

KATOKE ELLITE EXAMINATION BOARD

**A LEVEL PHYSICS**

**S.5 PHYSICS COMPETENCE**

**BASED ITEMS**

TERM TWO

**COMPILED BY,**  
KULE SASTINE S.5-KATOKE

0782757684 / 0759141548

SCH: St. Charles Voc SS -  
Kasanga

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### Item 1

A researcher at a local science institute is studying the behaviour of simple pendulums for use in timing devices. While conducting his experiment, he suspects that the time it takes for the pendulum to complete one full swing ( $T$ ) depends on;

- The mass ( $m$ ) of the bob
- The length ( $L$ ) of the string
- Acceleration due to gravity ( $g$ ) at his testing location.

However, he does not know the exact formula connecting these variables. During the discussion with a colleague, he was told that if the pendulum moves in a circular path, the centripetal force ( $F$ ) acting on the bob is given by  $F = \frac{mv^2}{r}$  where  $m$  is the mass of the bob,  $r$  is the radius of the path and  $v$  is the speed of the bob. The researcher is not sure about the correctness of the formula.

#### Task

As a learner of physics,

- (a) Help the researcher to derive the formula for the period of a simple pendulum
- (b) Use dimensional analysis to confirm whether the formula for centripetal force is correct
- (c) Enable the researcher to understand the limitations of using dimensional analysis to derive equations

### Item 2

During a fire emergency, a firefighter uses a water cannon to direct a stream of water towards a burning building. The nozzle is set to spray the water at an angle of  $60^\circ$  above the horizontal, with a speed of 20 m/s. The water stream travels a horizontal distance of 30 meters and just clears the roof of the building before descending on the other side. After the incident, the insurance company investigating the damage wants to know the exact height of the building.

#### Task

- (a) Help the insurance company to know the height of the building
- (b) How far beyond the building does the water land?
- (c) Describe one real life situation where the knowledge of projectile motion is applied.

### Item 3

During a science exhibition at your school, the science club plans to demonstrate how to determine the specific heat capacity of a liquid using the continuous flow method. They want to explain the procedures clearly to parents and visitors but some of the club members do not have any information about this method.

#### Task

As a student of physics help the club members to;

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- Understand the continuous flow method
- Know the advantages and disadvantages of the method described in (a) above
- Determine the specific heat capacity of the liquid using the table below ;

	Set 1	Set 2
Voltage	35	26
Current	2	2
Mass (kg) collected in 10 seconds	0.047	0.03
Inflow temperature	25	25
Outflow temperature	29	29

#### Item 4

As part of laboratory investigation to determine the specific latent heat of vaporisation of water, you are provided with 2 copper calorimeters, a steam trap, a thermometer and a stirrer. From the investigation, the following results were obtained:

- Mass of empty calorimeter = 150g
- Mass of water added = 340g
- Mass of condensed steam = 35g
- Initial temperature of the calorimeter and its contents = 15°C
- Temperature of steam = 100°C
- Final temperature of the mixture = 71°C

#### Hint

- Specific heat capacity of water = 4200 Jkg<sup>-1</sup>k<sup>-1</sup>
- Specific heat capacity of copper = 400 Jkg<sup>-1</sup>k<sup>-1</sup>

#### Task

As a student of physics;

- Describe how the specific latent heat of vaporisation of water can be determined using the above apparatus.
- Explain how you can minimise errors in (a) above
- Determine the specific latent heat of vaporisation of water

#### Item 5

A technology company is rolling out smart transport cards to facilitate the daily commute of its employees. These employees travel by bus from a trading centre to the company offices located near the main bus park, five days a week.

However, the company is currently facing a challenge in determining the exact amount of money to deposit on each smart card for a full month of travel.

On one particular day, the bus journey was recorded as follows: It started from rest at the trading centre and accelerated uniformly at 1.25 m/s<sup>2</sup> until it reached a speed of 72 km/h. The bus then continued at this constant speed for a

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distance of 50 km before decelerating uniformly at  $2 \text{ m/s}^2$  to come to a complete stop at the bus park.

The transport service charges Ushs 1,000 per kilometre of travel.

**Task:**

- (a) Represent the entire journey of the bus graphically
- (b) Advise the company on the minimum amount of money that should be deposited on each smart card to cover a full month's travel expenses.

**Item 6**

As part of your school's sports science project, your team is working with the athletics coach to help a long jumper improve his performance. During training, he takes off from ground level with an initial speed of  $5 \text{ m/s}$  at an angle of  $30^\circ$  to the horizontal. To qualify for the upcoming district competitions, a jumper must achieve a minimum horizontal distance of 9.0 metres from the point of take-off to the landing point.

**Task**

- (a) Help the school administration to know whether the jumper qualifies for the competitions.
- (b) Using principles of projectile motion, explain with evidence how the jumper can increase his horizontal distance.
- (c) Derive the equation of trajectory.

**Item 7**

A company that manufactures cooking utensils plans to develop a new type of metal saucepans that heat up quickly and uses less energy. However, the company does not yet know how to determine the specific heat capacity of the metal sample they intend to use.

Knowing the SHC of the metal will help the company estimate how much energy is required to raise the temperature of their saucepans, which directly affects cooking time and fuel efficiency.

**Task**

- (a) Advise the company manager on the steps he can take to determine the specific heat capacity of the sample and how they can ensure accurate results.
- (b) Using the data below, calculate the specific heat capacity of the metal block:
  - Mass of metal block = 1.8 kg
  - Voltage = 12 V

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- Current = 2 A
- Time of heating = 5 minutes
- Temperature increase = 30°C

### Item 8

Your school has recently acquired new physics lab equipment, including a continuous flow calorimeter designed to measure the specific heat capacity (SHC) of liquids. During a science club session, your group sets up the apparatus for a public exhibition. As part of the demonstration, your team is required to show visiting parents how the setup can be used to determine the SHC of a liquid, such as water.

Task

As a student of physics;

- (a) Use your set up to explain to the visitors how the specific heat capacity of the liquid can be determined.
- (b) Help them understand the advantages and disadvantages of using the above method
- (c) In such a method, 50g of water is collected in 1minute, the voltmeter and ammeter readings are 12.0V and 2.50A respectively. While the inflow and outflow temperatures are 20°C and 28°C respectively. When the flow rate is reduced to 25gmin<sup>-1</sup>, the voltmeter and ammeter read 8.8V and 1.85A respectively while the temperatures remain constant. Calculate the specific heat capacity of water

### Item 9

During a sports talent search, a long jumper of mass 60 kg lands badly, prompting concern over impulse control. He was in contact with the ground for 0.2 s and reduced his speed from 8 m/s to 0. Meanwhile, two athletes of masses 70 kg and 50 kg moving at 5 m/s and 4 m/s respectively collide at right angles and rebound at 30° and 60° to their original directions. A coach records a sprinter accelerating from rest at 2.5 m/s<sup>2</sup> and wants to know the distance covered in the 7th second. Officials seek advice on whether the trampoline collision was elastic or inelastic and how the law of conservation of momentum (with derivation) can explain such collisions.

Task: Help the officials to;

- (a) know the distance covered by the sprinter in the 7th second of his journey and whether the two athletes collided with energy loss or not.
- (b) know how to improve training and safety protocols during athletic events.

### Item 10

A drone launched at 20° narrowly clears a 10 m wall, 30 m away, near Kampala city buildings. Two planes A at 300 km/h on 010°, another B at 200 km/h on 340° fly with A west of B 40 km from the other. City engineers need to derive the drone's trajectory equation to predict its height and path. They must also know the drone's

speed and direction at any point in flight. Aviation officials require the time and distance of closest approach between the planes to avoid mid-air risks.

Task: Help the engineers and the officials to;  
(a) come up with an equation of trajectory and guide them in determining the drone's launch speed, velocity at the wall.

(b) know the time and minimum separation between the planes for safe operations.

### **Item 11**

During hillside construction in Mbale, two cement blocks (8 kg and 16 kg) slide down a 30° slope with 16kg ahead of 8kg connected by a rigid metal rod. Friction hinders their motion, with coefficients 0.25 and 0.5 respectively. Engineers need to know the system's acceleration and rod tension to avoid damaging materials. They also need your help explaining why pulling loaded wheelbarrows is easier than pushing, and whether friction here is conservative. They also need a guidance how they can know the value of coefficient of kinetic friction of a similar flat surface and needs to know the conservation of energy principle to help design safer transport.

Task;(a) Help the engineers to

- (i) to compute the acceleration and tension in the rod and guide them on the validity of the laws of solid friction.
  - (ii) Come up with the principle of conservation of energy and why its easy for them to pull wheelbarrow than pushing it.
- (b) Advise the engineers on the best way to determine coefficient of kinetic friction on the flat surface.

### **Item 12**

In Gulu market, a new metal canopy was blown away during a storm when tied by ropes exerting forces of 25 N West, 35 N North-East (45°), 20 N South, 15 N upward, and 12 N downward due to poor estimation of resultant force. An engineering student working with a water harvesting NGO needs to derive an equation for volumetric flow rate ( $v/t$ ) based on viscosity, pipe radius, and pressure difference without lab equipment. At a nearby school, a 5 m wooden ladder (mass 24 kg) leans at 70° against a smooth classroom wall. A mason of 12 kg (half the ladder's mass) climbs it while the ground, made of concrete, has  $\mu = 0.3$ .

Task:

(a) Guide the community to know the net force on the canopy.

(b) come up with the required flow model and guide the community to know how far the mason can climb before the ladder slips.

### **Item 13**

At Kasaana Clinic, the solar-powered mirror galvanometer used for detecting weak currents in patients' ECG sensors gives unstable readings. The technician suspects poor mirror alignment and wrong mirror size. Nearby, the clinic's corridor security

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uses two inclined mirrors at  $90^\circ$ , but staff complain the images deviate confusingly. Also, some short patients, averaging 1.50 m tall, can't see their full reflection in the mirror above the handwashing station.

Task:

- (a) Help the clinic determine the correct alignment based on laws of reflection.
- (b) Guide the technician to know the deviation angle between the two plane mirrors.
- (c) Advise the clinic manager on the minimum mirror height he should install for full self-view and explain to the staff how an optical lever affects galvanometer sensitivity.

#### Item 14

A physicist in the laboratory wanted to measure temperature of a body at different points and obtain the average in the determination of specific heat capacity. The suitable thermometer to use was a thermocouple of which he wanted the temperature in  $^\circ\text{C}$ . This thermocouple has a relationship with the temperature on the resistance thermometer with a relation  $R_\theta = R_0(1 + 50\alpha\theta + 100\alpha\theta^2)$  but he is not sure whether these two thermometers will agree on the measured temperature.

Task

- (a) Explain to the physicist the structure and how he can use this thermometer to measure temperature.
- (b) Guide the physicist in obtaining the corresponding temperature on the resistance thermometer to  $60^\circ\text{C}$  from this thermometer.
- (c) Help the physicist understand why these thermometers are showing different values for the same temperature and when are they most likely to agree.

#### Item 15

A student rubs a plastic rod with a wool cloth giving a rod a negative charge. The student then brings the charged rod close (but not touching) to a small, neutral metal sphere mounted on an insulating stand. The metal sphere is connected to the ground (earthed) using a wire during the process then removed before taking the rod away. He was doing all these following steps provided by the lab technician while in the lab. The student was tasked to tell the charge on the sphere but couldn't. The technician said that the study of charges can be used in a generator to produce electricity for home use.

Task; as a learner of physics, help the student;

- a) Understand the purpose of; rubbing the two objects, bringing the charged rod close to the neutral sphere and earthing.
- b) Determine the charge on the metal sphere.
- c) Describe how the statement of the technician is possible.

#### Item 16

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During the designing of a vehicle, an engineer mentioned some terms to his helpers such as **moment of a force, centre of gravity and stability** which are applicable during the design. In the same sense he wanted them to know more practically about the terms before designing. He had a uniform rod **AB** of length **2m** weighing **3.5kg**. He hangs a mass of **10kg** from end **A** and a mass of **2.6kg** from end **B**. The system was suspended from point **N** of the rod where **N** is **y** metres from end **A** so that the rod is horizontal.

**Task:**

As a physics student, help:

- (a) Explain the following terms to the helpers:
  - (i) Moment of a force
  - (ii) Centre of gravity
  - (iii) Stability
- (a) Understand the daily life application of:
  - (i) Moment of a force.
  - (ii) Principle of moment.
- (b) Explain the three different types of equilibrium.
- (c) Explain why the tyres are made wide and the designed vehicle short.
- (d) Determine the value of y.

**ITEM 17**

Your father hires a vehicle to transport you to school. While in the vehicle some terms were mentioned which are already in physics. The vehicle sets off from home at 6:00am and accelerates uniformly from rest to attain a final velocity of  $25\text{m s}^{-1}$  in 400s. On reaching the highway road, it maintains this velocity for 700s and it finally reaches the school at 8:30am.

**Task**

As a student of physics help your father to

- (a) (i) Draw a sketch of velocity time graph
- (ii) Determine the total distance covered and hence find the total amount of money the father paid if the hiring company charges a fee of UGX **800 per kilometre** of the distance covered.
- (b) understand the following terms and their SI units:
  - (i) speed
  - (ii) velocity
  - (iii) acceleration
- (c) briefly explain how the acceleration due to gravity can be determined in the laboratory if given a pendulum bob.

**ITEM 18**

In a physics lab, a student investigates how energy is stored and stored and transferred in an elastic system. She suspends a spring vertically and gradually adds

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weights. When a 2.0 kg mass is attached, the spring stretches by 10.0 cm. She then pulls the mass down by an additional 5.0 cm and releases it, initiating vertical oscillations. Assume the spring obeys Hooke's law, and there is no energy loss.

Later, the same spring is used to lift a 3.0 kg object vertically through a height of 1.5 m using a pulley system powered by a motor that takes 5.0 seconds.

**TASKS:**

- (a) Using the experimental data, determine the spring constant of the spring. Show your reasoning.
- (b) Using appropriate energy principles, derive an expression for the expression for the **maximum speed** of the 2.0 kg mass as it oscillates through equilibrium. Hence calculate the **maximum speed**.
- (c) Compare the **gravitational potential energy lost** with the **elastic potential energy gained** when the spring is stretched by 10.0 cm. Discuss whether mechanical energy is conserved at equilibrium.
- (d) The student claims, "elastic potential energy can be used to lift masses more efficiently than electric motors." Using energy and power concepts, **critically assess** this claim with reference to both stages of the experiment.
- (e) Derive an expression for the **energy stored per unit volume** in the spring, in terms of **stress** and **strain**. Clearly show your working.

**ITEM 19**

The data below was obtained during an experiment to determine the specific heat capacity of a liquid using the **continuous flow method**. The specimen liquid was to be used as a coolant in the chicken feeds power plant at **SEETA POULTRY FARM**.

The technician had earlier advised that any suitable liquid must have a specific heat capacity in a range of  $2300\text{Jkg}^{-1}\text{K}^{-1}$  to  $3500\text{Jkg}^{-1}\text{K}^{-1}$ .

	<b>EXPERIMENT 1</b>	<b>EXPERIMENT 2</b>
<b>P.D across heater (V)</b>	10.00	3.00
<b>Heating current (A)</b>	0.30	0.20
<b>Inflow temperature (°C)</b>	35	35
<b>Outflow temperature (°C)</b>	41	41
<b>Mass of liquid used (kg)</b>	0.25	0.03
<b>Time taken (s)</b>	200	120

As a physics student, help the society leaders to:

- i. Understand the difference between heat capacity and specific heat capacity, giving their respective SI unit.
- ii. Be aware of any advantages of the method used above.
- iii. Know any precautions taken in the above experiment.
- iv. Confirm if the specimen liquid tested is suitable for this purpose.

**ITEM 20**

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An employee drives from home to his work place every day and the meter of his vehicle is faulty. He some times exceeds the speed limit on the road with out knowing. When he started to drive from the compound, the son realized that his father accelerated the car to a speed of 72km/hr for 4 minutes, he maintained this speed for 6 minutes. Realizing he would be late he increased the speed to 90km/hr in a period of 10 minutes and finally decelerated to a stop at his work place for further 5 minutes.

**TASK**

- a) Help the employee to find out how far from his home to the work place.
- b) Help the employee to determine the average speed of the car.
- c) Advise the employee on how to avoid such challenges when driving back to home.

**ITEM 21**

Balls A and B of respective masses 5kg and 3kg move in a straight line in the same direction on the horizontal surface. When A knocks B which is moving at 15m/s, it stops but B continues to move in the same direction and comes to rest in a distance of 81.5cm. Assuming the coefficient of friction between the balls and the surface is 0.25.

**TASK**

- a) calculate the velocity of A before collision.
- b) Describe an experiment to determine the coefficient of kinetic friction.

**ITEM 22**

During the war of Ukraine and Russia, many residents in Ukraine were left starving since they never had what to eat. The UN sent helicopters to deliver packed food by releasing them from space with a parachute such that it lands safely. One bag was released with a velocity of 10m/s with a height from the ground being 45m. The target is at horizontal distance of 400m from the point of projection.

**TASK**

- a) Determine the time taken for the bag to reach the ground.
- b) Determine whether the residents in Ukraine were able to get the food.
- c) Explain how a parachute works to ensure the food I bags reach safely

**ITEM 23**

An engineering trainee working on a communication tower with two small charged components:

- Charge 1 ( $Q_1$ ):**  $+4\mu$  C located at Point A
- Charge 2 ( $Q_2$ ):**  $-3\mu$ C located at Point B

The distance between A and B is **6 meters**. The trainee is required to to place the signal antenna at a point P, which is located between the two charges where the Electric field intensity is zero as to avoid its malfunctioning.

**Task**

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As a physics student, assist the trainee to determine the required point.

#### ITEM 24

During a laboratory experiment, three small charged spheres are placed at the corners (labelled

clock wise) of a square with sides of 20 **cm**. The charges are:

- Charge at Corner A:**  $+3\mu\text{C}$
- Charge at Corner B:**  $-2\mu\text{C}$
- Charge at Corner C:**  $+4\mu\text{C}$

The experimenter would wish know the **electric field strength** and **potential at Corner D**, due to

the charges at other Corners.

As a physics student, Help the experimenter to determine these quantities

#### ITEM 25

An engineering trainee was provided with a box containing similar rods and required to separate those insulators and conductors. Luckily, he in possession of a plastic ruler, wool, and Gold leaf electroscope but not sure of what to do.

Later that day, the trainee was to work on a communication tower with two small charged components:

- Charge 1 ( $Q_1$ ):  $4\mu\text{C}$  located at Point A
- Charge 2 ( $Q_2$ ):  $3\mu\text{C}$  located at Point B

The distance between A and B is 6m. The trainee is required to place the signal antenna at a point P, which is located between the two charges where the Electric field intensity is zero as to avoid its malfunctioning.

Task

As a physics student,

- a) Guide the trainee on how to separate the rods
- b) assist the trainee to determine the required point.

#### Item 26

An old man who wanted to shave his bear went to a barber's saloon and was asked to sit in a chair placed at a distance of 2.0m facing a plane mirror. Another plane mirror was placed 6.0m at the back wall directly facing the first mirror. When the old man looked in the plane mirror he could see two images, one of his face and another image of the back of his head and wondered why the images were not one but separated from each other. According to the old man the images seen were real but the barber told him that the images were virtual.

**Task** : Using your knowledge of reflection of light, help the old man to

- (a) understand how the two images were formed.
- (b) determine the distance separating the two images seen in the mirror.
- (c) understand how the position of the image could be determined in a scientific investigation.
- (d) distinguish between real and virtual images.

#### Item 27

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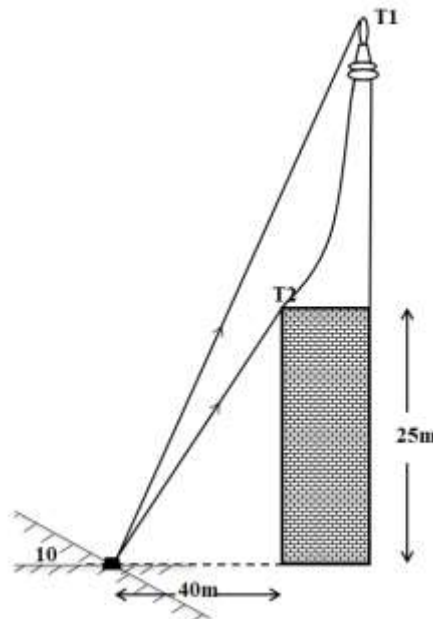
While playing with a ruler by rubbing it in hair a student of S2 realised that thereafter the ruler would attract small pieces of paper. When the student rubbed keys in his hand, he realized they had no effect on small pieces of paper. The student wondered why two rubbed objects behaved differently.

**Task :** Using your knowledge of electrostatics

- Explain to the student what happened to the ruler when rubbed in hair
- Explain why the ruler was able to attract small pieces of paper
- Explain why the metallic keys had no effect on the pieces of paper
- Describe a scientific investigation that the student would carry out to ascertain the nature of charge on the meter ruler after rubbing it in hair

### Item 28

Tom needs to measure the height of a tower on top of a 25m building in a crowded city. However, the surrounding buildings and narrow streets make it hard to get a direct measurement. To solve this problem, Tom uses the plane mirror method. He sets up a mirror 40m away from the building, initially facing the building directly. Tom adjusts the mirror to reflect a laser beam to the top of the tower (T1). After rotating the mirror  $10^\circ$ , the beam still hits the top of the building (T2). However Tom could not tell the type of reflection used and neither could he describe the nature of the image seen.



**Task:** Using your knowledge of physics to;

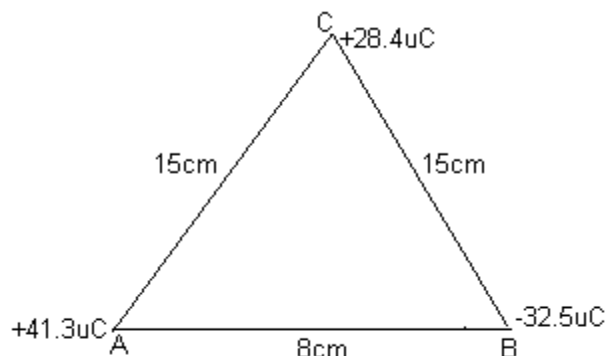
- describe the action of an optical instrument that could be used to determine directly the angle of elevation of the top point of the tower
- describe the nature of the image seen.
- distinguish the type of reflection applied from other types of reflection
- determine the tower's height above the ground.

### Item 29

business man who imports second hand car and sales them, of recently acquired a garage where the cars can be spray painted so that the cars look good to the

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customers. Before the garage could start spray painting the cars, the businessman consulted an engineer who told him that during spray painting paint particles repel each other but are attracted to the cars body and wondered if this would not waste the spray paint. The businessman was also told that the body of the car must be earthed during the spray painting. In one of the tests done by the engineer using an electronic microscope it was found that three paint particle from the nozzle of the spray were at one time arranged in a shape of a triangle ABC and carrying charge as shown in the figure below.



**Task:** using your knowledge of electrostatics, help the business man

- understand the law that governs charged particles
- know how an electrostatic paint spray works.
- determine the electrostatic force experienced by the charge at point C.
- understand how the body of car could be charged and yet remains at zero potential

### Item 30

In a nearby engineering university, a student was conducting a survey to measure the angle of elevation of a bright object in the sky, however he was not familiar of the method to employ. The student's supervisor also advised her not to use thick plane mirrors for the survey but she was not sure of the reason as to why. The procedure needed a test to verify the way in which light is reflected before everything commenced.

**Available materials:**

Two fully silvered thin plane mirrors, one half silvered thin plane mirror, a curved scale, a telescope.

**Task:**

As a learner of physics, prepare a guide for the researcher to make her understand:

- what reflection of light is and the laws that govern it.
- the reason as to why she was advised not to use thick plane mirrors.
- the device and mode of operation to determine the angle of elevation of the bright image in the sky.

### Item 31

During S.5 physics lessons, the teacher tasked members in their respective groups to outline the terms used in wave motion, in their responses the following terms were mentioned; wave length, period, amplitude. The teacher also told them that motion of a progressive wave can be analyzed using a general equation given by,  $y = 5\sin(100\pi t - 0.4\pi x)$ , where  $y$  and  $x$  are in meters and  $t$  is time in seconds.

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The teacher also made a mention of different methods of analysis applied to wave motion which included Huygen's principle.

Your O-level friend who has just reported now offers physics, and has missed three physics lessons,

Help your friend to;

Understand the meaning of the terms which were mentioned.

Determine; Amplitude, Period, Speed of the wave of the progressive wave given.

Understand Huygen's principle and show how it can be used in refraction of light.

### **Item 32**

You went with your young sister to the science show that was held in a certain hall to demonstrate some of the principles of static electricity and the following was exhibited;

- The van de Graaf generator was turned on and it made people's hair to stand up once they touched its conducting dome.
- Balloons rubbed with a piece of cloth and placed against the wall were seen to stick to the wall.

During the show, rain started with a lot of lightning strikes which terrified the audience but the MC told them not to worry because the hall had lightning conductors installed to safe guard against lightning.

On your way back home, your sister kept wondering what the MC was talking about and which magic was used during the show.

#### **Task**

As a learner of physics, help your sister to understand;

- i The working of the generator above and what made the hair to stand upon touching its dome.
- ii Why the balloons got stuck on the wall.
- iii The principle behind the working of the conductors which the MC was talking about.

### **Item 33**

In a Ugandan brick-making factory, workers are pushing heavy carts loaded with bricks across a rough concrete floor. Each cart has a mass of  $200\text{kg}$ , and the workers apply a horizontal force of  $800\text{N}$  to start the cart moving. Once moving, the cart requires a force of  $600\text{N}$  to keep it moving at a constant speed. The factory manager wants to reduce the effort required to move the carts to improve efficiency.

#### **Tasks:**

- a) Determine the coefficients of static and kinetic friction between the cart and the floor.
- b) Explain how the workers could reduce the force required to move the carts by modifying the floor or the cart's wheels.
- d) Contrast the frictional forces acting on the cart if the mass of the bricks is reduced by half. Would this significantly reduce the effort required?

### **Item 34**

A small hydroelectric power plant is being constructed near a waterfall in western Uganda. Water falls from a height of  $30\text{m}$  at a flow rate of  $400\text{kg s}^{-1}$ . The turbine converts 65% of the gravitational potential energy into electrical energy. The plant will supply electricity to a nearby village, but the engineers are concerned about the efficiency of the system.

#### **Tasks:**

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- a) Determine the power generated by the turbine.
- b) Explain how the engineers could increase the power output to  $100\text{KW}$  by modifying the flow rate or height of the waterfall.
- c) Describe the impact of energy losses due to friction in the pipes and suggest ways to minimize these losses.

**Item 35**

In a rural Ugandan community, a farmer is using a slingshot to scare away birds from his crops. He launches a small stone at an angle of  $30^\circ$  to the horizontal with an initial velocity of  $15\text{m s}^{-1}$ . The stone must clear a  $2\text{m}$  tall fence located  $20\text{m}$  away. The farmer wants to ensure the stone does not harm any birds beyond the fence.

**Tasks:**

- a) Determine whether the stone clears the fence.
- b) Explain how the farmer could adjust the launch angle or velocity to ensure the stone lands safely beyond the fence.
- c) Describe the effect of air resistance on the stone's trajectory and how it might affect the farmer's aim.

**Item 36**

A taxi is traveling along a straight road at a constant speed of  $20\text{m s}^{-1}$ . Suddenly, a goat runs onto the road  $50\text{m}$  ahead. The driver applies the brakes, causing the taxi to decelerate uniformly at  $4\text{m s}^{-2}$ . At the same time, a boda-boda (motorcycle) traveling in the opposite direction at  $15\text{m s}^{-1}$  is  $100\text{m}$  away from the taxi.

**Tasks:**

- a) Determine whether the taxi stops before hitting the goat.
- b) Explain whether the taxi and the boda-boda will collide if both continue moving at their current speeds.
- c) Describe how the driver's reaction time (assume  $0.5\text{s}$ ) affects the stopping distance of the taxi

**Item 37.**

In a bustling market in Kampala, a vendor is setting up a makeshift stall using a 5-meter-long wooden plank leaning against a wall. The plank has a mass of  $15\text{kg}$  and forms an angle of  $60^\circ$  with the ground. The vendor places a  $50\text{kg}$  sack of maize  $3\text{m}$  from the base of the plank. The ground is uneven, and the coefficient of static friction between the plank and the ground is  $0.4$ . The vendor is worried that the plank might slip, causing the sack to fall and injure someone.

**Tasks:**

- a) Determine the normal reaction force from the wall and the frictional force at the base of the plank.
- b) Explain whether the plank will slip under the current conditions. If it will, suggest a practical solution to prevent slipping.

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c) Contrast the forces acting on the plank if the angle is reduced to  $45^\circ$ . Would this make the stall more stable?

### Item 38

In a rural Ugandan village, a group of engineers is working on a project to construct a small footbridge over a river to connect two communities. The bridge will be made of locally sourced materials, including wooden beams and steel cables. The engineers propose a formula to calculate the maximum load  $W$  the bridge can support:  $W = k \sqrt{E \cdot A \cdot \Delta L} / L$ , where  $E$  is the Young's modulus of the steel cables,  $A$  is the cross-sectional area of the cables,  $\Delta L$  is the elongation under load,  $L$  is the original length of the cables, and  $k$  is a dimensionless constant. However, the village elders are concerned about the safety of the bridge and want to ensure the formula is scientifically valid before construction begins.

#### Tasks:

- Determine whether the proposed formula is dimensionally consistent.
- Explain to the village elders how the formula ensures the bridge's safety, using the given values:  $E = 2 \times 10^{11} \text{ Pa}$ ,  $A = 0.01 \text{ m}^2$ ,  $\Delta L = 0.03 \text{ m}$  and  $L = 20 \text{ m}$ . Calculate  $W$  when  $k = 2$ .
- Describe two potential sources of error in measuring  $\Delta L$  and suggest practical ways to minimize these errors in the field.

### Item 39

Students at a certain school organized a bicycle competition on a hill that is 120 m high. One of the participants, Mark, has a mass of 60 kg and his bicycle weighs 15 kg.

Mark starts at the bottom and pedals up the hill in 4 minutes along a paved path 300 m long. He does not stop and maintains a steady pace.

The mechanical efficiency of Mark's body during pedaling is 25%, meaning only 25% of the energy he uses goes into lifting him and the bicycle. The cost of energy intake (food) is about Shs 100,000 per 18,000 kJ.

#### Tasks:

- Calculate the total gravitational potential energy (GPE) gained by Mark and his bicycle by the time he reaches the top.
- Determine the useful power output in watts during the climb.
- Find the total energy input required by Mark's body considering the 25% efficiency.
- Calculate the cost of food energy required to complete the climb.
- Suggest the two ways to improve efficiency during such physical activities.

### Item 40

On a straight road near your school, a student is walking at a constant speed of 1.5 m/s towards a parked minibus. At the same moment, the minibus starts moving away from the student with a uniform acceleration of  $1.2 \text{ m/s}^2$  from rest.

You are asked by the Road Safety Club to analyse the situation and determine whether the student will ever catch up to the minibus or how close he can get before it moves too far.

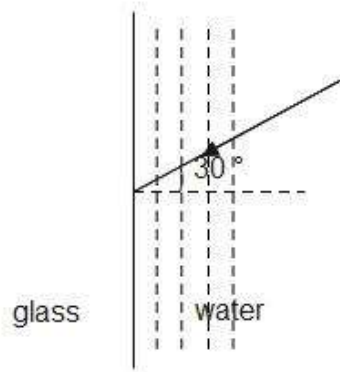
#### Tasks:

- (a) Formulate expressions for the displacement of the student and the displacement of the minibus after time  $t$  seconds.
- (b) Determine the minimum distance between the student and the minibus and the time at which it occurs.
- (c) Find the relative velocity between the student and the minibus after 4 seconds. Interpret what this value means in terms of their motion.

#### Item 41

A group of students at a vocational college is designing a solar-powered periscope system that allows users to observe distant objects near the ground without bending. The system uses a glass prism to bend light from outside into the user's eye through total internal reflection and controlled refraction.

They use a  $60^\circ$  glass prism ( $n = 1.5$ ) and aim for minimum deviation of the sunlight rays entering the prism. During testing, they also notice that when viewing objects in a tank of water ( $n = 1.33$ ) through a glass window as it's struck at an angle of  $30^\circ$  inside the water, the objects appear shifted or bent. Which left them confused.



#### Tasks:

As a physics student

- (a) Help the team to determine the angle of refraction when sunlight enters the glass prism from air at an angle of incidence of  $40^\circ$ .
- (b) Find the angle of minimum deviation of the prism they used.
- (d) Determine the angle of refraction in the glass and account for the apparent shift of objects seen through the tank wall.

#### ITEM 42

The Ugandan government constructed a suspension bridge over the Nile River to connect two major towns. The bridge's main cables are made of steel, with a total length of 500 meters and cross-sectional area of  $0.05\text{m}^2$ . The steel has a young's modulus of  $2 \times 10^{11}$  pa. A business man wished to travel from one of the towns to the other and used a lorry of mass 1000 tons including his mass. The man started his lorry and faced opposition due to friction since the road leading to the bridge was rough and the coefficient of friction is 0.32. On reaching the bridge, its length appear to increase slightly, he was left worried including the lorry's opposition

#### Task,

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as a physics Learner, help the businessman to;

- a) know the origin of the force that opposed his motion and state laws associated to it.
- b) Determine the maximum force the man applied to overcome opposition to his lorry if the road was horizontal
- c) Determine the elongation of the main cables of the bridge and give reasons why steel was most preferred the bridge's construction.

### ITEM 43

A rural Ugandan community is working to improve home insulation in the houses during hot days for safety for residents. One man while constructing his house was advised to use a double glazed window which had two glass sheets each of thickness 4.0mm, separated by a layer of air of thickness 1.5 mm. He was told that heat can be transferred in glass due to its thermo conductivity and if the inner air-glass surfaces had steady temperatures of 25 °c and 4 °c respectively, the outer air-glass surfaces will have some temperature. The man wished to know how heat is transferred in glass and the temperature of the outer air-glass surfaces but lacked knowledge.

#### Task.

As a physics learner, help the man to;

- a) know the temperature of the outer air-glass surfaces ( conductivity of glass= $0.72 \text{ Wm}^{-1}\text{K}^{-1}$ , and that of air= $0.025 \text{ Wm}^{-1}\text{K}^{-1}$ )
- b) Understand how heat is transferred in glass.
- c) Describe how thermo conductivity of glass can be determined.

### ITEM 45

A team of tourists decided to tour one of the lakes in western Uganda. As they reached there, they saw a ship being pulled by six tugboats each exerting Forces of 6N, 5N, 7N, 8N, 5N, and 9N acting in the direction N30°E, N30°W, S50°E, N60°W, N80°E and S40°W, respectively. The ship moved a distance of 100m in the direction of the resultant force and the tourists were worried about this happening yet they were different forces in the tugboats. As they went back, they used a car of mass 800kg with the engine working at a constant rate of 15kW and climbed a hill of inclination 1 in 98 against a constant resistance to motion of 420N. The car driver found it hard to climb the hill than they has descended it while going to the lake and was worried about it.

#### Task.

Help the tourists understand,

- a) The resultant force acting on the ship by the tugboats and the work done by the resultant force.
- b) Acceleration of a car up a hill when travelling with a speed of  $10\text{ms}^{-1}$
- c) Maximum speed of the car up the hill and its kinetic energy at this speed.
- d) Explain to the car driver why he found it harder while climbing the hill than while descending it.
- e) If the shock-absorbers of their car is noticed to oscillate at period of  $T = 2\pi \sqrt{\frac{l}{g}}$ , show whether this equation is dimensionally correct.

### ITEM 46

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In preparation for installing a speed governor, a transport company decides to test a new bus on a straight stretch of road. The road has a clearly marked “(maximum speed limit of 80 km/h)”. The bus is fined UGX 50,000 if it exceeds the maximum speed limit by  $1.5\text{ms}^{-1}$  and it is charged UGX 100,000 if it exceeds the maximum speed limit by more than  $1.5\text{ms}^{-1}$ .

**During the test:**

- The bus starts from rest and accelerates uniformly at  $1.6\text{m/s}^2$  for 15 seconds.
- It then travels at constant speed for 30 seconds.
- Finally, it decelerates uniformly to a stop over 10 seconds.

The students observing the test also record fuel use. The bus consumes 0.3 litres of fuel every 100 meters travelled. The cost of fuel is UGX 5,000 per litre.

The students are expected to analyze the bus’ motion, check if the speed limit was respected, and evaluate how speed affects fuel consumption and transport costs. However, students don’t know how to analyze the motion of the bus since they had not studied linear motion.

**Task.**

As an advanced level learner of physics who has studied motion,

- (i) Help the students to sketch a velocity-time graph for the motion of the bus described to be used to analyze the motion of the bus.
- (ii) Help the students to find out how much was the bus fined?
- (iii) Help the learners to determine the total cost of the fuel used during the test?
- (iv) How does a speed governor improve road safety?

**ITEM 47.**

A certain factory has machines which work on a daily basis and it is noticed that due to that, they have been complaining about machines becoming too hot every day due to over work. One of the workers suggested that they should introduce in a liquid that will always cool their machines and must be of high specific heat capacity. They were presented with Liquid X and water and wished to know which was best to be used. The worker decided to use continuous flow experiment to find out the best. While using liquid X, It was found that when a p.d applied was 12.0V, current 1.5A, a rate of flow of liquid of 50.0g/minute cause the temperature of inflow liquid to differ by  $10^{\circ}\text{C}$  . When the p.d was increased to 16.0V with current of 1.6A, the rate of flow of 90.0g/minute was required to produce the same temperature difference as before. The factory manager had less knowledge to interpret all this for the best choice.

**Task.**

As an advanced level Lerner of physics, help the factory manager to,

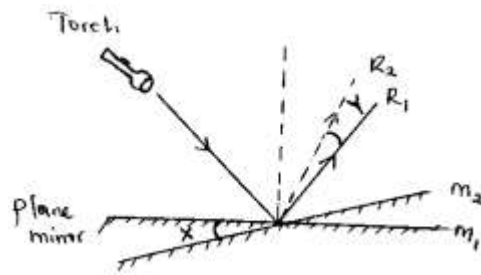
- a) Understand how continuous flow experiment is used to determine the specific heat capacity of liquid.
- b) Understand the Merits and demerits of using the above method.
- c) Understand which liquid among Liquid X and water to use for cooling the machines in their factory if the specific heat capacity of water is  $4200\text{kg}^{-1}\text{K}^{-1}$ .
- d) Understand why the worker suggested the liquid of high specific heat capacity.
- e) What was the value for the Rate of heat loss to the surrounding in the above experiment and how can it be minimized?

**ITEM 48.**

A certain student focused light from a torch on to a plane mirror placed in position  $m_1$ , he noticed that the ray was reflected to position  $R_1$ . He then decided to rotate the

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plane mirror to position  $m_2$  through an angle  $x$  while keeping the direction of the incident ray from the torch constant, he noticed that the reflected ray also got rotated through an angle  $y$  to position  $R_2$ . He went ahead and flashed the corrugated iron sheets could reflect torch scattered to



position  $R_2$ . He went ahead and flashed the corrugated iron sheets could reflect torch scattered to different directions.

**Task.**

As a scholar of physics;

- (c) Explain with the help of diagrams the difference in the above cases of reflection.
- (d) State the laws that govern the above phenomenon.
- (e) Derive the relationship between the angle of rotation of the plane mirror  $x$  and the angle of rotation of the reflected ray  $y$ .
- (f) If the plane mirror was rotated through angle  $x=30^\circ$ , determine the angle to which the reflected ray will be rotated
- (g) Explain the properties of images formed by the above type of plane mirror

If another plane mirror is introduced and made to be inclined to the above plane mirror at an angle  $\theta$ . Derive the relationship between the angle of deviation,  $d$  and the glancing angle,  $g$  produced.

**ITEM 49**

A certain village had water scarcity and they appealed to local leaders to provide them with water. The leaders hired water engineer and used a pump which draws  $3.6m^3$  of water of density  $1000kgm^{-3}$  from a well 5m below the ground in every minute, and issues it at ground level using a pipe of cross-sectional area  $40cm^2$ . The leaders wanted to know the speed at which water was to be issued out so that they sensitize the village about it, they further wanted to know whether the pipes used were good for proper planning in further. The engineer told them that they are about 80% efficient.

**TASKS.**

As a s.5 physics student, Help the leaders understand

- a) The speed with which water leaves the pipe
- b) The rate at which the pump is working
- c) If the pump is only 80% efficient, find the rate at which it must work
- d) Find the power wasted and suggest ways of minimizing it.

**END**  
**Good luck**

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