



Physics Scenario Based Items Revised Edition

Physics (Mengo Senior School)



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NEW ADVANCED SECONDARY SCHOOL CURRICULLUM

PHYSICS SCENARIO BASED ITEMS

P510/1

Second Edition 2026

Revised By: KIGGUNDU GEORGE WILLIAM

By

SAGEE FAMILY UGANDA

Email: sageefamilyuganda@gmail.com

Tel: +256 749 223639

STUDENT'S BIO DATA FORM

This textbook belongs to a future expert in Physics. Please fill in your details to begin your journey.

Name:

School Name:

Class: Senior Five () Senior Six ()

School Motto:

Personal Motto:

Date of Issue: **Date of Completion:**

Preferred Future Career (related to Physics): Tick (✓) where applicable

Engineer () Medical Doctor () Pilot () Architect ()

Data Scientist () Renewable Energy Expert () Research Physicist ()

Other:

ACKNOWLEDGEMENT

The development of this textbook has been a journey of passion and commitment to Physics education in Uganda. Since 2017, the writers have worked tirelessly to align this content with the evolving needs of the Ugandan student.

We extend our deepest gratitude to the **Sagee Family Uganda**. Their unwavering support, encouragement, and belief in this project have been the bedrock upon which this book was built. It is their faith in the power of education that has allowed us to compile this resource for you, the next generation of scientists .

TIPS FOR PASSING PHYSICS WITH EXCELLENCE

Physics is not about memorizing formulas; it is about understanding the poetry of the universe written in the language of mathematics. To excel in the new curriculum, follow these golden tips:

1. Embrace the "Learner-Centered" Approach: The new curriculum shifts focus from the teacher to you, the student. Don't wait to be fed information. Be curious. Conduct the suggested projects, participate in group discussions, and use ICT to research concepts beyond the textbook .

2. Master the Basics (Units & Dimensions): Many students lose marks due to incorrect units. Always work in SI units (meters, kilograms, seconds) unless stated otherwise. Understanding dimensions helps you check if your formulas are correct before you even calculate .

3. The Art of Problem-Solving:

Read & Visualize: Read the problem carefully. Identify the "knowns" and the "unknowns." Draw a simple diagram—a picture often reveals the physics at play .

The Formula Hunt: Don't just pick any formula. Identify the physical concept behind the question (e.g., Is it a conservation of energy problem? A kinematics problem?). Then, select the formula that links your knowns to your unknown .

Practice Daily: Physics is a hands-on subject. Solve at least two problems from each topic every day. Start with simple "one-dot" problems and progress to the challenging "two-dot" problems .

4. Connect to the Real World: When you learn about thermometry, relate it to why a doctor uses a thermometer. When you study optics, think about how your phone camera works. This "competency-based" understanding makes concepts stick and prepares you for application-based questions .

5. Communication is Key: In the new curriculum, how you present your answer matters. Use bullet points for theory questions to make your answer easy to read. Underline key terms like "vector" or "conservation of energy." For numerical, show every logical step .

THE FUTURE ASPECT OF PHYSICS

As you stand at the threshold of Advanced Secondary Education, you are not just here to pass an exam; you are here to prepare for a world that is being built by physics.

- ✓ **The Quantum Leap:** The world is moving towards Quantum Technology. The smartphones in your pockets, the MRI machines in hospitals, and the secure communications of the future are all rooted in quantum mechanics. Your study of modern physics is the first step towards understanding this revolution .
- ✓ **The Green Revolution:** Uganda, and the world, needs experts in Renewable Energy. Physics of semiconductors (solar cells) and electromagnetism (wind turbines) will be vital in solving the energy challenges of tomorrow.
- ✓ **The Data Era:** Physics trains you to be a problem-solver. The skills of modeling, data analysis, and critical thinking you will learn are the exact skills needed in Artificial Intelligence (AI) and Data Science. Physicists are now highly sought after in the tech industry to build the next generation of computers .
- ✓ **Limitless Careers:** Whether you dream of working at CERN, designing spacecraft, creating new medical technologies, or even starting your own tech company, Physics is the foundation. It is not just a subject; it is a license to innovate .

DEDICATION

This book is dedicated to the inquisitive minds of Uganda.

May you look at a flower and see not just its color, but the physics of light that makes it visible, the biology it supports, and the universe conspiring in its petals .

Go forth, ask "why," and change the world.

SAGEE FAMILY UGANDA

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;

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

- Write down the dimensional formula for energy.
- By applying the principle of dimensional homogeneity, derive the values of the exponents a , b , and c in the proposed equation.

- 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;

- Using dimensional analysis, show that the period T cannot depend on the mass m of the bob.
- 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.
- 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 (ΔP), the radius of the capillary (r), its length (l), and the viscosity of the liquid (η). 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 (η).
- (b) Assume the relationship is $Q = k (\Delta P)^a r^b \eta^c$. 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 (η). 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 $F = 6\pi \eta r v$. 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;

- Draw a free-body diagram showing all forces acting on the engine block.
- Calculate the tension in each cable when lifting the maximum load.
- Assess whether any cable is likely to break under this loading condition.
- 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;

- Calculate the total vertical force acting on the main cable.
- Determine the horizontal tension in the cable if the end supports are 10m high and 20m apart.
- Calculate the maximum tension in the cable.
- 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;

- Define the term 'moment of a force' as applied to this situation.
- Calculate where the 35kg child should sit if the 25kg child is 1.5m from the pivot.
- Explain how the mass of the plank affects the balance condition.
- 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;

- Calculate the minimum spanner length needed to loosen the bolt.
- Explain why applying force perpendicular to the spanner gives maximum moment.
- Describe what is meant by a 'couple' and give an example from automotive practice.
- 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, $g = 9.81 \text{ m/s}^2$, 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:

- Define the term free fall.
- Calculate the depth of the well, ignoring the time for sound to travel.
- Determine the velocity of the stone just before it hits the water.
- 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.
- 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:

- State the initial velocity of the coconut.
- Calculate the height of the coconut tree.
- What was the velocity of the coconut 2 seconds after it started falling?
- Calculate the distance the coconut fell during the final second of its motion (between $t=1.5\text{s}$ and $t=2.5\text{s}$).
- 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:

- Calculate the time taken for the package to hit the ground.
- What is the vertical component of the package's velocity just before impact?
- 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.
- Describe the energy transformation of the package during its fall.
- 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:

- Calculate the time taken for the ball to hit the ground for the first time.
- Find the velocity with which the ball hits the ground.
- On its first bounce, the ball rebounds with an upward velocity of 15 ms^{-1} . Calculate the maximum height it reaches after this bounce.
- How long does the ball take to reach this maximum height after the bounce?
- 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:

- State one precaution the students must take to ensure accurate results.
- Using the data from the trial ($s = 1.50 \text{ m}$, $t = 0.553 \text{ s}$), calculate the experimental value of the acceleration due to gravity, g .
- Calculate the percentage error in this experiment, given that the accepted value of g is 9.81 ms^{-2} .
- Suggest one source of error that could account for the difference.
- 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:

- Define a projectile.
 - Calculate the initial horizontal component of John's velocity.
- Calculate the maximum height John's center of mass reaches above the ground.
- Determine the total horizontal distance (the range) John jumps before landing in the sand pit.
- What is the magnitude and direction of John's velocity just before he lands?
- 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:

- Calculate the time taken for the ball to reach the goal line horizontally.
- Determine the height of the ball when it reaches the goal line.
- 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:

- Define the term work and state its SI unit.
- Calculate the total work done by the conductor and passengers in pushing the minibus.
- 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.
- Explain why a traffic officer who directs traffic but does not push the bus does no work on it.
- 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 in Budaka 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:

- Calculate the total work done by the first worker in lifting all the concrete blocks.
- Calculate the work done by the second worker in dragging the sack of sand.
- State the angle between force and displacement for which the work done is maximum.
- Explain why the work done by the second worker is less than if he had pulled the sack horizontally with the same force.
- 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:

- Calculate the work done by the oxen in ploughing the 100-meter furrow.
- What component of the oxen's force is actually doing the work to pull the plough forward? Calculate its magnitude.
- If the oxen took 5 minutes to complete this furrow, what was their average power output?
- Suggest one reason why the actual useful work done on the soil is less than the value calculated in (a).
- If the plough is lifted to turn the soil, what type of work is being done against? **Scenario 49**

The students of Kibuli 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:

- Calculate the work done by the student while carrying the books along the horizontal corridor. Explain your answer.
- Calculate the work done by the student in lifting the books onto the shelf.
- If she took 10 seconds to lift the books, what was her power output during the lifting process?
- 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.
- Define one joule of work.

Scenario 50

At a fruit processing plant in Jinja, 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 from Mount 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 in Kampala, 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 College in 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:

- What is the name given to the value of the frictional force just before the cabinet begins to move?
- Calculate the normal reaction force on the cabinet.
- Determine the coefficient of static friction between the cabinet and the concrete floor.
- 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.
- 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 in Mbale. 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:

- Explain why static friction is essential for the ladder to remain in equilibrium.
- Calculate the normal reaction at the wall.
- Determine the force of static friction at the base of the ladder.
- Calculate the minimum coefficient of static friction required at the ground to prevent the ladder from slipping.
- 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:

- Besides tension, what force provides the centripetal force for the bung's circular motion?
- If the coefficient of static friction is 0.5 and the normal reaction is 2 N, calculate the maximum static frictional force available.
- If the centripetal force required is 1.2 N, will the bung slip? Justify your answer.
- How would increasing the angular speed affect the frictional force required?
- State limiting friction.

Scenario 65

At a mining site in Kilembe, 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:

- Identify the two forces that oppose the initial upward motion of the cage.
- Calculate the maximum static frictional force if the normal reaction from the guide rails is 2000 N.
- 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.
- Why is it easier to keep the cage moving than to start it moving?
- 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:

- Define dynamic (kinetic) friction.
- Convert 72 kmh^{-1} to meters per second.
- Using the work-energy theorem, calculate the work done by kinetic friction in stopping the lorry.
- Calculate the coefficient of kinetic friction between the tyres and the road surface.
- 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:

- Calculate the component of the package's weight acting parallel to the incline.
- Calculate the kinetic frictional force acting on the package as it slides.
- Determine the net force acting on the package while it is sliding.
- Calculate the acceleration of the package relative to the ground while it is sliding.
- 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:

- Draw a diagram showing the forces acting on the sled as it moves down the slope.
- Calculate the net force acting on the sled parallel to the incline.
- Calculate the acceleration of the sled down the slope.
- If the slope is 100 meters long, calculate the speed of the sled at the bottom of the slope.
- 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:

- State the relationship between the engine's driving force and the total resistive force when the car moves at constant speed.
- Calculate the power developed by the engine to maintain this speed.
- If 40% of the total resistive force is due to kinetic friction, calculate the coefficient of kinetic friction between the tyres and the road.
- When the driver takes her foot off the accelerator, the car slows down. Explain why this happens.
- 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:

- Why must the block be moving at constant speed when taking the spring balance reading?
- Calculate the coefficient of kinetic friction between the block and the wooden track.
- Using the same setup, what would the spring balance read if they used a 4 kg block?
- State one precaution the students should take to ensure accurate results.
- 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;

- Explain the molecular mechanism that creates surface tension in liquids.
- Describe an experiment to measure the surface tension of water using a wire ring and a precision balance.
- 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.
- 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;

- Define capillary action and explain its molecular basis.
- Derive the relationship between capillary rise, tube diameter, and liquid density.
- 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° .
- 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;

- Explain how detergent molecules reduce surface tension at the molecular level.
- 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 $0.01 \text{ Pa}\cdot\text{s}$ 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 $2.0 \times 10^{-6} \text{ m}^2$ 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 m^2 shortens by 0.15 mm when supporting a load of $2.0 \times 10^5 \text{ N}$. 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 $2.0 \times 10^{11} \text{ Pa}$. 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 $4.0 \times 10^{-5} \text{ m}^2$. 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 $3.0 \times 10^{-5} \text{ m}^2$. 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 $2.0 \times 10^{10} \text{ Pa}$. 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 $2.1 \times 10^{11} \text{ Pa}$. 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;

- Explain how a maximum-minimum thermometer records temperature extremes.
- Describe the construction and working principle of a bimetallic thermometer.
- 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.
- 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;

- Define specific heat capacity and state its SI units.
- Calculate the heat energy required to raise the temperature of 2kg of water from 20°C to 80°C.
- Explain why water has a higher specific heat capacity than most common materials.
- 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 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).
- Explain why different coolants have different specific heat capacities.
- Suggest two properties of an ideal engine coolant besides high specific heat capacity.
- 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 ($c_{\text{soil}} = 800 \text{ Jkg}^{-1}\text{°C}$).
- (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;

- Define latent heat of fusion and state its units.
- Calculate the heat that must be removed to freeze 4kg of mango pulp at 0°C (latent heat of fusion = 250,000 Jkg⁻¹).
- Explain why temperature remains constant during phase change despite heat being removed.
- 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;

- Calculate the heat required to vaporize 2kg of ethanol already at its boiling point (latent heat of vaporization = 840,000 J/kg).
- Explain what happens to the heat energy during vaporization at the molecular level.
- Compare the latent heat of vaporization with the latent heat of fusion for the same substance.
- 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;

- 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).
- Explain how evaporation acts as a cooling process.
- Describe the energy transformations during the water cycle.
- 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;

- Calculate the heat required to melt 3kg of aluminum at its melting point (latent heat of fusion of aluminum = 397,000 Jkg⁻¹).
- Explain why the temperature of melting aluminum remains constant until all is liquid.
- A furnace supplies heat at 5000J per second. How long will it take to melt 2kg of aluminum?
- 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 0.001m² 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 ($k_{\text{copper}} = 400 \text{ Wm}^{-1}\text{°C}$).
- (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 1.5m^2 and thickness 0.02m has inner temperature 37°C and outer temperature 25°C . If thermal conductivity is $0.2\text{Wm}^{-1}\text{C}$, 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 ($k_{\text{copper}} = 400\text{Wm}^{-1}\text{C}$).
- (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 = $2.9 \times 10^{-3}\text{ mK}$).

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 $5\text{--}8^\circ\text{C}$, 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 ($\sigma = 5.67 \times 10^{-8} \text{ Wm}^{-2}\text{K}$).

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 ($R = 8.31 \text{ Jmol}^{-1}\cdot\text{K}$).
- (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 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).
- Explain why tire manufacturers recommend checking pressure when tires are cold.
- Calculate the number of air molecules in the tire at 20°C .
- 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 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).
- Explain why gas pressure decreases when temperature drops.
- If the temperature drops from 30°C to 15°C overnight, calculate the percentage decrease in pressure (volume constant).
- 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;

- State the basic assumptions of the kinetic theory of gases.
- Explain how gas pressure arises from molecular motion.
- If the speed of gas molecules doubles while density remains constant, how does pressure change?
- 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;

- Derive the expression for pressure exerted by a gas using kinetic theory.
- Explain why temperature is a measure of the average kinetic energy of molecules.
- Calculate the root mean square speed of oxygen molecules at 27°C (molar mass of $\text{O}_2 = 0.032 \text{ kg mol}^{-1}$).
- 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;

- Define the principal focus and focal length of a concave mirror.
- A concave mirror has a radius of curvature of 40 cm. Calculate its focal length.
- Explain why parabolic mirrors are used in solar concentrators rather than spherical mirrors.
- 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;

- An object is placed 30 cm from a concave mirror of focal length 15 cm. Calculate the image position.
- Describe the nature of the image formed in part (a).
- Explain why concave mirrors are used in medical instruments for examining body cavities.
- 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;

- Explain why convex mirrors are used as rear-view mirrors in vehicles.
- A convex mirror has a focal length of 20 cm. An object is placed 30 cm from the mirror. Calculate the image position.
- Compare the images formed by concave and convex mirrors.
- 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;

- 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.
- Describe one practical use of concave mirrors in daily life.
- 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;

- Derive the mirror formula for curved mirrors.
- An object 4 cm tall is placed 20 cm from a concave mirror of focal length 12 cm. Calculate the image height.
- Explain the difference between real and virtual images with reference to curved mirrors.
- 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;

- State Snell's Law of refraction and define refractive index.
- Calculate the angle of refraction when light enters water from air at an angle of incidence of 40° (refractive index of water = 1.33).
- Explain why a swimming pool appears shallower than it actually is.
- 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;

- Define critical angle and calculate it for the water-air boundary ($n_{\text{water}} = 1.33$).
- Explain why different materials have different refractive indices.
- 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° .
- 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

An 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 $+2 \mu\text{C}$ and $+3 \mu\text{C}$ 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 $+5 \mu\text{C}$ and $-3 \mu\text{C}$ are brought into contact and then separated. What is the final charge on each sphere?
- (c) Calculate the force between two charges of $+4 \mu\text{C}$ and $-6 \mu\text{C}$ 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 $1.6 \times 10^{-13} \text{ C}$ experiences a force of $8 \times 10^{-9} \text{ N}$ 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;

- Define capacitance and state its SI units.
- Calculate the capacitance of a parallel plate capacitor with plates of area 0.2 m^2 separated by 0.5 mm of air.
- Explain how the capacitance changes if the distance between plates is doubled.
- 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;

- Explain the function of a dielectric material in a capacitor.
- A parallel plate capacitor has a capacitance of $10 \mu\text{F}$ in air. Calculate its capacitance when filled with a dielectric of constant 5.
- Describe how the stored energy changes when a dielectric is inserted into a charged capacitor.
- 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;

- Derive the formula for the capacitance of a parallel plate capacitor.
- Calculate the area needed for a parallel plate capacitor with air dielectric to have a capacitance of $1 \mu\text{F}$ if the plates are 1 mm apart.
- Explain how capacitors help stabilize power supply in renewable energy systems.
- 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;

- 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 k Ω 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 $100\ \mu\text{F}$ 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 $100\ \Omega$ resistor. If the capacitance is $500\ \mu\text{F}$, 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 $1000\ \mu\text{F}$ 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 super 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 oneway 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 chargers 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;

- Explain how a centrifugal pump uses circular motion principles.
- Calculate the angular velocity of a pump impeller that rotates at 1500 rpm.
- Describe how centripetal force is related to the pressure developed in a centrifugal pump.
- 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;

- Explain the role of centripetal force in hammer throw.
- 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.
- Describe how an athlete maintains the circular path of the hammer before release.
- 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;

- Explain why riders don't fall when the floor drops away in a rotor ride.
- 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.
- 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;

- Describe the forces acting on the bob of a conical pendulum.
- Derive the expression for the period of a conical pendulum in terms of string length and angle.
- A conical pendulum of length 1.5 m makes an angle of 20° with the vertical. Calculate its period of revolution.
- 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;

- Explain the difference between a simple pendulum and a conical pendulum.
- 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.
- Describe how wind affects a plumb bob's motion and how this is accounted for in construction.
- 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;

- Explain how the angle of a conical pendulum changes with rotational speed.
- 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.
- Describe the energy transformations in a conical pendulum.
- 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;

- Explain how conical pendulum motion is applied in industrial screening equipment.
- Describe the relationship between the cone angle and the screening efficiency.
- Why is controlled circular motion important in material separation processes?
- 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;

- Derive the expression for the tension in the string of a conical pendulum.
- 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.
- Design an experiment to verify the theoretical relationship for a conical pendulum's period.
- 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;

- Explain why railway tracks are banked on curves.
- Derive the expression for the ideal banking angle of a curved track.
- Calculate the banking angle required for a railway curve of radius 400 m designed for trains moving at 80 km/h.
- 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;

- 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.
- Describe what happens to a vehicle on a curve if the centripetal force required exceeds the maximum frictional force available.
- 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;

- Explain why a cyclist must lean inward when negotiating a curve.
- A cyclist moving at 30 km/h goes around a curve of radius 20 m. Calculate the angle of lean required.
- Describe the forces acting on a cyclist moving on a curved path.
- 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;

- Explain how an aircraft executes a turn using banking.
- An aircraft flying at 200 m/s makes a turn with a radius of 1500 m. Calculate the banking angle required.
- Describe what is meant by a "coordinated turn" in aviation.

(d) Why understanding circular motion essential for 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;

- Derive the expression for the maximum safe speed on a banked curved road.
- 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.
- Explain how both banking and friction contribute to the safe negotiation of curves at high speeds.
- 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;

- Define simple harmonic motion and state the necessary conditions for it to occur.
- The displacement of an object in SHM is given by $x = 0.2 \sin(10t)$ meters. Calculate the maximum velocity and acceleration.
- Explain how the total mechanical energy remains constant during SHM and derive the expression for total energy.
- 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;

- 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.
- Sketch graphs showing how displacement, velocity, and acceleration vary with time for one complete cycle of SHM.
- 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 $2 \times 10^{-7} \text{ kg} \cdot \text{m}^2$ and a torsional constant of $3 \times 10^{-5} \text{ Nmrad}^{-1}$. 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 ($\alpha_{\text{steel}} = 1.2 \times 10^{-5}$).
- (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;

- State Newton's law of universal gravitation and explain all terms in the equation.
- 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).
- Explain why the gravitational force is considered universal.
- 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;

- Explain how gravitational acceleration varies with altitude and latitude.
- Calculate the value of g at the top of Mount Elgon (height 4300 m above sea level) compared to at sea level.
- Describe how gravitational measurements can reveal information about underground geological structures.
- 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;

- Describe the Cavendish experiment and explain how it measured the gravitational constant G .
- Two lead spheres of mass 50 kg each are placed with their centers 0.5 m apart. Calculate the gravitational force between them.
- Why was the measurement of G historically significant?
- 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;

- Explain how Newton's law of gravitation accounts for planetary orbits.
- 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.
- 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 determine 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;

- Explain the principle of superposition and how it leads to wave interference.
- Describe the conditions necessary for constructive and destructive interference.
- 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?
- 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;

- Explain how interference affects the sound quality of musical instruments.
- Two sound waves with frequencies 256 Hz and 260 Hz are produced simultaneously. Calculate the beat frequency heard.
- Describe how beats are formed and how they are used in tuning musical instruments.
- 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;

- Explain how interference patterns can provide information about underground structures.
- 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.
- Describe how seismic interference patterns are used in oil exploration.
- 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;

- Explain how stationary waves are formed on a stretched string.
- Describe the difference between nodes and antinodes in a stationary wave pattern.
- A string of length 0.6 m is fixed at both ends. Calculate the wavelength of the fundamental frequency.
- 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;

- Explain how stationary waves can form in transmission lines.
- Describe what happens at points of impedance mismatch in a cable.
- Why are stationary waves undesirable in communication cables?
- 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;

- Describe an experiment to demonstrate stationary waves on a string.
- A string under tension vibrates with three segments when driven at 120 Hz. Calculate the frequency needed to produce four segments.
- Explain how stationary waves differ from progressive waves.
- 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 an approaching car. Calculate the car's speed (speed of light = $3 \times 10^8 \text{ ms}^{-1}$).

- (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 $100\ \Omega$ 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 $2.5\ \text{mm}^2$ has resistivity $1.7 \times 10^{-8}\ \Omega\text{m}$. 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 ($1 \text{ u} = 931.5 \text{ MeV}/c^2$).
- (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;

- Iodine-131 decays to Xenon-131. Identify the type of decay and write the balanced nuclear equation.
- The initial activity of the spilled source was 3.2×10^7 Bq. Calculate the activity remaining after 24 days.
- Explain why beta and gamma radiation from Iodine-131 poses a significant external and internal hazard to humans.
- 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;

- Explain the principle behind radiocarbon dating.
- Calculate the age of the charcoal sample based on the measured activity.
- State one key assumption made in radiocarbon dating and one factor that could lead to an inaccurate date.
- 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;

- 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.
- Explain the advantage of using a radioactive isotope with a short half-life for Brachytherapy.
- Contrast the use of implanted radioactive seeds (Brachytherapy) with external beam radiotherapy in terms of how radiation is delivered to the tumor.
- 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;

- Define the term "radioactive waste" and give two examples of such waste from medical and research applications.
- 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?

END