing a graph of binding energy per nucleon against mass number. They discuss how this graph explains both nuclear fusion (in stars) and fission (in reactors). The lecturer uses the graph to explain why middle-mass nuclei are the most stable and why energy is released when very heavy nuclei split or very light nuclei combine.

Task:

As a learner of physics;

(a)Sketch a typical graph of binding energy per nucleon versus mass number and label the regions where fusion and fission are energy-releasing processes.

(b)Using the graph, explain why iron-56 is considered one of the most stable nuclei.
(c)The binding energy per nucleon for Uranium-235 is about 7.6 MeV, while for middle-mass nuclei it is about 8.5 MeV. Estimate the energy released when one U-235 nucleus fissions into two middle-mass nuclei.
(d)How does the concept of binding energy per nucleon provide a unified explanation for stellar energy and nuclear power?

Sub-topic 33.2: Radioactivity
Scenario 306
A severe storm has damaged a research facility in Kampala, leading to the rupture of a sealed container holding a powdered Iodine-131 source. Iodine-131 is a beta and gamma emitter with a half-life of 8 days. An emergency response team is dispatched to contain the spill, monitor radiation levels, and assess the risk of contamination to the environment and nearby water sources.
Task:
As a learner of physics;
(a)Iodine-131 decays to Xenon-131. Identify the type of decay and write the balanced nuclear equation.
(b)The initial activity of the spilled source was 3.2×10^7 Bq. Calculate the activity remaining after 24 days.
(c)Explain why beta and gamma radiation from Iodine-131 poses a significant external and internal hazard to humans.
(d)Describe two key safety procedures the emergency team must follow during the cleanup operation.
Scenario 307
Archaeologists working at a historical site in Bigo bya Mugenyi have discovered ancient pottery shards.To determine the age of the site, they use radiocarbon dating on charcoal samples found alongside the pottery. Carbon-14, with a half-life of 5730 years, is absorbed by living organisms, and its decay starts after death. The measured activity of the charcoal sample is found to be 25% of the activity of a modern living sample.
Task:
As a learner of physics;
(a)Explain the principle behind radiocarbon dating.
(b)Calculate the age of the charcoal sample based on the measured activity.
(c)State one key assumption made in radiocarbon dating and one factor that could lead to an inaccurate date.
(d)How does physics, through techniques like radiocarbon dating, contribute to our understanding of history and archaeology in Uganda?
Scenario 308
The Uganda Cancer Institute at Mulago Hospital uses a linear accelerator for radiotherapy.However, for certain complex cancers, a treatment called Brachytherapy is used, where small radioactive "seeds" (e.g., containing Iodine-125 or Palladium-103) are implanted directly into a tumor. A medical physicist must calculate the initial activity of the seeds to deliver a precise radiation dose over the treatment period, ensuring the cancer cells are destroyed while minimizing damage to surrounding healthy tissue.
Task:
As a learner of physics;
(a)Palladium-103 has a half-life of 17 days. If a seed must deliver a total dose equivalent to an initial activity of 4.0×10^7 Bq over 34 days, calculate the initial activity the seed must have when implanted.
(b)Explain the advantage of using a radioactive isotope with a short half-life for Brachytherapy.

(c)Contrast the use of implanted radioactive seeds (Brachytherapy) with external beam radiotherapy in terms of how radiation is delivered to the tumor.
(d)Why is the role of a medical physicist critical in modern cancer treatment?

Scenario 309
A large stockpile of radioactive waste is stored at a temporary facility in Nakasongola. This waste contains various isotopes with half-lives ranging from a few days to thousands of years. A government committee is tasked with developing a long-term management plan, which includes deciding whether to pursue deep geological disposal. They need to understand the decay processes of the waste to predict its hazard duration.
Task:
As a learner of physics;
(a)Define the term "radioactive waste" and give two examples of such waste from medical and research applications.
(b)A particular waste component is Strontium-90 (half-life 29 years). Calculate the fraction of Sr-90 that remains after 100 years.
(c)Explain why high-level radioactive waste with long-lived isotopes poses a significant challenge for disposal.
(d)Discuss one ethical consideration in managing radioactive waste for future generations.
Scenario 310
A farmer in the Kasese district has been advised to use a fertilizer rich in Phosphorus.A local agricultural extension officer explains that researchers have used the radioactive isotope Phosphorus-32 (a beta emitter) as a tracer to study how effectively plants absorb phosphorus from this type of fertilizer. By tracking the radiation, they determined the optimal application method and timing for maximum crop yield.
Task:
As a learner of physics;
(a)Explain how a radioactive tracer like Phosphorus-32 can be used to study plant nutrient uptake.
(b)Phosphorus-32 has a half-life of 14.3 days. If a sample has an initial activity suitable for tracing, explain why it would become useless after a few months.
(c)State two advantages of using radioactive tracers in agricultural research.
(d)How can such nuclear techniques contribute to improving food security in Uganda?

CHEMISTRY SCENARIO BASED ITEMS

Topic 1: Moles and Equations

Sub-topic 1.1: Masses of Atoms and Molecules, Accurate Relative Atomic Masses

Scenario 1

In the rugged highlands of Kasese District,a mineral prospector named Mr. Mbabazi made an exciting discovery: a rich vein of a mineral containing the element boron. To properly assess its commercial value and potential applications in the local glass manufacturing industry, he needed to determine its precise chemical composition. He collected a substantial sample and sent it to the Uganda Geological Laboratories in Entebbe for detailed isotopic analysis. The laboratory technicians, using a state-of-the-art mass spectrometer, determined that the boron in the sample consisted of two stable isotopes. They found that Boron-10, with an atomic mass of 10.013 amu, had a relative abundance of 19.9%, while Boron-11, with an atomic mass of 11.009 amu, made up the remaining 80.1% of the boron atoms present. Mr. Mbabazi now needs to understand this data to accurately report the findings to potential investors at the Ministry of Energy and Mineral Development, explaining why the atomic mass of his boron sample isn't a simple whole number and how this affects its potential industrial uses in making borosilicate glass and other chemical applications relevant to Uganda's growing industrial sector.

Task:

a)Define the term isotope.

b)Calculate the accurate relative atomic mass of the Boron sample from the mine.

c)State why the relative atomic mass of Boron is not a whole number.

d)The mass spectrometer is an instrument used to determine such isotopic abundances. State one property it uses to separate the isotopes.

Scenario 2

At the Uganda Cancer Institute in Kampala,Dr. Nalwanga, a senior medical physicist, was preparing a dosage of radioactive iodine-131 for a patient diagnosed with thyroid cancer. She gathered a group of medical interns to explain the procedure, emphasizing the importance of understanding nuclear chemistry in medical applications. She detailed how Iodine-131, with a mass number of 131, decays owever, one observant intern noticed a seeming contradiction: the periodic table on the wall listed the relative atomic mass of iodine as approximately 126.90, not 131. This led to a detailed discussion about the distinctions between mass number, which characterizes a specific isotope, and relative atomic mass, which represents a weighted average of all naturally occurring isotopes. Dr. Nalwanga used this teaching moment to elaborate on iodine's isotopic composition in nature, explaining that Iodine-127 is by far the most abundant isotope, which pulls the average atomic mass down significantly, despite the existence of other isotopes like Iodine-131 used in their medical work.

Task:

a)Distinguish between the terms mass number and relative atomic mass.

b)Iodine-131 has a mass number of 131. Calculate the number of neutrons in one atom of this isotope, given that its atomic number is 53.

c)Explain why the relative atomic mass of iodine listed on the periodic table is closer to 127 than to 131.

Scenario 3

At the Kilembe Mines copper smelting plant near Kasese,Engineer Tibuhaburwa faced a pressing quality control issue. A major shipment of copper anodes, destined for use in the Mukono electrical wiring factory, was suspected of contamination. Pure copper is vital for optimal electrical conductivity, and even small impurities could degrade the performance of the wires. He knew that natural copper consists primarily of two stable isotopes: Copper-63 with an isotopic mass of 62.930 amu and a natural abundance of 69.17%, and Copper-65 with an isotopic mass of 64.928 amu and an abundance of 30.83%. He ordered

a mass spectrometric analysis of the suspect batch. The results showed a slight but significant deviation from the standard isotopic ratio, indicating contamination with a foreign material that was altering the overall atomic mass. Engineer Tibuhaburwa now had to calculate the exact extent of this deviation, identify which copper isotope was being disproportionately affected by the contaminant, and recommend a process to rectify the issue to ensure Uganda's electrical products meet international quality standards and support the country's growing infrastructure development.

Task:

a)Calculate the accurate relative atomic mass of pure copper.

b)If the contaminated sample was found to have a lower relative atomic mass than pure copper, which isotope (Cu-63 or Cu-65) would you expect to be less abundant in that sample? Explain your answer.

c)Suggest a potential industrial method that could be used to separate isotopes, albeit on a small scale, to understand the nature of the contamination.

Sub-topic 1.2: Amount of Substance, Mole Calculations

Scenario 4

At the AgroPlus fertilizer plant in Jinja,the chief chemist, Mr. Ochieng, faced a critical production challenge. A large international order for ammonium sulfate fertilizer, crucial for boosting maize yields in the country, was due for shipment. The production team had prepared a massive batch, resulting in a 10 kg bag of pure ammonium sulfate, $(NH_4)_2SO_4$. However, to ensure precise quality control, accurate labeling, and correct pricing, Mr. Ochieng needed to determine the exact number of moles contained in each bag. This information was vital not only for inventory and sales but also for the farmers who relied on precise application rates to optimize their crop nutrition without causing environmental damage through overuse. He gathered his team and emphasized the importance of the mole concept as a bridge between the microscopic world of atoms and the macroscopic world of grams and kilograms, which they could measure in the factory. Understanding this would allow them to calculate the number of fundamental formula units and, specifically, the number of ammonium ions (NH_4^+), which are the key source of nitrogen for plants. This calculation was essential to guarantee that the fertilizer met the stated nutritional grade and complied with the standards set by the Uganda National Bureau of Standards.

Task:

a)Calculate the molar mass of ammonium sulfate, $(NH_4)_2SO_4$. (N=14, H=1, S=32, O=16)

b)How many moles of ammonium sulfate are present in the 10 kg bag?

c)Calculate the number of ammonium ions (NH_4^+) present in the bag.

Scenario 5

During a practical chemistry lesson at Kibuli Secondary School,the advanced-level students were conducting a titration to master the concepts of concentration and moles. The experiment involved neutralizing 25 cm^3 of a 2.0 M hydrochloric acid (HCl) solution with a standard sodium hydroxide (NaOH) solution. The teacher, Mr. Ssentamu, explained that this simple reaction, $HCl + NaOH \rightarrow NaCl + H_2O$, was fundamental to many industrial processes in Uganda, from treating acidic waste at the Nile Breweries to controlling pH in food processing. He tasked the students with calculating the exact amount of sodium hydroxide required for complete neutralization. One student, Aisha, carefully performed the titration, reaching the pale pink endpoint of the phenolphthalein indicator. However, to verify her practical skills, Mr. Ssentamu also required the theoretical calculations. He then presented a follow-up challenge: if the sodium hydroxide solution available was more dilute, with a concentration of only 0.5 M, how would that affect the volume needed? This exercise was designed to reinforce the direct relationship between moles, concentration, and volume, and to highlight the importance of accurate calculations in preparing reagents for medical laboratories and water quality testing across the country.

Task:

a)Calculate the number of moles of hydrochloric acid in the 25 cm^3 of 2M solution used.

b)Determine the number of moles of sodium hydroxide required for complete neutralization.

c)If the sodium hydroxide solution had a concentration of 0.5 M, calculate the volume of it that would be required for the reaction.

Scenario 6

A chemistry teacher at St.Mary's College Kisubi, Mrs. Nalubega, was demonstrating the principle of stoichiometry through the combustion of methane gas, the primary component of the natural gas used in their laboratory Bunsen burners. She ignited the burner and adjusted it to a clean, blue flame, explaining that this represented the complete combustion of methane (CH_4) according to the equation: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. To make the concept tangible, she posed a problem to her Senior Five class: if she were to burn exactly 8 grams of methane gas, how could they predict the amount of oxygen consumed and the resulting carbon dioxide produced? She emphasized that such calculations were not just academic; they were crucial for environmental science, helping to understand greenhouse gas contributions from different fuel sources, and for engineers designing biogas systems that are becoming increasingly common in rural Uganda. The students had to use the mole concept to navigate from the mass of a reactant to the moles of another reactant and finally to the mass of a product, thereby solving a real-world problem relevant to Uganda's energy and environmental landscape.

Task:

a)Calculate the number of moles in 8 grams of methane (CH_4). (C=12, H=1)

b)Using the reaction equation, determine the number of moles of oxygen gas (O_2) required to burn this methane completely.

c)What mass of carbon dioxide (CO_2) would be produced from this reaction?

Sub-topic 1.3: Chemical Formulae and Chemical Equations

Scenario 7

The low-lying,frequently flooded community of Katwe in Kampala has long battled a pervasive problem: the rapid rusting of corrugated iron roofing sheets. A community development officer, Mr. Kato, decided to use this issue to educate local youth volunteers about the chemistry of corrosion. He explained that rust is a form of hydrated iron(III) oxide, and its formation is a complex reaction involving iron, oxygen from the air, and water. He simplified the process for the demonstration, representing rust as Fe_2O_3. Mr. Kato tasked the group with writing a balanced chemical equation to understand the reactants and products. He then linked this knowledge to practical prevention methods, asking them to suggest ways to stop the reaction by excluding one of the essential reactants. Finally, to quantify the problem, he presented a calculation: if a typical roofing sheet contained 112g of iron that rusted completely, how much mass would be added in the form of rust? This exercise aimed to empower the community with scientific knowledge, helping them make informed decisions about material protection and saving significant costs in household maintenance.

Task:

a)Write a balanced chemical equation for the formation of rust (iron(III) oxide) from iron and oxygen.

b)State two ways, based on the reaction, to prevent iron from rusting.

c)If 112g of iron rusts completely, calculate the mass of iron(III) oxide produced. (Fe=56, O=16)

Scenario 8

The science club at Kampala Parents'School was in a frenzy of preparation for the annual national science fair. Their flagship project was a spectacular model volcano that would "erupt" using a classic chemical reaction: the reaction between baking soda (sodium hydrogencarbonate, $NaHCO_3$) and vinegar (a dilute solution of ethanoic acid, CH_3COOH). The students, led by their president David, knew the reaction

produced sodium ethanoate, water, and the carbon dioxide gas that caused the foaming eruption. To ensure a dramatic and controlled eruption, they needed to master the stoichiometry. They decided to use 8.4g of baking soda for the final demonstration. David gathered his team to plan the experiment, emphasizing the need to write a balanced equation first to understand the mole ratios. They then needed to calculate the exact amount of carbon dioxide gas this would produce to predict the volume of the "lava" flow. Understanding this relationship between the mass of a solid reactant and the volume of a gaseous product was key to making their project both visually impressive and scientifically accurate, demonstrating important principles of chemical reactions to the judges and audience.

Task:

a)Write a balanced chemical equation for the reaction between sodium hydrogencarbonate and ethanoic acid.

b)The students use 8.4g of baking soda. Calculate the number of moles used.

c)Determine the volume of carbon dioxide gas produced at room temperature from this amount. (Molar gas volume at RTP = 24 dm^3)

Scenario 9

The massive rotary kilns at the Tororo Cement Factory work tirelessly,heating limestone (calcium carbonate, $CaCO_3$) to high temperatures in a process known as calcination. Mr. Ogwang, a process engineer, was tasked with optimizing fuel efficiency and output for the plant. The key reaction, the thermal decomposition of limestone into quicklime (calcium oxide, CaO) and carbon dioxide gas, is the heart of cement production. He was reviewing the process data when he was interrupted by a group of visiting engineering students from Busitema University. He used the opportunity for an impromptu lecture, starting with the importance of writing a balanced chemical equation for the decomposition. He then presented a real-world problem: for a typical production run processing 50 tonnes of pure limestone, how much quicklime could the plant expect to produce? He explained that this calculation was fundamental to predicting yield, managing inventory, and calculating the carbon footprint of their operations. Finally, he connected the chemistry to its application, questioning the students on the vital role quicklime plays in the construction industry, thus linking the abstract chemical reaction to the tangible development of Uganda's infrastructure.

Task:

a)Write a balanced chemical equation for the thermal decomposition of calcium carbonate.

b)Calculate the mass of quicklime (CaO) produced when 50 tonnes of pure limestone is completely decomposed. (Ca=40, C=12, O=16)

c)State one major use of quicklime (CaO) in the construction industry.

Topic 2: ATOMIC AND ELECTRONIC STRUCTURE

Sub-topic 2.1: Electron Configurations of Atoms and Ions

Scenario 10

A technician at Makerere University repairs a photocopier,explaining that its drum is coated with selenium. Its specific electron configuration allows it to conduct electricity when exposed to light, forming an electrostatic image. Selenium (atomic number 34) is in the same group as oxygen. The technician needs to document how selenium's electron configuration makes it suitable for this application compared to its lighter counterpart, sulfur. Understanding this atomic property is key to maintaining office equipment across Uganda's institutions.

Task:

a)Write the electron configuration of a selenium atom.

b)Explain what happens to the electron configuration when selenium forms the Se^{2-} ion.

c)State the number of unpaired electrons in a selenium atom.

Scenario 11

At the Gaba Water Treatment Plant,a chemist uses aluminium sulfate (alum) as a coagulant. The Al^{3+} ion's electron configuration allows it to attract impurities, clarifying water for Kampala. The chemist trains new staff on why aluminium, a Period 3 metal, forms a 3+ ion and how this relates to its position in the periodic table and its reactivity, ensuring effective and safe water purification practices.

Task:

a)Write the electron configuration of an aluminium atom (atomic number 13).

b)Write the electron configuration of an Al^{3+} ion.

c)State which noble gas has the same electron configuration as the Al^{3+} ion.

Scenario 12

An engineer at a Namanve lighting company designs LEDs.She uses gallium (atomic number 31) in semiconductors. The color of light emitted depends on energy gaps influenced by gallium's electron configuration. She must select elements with specific electronic structures to produce different colors for traffic lights and displays, supporting Uganda's growing electronics sector.

Task:

a)Write the electron configuration of a gallium atom using subshell notation.

b)Identify the block (s, p, d, f) in the periodic table where gallium is located.

c)State whether a gallium atom is paramagnetic or diamagnetic. Explain your answer.

Sub-topic 2.2: Radioactivity and Its Applications

Scenario 13

At the Uganda Cancer Institute,a radiographer uses Cobalt-60 for radiotherapy. Its beta and gamma radiation target cancer cells. The source has a half-life of 5.27 years and must be replaced when its activity diminishes to ensure consistent treatment doses. Understanding its decay process and half-life is critical for patient safety and effective cancer care in the country.

Task:

a)Write a balanced nuclear equation for the beta decay of Cobalt-60.

b)Calculate the percentage of a Cobalt-60 sample that would remain after 21 years.

c)State why gamma radiation is particularly suitable for radiotherapy.

Scenario 14

Archaeologists at the Bigo bya Mugenyi site use Carbon-14 dating on a wooden artifact. They find it has 25% of the original Carbon-14 activity. This isotope decays predictably, with a half-life of 5730 years, allowing them to accurately date the ancient settlement and understand Uganda's early history. The team must calculate the artifact's age to confirm the site's timeline.

Task:

a)Write the nuclear equation for the beta decay of Carbon-14.

b)Given the half-life is 5730 years, calculate the age of the wooden artifact.

c)State one assumption made in Carbon-14 dating.

Scenario 15

In a Jinja steel mill,a quality controller uses a Strontium-90 source in a thickness gauge. The beta particles penetrate the steel sheets; weaker signals indicate thicker sheets. Strontium-90 has a half-life of 28.8 years. The source must be replaced once its activity falls below 10% to maintain quality control in manufacturing.

Task:

a)Strontium-90 decays to Yttrium-90. Write the nuclear equation for this decay.

b)Calculate how long the source can be used before replacement.
c)State why a beta emitter is preferred over an alpha emitter for this application.

Topic 3: BONDING AND STRUCTURE
Sub-topic 3.1: Formation of Ionic and Metallic Bonds
Scenario 16
At Lake Katwe,a salt farmer harvests sodium chloride crystals. A visiting chemist explains that the strong ionic bonds in NaCl give it a high melting point and solubility. These bonds form when sodium atoms lose electrons to chlorine atoms, creating a lattice of Na^+ and Cl^- ions. This structure is why the salt dissolves in lake water but forms solid crystals when the water evaporates.
Task:
a)Describe how an ionic bond forms between sodium and chlorine atoms.
b)Explain why solid sodium chloride does not conduct electricity but does so when molten.
c)State the coordination number of each ion in the sodium chloride crystal lattice.
Scenario 17
An electrician in Kampala uses copper for wiring due to its excellent conductivity from metallic bonding.In this bond, copper atoms release electrons into a 'sea' that moves freely, carrying current. This same delocalized electron pool allows copper to be malleable, drawn into wires for Uganda's expanding electrical grid without breaking the material.
Task:
a)Describe the nature of metallic bonding in copper.
b)Explain how metallic bonding accounts for the high electrical conductivity of copper.
c)State why copper is malleable and can be drawn into wires.
Scenario 18
At Tororo Cement,magnesium oxide lines furnaces as a refractory. The engineer explains that the high melting point is due to strong ionic bonding between Mg^{2+} and O^{2-} ions. The high charges and small sizes of the ions create a very strong electrostatic attraction, making MgO capable of withstanding extreme temperatures during clinker production.
Task:
a)Compare the strength of ionic bonding in magnesium oxide with that in sodium chloride, giving a reason.
b)Write the electron configuration of Mg^{2+} and O^{2-} ions.
c)Calculate the percentage ionic character in the Mg-O bond (electronegativity: Mg=1.2, O=3.5).

Sub-topic 3.2: Covalent Bonds and Molecular Structures
Scenario 19
An anesthetist at Mulago Hospital uses nitrous oxide(N_2O). A student asks about its structure. The doctor explains that its linear shape and specific bonding make it suitable as an anesthetic. Understanding its Lewis structure and properties ensures safe and effective use in surgical procedures, a key skill for medical professionals in Uganda.
Task:
a)Draw the Lewis structure for N_2O.
b)Use VSEPR theory to predict the molecular shape of N_2O.
c)State the approximate bond angle in the molecule.
Scenario 20
At the National Water plant,ozone (O_3) purifies water. Its effectiveness stems from its molecular structure and unstable bonding. A chemist explains that ozone's resonance structures and bent shape make it a

powerful oxidizing agent that destroys bacteria and organic impurities, ensuring safe drinking water for urban populations.

Task:

a)Draw the resonance structures of ozone (O_3).

b)Predict the O-O-O bond angle in ozone.

c)Calculate the average bond order for each O-O bond in ozone.

Scenario 21

At a dairy farm,ammonia (NH_3) is used in refrigeration. The technician explains that its polarity, due to its trigonal pyramidal shape and lone pair, allows it to dissolve readily in water. This high solubility is essential for its use in liquid fertilizers, a major input for Uganda's agricultural sector, unlike non-polar methane.

Task:

a)Use VSEPR theory to predict the molecular shape of ammonia (NH_3).

b)State and explain the bond angle in ammonia.

c)Explain why ammonia is highly soluble in water while methane is not.

Topic 4: PERIODICITY 1

Sub-topic 4.1: The Periodic Table

Scenario 22

At Mbarara University of Science and Technology,chemistry researchers discovered an unknown metallic element in mineral samples from the Kigezi highlands. Initial analysis showed properties similar to calcium but with higher density. The element appeared to occupy a position between calcium and titanium in the periodic table, suggesting it belonged to Group 3. Professor Mugisha and his research team needed to classify this element accurately to understand its potential applications in Uganda's growing technology sector. They conducted detailed tests to determine its electron configuration and chemical behavior, comparing it with known elements in the same period. The discovery prompted important discussions about how Moseley's work established the modern periodic law based on atomic number rather than atomic mass, which would be crucial for correctly placing this new element. The research team worked to predict its likely physical and chemical properties based on its position, considering how it might be used in alloy production or electronic components to support local industries.

Task:

a)State the block (s, p, d, or f) in which this Group 3 element would be located.

b)Predict two physical properties of this element based on its position in the periodic table.

c)Explain how Moseley's work led to the modern arrangement of the periodic table.

Scenario 23

Engineers at the Uganda Industrial Research Institute were developing semiconductor materials for solar panel production.They focused on element X from Period 3, Group 14, which showed ideal semiconductor properties with its intermediate electrical conductivity. Dr. Nakiwala and her team investigated why this element's atomic radius decreased compared to the element above it in the same group, despite having more electrons. They explored how doping this element with small amounts of phosphorus from Group 15 would alter its electrical properties, creating n-type semiconductors suitable for renewable energy applications. This research aimed to reduce Uganda's dependence on imported electronic components while promoting clean energy solutions. The team documented how the periodic trends in atomic structure directly influenced the element's technological applications, providing valuable insights for training technicians in the emerging electronics manufacturing sector.

Task:

a)Identify element X from Period 3, Group 14.

b)Explain why the atomic radius of element X is smaller than that of the element above it in the same group.
c)Predict how the electrical conductivity of element X changes when it is doped with an element from Group 15.

Scenario 24

At the Kabaale Petroleum Refinery,chemical engineers optimized a catalytic cracking process using a transition metal catalyst. Mr. Okello explained to junior engineers how the catalyst's position in the d-block provided unique electronic properties that enhanced the breakdown of heavy petroleum fractions into gasoline. The team analyzed how the incomplete d-subshell in these elements allowed for variable oxidation states and complex formation, crucial for catalytic activity. They compared different transition metals across the same period to identify the most cost-effective catalyst for Uganda's specific crude oil composition. This understanding helped improve fuel production efficiency while reducing operational costs, contributing to the country's goal of petroleum self-sufficiency. The training emphasized how periodic table knowledge directly impacted industrial process optimization in Uganda's emerging oil and gas sector.

Task:

a)State two characteristic properties of transition metals that make them good catalysts.
b)Explain how the electronic configuration of transition metals contributes to these properties.
c)Identify which period contains the largest number of transition metals.

Sub-topic 4.2: Variation in Trends of Properties Across Periods

Scenario 25

Researchers at Kyambogo University's Materials Science Department were developing advanced battery systems for Uganda's renewable energy storage needs.Dr. Kigozi and his team systematically studied Period 3 elements to identify optimal anode materials. They documented how atomic radius decreased from sodium to argon due to increasing nuclear charge, while ionization energy generally increased across the period. The team encountered the unexpected drop in ionization energy between Groups 2 and 13, which they explained through electron sub-shell theory. They also analyzed the dramatic variation in melting points, from sodium's low melting metal to silicon's giant covalent structure and phosphorus' molecular solid form. This comprehensive understanding of periodic trends enabled them to select the most promising materials for developing affordable, efficient batteries suited to Uganda's climate and energy requirements.

Task:

a)Explain the general trend in atomic radius across Period 3 from sodium to argon.
b)State which element in Period 3 has the highest ionization energy and explain why.
c)Predict how the melting points of the elements change across Period 3, explaining the trend.

Scenario 26

At the Gaba Water Treatment Plant,chemists were comparing aluminium and beryllium compounds for removing impurities from Lake Victoria water. Ms. Namutebi noticed unexpected similarities in their chemical behavior despite their different group positions. She organized a training session to explain the diagonal relationship between beryllium (Group 2) and aluminium (Group 13), highlighting how their similar charge densities led to comparable properties. The team examined how both elements formed covalent compounds, exhibited amphoteric characteristics in their oxides and hydroxides, and resisted reaction with water unlike their group members. This understanding helped optimize chemical usage in water treatment, ensuring effective purification while minimizing costs and environmental impact for Uganda's largest water treatment facility.

Task:
a)Identify the diagonal relationship between beryllium and aluminium.
b)State two chemical properties that show this diagonal relationship.
c)Explain why beryllium chloride is covalent while magnesium chloride is ionic.

Scenario 27

At a technology innovation hub in Kampala,engineers were characterizing silicon for local semiconductor device manufacturing. Mr. Ssebagala explained silicon's intermediate properties between its periodic neighbors aluminium and phosphorus. The team analyzed trends across Period 3, noting how electrical conductivity decreased from metallic sodium to semi-conducting silicon and further to insulating phosphorus and sulfur. They investigated why silicon's giant covalent structure gave it a much higher melting point than molecular phosphorus. The engineers also documented how the acid-base character of oxides transitioned from basic through amphoteric to acidic across the period, information crucial for understanding silicon dioxide's role in semiconductor fabrication. This knowledge supported Uganda's nascent electronics industry in selecting appropriate materials for device manufacturing.

Task:
a)Describe the trend in electrical conductivity across Period 3 elements.
b)Explain why silicon has a much higher melting point than phosphorus.
c)State how the acid-base character of oxides changes across Period 3

Sub-topic 4.3: Trends in Properties of Group 2 Elements

Scenario 28

A Kampala pharmaceutical company was developing a new antacid formulation using Group 2 elements.Dr. Nalubwama and her research team tested various compounds to identify the most effective and safest option for neutralizing stomach acid. They evaluated magnesium, calcium, and barium compounds, analyzing reaction rates and neutralization capacities. The team noted that while barium hydroxide was most effective chemically, its toxicity made it unsuitable for medicinal use. They documented the increasing solubility of hydroxides down the group and related this to reaction efficiency. Safety considerations led them to select magnesium hydroxide as the optimal active ingredient, providing effective relief while ensuring patient safety. The research contributed to developing affordable gastrointestinal medications for the Ugandan market.

Task:
a)Write a balanced chemical equation for the reaction between magnesium hydroxide and stomach acid (HCl).
b)Explain why barium compounds are not suitable for use in antacids despite being better at neutralizing acid.
c)Predict how the solubility of hydroxides changes down Group 2.

Scenario 29

A Jinja-based pyrotechnics company was developing new colored fireworks for Uganda's independence celebrations.Mr. Mukasa experimented with Group 2 elements to create vibrant flame colors: calcium for orange-red, strontium for crimson, and barium for green. He explained to his production team how the flame test results from electrons in these metals being excited by the flame's heat and emitting characteristic colors as they return to ground state. The team also studied the thermal stability trends of Group 2 carbonates, noting how decomposition temperatures increased down the group due to decreasing cation polarizing power. This understanding helped them create stable, colorful pyrotechnic compositions that met safety standards while providing spectacular visual displays.

Task:
a)State the color of the flame produced by barium compounds.

b)Explain why Group 2 elements produce characteristic flame colors.
c)Describe the trend in thermal decomposition of Group 2 carbonates down the group.

Scenario 30

The National Water and Sewerage Corporation conducted a comprehensive survey of water hardness across Uganda.Ms. Arach and her team analyzed samples from different regions, finding high concentrations of Group 2 ions in areas with limestone geology. They identified calcium and magnesium ions as the primary causes of both temporary and permanent hardness. The team educated community water committees about removing temporary hardness through boiling, which precipitates calcium carbonate. They explained the puzzling trend of decreasing sulfate solubility down Group 2 while hydroxide solubility increased, relating this to lattice and hydration energy changes. This knowledge helped design appropriate water treatment methods for different regions of Uganda.

Task:

a)Identify which Group 2 elements commonly cause water hardness.
b)Write a balanced chemical equation to show how temporary hardness can be removed by boiling.
c)Explain why the solubility of sulfates decreases down Group 2 while that of hydroxides increases.

Topic 5: THERMOCHEMISTRY

Sub-topic 5.1: Enthalpy Changes and Energy Profiles

Scenario 31

A small enterprise in Kampala,"WarmUg," is developing a reusable hand warmer for farmers and motorcycle riders during cold mornings. The design uses a supersaturated solution of sodium acetate that releases heat when crystallized. The lead chemist, Sarah, must create an energy profile diagram to explain this exothermic process to her team. She illustrates how the products have lower energy than the reactants, with the difference being the enthalpy change (ΔH), released as heat. Sarah emphasizes the importance of activation energy, which is provided by flexing the metal disc in the pouch, initiating crystallization. She also explains how the hand warmer can be "recharged" by boiling, which makes the process endothermic, absorbing heat to re-dissolve the crystals. Understanding these energy profiles helps the team optimize the formulation for maximum heat output and durability, supporting local innovation in personal thermal comfort products.

Task:

a)Draw a fully labeled energy profile diagram for the exothermic crystallization process.
b)Define the term 'activation energy' and show it on your diagram.
c)State how the energy profile would differ for the endothermic recharging process.

Scenario 32

A sports clinic in Jinja is designing an instant cold pack for treating athletes'injuries using ammonium nitrate and water. The head physiotherapist, Coach James, needs to explain the science to his staff. He describes how the dissolution of ammonium nitrate in water is endothermic, absorbing heat from the surroundings and causing the temperature to drop. He sketches an energy profile showing the reactants at a lower energy level than the products, with a positive ΔH. Coach James highlights the role of activation energy in starting the dissolution process, which occurs when the inner pouch is broken and the chemicals mix. Understanding this helps the staff use the cold packs effectively for immediate injury management, reducing swelling and pain for players in local football tournaments and athletics competitions.

Task:

a)Draw a fully labeled energy profile diagram for the endothermic dissolution of ammonium nitrate.
b)State the sign (positive or negative) of ΔH for this process and justify your answer.
c)Explain how the energy profile relates to the cooling effect experienced.

Scenario 33

At the Hima Cement plant,engineers are analyzing the energy changes in limestone decomposition to improve fuel efficiency. The process engineer, Mr. Omondi, explains that heating calcium carbonate to form quicklime and carbon dioxide is highly endothermic. He presents an energy profile diagram showing the reactants at a lower energy level than the products, with a large activation energy barrier overcome by the kiln's heat. Mr. Omondi discusses how understanding this profile helps in selecting better insulation and alternative fuels to reduce energy costs. He also links this to Uganda's industrial growth, where cement is vital for infrastructure, and efficiency gains can lower production costs and environmental impact.

Task:

a)Write a balanced chemical equation for the decomposition of limestone (calcium carbonate).

b)Sketch an energy profile diagram for this reaction, clearly showing the enthalpy change.

c)State whether this reaction is endothermic or exothermic, based on your diagram.

Sub-topic 5.2: Types of Enthalpy Changes and Hess's Law

Scenario 34

Scientists at the Ministry of Defence are researching hydrazine(N_2H_4) as a potential rocket fuel. Due to safety concerns, they cannot directly measure its enthalpy of formation in the lab. Dr. Amina and her team use Hess's Law, constructing a cycle from the enthalpies of combustion of hydrazine, nitrogen, and hydrogen. They explain how the law allows them to calculate the unknown enthalpy change indirectly, using known values from data tables. This method ensures accuracy while minimizing risks. The research aims to develop propulsion technology for satellite launch vehicles, positioning Uganda in the African space industry.

Task:

a)Define the term 'standard enthalpy of formation'.

b)Construct a Hess's Law cycle to show how the enthalpy of formation of hydrazine can be determined from combustion data.

c)State why Hess's Law is particularly useful in determining enthalpy changes that are difficult to measure directly.

Scenario 35

A nutritionist at Mulago Hospital is analyzing the energy content of a new high-energy food bar for athletes and patients.Using a calorimeter, she measures the enthalpy of combustion of the bar's ingredients. She then applies Hess's Law to calculate the energy available per gram, constructing a cycle that links the combustion data to the formation enthalpies of the products (CO_2 and H_2O). This helps in accurately labeling the food bar with its caloric content, ensuring it meets dietary standards and supports health initiatives in Uganda.

Task:

a)Define the term 'enthalpy of combustion'.

b)Construct a Hess's Law cycle showing how the enthalpy of formation of a food component can be determined from its enthalpy of combustion.

c)Calculate the energy content per gram of a substance given relevant enthalpy data.

Scenario 36

At a Lugazi-based chemical plant,engineers are optimizing ethanol production from ethene and steam. The reaction is exothermic, but direct measurement of ΔH is complex. Using Hess's Law, the team constructs a cycle involving the combustion enthalpies of ethene, ethanol, and water. This allows them to calculate the reaction enthalpy accurately, ensuring efficient heat management in the reactor. The project

supports local biofuel production, reducing Uganda's reliance on imported fuels and promoting sustainable energy.

Task:

a)Write a balanced chemical equation for the hydration of ethene to form ethanol.

b)Construct a Hess's Law cycle using enthalpies of combustion to calculate the enthalpy change for this reaction.

c)State two reasons why industrial processes might use reactions that are endothermic.

Sub-topic 5.3: Born-Haber Cycles and Lattice Energy

Scenario 37

A chemist at Mbarara University is studying the solubility patterns of Group 1 halides.She uses Born-Haber cycles to calculate lattice energies, explaining why salts like sodium chloride have high solubility while others do not. The cycle includes steps like atomization, ionization, and electron affinity, culminating in lattice formation. She shows how lower lattice energy increases solubility, as seen in potassium iodide compared to sodium fluoride. This research aids in selecting salts for pharmaceutical and agricultural use in Uganda.

Task:

a)Define the term 'lattice energy'.

b)Draw a Born-Haber cycle for the formation of sodium chloride.

c)Explain how lattice energy influences the solubility of ionic compounds.

Scenario 38

At a Tororo-based fertilizer plant,engineers are selecting metal halides as catalysts for ammonia production. They use Born-Haber cycles to compare lattice energies of different halides, as lower lattice energy often correlates with better catalytic activity due to easier dissociation. The cycles help them understand energy changes in formation and dissociation, ensuring optimal catalyst choice for efficient fertilizer synthesis to support Uganda's agriculture.

Task:

a)Draw a Born-Haber cycle for the formation of magnesium chloride.

b)Explain how the cycle can be used to calculate the electron affinity of chlorine.

c)State how lattice energy affects the thermal stability of ionic compounds.

Scenario 39

Researchers at Makerere University are developing magnesium-ion batteries as a cheaper alternative to lithium-ion.They use Born-Haber cycles to analyze the lattice energies of magnesium compounds, which influence ion mobility and battery efficiency. The cycles help identify compounds with optimal energy profiles for repeated charging and discharging. This innovation could lead to affordable energy storage solutions for rural Uganda, promoting renewable energy use.

Task:

a)Draw a Born-Haber cycle for the formation of magnesium oxide.

b)Explain why magnesium oxide has a higher lattice energy than sodium chloride.

c)State how lattice energy impacts the performance of battery materials.

Topic 6: ORGANIC CHEMISTRY I

Sub-topic 6.1: Introduction to Organic Compounds

Scenario 40

The Uganda National Bureau of Standards launched an investigation into suspected fuel adulteration at several Kampala petrol stations.Chemists analyzed samples and found unusual mixtures of hydrocarbons. Dr. Mbabazi, the lead investigator, needed to classify the organic compounds present to identify the

contaminants. His team identified alkanes, alkenes, and alkynes using chemical tests and spectroscopic methods. They explained how the unique nature of carbon, with its ability to form single, double, and triple bonds, creates diverse homologous series with different properties. The investigation revealed that adulterers were mixing cheaper alkynes with petrol, compromising fuel quality and damaging vehicle engines. This case highlighted the importance of understanding organic compound classification and functional groups in protecting Ugandan consumers and maintaining fuel standards.

Task:

a)Explain the unique nature of carbon that allows it to form diverse organic compounds.

b)Describe how you would distinguish between an alkane, alkene, and alkyne using chemical tests.

c)State the general molecular formula for a straight-chain alkyne and name the first member of this homologous series.

Scenario 41

At a pharmaceutical manufacturing plant in Entebbe,quality control chemists were struggling with inconsistent naming of organic compounds in their documentation. This led to confusion in importing raw materials and exporting finished drugs. The chief pharmacist organized intensive training on IUPAC nomenclature, emphasizing its importance in global trade and patient safety. The trainees practiced naming complex molecules with multiple functional groups, including alcohols, aldehydes, and carboxylic acids. They learned to identify parent chains, number carbon atoms correctly, and prioritize functional groups according to IUPAC rules. This standardization improved communication with international suppliers and regulators, ensuring Uganda's pharmaceuticals met global standards.

Task:

a)Name the following compound using IUPAC rules: CH_3-CH_2-CH(OH)-CH_3

b)Draw the structural formula for 2-methylpropan-1-ol

c)Explain why systematic IUPAC naming is preferable to common names in pharmaceutical manufacturing

Scenario 42

A chemical engineer at a Jinja-based paint factory was troubleshooting quality issues with their industrial solvents.She suspected that different structural isomers in their hydrocarbon solvents were causing inconsistent evaporation rates and finish quality. The engineer conducted a detailed isomer analysis, identifying chain, position, and functional group isomers in their solvent mixtures. She demonstrated how isomers with branched structures evaporated faster than straight-chain counterparts, while positional isomers of alcohols showed different solubility properties. This understanding allowed the factory to optimize their solvent blends for specific applications, improving product quality and reducing waste in Uganda's growing manufacturing sector.

Task:

a)Define the term 'structural isomerism'

b)Draw and name all possible structural isomers of pentanol ($C_5H_{11}OH$)

c)Explain how structural isomerism affects the physical properties of organic compounds

Sub-topic 6.2: Alkanes, Alkenes and Alkynes

Scenario 43

The discovery of natural gas reserves in the Bunyoro region prompted the government to develop utilization strategies.Chemical engineers from Makerere University analyzed the gas composition, finding mainly methane with smaller alkanes. They educated local communities about alkane properties and combustion characteristics, emphasizing complete combustion for clean energy. The team also demonstrated substitution reactions of alkanes with chlorine under UV light, explaining how these

reactions could be used to produce chlorinated solvents for local industries. This knowledge transfer empowered communities to participate in value addition to their natural resources.

Task:

a)Write balanced equations for the complete and incomplete combustion of methane

b)Describe the mechanism of free radical substitution in the reaction of methane with chlorine

c)State two environmental concerns associated with alkane combustion

Scenario 44

An agricultural engineer in Masaka was designing ethylene-based fruit ripening chambers for banana farmers.She needed to explain the chemistry of alkenes to farmers, focusing on ethylene's role as a plant hormone. The engineer demonstrated addition reactions of alkenes with bromine water and acidified potassium permanganate, showing how these tests confirm double bond presence. She also explained polymerization of ethene to make polyethylene plastics for fruit packaging. This integrated approach helped farmers understand both the ripening process and value addition opportunities for their produce.

Task:

a)Describe how you would test for the presence of a double bond in an organic compound

b)Write the mechanism for the addition of hydrogen bromide to ethene

c)Explain how Ziegler-Natta catalysts improve the polymerization of ethene

Scenario 45

A vocational training institute in Kasese was developing safety protocols for oxy-acetylene welding.The chemistry instructor needed to explain alkyne properties and reactions to welding students. He demonstrated the combustion of acetylene with pure oxygen, producing the high-temperature flame needed for welding. The training covered the linear structure of alkynes, their acidity compared to alkanes and alkenes, and safe handling procedures to prevent explosive decomposition. Students learned to identify alkyne functional groups and understand their unique reactivity patterns.

Task:

a)Write the equation for the complete combustion of acetylene (ethyne)

b)Explain why terminal alkynes are more acidic than other hydrocarbons

c)Describe the test used to distinguish between terminal and internal alkyne

Sub-topic 6.3: Halogen Compounds (Alkyl Halides)

Scenario 46

At an agricultural research station in Mbale,chemists were developing environmentally friendly pesticides based on alkyl halides. They needed to understand the reactivity of different halogen compounds to design effective but biodegradable formulations. The team studied nucleophilic substitution reactions of primary, secondary, and tertiary alkyl halides with hydroxide ions, noting how structure affects reaction mechanism (SN1 vs SN2). They also investigated elimination reactions that could produce unwanted alkene byproducts. This research aimed to create targeted pesticides that would break down safely in Uganda's tropical environment.

Task:

a)Compare the mechanisms of SN1 and SN2 reactions in alkyl halides

b)Explain how the nature of the halogen affects the reactivity of alkyl halides

c)State two factors that favor elimination over substitution in alkyl halides

Scenario 47

A Kampala-based pharmaceutical company was optimizing the synthesis of an antimalarial drug containing chlorine atoms.The process development chemists needed to select the best method for introducing halogen atoms into the organic molecule. They compared free radical halogenation, electrophilic addition to alkenes, and halogen exchange reactions. The team also studied the

environmental impact of different halogenated intermediates, choosing the most sustainable pathway that minimized toxic waste generation while maintaining high yield for affordable drug production.

Task:

a)Describe the free radical mechanism for the chlorination of methane

b)Write the reaction for the addition of bromine to ethene

c)Explain why aryl halides are less reactive than alkyl halides in nucleophilic substitution

Scenario 48

An environmental NGO in Wakiso District launched a program to recycle chlorinated solvents from automotive and dry-cleaning businesses.The project chemist needed to educate participants about the properties and safe handling of alkyl halides. She explained their density, boiling points, and immiscibility with water, which made them useful as solvents but also environmental hazards. The training covered proper disposal methods and chemical reactions that could detoxify these compounds before release into the environment.

Task:

a)Explain why many alkyl halides are immiscible with water despite their polar C-X bond

b)Describe the reaction of alkyl halides with alcoholic potassium hydroxide

c)State two environmental concerns associated with chlorinated solvents

Sub-topic 6.4: Benzene and Methyl Benzene

Scenario 49

A major industrial plant in Namanve that uses benzene as a solvent was undergoing a safety audit after several workers reported health issues.The safety officer, Mr. Tumwebaze, had to educate the staff about the unique structure and stability of benzene. He explained the concept of resonance and delocalized pi-electrons, which give benzene its unusual stability compared to alkenes. Mr. Tumwebaze demonstrated how this stability affects benzene's reactions, making it undergo electrophilic substitution rather than addition. He contrasted this with methyl benzene (toluene), which the plant was considering as a safer alternative due to its lower toxicity and higher reactivity in side-chain reactions. The audit concluded with recommendations to switch to methyl benzene where possible and implement stricter handling procedures for benzene.

Task:

a)Explain the resonance structure of benzene and how it contributes to its unusual stability.

b)Compare the reactivity of benzene and methyl benzene towards electrophilic substitution.

c)State two reasons why methyl benzene is considered a safer industrial solvent than benzene.

Scenario 50

A small-scale dye manufacturing cooperative in Jinja was exploring ways to produce azo dyes for the local textile industry.Their chemist, Ms. Nalubega, chose methyl benzene as the starting material due to its enhanced reactivity in electrophilic substitution compared to benzene. She explained to the cooperative members how the methyl group activates the benzene ring and directs incoming electrophiles to the ortho and para positions. The team practiced nitration and sulfonation reactions, carefully controlling conditions to achieve the desired substitution patterns. This project aimed to reduce Uganda's reliance on imported textile dyes and create employment opportunities in the chemical industry.

Task:

a)Describe the mechanism of nitration in methyl benzene.

b)Explain why the methyl group in methyl benzene is ortho-para directing.

c)Write the reaction for the oxidation of the side chain in methyl benzene.

Scenario 51
Environmental scientists from Makerere University were investigating benzene contamination in an industrial area of Kampala.They needed to understand benzene's chemical behavior to develop effective remediation strategies. The team studied benzene's resistance to oxidation and addition reactions, which makes it persistent in the environment. They explored using strong electrophiles to substitute hydrogen atoms with more biodegradable groups. The research also covered the health effects of benzene derivatives, particularly their carcinogenic properties, to raise awareness in affected communities and push for stricter industrial regulations.
Task:
a)Explain why benzene resists addition reactions that are typical of alkenes.
b)Describe the health and environmental impacts of benzene and its derivatives.
c)Suggest a chemical method that could make benzene less hazardous in contaminated soil.

Topic 7: EQUILIBRIA I
Sub-topic 7.1: The Concept of Chemical Equilibrium
Scenario 52
The Tororo Industrial Park fertilizer plant was struggling with low ammonia production efficiency in their Haber process operation.Engineer Okot gathered his team to analyze the equilibrium principles governing the reaction: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. They calculated the equilibrium constant Kc and found it was temperature-dependent. The team investigated how reaction conditions affected the equilibrium position, recognizing that while high pressure favored ammonia formation, operational costs increased significantly. They used Le Chatelier's principle to predict how changes in temperature, pressure, and concentration would shift the equilibrium, ultimately optimizing conditions for maximum yield while considering economic constraints in the Ugandan context.
Task:
a)Write the equilibrium constant expression (Kc) for the Haber process.
b)Use Le Chatelier's principle to explain how increasing pressure affects ammonia yield.
c)Calculate Kc given equilibrium concentrations of reactants and products.
Scenario 53
Chemistry students at Uganda Martyrs University were determining the equilibrium constant for ester formation in the reaction between ethanol and ethanoic acid.Dr. Kigozi emphasized the dynamic nature of equilibrium, where forward and reverse reactions proceed at equal rates in a closed system. Students carefully measured initial concentrations and used titration to find equilibrium concentrations. They encountered the concept of equilibrium constant and learned that its value indicates the extent of reaction completion. This practical reinforced theoretical knowledge while developing analytical skills relevant to Uganda's food and fragrance industries.
Task:
a)Define a 'dynamic equilibrium' in the context of chemical reactions.
b)Describe an experimental method to determine when equilibrium is established in esterification.
c)Explain what the magnitude of Kc reveals about the position of equilibrium.
Scenario 54
Environmental scientists monitoring Lake Victoria's water quality needed to understand equilibrium concepts in oxygen dissolution.They explained how the equilibrium between atmospheric oxygen and dissolved oxygen in water is affected by temperature and pressure changes. The team applied Le Chatelier's principle to predict how thermal pollution from industries could decrease oxygen levels, threatening aquatic life. They also studied how the equilibrium shifts with algal blooms that consume oxygen, providing crucial data for conservation efforts to protect East Africa's largest lake.

Task:
a)Write the equilibrium expression for oxygen dissolution in water.
b)Use Le Chatelier's principle to explain why oxygen solubility decreases with increasing temperature.
c)Suggest two ways to increase dissolved oxygen levels in aquatic ecosystems.

Sub-topic 7.2: Equilibria and the Chemical Industry
Scenario 55
A chemical plant in Kasese was establishing sulfuric acid production using the contact process.The engineers faced challenges in optimizing the oxidation of sulfur dioxide:
$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$. They analyzed how vanadium pentoxide catalyst affects the reaction rate without altering the equilibrium constant. The team balanced the need for high conversion (favored by low temperature) with practical reaction rates (favored by high temperature), ultimately choosing an optimum temperature. They also implemented pressure considerations and removal of product to shift equilibrium rightward, ensuring economic viability for this crucial industrial chemical in Uganda's mining sector.
Task:
a)Write the equilibrium expression for the oxidation of sulfur dioxide.
b)Explain the role of the catalyst in the contact process.
c)Justify the industrial choice of moderate temperature despite thermodynamic predictions.
Scenario 56
The government was exploring the feasibility of soda ash production from Lake Katwe minerals.Chemical engineers studied the Solvay process equilibrium systems, particularly the reaction between sodium chloride, ammonia, and carbon dioxide. They analyzed multiple equilibria involved and how careful control of temperature and concentration allowed efficient bicarbonate precipitation. The project aimed to reduce Uganda's dependence on imported soda ash, crucial for glass, detergent, and water treatment industries, while creating jobs in the salt mining region.
Task:
a)Identify two equilibrium systems involved in the Solvay process.
b)Explain how the common ion effect is utilized in this process.
c)State one economic benefit of establishing local soda ash production in Uganda.
Scenario 57
An energy company was designing a methanol plant using syngas from biomass:
$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$. The process engineers applied equilibrium principles to maximize methanol yield while minimizing production costs. They chose appropriate pressure and temperature conditions and decided on a copper-based catalyst. The team also implemented product removal strategies to shift equilibrium toward methanol formation. This renewable methanol project aligned with Uganda's green energy initiatives and provided an alternative to petroleum-based fuels.
Task:
a)Use Le Chatelier's principle to explain why high pressure favors methanol formation.
b)Describe how continuous removal of methanol affects the equilibrium position.
c)Calculate the equilibrium constant given partial pressures of gases.

Sub-topic 7.3: Ionic Equilibrium, Hydrolysis of Salts and Buffer Solutions
Scenario 58
Environmental scientists were alarmed by rising pH levels in Lake Bunyonyi,threatening its unique ecosystem. Investigation revealed that agricultural runoff containing basic salts was causing the problem. The team explained how salts like sodium carbonate undergo hydrolysis, producing hydroxide ions and

increasing pH. They conducted tests to measure the hydrolysis constant (K_h) of various salts present in the runoff. Using this data, they predicted the extent of pH change and recommended remediation strategies to local farmers, including using alternative fertilizers that form neutral solutions. This case highlighted the importance of understanding ionic equilibrium in environmental conservation.

Task:

a)Write the hydrolysis reaction for sodium carbonate and explain why it produces a basic solution.

b)Define the hydrolysis constant (K_h) and relate it to K_w and K_b.

c)Calculate the pH of a 0.1M sodium carbonate solution given $K_h = 2.1 \times 10^{-4}$.

Scenario 59

A research team at Mulago Hospital was developing buffer solutions for storing sensitive medications.They needed to create phosphate buffers that could maintain stable pH despite dilution or addition of small amounts of acids/bases. The team demonstrated how buffer solutions resist pH changes using the equilibrium between $H_2PO_4^-$ and HPO_4^{2-} ions. They calculated exact ratios of acid to conjugate base needed for different pH values and tested buffer capacity. This research was crucial for ensuring drug stability in Uganda's healthcare system, particularly for temperature-sensitive vaccines.

Task:

a)Explain how a phosphate buffer resists pH changes when small amounts of acid are added.

b)Calculate the ratio of $[HPO_4^{2-}]$ to $[H_2PO_4^-]$ needed to prepare a buffer of pH 7.4 ($K_a = 6.2 \times 10^{-8}$).

c)Define 'buffer capacity' and state two factors that affect it.

Scenario 60

A textile factory in Jinja was struggling with acidic wastewater damaging local water systems.Chemical engineers designed a treatment system using salt hydrolysis principles. They selected appropriate salts that would hydrolyze to produce basic solutions and neutralize the acidic waste. The team calculated exact quantities needed based on hydrolysis constants and monitored the process using pH meters. This solution provided a cost-effective way for Ugandan industries to meet environmental regulations while protecting aquatic life.

Task:

a)Identify which salt would be most effective for neutralizing acidic wastewater: NH_4Cl, Na_2CO_3, or KCl. Explain your choice.

b)Write the hydrolysis equation for your chosen salt.

c)Calculate the amount of salt needed to neutralize 1000L of wastewater at pH 3.0.

Sub-topic 7.4: Solubility Equilibria

Scenario 61

Urologists at Mengo Hospital noticed an increase in calcium oxalate kidney stones among patients.They launched an educational program explaining the solubility equilibrium of ionic compounds in urine. The doctors demonstrated how the ion product compared to K_{sp} determines precipitation, and how factors like pH and common ions affect solubility. Patients learned to modify their diet and fluid intake to maintain ion concentrations below K_{sp} values, significantly reducing stone formation in the Kampala community.

Task:

a)Write the solubility equilibrium expression for calcium oxalate (CaC_2O_4).

b)Explain how the common ion effect reduces calcium oxalate solubility.

c)Calculate whether precipitation will occur when $[Ca^{2+}] = 0.01M$ and $[C_2O_4^{2-}] = 0.001M$ ($K_{sp} = 2.3 \times 10^{-9}$).

Scenario 62

Health officials investigated lead poisoning cases in a Kampala neighborhood and traced it to lead pipes.Chemists explained the solubility equilibrium of lead compounds in water, particularly how pH

affects lead carbonate and hydroxide solubility. The team used K_{sp} calculations to predict lead concentrations in different water conditions and recommended optimal pH treatment at the water plant to minimize lead dissolution while ensuring safe drinking water for the affected community.

Task:

a)Write the solubility equilibrium for lead carbonate ($PbCO_3$).

b)Explain how decreasing pH increases lead solubility from pipes.

c)Calculate the molar solubility of $PbCO_3$ in pure water ($K_{sp} = 7.4 \times 10^{-14}$).

Scenario 63

A chemical company in Tororo was optimizing barium sulfate precipitation for paint pigment production.Engineers needed to maximize yield while controlling particle size by manipulating solubility equilibrium. They studied how temperature, pH, and common ions affected precipitation and used Q (ion product) versus K_{sp} comparisons to predict exactly when precipitation would begin. This precision allowed them to produce high-quality pigments for Uganda's growing paint industry while minimizing waste.

Task:

a)Write the solubility equilibrium expression for barium sulfate.

b)Explain how adding sodium sulfate affects barium sulfate solubility.

c)Calculate whether a solution containing $[Ba^{2+}] = 0.001M$ and $[SO_4^{2-}] = 0.0001M$ will form a precipitate ($K_{sp} = 1.1 \times 10^{-10}$).

Topic 8: EQUILIBRIA II

Sub-topic 8.1: Physical Equilibria

Scenario 64

A women's cooperative in Fort Portal was extracting essential oils from local plants using steam distillation.Chemists explained the physical equilibrium between immiscible liquids, where the vapor pressure (and thus boiling point) depends on the mole fractions of both components. The team demonstrated how this principle allows distillation at temperatures below water's boiling point, preserving delicate fragrances. This knowledge helped the cooperative produce high-quality oils for Uganda's growing aromatherapy and cosmetic industries.

Task:

a)Explain why immiscible liquids boil at temperatures lower than their individual boiling points.

b)Calculate the composition of vapor over a mixture of two immiscible liquids.

c)State two advantages of steam distillation over simple distillation for essential oil extraction.

Scenario 65

A biofuel plant in Masaka was producing ethanol from molasses and needed to separate ethanol-water azeotropes.Engineers explained how positive deviations from Raoult's Law create minimum-boiling azeotropes that limit distillation efficiency. The team explored alternative separation methods including adding a third component to break the azeotrope. This optimization was crucial for producing the 99% ethanol needed for blending with gasoline in Uganda's renewable energy program.

Task:

a)Define 'azeotrope' and explain why ethanol-water mixtures form azeotropes.

b)Sketch a vapor pressure-composition diagram for a solution showing positive deviation from Raoult's Law.

c)Suggest one industrial method for breaking the ethanol-water azeotrope.

Scenario 66

Engineers were designing a system to recover different salts from Lake Katwe brines using phase diagrams.They explained how the eutectic point in salt-water systems determines the crystallization

sequence during evaporation. The team used cooling curves to construct phase diagrams and identified optimal temperatures for harvesting specific salts. This scientific approach maximized salt recovery while minimizing energy costs for this important Ugandan mineral resource.

Task:

a)Define 'eutectic point' in a two-component system.

b)Explain how phase diagrams help in separating salt mixtures.

c)Sketch a simple phase diagram for a salt-water system and label the eutectic point.

Sub-topic 8.2: Colligative Properties

Scenario 67

A malfunctioning freezer at a Kampala blood bank caused plasma to freeze,damaging valuable donations. Pathologists explained how adding glycerol as a cryoprotectant lowers the freezing point via colligative properties. They calculated the exact glycerol concentration needed to prevent freezing at the storage temperature of -30°C. This understanding helped redesign the blood storage system, ensuring safe preservation of life-saving plasma for Ugandan hospitals.

Task:

a)Explain the molecular basis of freezing point depression.

b)Calculate the mass of glycerol needed to prevent 1L of plasma from freezing at -30°C.

c)State why colligative properties depend on the number of solute particles rather than their identity.

Scenario 68

A pharmaceutical company in Entebbe was investigating why some intravenous fluids caused patient complications.Chemists discovered improper salinity affected osmotic pressure, causing hemolysis or crenation of red blood cells. The team implemented rigorous quality control using freezing point depression measurements to ensure all IV fluids were isotonic with blood. This prevented medical complications and improved patient safety across Ugandan healthcare facilities.

Task:

a)Define 'osmotic pressure' and explain its importance in IV fluids.

b)Calculate the osmotic pressure of a 0.9% NaCl solution at body temperature.

c)Explain what happens to red blood cells in hypotonic and hypertonic solutions.

Scenario 69

A sugar factory in Lugazi was losing product through inefficient crystallization.Chemical engineers used boiling point elevation calculations to optimize the evaporation process. They determined the exact temperature profiles needed for maximum sugar recovery from molasses while minimizing energy consumption. This optimization increased yield by 15%, significantly boosting profitability for Uganda's important sugar industry.

Task:

a)Explain why adding solute increases the boiling point of a solvent.

b)Calculate the boiling point elevation of a 2m sucrose solution.

c)State two industrial applications of colligative properties other than food processing.

Topic 9: ORGANIC CHEMISTRY II

Sub-topic 9.1: Alcohols and Phenols

Scenario 70

A popular brewery in Kampala faced a sudden quality issue:their beer batches were developing a bitter, medicinal off-flavor. The head brewer, Ms. Nakato, suspected contamination during fermentation. Investigation revealed that cleaning agents containing phenols had contaminated the fermentation tanks. Ms. Nakato had to explain to her team the critical chemical differences between the ethanol they intended to produce and the introduced phenols. She demonstrated how phenols, unlike alcohols, are weakly acidic

and form colored complexes with iron(III) chloride, a test they could use for rapid contamination checks. This incident highlighted the importance of understanding functional group chemistry in maintaining product quality in Uganda's growing beverage industry.

Task:

a)Describe a chemical test to distinguish between ethanol and phenol.

b)Explain why phenol is more acidic than ethanol.

c)Write the reaction for phenol with bromine water.

Scenario 71

A research team at Makerere University was investigating the production of biofuels from sugarcane bagasse.They focused on converting plant biomass into various alcohols, including methanol, ethanol, and butanol. The team needed to understand the different reactivity of primary, secondary, and tertiary alcohols to optimize their conversion processes. They studied oxidation reactions using acidified potassium dichromate, noting how primary alcohols oxidize to aldehydes and then carboxylic acids, while secondary alcohols stop at ketones. This knowledge was crucial for developing efficient biofuel production methods to reduce Uganda's dependence on imported fossil fuels.

Task:

a)Write the oxidation reaction for a primary alcohol to a carboxylic acid.

b)Explain why tertiary alcohols are resistant to oxidation.

c)Describe how the Lucas test can distinguish between primary, secondary, and tertiary alcohols.

Scenario 72

A community-based enterprise in Gulu was producing disinfectants and antiseptics for local clinics and households.They used different alcohols and phenols in their formulations but needed to understand the relationship between molecular structure and antimicrobial effectiveness. The team studied how longer carbon chains in alcohols increase antibacterial activity but decrease water solubility. They also explored how phenols denature proteins more effectively than alcohols but are more toxic. This understanding allowed them to formulate safe, effective, and affordable disinfectants tailored to local needs in Northern Uganda.

Task:

a)Explain how the antimicrobial activity of alcohols changes with increasing molecular weight.

b)Compare the mechanism of antimicrobial action between alcohols and phenols.

c)State why dilute phenol solutions are preferred over concentrated ones for antiseptic use.

Sub-topic 9.2: Carbonyl Compounds (Aldehydes and Ketones)

Scenario 73

A medical technology startup in Kampala was developing affordable diabetes diagnostic strips for local clinics.The strips detect glucose in urine through a color change reaction with Benedict's solution. The chemists had to explain how glucose, an aldehyde sugar, reduces copper(II) ions to copper(I) oxide, producing the characteristic color change. They contrasted this with ketone bodies, which don't give this reaction, helping healthcare workers distinguish between different metabolic conditions common in Ugandan diabetic patients.

Task:

a)Describe the reaction between an aldehyde and Benedict's solution.

b)Explain why ketones do not react with Benedict's solution.

c)Write the mechanism for the nucleophilic addition of hydrogen cyanide to a carbonyl group.

Scenario 74

An agricultural processing company in Jinja was exploring ways to add value to local crops by extracting and synthesizing flavor compounds.Their chemists focused on carbonyl compounds, particularly

aldehydes and ketones responsible for many natural aromas. The team studied preparation methods including alcohol oxidation and hydration of alkynes. They also investigated reactions like aldol condensation that could create new fragrance molecules. This project aimed to develop Uganda's capacity in specialty chemicals for the food and cosmetics industries.

Task:

a)Describe two different methods for preparing aldehydes.

b)Explain the difference in reactivity between aldehydes and ketones in nucleophilic addition reactions.

c)Write the reaction for the preparation of a ketone from a secondary alcohol.

Scenario 75

A furniture factory in Wakiso using acetone and formaldehyde-based solvents reported several worker health issues.The safety officer organized training on carbonyl compound properties and hazards. He explained how formaldehyde's high reactivity makes it more irritating than acetone, and how both compounds can be detected using 2,4-DNP test. The training covered proper handling procedures and first aid measures for exposure, significantly improving workplace safety in Uganda's growing manufacturing sector.

Task:

a)Describe how to distinguish between an aldehyde and a ketone using chemical tests.

b)Explain why formaldehyde is more reactive than acetone in nucleophilic addition reactions.

c)State two health hazards associated with formaldehyde exposure.

Sub-topic 9.3: Carboxylic Acids and Derivatives

Scenario 76

A fruit processing plant in Masaka experienced massive spoilage of their mango juice products.Microbiological analysis revealed microbial production of short-chain carboxylic acids, causing souring and off-flavors. The quality control team needed to identify the specific acids present and understand their formation pathways. They used esterification tests and pH measurements to characterize the acids and implemented better sterilization processes. This case highlighted the importance of carboxylic acid chemistry in Uganda's fruit processing industry, which suffers significant post-harvest losses.

Task:

a)Describe the esterification reaction of a carboxylic acid with an alcohol.

b)Explain why carboxylic acids have higher boiling points than alcohols of similar molecular weight.

c)Write the reaction for the preparation of a carboxylic acid from a primary alcohol.

Scenario 77

A women's cooperative in Lira was producing traditional soap using local plant oils and ash.They wanted to improve their product quality and understand the saponification process scientifically. A chemist explained how triglycerides (esters) in oils react with sodium hydroxide to produce carboxylic acid salts (soap) and glycerol. The team learned to calculate the exact amount of alkali needed for complete saponification and tested their soap's properties based on the fatty acid composition. This knowledge helped them produce consistent, high-quality soap for local markets.

Task:

a)Write the saponification reaction for a triglyceride.

b)Explain how soap molecules clean greasy dirt.

c)Calculate the amount of NaOH needed to saponify 1kg of fat with average molecular weight 850g/mol.

Scenario 78

Researchers at the Pharmaceutical Research Institute in Entebbe were developing local production methods for essential medicines like aspirin.They needed to master carboxylic acid derivative chemistry,

particularly ester and amide formation. The team studied reaction mechanisms, optimizing conditions for maximum yield while minimizing side products. They also investigated the hydrolysis rates of different derivatives to ensure drug stability. This research supported Uganda's goal of increasing local drug manufacturing capacity and reducing import dependence.

Task:

a)Compare the relative reactivity of acid chlorides, esters, and amides.

b)Write the mechanism for the hydrolysis of an ester in basic medium.

c)Explain why amides are less reactive than esters in nucleophilic substitution reactions.

Topic 10: ELECTROCHEMISTRY

Sub-topic 10.1: Redox Reactions and Oxidation Numbers

Scenario 79

The National Water and Sewerage Corporation was troubleshooting their chlorination system in Kampala.Engineers needed to understand the redox chemistry involved in water disinfection where chlorine (0) is reduced to chloride (-1) while oxidizing organic contaminants. The team analyzed oxidation number changes in various disinfection byproducts and optimized chlorine dosing to ensure effective pathogen kill while minimizing harmful byproducts. This understanding helped maintain safe drinking water for Uganda's growing urban population.

Task:

a)Calculate the oxidation number of chlorine in ClO_2.

b)Balance the redox equation for chlorine reaction with water: $Cl_2 + H_2O \rightarrow HClO + HCl$

c)Explain why chlorine is both oxidized and reduced in this disproportionation reaction.

Scenario 80

The Uganda Railways Corporation was experiencing significant corrosion of steel bridges and tracks,especially in humid areas. Materials engineers conducted a study of redox reactions involved in rust formation, where iron(0) oxidizes to iron(III) oxide. The team identified areas with different oxygen concentrations creating electrochemical cells that accelerated corrosion. They implemented cathodic protection systems and developed maintenance schedules based on their redox chemistry understanding, significantly extending infrastructure lifespan.

Task:

a)Write the half-reactions for the rusting of iron.

b)Explain how the presence of salt water accelerates corrosion.

c)Describe one method of cathodic protection for iron structures.

Scenario 81

A gold mining company in Busia was treating wastewater containing toxic cyanide complexes.Environmental engineers used redox chemistry to break down cyanide by oxidation with chlorine or hydrogen peroxide. The team monitored the process using oxidation number changes and ensured complete conversion to less harmful products. This application of redox principles helped the mining industry meet Uganda's environmental standards while continuing operations.

Task:

a)Balance the redox equation for cyanide oxidation: $CN^- + OCl^- \rightarrow CNO^- + Cl^-$

b)Calculate the oxidation number of carbon in CN^- and CNO^-.

c)Explain why redox reactions are important in environmental chemistry.

Sub-topic 10.2: Electrochemical Cells and Applications

Scenario 82

A health center in the rural Kigezi region faced frequent power outages,jeopardizing the refrigeration of vaccines. An engineering team was tasked with designing a reliable backup power system using galvanic cells. They constructed simple zinc-copper voltaic cells, explaining how the spontaneous redox reaction generates electrical energy. The team calculated cell potentials using standard electrode potential tables and connected multiple cells in series to achieve the required voltage. They also educated clinic staff on maintenance and safe disposal, ensuring the vaccines remained viable and supporting healthcare delivery in remote areas of Uganda.

Task:

a)Calculate the standard cell potential for a Zn^{2+}/Zn and Cu^{2+}/Cu cell.

b)Write the half-cell reactions and the overall cell reaction.

c)Explain why the zinc electrode loses mass over time in this cell.

Scenario 83

A jewelry makers'cooperative in Kampala wanted to improve their products by electroplating with silver and gold. A chemist taught them the principles of electrolytic cells, where electrical energy drives non-spontaneous reactions. The team practiced calculating the time and current needed to deposit specific metal thicknesses using Faraday's laws. They learned to prepare clean surfaces and control conditions to achieve smooth, adherent coatings. This knowledge enabled the artisans to enhance their products' value and appeal, boosting their incomes in Uganda's competitive crafts market.

Task:

a)Distinguish between galvanic and electrolytic cells.

b)Calculate the time required to deposit 2.0g of silver using a 2A current.

c)State two factors that affect the quality of an electroplated coating.

Scenario 84

Agricultural scientists in Mbale were concerned about corrosion of metal components in irrigation systems,which was contaminating soil and water. They used the concept of standard electrode potentials to predict which metals would corrode when buried in different soil types. The team set up experiments to measure corrosion rates and identified that acidic soils and dissolved salts accelerated the process. Their findings led to recommendations for using more resistant metals and protective coatings, safeguarding both the irrigation infrastructure and the environment.

Task:

a)Predict whether iron will corrode when in contact with copper in moist soil. Justify using E° values.

b)Explain how soil pH affects the corrosion rate of metals.

c)Suggest a metal that could be used as a sacrificial anode to protect iron from corrosion.

Sub-topic 10.3: Electrolysis and Faraday's Laws

Scenario 85

A youth group in Jinja started a business recycling aluminum scrap into useful products.They used electrolysis to purify the metal and needed to understand Faraday's laws to control the process efficiently. The members learned to calculate the amount of aluminum deposited or dissolved based on current and time. They optimized their setup to maximize yield while minimizing energy costs, turning waste into income and contributing to environmental conservation in Uganda.

Task:

a)State Faraday's first law of electrolysis.

b)Calculate the mass of aluminum deposited when a 5A current passes through molten Al_2O_3 for 3 hours.

c)Write the half-reaction for the deposition of aluminum at the cathode.

Scenario 86
Researchers at Kyambogo University were exploring hydrogen production as a clean fuel alternative.They built an electrolysis apparatus to split water into hydrogen and oxygen, applying Faraday's laws to determine gas volumes produced. The team faced challenges with efficiency due to the high overpotential of oxygen evolution. They experimented with different catalysts and electrolytes to improve the process, aiming to make green hydrogen a viable energy source for Uganda's future.
Task:
a)Write the half-reactions for the electrolysis of acidified water.
b)Calculate the volume of hydrogen produced at STP by a 2A current in 1 hour.
c)Explain why adding an electrolyte is necessary for water electrolysis.
Scenario 87
An auditor visited a copper refining plant in Kilembe to assess its efficiency.The plant used electrolysis to purify copper, and the auditor applied Faraday's laws to check if the actual copper production matched theoretical predictions. Discrepancies were found due to side reactions and current inefficiencies. The auditor recommended improvements to electrode design and current management, which increased the plant's output and profitability, supporting Uganda's mining sector.
Task:
a)Describe the process of electrolytic refining of copper.
b)Calculate the current efficiency if 5.0g of copper is deposited instead of the expected 5.5g.
c)State two common impurities found in blister copper.

Topic 11: PERIODICITY II
Sub-topic 11.1: Trends in Properties of Group 14 Elements
Scenario 88
A technology institute in Kampala was researching the potential for local microchip production.They focused on silicon from Group 14, studying its semiconductor properties and how they differ from carbon (diamond) and germanium. The team explored the trend from non-metallic to metallic character down the group and how this affects electrical conductivity. They also investigated silicon's oxide layer, which is crucial for chip manufacturing. This foundational research aimed to position Uganda in the global technology value chain.
Task:
a)Explain the trend in electrical conductivity down Group 14.
b)Compare the structure and bonding in diamond and silicon.
c)State why silicon is preferred over germanium for making semiconductors.
Scenario 89
Environmental scientists in Uganda were studying carbon dioxide emissions from various sources.They compared CO_2 to other Group 14 oxides like SiO_2 and PbO_2, explaining differences in volatility and acidity based on periodic trends. The team highlighted how carbon's unique ability to form stable double bonds with oxygen makes CO_2 a gas, while SiO_2 is a solid. This understanding informed policies on emissions control and climate change mitigation in Uganda.
Task:
a)Compare the acidity of CO_2 and SiO_2.
b)Explain the trend in thermal stability of Group 14 hydrides.
c)Write the reaction between CO_2 and limewater.
Scenario 90
An environmental NGO in Wakiso addressed the improper disposal of lead-acid batteries,which was causing soil contamination. They educated the community about lead's position in Group 14 and its toxic

properties compared to other group elements. The NGO set up a recycling program that safely extracted lead and its compounds, demonstrating redox reactions involving lead. This initiative protected the environment and created jobs in Uganda's waste management sector.

Task:

a)Describe the trend in metallic character down Group 14.

b)Write the reaction at the anode in a lead-acid battery.

c)State two health hazards associated with lead exposure.

Sub-topic 11.2: Trends in Properties of Group 17 Elements

Scenario 91

The National Water and Sewerage Corporation evaluated different halogens for water treatment.They compared chlorine, bromine, and iodine in terms of disinfecting power, solubility, and cost. The team explained how oxidizing ability decreases down the group, making chlorine the most effective disinfectant. They also considered the formation of disinfection byproducts and adjusted pH to optimize chlorine efficiency, ensuring safe drinking water for Ugandan households.

Task:

a)Explain the trend in oxidizing power down Group 17.

b)Write the reaction between chlorine and water.

c)State why iodine is less soluble in water than chlorine.

Scenario 92

A salt processing plant in Lake Katwe was producing iodized salt to prevent iodine deficiency disorders.Quality controllers monitored the iodine content, understanding its volatility and sublimation properties. They tested for iodine using starch solution and ensured proper packaging to prevent iodine loss. This program helped combat goiter and other iodine-related health issues in Uganda.

Task:

a)Describe the test for iodine using starch.

b)Explain why iodine sublimes more easily than chlorine.

c)Calculate the percentage of iodine in potassium iodate (KIO_3).

Scenario 93

A chemical plant in Namanve producing sodium hypochlorite bleach trained workers on halogen chemistry.They covered chlorine's high reactivity and toxicity compared to other halogens. The team demonstrated the disproportionation reaction of chlorine with cold, dilute NaOH to produce bleach. Safety protocols were emphasized to prevent accidents, protecting workers and the environment in Uganda's chemical industry.

Task:

a)Write the reaction for the formation of bleach from chlorine and NaOH.

b)Compare the bond energies of Cl_2, Br_2, and I_2.

c)State two safety precautions when handling chlorine gas.

Sub-topic 11.3: The d-Block Transition Elements

Scenario 94

Engineers at a Kampala auto workshop were developing cheaper catalytic converters using transition metals like iron and copper instead of platinum.They studied how variable oxidation states and surface adsorption properties make transition metals good catalysts. The team tested their converters' efficiency in reducing vehicle emissions, contributing to cleaner air in Ugandan cities.

Task:

a)Explain why transition elements show variable oxidation states.

b)Describe how a catalytic converter reduces NO emissions.
c)State two other industrial uses of transition metal catalysts.

Scenario 95

A gemology center in Mbale was identifying and valuing colored stones.They explained how transition elements like chromium in emeralds and iron in amethysts cause colors through d-d electron transitions. The team used spectroscopy to analyze these transitions and detect synthetic gems, supporting Uganda's growing gemstone industry.

Task:

a)Explain how transition elements cause color in compounds.
b)Why are zinc and scandium not considered typical transition elements?
c)Calculate the oxidation state of chromium in $Cr_2O_7^{2-}$.

Scenario 96

A pharmaceutical company in Entebbe was formulating iron supplements to treat anemia. They faced challenges with iron's oxidation from Fe^{2+} to Fe^{3+} in storage, which reduced bioavailability. Chemists used complex formation with ligands like EDTA to stabilize Fe^{2+} and prevent oxidation. This ensured effective supplements for addressing anemia, a common health issue in Uganda.

Task:

a)Explain the biological importance of iron in hemoglobin.
b)Write the electron configuration of Fe^{2+} and Fe^{3+}.
c)Why are Fe^{2+} compounds usually green while Fe^{3+} compounds are yellow/brown?

Topic 12: REACTION KINEMATICS

Sub topic 12.1: Rate equations and order of reactions

Scenario 109

A dairy cooperative in Mbarara was experiencing significant financial losses due to the rapid spoilage of milk during transportation to processing centers.The spoilage, caused by bacterial fermentation, is a chemical reaction whose rate needed to be slowed. The cooperative's chemist, Mr. Tugume, organized a workshop for the farmers and drivers. He explained how the rate of bacterial growth and the ensuing souring of milk is highly dependent on temperature. He demonstrated this by showing how milk left in the sun spoils much faster than milk kept in a cool shade. The campaign promoted the use of insulated cooler boxes during transit and highlighted the importance of the Arrhenius equation, which quantitatively describes how reaction rates increase exponentially with temperature. This simple understanding helped drastically reduce spoilage, increasing the farmers' profits.

Task:

a)State the Arrhenius equation and define its terms.
b)Explain why storing milk at a lower temperature slows down the spoilage reaction.
c)If the rate of spoilage doubles with a 10°C rise in temperature, calculate the activation energy for the process (use the appropriate approximation).

Sub topic 12.2: Factors affecting the rates of reaction

Scenario 110

The mechanics at a large boda boda (motorcycle) repair shop in Kampala were concerned about the rapid rusting of motorcycle parts, especially during the rainy season. The head mechanic, Ms. Nansubuga, researched how to slow down the corrosion reaction. She explained to her apprentices that rusting is an electrochemical process that requires both water and oxygen. She demonstrated how spraying a thin layer of oil on metal parts creates a protective barrier. This barrier does not change the reaction's activation energy but drastically reduces the frequency of collisions between the metal surface and the reactants

(water & oxygen) by physically separating them. Implementing this simple, cost-effective practice significantly extended the lifespan of the motorcycles.

Task:

a)Explain how a protective oil layer affects the collision theory parameters to reduce the rusting rate.

b)Rusting is faster in salty water. Suggest a reason for this observation.

c)Apart from creating a barrier, name one other method to prevent rusting and briefly explain how it works.

Scenario 111

Following a near-miss incident,the safety officer at a large maize milling plant in Jinja conducted a mandatory safety training on the hazards of grain dust. He explained that a dust explosion is an extremely rapid combustion reaction. He demonstrated that while a pile of maize flour burns slowly, a fine cloud of the same flour suspended in air can explode violently when ignited. He emphasized that this is because pulverizing the solid maize into a fine dust increases its surface area exponentially, allowing oxygen molecules to collide with a vastly greater number of fuel particles simultaneously. This training led to the strict enforcement of housekeeping rules to minimize dust accumulation.

Task:

a)Using the concepts of surface area and collision theory, explain why a dust explosion is more violent than the burning of a solid lump.

b)State the three components of the "fire triangle" necessary for combustion.

c)Besides controlling dust, suggest one other safety measure to prevent such explosions in a mill.

Scenario 112

A wave of catalytic converter thefts from vehicles in Entebbe prompted a police awareness campaign.A police chemist was invited to explain the device's importance. She explained that a car's engine produces harmful gases like carbon monoxide (CO) and unburnt hydrocarbons. The catalytic converter uses a platinum-rhodium catalyst to provide an alternative reaction pathway with a lower activation energy for the conversion of these pollutants into less harmful carbon dioxide and water vapor. This allows the reactions to occur rapidly at the exhaust system's temperature, which would otherwise be too low. The campaign helped the public understand the environmental and health value of the device, encouraging better vigilance.

Task:

a)Explain the role of the platinum catalyst in a catalytic converter in terms of activation energy.

b)Write a balanced equation for the oxidation of carbon monoxide (CO) to carbon dioxide (CO_2) inside a catalytic converter.

c)Why are catalysts like platinum not consumed in the reactions they speed up?

Scenario 113

A women's group in Gulu was producing homemade passion fruit juice for sale at the local market.To ensure its safety and extend its shelf life, they were taught the basics of pasteurization. The facilitator explained that spoilage is caused by microorganisms, whose destruction follows the principles of reaction kinetics. Heating the juice to a specific temperature for a precise time ensures that the rate of the "reaction" (killing the microbes) is fast enough to be effective. She highlighted that this is a delicate balance; higher temperatures or longer times, while more effective, can also degrade the juice's flavor and nutrients, demonstrating how changing conditions affects the rates of multiple, competing reactions.

Task:

a)Pasteurization controls the rate of microbial death. Name the factor being manipulated and state how it affects the reaction rate.

b)Why is it important to cool the juice rapidly after the heating process is complete?

c)If the rate of microbial destruction is known to double for every 10°C rise in temperature, and it takes 5 minutes at 70°C, estimate the time needed at 60°C.

Scenario 114

Park rangers at Murchison Falls National Park were using chemical light sticks for night patrols to deter poachers without using bright lights that could scare animals.The head ranger explained that the light is produced by a chemical reaction (chemiluminescence) whose rate is controlled by temperature. On cooler nights, the light lasted longer but was dimmer, while on warmer nights, it was brighter but drained quickly. Rangers learned to slightly warm the sticks in their hands for a brighter light when inspecting an area and to cool them in river water to conserve the reaction for longer patrols, demonstrating practical control over reaction rates in the field.

Task:

a)Explain why the light stick glows brighter when warmed, using concepts of particle energy and collision theory.

b)Sketch a graph showing the relationship between the initial brightness of the glow and the temperature.

c)If a light stick lasts for 8 hours at 20°C, would you expect it to last for more or less than 8 hours at 30°C? Explain your answer.

Scenario 115

At the Hima cement factory,engineers were monitoring the calcination process where limestone ($CaCO_3$) is heated to produce quicklime (CaO). They found that grinding the limestone into a fine powder before feeding it into the kiln significantly increased the production rate. The plant manager explained that this increase in surface area allowed heat and the reaction to penetrate the material more efficiently, allowing them to lower the kiln temperature slightly, which saved on fuel costs while maintaining their output targets for Uganda's construction industry.

Task:

a)Explain how decreasing the particle size of limestone increases the rate of its thermal decomposition.

b)Write a balanced chemical equation for the thermal decomposition of limestone.

c)State one economic benefit of increasing the reaction rate in this industrial process.

Scenario 116

A silversmith in Mpigi was frustrated that her intricately designed jewelry was tarnishing(reacting with atmospheric sulfur to form black Ag_2S) in her workshop, which was located near a road with high traffic emissions. She consulted a chemist who explained that the tarnishing was faster in her workshop than in a cleaner environment because sulfur dioxide (SO_2) from vehicle exhaust acted as a catalyst for the reaction. The chemist recommended installing an air filtration system, which removed the SO_2 and significantly slowed down the tarnishing rate, preserving the jewelry's shine.

Task:

a)Define a catalyst and explain how the presence of SO_2 gas increased the tarnishing rate of silver.

b)Write a balanced chemical equation for the formation of silver sulfide (Ag_2S) from silver and atmospheric hydrogen sulfide (H_2S).

c)Why would polishing the silver jewelry also help to slow down the tarnishing process?

Scenario 117

A traditional brewer in Bushenyi was producingtonto (a local banana beer) and noticed that the fermentation rate was inconsistent. An agricultural extension officer explained that the concentration of yeast, which acts as a biological catalyst, was crucial. By measuring the sugar concentration at the start and carefully adding a standardized amount of yeast, the brewer could control the rate of ethanol production. The officer also highlighted that temperature was a key factor; fermentation was too slow in the cool mornings and too violent in the hot afternoons, so maintaining a steady, optimal temperature was essential for a consistent and high-quality product.

Task:

a)Yeast is a biological catalyst. How does increasing the amount of yeast affect the rate of fermentation?

b)The fermentation of glucose is exothermic. How might this inherent property of the reaction affect the rate if the heat is not dissipated?

c)State two factors, other than yeast concentration and temperature, that could affect the rate of fermentation.

Scenario 118

Fish farmers in Kajjansi faced frequent fish kills in their ponds during hot,still nights. An aquaculturist from the Ministry of Agriculture explained that the dissolved oxygen (O_2) levels dropped because the respiration rates of fish and other organisms increased with temperature. Furthermore, without wind to mix the water, oxygen from the air couldn't dissolve quickly enough to replenish what was consumed. The solution was to use electric air pumps to bubble air through the water, thereby increasing the concentration of the dissolved oxygen reactant and preventing the "reaction" of fish suffocation.

Task:

a)Explain the two factors that caused the decreased oxygen levels in the pond at night.

b)How does bubbling air through the water increase the rate of oxygen transfer into the water?

c)Sketch a graph to show how the rate of a reaction typically depends on the concentration of a reactant.

Scenario 119

Vendors at the Mbale market noticed that the vibrant colors of their Kitenge fabrics were fading quickly when displayed in direct sunlight.A textile chemist explained that the dyes were undergoing photochemical degradation, and the intense ultraviolet (UV) light in sunlight was providing the activation energy for these reactions. The chemist recommended using UV-protective sprays on the fabrics and displaying them under shades or canopies. This simple intervention significantly slowed down the fading reaction, protecting the vendors' valuable stock.

Task:

a)Explain the role of UV light in increasing the rate of the color-fading reaction.

b)Suggest why different colors on the same fabric might fade at different rates.

c)Name the factor affecting the reaction rate that is being controlled by using a protective spray.

Scenario 120

pharmaceutical company in Kampala was developing effervescent antacid tablets that would fizz and dissolve rapidly in water.The formulation chemists were experimenting with different particle sizes of citric acid and sodium bicarbonate. They found that using finely powdered ingredients created a much faster initial fizz, which was desirable. However, they had to balance this with the need for the tablets to be mechanically strong enough for packaging and transport. This involved optimizing the rate of the reaction for both user experience and product stability.

Task:

a)Write a balanced chemical equation for the reaction between citric acid (a triprotic acid can be generalized as H^+) and sodium bicarbonate (HCO_3^-) that produces the fizz.

b)Explain why a tablet made from powdered reactants fizzes faster than one made from coarse crystals.

MATHEMATICS SCENARIO BASED ITEMS

Topic 1: NUMERICAL CONCEPTS

Sub-topic 1.1: Indices

Scenario 1

A rapidly growing tech startup in Kampala,"ByteHub Uganda," is projecting its user base growth for investors. Their analytics team has modeled the growth using the formula $U(t) = 500 \times 2^{0.5t}$, where U is the number of users and t is the time in months. The board of directors needs to make critical decisions about server capacity and funding rounds based on these projections. They need to know the expected user base 6 months from now and understand how long it will take to reach a milestone of 10,000 users to secure the next phase of venture capital funding. Accurately applying the laws of indices is essential for these calculations, as even a small miscalculation could lead to either costly over-provisioning of resources or catastrophic system failure due to underestimation.

Task:

a)Calculate the projected number of users after 6 months.

b)Determine how many months it will take for the user base to reach 10,000.

c)State what the base and the exponent represent in the context of this model.

Scenario 2

The National Agricultural Research Organisation(NARO) is studying the propagation of a beneficial soil bacterium in a new fertilizer. Under ideal conditions in the lab, a single bacterium divides into two every 30 minutes. The population growth is modeled by $P(t) = P_0 \times 2^{2t}$, where P_0 is the initial population and t is the time in hours. Researchers need to predict the population size after 4 hours starting from an initial colony of 100 bacteria to ensure there are enough bacteria to effectively treat one hectare of farmland. This helps in determining the correct and cost-effective amount of fertilizer to produce for Ugandan farmers, directly impacting crop yields and food security in the region.

Task:

a)Calculate the population of bacteria after 4 hours.

b)If the culture medium can only support 1,000,000 bacteria, how long will it take to reach this capacity from the start?

c)Explain why the exponent in the model is $2t$ and not just t .

Scenario 3

A financial advisor at Stanbic Bank Uganda is explaining the power of compound interest to a young client who wants to save for university. A savings account offers an annual interest rate of 8%, compounded annually. The future value of the investment is given by the formula $A = P(1 + r)^n$, where P is the principal, r is the interest rate, and n is the number of years. The client, who has UGX 500,000 to invest, wants to know how much the investment will be worth in 5 years and how long it will take for her money to double, enabling her to make an informed decision about her financial future and educational goals.

Task:

a)Calculate the future value of the UGX 500,000 investment after 5 years.

b)Determine the number of years it will take for the initial investment to double.

c)State one way the client could decrease the time it takes for her investment to double.

Sub-topic 1.2: Logarithms

Scenario 4

Acoustic engineers are assessing noise pollution at a new factory site in Namanve Industrial Park.They measure the sound intensity at the perimeter wall to be 5×10^{-4} Wm^{-2}. Ugandan law mandates that industrial noise must not exceed 75 dB at residential boundaries, calculated using $P = 10\log_{10}(\frac{I}{L})$, with $L = 10^{-12}$ Wm^{-2}. The factory managers must determine if they are compliant or if they need to invest in expensive sound-dampening measures to avoid fines and legal action from the nearby community, which has already raised concerns about the potential impact on their quality of life.

Task:

a) Calculate the sound level in decibels for the measured intensity.

b) Determine the maximum permissible sound intensity I that corresponds to the 75 dB legal limit.

c) Explain why using a logarithmic scale is more practical than a linear scale for measuring sound intensity in this context.

Scenario 5

A data scientist at a telecommunications company is analyzing the server load for their new mobile money platform. The load on the servers follows the model $L(t) = k \log_2(t + 1)$, where t is the number of concurrent users. During a peak hour, with 1024 users, the load is measured at 50 units. The operations team needs to predict the server load when 4096 users are active simultaneously to decide if the current server infrastructure can handle the anticipated growth during the festive season or if a costly upgrade is necessary to prevent system failure.

Task:

a)Use the given data to find the value of the constant k .

b)Calculate the predicted server load for 4096 concurrent users.

c)State what the value '1' in the term $(t + 1)$ likely represents in this model.

Scenario 6

Public health officials are tracking the spread of an infectious disease in a rural Ugandan district.The effective reproduction number R_t is a crucial metric. If R_t is 2, it means each infected person spreads the disease to 2 others. The growth rate can be analyzed using logarithms. If the number of cases increases from 10 to 160 over a period, officials need to calculate the average R_t to understand the speed of transmission and decide whether to implement lockdowns, which have significant economic and social consequences for the community.

Task:

a)The number of cases follows $C = C_0 X (R_t)^n$, where n is the number of transmission cycles. If cases grow from 10 to 160, and $n=3$, calculate R_t.

b)Express the number of transmission cycles n in terms of C , C_0 , and R_t using logarithms.

c)If R_t is found to be 1.5, is the outbreak growing or shrinking? Explain.

Sub-topic 1.3: Surds

Scenario 7

An architect is designing a uniquely shaped national monument for a Kampala roundabout.The design features a large equilateral triangle with a side length of $8\sqrt{3}$ meters. To source the correct amount of a special, expensive cladding material for the perimeter, the contractor needs the exact perimeter length. Providing a decimal approximation could lead to a costly over-ordering or under-ordering of material, so the exact value in surd form is essential for precise costing and procurement before construction begins.

Task:

a)Calculate the exact perimeter of the equilateral triangle in surd form.

b)Find the area of the triangle, also in surd form.
c)Provide a rational approximation of the perimeter to 2 decimal places for the logistics team, who require numerical values for transport planning.

Scenario 8

A land surveyor is demarcating a rectangular plot of land for a new school in Wakiso District. The plot is $(5\sqrt{2} + 10)$ meters long and $(5\sqrt{2} - 10)$ meters wide. The school administration needs to know the exact area of the land for legal documentation and to plan the placement of buildings and playgrounds. Using surds ensures the legal documents are mathematically precise, avoiding future boundary disputes with neighboring landowners.

Task:

a)Show that the area of the plot is a rational number.
b)Calculate the exact area.
c)If a fence is to be built around the plot, calculate the exact length of the diagonal to determine the amount of fencing material needed for the corners.

Scenario 9

A civil engineer is inspecting a collapsed section of a road embankment.The cross-section of the stable embankment is a right-angled triangle with a vertical height of $4\sqrt{5}$ meters and a base of $2\sqrt{5}$meters. To design a reinforcing support, the engineer needs the exact length of the sloping side (the hypotenuse). Using surds provides the precision required for structural calculations, ensuring the support is designed to the correct specifications to prevent further collapses and ensure public safety.

Task:

a)Calculate the exact length of the hypotenuse of the triangular cross-section.
b)Find the exact perimeter of this triangular cross-section.
c)Rationalize the denominator of the expression for the hypotenuse if it were written as a fraction.

Topic 2: EQUATIONS AND INEQUALITIES

Sub-topic 2.1: Linear and Simultaneous Equations

Scenario 10

A manager at a Nakawa market cooperative needs to track the week's sales of maize and beans.The cooperative sold a total of 300 kg of both crops. The total revenue was UGX 1,200,000. If maize is sold at UGX 3,000 per kg and beans at UGX 5,000 per kg, the manager must determine the exact breakdown to calculate profits, pay the farmers, and plan next week's stock. An error in this calculation could lead to financial losses or disputes with the suppliers.

Task:

a)Formulate a pair of simultaneous equations to represent this situation.
b)Solve the equations to find the kilograms of maize and beans sold.
c)If the price of beans increases by 10%, how would this affect the solution if the total revenue and quantity remained the same?

Scenario 11

A delivery company in Kampala uses a fleet of motorcycles(bodas) and vans. On a particular day, the total number of vehicles used was 25. The total number of wheels counted (excluding spares) was 70. A logistics planner needs to know how many of each vehicle type were operational that day to analyze fuel consumption patterns and plan for maintenance schedules, which are different for the two vehicle types.

Task:

a)Formulate a pair of simultaneous equations to represent this situation. (Assume a motorcycle has 2 wheels and a van has 4).
b)Solve the equations to find the number of motorcycles and vans.

c)If three vans were undergoing repair that day, what would the new total number of wheels have been?

Scenario 12

A chemist at a Jinja water treatment plant is preparing a disinfectant solution.She needs to mix two solutions: one with a 30% chlorine concentration and another with a 60% chlorine concentration, to obtain 10 liters of a 45% chlorine solution. The exact volumes of each starting solution are critical. Too much chlorine wastes resources and poses an environmental hazard, while too little fails to purify the water, risking public health.

Task:

a)Formulate a pair of simultaneous equations to represent this situation.

b)Solve the equations to find the required volume of each solution.

c)If she only had 8 liters of the 60% solution, what concentration would the resulting mixture have if she used all of it and made up the rest with the 30% solution to get 10 liters?

Sub-topic 2.2: Quadratic Equations

Scenario 13

A local football club is analyzing the trajectory of a penalty kick.The height h of the ball in meters is modeled by the equation $h = 2 + 15t - 5t^2$, where t is the time in seconds. The coach wants to know if the ball will be high enough to clear a 10-meter-high defensive wall at the time $t = 1.5$ seconds, and also the total time the ball spends in the air to coach players on timing their runs.

Task:

a)Calculate the height of the ball at $t = 1.5$ seconds.

b)Determine the total time the ball remains in the air

c)What is the maximum height reached by the ball?

Scenario 14

A farmer in Masaka wants to fence a rectangular vegetable garden against a wall.She has 40 meters of fencing material for the other three sides. To maximize the growing area, which is crucial for her income, she needs to find the dimensions that will give the largest possible area. This is a classic optimization problem that can be solved by forming and analyzing a quadratic equation.

Task:

a)If the side perpendicular to the wall is x meters, show that the area A is given by $A = x(40 - 2x)$

b)Rewrite this expression in the standard quadratic form.

c)Find the dimensions that maximize the area and state this maximum area.

Scenario 15

The profit P in thousands of Ugandan Shillings for a small business selling handmade crafts is modeled by the equation $P = -2n^2 + 40n - 72$, where n is the number of items sold in hundreds. The business owner needs to know the "break-even" points (where profit is zero) to set realistic sales targets and to determine the number of items that must be sold to start making a profit.

Task:

a)Find the number of items sold when the profit is zero (solve for n when $P=0$).

b)How many items must be sold to maximize profit?

c)What is the maximum profit achievable?

Sub-topic 2.3: Quadratic Inequalities

Scenario 16

A manufacturing plant in Kasese produces solar panel components.The daily profit P in millions of Ugandan Shillings is modeled by the inequality $P > -x^2 + 14x - 33$, where x is the number of workers per shift. The plant manager needs to determine the range of workers per shift that will ensure the

company remains profitable ($P > 0$) to optimize labor costs while maintaining production efficiency and avoiding operational losses.

Task:

a)Solve the quadratic inequality $-x^2 + 14x - 33 > 0$ to find the range of x .

b)If the plant can only accommodate a maximum of 12 workers per shift, does this fall within the profitable range?

c)Interpret what happens to the profit if the number of workers is 3.

Scenario 17

An architect is designing an arched window for a new community center in Gulu.The arch is modeled by the equation $y = -\frac{1}{4}x^2 + 3x$, where y is the height in meters and x is the horizontal distance from the left side. For the window to be functional, its height must be greater than 5 meters. The architect needs to find the horizontal distance x where the arch meets this height requirement to ensure the design complies with both aesthetic and practical specifications.

Task:

a)Set up the quadratic inequality that represents the condition $y > 5$.

b)Solve the inequality to find the range of x where the arch height exceeds 5 meters.

c)What is the maximum height of the arch, and at what x value does it occur?

Scenario 18

A ball is thrown vertically upward from a building in Kampala.Its height h in meters above the ground at time t seconds is given by $h = 40 + 15t - 5t^2$. Safety regulations require that during a fireworks display, the ball must be at least 30 meters above the ground to be visible and safe. The event planner needs to determine the time interval during which the ball meets this safety requirement.

Task:

a)Set up the quadratic inequality for $h \geq 30$.

b)Solve the inequality to find the time interval t for which the ball is at least 30 meters high.

c)For how many seconds is the ball above 40 meters?

Sub-topic 2.4: Polynomials

Scenario 19

An engineer is testing the stress tolerance of a new composite beam.The beam's deflection D in millimeters under a load is modeled by the polynomial $D(x) = x^3 - 6x^2 + 11x - 6$, where x is the load in tons. The beam fails if deflection exceeds 10mm. The engineer needs to find the load values where deflection is zero to understand the beam's fundamental behavior before testing its limits.

Task:

a)Show that $x = 1$ is a root of the polynomial $D(x)$.

b)Factorize the polynomial $D(x)$ completely.

c)Based on the roots, between what load values does the deflection change direction?

Scenario 20

A financial analyst at a Ugandan bank is modeling an investment's growth over time. The value V of the investment after t years is given by the polynomial $V(t) = t^3 - 9t^2 + 24t - 16$ (in millions of UGX). The client wants to know when the investment will return to its initial value (i.e., when $V(t) = 0$) to assess the break-even point and make decisions about early withdrawal.

Task:

a)Use the Factor Theorem to show that $t = 4$ is a root of $V(t)$.

b)Factorize $V(t)$ completely.

c)What are all the times when the investment returns to its initial value?

Scenario 21

A chemist is studying the rate of a catalytic reaction.The reaction rate R at temperature T (in °C) is given by $R(T) = T^3 - 12T^2 + 41T - 42$. The reaction becomes inefficient when the rate is zero. The lab needs to identify the critical temperatures where this occurs to avoid operating under those conditions and to optimize the reaction for industrial-scale chemical production.

Task:

a)Verify that $T = 2$ is a root of the polynomial $R(T)$.

b)Factorize $R(T)$ completely to find all temperatures where the reaction rate is zero.

c)If the optimal operating temperature is between 5°C and 10°C, is the reaction rate positive in this range?

Topic 3: COORDINATE GEOMETRY 1

Sub-topic 3.1: Straight Lines

Scenario 22

The Kampala Capital City Authority(KCCA) is planning a new public bus route to connect the bustling commercial hub of Nakasero Market with the rapidly growing residential area of Ntinda. City planners are using coordinate geometry to design the most efficient and straightest possible route on their city grid map. They have placed Nakasero Market at coordinates (2, 5) and a key transfer point at (8, 17) on their grid, where each unit represents 500 meters. The primary challenge is to determine the exact equation of the bus route line to calculate its length, project fuel costs, and identify where it will intersect with other major routes for scheduling purposes. Furthermore, they need to ensure the route maintains a gradient that is feasible for the city's buses, especially during the rainy season when steep inclines can become hazardous. Accurate calculation is essential for budgeting and for creating an effective public transport system that reduces traffic congestion in the city center.

Task:

a)Calculate the gradient of the straight line representing the proposed bus route.

b)Determine the equation of the line in the form $y = mx + c$.

c)The existing Busuba Road follows the line $y = 3x + 1$. Determine the coordinates of the point where the new bus route will intersect Busuba Road.

Scenario 23

A large-scale agricultural project in the Teso sub-region is dividing a vast,rectangular piece of land for maize, sorghum, and soybean cultivation. The land is mapped on a coordinate grid with corners at A(1, 2), B(7, 5), C(10, 11), and D(4, 8). The project manager needs to verify that the land is indeed rectangular to ensure the irrigation plans and plot allocations are accurate. This involves checking if the angles at the vertices are right angles. Additionally, they need to find the coordinates of the central point where a shared water reservoir will be located, ensuring it is equidistant from all four corners for efficient water distribution. An error in these geometric calculations could lead to unequal water access for different crop sections, potentially jeopardizing the yield of the entire project, which is critical for regional food security.

Task:

a)Show that the quadrilateral ABCD is a rectangle by calculating the gradients of its sides.

b)Calculate the coordinates of the midpoint of diagonal AC.

c)Verify that the midpoint of diagonal BD is the same as that of AC, confirming it is the center.

Scenario 24

The Ministry of Education is rolling out a new program to deliver digital learning tablets to remote rural schools.A drone delivery service is trialed to fly from a distribution warehouse at point W(0, 10) to a school at point S(12, 2) on a perfectly straight path. Air traffic control needs the equation of this flight path for monitoring. Partway through the flight, a storm cell is detected along the line $y = \frac{1}{2}x + 6$. It is

critical to determine if the drone's path will intersect this hazardous weather system, necessitating a course change. The drone operator must calculate the shortest distance from the warehouse to the storm line to assess the initial risk and the point of potential intersection to plan an alternative route, ensuring the safe and timely delivery of the educational resources.

Task:

a)Find the equation of the straight-line flight path from W to S.

b)Calculate the point of intersection between the drone's path and the storm line.

c)If the storm is active within 2 km of its line, will the warehouse be at risk based on the shortest distance?distance

Topic 4: PARTIAL FRACTIONS

Sub-topic 4.1: Linear Factor

Scenario 25

A team of civil engineers in Uganda is working on a complex structural analysis for a new bridge over the Nile River.The stress distribution on a critical beam is modeled by a complex rational function: $\frac{5x+11}{x^2+3x+2}$. To integrate this function and calculate the total load-bearing capacity of the beam over a specific interval, they must first decompose it into simpler partial fractions. This process is crucial because the integral of the complex function is not readily apparent, but the integrals of the resulting simpler fractions are standard and easy to compute. The safety of the entire bridge structure depends on accurately determining the total stress, and any miscalculation in this decomposition could lead to an underestimation of the load, potentially resulting in catastrophic structural failure. The team must carefully factor the denominator and solve for the constants in the numerators to proceed with their integration and subsequent safety verification.

Task:

a)Factorize the denominator of the expression $\frac{5x+11}{x^2+3x+2}$.

b)Express the function in the form of partial fractions: $\frac{A}{(X+1)} + \frac{B}{(X+2)}$.

c)Find the values of the constants A and B.

Sub-topic 4.2: Quadratic Factor

Scenario 26

In the development of a new mobile signal processing algorithm for a Ugandan tech startup,engineers encounter a transfer function that describes the filter's behavior: $\frac{3x^2+4x+5}{(x+1)(x^2+1)}$. To analyze the filter's response to different frequencies, they need to perform an inverse Laplace transform, which requires decomposing this complex function into partial fractions. The denominator includes an irreducible quadratic factor $(x^2 + 1)$ that cannot be broken down into real linear factors. This presents a specific challenge, as the numerator over the quadratic factor must be of the form $Bx + C$. Correct decomposition is vital for the subsequent transformation into the time domain, which will determine the filter's effectiveness in clearing up signal noise in Uganda's often congested mobile networks.

Task:

a)Set up the correct form for the partial fraction decomposition of $\frac{3x^2+4x+5}{(x+1)(x^2+1)}$

b)Find the values of the constants A, B, and C.

c)Once decomposed, the term $\frac{2x+3}{x^2+1}$ can be split. Show how this would be done.

Sub-topic 4.3: Repeated Factor

Scenario 27

A financial modeling team at the Bank of Uganda is analyzing the long-term growth of a national investment fund.The rate of growth is given by a complex rational function: $\frac{x^2+x+1}{(x-1)3}$. To project the total value of the fund over a 20-year period, they need to integrate this growth rate function. The presence of a repeated linear factor $(x-1)^3$ in the denominator necessitates a specific approach to partial fractions. The decomposition must account for each power of the repeated factor, leading to three separate terms. An accurate decomposition is critical here, as even a small error in the constants could lead to a multi-billion shilling miscalculation in the projected value of the national fund, affecting future economic policy and public sector budgeting.

Task:

a)Write the correct form for the partial fraction decomposition of $\frac{x^2+x+1}{(x-1)3}$.

b)Find the values of the constants A, B, and C.

c)If the denominator were $(x-1)^2(x+2)$, how would the form of the partial fractions change? Write the new form.

Topic 5: TRIGONOMETRY

Sub-topic 5.1: Trigonometrical Ratios

Scenario 28

A team of archaeologists is excavating a newly discovered ancient pyramid-like structure in the Karamoja region. To document the site accurately, they need to calculate the height of the structure without climbing it, to avoid causing damage. They set up a surveyor's theodolite 50 meters from the base of the structure and measure the angle of elevation to the top as 35 degrees. The instrument itself is 1.5 meters tall. Using the tangent ratio, which relates the opposite side (the height of the structure above the instrument) to the adjacent side (the distance from the base), they can calculate the total height. This non-invasive method is crucial for preserving the integrity of the historical site while still gathering essential data for their research and for reporting to the Uganda Museum.

Task:

a)Sketch a right-angled triangle representing this situation.

b)Calculate the height of the structure above the theodolite's sightline.

c)Calculate the total height of the ancient structure from the ground to its peak.

Sub-topic 5.2: Graphs of sinθ, cosθ, tanθ

Scenario 29

An electrical engineer at Umeme,Uganda's main electricity distributor, is analyzing the voltage in a national grid circuit. The voltage fluctuates sinusoidally with time according to the function $V(t) = 240\sin(100\pi t)$ volts, where t is in seconds. To ensure the grid's stability and protect connected appliances, the engineer must visualize this sine wave. She needs to understand key features of the graph: its amplitude, which indicates the peak voltage; its period, which determines the frequency of the alternating current; and its phase, which is crucial for synchronizing multiple power sources. Understanding this graph is fundamental to diagnosing power quality issues, such as sags or surges, that can affect industries and homes across the country.

Task:

a)State the amplitude and period of the voltage function $V(t)$.

b)Calculate the frequency of the alternating current in Hertz.

c)Determine the voltage at time $t = 0.01$ seconds.

Sub-topic 5.3: Compound Angle Formulae

Scenario 30

A pilot flying a small charter plane from Kajjansi Airfield to Kidepo National Park needs to calculate the most fuel-efficient heading.The plane needs to fly due north, but a strong wind is blowing from the direction N30°E at 80 km/h. The plane's airspeed (speed relative to the air) is 300 km/h. To find the correct compass heading and the resulting ground speed, the pilot must resolve the velocities into components and use the sine and cosine rules, which are derived from compound angle concepts. The ground speed is the vector sum of the airspeed and wind velocity. An error in this calculation could cause the plane to drift significantly off course, wasting fuel and potentially leading to a dangerous situation over a remote national park.

Task:

a)Represent this situation with a vector diagram.

b)By resolving vectors, show that the eastward component of the plane's velocity must cancel the eastward component of the wind.

c)Calculate the heading (angle from north) the pilot must fly and the resulting ground speed.

Sub-topic 5.4: Compound Angle Formulae and Derived Identities

Scenario 31

A team of telecommunications engineers is designing a new cellular tower on a hill overlooking Kampala.The signal strength between the new tower and an existing tower is modeled by a complex waveform that depends on the precise calculation of signals arriving at different phases. The engineers encounter an expression for the combined signal: $\sin(45^\circ + 30^\circ)$. To simplify their analysis and input this into their signal simulation software, they must expand this using the compound angle formula. The accuracy of this expansion is critical, as it affects the predicted coverage area of the new tower. An error could lead to gaps in network coverage for thousands of users or an overestimation of the service area, resulting in costly post-installation adjustments. Using the exact values derived from the compound angle formulae, rather than decimal approximations, ensures the mathematical model of the signal propagation remains precise.

Task:

a)Use the compound angle formula for sine to expand $\sin(75^\circ)$.

b)Using known exact values for $\sin(45^\circ)$, $\cos(45^\circ)$, $\sin(30^\circ)$, and $\cos(30^\circ)$, calculate the exact value of $\sin(75^\circ)$.

c)Hence, prove that $\sin(75^\circ) + \sin(15^\circ) = \sqrt{\frac{3}{4}}$.

Scenario 32

In an advanced physics experiment at Makerere University,students are studying the interference pattern of two coherent light waves. The intensity I of the resulting wave at a point is given by the equation $I = 4I_0 \cos^2(\frac{\Delta\theta}{2})$, where $\Delta\theta$ is the phase difference. To analyze how the intensity changes with phase difference, they need to express $\cos^2(\frac{\Delta\theta}{2})$ in a simpler form. This requires the use of the double-angle identity derived from compound angle formulae, specifically
$\cos(2A) = 2\cos^2(A) - 1$. Understanding this identity allows them to rewrite the intensity formula as $I = 2I_0(1 + \cos(\Delta\theta))$, which is much easier to graph and interpret. This interpretation is fundamental to understanding phenomena like diffraction gratings and thin-film interference, which have applications in laser technology and optical sensors.

Task:

a)Starting from the double-angle identity $\cos(2A) = 2\cos^2(A) - 1$, show that $\cos^2(A) = \frac{1+\cos 2A}{2}$.

b)Hence, express the intensity $I = 4I_0 \cos^2(\frac{\Delta\theta}{2})$ in the form $I = kI_0(1 + \cos(\Delta\theta))$, stating the value of k .

Scenario 33

A structural engineer is modeling the vibration of a suspension bridge cable during a storm.The vertical displacement, y , of the cable is found to be a combination of two harmonic motions described by $y = 3\sin(x) + 4\cos(x)$, where x is related to time and position. To analyze the amplitude of the total vibration—a critical factor for assessing structural fatigue—the engineer must combine these two trigonometric terms into a single sine function. This involves using the identity $R\sin(x + \alpha)$, which is derived from the compound angle formula. Finding the amplitude R and the phase shift \alpha is essential for determining the maximum stress on the cable and ensuring the bridge's design can withstand extreme weather conditions, a vital safety consideration for infrastructure in Uganda.

Task:

a)Express $3\sin(x) + 4\cos(x)$ in the form $R\sin(x + \alpha)$, where $R > 0$ and $0° < \alpha < 90°$.

b)Calculate the amplitude R of the resulting vibration.

c)Calculate the phase angle α to the nearest degree.

Sub-topic 5.5: Solution of Triangles

Scenario 34

A team of geographers from Makerere University is conducting a survey to map a remote,triangular-shaped section of the Rwenzori Mountains. They need to calculate the exact area of this region for a conservation study. Due to the rugged terrain, they can only directly measure two sides and the angle between them. The sides measured are 8 km and 11 km, with an included angle of 60°. Using the formula for the area of a triangle, Area= $\frac{1}{2}$absin C, they can determine the precise area without having to traverse the dangerous third side. This calculation is crucial for accurately reporting the size of the conservation zone to the Uganda Wildlife Authority and for planning future research expeditions in the area.

Task:

a)State the formula for the area of a triangle given two sides and the included angle.

b)Calculate the area of the triangular region using the given measurements.

c)If the included angle were 30° instead of 60°, how would the area change? Calculate the new area.

Scenario 35

A disaster response team from the Office of the Prime Minister needs to airlift supplies to a village cut off by floods.The village is located between two relief camps. From Camp A, the village is 15 km away on a bearing of 050°. From Camp B, the village is 12 km away on a bearing of 110°. The team at Camp A needs to know the direct distance between Camp A and Camp B to coordinate the logistics and share fuel resources. Using the cosine rule, they can calculate this distance accurately, ensuring efficient coordination of the emergency response and avoiding any delays in delivering critical supplies like food, medicine, and tents to the affected population.

Task:

a)Sketch a diagram representing the positions of Camp A, Camp B, and the village, labeling all known sides and angles.

b)Calculate the angle at the village between the lines to Camp A and Camp B.

c)Apply the cosine rule to find the direct distance between Camp A and Camp B.

Scenario 36

Engineers are assessing the stability of a historic monument,the Kasubi Tombs, which has a triangular facade. They need to find all the angles of this triangular structure to analyze stress distribution. They

measure the three sides of the triangle to be 25 meters, 32 meters, and 40 meters. However, they cannot safely measure the angles directly with traditional tools. By applying the cosine rule, they can calculate each angle accurately. This information is vital for creating a precise digital model of the structure, which will be used to plan restoration work and ensure the long-term preservation of this UNESCO World Heritage Site for future generations.

Task:

a)State the cosine rule formula used to find an angle when three sides are known.

b)Calculate the largest angle in the triangular facade.

c)Using the fact that angles in a triangle sum to 180°, find the remaining two angles.

Topic 6: DESCRIPTIVE STATISTICS

Sub-topic 6.1: Measures of Dispersion

Scenario 37

The Ministry of Health is analyzing the consistency of medication delivery times from a central warehouse to 10 regional hospitals.Timely delivery is critical for patient care. The delivery times (in hours) for the last shipment were: 24, 26, 28, 22, 35, 20, 27, 25, 29, 24. The Minister is concerned about the reliability of the service. While the average delivery time might seem acceptable, a high dispersion would indicate unpredictable service, which is dangerous for hospitals relying on essential drugs. The logistics team must calculate the range, variance, and standard deviation of these times to identify if the delivery system needs a complete overhaul or just minor adjustments. A high standard deviation would confirm that some hospitals face significant delays, risking drug stock-outs and impacting healthcare quality across the country.

Task:

a)Calculate the range of the delivery times.

b)Calculate the standard deviation of the delivery times.

c)If the standard deviation is high, what does this indicate about the reliability of the delivery service?

Scenario 38

The Uganda National Examinations Board(UNEB) is reviewing the performance of two secondary schools in the 2024 Advanced Level Mathematics examinations. School A has a mean grade of B, and School B also has a mean grade of B. However, UNEB suspects that School B's performance is highly inconsistent, with many students failing and a few scoring very highly, possibly due to a focus on only the top students. To investigate this fairly, they analyze the scores. School A's scores: 70, 75, 72, 68, 75. School B's scores: 90, 40, 85, 35, 80. Calculating the variance and standard deviation for both sets will reveal the consistency of teaching and learning. This analysis helps UNEB identify schools that need systemic support rather than just those with low average grades.

Task:

a)Calculate the mean score for both School A and School B.

b)Calculate the variance for School B's scores.

c)Based on your calculations, which school has more consistent performance? Explain your answer.

Scenario 39

An agronomist at the National Agricultural Research Organisation(NARO) is testing two new varieties of maize (Variety A and Variety B) for drought resistance. After a controlled drought period, the yield (in kg per hectare) from several test plots is recorded. The mean yield for both varieties is similar, around 1500 kg/ha. However, the agronomist needs to recommend the variety that provides a more reliable and consistent yield to farmers, as stability is crucial for food security and income. A variety with a lower standard deviation is less risky for a subsistence farmer. The yield data for Variety A is tightly clustered,

while for Variety B it is spread out. Calculating the interquartile range (IQR) and standard deviation will provide a clear picture of consistency, guiding the final recommendation to the Ministry of Agriculture.

Task:

a)Explain why the mean yield alone is not sufficient for making a recommendation to farmers.
b)Describe what a larger standard deviation indicates about the yield of a maize variety.
c)If you were to advise a subsistence farmer, which statistical measure (mean, median, standard deviation) would be most critical for their decision? Justify your answer.

Sub-topic 6.2: Measures of Relative Positions

Scenario 40

The Uganda Ministry of Public Service is conducting a nationwide salary review for civil servants. They have collected the annual salary data for all Grade 5 officers, which follows a normal distribution with a mean of UGX 18,000,000 and a standard deviation of UGX 2,500,000. A teachers' union is advocating for a salary increase, arguing that their members are falling behind. To make a data-driven case, they need to determine the relative standing of a teacher earning UGX 21,000,000. By calculating the z-score, they can express this salary in terms of standard deviations from the mean, showing whether it is average, above average, or exceptional compared to their peers. This objective measure is more powerful in negotiations than simply stating the salary figure, as it contextualizes the income within the entire distribution.

Task:

a)Calculate the z-score for a Grade 5 officer with an annual salary of UGX 21,000,000.
b)Interpret what this z-score means in the context of the salary distribution.
c)If another officer has a z-score of -1.2, what is their approximate annual salary?

Scenario 41

A large university in Uganda,such as Makerere, uses standardized test scores for postgraduate admissions. The scores for the Graduate Entrance Exam (GEE) are normally distributed with a mean of 60 and a standard deviation of 8. The admissions committee needs to set a fair cutoff score to select the top 15% of applicants for a competitive scholarship program. They cannot simply use a raw score; they must find the score that corresponds to the 85th percentile (since the top 15% means the score is higher than 85% of applicants). Using percentile ranks and z-tables, they can determine the exact cutoff score, ensuring a transparent and statistically sound selection process for awarding these valuable scholarships.

Task:

a)Explain what the 85th percentile represents in this context.
b)Find the z-score that corresponds to the 85th percentile (you may use a z-table or the known approximation).
c)Calculate the minimum GEE score required to be in the top 15% of applicants.

Scenario 42

A national hospital is monitoring the recovery times for a specific surgical procedure.The recovery time is normally distributed with a mean of 14 days and a standard deviation of 3 days. Hospital management wants to identify patients with exceptionally slow recovery times who might need additional medical support or have underlying complications. They decide to flag any patient whose recovery time is above the 95th percentile for a special review by a senior medical team. To implement this protocol, they need to calculate the recovery time that corresponds to the 95th percentile. This use of percentiles helps in allocating limited medical resources efficiently and proactively managing patient care.

Task:

a)What is the z-score corresponding to the 95th percentile?
b)Calculate the recovery time (in days) that corresponds to the 95th percentile.

c)If a patient has a recovery time with a z-score of -2, what is their recovery time, and how would you interpret this?

Topic 7: SCATTER DIAGRAMS AND CORRELATIONS
Sub-topic 7.1: Scatter Diagram
Scenario 43
The Kampala City Council Authority (KCCA) is investigating the relationship between daily hours of sunshine and the sales of bottled water in the city center. They suspect that hotter, sunnier days lead to higher water sales. A data analyst collects data over 15 days, recording the average daily sunshine hours and the number of cases of water sold by a major vendor. Before calculating any complex statistics, the analyst must create a scatter diagram. This visual tool will provide an immediate, intuitive understanding of the potential relationship. Plotting sunshine hours on the x-axis and water sales on the y-axis will reveal if the points generally form an upward trend, a downward trend, or no pattern at all. This first step is crucial for deciding whether to proceed with a formal correlation analysis, which could influence how vendors manage their inventory and staffing based on weather forecasts.
Task:
a)State which variable should be the independent variable (plotted on the x-axis) and which should be the dependent variable (plotted on the y-axis).
b)Describe what the analyst would expect to see on the scatter diagram if there is a positive correlation between sunshine hours and water sales.
c)What might a scatter diagram that shows no correlation look like?

Sub-topic 7.2: Correlation
Scenario 44
The management of a large matatu(public transport) company in Uganda wants to understand the factors affecting their daily fuel costs. They hypothesize that the number of kilometers driven by their fleet is a major driver of cost. After collecting data for a month, they plot a scatter diagram which shows a strong linear pattern. To quantify the strength and direction of this relationship, they calculate the Pearson's product-moment correlation coefficient (r). This numerical value, which will fall between -1 and +1, will provide an objective measure. A value close to +1 would confirm a strong positive correlation, allowing management to create more accurate budgets and identify routes that are less fuel-efficient.
Understanding this correlation is a key step towards implementing a cost-saving strategy for the entire company.
Task:
a)State the possible range of values for the Pearson's correlation coefficient, r.
b)If the calculated value of r is 0.88, how would you interpret the strength and direction of the relationship?
c)Why is it important to obtain a scatter diagram before calculating the correlation coefficient?
Scenario 45
A real estate agency in Entebbe is building a model to advise clients on property pricing. They want to investigate the claim that there is a relationship between the size of a house (in square meters) and its selling price. After gathering data from recent sales, they create a scatter diagram. The diagram suggests a relationship, but it is not perfectly linear. To confirm the strength of this monotonic relationship (whether one variable tends to increase as the other increases, but not necessarily at a constant rate), they decide to calculate Spearman's rank correlation coefficient. This method is more appropriate than Pearson's if the relationship is non-linear or the data is based on ranks. The result will help the agency set more realistic and data-driven asking prices for their clients' properties.

Task:
a)Differentiate between Pearson's and Spearman's correlation coefficients.
b)When is it more appropriate to use Spearman's rank correlation coefficient?
c)If Spearman's coefficient is calculated to be -0.95, what does this indicate about the relationship between house size and price?

Topic 8: DYNAMICS 1
Sub-topic 8.1: Resultant and Components of Forces
Scenario 46
A team of engineers is designing a new cable-stayed footbridge over a stream in a Kampala park.A key cable is attached to a central pylon and exerts a force of 1000 N at an angle of 30° to the horizontal. To ensure the bridge's stability, the engineers must calculate the horizontal and vertical components of this force. The horizontal component will affect the lateral stability of the pylon, while the vertical component supports the weight of the bridge deck. Accurate calculation of these components is crucial for selecting appropriately strong materials for the pylon and the deck supports, ensuring the safety of hundreds of daily pedestrians.
Task:
a)Calculate the horizontal component of the force in the cable.
b)Calculate the vertical component of the force in the cable.
c)If the angle were increased to 45°, what would happen to the magnitude of the horizontal component? Explain your reasoning.
Scenario 47
During the setup for the annual Kampala City Festival,workers need to position a heavy stage lighting rig weighing 1500 N. Two ropes are attached to the rig. One rope is pulled with a force of 800 N due East. The other rope is pulled with a force of 600 N due North. The site manager needs to know the magnitude and direction of the resultant force acting on the rig to ensure the ropes and anchoring points are strong enough to handle the total force without snapping, which could cause serious injury and damage to the equipment.
Task:
a)Sketch a vector diagram representing the two forces.
b)Calculate the magnitude of the resultant force.
c)Calculate the direction of the resultant force as a bearing.
Scenario 48
A boat is being pulled by two tugboats in Port Bell on Lake Victoria.Tugboat A exerts a force of 4000 N in a direction N30°E. Tugboat B exerts a force of 3000 N in a direction N60°E. The harbour master needs to find the resultant force on the boat to predict its path and avoid collisions with other vessels in the busy port. This requires resolving both forces into their North and East components before summing them to find the overall resultant force and its direction.
Task:
a)Resolve the 4000 N force into its North and East components.
b)Resolve the 3000 N force into its North and East components.
c)Hence, find the magnitude and direction (as a bearing) of the resultant force acting on the boat.

Sub-topic 8.2: Friction
Scenario 49
A factory owner in Namanve Industrial Park is designing a conveyor belt system to move heavy crates.A crate weighing 200 N is placed on the belt, which is inclined at an angle of 15° to the horizontal. The

coefficient of friction between the crate and the belt is 0.4. The engineer needs to determine whether the crate will slide down the belt when the conveyor is stopped for loading, or if friction is sufficient to hold it in place. This analysis is critical for designing a safe system that prevents crates from sliding back and causing accidents or damage to goods.

Task:

a)Calculate the component of the crate's weight acting parallel to the inclined belt.

b)Calculate the maximum frictional force available to prevent sliding.

c)Based on your calculations, state whether the crate will remain at rest or slide down the incline.

Scenario 50

A driver is traveling along a wet road in Jinja when they need to stop suddenly.The car has a mass of 1200 kg and the coefficient of friction between the tires and the wet road is 0.3. The driver needs to know the minimum stopping distance when braking from 60 kmh^{-1}. Understanding the role of friction in deceleration is essential for promoting safe driving speeds, especially in adverse weather conditions, and is a key part of driver education programs run by the Uganda Police Force.

Task:

a)Calculate the maximum frictional force that can act to decelerate the car.

b)Calculate the deceleration of the car due to this frictional force.

c)Using equations of motion, calculate the minimum stopping distance from 60 km/h.

Scenario 51

A construction worker in Entebbe is pushing a 50 kg toolbox across a concrete floor. The worker applies a force of 200 N at an angle of 25° downwards from the horizontal. The coefficient of friction between the toolbox and the floor is 0.5. The foreman needs to know if this force is sufficient to move the toolbox, or if the worker needs assistance. This ensures efficient workflow and prevents worker injury from straining to move a stuck object.

Task:

a)Calculate the normal reaction force between the toolbox and the floor. (Remember the applied force has a downward component).

b)Calculate the maximum static frictional force.

c)Calculate the horizontal component of the applied force and determine if the toolbox will move.

Sub-topic 8.3: Connected Particles

Scenario 52

In a warehouse in Kampala's Industrial Park,a worker needs to lift a heavy crate of mass 80 kg using a rope thrown over a fixed pulley. The worker, who has a mass of 70 kg, pulls downwards on the other end of the rope. The system is modeled as two particles connected by a light, inextensible rope over a smooth pulley. The warehouse manager needs to calculate the acceleration of the crate and the tension in the rope to ensure that the rope's breaking strain is not exceeded and that the crate can be lifted safely without the worker losing control. This analysis is crucial for workplace safety and for selecting the appropriate equipment for the job.

Task:

a)Sketch the system and label the forces acting on the crate and the worker.

b)Apply Newton's Second Law to both the crate and the worker to form two simultaneous equations.

c)Solve the equations to find the acceleration of the system and the tension in the rope.

Scenario 53

A farmer in Masaka is using a pulley system to draw water from a well.A bucket of water with a total mass of 15 kg is connected by a rope to a counterweight of mass 10 kg. The rope passes over a fixed, smooth pulley. When released, the system begins to move. The farmer needs to know how long it will

take for the bucket to be lifted 8 meters from rest. This information helps the farmer estimate the time needed to fetch water, which is crucial for daily planning, especially during the dry season when water is scarce and multiple trips are necessary.

Task:

a)Calculate the acceleration of the system when it is released.

b)Using the equations of motion, calculate the time taken for the bucket to rise 8 meters from rest.

c)What would be the effect on the acceleration if the pulley was not smooth? Explain.

Scenario 54

During a physics demonstration at a school in Gulu,a teacher sets up a system with two masses on a smooth, horizontal table. Mass A (4 kg) is connected by a light, inextensible string to Mass B (6 kg), which hangs vertically over the edge of the table. The string passes over a smooth pulley at the table's edge. The teacher releases the system from rest and asks the students to predict the motion. The students must calculate the acceleration of the system and the tension in the string to understand the principles of connected particles and Newton's Laws of Motion, which are fundamental concepts in mechanics.

Task:

a)Draw a diagram showing all the forces acting on both masses.

b)Write down the equation of motion for each mass.

c)Solve the equations to find the acceleration of the system and the tension in the string.

Topic 9: PROBABILITY THEORY

Sub-topic 9.1: Probability Theorems

Scenario 55

A mobile money agent in Kampala has two separate lines for customers:one for deposits and one for withdrawals. The probability that a customer arrives for a deposit in any given minute is 0.6, and the probability that a customer arrives for a withdrawal is 0.4. These events are independent. The agent needs to calculate the probability that in a given minute, at least one customer arrives (either for deposit or withdrawal) to determine whether to keep both lines open during slow periods or consolidate them to reduce operational costs while maintaining service quality.

Task:

a)Calculate the probability that at least one customer arrives in a given minute.

b)What is the probability that both types of customers arrive in the same minute?

c)If the events were mutually exclusive, how would your calculation in part (a) change?

Scenario 56

A hospital in Jinja is studying patient flow through its outpatient department.The probability that a patient needs to see a doctor is 0.7, and the probability that a patient needs laboratory tests is 0.5. The probability that a patient needs both is 0.3. The hospital administrator wants to know the probability that a randomly selected patient needs either a doctor or laboratory tests to better allocate staff resources and reduce patient waiting times, which is a key performance indicator for the hospital's quality of care.

Task:

a)Represent this situation using a Venn diagram.

b)Calculate the probability that a patient needs either a doctor or laboratory tests.

c)Calculate the probability that a patient needs only laboratory tests.

Scenario 57

A quality control inspector at a beverage factory in Entebbe is testing bottles from two production lines.Line A produces 60% of the bottles, with a defect rate of 2%. Line B produces 40% of the bottles, with a defect rate of 4%. The inspector randomly selects a defective bottle. The production manager needs to know the probability that this defective bottle came from Line B to identify which production line

requires maintenance and quality improvement measures, potentially saving the company significant costs in wasted materials and reputation damage.

Task:

a)Draw a tree diagram to represent this situation.

b)Calculate the overall probability of selecting a defective bottle.

c)Use Bayes' Theorem to find the probability that a defective bottle came from Line B.

Sub-topic 9.2: Applications of Probability in Real Life

Scenario 58

An insurance company in Kampala is developing a new life insurance product.Based on national health statistics, the probability that a 40-year-old person lives to age 70 is 0.85. The company needs to calculate the probability that out of 5 randomly selected 40-year-old policyholders, at least 4 will live to age 70. This calculation is crucial for pricing the insurance product correctly and ensuring the company remains financially solvent while offering competitive rates to customers in Uganda's growing insurance market.

Task:

a)State whether this is a binomial probability situation and justify your answer.

b)Calculate the probability that exactly 4 out of 5 policyholders live to age 70.

c)Calculate the probability that at least 4 out of 5 policyholders live to age 70.

Scenario 59

A public health researcher is studying the effectiveness of a new malaria prevention program in a rural Ugandan district.Before the program, the prevalence of malaria in children under 5 was 30%. After implementing the program, the researcher randomly selects 20 children and finds that 4 have malaria. The researcher needs to determine the probability of observing 4 or fewer cases if the prevalence rate is still 30% to assess whether the program has been statistically significantly effective, which could influence future public health policy and funding decisions.

Task:

a)Calculate the probability of finding exactly 4 malaria cases in the sample of 20 children.

b)Calculate the probability of finding 4 or fewer malaria cases in the sample.

c)Based on your result, what might you conclude about the effectiveness of the program?

Scenario 60

A telecommunications company is planning the capacity for its new data center in Wakiso.The company knows that on average, each customer connects to the service for 2 hours per day. The company needs to calculate the probability that more than 1000 customers are simultaneously connected during peak hours to ensure the system can handle the load without crashing. This probability analysis helps determine the optimal server capacity, balancing infrastructure costs against the risk of service interruption in Uganda's rapidly expanding digital economy.

Task:

a)What probability distribution would be appropriate for modeling this situation?

b)State the parameter(s) of this distribution for this scenario.

c)Explain how the company would use this probability distribution in its capacity planning.

Topic 10: DIFFERENTIATION 1

Sub-topic 10.1: Gradient of a Curve

Scenario 61

An environmental scientist is studying the pollution level in Lake Victoria.The concentration of a pollutant, C in mg/liter, at a point x meters from a discharge point is given by the function $C(x) = x^3 - 6x^2 + 9x + 2$. The scientist needs to find the point where the pollution concentration is increasing most rapidly to prioritize cleanup efforts. This requires finding the gradient function (derivative) of $C(x)$ and then analyzing its behavior. Identifying this critical point will help environmental agencies in Uganda and Tanzania allocate limited resources effectively to protect the lake's ecosystem and the livelihoods of millions who depend on it.

Task:

a)Find the derivative (gradient function) of $C(x) = x^3 - 6x^2 + 9x + 2$.

b)Calculate the gradient of the curve at $x = 1$ meter and interpret what this value means.

c)Find the coordinates of the point where the gradient of the concentration curve is zero.

Scenario 62

A sports physiologist at the Uganda Olympic Committee is analyzing the performance of a 400m runner.The distance, s meters, covered by the runner after t seconds is modeled by the function $s(t) = 0.2t^3 + 4t^2 + 5t$. The coach wants to know the runner's instantaneous velocity at exactly $t = 5$ seconds to assess their mid-race performance and compare it with their starting and finishing speeds. The instantaneous velocity is given by the derivative of the displacement function with respect to time. This analysis helps in tailoring training programs to improve an athlete's performance in specific phases of a race.

Task:

a)State what the derivative represents in this context.

b)Find the function for the runner's instantaneous velocity.

c)Calculate the runner's velocity at $t = 5$ seconds.

Scenario 63

A mechanical engineer is testing the efficiency of a new engine design.The efficiency, E , as a function of the engine speed, R in revolutions per minute (RPM), is given by $E(R) = -0.001R^3 + 0.15R^2 + 20R$. The engineer needs to find the engine speed at which the efficiency is maximized. This requires finding the derivative of the efficiency function and solving for where the gradient is zero. Determining this optimal RPM is crucial for programming the engine's control unit to operate at its most efficient point, saving fuel and reducing emissions for vehicles in Uganda's transport sector.

Task:

a)Find the derivative $E'(R)$.

b)Set $E'(R) = 0$ to find the critical points.

c)Which of these critical points represents a realistic operating RPM for a maximum? Justify your answer.

Sub-topic 10.2: Gradient Functions

Scenario 64

An urban planner is designing a new road over a hilly terrain in Kabale District.The elevation of the road surface, y meters, at a horizontal distance x meters from the start, is modeled by the function $y = 0.01x^3 - 0.15x^2 + 2x$. The planner needs to ensure that the road's gradient never exceeds 8% for safety reasons. The gradient of the road at any point is given by the derivative $\frac{dy}{dx}$. By analyzing this gradient function, the planner can identify the steepest sections of the road and modify the design if necessary before construction begins.

Task:

a)Find the gradient function $\frac{dy}{dx}$ for the road's elevation.

b)Calculate the gradient at $x = 50$ meters.

c)Find the maximum gradient of the road and the point where it occurs.

Scenario 65

An economist at the Bank of Uganda is modeling the country's GDP growth.The GDP, G in trillion UGX, is projected to follow the model $G(t) = 120 + 2t + 0.1t^2 - 0.005t^3$, where t is the number of years from now. The economist is interested in the rate of economic growth, which is the derivative of the GDP function. Analyzing this gradient function will help predict when the growth rate will start to slow down, informing long-term fiscal and monetary policy decisions for the nation's economic stability.

Task:

a)Find the gradient function $G'(t)$, which represents the GDP growth rate.

b)Calculate the projected growth rate 5 years from now.

c)Determine the year when the GDP growth rate is expected to be at its maximum.

Scenario 66

A civil engineer is inspecting a slightly bent metal beam in a building structure in Kampala.The deflection of the beam from its original straight position is given by the function $y = 0.0001x(20 - x)^2$, where x is the distance from one end. To assess the severity of the bend, the engineer needs to find the points where the beam is steepest (maximum gradient) and the points where it is flat (zero gradient). This analysis is critical for deciding whether the beam needs reinforcement or replacement to ensure the structural integrity of the building.

Task:

a)Expand the function for y and then find its derivative $\frac{dy}{dx}$.

b)Find the values of x where the gradient of the beam is zero.

c)Evaluate the gradient at the midpoint, $x = 10$.

Sub-topic 10.3: Composite Functions

Scenario 67

A meteorologist at the Uganda National Meteorological Authority is modeling how temperature changes with altitude in the Rwenzori Mountains.The temperature T in °C depends on the atmospheric pressure P in kPa, given by $T(P) = 20 - 5P$. Furthermore, the pressure P decreases with altitude h in meters according to $P(h) = 100 - 0.01h$. The meteorologist needs to find a single function that directly gives the temperature as a function of altitude for hikers and aviation services. This requires forming the composite function $T(P(h))$, which will allow for direct prediction of temperature at any given altitude, crucial for flight planning and mountaineering safety.

Task:

a)Form the composite function $T(h)$ by substituting $P(h)$ into $T(P)$.

b)Simplify the composite function $T(h)$.

c)Using the composite function, calculate the temperature at an altitude of 1500 meters.

Scenario 68

An environmental scientist is studying the spread of an invasive plant species in Lake Victoria.The area covered by the plant, A in square kilometers, depends on the nutrient concentration N in the water, given by $A(N) = 2N^2$. The nutrient concentration N itself increases over time t in weeks due to agricultural runoff, following $N(t) = 5 + 0.5t$. The scientist wants to predict the area covered by the plant after 10 weeks to assess the urgency of intervention measures. This requires differentiating the composite function $A(N(t))$ with respect to time to find the rate at which the plant is spreading.

Task:

a)Form the composite function $A(t)$ that gives area directly as a function of time.

b)Use the chain rule to find the derivative $\frac{dA}{dt}$.

c)Calculate the rate at which the plant is spreading after 10 weeks.

Scenario 69

An automotive engineer at Kiira Motors is testing the fuel efficiency of a new electric vehicle prototype.The vehicle's range R in kilometers is a function of its battery charge level C in kWh, given by $R(C) = 8C - 0.1C^2$. During a test drive, the charge level decreases over time t in hours according to $C(t) = 60 - 10t$. The engineer needs to find how quickly the vehicle's predicted range is decreasing after 2 hours of driving to validate the battery management system's accuracy. This requires applying the chain rule to the composite function $R(C(t))$.

Task:

a)State the chain rule for differentiation.

b)Use the chain rule to find an expression for $\frac{dR}{dt}$.

c)Calculate the rate of change of the vehicle's range with respect to time after 2 hours.

Sub-topic 10.4: Implicit Functions

Scenario 70

A civil engineer is designing a curved arch for a bridge in Jinja.The shape of the arch is defined by the equation $x^2 + 4y^2 = 100$, where x and y are in meters. To determine the steepness of the arch at specific points for structural analysis and material stress calculations, the engineer needs to find the gradient $\frac{dy}{dx}$ without explicitly solving for y. Using implicit differentiation is the most efficient method, as solving for y would result in two functions (top and bottom halves of the arch).

Task:

a)Differentiate both sides of the equation $x^2 + 4y^2 = 100$ with respect to x.

b)Solve the resulting equation for $\frac{dy}{dx}$.

c)Find the gradient of the arch at the point where $x = 6$ meters and $y > 0$.

Scenario 71

An economist at Makerere University is analyzing the relationship between a country's inflation rate x and its unemployment rate y, modeled by the equation $xy + x + y = 10$. This relationship is known as a Phillips curve variant. The economist wants to find the rate at which unemployment changes with respect to inflation ($\frac{dy}{dx}$) when the inflation rate is 2%. This analysis helps in understanding the trade-off between these two critical economic indicators and in formulating national economic policy.

Task:

a)Differentiate the equation $xy + x + y = 10$ implicitly with respect to x.

b)Solve for $\frac{dy}{dx}$ in terms of x and y.

c)Given that when $x = 2$, $y = 2$, calculate the value of $\frac{dy}{dx}$.

Scenario 72

A physicist at the International University of East Africa is studying the path of a charged particle in a magnetic field.The particle's path is described by the equation $\sin(xy) = x + y$. To analyze the particle's velocity components, the physicist needs to find the relationship between $\frac{dy}{dx}$ and the variables x and y

at any point on its trajectory. This requires implicit differentiation of the transcendental equation, which cannot be easily solved for y.

Task:

a)Differentiate both sides of $\sin(xy) = x + y$ with respect to x.

b)Apply the chain rule carefully to differentiate $\sin(xy)$.

c)Solve the resulting equation for $\frac{dy}{dx}$.

Sub-topic 10.5: Products and Quotients of Functions

Scenario 73

A pharmaceutical company in Kampala is modeling the concentration of a new malaria drug in a patient's bloodstream over time.The concentration $C(t)$ in mg/L is given by the function $C(t) = 5t\,e^{-0.2t}$, where t is time in hours. This function is a product of a polynomial term $(5t)$ and an exponential decay term $(e^{-0.2t})$. Medical researchers need to find the rate of change of the drug concentration, $C'(t)$, to determine the time when the concentration is at its peak, which is crucial for establishing the optimal dosage interval for maximum therapeutic effect.

Task:

a)Identify the two functions $u(t)$ and $v(t)$ whose product gives $C(t)$.

b)Apply the product rule to find the derivative $C'(t)$.

c)Set $C'(t) = 0$ to find the time t when the drug concentration is at its maximum.

Scenario 74

An environmental engineer is studying the rate of cooling of a geothermal spring in Fort Portal after being disturbed.The temperature T in °C at time t hours is modeled by $T(t) = 80/t^2 + 4$. This function is a quotient, with a constant numerator and a polynomial denominator. The engineer needs to find how quickly the temperature is decreasing at $t = 2$ hours to understand the recovery rate of the spring's ecosystem. This requires applying the quotient rule for differentiation.

Task:

a)State the quotient rule for differentiation.

b)Use the quotient rule to find $T'(t)$.

c)Calculate $T'(2)$ and interpret what this value means in the context of the problem.

Scenario 75

An economist at the Bank of Uganda is analyzing the country's debt-to-GDP ratio.The ratio $R(t)$ is modeled as $R(t) = 0.5t^2/(1 + 0.1t)$, where t is the number of years from the present. This is a quotient of two functions of t. To forecast future fiscal stability, the economist needs to find the rate of change of this ratio, $R'(t)$. This will help predict whether the debt burden is growing at a sustainable rate or if policy interventions are needed.

Task:

a)Identify the functions $u(t)$ and $v(t)$ for the numerator and denominator.

b)Apply the quotient rule to find an expression for $R'(t)$.

c)Calculate $R'(5)$ and state whether the debt-to-GDP ratio is increasing or decreasing after 5 years.

Sub-topic 10.6: Applications of Differentiation 1

Scenario 76

A local artisan in Mpigi makes and sells wooden sculptures.Her profit P in Ugandan Shillings from selling x sculptures is given by $P(x) = -2x^3 + 30x^2 - 96x$. To maximize her earnings, she needs to determine the number of sculptures she should produce and sell each month. This involves finding the turning points of the profit function by setting its derivative to zero and then using the second derivative to distinguish between maximum and minimum profit points.

Task:

a)Find the first derivative $P'(x)$.

b)Find the critical points by solving $P'(x) = 0$.

c)Use the second derivative test to determine which critical point gives a maximum profit.

Scenario 77

A water tank at a school in a rural area is being filled.The volume V of water in the tank in liters at time t minutes is given by $V(t) = 0.1t^3 - 2t^2 + 12t$ for $0 \leq t \leq 10$. The school custodian needs to find the time when the water is flowing into the tank at the fastest rate. The rate of water flow is the derivative of the volume, $V'(t)$. The maximum flow rate corresponds to the maximum of this derivative function.

Task:

a)Find the flow rate function $V'(t)$.

b)Find the critical points of the flow rate function $V'(t)$.

c)Determine the time t during the filling process when the flow rate is greatest.

Scenario 78

A drone is being tested for delivering medical supplies.Its height h in meters at time t seconds is given by $h(t) = t^3 - 9t^2 + 24t$. The engineering team needs to analyze the drone's vertical motion, specifically finding when it is ascending and when it is descending. They also need to find its velocity and acceleration at specific times to ensure safe and stable flight. The velocity is the first derivative of height, and acceleration is the second derivative.

Task:

a)Find the velocity function $v(t) = h'(t)$.

b)Find the acceleration function $a(t) = h''(t)$.

c)Determine the time intervals during the first 6 seconds when the drone is ascending (i.e., $v(t) > 0$).

Topic 11: INTEGRATION 1

Sub-topic 11.1: Indefinite Integral

Scenario 79

An environmental scientist is studying the rate of absorption of a new organic fertilizer in the soil.The rate of absorption, $R(t)$ in grams per day, is given by the function $R(t) = 6t^2 - 4t + 5$, where t is the time in days. To determine the total amount of fertilizer absorbed by the soil after a certain period, the scientist needs to find the integral of this rate function. This indefinite integral will provide a general formula for the total absorption, which is crucial for calculating the optimal quantity of fertilizer to use in Ugandan agricultural projects to maximize crop yield while minimizing cost and environmental impact.

Task:

a)Find the indefinite integral $\int 6t^2 - 4t + 5 \, dt$.

b)Explain what the constant of integration represents in this context.

c)If it is known that 10 grams were absorbed by day 1, find the particular solution for the total absorption.

Scenario 80

A mechanical engineer at a manufacturing plant in Namanve is analyzing the rate of production of a machine.The machine's production rate, $P'(t)$ in units per hour, is modeled by $P'(t) = 3e^{0.1t} + 4$. The production manager needs a function that predicts the total number of units produced after t hours to plan inventory and shipments. Finding the indefinite integral of the production rate function will give the general form of the total production function, which is essential for efficient supply chain management in Uganda's growing manufacturing sector.

Task:

a)Find the indefinite integral $\int (3e^{0.1t} + 4)dt$.

b)If the machine had produced 15 units by the start of the measurement (t=0), determine the constant of integration.

c)Write the specific total production function $P(t)$.

Scenario 81

An economist at Makerere University is modeling the marginal cost of producing a new solar lamp.The marginal cost function is $C'(x) = 0.04x + 20$, where x is the number of units produced. To find the total cost function, which is essential for pricing and profitability analysis, the economist needs to integrate the marginal cost function. This will help Ugandan solar companies determine the most cost-effective production levels to make clean energy affordable.

Task:

a)Find the indefinite integral $\int(0.04x + 20)dx$.

b)If the fixed costs (cost when x=0) are 500,000 UGX, find the constant of integration.

c)Write the specific total cost function $C(x)$.

Sub-topic 11.2: Definite Integral

Scenario 82

A civil engineer is calculating the amount of material needed to build a curved road embankment.The cross-sectional area of the embankment can be modeled by the function $A(x) = x^2 + 2x + 1$ (in square meters) between $x = 0$ and $x = 5$ meters. The total volume of material required for a 100-meter long embankment is found by integrating this area function over the given interval and then multiplying by the length. Accurate calculation is crucial for budgeting and procuring the correct amount of soil and aggregate, preventing costly project delays in Uganda's infrastructure development.

Task:

a)Set up the definite integral to find the average cross-sectional area from $x=0$ to $x=5$.

b)Calculate the definite integral $\int_0^5 x^2 + 2x + 1\, dx$.

c)Find the total volume of material needed for the 100-meter long embankment.

Scenario 83

A public health researcher is analyzing the total number of malaria cases reported in a district during a rainy season. The rate of new cases per week is given by $R(t) = 50 + 10t - t^2$, where t is time in weeks for $0 \leq t \leq 10$. The researcher needs to find the total number of cases over the entire 10-week period to assess the severity of the outbreak and allocate medical resources effectively. This requires calculating the definite integral of the rate function over the given time interval.

Task:

a)Set up the definite integral for the total number of cases from week 0 to week 10.

b)Calculate $\int_0^{10} 50 + 10t - t^2\, dt$.

c)Interpret what the result represents in the context of the malaria outbreak.

Scenario 84

A water resources engineer is studying the total water flow in a river during the rainy season.The flow rate, $F(t)$ in cubic meters per second, is given by $F(t) = (100 + 20\sin\frac{\pi t}{6})$, where t is the time in months $(0 \leq t \leq 6)$. The engineer needs to calculate the total volume of water that passed a monitoring station during this 6-month period to manage reservoir levels and plan for irrigation needs in the dry season. This involves finding the definite integral of the flow rate function.

Task:

a)Set up the definite integral for the total water volume from t=0 to t=6.

b)Calculate $\int_0^6 100 + 20\sin\frac{\pi t}{6}\, dt$ dt .

c)If the reservoir capacity is 16,000,000 m^3, what percentage of the reservoir did this flow represent?

Sub-topic 11.3: Applications of Integration (Area)

Scenario 85

The Kampala City Council Authority(KCCA) is planning to create a new public park in a previously unused plot of land. The boundaries of the park are defined by two curves: the path of a small stream, modeled by $y = x^2 + 1$, and a walking path, modeled by $y = x + 3$, where x and y are in meters. The area between these two curves, from their intersection points, will be developed into a green space. The parks department needs to calculate the exact area of this land to budget for sod, plants, and irrigation systems. This requires using integration to find the area between two curves, a fundamental application that ensures efficient use of public funds and optimal urban planning.

Task:

a)Find the points of intersection between the curves $y = x^2 + 1$ and $y = x + 3$.

b)Set up the definite integral to find the area enclosed between these two curves.

c)Calculate this area.

Scenario 86

An architect is designing a modern building with a unique curved wall.The wall's profile follows the curve $y = \sqrt{x}$ from $x = 1$ to $x = 4$, and the ground level is at $y = 0$. To estimate the cost of the special glass needed for this wall, the architect must calculate the area of the wall's surface. In the initial design phase, this can be approximated by finding the area under the curve $y = \sqrt{x}$ between the specified bounds. Accurate area calculation is crucial for material procurement and cost estimation in Uganda's growing construction industry.

Task:

a)Sketch the curve $y = \sqrt{x}$ from $x = 1$ to $x = 4$.

b)Set up the definite integral to find the area under the curve between these x-values.

c)Calculate this area.

Scenario 87

An agricultural researcher is studying the yield of a new variety of maize.The yield distribution across a test field is modeled by the probability density function $f(x) = -\frac{1}{50}(x - 10)^2 + 2$ for $0 \leq x \leq 20$, where x represents the distance in meters from a central irrigation point and $f(x)$ represents the yield in kgm^{-2}. The researcher needs to find the total yield from a 1-meter wide strip running from $x = 5$ to $x = 15$ to understand how yield changes with distance from water. This involves finding the area under the yield curve, which represents the total yield.

Task:

a)Set up the definite integral for the total yield from $x = 5$ to $x = 15$.

b)Calculate $\int_5^{15} -\frac{1}{50}(x - 10)2 + 2\, dx$.

c)Interpret the result in the context of the maize yield

Sub-topic 11.4: Mean Value of a Function

Scenario 88

An energy company is analyzing the power output of a small solar farm in Mbarara over a 12-hour period(from 6:00 to 18:00). The power output $P(t)$ in kilowatts is modeled by the function $P(t) = 100\sin(\frac{\pi t}{12}) + 50$, where t is the time in hours after 6:00. To design an effective battery storage system and plan for grid integration, engineers need to know the average power output over this period. This

requires calculating the mean value of the power function, which provides a crucial benchmark for energy production planning in Uganda's renewable energy sector.

Task:

a)State the formula for the mean value of a function $f(x)$ over the interval $[a, b]$.

b)Set up the calculation for the mean power output from $t=0$ to $t=12$.

c)Calculate the mean value of the power function.

Scenario 89

A water treatment plant in Gulu is monitoring the concentration of a chemical additive in the water supply throughout the day.The concentration $C(t)$ in parts per million varies according to $C(t) = 0.1t^2 - 2.4t + 15$ for $0 \leq t \leq 12$ hours. Health regulations require that the average concentration over any 12-hour period must not exceed 10 ppm. The plant manager needs to calculate the mean concentration to ensure compliance with safety standards and protect public health.

Task:

a)Set up the definite integral to find the mean value of $C(t)$ from $t=0$ to $t=12$.

b)Calculate the mean concentration over this period.

c)Determine if the plant is operating within the regulatory limit.

Scenario 90

A traffic engineer is studying vehicle flow rate on Entebbe Road during morning rush hour(7:00 to 9:00 AM). The flow rate $F(t)$ in vehicles per minute is given by $F(t) = -5(t - 1)^2 + 80$, where t is measured in hours after 7:00 AM. To plan for road widening and traffic management systems, the engineer needs to find the average flow rate during this 2-hour period. This mean value will help determine the necessary capacity for future infrastructure projects in Uganda's rapidly growing urban centers.

Task:

a)Determine the interval for t corresponding to 7:00-9:00 AM.

b)Calculate the mean value of $F(t)$ over this interval.

c)If the road's current capacity is 70 vehicles per minute, is the average flow exceeding capacity?

Topic 12: PERMUTATIONS AND COMBINATIONS

Sub-topic 12.1: Permutations and Combinations

Scenario 91

The Uganda National Examinations Board(UNEB) is designing the seating arrangement for a national scholarship examination to be held at a major venue in Kampala. There are 20 distinct scholarship candidates from different regions of the country, and they must be seated in a row of 20 specially assigned seats. To ensure the integrity of the examination process and prevent any possibility of collaboration or cheating, UNEB officials need to calculate the total number of possible distinct seating arrangements for these candidates. This calculation involves understanding the concept of permutations, where the order of arrangement matters significantly. The officials must consider that each candidate is unique and changing the position of any two candidates creates a completely different seating arrangement. This thorough planning is essential for maintaining the credibility of the national scholarship program and ensuring fair conditions for all exceptional students competing for these prestigious awards.

Task:

a)Calculate the total number of possible distinct seating arrangements for the 20 candidates.

b)If two particular candidates from the same school must not sit next to each other, how would this restriction affect the calculation?

c)Explain why this is a permutation problem rather than a combination problem.

Scenario 92

The Ministry of Health is forming specialized rapid response teams to address disease outbreaks across Uganda's diverse regions.From a pool of 15 highly qualified medical professionals with different specializations (epidemiologists, virologists, public health experts, and clinicians), the ministry needs to select 5 members for each regional team. The selection committee must calculate how many different teams can be formed, considering that each professional brings unique expertise and the composition of the team affects its effectiveness in responding to specific health emergencies. This scenario requires understanding combinations rather than permutations, as the order of selection doesn't matter - only which professionals are included in the team. Accurate calculation is crucial for ensuring that all possible team configurations are considered when deploying resources to handle potential outbreaks in different parts of the country, from the border regions to remote rural areas.

Task:

a)Calculate the number of different teams of 5 that can be selected from 15 professionals.

b)If the team must include at least 2 epidemiologists from the 4 available, how would this constraint change the calculation?

c)Explain why this is a combination problem rather than a permutation problem.

Scenario 93

A major telecommunications company in Uganda is implementing enhanced security protocols for its mobile money platform.The new system requires users to create a 6-character PIN where the first 3 characters must be distinct letters from the English alphabet and the last 3 characters must be distinct digits from 0-9. The security team needs to calculate the total number of possible unique PIN combinations to assess the system's vulnerability to brute-force attacks. This complex scenario involves both permutations of letters and permutations of digits, requiring the application of the fundamental counting principle. The calculation must account for the case sensitivity of letters and the requirement that all characters within each section be distinct. This security analysis is critical for protecting millions of Ugandan mobile money users from potential fraud and ensuring the integrity of one of the country's most important financial technologies.

Task:

a)Calculate the number of ways to choose and arrange 3 distinct letters from the 26-letter alphabet.

b)Calculate the number of ways to choose and arrange 3 distinct digits from 0-9.

c)Apply the fundamental counting principle to find the total number of possible 6-character PINs.

Topic 13: SERIES

Sub-topic 13.1: Arithmetic Progression (A.P.)

Scenario 94

The Ministry of Works and Transport is planning a massive infrastructure project to install solar-powered streetlights along a newly constructed highway stretching 100 kilometers from Kampala to Masaka.The project design specifies that streetlights must be placed at regular intervals, with the first light at the 2-kilometer mark and the final light exactly at the 98-kilometer mark. If the total number of streetlights to be installed is 50, the project engineers need to determine the exact interval between consecutive streetlights and the precise position of each light along the highway. This problem represents a classic arithmetic progression where the positions of the streetlights form a sequence with a constant difference. Accurate calculation is essential for budgeting the exact number of materials needed, planning the construction schedule, and ensuring uniform illumination along the entire highway for driver safety, especially during nighttime travel when the road is used by both commercial trucks and private vehicles.

Task:

a)Identify the first term and the number of terms in this arithmetic progression.

b)Calculate the common difference between the positions of consecutive streetlights.
c)Find the position of the 25th streetlight along the highway.

Sub-topic 13.2: Geometric Progression (G.P.)
Scenario 95
A virologist at the Uganda Virus Research Institute is studying the transmission pattern of a new viral strain detected in the country.In a controlled observation, a single infected individual transmits the virus to 3 new people in the first transmission cycle. Each of these newly infected individuals then transmits the virus to 3 more people in the next cycle, and this pattern continues consistently. The public health team needs to project the total number of infected people after 6 complete transmission cycles to prepare adequate medical facilities, isolation centers, and preventive measures. This scenario perfectly illustrates a geometric progression where each term is obtained by multiplying the previous term by a constant ratio. Understanding this exponential growth pattern is crucial for implementing timely interventions to prevent a potential epidemic that could overwhelm Uganda's healthcare system, particularly in rural areas with limited medical resources.
Task:
a)Identify the first term and common ratio of this geometric progression.
b)Calculate the number of newly infected people in the 5th transmission cycle.
c)Calculate the total number of infected people after 6 transmission cycles (including the initial case).

Sub-topic 13.3: Proof by Induction
Scenario 96
A computer science researcher at Makerere University is developing a new algorithm for optimizing data storage in Uganda's growing digital infrastructure.During the algorithm analysis, the researcher encounters a mathematical pattern where the sum of the first n odd positive integers appears to equal n^2 for all natural numbers n. Before implementing this finding into the algorithm's core logic, which will be used by various government agencies and private companies, the researcher must provide a rigorous mathematical proof that this relationship holds true for all possible cases. Proof by mathematical induction provides the perfect method for this verification, establishing the truth for the base case and then demonstrating that if the statement holds for an arbitrary case k, it must also hold for the next case k+1. This thorough mathematical validation is essential before deploying the algorithm in critical systems where data integrity and storage efficiency are paramount for Uganda's digital transformation journey.
Task:
a)Verify the statement that the sum of the first n odd numbers equals n^2 for the base case n=1.
b)Form the inductive hypothesis by assuming the statement is true for n=k.
c)Using the inductive hypothesis, prove that the statement must also be true for n=k+1.

Sub-topic 13.4: Binomial Expansion
Scenario 97
An agricultural engineer is developing a predictive model for crop yield under varying weather conditions for Uganda's National Agricultural Research Organization.The model incorporates a complex probability component expressed as $(1 + 0.05)^8$, which represents the cumulative effect of small daily growth variations over an 8-day critical growth period. Calculating this value directly would be computationally intensive, but using the binomial theorem provides an efficient approximation method. The engineer needs to expand this expression to estimate the expected yield multiplier accurately, which will help farmers make informed decisions about planting schedules and resource allocation. This application of binomial expansion is particularly valuable for subsistence farmers who rely on precise yield predictions

for food security and income stability in a country where agriculture employs over 70% of the workforce and contributes significantly to the national economy.

Task:

a)Write out the first four terms of the binomial expansion of $(1 + 0.05)^8$.

b)Calculate the approximate value using these first four terms.

c)Estimate the percentage error of your approximation compared to the exact value.

Scenario 98

A financial analyst at the Bank of Uganda is modeling compound interest scenarios for the country's emerging small and medium enterprise sector.The analyst encounters expressions of the form $(a + b)^n$ where a represents the principal amount, b represents the interest rate, and n represents the number of compounding periods. Using the binomial theorem, the analyst can expand these expressions to understand how different components contribute to the final amount. This analysis helps in developing financial products tailored to Ugandan businesses, particularly those in rural areas where access to capital remains a significant challenge for economic development and poverty reduction initiatives supported by both government and international development partners.

Task:

a)Expand $(1 + x)^5$ using the binomial theorem.

b)Use your expansion to approximate $(1.02)^5$.

c)If a small business borrows 1,000,000 UGX at 2% monthly interest for 5 months, use your approximation to estimate the total amount owed.

Scenario 99

A statistics officer at the Uganda Bureau of Statistics is working on demographic projections for the country's rapidly growing population.The officer needs to calculate probabilities involving binomial distributions where expressions like $(p + q)^n$ frequently appear, with p representing the probability of an event and q representing the probability of its complement. The binomial theorem provides a systematic way to expand such expressions and extract specific terms corresponding to particular demographic scenarios. This mathematical tool is indispensable for accurate population forecasting, which informs national planning in critical areas such as healthcare, education, housing, and infrastructure development across Uganda's diverse regions from the densely populated Kampala area to the more sparsely populated Karamoja region.

Task:

a)Expand $(x + y)^4$ completely using the binomial theorem.

b)Find the coefficient of the x^3y term in the expansion of $(2x + y)^5$.

c)In a population study, if the probability of a household having internet access is 0.3, what is the probability that exactly 3 out of 5 randomly selected households have internet access?

Topic 14: RANDOM VARIABLES

Sub-topic 14.1: Discrete Random Variables

Scenario 100

The Uganda National Meteorological Authority is analyzing the number of days with significant rainfall during the crucial planting season in the Mbale region,known for its high agricultural output. They define a "significant rainfall day" as one with more than 20mm of precipitation. Historical data suggests that in the 90-day planting season, the number of such days, which we can call the random variable X, varies between 20 and 40. The authority needs to model X as a discrete random variable to calculate the probability of different rainfall scenarios. This model is vital for advising farmers on optimal planting times, crop selection, and irrigation planning. Accurate predictions can significantly impact food security and the economic stability of thousands of farming households in this fertile region.

Task:

a)Explain why the number of significant rainfall days, X, is considered a discrete random variable.

b)If the probability distribution is given by $P(X = x) = kx$ for $x = 20, 21, ..., 40$, find the value of the constant k.

c)Calculate the expected number of significant rainfall days during the planting season.

Scenario 101

A mobile network operator is analyzing the number of daily customer service calls received at its Kampala call center.The random variable Y represents the number of calls related to mobile money transaction issues. Based on past data, the probability distribution of Y is partially known. The company wants to fully define this distribution to staff the call center appropriately, ensuring short wait times and high customer satisfaction. Understaffing leads to customer frustration, while overstaffing increases operational costs unnecessarily. This analysis is crucial for maintaining competitiveness in Uganda's rapidly growing telecommunications sector.

Task:

The probability distribution of Y is given by the table below. Find the missing probability a.

Y	0	1	2	3	4
P(Y)	0.1	0.3	a	0.2	0.1

a) Find the value of a.

b)Calculate the expected number of daily mobile money related calls, $E(Y)$.

c)Calculate the variance of Y, $Var(Y)$.

Scenario 102

A public health official is studying the number of new malaria cases reported per week at a specific clinic in a high-risk district.The random variable Z follows a distribution where its probabilities are proportional to the number of cases. Understanding the behavior of Z is essential for resource allocation, such as stocking antimalarial drugs, diagnostic kits, and scheduling medical personnel. Efficient management directly impacts the clinic's ability to effectively combat malaria, a major public health challenge in Uganda.

Task:

Suppose the probability mass function of Z is $P(Z = z) = c.z$ for $z = 1, 2, 3, 4$, and 0 otherwise.

a)Find the normalization constant c.

b)Find the probability that there are more than 2 new cases in a week, $P(Z > 2)$.

c)Calculate the expected value $E(Z)$.

Sub-topic 14.2: Continuous Random Variables

Scenario 103

A team of water quality engineers is monitoring the concentration of a specific mineral in the water supply of a newly developed urban area in Wakiso District.The concentration C (in milligrams per liter) is modeled as a continuous random variable with a probability density function (pdf) that is constant between 0.5 mg/L and 2.5 mg/L. Concentrations outside this range are considered abnormal. The team needs to determine the probability that a randomly collected water sample falls within the national safety standard of 1.0 to 2.0 mg/L. This analysis is critical for ensuring the health of the community and complying with Uganda's national water quality regulations.

Task:

a)If C is uniformly distributed between 0.5 and 2.5, write down its probability density function, $f(c)$

b)Calculate the probability that a water sample has a mineral concentration between 1.0 and 2.0 mg/L, $P(1.0 \leq C \leq 2.0)$.
c)Find the expected (mean) mineral concentration.

Scenario 104

An electrical engineer at the Uganda Electricity Transmission Company Ltd(UETCL) is analyzing the daily peak load (maximum power demand) on a particular substation serving a growing industrial park. The peak load L (in Megawatts) can be modeled by a continuous random variable with the probability density function $f(l) = k\,l\,(10 - l)$ for $0 \leq l \leq 10$, and 0 elsewhere. Understanding this distribution is vital for planning grid upgrades, preventing blackouts, and ensuring a reliable power supply that supports industrial growth and job creation in the region.

Task:

a)Find the value of k that makes $f(l)$ a valid probability density function.
b)Calculate the probability that the daily peak load exceeds 8 MW, $P(L > 8)$.
c)Determine the median peak load.

Scenario 105

A biologist studying the growth patterns of a particular tree species in the Mabira Forest Reserve measures the height of fully matured trees.The height H (in meters) is modeled as a continuous random variable with the cumulative distribution function (CDF) $F(h) = 1 - e^{-0.2h}$ for $h \geq 0$. This information helps in understanding the forest's ecology, estimating carbon sequestration, and developing sustainable forestry management practices that balance conservation with the economic needs of local communities.

Task:

a)Use the CDF to find the probability that a randomly selected tree is taller than 10 meters, $P(H > 10)$.
b)Find the probability density function (pdf) $f(h)$ of the tree height.
c)Calculate the probability that a tree's height is between 5 and 15 meters.

Topic 15: PROBABILITY DISTRIBUTIONS

Sub-topic 15.1: Binomial Distribution

Scenario 106

A quality control inspector at a bottled water plant in Mbarara is responsible for ensuring the purity of the final product.The production line has a known historical defect rate where 2% of bottles fail a stringent purity test. Each day, the inspector randomly selects and tests 50 bottles from the production line. The management needs to know the probability of finding a certain number of defective bottles in this daily sample to assess the consistency of their production process and maintain their certification with the Uganda National Bureau of Standards (UNBS). This scenario perfectly models a binomial distribution, where each bottle test is an independent Bernoulli trial with two outcomes: pass or fail (defective).

Task:

a)State the two parameters, n and p , for the binomial distribution in this context.
b)Calculate the probability that the inspector finds exactly one defective bottle in the daily sample of 50.
c)Calculate the probability that the inspector finds at least two defective bottles.

Scenario 107

A vaccination team is conducting a door-to-door measles immunization campaign in a rural village in Nakaseke District.Based on previous campaigns, they estimate that the probability of a household agreeing to vaccinate their eligible children is 0.75. The team plans to visit 20 households in a day. The district health officer needs to predict the number of households that will likely consent to the vaccination to plan for the required number of vaccine doses and logistical support. This allows for efficient resource allocation, minimizing waste of precious vaccines and ensuring the campaign's success in protecting children from preventable diseases.

Task:

a)Define a suitable random variable X for this scenario and state its distribution.

b)Calculate the expected number (mean) of households that will consent to vaccination.

c)Find the probability that more than 15 households will consent.

Scenario 108

A mathematics tutor in Kampala is preparing students for a national exam.She knows that a student has an 80% chance of correctly solving a particular type of problem. In a practice test containing 10 of these problems, she wants to analyze a student's performance. Understanding the binomial distribution allows her to distinguish between random variation in scores and a genuine change in a student's understanding, enabling her to provide targeted help and improve learning outcomes.

Task:

a)What is the probability that a student solves exactly 8 out of the 10 problems correctly?

b)What is the probability that a student solves at least 8 problems correctly?

c)Calculate the variance of the number of correctly solved problems.

Sub-topic 15.2: Uniform Rectangular Distribution

Scenario 109

A city bus on a specific route in Jinja is scheduled to arrive at a particular stop every 30 minutes.However, due to unpredictable traffic conditions, a passenger arriving randomly at the stop experiences a waiting time that is uniformly distributed between 0 and 30 minutes. The city's transport authority wants to understand the passenger experience to assess the need for more frequent services or better schedule adherence. Analyzing this uniform distribution of waiting times provides concrete data on passenger wait times, which is a key metric for public satisfaction and the efficiency of the urban transport system.

Task:

a)Write down the probability density function (pdf) for the waiting time T.

b)Calculate the probability that a passenger waits for less than 5 minutes.

c)Find the average (expected) waiting time for a passenger.

Scenario 110

A soil scientist is analyzing the pH level of soil samples from a large,uniformly managed agricultural field in the Kigezi highlands. Preliminary analysis suggests that the pH levels in the field are uniformly distributed between 5.5 and 7.0. This information is critical for determining the correct amount of lime needed to neutralize the soil acidity for optimal crop growth, directly impacting the yield and profitability for the local farming cooperative.

Task:

Let the random variable X represent the soil pH level.

a)State the probability density function $f(x)$ for X.

b)The ideal pH for the intended crop is between 6.0 and 6.5. What is the probability that a randomly selected soil sample is in this ideal range?

c)Calculate the standard deviation of the pH level.

Scenario 111

An IT manager at a large organization in Entebbe is analyzing the time it takes for the central server to respond to a user request(server latency). During a stable operational period, the latency is found to be uniformly distributed between 50 milliseconds and 150 milliseconds. Understanding this distribution is essential for setting performance benchmarks, identifying potential system slowdowns, and ensuring a smooth user experience for hundreds of employees who rely on the system for their daily tasks.

Task:
Let L be the server latency in milliseconds.
a)Sketch the probability density function (pdf) for L .
b)The service level agreement (SLA) states that latency should not exceed 100 ms. What is the probability that a random request violates this SLA?
c)Find the median server latency.

Sub-topic 15.3: Normal Distribution
Scenario 112
The Uganda National Examinations Board(UNEB) is analyzing the scores of the recent Uganda Advanced Certificate of Education (UACE) Mathematics examination. The scores are found to be normally distributed with a mean of 65 and a standard deviation of 12. UNEB needs to determine the percentage of candidates who scored above 80 to award distinctions, and the score that represents the top 10% of candidates for scholarship considerations. This use of the normal distribution allows for fair and standardized comparison of candidate performance across different years and examination cycles.
Task:
a)Calculate the proportion (probability) of candidates who scored more than 80.
b)Find the minimum score required to be in the top 10% of candidates.
c)What percentage of candidates scored between 50 and 75?
Scenario 113
A manufacturer of medical syringes in Kampala must ensure that the volume of each syringe is highly consistent.The filling machine produces syringes with volumes that are normally distributed with a mean of 5.0 ml and a standard deviation of 0.05 ml. Regulatory standards require that 99% of syringes must contain between 4.9 ml and 5.1 ml. The quality assurance team needs to verify if the manufacturing process meets this strict requirement, as under-dosing or over-dosing can have serious implications for patient care and drug efficacy in Ugandan hospitals and clinics.
Task:
a)Calculate the probability that a randomly selected syringe has a volume between 4.9 ml and 5.1 ml.
b)Does the process meet the regulatory standard of 99%? Justify your answer.
c)To what value would the standard deviation need to be reduced to ensure that 99.9% of syringes fall within the 4.9 ml to 5.1 ml range?
Scenario 114
An anthropologist is studying the heights of adult males in a specific ethnic group in the Karamoja region.The heights are normally distributed with a mean of 172 cm and a variance of 49 cm^2. This research contributes to understanding human physical variation and is also useful for designing ergonomic tools, furniture, and infrastructure that are better suited to the local population, thereby improving comfort and productivity.
Task:
a)Find the probability that a randomly selected adult male from this group is taller than 180 cm.
b)Find the height that is exceeded by 75% of the population.
c)If four men are selected at random, what is the probability that their average height is less than 170 cm?

Sub-topic 15.4: Normal Approximation to the Binomial Distribution
Scenario 115
A large regional hospital in Mbale is analyzing its outpatient department's patient satisfaction survey.Historically, from extensive data, they know that 70% of patients rate the service as "satisfactory." In the latest survey, they collected responses from 200 randomly selected patients. The hospital

administration wants to know the probability that more than 150 of these patients reported being satisfied. Calculating this directly using the binomial distribution would be computationally intensive due to the large sample size (n=200). The statistician on staff suggests using the normal distribution as an approximation to the binomial distribution to simplify the calculation while maintaining acceptable accuracy, allowing management to quickly gauge recent performance trends.

Task:

a)State the conditions for using a normal approximation for a binomial distribution. Check if they are satisfied in this case.

b)Calculate the mean (μ) and standard deviation (σ) of the approximating normal distribution.

c)Using the normal approximation with continuity correction, find the probability that more than 150 patients reported satisfaction.

Scenario 116

A nationwide telecommunications company in Uganda is auditing the success rate of its mobile money cash-out transactions.The company knows that the probability of any single transaction failing due to network or system error is 5%. On a typical day, a single agent performs 500 such transactions. The risk management department needs to estimate the probability that the agent experiences more than 30 failed transactions in a day. This helps in identifying agents or regions that might need technical support or system upgrades. Using the normal approximation to the binomial distribution makes this estimation feasible and efficient for monitoring the performance of thousands of agents across the country in near real-time.

Task:

a)Justify why the normal approximation is suitable for this problem.

b)Find the mean and standard deviation for the normal approximation.

c)Use the normal approximation with continuity correction to estimate the probability of having more than 30 failed transactions.

Scenario 117

A large-scale bean seed producer in Masaka supplies seeds to farmers across East Africa.The producer claims that their germination rate is 90%. A quality control inspector from the Uganda National Bureau of Standards (UNBS) visits the facility and randomly tests a batch of 1000 seeds. The inspector will flag the batch for further review if the number of seeds that germinate is below a certain threshold, suggesting the true germination rate might be lower than advertised. To set this threshold appropriately, the UNBS needs to know the distribution of the number of germinated seeds. Using the normal approximation to the binomial distribution allows them to easily calculate probabilities and set fair, statistically sound quality control limits that protect farmers without unfairly penalizing the producer.

Task:

a)Calculate the mean and standard deviation for the number of germinated seeds in the batch of 1000.

b)Using the normal approximation, find the probability that fewer than 875 seeds germinate.

c)The producer wants to be 95% confident that a batch will not be flagged. What is the minimum number of seeds (in a test of 1000) that must germinate to meet this standard? (Hint: Find the value k such that $P(X \geq k) = 0.95$).

Topic 16: ERROR ANALYSIS

Sub-topic 16.1: Errors

Scenario 118

A team of civil engineers is conducting a land survey for a new road project connecting two towns in the Busoga region. They need to calculate the total area of a rectangular plot of land. The length of the plot is measured as 250.5 meters, with a possible error of ±0.2 meters. The width is measured as 180.3 meters,

with a possible error of ±0.1 meters. The procurement department needs to know the maximum possible error in the calculated area to budget for extra materials (like asphalt and gravel) that might be needed due to measurement uncertainties. This analysis of error propagation ensures the project stays within budget and is completed on schedule, even if the initial measurements were at the extreme ends of their error ranges.

Task:

a)Calculate the nominal area of the plot (using the measured length and width).

b)Estimate the maximum possible absolute error in the area calculation.

c)Calculate the relative error and the percentage error in the area.

Sub-topic 16.2: Propagation of Errors

Scenario 119

A pharmacist at Mulago National Referral Hospital is preparing an intravenous(IV) saline solution. The concentration C of the solution depends on the mass of salt m and the volume of water V , given by $C = \frac{m}{V}$. The mass is measured as 9.0 grams with an absolute error of ±0.1 grams. The volume is measured as 1.0 liter with an absolute error of ±0.02 liters. An incorrect concentration can be dangerous for patients. The hospital's quality control requires an understanding of how the errors in mass and volume measurement propagate to create an error in the final concentration, ensuring patient safety and adherence to strict medical standards.

Task:

a)Calculate the nominal concentration of the saline solution.

b)Using the formula for error propagation in a quotient, estimate the absolute error in the concentration, ΔC .

c)Find the percentage error in the concentration.

Sub-topic 16.3: Errors in Functions

Scenario 120

A physicist at Makerere University is determining the period T of a simple pendulum using the formula $T = 2\pi\sqrt{\frac{L}{g}}$, where L is the length of the string. In an experiment, the length is measured as L = 1.00 meter with a possible error of $\Delta L = \mp 0.005$ meters. The value of g (acceleration due to gravity) is taken as 9.81 m/s² and is assumed to be exact for this purpose. The student needs to find out how the error in measuring the length affects the calculated value of the period. This understanding is crucial for evaluating the precision of the experimental results and for reporting them with appropriate significant figures and confidence intervals in their final research paper.

Task:

a)Calculate the nominal value of the period T .

b)Use differentials (or error propagation for a function of one variable) to estimate the absolute error in the period, ΔT .

c)Calculate the percentage error in the period.

Topic 17: VECTORS

Sub-topic 17.1: Vectors in Three Dimensions

Scenario 121

A team of geologists from the Directorate of Geological Survey and Mines is conducting a subsurface mineral exploration in the Kasese region.They are using 3D seismic imaging technology to map a potential mineral vein. The coordinates of three key sensor points relative to a central base camp are given

as: Sensor A (500, 200, -50), Sensor B (300, -100, -80), and Sensor C (-100, 400, -30), where the units are in meters and the z-coordinate represents depth (negative for below surface). The team needs to calculate the vectors between these sensors and their magnitudes to understand the spatial geometry of the mineral vein and plan their drilling operations accurately. This 3D vector analysis is crucial for minimizing drilling costs and maximizing the yield of valuable minerals for Uganda's growing mining sector.

Task:

a)Find the vector $\overrightarrow{AB}$ from Sensor A to Sensor B.

b)Calculate the magnitude (length) of vector $\overrightarrow{AB}$, which represents the straight-line distance between the two sensors.

c)Find the position vector of the midpoint between Sensor A and Sensor C.

Scenario 122

An air traffic controller at Entebbe International Airport is tracking the position of an ascending aircraft shortly after takeoff. The control tower is at the origin (0, 0, 0). At a specific moment, the aircraft is at position A (2000, 1500, 500) meters, and one minute later, it is at position B (5000, 3000, 1500) meters. The controller needs to determine the displacement vector of the aircraft during that minute, the distance it traveled, and its average velocity vector. This information is vital for maintaining safe separation between aircraft and ensuring efficient management of Ugandan airspace.

Task:

a)Find the displacement vector $\overrightarrow{AB}$ of the aircraft.

b)Calculate the distance the aircraft traveled in that minute (the magnitude of its displacement).

c)If the time taken was exactly 60 seconds, what is the average velocity vector of the aircraft? (Velocity = Displacement / Time)

Scenario 123

A civil engineer is designing the support structure for a new communication tower in Kampala.Three support cables are attached to the tower at a point T(0, 0, 50) meters and anchored to the ground at points A(20, 0, 0), B(0, 20, 0), and C(-15, -15, 0). The engineer needs to find the force vectors along each cable, assuming they are perfectly straight and under tension. Understanding these 3D vectors is essential for calculating the stresses on the tower and ensuring its stability during strong winds, which is a critical safety consideration for tall structures in Uganda.

Task:

a)Find the vector representing cable TA.

b)Calculate the magnitude of the vector for cable TB.

c)Find a unit vector in the direction of cable TC.

Sub-topic 17.2: Lines in Two and Three Dimensions

Scenario 124

A search and rescue team is operating in the mountainous Rwenzori region.The path of a missing hiker's last known route is modeled as a straight line in 3D space. The hiker started at point P(1, 2, 0) and was moving in the direction of vector $\mathbf{d} = (2, -1, 3)$. The rescue team, located at base camp R(5, 0, 6), needs to determine the equation of the hiker's path and find the closest point on this path to their base camp to plan the most efficient interception route. This application of 3D line equations can significantly reduce search time in difficult terrain, potentially saving lives.

Task:

a)Find the vector equation of the line representing the hiker's path.

b)Write the parametric equations of the line.

c)Calculate the shortest distance from the base camp R(5, 0, 6) to the hiker's path.

Scenario 125

An architect is designing a modern building with a prominent straight steel beam that runs diagonally through a large atrium.In the building's 3D coordinate system, the beam passes through points M(2, 1, 4) and N(5, 7, -2). The structural engineer needs the equations of the line along this beam to interface with other structural elements and to calculate loads and stresses accurately. This precise mathematical description is crucial for the structural integrity of the building, which is set to become a new landmark in Kampala's skyline.

Task:

a)Find the direction vector of the line through points M and N.

b)Write down the Cartesian (symmetric) equations of the line.

c)Determine if the point Q(8, 13, -8) lies on this beam.

Scenario 126

A drone is programmed to fly on a straight-line patrol path over a wildlife reserve to monitor for poaching activity. The path is defined by the line $\mathbf{r} = (1, 0, 2) + \lambda(3, 1, -1)$, where the coordinates are in kilometers from a central ranger station. The rangers receive a signal from a poaching incident at point S(10, 3, -1). They need to determine if the incident is on the drone's patrol path and, if not, how far it is from the path to decide if they should redirect the drone or send a ground team. This efficient use of resources is key to protecting Uganda's valuable wildlife.

Task:

a)Write the parametric equations for the drone's path.

b)Determine whether the point S(10, 3, -1) lies on the drone's path.

c)Find the perpendicular distance from point S to the drone's path.

Sub-topic 17.3: Planes

Scenario 127

A geotechnical engineer is analyzing a large,flat rock slab on a hillside in Kabale that is at risk of sliding. The slab is modeled as a plane in 3D space that passes through three points measured by GPS: U(1, 1, 2), V(3, 4, 1), and W(2, 3, 5), with coordinates in meters. The engineer needs to find the equation of this plane to calculate its orientation and the stress forces acting upon it. This analysis is critical for assessing landslide risk and designing preventive measures to protect the nearby community and infrastructure.

Task:

a)Find two vectors that lie in the plane, for example, UV and UW.

b)Calculate the normal vector to the plane using the cross product.

c)Hence, find the Cartesian equation of the plane.

Scenario 128

An interior designer is planning the layout for a large exhibition hall in the new Uganda National Museum. One of the main walls is a vast, flat surface. In the building's 3D coordinate system, the wall (a plane) has a normal vector $\mathbf{n} = (2, -1, 3)$ and contains the point (0, 5, 0). The designer needs to install a large, heavy display screen that must be mounted perpendicular to this wall. Knowing the exact equation of the plane is necessary to design the mounting brackets and ensure the screen is perfectly aligned, enhancing the visitor experience.

Task:

a)Write down the equation of the plane representing the wall.

b)A mounting point is at P(2, 4, 1). Determine if this point lies on the plane.

c)Find the distance from the origin (0, 0, 0) to the plane.

Scenario 129

An aviation engineer is simulating the flight path of an aircraft approaching Entebbe International Airport for landing.The ideal landing approach is defined by a specific glide path, which can be represented as a line in space. This glide path must lie within a "safe approach" plane, defined by the equation $2x - y + 3z = 6$. The engineer needs to verify that a proposed flight path, given by the line $r = (0, 6, 0) + \mu(1, 2, 0)$, lies entirely within this safe approach plane to ensure the aircraft meets all safety regulations during its final descent.

Task:

a)Show that the direction vector of the line is parallel to the plane. (Hint: It should be perpendicular to the plane's normal vector).

b)Show that a point on the line satisfies the plane's equation.

c)Based on (a) and (b), conclude whether the entire line lies in the plane.

Topic 18: DIFFERENTIATION 2

Sub-topic 18.1: Trigonometric Functions

Scenario 130

A marine engineer is designing a floating pontoon system for a new ferry terminal on Lake Victoria.The pontoon rises and falls with the water waves, and its vertical displacement h (in meters) from its average position is modeled by the function $h(t) = 2\sin(0.5t) + 0.5\cos(0.5t)$, where t is time in seconds. To design a safe and stable gangway that connects the pontoon to the shore, the engineer needs to analyze the pontoon's velocity and acceleration. This involves differentiating the displacement function, which is a combination of trigonometric functions. Understanding these rates of change is crucial for ensuring the gangway can accommodate the pontoon's movement without breaking or becoming unsafe for passengers, especially during stormy weather on the lake.

Task:

a)Find the velocity function $v(t)$ by differentiating $h(t)$ with respect to time.

b)Find the acceleration function $a(t)$ by differentiating $v(t)$.

c)Calculate the initial velocity and acceleration (at $t = 0$).

Scenario 131

An energy company is modeling the alternating current(AC) generated by a new hydroelectric turbine on the Nile. The voltage V (in volts) varies with time t (in seconds) according to the function $V(t) = 340\sin(120\pi t)$. To understand how the voltage changes at any given instant—which is vital for synchronizing the power grid and protecting electrical equipment from sudden surges—engineers need to find the rate of change of voltage. This requires differentiating the sine function, a fundamental concept in electrical engineering for analyzing AC circuits that power homes and industries across Uganda.

Task:

a)Find the derivative $\frac{dV}{dt}$, which represents the instantaneous rate of change of voltage.

b)Calculate the rate of change of voltage at time $t = 0.01$ seconds.

c)Find the maximum rate at which the voltage can change.

Scenario 132

An architect is designing a spectacular arched entrance for a new cultural center in Gulu.The arch is shaped like an inverted cosine curve. The height y (in meters) of the arch at a horizontal distance x (in meters) from its center is given by $y = 5\cos(0.2x)$ for $-15 \leq x \leq 15$. To ensure the arch is structurally sound and to plan the installation of decorative elements, the architect needs to know the steepness (gradient) of the arch at various points. This requires differentiating the cosine function, allowing the

architect to identify where the curve is steepest and where it is flat, which influences both the design and the construction methodology.

Task:

a)Find the gradient function $\frac{dy}{dx}$.

b)Calculate the gradient of the arch at a point 5 meters from the center (x = 5).

c)Find the points where the arch is perfectly horizontal (i.e., where the gradient is zero).

Sub-topic 18.2: Exponential, Logarithmic and Inverse Trigonometric Functions

Scenario 133

A epidemiologist at the Ministry of Health is modeling the early growth of a disease outbreak in a densely populated area of Kampala.In the initial phase, the number of infected people N can be modeled by the exponential function $N(t) = 100e^{0.2t}$, where t is the time in days. To allocate medical resources effectively and plan containment strategies, health officials need to predict not just the number of cases, but also the daily growth rate of new infections. This requires differentiating the exponential function to understand how quickly the outbreak is accelerating, which is critical for implementing timely public health interventions.

Task:

a)Find the derivative $\frac{dN}{dt}$, which represents the daily growth rate of infections.

b)Calculate the number of new infections per day at $t = 5$ days.

c)Explain what the value 0.2 in the exponent represents in the context of the outbreak.

Scenario 134

A financial analyst at the Bank of Uganda is studying the impact of inflation on the purchasing power of the Ugandan Shilling.The real value V of a certain amount of money after t years of constant inflation is modeled by $V(t) = V_0e^{-0.05t}$, where V_0 is the initial value. To advise the public and policymakers on the erosion of savings over time, the analyst needs to find the instantaneous rate at which purchasing power is decreasing. This involves differentiating the exponential decay function, providing a clear measure of how inflation affects the economy and individual savings.

Task:

a)Find the derivative $\frac{dV}{dt}$.

b)Calculate the rate of decrease in purchasing power after 2 years if the initial value V_0 is 1,000,000 UGX.

c)Interpret the meaning of the negative sign in your answer for part (b).

Scenario 135

An acoustic engineer is calibrating the sound system for the National Theatre to ensure the sound intensity levels are perfect for both quiet dialogues and loud musical performances.The perceived loudness L (in decibels) is related to the sound intensity I by the logarithmic function $L(I) = 10\log(I)$, where I is measured in watts per square meter. To understand how small changes in amplifier power (which affects intensity) will impact the perceived volume, the engineer needs to differentiate this logarithmic function. This ensures that fine-tuning the equipment leads to the desired auditory experience for the audience.

Task:

a)Differentiate $L(I) = 10\log(I)$ with respect to I

b)Calculate the rate of change of loudness with respect to intensity when $I = 10^{-6}W/m^2$ (a typical conversation level).

c)What does the result from part (b) tell you about how sensitive the perceived loudness is to changes in intensity at that level?

Sub-topic 18.3: Maclaurin's Series

Scenario 136

A computer graphics engineer at a Ugandan animation studio is developing a 3D modeling software for local architects.The software needs to render complex curved surfaces, but the rendering engine can only process polynomial functions efficiently. The engineer encounters the function $f(x) = \sin(x)$, which is essential for creating smooth, organic shapes. To approximate this function within the software, they decide to use a Maclaurin series expansion. This allows them to replace the computationally expensive sine function with a polynomial that is accurate for small values of x (like those used in detailed architectural elements), significantly speeding up the rendering process without sacrificing visual quality for Uganda's growing digital design industry.

Task:

a)Write down the first four non-zero terms of the Maclaurin series for $f(x) = \sin(x)$.

b)Use your series to approximate $\sin(0.1)$ radians.

c)Estimate the percentage error of your approximation compared to the calculator value of $\sin(0.1)$.

Scenario 137

A financial quantitative analyst("quant") at a Kampala investment firm is modeling the growth of a complex financial derivative. The value of the derivative depends on the function $g(x) = e^x$, but the firm's risk assessment model requires a polynomial form to run thousands of rapid simulations. The analyst uses the Maclaurin series expansion for the exponential function to create a simplified, yet accurate, model for small fluctuations in the market variable x . This enables the firm to quickly assess potential risks and returns on investments, contributing to more stable and informed financial decision-making in Uganda's emerging capital markets.

Task:

a)Find the Maclaurin series for $g(x) = e^x$ up to the term in x^4 .

b)Use this series to approximate the value of $e^{0.2}$.

c)If the analyst used only the first three terms of the series, what would be the absolute error in the approximation for $e^{0.2}$?

Scenario 138

A civil engineer is working on the structural analysis of a newly designed,gently curved bridge in Jinja. The curve of the main support cable is described by the function $h(x) = \ln(1 + x)$, where x is the horizontal distance from the bridge's center. To calculate the bending moments and stresses in the cable using standard engineering software that prefers polynomial inputs, the engineer approximates the logarithmic function using its Maclaurin series. This approximation is valid for the small values of x relevant to the bridge's curvature and ensures the structural calculations are both accurate and feasible, guaranteeing the safety and longevity of the infrastructure.

Task:

a)Derive the Maclaurin series for $h(x) = \ln(1 + x)$ up to the term in x^4 .

b)State the interval of values for x for which this series expansion is valid.

c)Use the series to approximate $\ln(1.05)$.

Sub-topic 18.4: Further Curve Sketching

Scenario 139

An environmental scientist is modeling the concentration C of a pollutant in a stream near an industrial area in Namanve over time. The concentration is given by the function $C(t) = \frac{t}{t^2+1}$ for $t \geq 0$, where t is time in days. To communicate the findings effectively to policymakers and the public, the scientist needs to sketch a clear and accurate graph of this function. This involves finding intercepts, asymptotes, critical

points (maximum concentration), and intervals of increase and decrease. A well-drawn graph can powerfully illustrate how the pollutant concentration peaks and then gradually dissipates, informing decisions on environmental regulation and clean-up efforts.

Task:

a)Find the y-intercept and any horizontal asymptotes of the function $C(t)$.

b)Find the first derivative $C'(t)$ and use it to determine the time t at which the pollutant concentration is at its maximum.

c)Sketch the graph of $C(t)$ for $t \geq 0$, clearly labeling the maximum point and the horizontal asymptote.

Scenario 140

An economist at Makerere University is studying a model for the cost of producing a new agricultural tool.The average cost per tool, $A(x)$ in Ugandan Shillings, when x tools are produced is given by $A(x) = \frac{x^2-5x+20}{x}$, for $x > 0$. To advise local manufacturers on the most efficient scale of production, the economist needs to sketch the graph of this average cost function. The sketch will visually reveal the production level that minimizes the average cost, which is crucial for enhancing the profitability and sustainability of small-scale manufacturing in Uganda.

Task:

a)Simplify the function $A(x)$ and find the equation of any oblique asymptote.

b)Find the first derivative $A'(x)$ and determine the number of tools x that minimizes the average cost.

c)Sketch the graph of $A(x)$, showing the asymptote and the minimum point.

Scenario 141

A physicist is analyzing the energy distribution E(\lambda) of radiation emitted from a prototype solar panel developed at a Ugandan tech hub. The function is given by $E(\lambda) = \frac{5\lambda^4}{e^{\lambda}-1}$ for $\lambda > 0$, where λ is the wavelength. This complex function has a distinctive peak, and sketching its curve is essential for understanding at which wavelength the panel emits the most energy. This information helps engineers optimize the panel's material composition to capture the most sunlight, boosting the efficiency of solar energy—a key renewable resource for Uganda.

Task:

a)State what happens to $E(\lambda)$ as $\lambda \longrightarrow 0^+$ and as $\lambda \longrightarrow \infty$ (find the horizontal asymptote).

b)The derivative of this function is complex, but it is known that the graph has a single turning point. Based on the function's behavior, sketch a plausible graph of $E(\lambda)$ for $\lambda > 0$, showing its behavior near zero and infinity and indicating the single maximum point.

c)What feature of the graph is most important for the solar panel engineers?

Topic 19: INTEGRATION 2

Sub-topic 19.1: Function and its Derivative (Change of Variables)

Scenario 142

A water engineer at the National Water and Sewerage Corporation is modeling the rate at which a new reservoir in Kiruhura District is being filled.The rate of water flow into the reservoir is given by the function $R(t) = 20t(t^2 + 4)^2$ cubic meters per hour, where t is the time in hours. To calculate the total volume of water accumulated in the reservoir after the first 3 hours of operation, the engineer needs to integrate this rate function. The presence of the composite function $(t^2 + 4)^2$ suggests that the method of integration by substitution (change of variables) is the most efficient approach. Accurately determining this volume is crucial for managing water release schedules and ensuring a stable supply for irrigation and domestic use in the surrounding communities.

Task:

a)Identify a suitable substitution u for the integral $\int 20t(t^2 + 4)^2 \, dt$.

b)Using this substitution, find the indefinite integral.
c)Hence, calculate the total volume of water that has flowed into the reservoir in the first 3 hours.

Scenario 143

A biologist at Mbarara University is studying the growth rate of a bacterial culture used in a biogas production experiment. The growth rate is modeled by the function $G(t) = \frac{3t^2}{\sqrt{t^3+9}}$ bacteria per minute. To predict the total increase in the bacterial population between $t = 0$ and $t = 2$ minutes, the biologist must integrate this growth rate function. The structure of the function, with t^2 in the numerator and a square root of a cubic function in the denominator, makes integration by substitution the ideal method. This calculation helps in optimizing the biogas production process, a key renewable energy technology for rural Uganda.

Task:

a)For the integral $\int \frac{3t^2}{\sqrt{t^3+9}}\,dt$, state an appropriate substitution for u.
b)Rewrite the integral in terms of u and du, and then solve it.
c)Evaluate the definite integral from $t = 0$ to $t = 2$ to find the total increase in the bacterial population over that time.

Scenario 144

An economist is analyzing the marginal revenue for a locally manufactured product in Kampala.The marginal revenue function is given by $MR(x) = x\sqrt{2x^2+5}$, where x is the number of units sold in hundreds. To find the total revenue function, the economist needs to integrate the marginal revenue. The composite function under the square root indicates that a substitution method will simplify the integration process. This analysis is vital for the company to understand its revenue structure and make informed production and pricing decisions in a competitive market.

Task:

a)For the integral $\int x\sqrt{2x^2+5}\,dx$, choose a substitution u that will simplify the expression.
b)Find the indefinite integral using this substitution.
c)If the total revenue is zero when no units are sold, find the constant of integration and write the specific total revenue function.

Sub-topic 19.2: Exponential and Logarithmic Functions

Scenario 145

A public health official is tracking the rate of administration of a new vaccine during a mass vaccination campaign in the Lango sub-region.The rate at which vaccines are administered is modeled by $A(t) = 500e^{0.1t}$ vaccines per day, where t is time in days. To evaluate the campaign's success and plan for future initiatives, the official needs to calculate the total number of vaccines administered from day 5 to day 10 of the campaign. Integrating this exponential function will provide the total, demonstrating the power of exponential growth in successful public health interventions.

Task:

a)Find the indefinite integral $\int 500e^{0.1t}\,dt$.
b)Calculate the total number of vaccines administered between day 5 and day 10.
c)What does the value 0.1 in the exponent represent in the context of the campaign?

Scenario 146

A chemical engineer at a Jinja-based sugar factory is studying the rate of a catalytic reaction used in processing molasses.The reaction rate $R(t)$ is given by $R(t) = \frac{10}{t+1}$ grams per second, for $t \geq 0$. To determine the total amount of product formed in the first 9 seconds of the reaction, the engineer must

integrate this function. The integral of $\frac{1}{t+1}$ is a natural logarithm, making this a key application of integrating functions that yield logarithmic results, which is essential for optimizing industrial processes.

Task:

a)Find the indefinite integral $\int \frac{10}{t+1}\ dt$.

b)Calculate the total product formed from $t = 0$ to $t = 9$ seconds.

c)Explain why the result is a logarithmic function.

Scenario 147

A financial analyst is modeling the depreciation of a fleet of new motorcycles(boda bodas) for a Kampala transport cooperative. The value $V(t)$ of a motorcycle decreases at a rate proportional to its current value, leading to a differential equation $\frac{dV}{dt} = -kV$. The solution to this equation is an exponential decay function. To find the average value of a motorcycle over its first 3 years of service, the analyst needs to integrate this exponential decay function and divide by the time interval. This calculation is critical for the cooperative's accounting, insurance, and long-term financial planning.

Task:

Suppose the value of a motorcycle is $V(t) = 5{,}000{,}000e^{-0.2t}$ UGX, where t is in years.

a)Find the average value of the motorcycle over the first 3 years.

(Recall: Average value $= \frac{1}{b-1}\int f(x)\ dx$)

b)Interpret what the value 0.2 in the exponent means for the depreciation.

c)After how many years will the motorcycle's value be half of its original value?

Sub-topic 19.3: Trigonometric Functions

Scenario 148

A power engineer at the Uganda Electricity Generation Company Ltd(UEGCL) is analyzing the alternating current (AC) power output from the Isimba Hydropower Plant. The instantaneous power delivered to a resistive load is given by $P(t) = V_0I_0\sin^2(\omega t)$, where V_0 and I_0 are peak voltage and current, and \omega is the angular frequency. To calculate the average power over one complete cycle a crucial value for billing and grid stability—the engineer must integrate this trigonometric function. Using the trigonometric identity $\sin^2(\theta) = \frac{1-\cos 2\theta}{2}$ simplifies the integration process, demonstrating a direct application of integrating even powers of sine.

Task:

a)Using the identity, rewrite $P(t) = 1000\sin^2(100\pi)$ in an integrable form. (Assume $V_0I_0 = 1000$ Watts).

b)Find the average power over one period, $T = \frac{2\pi}{100\pi} = 0.02$ seconds. (Average $= \frac{1}{T}\int_0^T P(t)dt$)

c)State the final average power in Watts.

Scenario 149

A civil engineer is designing a parabolic arch for a bridge over the River Nile in Pakwach. For a specific stress analysis, they need to calculate the integral of an odd power of cosine over a symmetric interval. The force distribution along a cross-section of the arch is modeled by $F(\theta) = \cos^3(\theta)$ for $-\frac{\pi}{2} \leq \theta \leq \frac{\pi}{2}$. The total load is found by integrating this function. The engineer simplifies the integral by factoring and using a Pythagorean identity, a common technique for integrating odd powers of trigonometric functions, ensuring the bridge design can handle the calculated stress.

Task:

a)Express $\cos^3(\theta)$ as $\cos(\theta)(1 - \sin^2(\theta))$.

b)Use the substitution $u = \sin(\theta)$ to find the indefinite integral \int \cos^3(\theta) \, d\theta .

c)Evaluate the definite integral $\int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} \cos^3\theta \, d\theta$. Explain the result based on the properties of the function.

Scenario 150

A signal processing engineer at a Ugandan telecommunications company is working on a noise cancellation algorithm. The algorithm requires calculating the integral of the product of two different trigonometric functions, which appears when analyzing signal interference. The specific integral encountered is $\int \sin(3t)\cos(2t)\, dt$. Instead of using a complicated substitution, the engineer employs the Factor Formulae (product-to-sum identities) to rewrite the product as a sum of simpler sine functions, which are straightforward to integrate. This efficient method helps in processing signals faster, improving call quality for millions of users.

Task:

a)Use the product-to-sum identity: $\sin(A)\cos(B) = \frac{1}{2}[\sin(A+B) + \sin(A-B)]$ to rewrite the integrand $\sin(3t)\cos(2t)$.

b)Integrate the resulting expression with respect to t .

c)Hence, find $\int_0^{\frac{\pi}{2}} \sin(3t)\cos(2t)\, dt$.

Sub-topic 19.4: Partial Fractions

Scenario 151

A chemical engineer at a Tororo-based fertilizer plant is modeling the concentration of a catalyst during a batch reaction process.The rate of change of concentration is given by the rational function $\frac{dC}{dt} = \frac{5}{(t+1)(t+3)}$. To find the concentration C as a function of time t , the engineer must integrate this expression. The presence of distinct linear factors in the denominator makes the method of partial fractions the most efficient technique. Accurately modeling the catalyst concentration is essential for controlling the reaction rate and ensuring the final fertilizer product meets quality standards.

Task:

a)Decompose $\frac{5}{(t+1)(t+3)}$ into partial fractions.

b)Hence, find the indefinite integral $\int \frac{5}{(t+1)(t+3)}\, dt$.

c)If the initial concentration at t=0 is 0, find the constant of integration and write the specific solution for C(t) .

Scenario 152

An environmental scientist is studying the decay of a pollutant in Lake Victoria. The decay rate is modeled by the function $R(x) = \frac{x+7}{x^2+x-2}$, where x is time in weeks. To determine the total amount of pollutant that has decayed over a certain period, the scientist needs to integrate this function. The first step is to factor the denominator and apply partial fractions to decompose the complex rational function into simpler terms that can be easily integrated, providing vital data for environmental protection efforts.

Task:

a)Factor the denominator $x^2 + x - 2$.

b)Express $\frac{x+7}{x^2+x-2}$ in partial fractions.

c)Find the indefinite integral $\int \frac{x+7}{x^2+x-2}\, dx$.

Scenario 153

An economist is analyzing the cumulative investment flow I(t) into Uganda's renewable energy sector. The rate of investment is given by the function $I'(t) = \frac{2}{t(t+2)}$ (in billions of UGX per year). To project the

total investment over a 5-year plan, the economist must integrate this rate function from t=1 to t=5 . Using partial fractions to handle the integral of this rational function allows for a clear and accurate projection, which is crucial for government policy and attracting further international investment.

Task:

a)Decompose $\frac{2}{t(t+2)}$ into partial fractions.

b)Find the indefinite integral $\int \frac{2}{t(t+2)}\, dx$.

c)Calculate the total investment from year 1 to year 5.

Sub-topic 19.5: Integration by Parts

Scenario 154

A mechanical engineer at Kiira Motors is analyzing the total energy dissipated by the brakes of a new electric bus model during a specific deceleration test in Kampala.The power dissipation as a function of time is given by $P(t) = 5te^{-0.2t}$ (in kilowatts). The total energy dissipated is the integral of power over time. The function is a product of a polynomial (t) and an exponential function $(e^{-0.2t})$, making integration by parts the ideal method. Accurately calculating this energy is crucial for designing the brake cooling system and ensuring the vehicle's safety and reliability on Uganda's demanding urban routes.

Task:

a)For the integral $\int 5te^{-0.2t}\, dt$, identify the functions u and dv for the integration by parts formula

b)Apply integration by parts to find the indefinite integral.

c)Calculate the total energy dissipated (in kilowatt-seconds) from $t = 0$ to $t = 10$ seconds.

Scenario 155

A software developer at a tech hub in Kampala is writing an algorithm to calculate the area under a curve that represents signal processing data.The function to be integrated is $f(x) = x\ln(x)$ for $x \geq 1$. This function is the product of an algebraic term (x) and a logarithmic term (ln(x)) . The developer recognizes that integration by parts is necessary, choosing $u = \ln(x)$ to simplify the integral, as its derivative $\frac{1}{x}$ is easier to manage. This calculation is a key step in optimizing the signal processing algorithm for use in mobile applications across Uganda.

Task:

a)Apply the integration by parts formula to find $\int x\ln(x)dx$

b)Use the result from part (a) to evaluate $\int_1^e x\ln(x)dx$.

c)Confirm your result by differentiating your answer from part (a).

Scenario 156

An audio engineer is designing a sound filter for a new community radio station in a rural area.The filter's impulse response involves integrating a function of the form $\int \frac{t^2}{\cos t}\, dt$. This requires applying the integration by parts method twice in succession due to the t^2 term. Mastering this technique allows the engineer to precisely model the filter's behavior, ensuring clear audio transmission for educational and informational programs that are vital for rural development.

Task:

a)To find $\int \frac{t^2}{\cos t}\, dt$, apply integration by parts once, using $u = t^2$ and $dv = \cos(t)\, dt$.

b)The resulting integral will still contain a 't' term. Apply integration by parts a second time to complete the solution.

c)Write down the final expression for the indefinite integral $\int \frac{t^2}{\cos t}\, dt$.

Topic 20: DYNAMICS 2

Sub-topic 20.1: Resultant Velocity

Scenario 157

A ferry captain is navigating a boat across Lake Victoria from Entebbe to Lukaya.The boat's engine can propel it at 15 km/h due north relative to the water. However, a strong current is flowing at 5 km/h from the west (i.e., due east). The captain needs to determine the boat's actual speed and direction over the lakebed (its resultant velocity) to accurately estimate the time of arrival and set the correct course to reach the intended destination. Miscalculation could lead to the boat drifting significantly off course, wasting fuel and time. This vector addition problem is fundamental to navigation on all of Uganda's major water bodies.

Task:

a)Represent the boat's velocity and the current's velocity as vectors.
b)Calculate the magnitude of the resultant velocity (the boat's actual speed).
c)Calculate the true bearing of the boat's path across the lake.

Scenario 158

An aircraft pilot needs to fly from Gulu Airport to Kidepo Valley National Park on a bearing of 060°.The aircraft's airspeed (speed relative to the air) is 200 km/h. A wind is blowing from the north at 30 km/h. To follow the desired ground track, the pilot must point the aircraft's nose (its heading) into the wind. The navigator must calculate this heading and the resulting ground speed to file an accurate flight plan and ensure sufficient fuel for the journey over the remote Karamoja region.

Task:

a)Resolve the wind velocity into components acting along and perpendicular to the desired track (060°).
b)Determine the aircraft's required heading to compensate for the wind drift.
c)Calculate the aircraft's ground speed along the desired track.

Scenario 159

A search and rescue team is operating a drone to locate a missing person in the Rwenzori Mountains.The drone can fly at 10 m/s relative to the air. A steady wind is blowing from the southwest at $4\sqrt{2}$ m/s (which gives components of 4 m/s from the west and 4 m/s from the south). The operator needs to direct the drone on a straight-line path with a bearing of 045° (northeast) relative to the ground. To achieve this, the drone must be pointed in a different direction to counteract the wind. Calculating the correct resultant velocity and heading is critical for efficiently covering the search area.

Task:

a)Find the resultant velocity vector that the drone must have to track 045° over the ground.
b)Calculate the heading (direction) the drone must be pointed to achieve this resultant velocity.
c)What will the drone's ground speed be?

Sub-topic 20.2: Relative Motion

Scenario 160

Two boats,A and B, are on Lake Albert. Boat A is located 2 km due east of a lighthouse and is moving due north at 20 km/h. Boat B is located 3 km due north of the same lighthouse and is moving due east at 15 km/h. The coast guard needs to determine if the boats are on a collision course and, if not, find the distance of closest approach between them to assess any risk. This problem involves analyzing the relative motion of one boat with respect to the other.

Task:

a)Find the initial position vector of Boat B relative to Boat A.
b)Find the velocity vector of Boat B relative to Boat A.
c)Calculate the shortest distance between the two boats during their motion.

Scenario 161

Two public buses,the "Nalubaale Express" and the "Speke Coach," are traveling on two straight, perpendicular roads that intersect at a junction in Kampala. The Nalubaale Express is approaching the junction from the west at a constant speed of 60 km/h and is 2 km away. The Speke Coach is approaching from the south at 80 km/h and is 1.5 km away. A traffic control AI needs to calculate the time before they are closest to each other and that minimum distance to evaluate the risk of a collision and manage traffic signals if necessary.

Task:

a)Set up equations for the position of each bus as a function of time, t hours.

b)Find an expression for the distance between the two buses at time t.

c)Find the time t at which this distance is a minimum and calculate the minimum distance.

Scenario 162

During military training exercises in Nakasongola,two armored vehicles are maneuvering. Vehicle P is moving with a velocity of $(3i + 4j)$ m/s, and Vehicle Q has a velocity of $(5i - 2j)$ m/s. The commander in Vehicle Q needs to know the velocity of Vehicle P as seen from his own vehicle. This relative velocity is crucial for tactical positioning, targeting, and avoiding friendly fire incidents during the simulated combat scenario.

Task:

a)State the formula for the velocity of P relative to Q.

b)Calculate the velocity of Vehicle P relative to Vehicle Q.

c)What is the speed of Vehicle P as observed by the commander in Vehicle Q?

Sub-topic 20.3: Projectiles

Scenario 163

The Uganda Wildlife Authority (UWA) is designing a new system to safely tranquilize aggressive elephants from a distance. The tranquilizer dart is fired from a high-pressure gun at an initial speed of 80 m/s. To ensure the dart reaches an elephant typically 150 meters away, the ranger needs to know the correct launch angle. Ignoring air resistance, the ranger must calculate the required angle so that the dart's horizontal range is exactly 150 meters. This ensures the humane and effective immobilization of the animal for relocation or medical treatment.

Task:

a)State the formula for the horizontal range R of a projectile launched with speed u at an angle θ to the horizontal.

b)Calculate the two possible launch angles that will give a range of 150 m with an initial speed of 80 m/s.

c)Which of the two angles would be more practical for this application and why?

Scenario 164

During a cultural festival in Jinja,a cannon is used to launch a payload of confetti over the crowd. The confetti capsule is launched from ground level with an initial velocity of 25 m/s at an angle of 60° to the horizontal. The event organizers need to know the maximum height reached by the capsule and the total time it remains in the air to coordinate the explosion for maximum visual effect and ensure it happens safely above the spectators.

Task:

a)Calculate the maximum height reached by the projectile.

b)Calculate the total time of flight.

c)Determine the horizontal distance from the launch point where the confetti capsule should be set to explode (at the peak of its trajectory).

Scenario 165

An engineer is testing the water jets of a new fountain for the Kampala City Square.One jet is designed to launch water at 10 m/s from a nozzle inclined at 30° to the horizontal. The water is meant to land in a catchment pool that starts 5 meters away from the nozzle. The engineer needs to verify if the water will clear the edge of the pool and determine the maximum height of the fountain to ensure it meets the aesthetic design specifications.

Task:

a)Find the time taken for the water to reach the point 5 meters horizontally from the nozzle.

b)Calculate the height of the water at this horizontal distance. Will it have already landed, or will it clear a 0.5-meter high pool edge?

c)Calculate the maximum height of this water jet.

Topic 21: TRAPEZIUM RULE

Sub-topic 21.1: Estimating an Integral

Scenario 166

A hydrologist at the Ministry of Water and Environment is analyzing the cross-sectional area of the River Nile at a point near Jinja to estimate the flow rate.The width of the river at this point is 20 meters. Depth measurements are taken at 4-meter intervals across the river, yielding the following depths (in meters): 0, 1.2, 2.5, 3.1, 2.8, 1.9, 0. The hydrologist needs to estimate the cross-sectional area of the river. Since the shape is irregular, the Trapezium Rule provides a suitable numerical method for this estimation, which is crucial for calculating the volume of water flowing downstream to the power plant.

Task:

a)Sketch the cross-section with the given data points.

b)Use the Trapezium Rule with 6 strips (7 ordinates) to estimate the cross-sectional area.

c)State one way to improve the accuracy of this estimate.

Scenario 167

An environmental scientist is studying the rate of carbon dioxide absorption by a forest plantation in the Bugoma Forest area.The rate of absorption, $R(t)$ in tons per day, was recorded at the start of each month for a year. The values are complex and do not fit a simple function. To find the total amount of CO_2 absorbed over the year, the scientist needs to integrate the rate function. Using the available discrete data points, the Trapezium Rule offers a practical way to approximate this definite integral and assess the forest's carbon sequestration potential, a key metric for climate change mitigation efforts in Uganda.

Task:

Suppose the following simplified data represents the rate at the start of each month for 6 months: $R = \{2, 5, 7, 6, 4, 3\}$ tons/day.

a)State the width h of each strip if the data covers a 6-month period.

b)Apply the Trapezium Rule to estimate the total CO_2 absorbed over the 6 months.

c)What is the unit of your final answer, and what does it represent?

Scenario 168

An electrical engineer at Umeme Ltd.is analyzing the power consumption of a small factory in Namanve over a 24-hour period. The power $P(t)$ in kilowatts was logged every 4 hours. The values are: $P = \{50, 150, 200, 180, 120, 80, 60\}$. The total energy consumed is the integral of power over time. Since the function is not known, the engineer uses the Trapezium Rule to estimate the total energy usage in kilowatt-hours (kWh). This helps the factory manager understand daily energy costs and identify peak usage periods.

Task:

a)List the 7 ordinates y_0 to y_6 from the data.

b)Apply the Trapezium Rule formula to estimate the integral $\int_0^{24} P(t)\,dt$.
c)State the estimated total energy consumption in kWh.

Sub-topic 21.2: Percentage Error
Scenario 169
A civil engineer needs to calculate the area of a land plot bounded by a curved road and a straight boundary.The perpendicular distances from the straight boundary to the curve are known at 5-meter intervals. The exact area can be found by integrating the function f(x) = 10 + $\sqrt{x}$ from x=0 to x=20 . To check the reliability of a field measurement done using the Trapezium Rule with 4 strips, the engineer calculates the percentage error between the trapezium estimate and the exact integral value. This validates the field method for rapid land area assessment in Uganda's ongoing road expansion projects.
Task:
a)Calculate the exact value of $\int_0^{20} 10 + \sqrt{x}\ dx$.
b)Use the Trapezium Rule with 4 strips (h=5) to estimate the integral.
c)Calculate the percentage error of the trapezium estimate compared to the exact value.
Scenario 170
A physics student at Makerere University is using a sensor to measure the force exerted on a moving object over time.The data is collected at discrete intervals, and the student uses the Trapezium Rule to estimate the total impulse (the integral of force with respect to time). To understand the accuracy of this method for their experiment, they test it on a function with a known integral: $\int_0^6 x^2\,dx$. Comparing the trapezium estimate with the exact value allows the student to report a percentage error, which is essential for evaluating the experimental setup's precision.
Task:
a)Find the exact value of $\int_0^6 x^2\,dx$
b)Estimate the integral using the Trapezium Rule with 3 strips (h=2).
c)Calculate the percentage error of this estimate.
Scenario 171
A financial analyst is modeling the total revenue over a quarter (90 days) where the daily revenue rate r(t) is given by the function $r(t) = 1000e^{0.001t}$. The exact total revenue is $\int_0^{90} r(t)dt$. The analyst wants to use the Trapezium Rule for a quick approximation but needs to quantify the potential error if they use only 9 strips (10 data points, one every 10 days). Calculating the percentage error helps decide if this level of approximation is acceptable for the preliminary report to the board of directors.
Task:
a)Calculate the exact value of $\int_0^{90} r(t)dt$.
b)Estimate the integral using the Trapezium Rule with 9 strips (h=10).
c)Find the percentage error in the trapezium estimate.

Topic 22: SAMPLING DISTRIBUTION
Sub-topic 22.1: Distribution of Sampling Mean
Scenario 172
The Uganda Bureau of Statistics(UBOS) is conducting a study on household electricity consumption in Kampala. From historical data, they know that the monthly consumption for a household is normally distributed with a mean (μ) of 250 kWh and a standard deviation (σ) of 50 kWh. UBOS plans to take a random sample of 100 households to estimate the average consumption. The statisticians need to determine the probability that the sample mean will be greater than 260 kWh. This involves

understanding the distribution of the sample mean, which is crucial for planning energy distribution and identifying potential shifts in consumption patterns that could strain the national grid.

Task:

a)State the mean and standard deviation (standard error) of the sampling distribution of the sample mean for a sample size of $n = 100$.

b)Calculate the z-score for a sample mean of $x = 260$ kWh.

c)Find the probability that the sample mean exceeds 260 kWh.

Scenario 173

A large maize mill in Mbale receives shipments of maize from local farmers. The weight of a fully loaded truck is known to be normally distributed with a mean of 10,000 kg and a standard deviation of 400 kg. The quality control manager randomly selects 25 trucks and weighs them to check if the average load is consistent with the expected mean. The manager needs to know the probability that the average weight of this sample is less than 9,900 kg, which would indicate a potential issue with the loading process or the scales.

Task:

a)Describe the distribution of the sample mean weight for samples of size $n = 25$.

b)Calculate the standard error of the mean.

c)Find the probability that the sample mean weight is less than 9,900 kg.

Scenario 174

A mobile money company analyzes the average transaction value. The transaction values are heavily right-skewed with a mean of UGX 50,000 and a standard deviation of UGX 20,000. Due to the Central Limit Theorem, the company knows that the distribution of the sample mean for large samples will be approximately normal. For their annual audit, they take a random sample of 64 transactions. The auditors need to know the probability that the average transaction value in this sample falls between UGX 48,000 and UGX 52,000 to assess the accuracy of their financial reporting.

Task:

a)State the mean and standard error of the sampling distribution for $n = 64$.

b)Calculate the z-scores for sample means of UGX 48,000 and UGX 52,000.

c)Find the probability that the sample mean lies between UGX 48,000 and UGX 52,000.

Sub-topic 22.2: Point Estimation

Scenario 175

A pharmaceutical company in Entebbe is testing the purity of a new batch of antimalarial tablets.The active ingredient content per tablet should be 500 mg. The quality control team takes a random sample of 30 tablets from the production line and measures the active ingredient. The sample mean is calculated to be 498 mg. The team uses this single value, the point estimate, as the best guess for the true population mean of the entire batch. This point estimate is critical for deciding whether to release the batch for distribution or to reject it, ensuring that patients receive the correct dosage.

Task:

a)What is the point estimate for the population mean active ingredient content?

b)Is this point estimate a parameter or a statistic?

c)State one limitation of relying solely on a point estimate.

Scenario 176

The Ministry of Agriculture wants to estimate the average yield of maize(in tons per hectare) for smallholder farmers in the Lango sub-region this season. It is impractical to measure every farm, so they commission a survey. A random sample of 50 farms is selected, and the sample mean yield is calculated to be 2.5 tons per hectare. This value serves as the point estimate for the true average yield across the

entire region. This estimate is vital for forecasting national food security and planning for potential imports or exports.

Task:

a)Identify the parameter being estimated and the point estimator used.

b)The sample standard deviation is found to be 0.4 tons/hectare. What is the point estimate for the population variance?

c)Why is it important that the sample is random?

Scenario 177

A university administrator wants to estimate the proportion of students who are satisfied with the new online learning platform.A random sample of 200 students is surveyed, and 150 of them express satisfaction. The sample proportion $p = \frac{150}{200} = 0.75$ is used as a point estimate for the true population proportion p of all students who are satisfied. This information helps the administration decide whether to continue investing in the platform.

Task:

a)What is the point estimate for the population proportion p ?

b)Calculate the standard error of this point estimate.

c)If another sample of 200 students were taken, would you expect the point estimate to be exactly 0.75 again? Explain.

Sub-topic 22.3: Interval Estimation

Scenario 178

Following the maize yield survey in Lango sub-region(Scenario 176), the Ministry of Agriculture realizes that a single point estimate of 2.5 tons/hectare does not convey the uncertainty in the estimate. They decide to construct a 95% confidence interval for the true average yield. With a sample mean of 2.5, a sample standard deviation of 0.4, and a sample size of 50, they can calculate an interval that they are 95% confident contains the true population mean. This interval provides a range of plausible values, which is more informative for policy-making than a single number.

Task:

a)Calculate the standard error of the mean.

b)Find the critical z-value for a 95% confidence level.

c)Construct a 95% confidence interval for the true average maize yield.

Scenario 179

A public health researcher wants to estimate the average blood pressure of adults in a specific district.From a random sample of 40 adults, the sample mean is 128 mmHg and the sample standard deviation is 15 mmHg. Since the population standard deviation is unknown and the sample size is less than 60, the researcher uses the t-distribution to construct a 99% confidence interval. This interval will provide a range that is very likely to contain the true district-wide average blood pressure, helping to identify potential public health risks.

Task:

a)State the degrees of freedom for the t-distribution in this case.

b)Find the critical t-value for a 99% confidence interval.

c)Construct the 99% confidence interval for the population mean blood pressure.

Scenario 180

The university administrator from Scenario 177,who found a sample proportion of 0.75, now wants to construct a 90% confidence interval for the true proportion of satisfied students. This interval will show a range of values that is likely to contain the **actual** satisfaction rate for the entire student population, giving a better sense of the estimate's precision than the point estimate alone.

Task:
a)Calculate the standard error for the sample proportion.
b)Find the critical z-value for a 90% confidence level.
c)Construct a 90% confidence interval for the true population proportion p.

Topic 23: ITERATIVE METHODS
Sub-topic 23.1: Interpolation and Extrapolation
Scenario 181
A hydrologist at the Ministry of Water and Environment is analyzing water level data from Lake Victoria. The water level L (in meters above sea level) was recorded at specific times. At 6:00 AM, the level was 1133.50 m; at 10:00 AM, it was 1133.65 m; and at 2:00 PM, it was 1133.55 m. The hydrologist needs to estimate the water level at 12:00 PM (interpolation) to fill a data gap and predict the level at 6:00 PM (extrapolation) for dam management purposes. Using linear interpolation between the closest known points provides a simple yet effective method for these estimations, which are critical for managing water release schedules at the Owen Falls Dam.
Task:
a)Using the data points for 10:00 AM (1133.65 m) and 2:00 PM (1133.55 m), estimate the water level at 12:00 PM via linear interpolation.
b)Estimate the water level at 6:00 PM by extrapolating from the 2:00 PM data point, assuming the rate of change between 10:00 AM and 2:00 PM continues.
c)State one risk associated with using extrapolation for prediction.
Scenario 182
An economist at the Bank of Uganda is studying the relationship between the interest rate(%) and the volume of loans (UGX billions) issued by commercial banks. Data is available for interest rates of 5%, 10%, and 15%, with corresponding loan volumes of 500, 400, and 200 billion UGX respectively. The economist needs to estimate the loan volume that would correspond to an interest rate of 12%, a value not directly observed in the data. This process of interpolation helps the central bank understand the potential impact of its monetary policy decisions on private sector credit.
Task:
a)Identify the two data points that should be used to interpolate the loan volume at 12%.
b)Use linear interpolation between these points to estimate the loan volume at a 12% interest rate.
c)If the interest rate were to rise to 18%, extrapolate to estimate the potential loan volume.
Scenario 183
An agricultural researcher is measuring the growth of a bean plant over time.The height of the plant was recorded on day 5 (10 cm), day 10 (16 cm), and day 15 (19 cm). The researcher needs to estimate the plant's height on day 12, a day for which data is missing, to complete a growth chart. This is a classic case for interpolation. Additionally, predicting the height on day 20 via extrapolation can help forecast the plant's maturity, although this is less reliable.
Task:
a)Estimate the height of the bean plant on day 12 using linear interpolation.
b)Estimate the height on day 20 using extrapolation from the last two data points.
c)Why is the estimate for day 20 likely to be less accurate than the estimate for day 12?

Sub-topic 23.2: Location of Roots
Scenario 184
A civil engineer is designing a new water pipeline that must follow a specific gradient.The elevation of the pipeline is modeled by the function $f(x) = x^3 - 3x^2 - 4x + 12$, where x is the horizontal distance in

kilometers. The pipeline must be laid where the elevation is exactly 10 meters above the baseline (i.e., where $f(x) = 10$). The engineer needs to find the horizontal distance x where this occurs. Rearranging gives $g(x) = x^3 - 3x^2 - 4x + 2 = 0$. The first step is to locate the interval where the root lies by evaluating $g(x)$ for different values of x and finding a sign change, which indicates a root lies between them.

Task:

a)Evaluate $g(x)$ for $x = 0$ and $x = 2$.

b)Based on your results, does a root exist between $x = 0$ and $x = 2$? Justify your answer.

c)Evaluate $g(3)$ and state another interval that contains a root.

Scenario 185

A financial analyst is trying to determine the internal rate of return(IRR) for a potential investment in a solar farm. The net present value (NPV) is a function of the discount rate r , given by $NPV(r) = -100 + \frac{40}{1+r} + \frac{60}{(1+r)^2} + \frac{50}{(1+r)^3}$. The IRR is the value of r that makes $NPV(r) = 0$. The analyst needs to find this root. By evaluating the function for different values of r , they can locate an interval where the sign of $NPV(r)$ changes, confirming the existence of a root within that interval.

Task:

a)Calculate $NPV(r)$ for $r = 0.0$ (0%).

b)Calculate $NPV(r)$ for $r = 0.1$ (10%).

c)Based on your calculations, confirm that a root (the IRR) lies between $r= 0.0$ and $r= 0.1$.

Scenario 186

An environmental scientist is modeling the concentration of a pollutant in a lake over time. The concentration $C(t)$ is given by $C(t) = e^{-0.2t} - 0.5t + 1$. The scientist wants to find the time t when the concentration drops to zero (i.e., find the root of $C(t) = 0$). This time represents when the lake is expected to be free of the pollutant. The first step is to locate the interval where this root lies by testing values of t and looking for a sign change in $C(t)$.

Task:

a)Evaluate $C(t)$ for $t = 0$ and $t = 2$.

b)Is there a root between $t=0$ and $t=2$? Explain.

c)Evaluate $C(t)$ for $t=3$ to further narrow down the interval containing the root.

Sub-topic 23.3: Newton Raphson Method

Scenario 187

A structural engineer needs to find the critical load factor \lambda for a bridge design, which is a root of the equation $x^3 + 2x - 5 = 0$. An initial rough estimate suggests x is close to 1.3. The Newton-Raphson method provides a fast, iterative way to find an accurate solution. This precise calculation is essential for ensuring the bridge can withstand expected loads without costly over-engineering, a key consideration for infrastructure projects in Uganda.

Task:

Let $f(x) = x^3 + 2x - 5$.

a)Find the derivative $f'(x)$.

b)Using $x_0 = 1.3$ as the initial guess, perform one iteration of the Newton-Raphson method to find x_1 .

c)State the formula for the Newton-Raphson method.

Scenario 188

A computer scientist is developing a graphics algorithm that requires calculating the inverse of a number using only addition and multiplication(i.e., without division). This can be done by finding the root of $f(x) = a - \frac{1}{x}$, which simplifies to $f(x) = ax - 1 = 0$, where a is the number. For $a = 5$, the root is $x = 0.2$ The scientist uses the Newton-Raphson method with an initial guess of $x_0 = 0.5$ to quickly converge to

the solution, optimizing the algorithm's performance for real-time rendering in Ugandan-made mobile applications.

Task:

For $f(x) = 5x - 1$

a)Find the derivative $f'(x)$.

b)Perform two iterations of the Newton-Raphson method starting from $x_0 = 0.5$.

c)How does the speed of this convergence demonstrate the strength of the Newton-Raphson method?

Scenario 189

An electrical engineer is analyzing a circuit where the voltage V satisfies the equation $V + 2\ln(V) - 3 = 0$. An approximate solution is needed for simulation software. The engineer knows that V is positive and roughly around 2. The Newton-Raphson method is an efficient way to find a precise solution for this transcendental equation, which cannot be solved algebraically. This allows for accurate modeling of the circuit's behavior.

Task:

Let $f(V) = V + 2\ln(V) - 3$.

a)Find the derivative $f'(V)$.

b)Using $V_0 = 2$ as the initial guess, perform one iteration of the Newton-Raphson method to find V_1 .

c)Why is the Newton-Raphson method particularly suitable for this problem compared to simpler methods like bisection?

Topic 24: COORDINATE GEOMETRY 2

Sub-topic 24.1: Locus

Scenario 190

A city planner in Kampala is designing a new park.A key feature is a fountain that will be placed such that its distance from two intersecting footpaths (which act as the x-axis and y-axis) is always equal. The planner needs to find the equation of the path that the fountain's center must follow. This path is a locus defined by the condition that its perpendicular distances to the two axes are equal. Understanding this locus helps in precisely positioning the fountain and other symmetrical elements within the park's design, ensuring aesthetic balance.

Task:

a)If a point $P(x, y)$ is equidistant from the x-axis and the y-axis, write an equation relating x and y . (Hint: Distance from the x-axis is $|y|$, from the y-axis is $|x|$).

b)Simplify this equation to find the locus of all such points P .

c)Sketch the locus on a coordinate plane.

Scenario 191

An architect is designing a modern building with a curved glass facade.The curve is defined by a locus: every point on the curve is twice as far from the point (3, 0) as it is from the line $x = -3$. This specific geometric property will create a unique parabolic reflection of sunlight. The architect needs the equation of this locus to create precise digital models and construction plans for the builders.

Task:

a)Let $P(x, y)$ be a point on the locus. Write an expression for its distance from the point (3, 0).

b)Write an expression for the perpendicular distance from $P(x, y)$ to the line $x = -3$.

c)Use the given condition (distance from point is twice the distance from line) to derive the equation of the locus.

Scenario 192

A telecommunications company is installing a new radio tower.The signal strength is strongest for receivers that are exactly 3 km closer to this new tower (located at (0, 4)) than to an existing tower

(located at (0, -4)). The engineers need to map the area of optimal signal strength. The boundary of this area is a locus defined by the constant difference in distances to two fixed points, which forms a hyperbola. This analysis is crucial for network planning and customer communication.

Task:

a)Let $P(x, y)$ be a point on the locus. Write an equation stating that the distance from P to (0, 4) is 3 km less than the distance from P to (0, -4).

b)Simplify this equation to find the standard form of the hyperbola.

c)What are the coordinates of the foci of this hyperbola?

Sub-topic 24.2: The Circle

Scenario 193

A civil engineer is designing a circular roundabout at a major intersection in Entebbe.The center of the roundabout is planned at coordinates (5, 2) on the city grid, and it must have a radius of 30 meters to accommodate the expected traffic flow. The engineer needs the equation of this circle to interface with road design software and to calculate the exact coordinates for the curb and landscaping elements. This precise mathematical definition ensures the roundabout is built correctly the first time, saving time and resources.

Task:

a)Write down the standard equation of a circle with center (h, k) and radius r.

b)State the equation of the roundabout with center (5, 2) and radius 30.

c)A lamppost is planned at point (20, 2). Determine if this lamppost lies on the circumference of the roundabout, inside it, or outside it.

Scenario 194

A land surveyor is mapping a plot of land bounded by three straight fences.The owner wants to build a circular water reservoir that touches all three fences. The equations of the fences are $y = 0$, $x = 0$, and $y = 8 - 2x$. The surveyor realizes that the center of the required circle must be equidistant from all three lines. This center is the incenter of the triangle formed by the fences, and the distance to any line is the radius. Finding this circle is essential for planning the construction.

Task:

a)The center (h, k) of the circle is equidistant from the lines $y=0$, $x=0$, and $y=8-2x$. Write an equation relating h and k using the distance from (h, k) to $y=0$ and $x=0$.

b)Write another equation using the perpendicular distance from (h, k) to the line $y = 8 - 2x$ (or $2x + y - 8 = 0$).

c)Solve these equations to find the coordinates of the center (h, k).

Scenario 195

An archaeologist discovers the remnants of a ancient circular stone structure.Through excavation, three points on the original circumference are found: A(1, 1), B(2, 4), and C(5, 3). To reconstruct the full plan of the structure, the archaeologist needs to find the equation of the circle that passes through these three points. This involves finding the center and radius from the general equation of a circle.

Task:

a)Substitute each point A, B, and C into the general equation of a circle $x^2 + y^2 + 2gx + 2fy + c = 0$ to form three equations.

b)Solve these simultaneous equations to find the values of g, f, and c.

c)Hence, state the center and radius of the ancient structure.

Sub-topic 24.3: Parabola

Scenario 196

An engineer is designing a solar cooker for a rural community in Uganda.The cooker uses a parabolic reflector to focus sunlight onto a single point (the focus) where the cooking pot is placed. The reflector's cross-section is a parabola with its vertex at the origin (0, 0) and its axis along the x-axis. If the focus is placed 0.5 meters from the vertex, the engineer needs the equation of the parabola to manufacture the reflector with the correct curvature for maximum efficiency.

Task:

a)For a parabola with vertex at (0,0) and focus at (a, 0), what is its standard equation?

b)Given the focus is at (0.5, 0), state the value of a and write the equation of the parabola.

c)How wide is the reflector (the length of the latus rectum) to ensure the pot holder is the correct size?

Scenario 197

A suspension bridge is being planned over a river.The main cable hangs in the shape of a parabola. The towers on either side are 100 meters high and 200 meters apart. The lowest point of the cable is 20 meters above the water level, midway between the towers. Civil engineers need the equation of this parabola to calculate the length of the cable and the forces acting on the towers, which is critical for the structural design and safety of the bridge.

Task:

a)Set up a coordinate system with the origin at the lowest point of the cable. The parabola opens upwards. If the towers are 100 m apart horizontally from the origin, and the cable is 80 m higher at the towers, what is a point on the parabola?

b)Using the standard form $x^2 = 4ay$, find the value of a .

c)Write the equation of the parabola.

Scenario 198

A satellite dish is being installed to receive educational broadcasts in a remote school.The dish has a parabolic shape to reflect signals to a receiver at the focus. The dish is 2 meters wide and 0.5 meters deep. The installer needs to know how far from the vertex (the deepest point) to place the receiver. This requires finding the focus of the parabola that models the dish's cross-section.

Task:

a)Model the dish's cross-section as a parabola with its vertex at (0,0) and opening upwards. If the dish is 2 m wide and 0.5 m deep, what are the coordinates of the rim points?

b)Using the standard form $x^2 = 4ay$, substitute the coordinates of a rim point to find a .

c)How far from the vertex should the receiver (the focus) be placed?

Sub-topic 24.4: Ellipse

Scenario 199

An architect is designing a"whispering gallery" for a new national museum. The room has an elliptical shape. When a person stands at one focus and whispers, the sound is reflected by the walls and can be clearly heard at the other focus. The room is to be 20 meters long (the major axis) and 12 meters wide (the minor axis). The architect needs to find the precise location of the two foci to design the seating and acoustic panels correctly.

Task:

a)For an ellipse centered at the origin with a horizontal major axis, what is its standard equation in terms of a and b , where $2a$ is the major axis and $2b$ is the minor axis?

b)Given $2a = 20$ and $2b = 12$, find a and b .

c)Calculate the distance c from the center to each focus using the relationship $c^2 = a^2 - b^2$.

Scenario 200

A gardener is planning an elaborate elliptical flower bed for a city park.The bed will be marked out with string tied between two stakes (the foci). The total length of the string is 10 meters. The gardener wants the ellipse to be 6 meters wide at its narrowest point (the minor axis). To set this up, the gardener needs to calculate how far apart to place the two stakes and the length of the semi-major axis.

Task:

a)The total length of the string is $2a$. Given this is 10 m, find a .

b)The minor axis is $2b = 6$ m. Find b .

c)Use the relationship $c^2 = a^2 - b^2$ to find c , the distance from the center to each focus. How far apart should the stakes be placed?

Scenario 201

An astronomer is tracking the orbit of a Ugandan satellite around the Earth.The orbit is elliptical. At its closest point (perigee), the satellite is 500 km from the Earth's center, and at its farthest point (apogee), it is 700 km away. The Earth's center is at one focus of the ellipse. The astronomer needs the equation of the elliptical orbit to predict the satellite's position at any given time for communication and data collection purposes.

Task:

a)In an elliptical orbit, the perigee distance is $a - c$ and the apogee distance is $a + c$. Given these are 500 km and 700 km respectively, form two equations and solve for a and c .

b)Find b , the semi-minor axis, using $b^2 = a^2 - c^2$.

c)Write the equation of the satellite's orbit, assuming the major axis is horizontal and the center of the ellipse is at the origin.

Topic 25: COMPLEX NUMBERS

Sub-topic 25.1: Imaginary Numbers

Scenario 202

An electrical engineering student at Kyambogo University is analyzing an AC circuit that has both resistance and inductance. The impedance Z of such a circuit is a complex number, given by $Z = R + j\omega L$, where R is the resistance, ω is the angular frequency, L is the inductance, and j is the imaginary unit (where $j^2 = -1$). The student needs to calculate the impedance for a circuit where $R = 4\omega$, $\omega L = 3\omega$. Understanding how to represent and manipulate this complex number is fundamental to predicting the circuit's behavior, such as the phase difference between voltage and current, which is crucial for designing efficient electrical systems across Uganda.

Task:

a)Write the impedance Z in the form $a + bj$.

b)Calculate the magnitude (modulus) of the impedance, $|Z|$.

c)Explain why the impedance cannot be represented by a single real number in this AC circuit.

Scenario 203

A control systems engineer is designing a stability analysis for an automated irrigation system.The system's transfer function has a pole at $s = -2 + 5j$. The engineer needs to understand the nature of this complex root. If the real part is negative, the system is stable; if positive, it is unstable. The imaginary part relates to the oscillation frequency of the system's response. Identifying and interpreting these complex roots is essential for ensuring the irrigation system responds predictably and without destructive oscillations to commands from the central control unit.

Task:

a)Plot the complex number $-2 + 5j$ on an Argand diagram.

b)State the real part and the imaginary part of this number.

c)Based on the real part, would you predict the system to be stable or unstable?

Scenario 204

A mathematician is exploring the fundamental theorem of algebra,which states that a polynomial of degree n has exactly n roots in the complex number system. They consider the simple quadratic equation $x^2 + 1 = 0$. This equation has no solutions in the real number system because no real number squared gives -1. The introduction of the imaginary unit j (where $j^2 = -1$) is necessary to solve such equations, forming the foundation for complex numbers which are indispensable in advanced mathematics, engineering, and physics.

Task:

a)Solve the quadratic equation $x^2 + 1 = 0$ for x .

b)Write the two solutions in the form $a + bj$.

c)Verify your solutions by substituting them back into the original equation.

Sub-topic 25.2: Algebra of Complex Numbers

Scenario 205

A signal processing engineer at a telecommunications company in Kampala is combining two signal waves.The first wave is represented by the complex number $z_1 = 3 + 4j$ and the second by $z_2 = 1 - 2j$. The combined signal is the sum of these two complex numbers. The engineer needs to find this resultant signal to analyze its amplitude and phase. Correctly adding complex numbers is a routine but critical operation in signal processing for mobile networks, ensuring clear communication for millions of users.

Task:

a)Find the sum $z_1 + z_2$.

b)Find the product $z_1 \times z_2$.

c)Find the quotient of z_1 & z_2.

Scenario 206

A physicist is modeling the interference pattern of two light waves.The waves are represented by complex numbers $A = 2 + j$ and $B = 1 + 3j$. The intensity of the interference is related to the square of the magnitude of the sum of these complex numbers. The physicist needs to calculate $|A + B|^2$ to predict the brightness of the interference fringes in an experiment. This application is key to understanding wave optics, which has applications in laser technology and precision measurement instruments.

Task:

a)Calculate $A + B$.

b)Find the magnitude $|A + B|$.

c)Hence, find $|A + B|^2$.

Scenario 207

An economist is using a quadratic formula to model economic growth,which yields complex solutions. The solutions are $z = 2 + 3j$ and its complex conjugate. The economist needs to verify that these are indeed roots of the quadratic equation $z^2 - 4z + 13 = 0$. Understanding how complex roots work in pairs (conjugates) and how to substitute them into equations is vital for accurate economic forecasting models that can handle oscillatory behavior.

Task:

a)State the complex conjugate of $z = 2 + 3j$.

b)Substitute $z = 2 + 3j$ into the expression $z^2 - 4z + 13$ and show that the result is zero.

c)Explain why complex roots of real-coefficient polynomials always come in conjugate pairs.

Sub-topic 25.3: Argand Diagram and Polar Form

Scenario 208

An avionics engineer is plotting the position of an aircraft on a radar screen.The aircraft's position relative to the control tower is given by the complex number $z = 3 + 4j$, where the real axis represents East-West and the imaginary axis represents North-South (units in km). The engineer needs to convert this Cartesian coordinate into polar form (modulus and argument) to determine the actual distance and bearing of the aircraft from the tower, which is the standard format used for air traffic control communications.

Task:

a)Plot the point $z = 3 + 4j$ on an Argand diagram.

b)Calculate the modulus $r = |z|$, which represents the distance from the origin.

c)Calculate the argument $\theta = \arg(z)$, which represents the bearing from due east.

Scenario 209

An electrical engineer is analyzing the phase relationship between voltage and current in a capacitive circuit. The complex impedance is $Z = 5 - 5j$ ohms. To find the phase angle π by which the voltage lags the current, the engineer needs to find the argument of this complex number. The polar form $Z = r(\cos\theta + j\sin\theta)$ makes it easy to extract this phase information, which is crucial for designing power factor correction circuits to improve the efficiency of Uganda's electrical grid.

Task:

a)Find the modulus r of $Z = 5 - 5j$.

b)Find the argument θ of Z . (Ensure you identify the correct quadrant).

c)Write Z in polar form.

Scenario 210

A mathematician is solving the cubic equation $z^3 = 8$. They know one real root is $z = 2$, but the fundamental theorem of algebra states there should be three roots in total. To find the other two complex roots, they decide to write the number 8 in polar form and then use De Moivre's Theorem. This approach elegantly reveals all roots, demonstrating the power of the polar form for solving polynomial equations.

Task:

a)Write the real number 8 in polar form.

b)Use the formula for the n th roots of a complex number to find all three cube roots of 8.

c)Represent all three roots on a single Argand diagram.

Sub-topic 25.4: Locus

Scenario 211

A telecommunications engineer is designing a cellular network for a hilly region in Kabale.A signal booster must be placed such that its distance from two existing towers (represented by complex numbers $z_1 = -3 + 0j$ and $z_2 = 3 + 0j$) is equal. This ensures balanced signal distribution. The set of all possible points for the booster forms a locus. The engineer recognizes this as the perpendicular bisector of the line segment joining the two towers. Finding the equation of this line is crucial for selecting optimal booster locations on the map.

Task:

a)The condition is $|z - z_1| = |z - z_2|$. Substitute $z_1 = -3$ and $z_2 = 3$.

b)Let $z = x + yj$. Substitute into the equation from (a) and simplify to find the Cartesian equation of the locus.

c)Describe the geometric shape of this locus.

Scenario 212

A satellite operator needs to define a"keep-out zone" around a satellite located at position $z_0 = 1 + 2j$ in the complex plane (representing coordinates in space). The zone is defined as all points within a distance

of 4 units from the satellite to avoid collisions with space debris. This region is a circular disk. The operator needs the inequality that describes this locus to program into the satellite's collision avoidance system.

Task:

a)Write the inequality that represents all points z whose distance from $z_0 = 1 + 2j$ is less than or equal to 4.

b)Let $z = x + yj$. Substitute into the inequality and express it in Cartesian form.

c)What is the center and radius of the circle that forms the boundary of this locus?

Scenario 213

A robotics engineer is programming an autonomous vehicle to follow a specific path in a warehouse.The path is defined by the locus of points z such that the argument of $(z - (1 + j))$ is $\frac{\pi}{4}$ radians. This means the vehicle must move along a straight line emanating from the point 1+j at a fixed angle. The engineer needs the Cartesian equation of this line to code the vehicle's navigation system.

Task:

a)The condition is $\arg(z - (1+j)) = \frac{\pi}{4}$. Let $z = x + yj$.

b)Find an expression for $\arg(x - 1 + (y-1)j)$.

c)Using the fact that $\tan(\arg(u)) = \frac{Im}{Re}$, find the Cartesian equation of this locus.

Sub-topic 25.5: De Moivre's Theorem

Scenario 214

An electrical engineer is analyzing a three-phase power system,a common method for electrical power generation, transmission, and distribution used in Uganda's national grid. The three phase voltages are separated by 120°. Using De Moivre's Theorem, the engineer can represent these voltages as complex numbers: $V, V\omega, V\omega^2$, where ω is the complex cube root of unity. This representation simplifies the analysis of power flow and balance in the system, which is essential for maintaining a stable and efficient grid.

Task:

a)Find the complex cube roots of unity, i.e., solve $z^3 = 1$. (Hint: Write 1 in polar form).

b)Show that $1 + \omega + \omega^2 = 0$.

Scenario 215

A computer graphics programmer needs to compute $(1 + j)^{10}$ to rotate an object in a 2D simulation for an educational app developed in Kampala. Calculating this directly would be very inefficient. Instead, the programmer converts $1+j$ to polar form and applies De Moivre's Theorem, which states $[r(\cos\theta + j\sin\theta)]^n = r^n(\cos n\theta + j\sin n\theta)$. This allows for a quick and precise calculation of the high power, enabling smooth animations.

Task:

a)Convert $z = 1 + j$ to polar form.

b)Use De Moivre's Theorem to find z^{10}.

c)Convert your answer back to Cartesian (a+bj) form.

Scenario 216

A mathematician is exploring patterns in trigonometric identities.They suspect that $\cos(3\theta)$ can be expressed in terms of powers of $\cos\theta$. Using De Moivre's Theorem and the binomial expansion, they can derive a triple-angle formula. This process demonstrates the deep connection between complex numbers and trigonometry, with applications in signal processing and physics.

Task:

a)State De Moivre's Theorem.

b)Write $(\cos\theta + j\sin\theta)^3$ in two ways: using De Moivre's Theorem and using the binomial expansion.

c)By equating the real parts of both expressions, derive the identity for $\cos(3\theta)$.

Topic 26: DIFFERENTIAL EQUATIONS

Sub-topic 26.1: Differential Equations

Scenario 217

A biomedical engineer at Mulago Hospital is modeling the concentration C(t) of a drug in a patient's bloodstream. The rate at which the drug is eliminated is proportional to its current concentration. This leads to the differential equation $\frac{dC}{dt}$ = -kC, where $k > 0$ is the elimination constant. Solving this equation allows doctors to predict how long the drug remains at therapeutic levels, which is critical for determining correct dosing intervals for antibiotics and other essential medicines.

Task:

a)Classify the differential equation $\frac{dC}{dt}$ = -kC . (Is it ordinary/partial? What order? Linear/Non-linear?).

b)Solve this differential equation by separating the variables to find the general solution for C(t)

c)If the initial concentration at t=0 is C_0 , find the particular solution.

Scenario 218

An environmental scientist is studying the population P(t) of a protected bird species in the Mabira Forest Reserve. The population grows at a rate proportional to the current population (exponential growth), but also faces a limitation due to carrying capacity K of the forest (logistic growth). A simple logistic model is given by $\frac{dP}{dt}$ = rP(1 - $\frac{P}{K}$). Solving this differential equation helps conservationists predict the long-term population and assess the success of their protection efforts.

Task:

a)The equation $\frac{dP}{dt}$ = rP(1 - $\frac{P}{K}$) is a first-order differential equation. Is it separable?

b)By separating variables, show that the equation can be written as: $\int \frac{dP}{1-\frac{P}{K}} = \int r\, dt.$

c) (Optional/Challenge) The solution involves partial fractions. Set up the partial fraction decomposition for $\frac{1}{1-\frac{P}{K}}$.

Scenario 219

A mechanical engineer is analyzing the displacement x(t) of a shock absorber on a newly assembled bodaboda (motorcycle). The system is modeled by the differential equation $\frac{d^{2x}}{dt^2} + 3\frac{dx}{dt} + 2x = 0$, which represents damped harmonic motion. Solving this second-order differential equation reveals whether the shock absorber will smoothly return to equilibrium or oscillate violently, directly impacting rider safety and comfort on Uganda's often bumpy roads.

Task:

a)What is the order of the differential equation $\frac{d^{2x}}{dt^2} + 3\frac{dx}{dt} + 2x = 0$?

b)To solve it, we assume a solution of the form $x = e^{mt}$. Substitute this into the equation to find the auxiliary (characteristic) equation.

c)Solve the auxiliary equation for m .

Sub-topic 26.2: Solving First Order Differential Equations

Scenario 220

A chemical engineer at a Tororo-based fertilizer plant is studying the mixing process in a large tank.A salt solution with a concentration of 2 kgL^{-1} enters the tank at 5 $Lmin^{-1}$. The well-stirred mixture leaves the tank at the same rate. The tank initially contains 100 L of pure water. The engineer needs to find the amount of salt A(t) in the tank at any time t . This leads to a first-order linear differential equation of the form $\frac{dA}{dt}$ = Rate in - Rate out. Solving this equation is essential for quality control and ensuring the final product has the correct concentration.

Task:

a)The rate of salt entering is 2 kgL^{-1} x 5$Lmin^{-1}$ = 10 $kgmin^{-1}$. The rate leaving is $\frac{A(t)}{100}$ X 5. Form the differential equation for $\frac{dA}{dt}$

b)Write the equation in the standard linear form $\frac{dA}{dt}$ + P(t)A = Q(t) .

Scenario 221

An ecologist is modeling the population N(t) of an invasive plant species in Queen Elizabeth National Park. The growth rate is proportional to the population, but the park authorities are implementing a constant removal strategy, harvesting h plants per unit time. This situation is modeled by the differential equation $\frac{dN}{dt}$ = kN - h , where k is the growth constant. Solving this equation helps predict if the removal strategy will eventually eradicate the invasive species or if more aggressive measures are needed.

Task:

a)The equation $\frac{dN}{dt}$ - kN = -h is a first-order linear differential equation. Find the integrating factor.

b)Use the integrating factor to find the general solution for N(t) .

Scenario 222

A food scientist at a dairy processing plant in Kampala is modeling the temperature T(t) of a milk pasteurization vat as it cools down. According to Newton's Law of Cooling, the rate of change of temperature is proportional to the difference between the vat's temperature and the ambient room temperature T_a . This gives the equation $\frac{dT}{dt}$ = -k(T - T_a) . Solving this separable differential equation allows the scientist to determine how long the milk must cool before it can be safely packaged, ensuring product quality and safety.

Task:

a)Show that the equation $\frac{dT}{dt}$ = -k(T – T_a) is separable.

b)Separate the variables and integrate both sides to find the general solution for T(t) .

c)If the milk starts at T(0) = 90^C , the room is $T_a = 25^C$, and k=0.1 , find the particular solution.

Sub-topic 26.3: Application of Differential Equations

Scenario 223

An epidemiologist at the Uganda Virus Research Institute is modeling the early spread of an infectious disease in a densely populated area of Kampala using a simple SIR model.In the initial phase, the rate of new infections $\frac{dI}{dt}$ is proportional to the number of infected people I and the number of susceptible people S . Assuming S is approximately constant initially, this leads to $\frac{dI}{dt} = \varphi S_1$, which has an exponential solution. Solving this equation helps predict the initial growth rate of the outbreak, which is critical for allocating medical resources and planning containment strategies.

Task:

a)Solve the differential equation $\frac{dI}{dt} = kI$ (where $k = \varphi S$) to find $I(t)$.

b)If the number of infected people doubles every 5 days, find the value of the constant k .

c)If 100 people are initially infected, how many will be infected after 15 days?

Scenario 224

An economist at the Bank of Uganda is modeling the price $P(t)$ of a staple food commodity. They propose that the rate of change of price is proportional to the difference between the demand D and supply S , where both demand and supply are linear functions of price:

$D = a - bP$ and $S = -c + dP$. This leads to the differential equation

$\frac{dP}{dt} = k[(a - bP) - (-c + dP)] = k(a + c) - k(b+d)P$. Solving this equation helps predict price stability and informs market intervention policies to control inflation.

Task:

a)Show that the differential equation can be written in the linear form $\frac{dP}{dt} + k(b+d)P = k(a+c)$.

b)What is the equilibrium price P_e (the price where $\frac{dP}{dt} = 0$)?

c)Describe the significance of this equilibrium price for the Ugandan market.

Scenario 225

A mechanical engineer is designing the suspension system for a new bus model intended for Ugandan roads.The vertical displacement $y(t)$ of the bus after hitting a pothole is modeled by the second-order differential equation $m\frac{d^2y}{dt^2} + c\frac{dy}{dt} + ky = 0$, where m is mass, c is the damping coefficient, and k is the spring constant. Solving this equation reveals whether the suspension will provide a comfortable ride (underdamped, with oscillations) or a stiff, jarring one (overdamped).

Task:

a)For a simplified case with no damping ($c=0$), the equation becomes $\frac{d^2y}{dt^2} + \phi^2 y = 0$, where $\phi^2 = km^{-1}$. What is the general solution to this equation?

b)This solution describes simple harmonic motion. What physical quantity does ϕ represent?

c)How would the introduction of damping ($c > 0$) affect the motion of the bus?

Topic 27: FLOW CHARTS

Sub-topic 27.1: Algorithms and Presenting Them on Flow Charts

Scenario 226

A software developer at a fintech startup in Kampala is designing the core logic for a mobile money transfer approval system. The algorithm must check if a user has sufficient balance, if the recipient's number is valid, and if the transaction amount is within the daily limit. The developer needs to represent this decision-making process clearly for the rest of the team and for client presentations. A flowchart is the perfect tool to visualize the algorithm's logical flow, using standardized symbols for start/end, processes, decisions, and input/output.

Task:

a)List the key steps (inputs, decisions, outputs) involved in the mobile money transfer process described.

b)Draw a flowchart that represents this algorithm. Use appropriate symbols for Start/End, Process, Decision, and Input/Output.

c)Why is a flowchart preferable to a paragraph of text for explaining this algorithm to non-programmers?

Scenario 227

A mathematics teacher at a secondary school in Gulu wants to create a clear guide for students on how to find the roots of a quadratic equation $ax^2 + bx + c = 0$. The process involves calculating the discriminant $D = b^2 - 4ac$ and then following different paths based on whether $D > 0$, $D = 0$, or $D < 0$. The teacher decides to present this algorithm as a flowchart to help students visualize the logical steps and understand the different cases for the roots (real and distinct, real and equal, or complex).

Task:

a)Write down the step-by-step algorithm for solving a quadratic equation.

b)Represent this algorithm using a flowchart.

c)In the flowchart, how many decision diamonds are needed?

Scenario 228

A logistics manager for a delivery company in Jinja needs to optimize the package sorting process at their warehouse.The algorithm for sorting involves checking the package's weight, dimensions, and destination zone to assign it to the correct delivery truck. The manager sketches a flowchart to standardize the procedure, ensuring all workers follow the same efficient process. This reduces errors and speeds up operations, which is crucial for meeting delivery targets in Uganda's growing e-commerce sector.

Task:

a)Identify the inputs and outputs for the package sorting algorithm.

b)Identify the key decisions that determine which truck a package is assigned to.

c)Draw a simple flowchart for this sorting process, including at least two decision points.

Sub-topic 27.2: Performing Dry Runs

Scenario 229

A programmer is testing a simple algorithm designed to calculate the factorial of a non-negative integer n, where factorial $n! = n \times (n-1) \times \ldots \times 1$, and $0! = 1$. The algorithm uses a loop. Before writing the actual code, the programmer performs a dry run (a paper test) with a small input value like n=4 to verify the logic. This involves manually stepping through each instruction, tracking the values of variables, and checking if the final output is correct (which should be 24). This process helps catch logical errors early, saving valuable debugging time later.

Task:

The algorithm is:

1. Start
2. Read n
3. Set $f = 1$, $i = 1$
4. While $i \leq n$:
   $f = f \times i$
   $i = i + 1$
5. Print f
6. End

a)Perform a dry run of this algorithm for $n=4$. Create a table to track the values of n, f, and i after each step.

b)What is the final output?

c)What is the purpose of initializing f to 1?

Scenario 230

A student is learning about an algorithm that finds the largest number in a list. The algorithm iterates through the list, comparing each element to the current maximum. The student performs a dry run with the sample list [7, 2, 9, 4] to understand how the algorithm works. Manually tracing the values helps the

student grasp the concept of iteration and comparison, which are fundamental building blocks in computer science and data analysis.

The algorithm is:

1. Start with a list of numbers.
2. Set max = the first number in the list.
3. For each subsequent number in the list:
   If the number > max , then set max = number
4. Output max .

Task:

a)Perform a dry run with the list [7, 2, 9, 4] . Track the value of max after each comparison.

b)What is the final output of the algorithm?

c)Why is it important to initialize max to the first element of the list?

Scenario 231

A business analyst has designed a flowchart for a loan approval process at a microfinance institution.The process checks an applicant's credit score and income level. Before implementing this process, the analyst performs a dry run with test cases to ensure it correctly approves qualified applicants and rejects unqualified ones. This validation step is crucial to prevent financial losses for the institution and to ensure fair access to credit for small business owners in Uganda.

Consider this simplified loan criteria from a flowchart:

Start
Input Credit Score, Annual Income
If Credit Score > 650 AND Annual Income > 5,000,000 UGX then
 Output "Approved"
Else
 Output "Denied"
 End

Task:

a)Perform a dry run for an applicant with a Credit Score of 700 and an Annual Income of 6,000,000 UGX. What is the output?

b)Perform a dry run for an applicant with a Credit Score of 600 and an Annual Income of 10,000,000 UGX. What is the output?

c)What is the advantage of testing an algorithm with multiple dry runs using different inputs?

Scenario 232

A software developer at a Ugandan hospital is designing a triage algorithm to prioritize patient care in the emergency department. The flowchart checks vital signs like heart rate, blood pressure, and consciousness level to categorize patients as "Critical," "Urgent," or "Non-Urgent." Before implementing this system in a live environment, the developer must perform exhaustive dry runs with various patient profiles to ensure the logic is sound and no critical cases are misclassified. A single error in the flowchart could have serious consequences for patient outcomes.

Task:

Consider a simplified triage flowchart:

1. Start
2. Input Heart Rate (HR), Systolic BP, Conscious (Y/N)
3. If Conscious = 'N' OR Systolic BP < 90, output "CRITICAL"
4. Else, if HR > 130 OR HR < 50, output "URGENT"
5. Else, output "NON-URGENT"
6. End

Task:

a)Perform a dry run for an unconscious patient with HR=80, BP=120. What is the output?

b)Perform a dry run for a conscious patient with HR=140, BP=100. What is the output?

Scenario 233

An agricultural engineer is designing a smart irrigation algorithm for a large-scale maize farm in the Teso sub-region. The system uses soil moisture sensors and weather forecast data to decide whether to activate the sprinklers. The algorithm's flowchart is complex, involving multiple decision points. The engineer performs a dry run for a scenario where the soil moisture is low but the weather forecast predicts heavy rain within the hour. This tests whether the algorithm correctly avoids unnecessary irrigation, saving water and energy costs for the farm.

Task:

A simplified version of the algorithm is:

1. Start
2. Input Soil_Moisture, Rain_Forecast (mm/h)
3. If Soil_Moisture < 30 AND Rain_Forecast < 5 then
   · Output "IRRIGATE"
4. Else
   · Output "DO NOT IRRIGATE" 5. End

Task:

a)Perform a dry run for Soil_Moisture=25%, Rain_Forecast=10 mm/h. What is the output?

b)Perform a dry run for Soil_Moisture=35%, Rain_Forecast=2 mm/h. What is the output?

Scenario 234

A financial technology company in Kampala is automating its"Know Your Customer" (KYC) verification process. The algorithm checks a user's submitted documents and flags accounts for manual review if certain risk factors are present, such as mismatched information or a high-risk country of origin. A business analyst performs a dry run with a test case where a user's national ID name doesn't match their mobile money registration name. This ensures the algorithm correctly flags the account for further investigation, helping to prevent fraud and comply with Ugandan financial regulations.

Task:

A simplified KYC flowchart:

1. Start
2. Input ID_Name, Registered_Name, Country
3. If ID_Name ≠ Registered_Name then
   · Output "FLAG FOR REVIEW"
4. Else, if Country is in [High-Risk List] then
   · Output "FLAG FOR REVIEW"
5. Else
   · Output "APPROVED" 6. End

Task:

a)Perform a dry run for a user where ID_Name="Kato John", Registered_Name="John Kato", Country="Uganda". What is the output?

b)Perform a dry run for a user where ID_Name="Jane Auma", Registered_Name="Jane Auma", Country=[A high-risk country]. What is the output?

c)In a dry run, what is the purpose of tracking the path taken through the flowchart's decision diamonds?

END