| Class | Full Name | Index Number |
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*I believe, therefore I am*

# Preliminary Examination 2024

# O

# 6091/02

**PHYSICS**
Secondary 4 Express
Paper 2 Structured and Free Response

**22 August 2024** **1 hour 45 minutes**

Candidates answer on Question Paper.
No additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your name and index number on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs
Do not use staples, paper clips, glue or correction fluid.

**Section A**
Answer **all** questions.
Write your answers in the spaces provided.

**Section B**
Answer **one** question.
Write your answers in the spaces provided.

Indicate your choice in the table provided below.

Candidates are reminded that **all** quantitative answers should include appropriate units.
The use of an approved scientific calculator is expected, where appropriate.
Candidates are advised to show all their working in a clear and orderly manner, as more marks are awarded for sound use of Physics than for correct answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| Section A | 70 |
| | |
| Section B | |
| | 10 |
| Total | 80 |

This document consists of **24** printed pages, including the cover page.

## Section A

Answer **all** questions.

For Examiner's Use

**1** **(a)** Define velocity.

…….. [1]

**(b)** A 7.5 kg rock is thrown vertically upwards from the surface of a planet. The rock leaves the surface of the planet with a speed of 4.0 m $s^{-1}$ at time t = 0. Fig. 1.1 shows the velocity-against time graph of the rock.

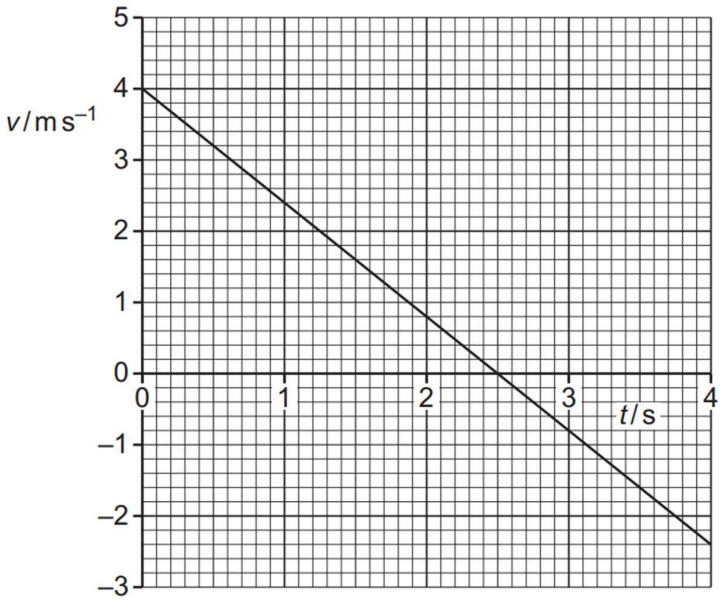


**Fig. 1.1**

Assume that the planet does not have an atmosphere and that the resistive force acting on the rock is negligible.

**(i)** Using the graph, determine the weight of the rock on the planet.

weight = ……. [3]

For Examiner's Use

**(ii)** Calculate the maximum height the rock reached before it starts falling.

maximum height = ..... [1]

**(iii)** The same rock was thrown vertically upwards on Earth with a speed of 4.0 m $s^{-1}$. Assuming resistive forces are also negligible on Earth and acceleration due to gravity is 10 $m/s^2$, draw the velocity against time graph of the rock and label it E on Fig. 1.1. [2]

[Total: 7]

**2** A very deep tank is used when training sailors to escape from submarines. The tank is cylindrical and open to the air at the top. Fig. 2.1 shows the tank.

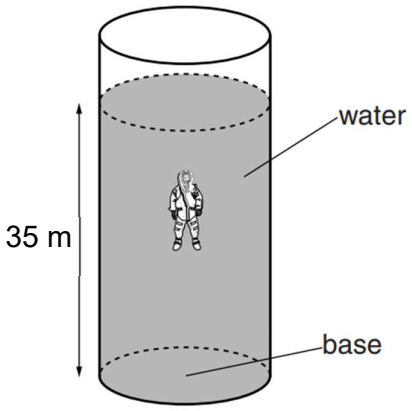


**Fig. 2.1** (not to scale)

The area of the base of the tank is 4.2 x $10^5$ $cm^2$ and the tank is filled with water to a depth of 35 m.

**(a)** The density of water is 1000 kg / $m^3$. Calculate the pressure, due to the water, on the base of the tank.

pressure = ..... [1]

For Examiner's Use

**(b)** The pressure in the water at the base of the tank is 450 kPa.

**(i)** Explain why the pressure in the water at the base of the tank differs from the value calculated in **(a)**.

.....

..... [1]

**(ii)** Calculate the force exerted on the base of the tank.

force = ..... [1]

**(c)** Force is a vector quantity and pressure is a scalar quantity. State how a vector quantity differs from a scalar quantity.

.....

..... [1]

**(d)** Fig. 2.2 shows the equipment that is used to measure the pressure of the gas in a flask at sea level.

For Examiner's Use

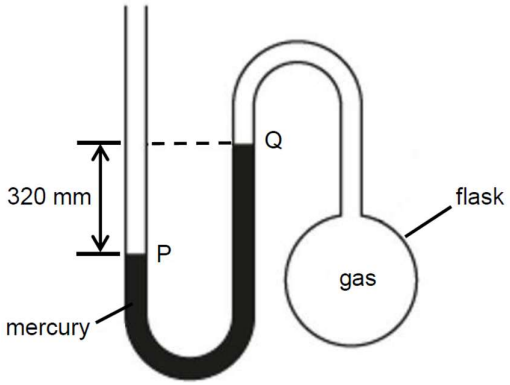


**Fig. 2.2**

The atmospheric pressure is $1.0 \times 10^5$ Pa at sea level. The distance between mercury level P and mercury level Q is 320 mm. The density of mercury is 13600 kg / $m^3$. Determine the pressure of the gas inside the flask in mm Hg.

pressure = …… mm Hg [2]

[Total: 6]

**3** The boiling point of nitrogen is –196 °C. Liquid nitrogen, below its boiling point, is stored in a vacuum flask, as shown in Fig. 3.1.

For Examiner's Use

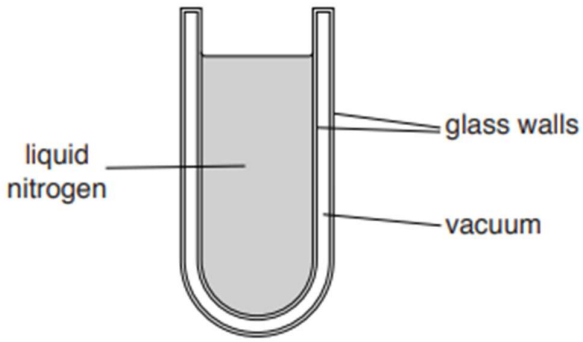


**Fig. 3.1**

The flask has two glass walls with a vacuum between them.

**(a)** State where, in the apparatus shown in Fig. 3.1, evaporation occurs.

…….. [1]

**(b)** Other than the location where evaporation occurs, describe **two** other differences between evaporation and boiling.

……..

……..

……..

……. [2]

**(c)** State and explain the advantage of having a vacuum between the two glass walls.

……..

……..

……..

…….. [2]

For Examiner's Use

**(d)** The liquid nitrogen reaches –196 °C, its boiling point. A small piece of metal at 20 °C is lowered slowly into the liquid nitrogen.

The small piece of metal has a mass of 50 g. When it is lowered into the liquid nitrogen, the metal cools to –196 °C.

The specific heat capacity of the metal is 390 kJ / (kg K).
The specific latent heat of vaporisation of nitrogen is 200 J / g.

Calculate

**(i)** the thermal energy lost from the metal as it cools,

thermal energy = …….. [2]

**(ii)** the mass of nitrogen that boils away.

mass = …… [1]

[Total: 8]

**4** Fig. 4.1 gives the names of the five components of the electromagnetic spectrum arranged by decreasing frequency.

| | | | | |
|---|---|---|---|---|
| X-rays | Microwaves | Ultra-violet | Infra-red | Radiowaves |

**Fig. 4.1**

**(a)** State the component in Fig. 4.1 which is **not** in the correct position.

…… [1]

For Examiner's Use

**(b)** State which of the five components [2]

**(i)** has smallest wavelength, ……

**(ii)** is used for home Wi-Fi signal, ……

**(iii)** is used in a television remote control. ……..

**(c)** Explain why ultrasound is **not** a component of the electromagnetic spectrum.

……...

…… [1]

**(d)** Ultrasound and X-rays are used in hospitals to produce images of regions in the human body. Both procedures need a source of waves and a detector.

**ultrasound**


**Fig. 4.2**

**X-ray**


**Fig. 4.3**

Draw and label the positions of the source and the detector

**(i)** on Fig. 4.2, when ultrasound produces an image of region P, [1]

**(ii)** on Fig. 4.3, when X-rays produce an image of region Q. [1]

[Total: 6]

For Examiner's Use

**5** **(a)** A student rubs a plastic ruler against a piece cloth made of wool. The student tests the ruler and finds it is positively charged. Explain how the ruler becomes positively charged.

.....

..... [1]

**(b)** An insecticide sprayer charges droplets of insecticide. Fig. 5.1 shows the sprayer being used to spray a leaf.

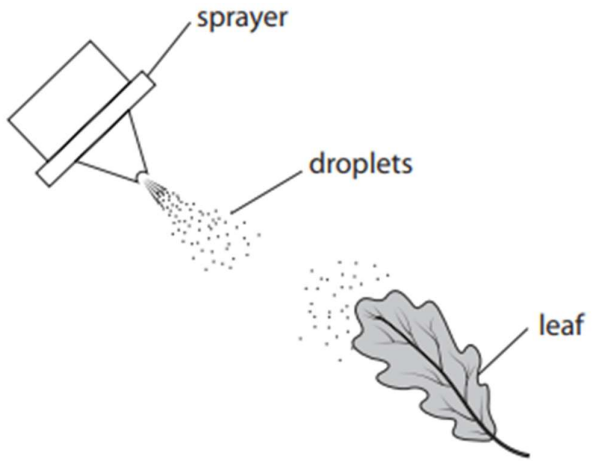


**Fig. 5.1**

The leaf is connected to the ground (earthed). Explain how charging the droplets helps to make sure that the leaf gets covered with insecticide. You may add to Fig. 5.1, including the sign (+ or −) of any charges, to help you explain.

……

……

……

……

……

…… [3]

[Total: 4]

For Examiner's Use

**6** Fig. 6.1 shows a metal rod placed between the poles of a magnet.

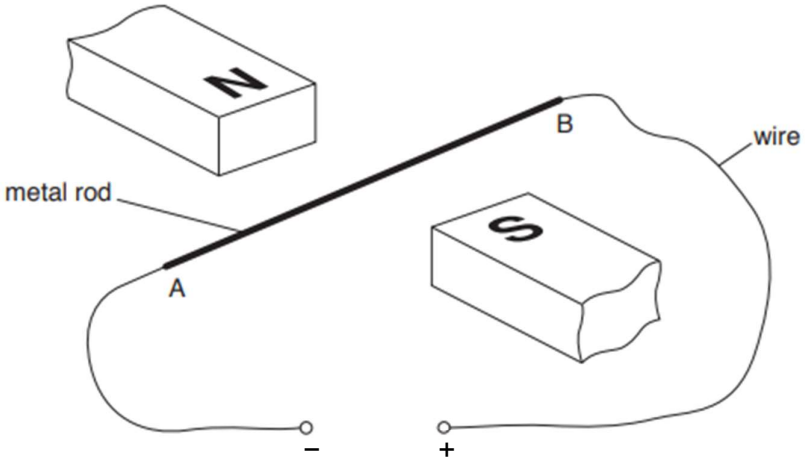


**Fig. 6.1**

**(a)** End A of the rod is connected to the negative terminal of a d.c. power supply and end B is connected to the positive terminal.

On Fig. 6.1,

**(i)** draw an arrow to show the direction of the current in the metal rod and label this as P. [1]

**(ii)** draw the direction of the magnetic field between the two poles of the magnet and label Q. [1]

**(b)** Describe and explain what happens to the metal rod when the power supply is switched on.

.....

.....

.....

.....

.....

..... [3]

**(c)** State one application of the phenomenon described in **(b)**.

..... [1]

[Total: 6]

**7** Fig. 7.1 shows a piece of magnetic data storage tape passing under a recording head. An alternating current is passed through the coil. The tape is coated with a permanent magnetic material which becomes magnetised.

For Examiner's Use

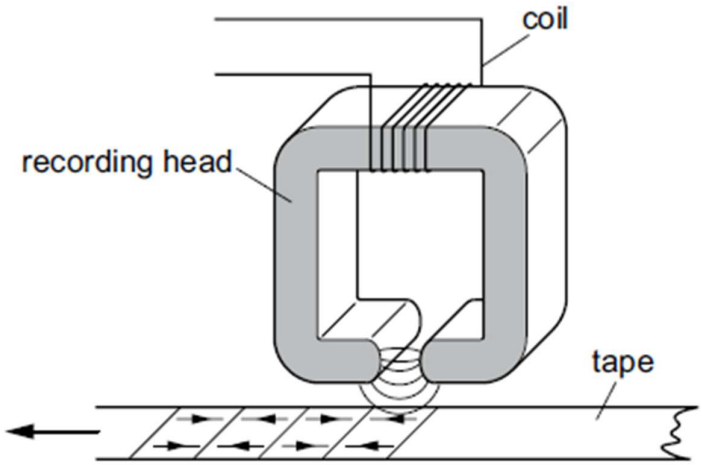


**Fig. 7.1**

**(a)** **(i)** Explain why the tape becomes magnetised.

……

…… [1]

**(ii)** Fig. 7.1 shows that the sections of the tape are magnetised in opposite directions. Explain how this is caused.

……

…… [1]

**(iii)** The tape is moved slower past the recording head. State how this changes the pattern on the tape.

……

…… [1]

For Examiner's Use

**(b)** Suggest an advantage and a disadvantage of using temporary magnetic material to make the magnetic data storage tape.

Advantage: ……

……....

Disadvantage: ……..

…… [2]

[Total: 5]

**8** A power station generates electrical energy at 25000 V, 12000 A. The generator in the power station is connected to the primary coil of an ideal transformer. The transformer changes the voltage before the electrical energy is transmitted across the country. The output from the secondary coil of the transformer is 400000 V.

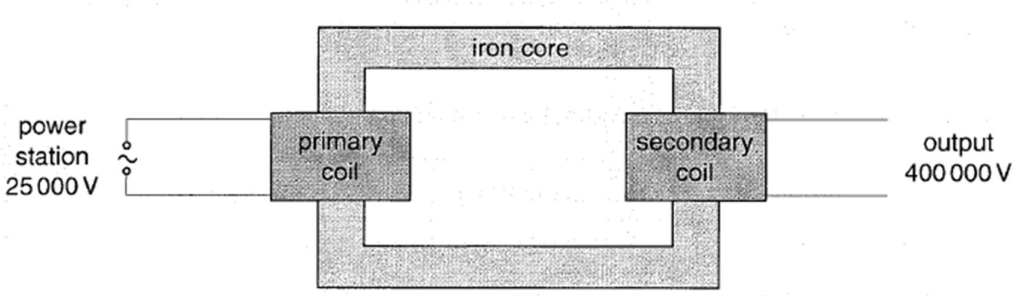


Fig. 8.1

**(a)** State what is conserved in an ideal transformer.

…… [1]

**(b)** Explain how a current in the primary coil produces an output voltage in the secondary coil.

……

……

……

……

……

…… [3]

**(c)** Calculate the ratio of the number of turns in the primary coil to the number of turns in the secondary coil.

For Examiner's Use

ratio = ..... [1]

**(d)** Calculate the output current from the transformer.

current = ..... [1]

**(e)** Hence or otherwise, calculate the output power of the transformer.

power = ..... [1]

**(f)** State one advantage of using a high voltage for the transmission of electrical energy.

.....

..... [1]

[Total: 8]

**9** **(a)** Two light signals, green light and violet light, are sent from a transmitter to a receiver by two different methods in Fig. 9.1.

For Examiner's Use

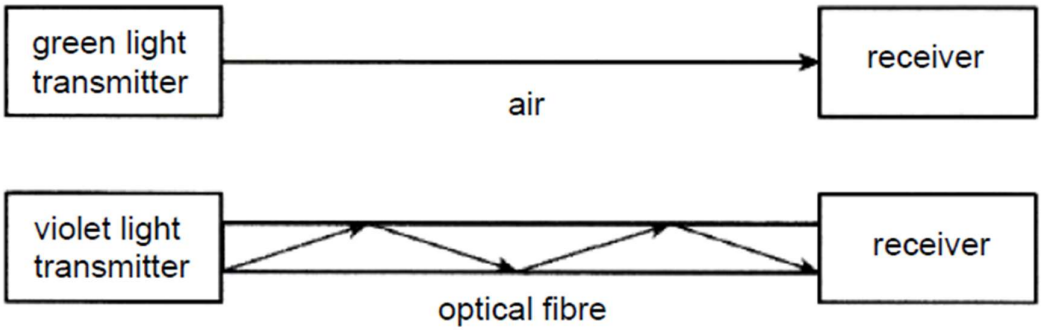


**Fig. 9.1**

The structural composition of the optical fibre through which the violet light travels is as shown in Fig. 9.2.

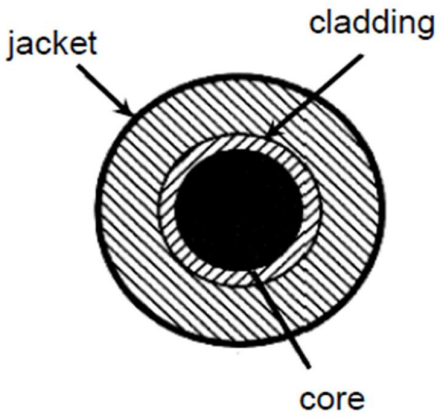


**Fig. 9.2**

**(i)** State what is meant by a refractive index of 1.3.

.....

..... [1]

**(ii)** Name the phenomenon which prevents the violet signal from escaping from the optical fibre.

..... [1]

For Examiner's Use

**(iii)** State and explain whether the core or cladding has a lower refractive index.

.....

.....

.....

..... [2]

**(iv)** Compared to the green light, the violet light takes a longer time to arrive at the receiver. Suggest two reasons for this.

.....

.....

.....

..... [2]

**(b)** Fig. 9.3 shows the graph of the angle of refraction *r* against the angle of incidence *i*, when a light ray travels from the material indicated in the graph into air.

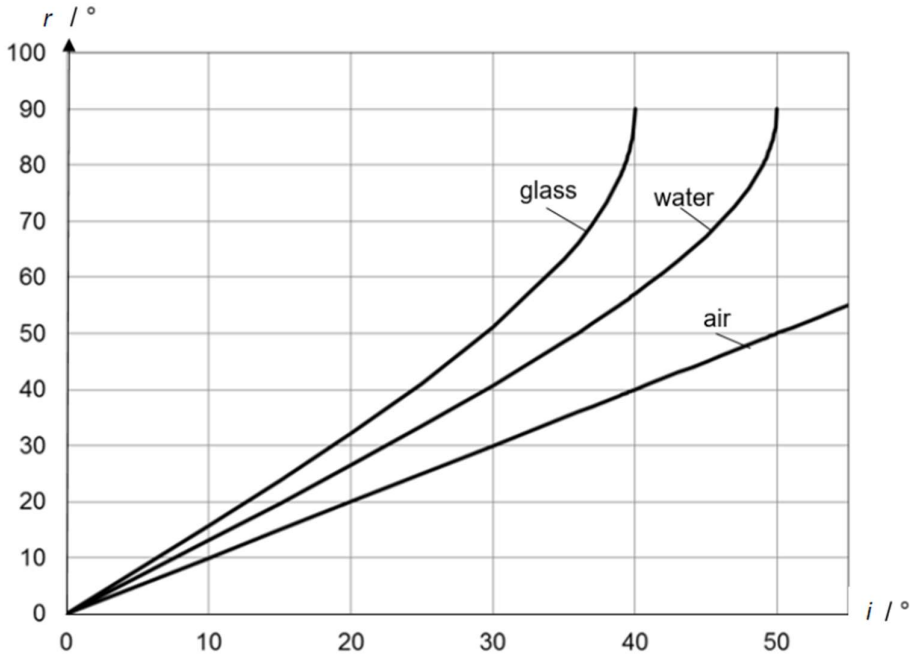


**Fig. 9.3**

**(i)** Using the data from Fig. 9.3, explain what happens to the light ray if the angle of incidence exceeds 50 ° in water.

For Examiner's Use

……

……

……

…… [2]

**(ii)** Determine the refractive index of glass.

refractive index = …… [2]

[Total: 10]

**10** An isotope of Radium is radioactive. It emits only alpha particles. It is also known that radioactive decay is random and spontaneous.

For Examiner's Use

**(a)** Explain what is meant by spontaneous decay.

..... [1]

**(b)** In the nuclide notation, radium-226 is written as $^{226}_{88}Ra$.

When a nucleus of radium-226 emits an alpha-particle (α), it decays to an isotope of Radon (Rn).

Complete the decay equation below for this decay. [2]

$$^{226}_{88}Ra \rightarrow \ ^{\ldots\ldots}_{\ldots\ldots}Rn \ + \ ^{\ldots\ldots}_{\ldots\ldots}\alpha$$

**(c)** An experiment was conducted to find the range of alpha particles in air. The results of the experiment are shown in the Table 10.1.

**Table 10.1**

| **Distance from the Source to the Detector / cm** | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 |
|---|---|---|---|---|---|---|---|---|---|
| **Count Rate / counts per minute** | 885 | 662 | 429 | 345 | 280 | 20 | 19 | 21 | 19 |

**(i)** Estimate the background radiation count rate.

..... [1]

**(ii)** Hence, calculate the count rate of the radioactive source when it is placed at distance of 3.0 cm.

count rate =..... [1]

For Examiner's Use

**(iii)** State the value for the maximum distance that alpha particles can travel from the source. Explain your answer.

.....

.....

..... [2]

**(d)** Fig. 10.2 shows the decay curve for a sample of a beta-emitting radioactive isotope. The percentage activity is the percentage of unstable atomic nuclei in the isotope that decay per second in a given sample.


**Fig. 10.2**

**(i)** State the half-life of the radioactive isotope.

..... [1]

**(ii)** The decay product of the beta-emitting isotope is not radioactive. Explain why the sample of the radioactive isotope will be safer after 20 days than after 5 days. Support your answer using the graph.

.....

.....

.....

..... [2]

[Total: 10]

For Examiner's Use

## Section B

Answer **one** question from this section.

**11 (a)** A piece of stiff cardboard is attached to a plank of wood by two sticky tapes as shown in Fig. 11.1.

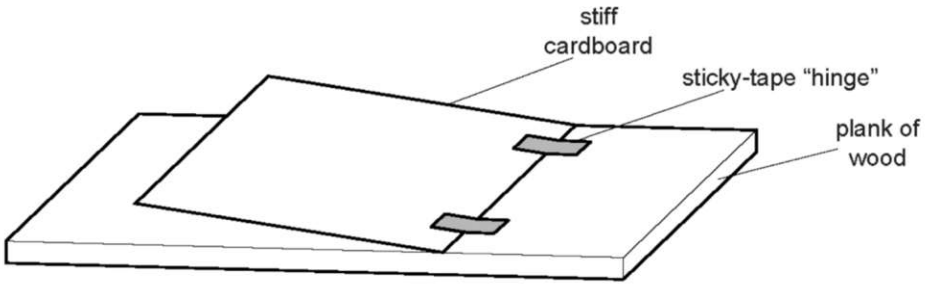


**Fig. 11.1**

**(i)** The cardboard is to be lifted by a force F, so that it turns about the hinges. Force F is to be as small as possible.

Draw force F on Fig. 11.1 to show that it fulfils this requirement. [1]

**(ii)** A box of matches is balanced on the cardboard as shown in Fig. 11.2.

For Examiner's Use

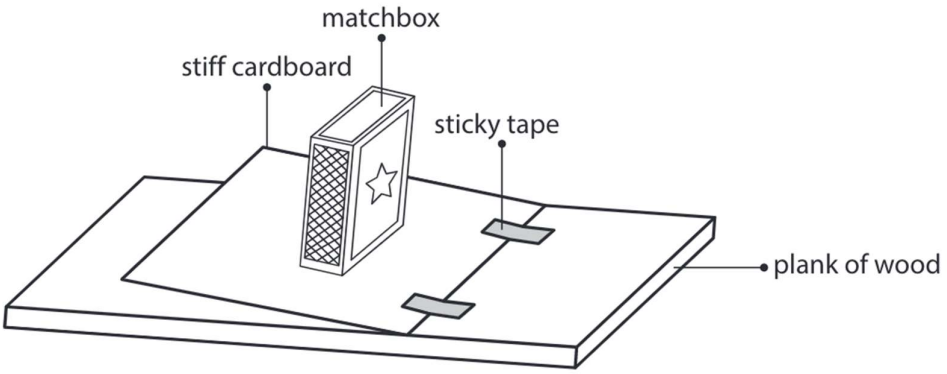


**Fig. 11.2**

The left-hand edge of the cardboard is gradually raised. The box does not slide. Explain what will eventually happen to the box of matches as the edge is raised.

……...

……...

……...

……...

……...

…… [3]

**(b)** In Fig. 11.3, a uniform plank of length 6.0 m and weight 400 N is suspended by two strings at X and Y. A box of mass 2.5 kg is placed on the plank.

For Examiner's Use

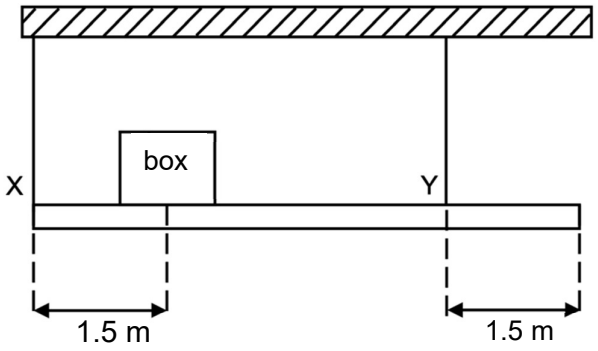


**Fig. 11.3**

**(i)** On Fig. 11.3, draw and label arrows to represent all the forces acting on the plank. [2]

**(ii)** The plank is in equilibrium, calculate the force on strings X and Y.

force on string X = ……

force on string Y = …….. [4]

[Total: 10]

**12** Fig. 12.1 shows the I-V characteristic graph of an electrical component X.

For Examiner's Use

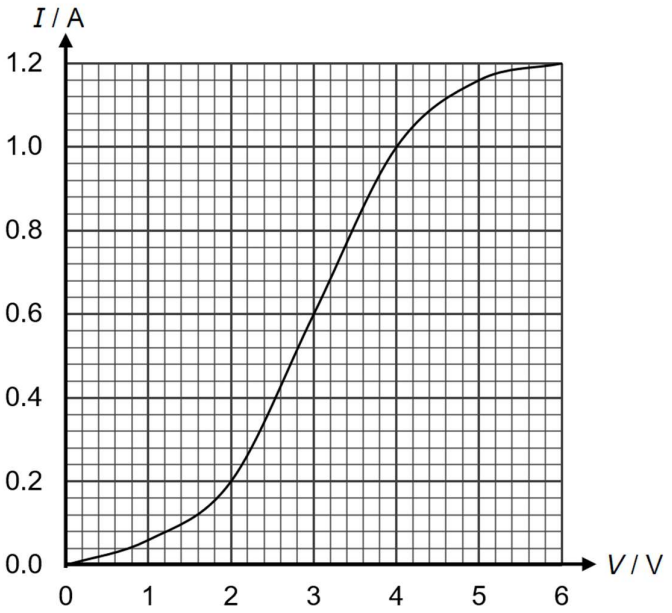


**Fig. 12.1**

**(a)** Describe how the resistance of X changes when the potential difference across it varies from 0 V to 2.0 V.

.....

..... [1]

**(b)** State the range of potential differences within which X behaves like an ohmic conductor. Explain your answer.

.....

.....

.....

..... [2]

**(c)** A fixed resistor has an unknown resistance.

Describe, with the aid of a diagram, how the resistance of this fixed resistor can be determined experimentally.

For Examiner's Use

.....

.....

.....

.....

.....

.....

.....

..... [3]

**(d)** Fig. 12.2 shows electrical component X connected to a fixed resistor and a battery of electromotive force (e.m.f.) 6.0 V.

For Examiner's Use

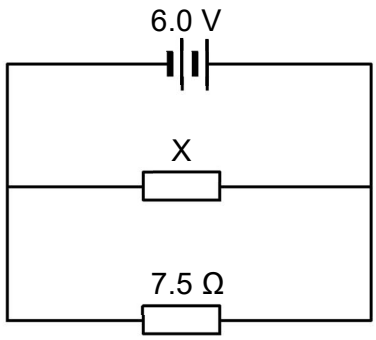


**Fig. 12.2**

The fixed resistor has a resistance of 7.5 Ω.

**(i)** Explain what is meant by resistance of 7.5 Ω.

……. [1]

**(ii)** On Fig. 12.1, sketch the I-V characteristics graph for the 7.5 Ω resistor. Label this graph Y. [1]

**(iii)** Determine the total current delivered by the battery in the circuit.

total current = …….. [2]

[Total: 10]