**ST. JOSEPH'S INSTITUTION**
**PRELIMINARY EXAMINATION 2024**
**(YEAR 4)**

| | |
|---|---|
| CANDIDATE NAME | **MARK SCHEME** |
| CLASS | |
| INDEX NUMBER | |

**PHYSICS** **6091/02**

**Paper 2** **9 September 2024**

Candidates answer on the Question Paper.
No Additional Materials are required.

**1 hour 45 minutes**
**(08:05 – 09:50)**

**READ THESE INSTRUCTIONS FIRST**

Write your name, class 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.

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.

**Section A**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| / 6 | / 8 | / 5 | / 8 | / 8 |
| 6 | 7 | 8 | 9 | - |
| / 5 | / 10 | / 10 | / 10 | - |

**Section B**

| 10 | 11 |
|---|---|
| / 10 | / 10 |

| For examiner's use | |
|---|---|
| Section A | 70 |
| Section B | 10 |
| Total | 80 |

## Section A

Answer **all** questions.

**1** A car is speeding along a straight road that has a speed limit of 50 km/h.
The car passes a policeman on a stationary motorcycle at $t = 0$.
The policeman starts chasing the car, using his motorcycle, at $t = 0.50$ s.

Fig. 1.1 shows the velocity-time graph of the car.

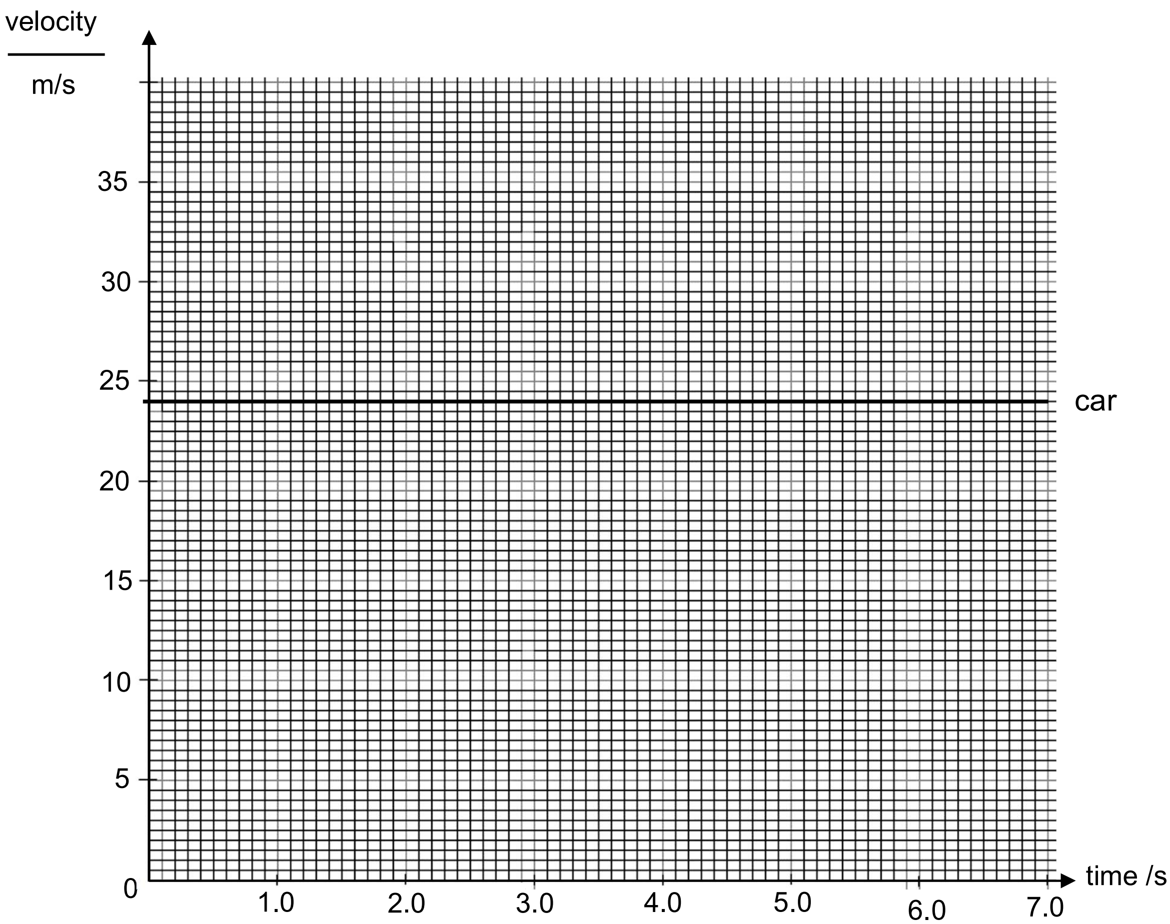



**Fig. 1.1**

**(a)** Using information from Fig.1.1, show that the car has exceeded the speed limit.

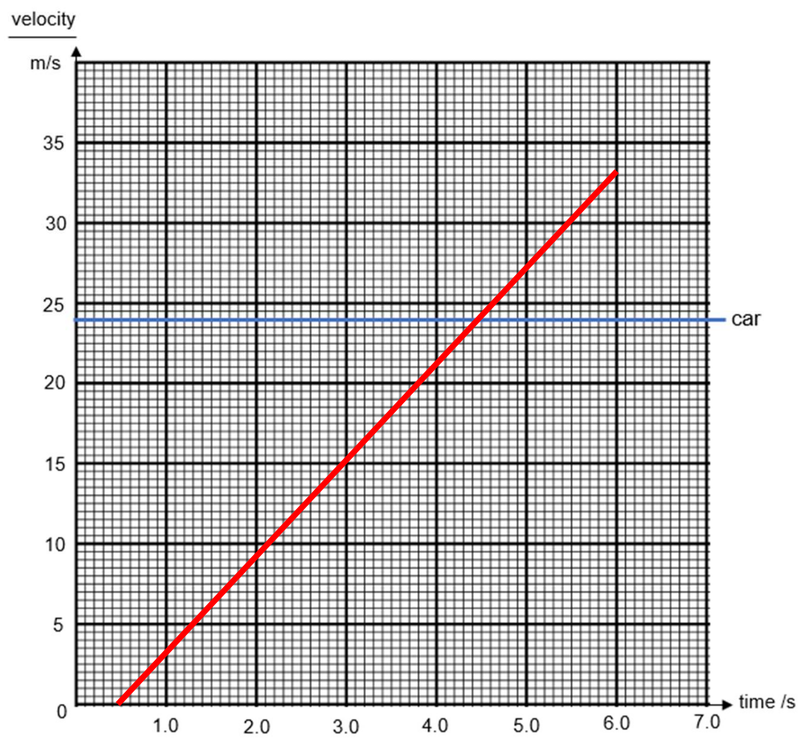
50 km/h = 14 m/s
Or 24 m/s = 86.4 km/h
Since speed > 50 km/h therefore car is speeding

**(b)** The velocity of the policeman's motorcycle increases uniformly from rest at $t$ = 0.50 s at a rate of 6.0 m/s$^2$.

**(i)** On Fig 1.1,

- draw the velocity-time graph of the policeman's motorcycle from $t$ = 0 until $t$ = 6.0 s
- indicate the velocity of the motorcycle at $t$ = 6.0 s.

Show all relevant working.




$$a = \frac{v-u}{t}$$

$v = u + at$

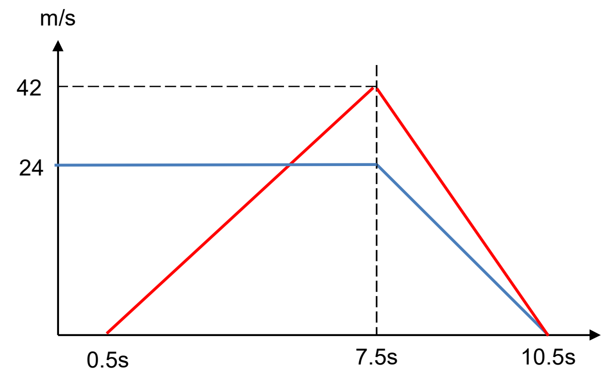
$= 0 + (6.0)(5.5)$

$= 33.3$ m/s

straight line from 0 m/s to 33 m/s from t = 0.50 s to t = 6.0 s

**(ii)** At $t$ = 7.5 s, the car notices the motorcycle and starts decelerating uniformly from 24 m/s to rest. The motorcycle also decelerates uniformly, and at $t$ = 10.5 s, both come to a complete stop.

Calculate the distance between them at $t$ = 10.5 s.



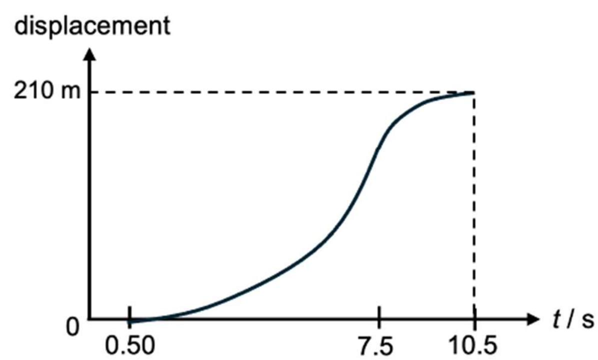

Distance travelled by car between t = 0s and 10.5s
= ½ (10.5 + 7.5)×24 = 216 m

Velocity of motorcycle at t = 7.5:
a = (v – u)/t
6.0 = (v – 0)/(7.5 – 0.5) = v/7.0
v = 6.0m/s$^2$ ×7.0s = 42 m/s

Distance travelled by motorcycle = area under *v*-*t* graph
= ½ × 10.0s ×42m/s = 210 m

Distance apart = 6.0 m

**(iii)** Sketch the displacement-time graph of the motorcycle on the axes provided in Fig. 1.2.



**2** Fig. 2.1 shows a block of weight 50 N being pulled up a smooth slope at a constant velocity, using a wire attached to a motor.

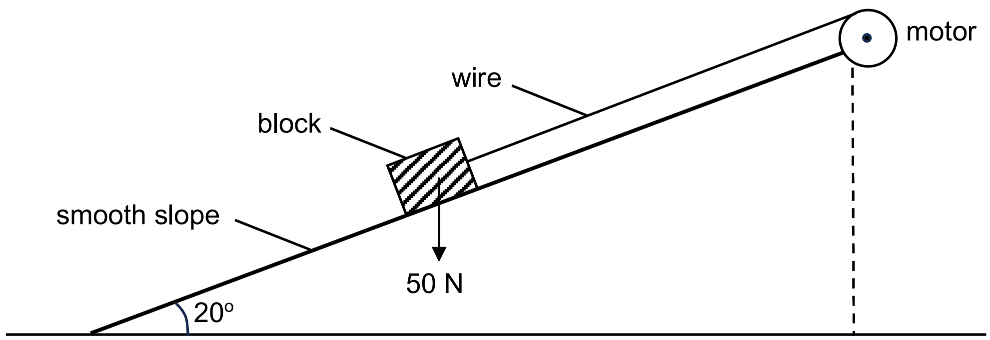
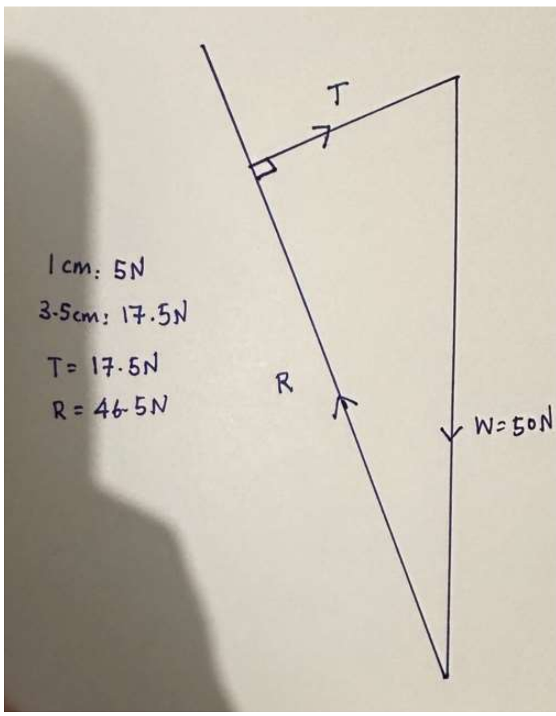



**Fig. 2.1**

**(a)** By drawing a scaled diagram, determine the tension in the wire.




T = 17.5 N or (16.6 N – 18.4) N

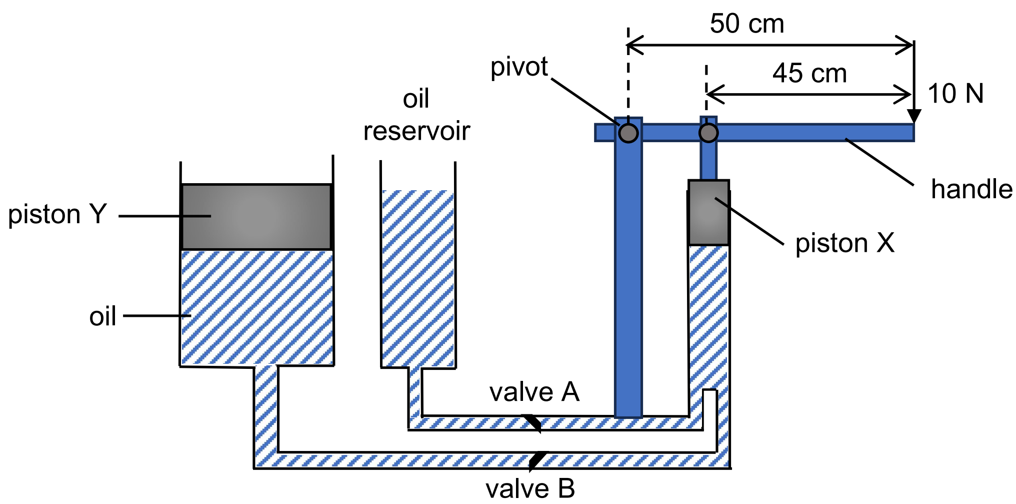
**(b)** **(i)** Calculate the useful power output of the motor in pulling the block up the slope, given that the block is moving with a constant velocity of 0.75 m/s.

P = F x v = 17.5N x 0.75m/s = 13 W

**(ii)** State two reasons why the rate of increase of energy in the gravitational potential store is equal to the useful power output of the motor.

No work done against friction as slope is smooth,
and energy in the kinetic store is unchanged as velocity is constant.

| | | | |
|---|---|---|---|
| | **(c)** | State and explain the change in the motion of the block if the gradient of the slope is lowered until it is horizontal, while the tension in the wire remains unchanged. | |
| | | The block will speed up/accelerate.<br><br>The normal reaction force would be equal to the weight of the block when the surface is horizontal,<br><br>hence the tension is the <u>resultant force</u> which causes the block to accelerate. | |

| | | | |
|---|---|---|---|
| **3** | Fig. 3.1 shows a hand-operated hydraulic jack. A downward force of 10 N is applied on the handle, causing piston X to move downwards. This in turn causes an upward force to act on piston Y. A load placed on piston Y can then be raised.<br><br>**Fig. 3.1** | | |
| | **(a)** | Calculate the magnitude of the minimum force exerted on piston X given that the downward force on the handle is 10 N. | |
| | | 10N x 50cm = $F$ x 5cm<br>$F$ = 100 N | |
| | **(b)** | In another instance, a force of 50 N exerted on piston X results in an upward force of 200 N on piston Y. Given that piston X has a diameter of of 1.5 cm, calculate the diameter *d* of piston Y. | |
| | | $p_X = p_Y$<br>$50/(\pi 1.5^2) = 200/(\pi d^2)$<br>$d$ = 3.0 cm | |
| | **(c)** | Explain, with reference to the design of the hydraulic jack, why the force exerted on piston Y is larger than that exerted on piston X. | |
| | | (Pascal law) Pressure due the force on piston X is transmitted uniformly through the oil to piston Y. The increased force is the product of the pressure and the larger cross-sectional area of piston Y. | |
| | (d) | In one occasion, air bubbles are observed in the oil tank under piston Y.<br><br>Explain how this affects the efficiency of the hydraulic jack. | |
| | | Some work will be done to compress the air bubble, causing the work done on piston Y to decrease. This reduces the efficiency of the system. | |

**4** Fig. 4.1 shows the top view of successive crests of plane water waves at a particular instant. The waves are generated at a rate of 4.0 waves per second travelling in the direction shown.

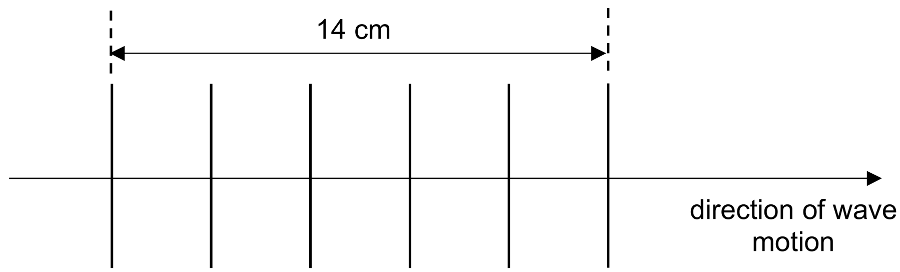



**Fig. 4.1** (top view)

**(a)** Determine the

**(i)** wavelength, and

Wavelength = 14cm ÷ 5 = 2.8 cm

**(ii)** wave speed of the water waves.

$v$ = 4.0 x 2.8 = 11.2 cm/s

**(b)** Fig. 4.2 shows a side-view of a section of the wave of amplitude 2.0 cm, at $t$ = 0.

X is a point on the wave.

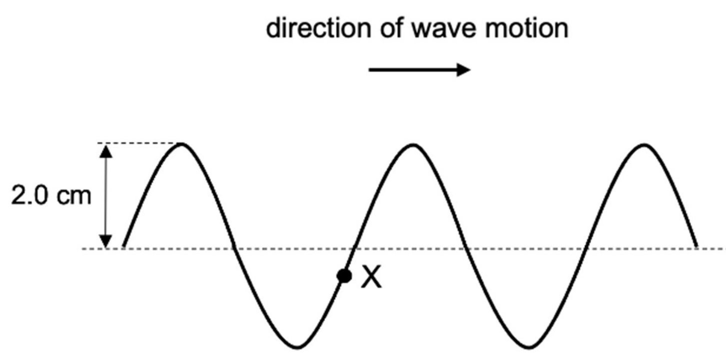
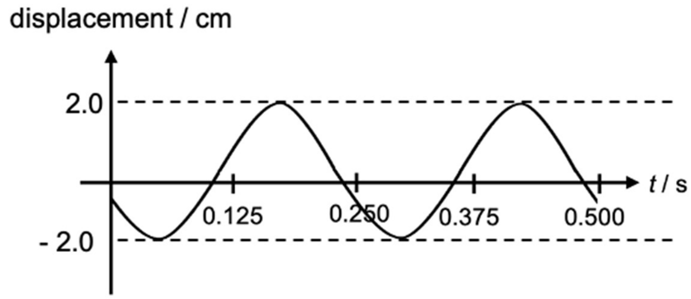



**Fig. 4.2** (side view)

Sketch the displacement-time graph of point X from $t$ = 0 to $t$ = 0.500 s on the axes provided in Fig. 4.3.




**(c)** Upon entering region B of different depth, the direction of travel of the plane waves turns through 20° as shown in Fig. 4.4.

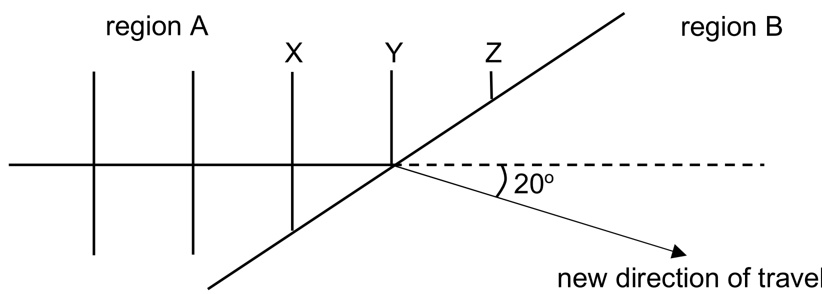
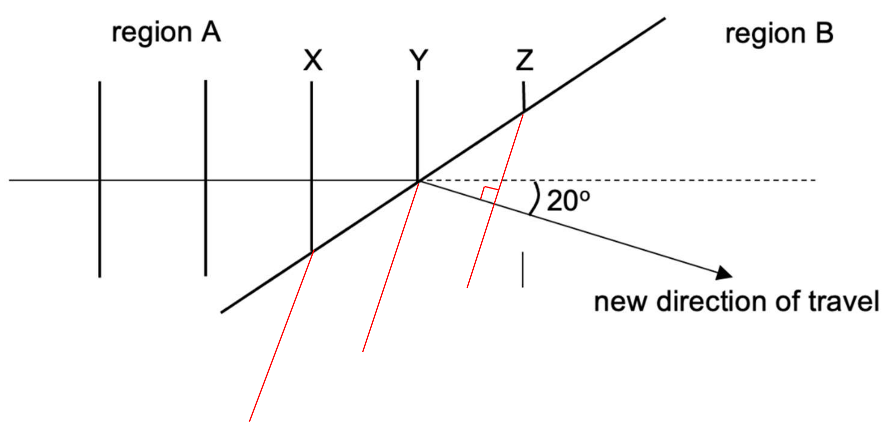



**Fig. 4.4** (top view)

**(i)** Complete Fig. 4.2 by drawing lines to represent the crests of waves X, Y and Z in region B.

**Solution**



| | | | |
|---|---|---|---|
| | | **(ii)** | Compare the depths of the water in regions A and B, supporting your answer with a reason. |
| | | By $v = f\lambda$, for the same frequency and shorter wavelength, the wave speed is lower, therefore the depth has decreased in B (more friction with bottom of tank).<br><br>The water in region B is shallower. | |

| | | |
|---|---|---|
| 5 | (a) | Object O of height 1.0 cm is placed 2.0 cm in front of a thin convex lens.<br><br>Fig. 5.1 shows the upright object O and the principal axis. The light from object O forms a real and inverted image that is three times the size of the object. |

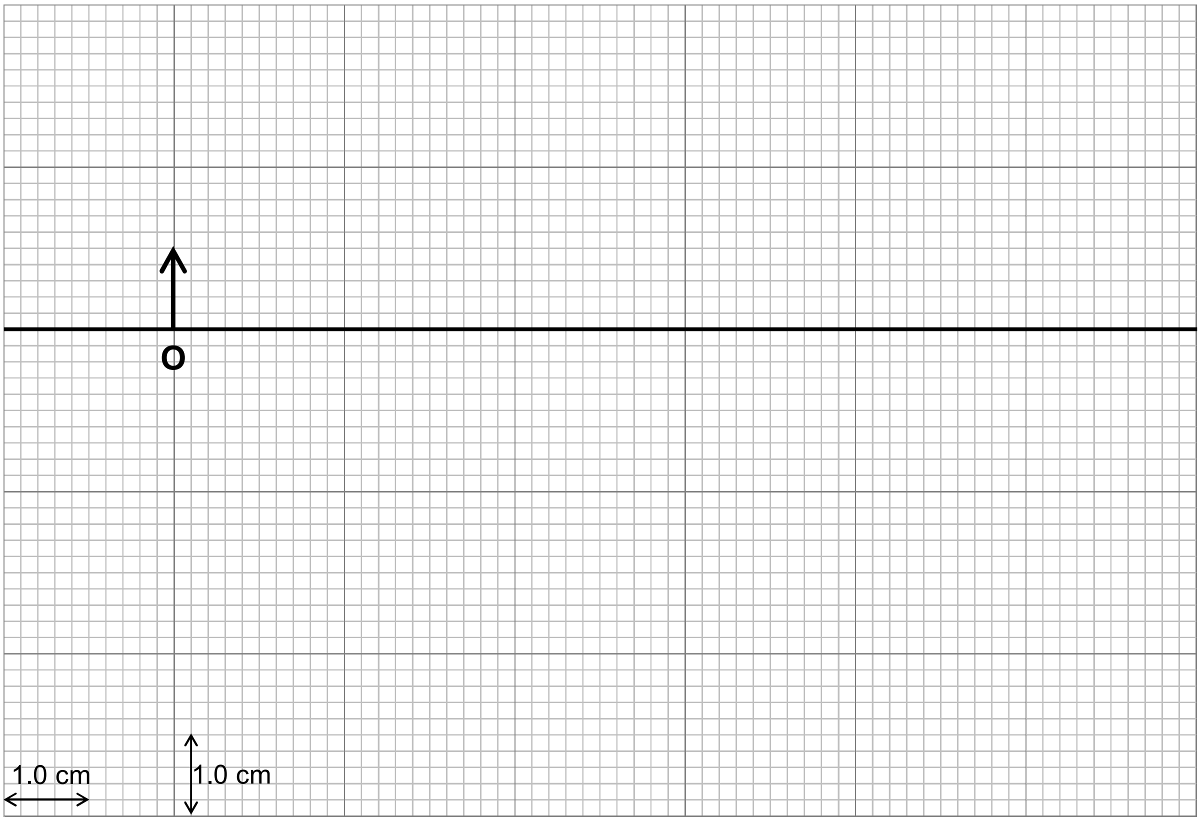
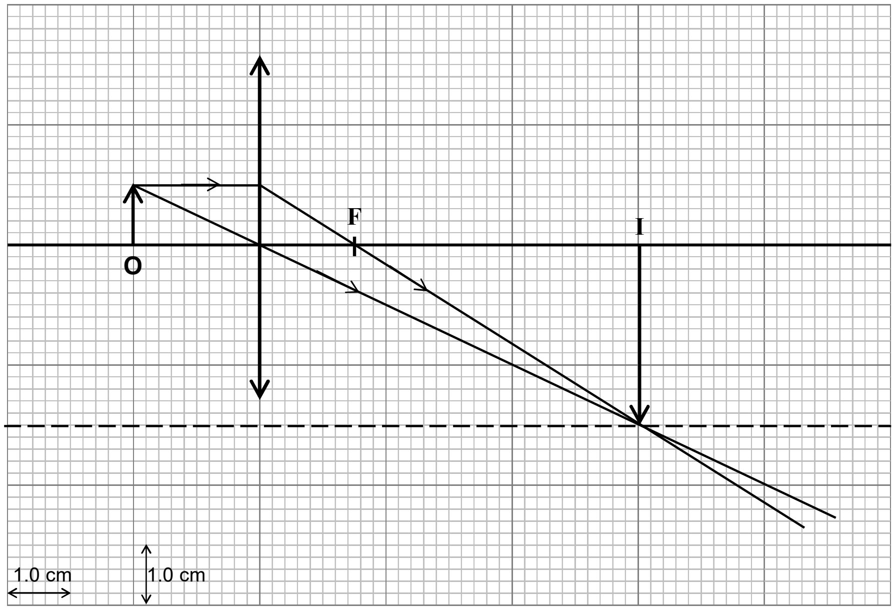



**Fig. 5.1**

| | | | | | |
|---|---|---|---|---|---|
| | | (i) | On the grid provided in Fig. 5.1, | | |
| | | | 1. | draw two rays of light from the top of the object to the image, and | [1] |
| | | | | | |
| | | | 2. | mark the image with the letter ‘I’ and the focal point with the letter ‘F’. | [1] |




**(ii)** Hence, determine the distance of the image from the lens, and the focal length of the lens.

Image distance = **6.0 cm** (between 5.8 cm and 6.2 cm)

Focal length = **1.5 cm** (between 1.3 cm and 1.7 cm)

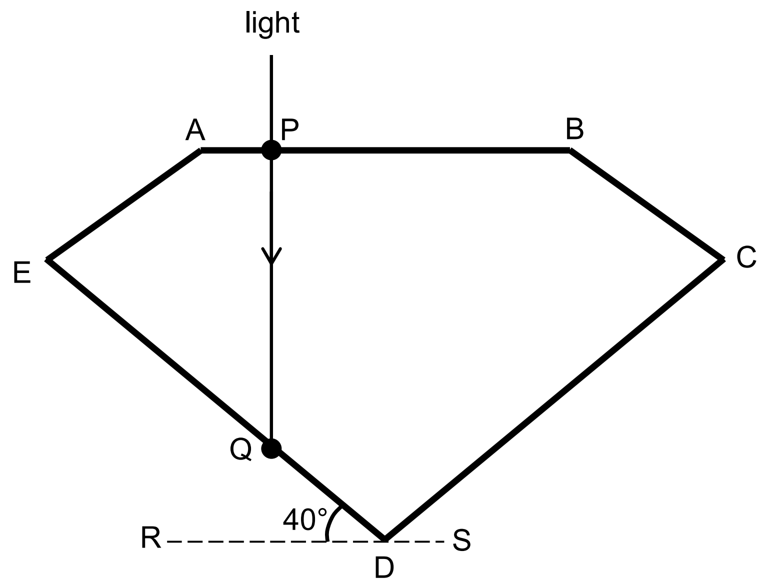
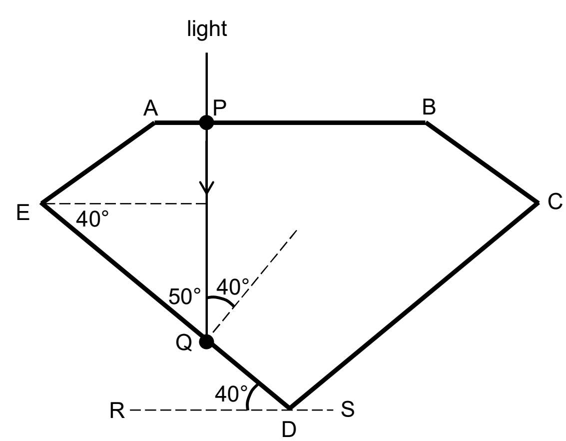
**(iii)** The object is moved 1.0 cm away from the lens.

State and explain the direction in which the lens should be moved to obtain a magnified image, by not changing the position where the clear image is formed.

The lens should be moved (left) towards the object.

To obtain a magnified image, the image object distance needs to be between *F* and 2*F*. Since the focal length remains at 1.5 cm, the object needs to be greater than 1.5 cm and less than 3.0 cm from the lens.

This can be achieved by moving the lens towards the object.

| | | | |
|---|---|---|---|
| | **(b)** | Fig. 5.2 shows the side-view of a diamond ABCDE.<br><br>**Fig. 5.2** (not to scale)<br>A vertical ray of light enters the horizontal face AB of the diamond through point P.<br>The refractive index of the diamond is 2.46. | |
| | | | $\sin \theta_c = 1 / n = 1/(2.46) = 0.407$<br>$\theta_c$ = **<u>23.9° (accept 24°)</u>** |
| | | **(ii)** | The face DE of the diamond is at an angle of 40° to line RS, which is parallel with face AB.<br>State the angle of incidence of the ray of light at Q, and describe and explain the path of the ray immediately after Q. |
| | | | <br>The light makes an <u>angle of incidence of 40°</u> at point Q. As 40° is <u>greater than</u> the diamond's <u>critical angle</u> |

| | | | | |
|---|---|---|---|---|
| | | | and the light is travelling from an optically denser medium to an optically less dense medium, it will go through total internal reflection (TIR). | |

**6** Fig. 6.1 shows two uncharged metal spheres $S_1$ and $S_2$ suspended using insulating threads.

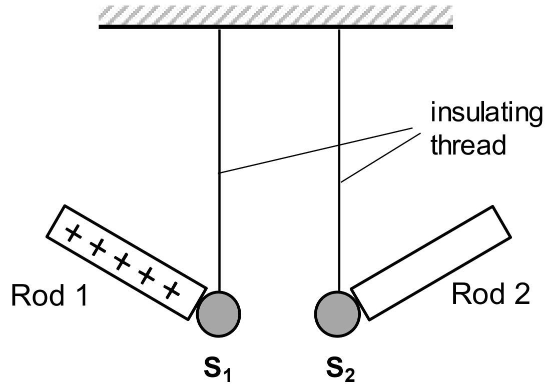



**Fig. 6.1**

Rod 1 and Rod 2 are conductors that are held using insulating threads. Rod 1 touches sphere $S_1$ while rod 2 touches sphere $S_2$. Rod 1 is positively charged.

The metal spheres move apart when the rods are removed, as shown in Fig. 6.2.

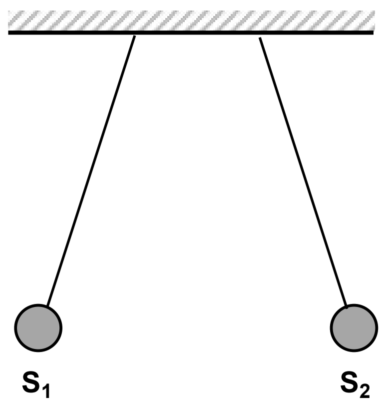



**Fig. 6.2**

**(a)** Explain how this shows that Rod 2 is positively charged.

When Rod 1 touches sphere $S_1$, electrons from $S_1$ flows to Rod 1, making sphere $S_1$ positively charged.

Since $S_1$ and $S_2$ are repelling each other, it shows that $S_2$ is also positively charged, after Rod 2 touches it.

Hence Rod 2 is initially positively charged.

| | | |
|---|---|---|
| | **(b)** | Sphere $S_2$ is then earthed.<br><br>State and explain the subsequent motion of the spheres $S_1$ and $S_2$. |
| | | When $S_2$ is earthed, the charges in $S_2$ are neutralised. As such a repulsive electric will not be present.<br><br>At the same time, negative charges will be induced on $S_2$ on its surfaced closer to $S_1$, causing an attractive electric force on each sphere. Both spheres will start to move towards each other.<br><br>When the spheres touch each other, the charges in $S_1$ are redistributed between the spheres causing them to repel each other. |

**7** Fig. 7.1 shows two magnets, supported on a yoke, placed on an electronic balance. The magnets produce a uniform horizontal magnetic field in the region between them. A copper wire DE connected in the circuit is clamped horizontally at right angles to the magnetic field.

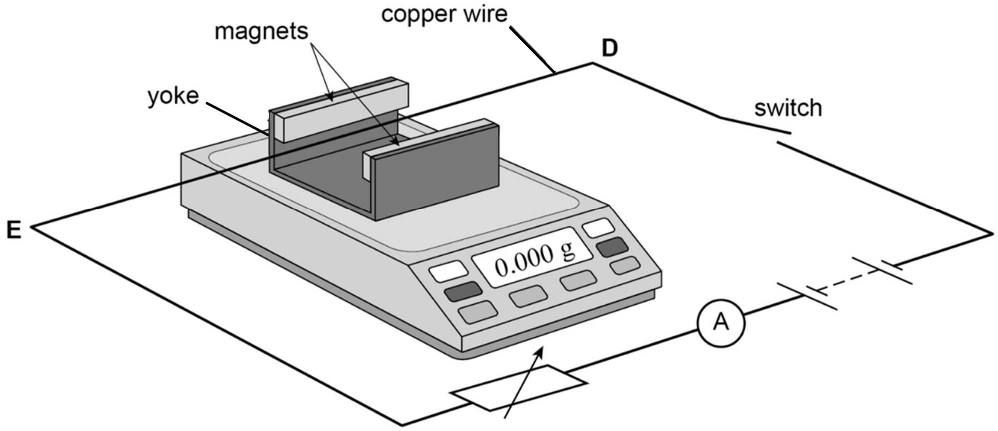



**Fig. 7.1**

**(a)** Explain why, when the switch is closed, a force is exerted on the wire DE.

Magnetic field of current in wire interacts with external magnetic field

Resultant magnetic field causes a force to act on the wire.

**(b)** Fig. 7.2 shows the top view of part of the set-up in Fig. 7.1 with sides X and Y of the magnets facing each other.

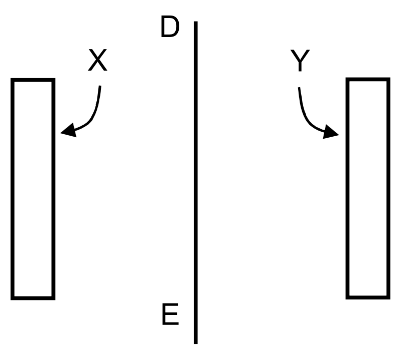



**Fig. 7.2** (top view)

When the switch is closed, the reading on the electronic balance increases.

State and explain the polarities of the sides X and Y respectively.

X: South
Y: North

In order for the readings on the balance to increase, there must be a downward force acting on the magnet (connected to the yoke) by the wire. As such, there must be a force of equal magnitude acting upwards on the wire by the magnet when the switch is closed.

Thus, the magnetic field must be directed from Y to X (i.e. X is South pole, while Y is North pole).

**(c)** Fig. 7.3 shows the top view of a small compass placed between the magnets. The compass needle is held stationary in the position shown.

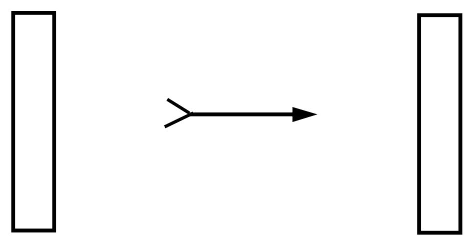


**Fig. 7.3** (top view)

State and explain what subsequently happens to the compass needle if the compass needle is no longer held stationary in the position shown.

Rotates 180 degrees until it is aligned with the uniform magnetic field.

Unlike poles attract so N pole of compass needle is attracted to S pole of uniform magnetic field (repelled by N pole of uniform magnetic field)

**(d)** The battery is removed and the ammeter is connected to the switch.
The switch is then closed.

When the wire DE is moved vertically downwards between the magnets, the ammeter shows a momentary reading.

**(i)** Explain why the ammeter shows a momentary reading.

Magnetic field lines linking the wire DE changes when the wire moves in the magnetic field / DE experiences a change of flux linkage when it moves in the magnetic field.

causing an induced emf and hence an induced current to flow in the wire.

| | | | |
|---|---|---|---|
| | | **(ii)** | Describe and explain the change, if any, to the reading on the electronic balance as the wire DE is moved. |
| | | Reading increases.<br><br>The induced current causes a force to act on the wire which opposes the direction in which the wire was moved.<br><br>Hence there is still an equal and opposite downward force on the electronic balance. | |

**8** The electrical power supply in Newtown is generated using a steam turbine-driven power station, which includes a boiler, a turbine, a cooling system, and an a.c. generator.

Fig. 8.1 describes the energy transfers between different sections in the power station.

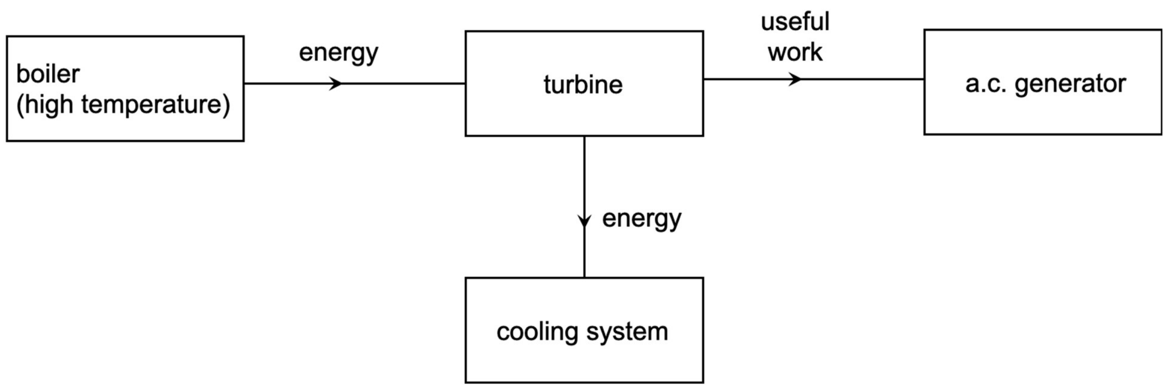



**Fig. 8.1**

Steam produced in the boiler is used to turn the turbine rotors to produce useful work, rotating the electrical coils in the a.c. generator. The steam is subsequently cooled in the cooling system using cold running water. The condensed steam is then returned to the boiler to be reused.

Further data for the power station are given in Table 8.1.

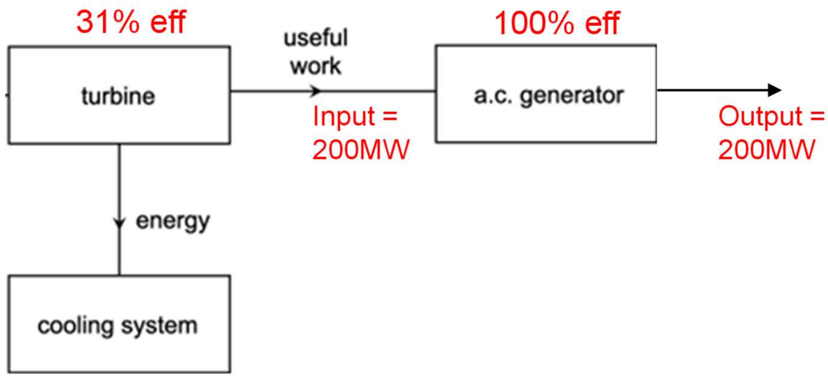
**Table 8.1**

| | |
|---|---|
| Electrical power output by the a.c. generator | 200 MW |
| Efficiency of electrical a.c. generator | 100 % |
| Efficiency of turbine | 31 % |
| Specific heat capacity of water | 4200 J/(kg ℃) |
| Specific latent heat of vaporisation | $2.3\times10^{6}$ J/kg |

**(a)** **(i)** State what is meant by *efficiency*.

It is the ratio of the energy/power output of a system to its energy/power input.

| | | | |
|---|---|---|---|
| | | **(ii)** | Show that the rate of energy transfer to the cooling system cannot exceed 450 MW. |




To calculate maximum rate of energy flow to the cooling system, we need to assume all energy lost by the turbine is transferred to the cooling system.

$$\text{efficiency } \varepsilon = \frac{\text{rate of useful work } P_o}{\text{rate of energy transfer to turbine } P_t} \times 100\%$$
$$= \frac{\text{Electrical power output } P_o}{P_t} \times 100\%$$

For turbine: 200MW / Input x 100% = 31%
Therefore Input = 200MWx100% / 31%

$$= \frac{200\text{MW}}{0.31}$$

= 645 MW
= 650 MW

$P_t = P_o$ + rate of energy transfer to the cooling system $P_C$
$P_C = P_t - P_o = 650 - 200$
= 450 MW

| | | | |
|---|---|---|---|
| | | **(iii)** | In the cooling system, steam enters at an initial temperature of 100 ℃, before it condenses and cools to a temperature of 57 ℃. The water produced is then returned to the boiler.<br><br>Determine the maximum rate at which water at 57 ℃ is produced in the cooling system. |
| | | | rate of energy transfer $= \frac{mc\Delta\theta}{\Delta t} + \frac{ml_v}{\Delta t}$<br>$= \left(\frac{m}{\Delta t}\right)(c\Delta\theta + l_v)$<br>$\frac{m}{\Delta t} = \frac{\text{rate of energy transfer}}{c\Delta\theta + l_v}$<br>$= \frac{450\times10^6}{[4.2(100-57)+2300]\times10^3}$<br>=180 kg/s |
| | | **(iv)** | Explain why the answer in **(a)(iii)** is higher than the actual rate of water production in the cooling system. |
| | | | The value obtained in (a)(iii) is higher than the actual value, as not all the energy loss in the turbine will be transferred to the cooling system. |
| | | **(v)** | With reference to the a.c. generator, describe one change which can be implemented to increase the voltage output of the a.c. generator. |
| | | | 1. Increase the size of the coil<br>2. Increase magnetic field strength / magnetic flux density that the coil is immersed in.<br>3. Increase the rate of rotation of the coils in the a.c. generator. |

**(b)** A transformer shown in Fig. 8.2 is connected to the a.c. generator before electrical power is transmitted to the houses in Newtown via transmission lines.

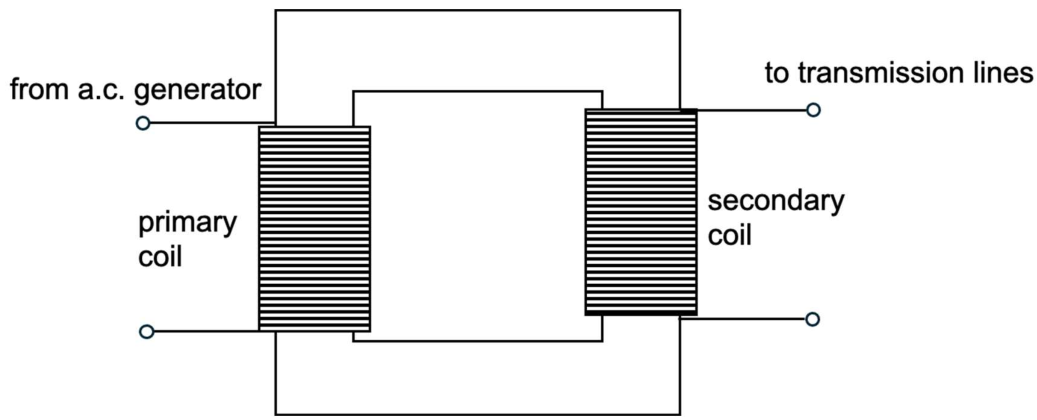



**Fig. 8.2**

Table 8.2 shows the specifications of some coils available for the construction of the transformer, as well as other relevant information.

**Table 8.2**

| | |
|---|---|
| Number of turns of coil P | 50 |
| Number of turns of coil Q | 400 |
| Number of turns of coil S | 500 |
| Number of turns of coil T | 2000 |
| Voltage output of the a.c. generator | 24 kV |
| Voltage across the transmission cables | 120 kV |

**(i)** Using data from Table 8.2, determine which coils should be used as the primary and the secondary coils of the transformer respectively.

$$\frac{N_p}{N_s} = \frac{24kV}{120kV}$$

$$\frac{N_p}{N_s} = 0.2$$

$$= \frac{400}{2000}$$

$$= \frac{N_{coil\ Q}}{N_{coil\ T}}$$

primary coil = coil Q
secondary coil = coil T

| | | | |
|---|---|---|---|
| | | **(ii)** | Explain how the transformer in Fig. 8.2 minimises energy loss in the transmission of electrical power. |
| | | | The purpose of the transformer is to step up the voltage before the power is transmitted through the electrical cables.<br><br>This is to ensure that the current in the power cables remain low, so that the loss/dissipation of energy can be kept to a minimum. |

| | | | | |
|---|---|---|---|---|
| **9** | **(a)** | The process of nuclear fusion can involve particles like the isotopes of hydrogen.<br><br>This process generally occurs in two steps:<br><br>1. Isotopes of hydrogen $^{2}_{1}$H and $^{3}_{1}$H combine to form the nuclide $^{5}_{2}$He.<br>2. $^{5}_{2}$He rapidly decays to another isotope of helium, $^{4}_{2}$He. $1.8\times10^{-14}$ J of energy is released in this process, some of which are in the form of gamma rays. | | |
| | | **(i)** | Write an equation representing the decay process in step 2. | |
| | | | $^{5}_{2}\text{He} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n} + \gamma$ | |
| | | **(ii)** | The decay of $^{5}_{2}$He is a random and spontaneous process. | |
| | | | **1.** | Explain what is meant by a *random* decay. |
| | | | | time between emissions is unpredictable<br><br>**or**<br><br>emission can occur at any time / in any direction |
| | | | **2.** | Explain what is meant by a *spontaneous* decay. |
| | | | | emission cannot be controlled / affected by outside influences<br><br>e.g. unaffected by temperature / pressure or emission happens on its own. |

| | | | | | |
|---|---|---|---|---|---|
| | | | **3.** | A source of ${}^{5}_{2}He$ emits $1.2\times10^{21}$ neutrons per second.<br><br>Calculate the amount of energy released from the source in 1 minute. | |
| | | | | rate of decay, $n_d$ = rate of neutron emitted, $n_n$<br>total number of decay in 1 minute = 60 $n_n$<br>$= 60\times1.2\times10^{21}$<br>$= 7.2\times10^{22}$<br><br>total amount of energy released =<br>$(7.2\times10^{22})\times(1.8\times10^{-14})$<br>$= 1.3\times10^{9}$ J | |

| | | | | |
|---|---|---|---|---|
| | **(b)** | A student investigates the emission from an unknown radioactive source. The source is 10 cm in front of a detector and 2 cm from the lead shield opening, as shown in Fig 9.1. A strong magnetic field between the source and the detector is then switched on. | | |

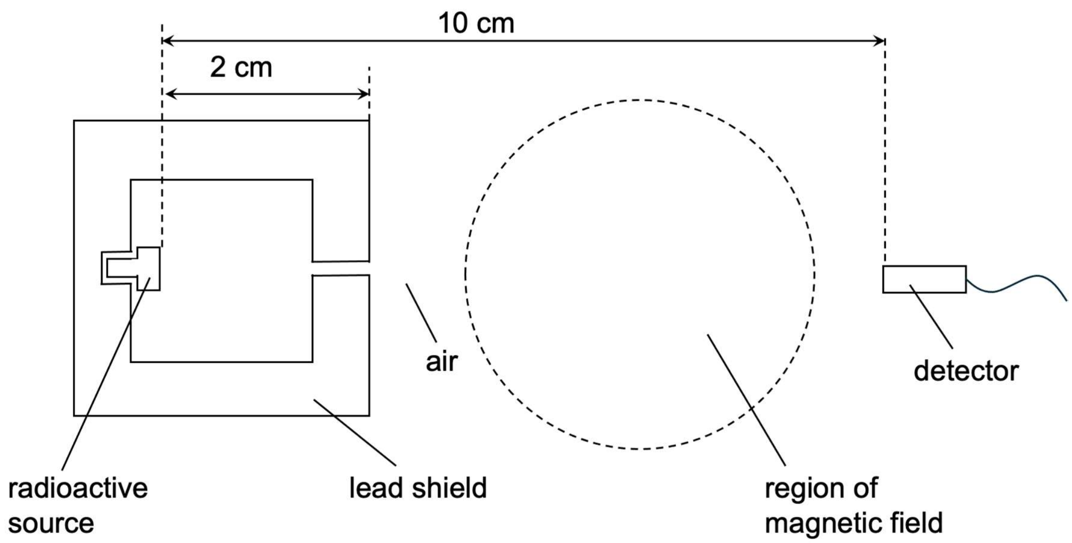



**Fig. 9.1**

The results are as shown in Table 9.1.

**Table 9.1**

| | average count per minute |
|---|---|
| without magnetic field | 4500 |
| with magnetic field | 2000 |
| background radiation | 50 |

When the detector is placed just at the opening of the lead shield, the detector registers an average of 4750 counts per minute.

| | | | | |
|---|---|---|---|---|
| | | **(i)** | State the probable type(s) of radiation that the source emits. | |
| | | | $\gamma$-rays and beta particles. | |
| | | **(ii)** | Explain your answer in **(b)(i)**. | |
| | | | As the count rate decreases with the magnetic field switched on, it is evident that the radiation consists of charged particles.<br><br>However, since alpha particles are stopped by small thickness of air (~4cm), the radiation should only contain beta particles.<br><br>Moreover, when the detector is placed at the opening of the lead container, there is not a significant increase in the count rate. | |

| | | | |
|---|---|---|---|
| | | | This shows that there is a high possibility that there is no alpha particles present.<br><br>With the magnetic field turned on, there is still a substantive amount of radiation**.** This shows that the radiation present also contains radiation that does not have a charge. Thus it has to be $\gamma$-rays. |

**Section B**

Answer **one** question from this section.

| | | |
|---|---|---|
| **10** | A fully charged car battery has an electromotive force of 12 V and an in-built resistance of 2.6 Ω. This battery can deliver a constant current of 2.1 A for a period of 5.0 hours. | |
| | **(a)** | Explain what is meant by a power source with an *electromotive force of 12 V*. |
| | | It means that 12 J of work is done by the power source in order to drive 1 C of charge through the whole circuit. |
| | **(b)** | The charge of an electron is $-1.6 \times 10^{-19}$ C.<br><br>Calculate the total number of electrons passing through the battery over a duration of 5.0 hours. |
| | | $I = \frac{\Delta Q}{\Delta t}$<br>$= \frac{\Delta N q_e}{\Delta t}$<br>$N = \frac{I \Delta t}{\Delta q_e}$<br>$= \frac{2.1(5 \times 60^2)}{1.6 \times 10^{-19}}$<br>$= 2.4 \times 10^{23}$ |

**(c)** The fully charged car battery with an in-built resistance of 2.6 Ω is connected to a starter motor, four sidelights and two headlights as shown in Fig. 10.1.

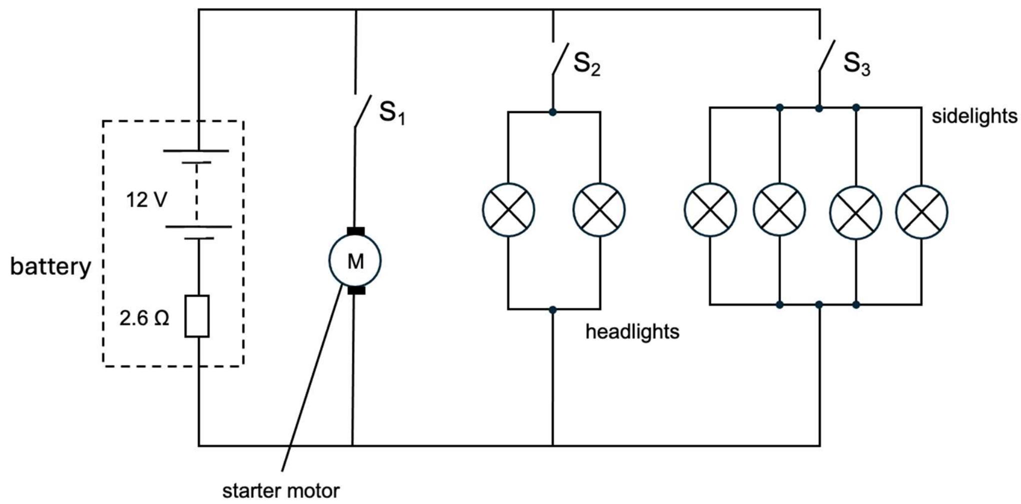



**Fig. 10.1**

At 12 V, the power rating of each headlight is 48 W.

**(i)** Calculate the resistance of a single headlight at the operating voltage of 12 V.

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P}$$

$$= \frac{12V^2}{48W}$$

$$= 3.0\ \Omega$$

**(ii)** 2.0 m of the filament material used in the headlights has a resistance of 63.2 Ω when it is operating at 12 V.

Calculate the length of the filament of the headlight.

For a uniform filament wire, *R* is proportional to L:

$$\frac{R_1}{L_1} = \frac{R_2}{L_2}$$

$$L_2 = \frac{L_1}{R_1} R_2$$

$$= \frac{2.0m}{63.2\Omega}(3.0\Omega)$$

$$= 0.095\ m$$

| | | | | |
|---|---|---|---|---|
| | | **(iii)** | The resistance of each sidelight is 24 Ω.<br><br>Switches $S_2$ and $S_3$ are closed and switch $S_1$ is open.<br><br>Calculate | |
| | | | **1.** | the effective resistance in the circuit, and |
| | | | | $R_{light} = \left(\frac{1}{3}+\frac{1}{3}+\frac{1}{24}+\frac{1}{24}+\frac{1}{24}+\frac{1}{24}\right)^{-1}$<br>$= 1.2\ \Omega$<br><br>$R_{eff} = R_{light} + 2.6$<br>$= 3.8\ \Omega$ |
| | | | **2.** | the current in the battery. |
| | | | | $Emf = IR_{eff}$<br>$I = \frac{Emf}{R_{eff}} = \frac{12V}{3.8\Omega}$<br>$= 3.2\ A$ |
| | **(d)** | The sidelights and headlights are switched on. $S_1$ is then closed.<br><br>Explain why all the lights become less bright when $S_1$ is closed. | | |
| | | | When the starter motor is switched on ($S_1$ closed), the effective resistance of the parallel group of lights and the starter motor will decrease,<br><br>Since the 2.6Ω resistor is in series with the parallel group, the p.d. across the parallel group will decrease (potential divider principle), while p.d. across 2.6Ω increases.<br><br>$V^2/R$ for the lights will decrease, and hence they will be dimmer. | |

**11** Fig. 11.1 shows the oven chamber of an old firewood pizza oven. Pizzas and other items are cooked on the oven floor.

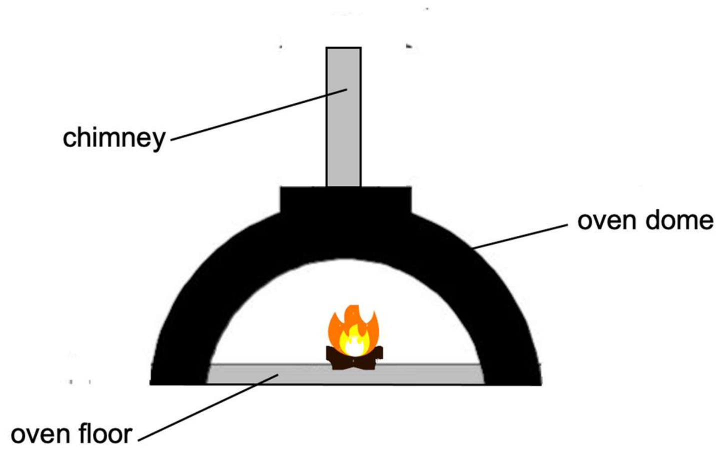



**Fig. 11.1**

The environment within the oven chamber can reach very high temperatures.

To hasten the temperature rise, a chef closes the door to the oven chamber after igniting the firewood.

After multiple uses, the chimney gets clogged.

**(a)** Using ideas about molecules, explain why the pressure within the oven chamber increases after the door to the chamber is closed.

As the firewood burns, energy is transferred to the internal store of the air molecules within the oven chamber by heating.

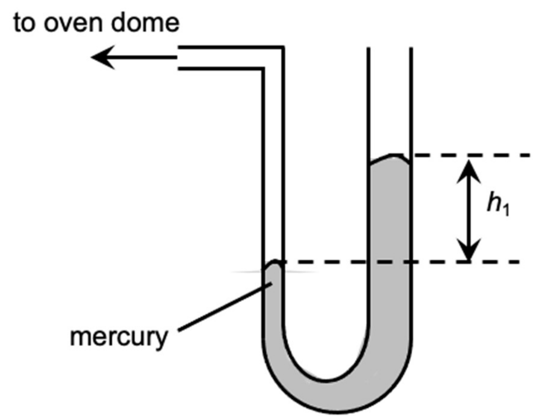
This causes the frequency and force of collisions between the air molecules and the surface of the pot to increase.

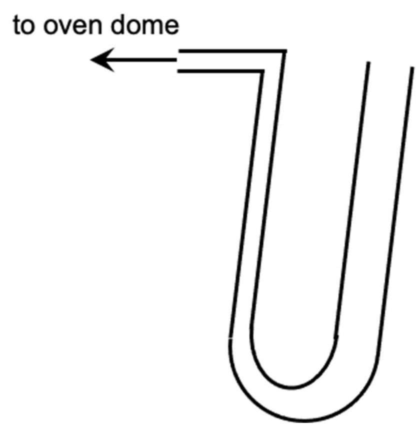
This results in an increase in force per unit area or pressure.

**(b)** The oven floor and dome are made of poor conductors like firebricks to retain heat better.

Explain what this suggests about the behaviour of the electrons in the firebricks.

There are no free/mobile electrons available to transfer energy within the firebricks.

| | | |
|---|---|---|
| | **(c)** | The pizza oven is equipped with a mercury-filled U-tube. One arm of the U-tube is connected to the oven dome and the other arm is exposed to the surroundings outside the oven.<br><br>The right arm of the U-tube has a cross-sectional area twice as large as that of the left arm. The vertical height difference $h_1$ in mercury levels between each arm of the U-tube as shown in Fig. 11.2.<br><br><br><br><br>**Fig. 11.2**<br><br>The gas pressure in the oven is 105 kPa and atmospheric pressure is 100 kPa.<br><br>The density of mercury is 13 600 kg/m$^3$. |

| | | | |
|---|---|---|---|
| | | **(i)** | Calculate the vertical height difference $h_1$.<br><br>Give your answer in cm. |
| | | | The pressure difference in both arms is only dependant on the vertical height difference.<br><br>$p_{gas} = h_1 \rho g + p_{atm}$<br>$h_1 = \dfrac{p_{gas} - p_{atm}}{\rho g}$<br>$= \dfrac{(105 - 100) \times 10^3}{13.6 \times 10^3 \times 10}$<br>$= 0.0368$ m<br>$= 37$ mm<br>$= 3.7$ cm |
| | | **(ii)** | The U-tube is replaced with another U-tube that is tilted at an angle, as shown in Fig. 11.3.<br><br>This U-tube has the same dimensions as the previous U-tube (Fig. 11.2).<br><br><br><br>**Fig. 11.3**<br><br>The gas pressure in the oven chamber and atmospheric pressure remain unchanged.<br><br>State and explain the change, if any, to vertical height difference $h_1$ in the tilted U-tube. |
| | | | Since $h_1$ is dependent on only the vertical height difference, and that mercury is used,<br>the value of $h_1$ is will not change. |

| | | | |
|---|---|---|---|
| | | **(iii)** | To detect smaller pressure changes in the oven dome, the U-tube should be filled with a liquid of lower density than mercury.<br><br>Suggest why this is so. |
| | | | For the same pressure difference, the height difference in the liquid levels is inversely proportional to the density of the liquid.<br><br>Thus, with the lower density, small pressure differences will be represented by larger height differences. |
| | **(d)** | A pizza is put next to the fire on the oven floor to be cooked. | |
| | | **(i)** | Using ideas about molecules, describe how energy is transferred within the pizza by conduction. |
| | | | The molecules in the pizza at the hotter end gain energy and vibrate faster.<br><br>They collide with neighbouring molecules, transferring energy, causing the neighbouring molecules to vibrate faster. |
| | | **(ii)** | Describe one other process through which energy is transferred to the pizza. |
| | | | Energy is transferred to the pizza via radiation of infrared rays from the fire flame/inner surfaces of the oven chamber to the food.<br><br>(Thermal energy from convection current is not transferred sideways) |

**END OF PAPER**

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