



Cambridge International AS & A Level

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PHYSICS

9702/21

Paper 2 AS Level Structured Questions

October/November 2022

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **20** pages. Any blank pages are indicated.

Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ ($\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1}$)
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

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- 1 (a) The boxes in Fig. 1.1 contain terms on the left-hand side and examples of these terms on the right-hand side.

Draw a line between each term on the left and the correct example on the right.

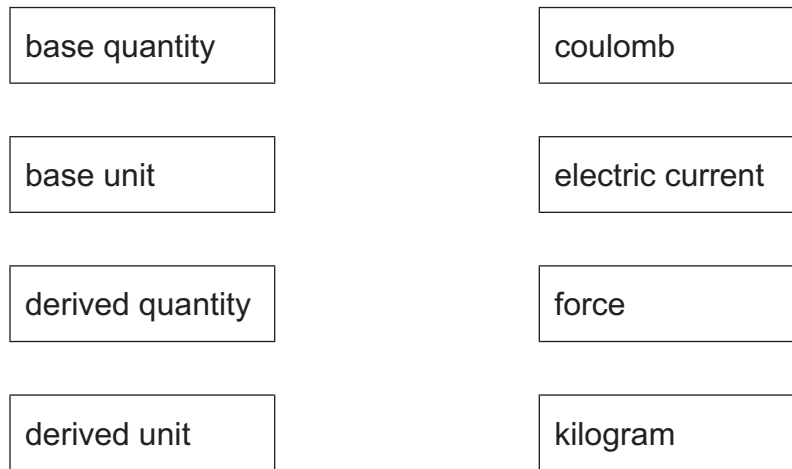


Fig. 1.1

[2]

- (b) A set of experimental measurements is described as precise and not accurate.

State what is meant by:

- (i) precise

.....
 [1]

- (ii) not accurate.

.....
 [1]

- (c) An object of mass m travels with speed v in a circle of radius r . The force F acting on the object is given by

$$F = \frac{mv^2}{r}.$$

The percentage uncertainties of three of the quantities are given in Table 1.1.

Table 1.1

quantity	percentage uncertainty
F	$\pm 3\%$
m	$\pm 4\%$
r	$\pm 5\%$

The value of v is determined from F , m and r .

- (i) Calculate the percentage uncertainty in v .

percentage uncertainty = ... % [2]

- (ii) The value of v is 15.0 ms^{-1} .

Calculate the absolute uncertainty in v .

absolute uncertainty = ... ms^{-1} [1]

[Total: 7]

- 2 A steel ball is projected horizontally from the top of a table, as shown in Fig. 2.1.

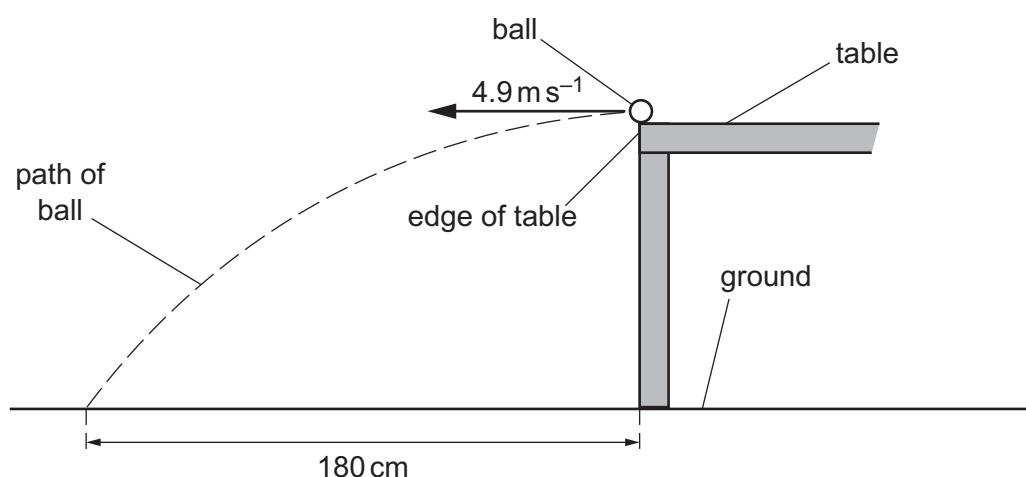


Fig. 2.1 (not to scale)

The ball is projected horizontally at a speed of 4.9 m s^{-1} . The ball lands on the ground a horizontal distance of 180 cm from the edge of the table.

Assume that air resistance is negligible.

- (a) (i) Calculate the time taken for the ball to reach the ground.

time = ... s [1]

- (ii) Calculate the vertical component of the velocity of the ball as it hits the ground.

velocity = ... m s^{-1} [2]

- (iii) Determine the magnitude and the angle to the horizontal of the velocity of the ball as it hits the ground.

magnitude of velocity = ... ms^{-1}

angle to the horizontal = ... $^{\circ}$
[3]

- (b) The ball is projected by means of a compressed spring which is attached to a fixed block as shown in Fig. 2.2.

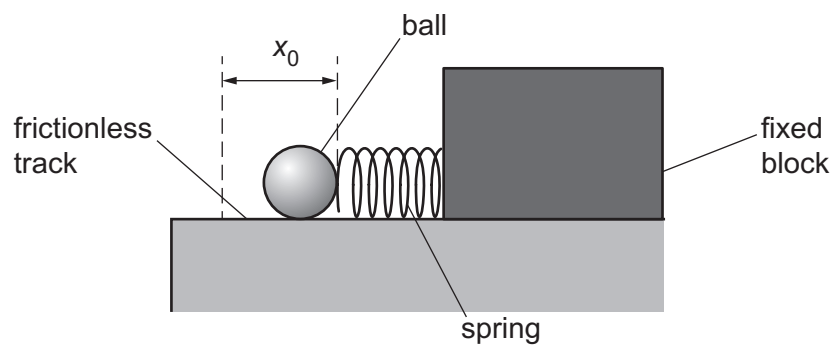


Fig. 2.2

The ball is placed on a frictionless track in front of the spring. The ball is then pulled back so that the spring has compression x_0 .

When the spring is released, the ball is projected horizontally as shown in Fig. 2.3.

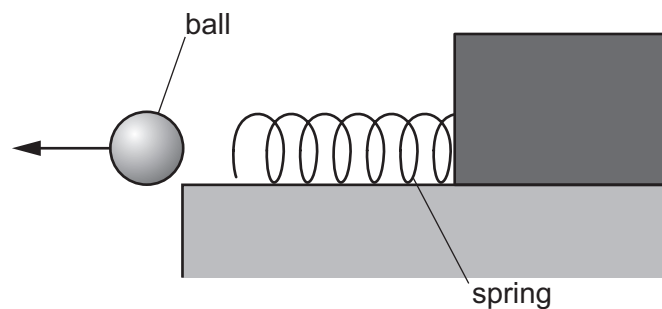


Fig. 2.3

The variation with compression x of the applied force F for the spring is shown in Fig. 2.4.

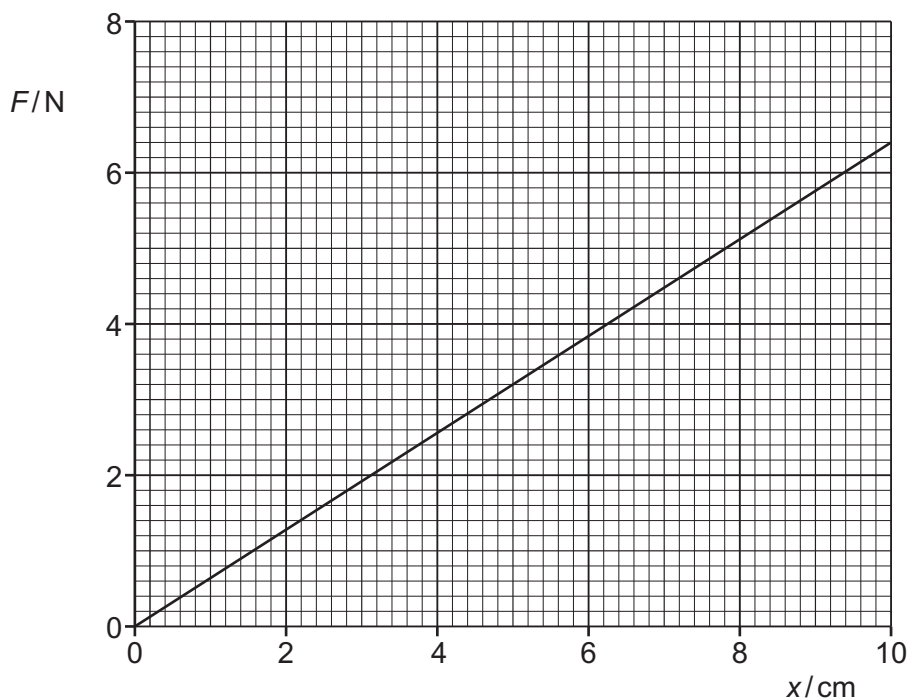


Fig. 2.4

The ball is a uniform sphere of steel of diameter 0.016 m and mass 0.017 kg.

- (i) Calculate the density of the steel.

density = ... kg m^{-3} [3]

- (ii) All of the elastic potential energy in the spring is converted into kinetic energy of the ball. The speed of the ball as it leaves the spring is 4.9 m s^{-1} .

Show that the maximum elastic potential energy of the spring is 0.20 J.

- (iii) Use Fig. 2.4 to determine the spring constant k of the spring.

$$k = \dots\dots\dots \text{Nm}^{-1} \quad [2]$$

- (iv) Use your answer in (b)(iii) and the value of energy given in (b)(ii) to determine the compression x_0 of the spring.

$$x_0 = \dots\dots\dots \text{m} \quad [2]$$

- (c) The steel ball is replaced by a polystyrene ball of the same diameter but of much lower mass. The spring is given compression x_0 and is then released.

Air resistance on this ball is **not** negligible after it leaves the spring.

Explain:

- (i) why this ball leaves the spring with a greater speed than that of the steel ball

.....

 [1]

- (ii) why this ball takes a longer time to reach the ground than the steel ball.

.....

 [1]

[Total: 17]

- 3 (a) (i) Define power.

.....
..... [1]

- (ii) Mechanical power P can be calculated using the formula $P = Fv$.

Use the concept of work and the definition of power to show how this formula is derived.

[2]

- (b) The engine of a lorry provides 130 kW of power to the lorry's wheels when it is travelling at a constant speed of 25 m s^{-1} along a straight horizontal road.

Show that the resistive force opposing the forward motion of the lorry is 5200 N.

[1]

- (c) The lorry in (b) travels up a straight section of road that is inclined at an angle θ to the horizontal, as shown in Fig. 3.1.

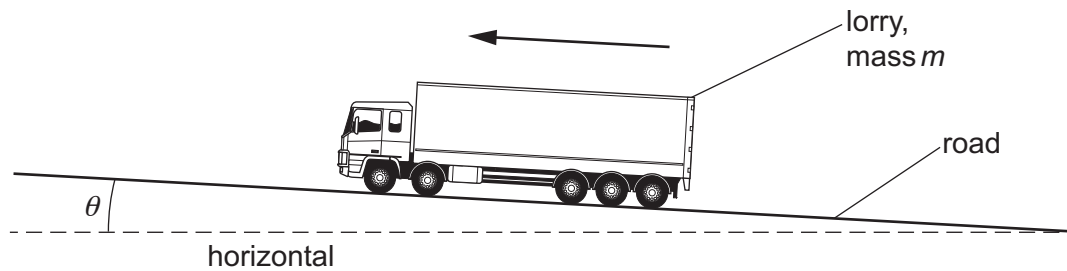


Fig. 3.1 (not to scale)

The lorry has mass m and the acceleration of free fall is g .

- (i) Determine an expression, in terms of m , g and θ , for the component of the weight of the lorry that acts parallel to the surface of the road.

[1]

- (ii) The total resistive force remains unchanged at 5200 N and the engine now provides greater power to maintain the speed of 25 m s^{-1} . The total mass m of the lorry is 36 000 kg. The angle θ is 1.4° .

Determine the power, in kW, now provided by the engine.

power = ... kW [3]

[Total: 8]

4 (a) Polarisation is a phenomenon associated with light waves but not with sound waves.

(i) State the meaning of polarisation.

.....

 [1]

(ii) State why light waves can be plane polarised but sound waves cannot.

.....

 [1]

(b) Two polarising filters A and B are positioned so that their planes are parallel to each other and perpendicular to a central axis line XY, as shown in Fig. 4.1.

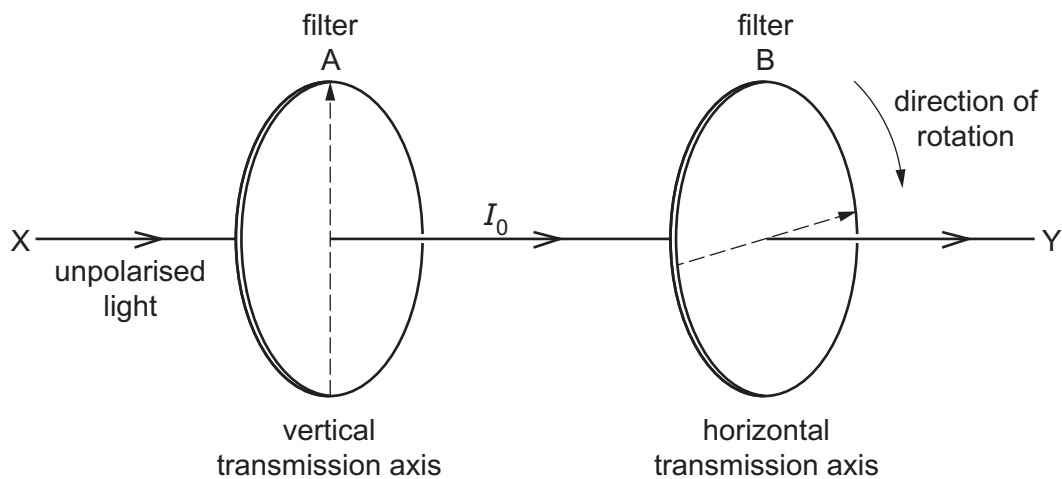


Fig. 4.1

The transmission axis of filter A is vertical and the transmission axis of filter B is horizontal.

Unpolarised light of a single frequency is directed along the line XY from a source positioned at X. The light emerging from filter A is vertically plane polarised and has intensity I_0 .

Filter B is rotated from its starting position about the line XY, as shown in Fig. 4.1.

After rotation, the intensity of the light emerging from filter B is $\frac{1}{4} I_0$.

Calculate the angle of rotation of filter B from its starting position.

angle of rotation = ... ° [3]

- (c) A microwave of intensity I_0 and amplitude A_0 meets another microwave of the same frequency and of intensity $\frac{1}{4} I_0$ travelling in the opposite direction. Both microwaves are vertically plane polarised and superpose where they meet.

- (i) Explain, without calculation, why these two waves cannot form a stationary wave with zero amplitude at its nodes.

.....

 [2]

- (ii) Determine, in terms of A_0 , the maximum amplitude of the wave formed.

maximum amplitude = ... A_0 [3]

[Total: 10]

- 5 (a) State Ohm's law.

.....

.....

..... [2]

- (b) The variation of current I with potential difference V for a filament lamp is shown in Fig. 5.1.

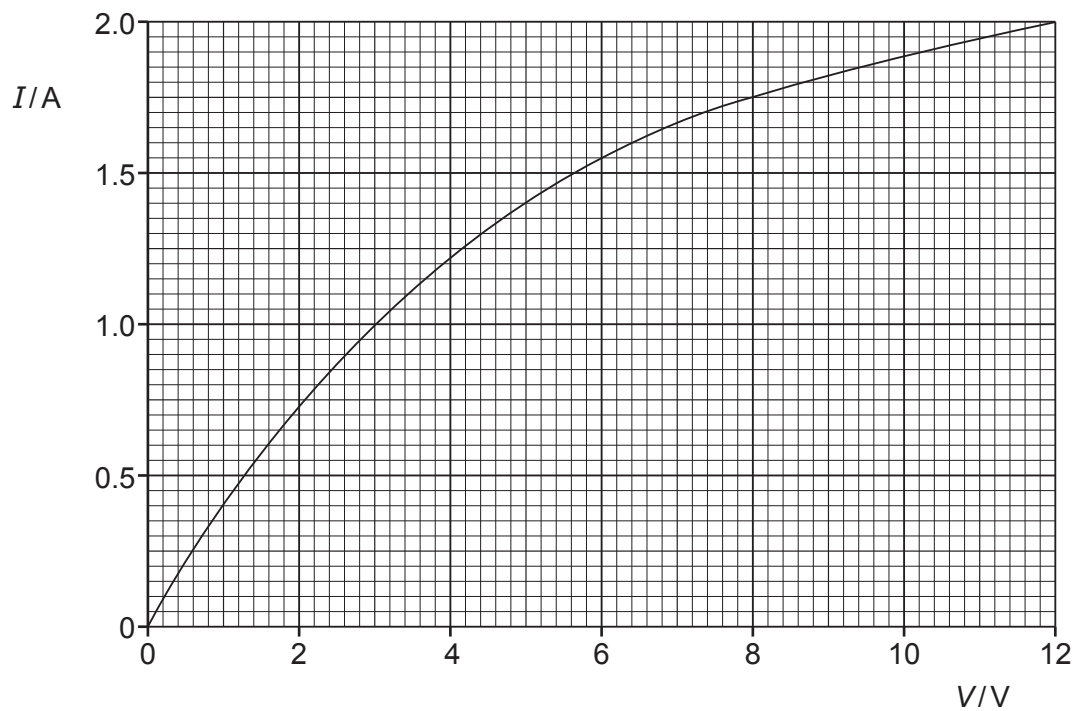


Fig. 5.1

The resistance of the filament lamp increases with potential difference.

- (i) State how Fig. 5.1 shows this.

.....

..... [1]

- (ii) Explain why the resistance varies in this way.

.....

..... [1]

- (c) Fig. 5.2 shows a circuit with a battery of electromotive force (e.m.f.) 12.0 V connected to a linear potentiometer AB and two identical filament lamps P and Q.

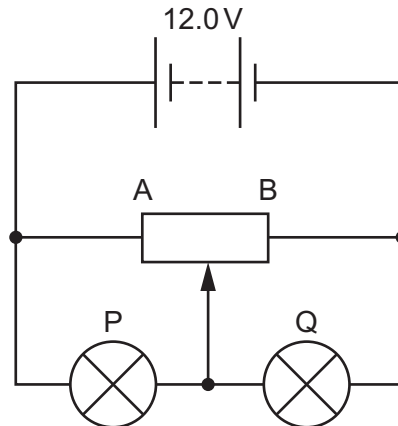


Fig. 5.2

The battery has negligible internal resistance and the lamps each have the same I - V characteristic shown in Fig. 5.1.

When the slider of the potentiometer is at its midpoint, as shown in Fig. 5.2, the current I in the battery is 1.78 A.

Determine:

- (i) the current in lamp P

current = ... A [1]

- (ii) the total power dissipated in lamps P and Q

total power = ... W [2]

- (iii) the resistance of the potentiometer between its ends A and B.

resistance = ... Ω [2]

(d) The slider of the potentiometer in (c) is moved to end A.

State and explain the effect on the brightness of lamps P and Q.

lamp P:

.....

lamp Q:

.....

[2]

[Total: 11]

- 6 (a) A lepton is an example of a fundamental particle.

State what is meant by fundamental particle.

.....
 [1]

- (b) A lambda particle Λ^0 is a hadron that consists of an up (u) quark, a down (d) quark and a strange (s) quark.

Show that the charge on the Λ^0 particle is zero.

[2]

- (c) The Λ^0 particle is unstable. It can decay into a neutron (n) and a pion (π^0) as shown by

$$\Lambda^0 \rightarrow n + \pi^0.$$

The π^0 particle consists of an up quark and an up antiquark.

- (i) Compare the properties of an up quark and an up antiquark.

.....

 [2]

- (ii) Explain why the neutron is classed as a baryon and the π^0 particle is classed as a meson.

.....

 [2]

[Total: 7]

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electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

- 1 (a) State what is meant by work done.

.....
 [1]

- (b) Use the answer to (a) to determine the SI base units of power.

SI base units [2]

- (c) The maximum useful output power P of a car travelling on a horizontal road is given by

$$P = v^3 b$$

where v is the maximum speed of the car and b is a constant.

For the car,

$P = 84 \text{ kW} \pm 5\%$
 and $b = 0.56 \pm 7\%$ in SI units.

- (i) Calculate the value of v .

$v = \dots\dots\dots \text{ms}^{-1}$ [2]

- (ii) Determine the absolute uncertainty in the value of v .

absolute uncertainty = ... ms^{-1} [2]

[Total: 7]

- 2 A spherical balloon is filled with a fixed mass of gas. A small block is connected by a string to the balloon, as shown in Fig. 2.1.

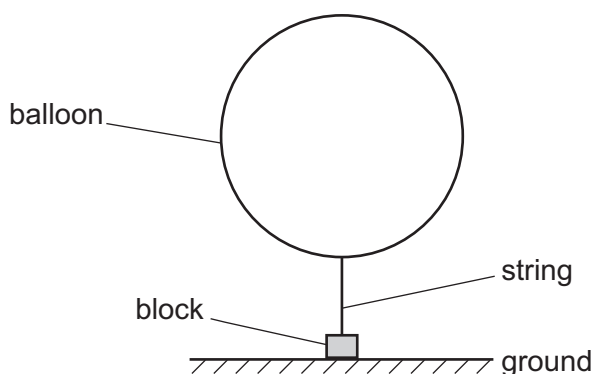


Fig. 2.1 (not to scale)

The block is held on the ground by an external force so that the string is vertical. The density of the air surrounding the balloon is 1.2 kg m^{-3} . The upthrust acting on the balloon is 0.071 N . The upthrust acting on the string and block is negligible.

- (a) By using Archimedes' principle, calculate the radius r of the balloon.

$r = \dots\dots\dots \text{ m [2]}$

- (b) The total weight of the balloon, string and block is 0.053 N .

The external force holding the block on the ground is removed so that the released block is lifted vertically upwards by the balloon.

Calculate the acceleration of the block immediately after it is released.

acceleration = $\dots\dots\dots \text{ ms}^{-2} [3]$

- (c) The balloon continues to lift the block. The string breaks as the block is moving vertically upwards with a speed of 1.4 m s^{-1} . After the string breaks, the detached block briefly continues moving upwards before falling vertically downwards to the ground. The block hits the ground with a speed of 3.6 m s^{-1} .

Assume that the air resistance on the block is negligible.

- (i) By considering the motion of the block after the string breaks, calculate the height of the block above the ground when the string breaks.

height = ... m [2]

- (ii) The string breaks at time $t = 0$ and the block hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the velocity v of the block with time t from $t = 0$ to $t = T$.

Numerical values of t are not required. Assume that v is positive in the upward direction.

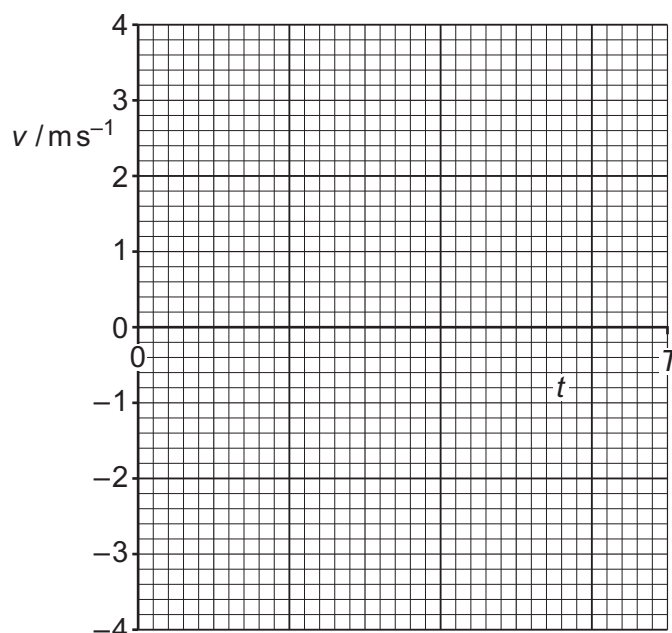


Fig. 2.2

[2]

[Total: 9]

- 3 (a) State what is meant by the centre of gravity of an object.

.....
 [1]

- (b) A uniform beam AB is attached by a frictionless hinge to a vertical wall at end A. The beam is held so that it is horizontal by a metal wire CD, as shown in Fig. 3.1.

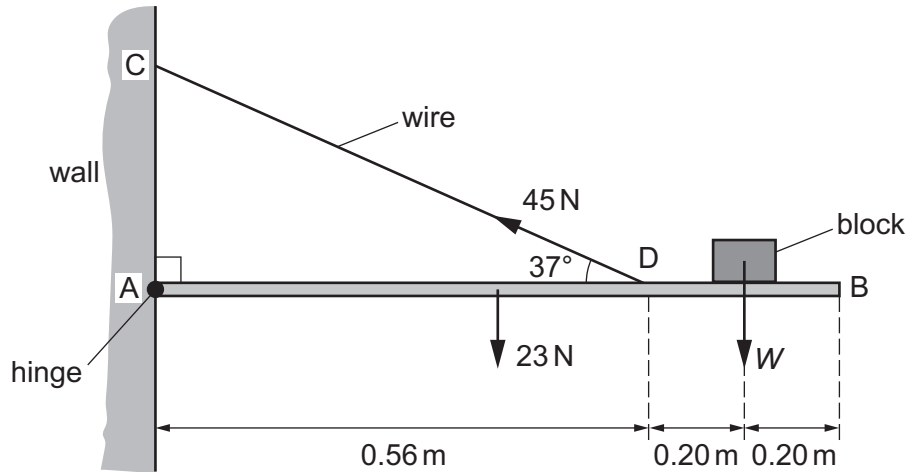


Fig. 3.1 (not to scale)

The beam is of length 0.96 m and weight 23 N. A block of weight W rests on the beam at a distance of 0.20 m from end B. The wire is attached to the beam at point D which is a distance of 0.40 m from end B. The wire exerts a force on the beam of 45 N at an angle of 37° to the horizontal. The beam is in equilibrium.

- (i) Calculate the vertical component of the force exerted by the wire on the beam.

vertical component of the force = ... N [1]

- (ii) By taking moments about A, calculate the weight W of the block.

$W =$ N [3]

- (iii) The hinge exerts a force on the beam at end A.

Calculate the horizontal component of this force.

horizontal component of force = ... N [1]

- (iv) The block is now placed closer to point D on the beam.

State whether this change will increase, decrease or have no effect on the tension in the wire.

..... [1]

- (v) The stress in the wire is 5.3×10^7 Pa. The wire is now replaced by a second wire that has a radius which is three times greater than that of the original wire. The tension in the wire is unchanged.

Calculate the stress in the second wire.

stress = ... Pa [2]

[Total: 9]

- 4 A horizontal spring is fixed at one end. A block is pushed against the other end of the spring so that the spring is compressed, as shown in Fig. 4.1.

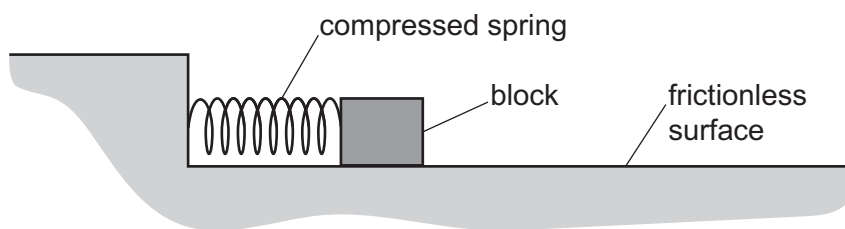


Fig. 4.1

The block is released and accelerates along a horizontal frictionless surface as the spring returns to its original length. The block leaves the end of the spring with a speed of 2.3 m s^{-1} , as shown in Fig. 4.2.

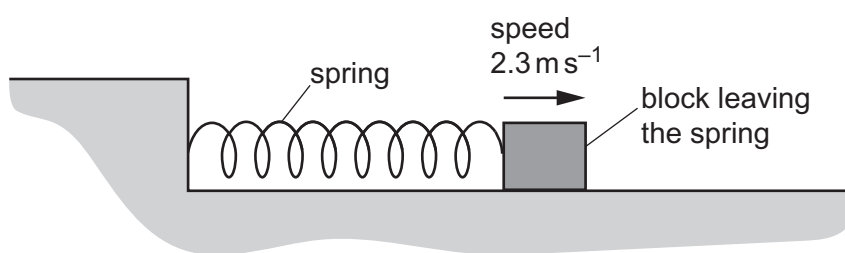


Fig. 4.2

The block has a mass of 250 g and the spring has a spring constant of 420 N m^{-1} .

Assume that the spring always obeys Hooke's law and that all the elastic potential energy of the spring is transferred to the kinetic energy of the block.

- (a) Calculate the kinetic energy of the block as it leaves the spring.

kinetic energy = ... J [2]

- (b) Calculate the compression of the spring immediately before the block is released.

compression = ... m [2]

- (c) After leaving the spring, the block moves along the surface until it hits a barrier at a speed of 2.3 m s^{-1} . The block then rebounds at a speed of 1.5 m s^{-1} and moves back along its original path. The block is in contact with the barrier for a time of 0.086 s .

Calculate:

- (i) the change in momentum of the block during the collision

change in momentum = ... N s [2]

- (ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

- (d) The maximum compression x of the spring is now varied in order to vary the kinetic energy E_K of the block as it leaves the spring. Assume that all the elastic potential energy in the spring is always transferred to the kinetic energy of the block.

On Fig. 4.3, sketch a graph to show the variation with x of E_K .

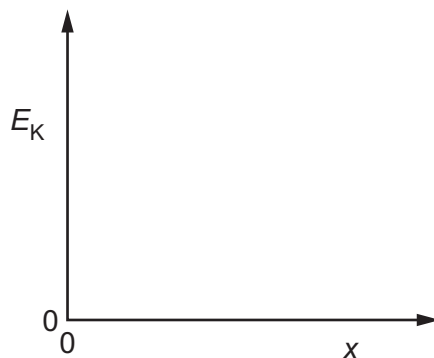


Fig. 4.3

[1]

[Total: 8]

- 5 (a) Two progressive sound waves meet to form a stationary wave. The two waves have the same amplitude, wavelength, frequency and speed.

State the other condition that must be fulfilled by the two waves in order for them to produce the stationary wave.

..... [1]

- (b) A stationary wave is formed on a string that is stretched between two fixed points A and B. Fig. 5.1 shows the string at time $t = 0$ when each point is at its maximum displacement.

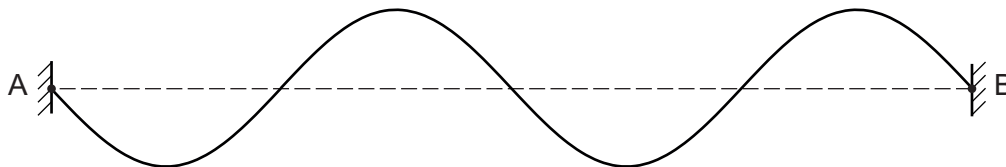


Fig. 5.1

Distance AB is 0.80 m. The period of the stationary wave is 0.016 s.

- (i) On Fig. 5.1, sketch a solid line to show the position of the string:

- at time $t = 0.004$ s (label this line P)
- at time $t = 0.024$ s (label this line Q).

[2]

- (ii) Determine the speed of a progressive wave along the string.

speed = ... ms^{-1} [3]

- (c) A beam of vertically polarised light of intensity I_0 is incident normally on a polarising filter that has its transmission axis at 30° to the vertical, as shown in Fig. 5.2.

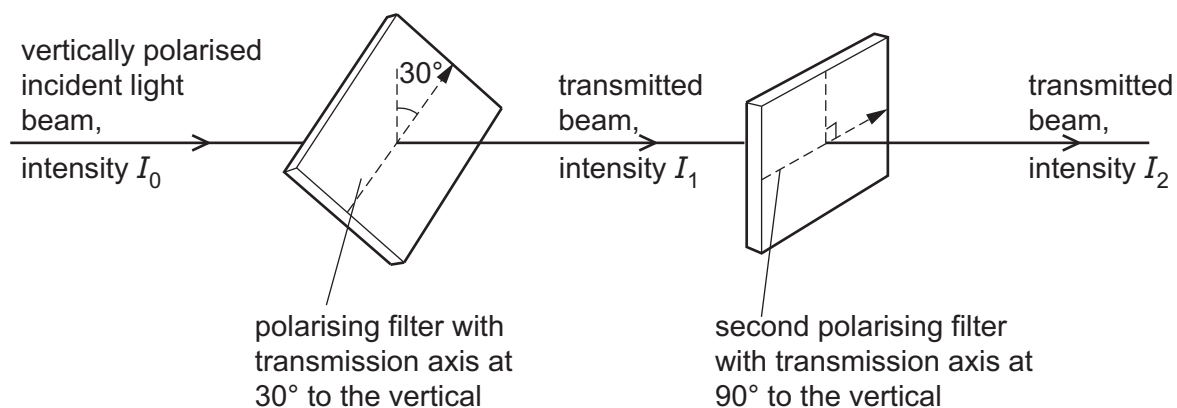


Fig. 5.2

The transmitted light from the first polarising filter has intensity I_1 . This light is then incident normally on a second polarising filter that has its transmission axis at 90° to the vertical. The transmitted light from the second filter has intensity I_2 .

Calculate:

- (i) the ratio $\frac{I_1}{I_0}$

$$\frac{I_1}{I_0} = \dots\dots\dots [2]$$

- (ii) the ratio $\frac{I_2}{I_0}$.

$$\frac{I_2}{I_0} = \dots\dots\dots [2]$$

[Total: 10]

- 6 (a) Define electric potential difference.

.....
 [1]

- (b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

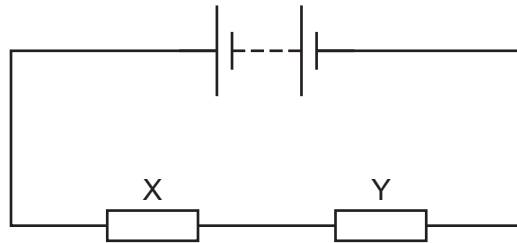


Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

State and explain which resistor dissipates more power.

.....

 [3]

- (c) A battery of electromotive force (e.m.f.) 9.0V and internal resistance r is connected to two resistors P and Q, as shown in Fig. 6.2.

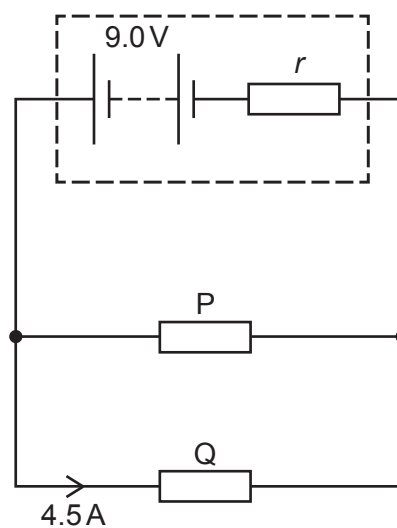


Fig. 6.2

A total charge of 650 C moves through resistor P in a time interval of 540 s. During this time resistor P dissipates 4800 J of energy. The current in resistor Q is 4.5 A. Assume that the e.m.f. of the battery remains constant.

Calculate:

- (i) the current in resistor P

current = ... A [2]

- (ii) the potential difference across resistor P

potential difference = ... V [2]

- (iii) the internal resistance r of the battery.

$r =$ Ω [2]

[Total: 10]

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- 7 (a) Describe the structure of an **atom** of uranium-238, $^{238}_{92}\text{U}$.

.....

 [2]

- (b) The decay of uranium-238 is shown by the equation



For nucleus X, calculate the ratio, in C kg^{-1} , of

$$\frac{\text{charge}}{\text{mass}}.$$

ratio = ... C kg^{-1} [3]

- (c) Two particles P and Q each consist of three quarks. These quarks are up (u) or down (d) quarks.

Particle P has no overall charge.

Particle Q has an overall charge of $+2e$, where e is the elementary charge.

State the quark composition of:

- (i) particle P

..... [1]

- (ii) particle Q.

..... [1]

[Total: 7]

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9702/23

October/November 2022

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **16** pages. Any blank pages are indicated.

Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

- 1 The rate of flow Q of a liquid along a narrow pipe of length L and radius r is given by

$$Q = \frac{\alpha r^4}{L}$$

where α is a constant.

An experiment is carried out to determine the value of α . The data from the experiment are shown in Table 1.1.

Table 1.1

quantity	value	percentage uncertainty
Q	$2.72 \times 10^{-8} \text{ m}^3 \text{ s}^{-1}$	$\pm 3\%$
r	$7.1 \times 10^{-5} \text{ m}$	$\pm 2\%$
L	$2.5 \times 10^{-2} \text{ m}$	$\pm 4\%$

- (a) Use information in Table 1.1 to show that the SI base unit of α is s^{-1} .

[1]

- (b) Show that the percentage uncertainty in α is 15%.

[1]

- (c) Calculate α with its absolute uncertainty. Give your answer to an appropriate number of significant figures.

$$\alpha = (\dots \pm \dots) \times 10^7 \text{ s}^{-1} \quad [3]$$

[Total: 5]

- 2 The engine of a toy rocket pushes gases vertically downwards and this results in the rocket accelerating vertically upwards from the ground.

The rocket starts to move from rest at time $t = 0$. The variation with time t of the vertical velocity v of the rocket for the first 0.30 s of the flight is shown in Fig. 2.1.

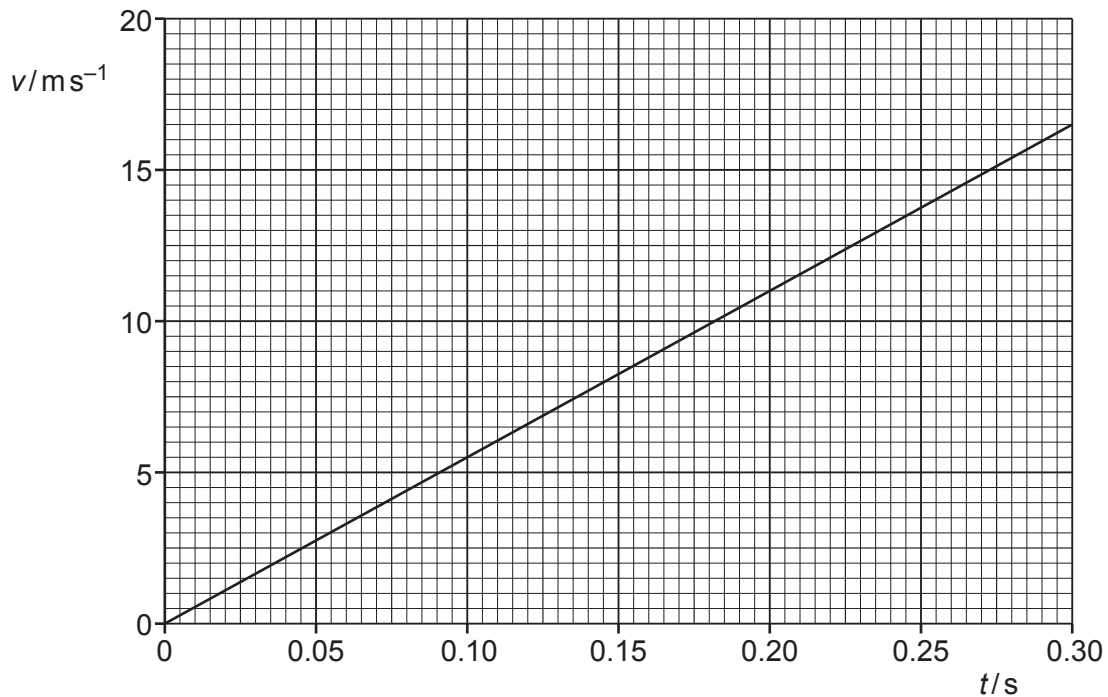


Fig. 2.1

As the rocket moves, the thrust force T provided by the rocket engine is 16 N. Assume that the mass of the rocket is constant for this part of its flight.

Assume that air resistance is negligible.

(a) For this part of the rocket's flight:

- (i) show that the acceleration of the rocket is 55 m s^{-2}

[1]

- (ii) state an expression for the resultant force F experienced by the rocket in terms of the thrust force T and the weight W of the rocket

[1]

- (iii) calculate the mass of the rocket.

mass = ... kg [2]

- (b) At time $t = 0.30$ s, a small piece of metal separates from the rocket.

Calculate:

- (i) the height of the rocket above the ground at $t = 0.30$ s

height = ... m [2]

- (ii) the speed at which the piece of metal strikes the ground.

speed = ... ms^{-1} [3]

[Total: 9]

- 3 (a) State the principle of moments.

.....

.....

..... [2]

- (b) A hollow plastic sphere is attached at one end of a bar. The sphere is partially submerged in water and the bar is attached to a fixed vertical support by a pivot P, as shown in Fig. 3.1.

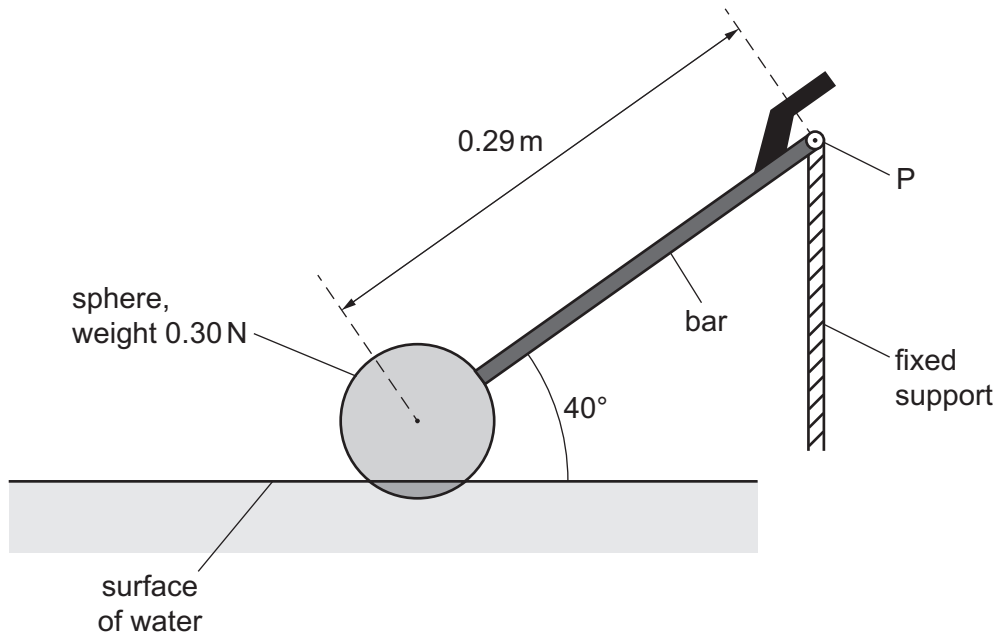


Fig. 3.1 (not to scale)

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. Assume that the weight of the bar is negligible.

Calculate the moment of the weight of the sphere about P.

moment = ... Nm [2]

- (c) The system shown in Fig. 3.1 is part of a mechanism that controls the amount of water in a tank.

Water enters the tank and causes the sphere to rise. This results in the bar becoming horizontal. Fig. 3.2 shows the system in its new position.

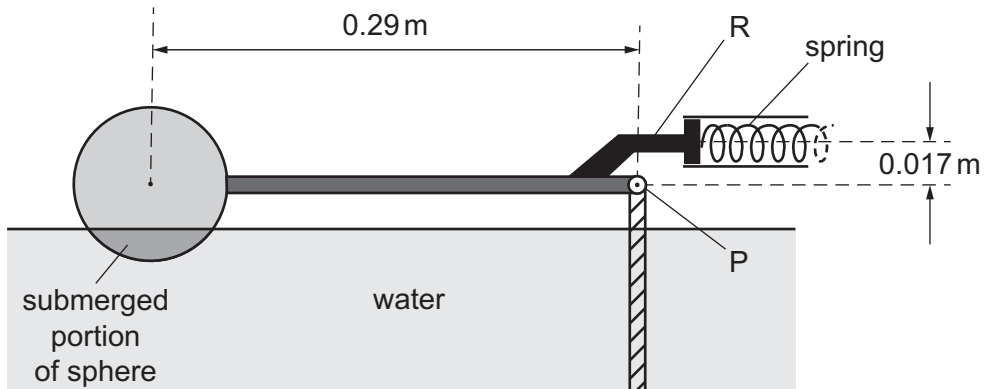


Fig. 3.2 (not to scale)

In this position the rod R exerts a force to compress a horizontal spring that controls the water supply to the tank. R is positioned at a perpendicular distance of 0.017 m above P.

The variation of the force F applied to the spring with compression x of the spring is shown in Fig. 3.3.

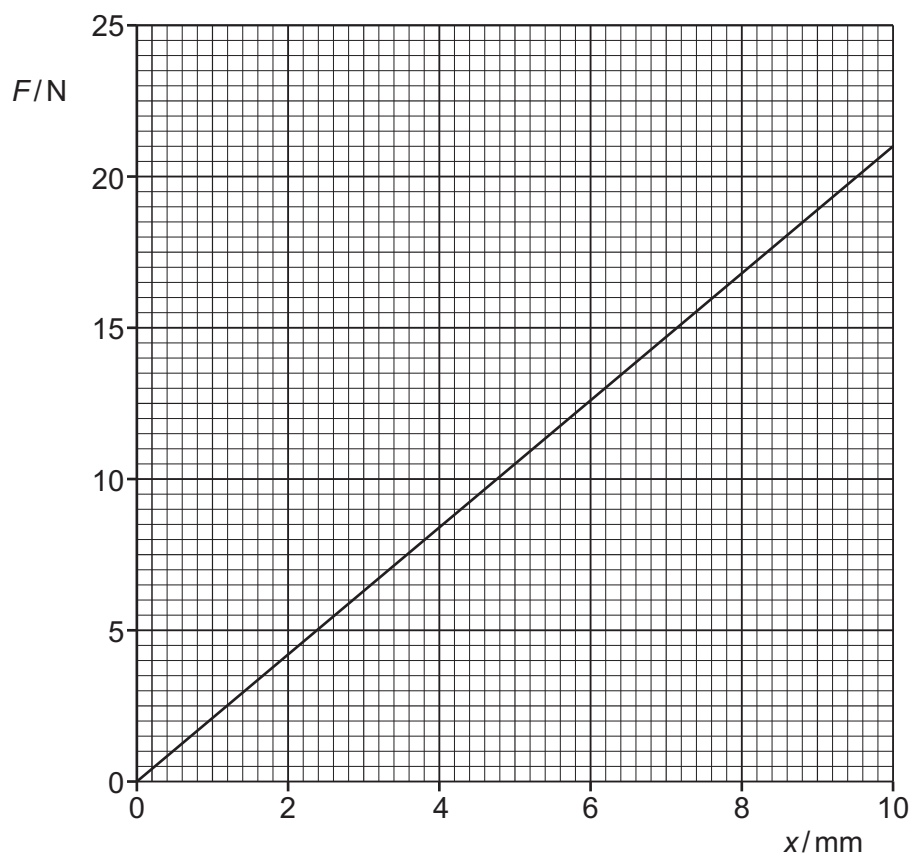


Fig. 3.3

- (i) Use Fig. 3.3 to calculate the spring constant k of the spring.

$$k = \dots\dots\dots \text{Nm}^{-1} \quad [2]$$

- (ii) At the position shown in Fig. 3.2, the system is stationary and in equilibrium.

The radius of the sphere is 0.0480 m and 26.0% of the volume of the sphere is submerged.

The density of water is $1.00 \times 10^3 \text{kg m}^{-3}$.

Show that the upthrust on the sphere is 1.18 N.

[2]

- (iii) By taking moments about P, determine the force exerted on the spring by the rod R.

$$\text{force} = \dots\dots\dots \text{N} \quad [2]$$

- (iv) Calculate the elastic potential energy E_p of the compressed spring.

$$E_p = \dots\dots\dots \text{ J [2]}$$

- (d) When the sphere moves from the position shown in Fig. 3.1 to the position shown in Fig. 3.2, the upthrust on the sphere does work.
Assume that resistive forces are negligible.

Explain why the work done by the upthrust is not equal to the gain in elastic potential energy of the spring.

.....
..... [1]

[Total: 13]

- 4 (a) A progressive longitudinal wave travels through a medium from left to right. Fig. 4.1 shows the positions of some of the particles of the medium at time t_0 and a graph showing the particle displacements at the same time t_0 .

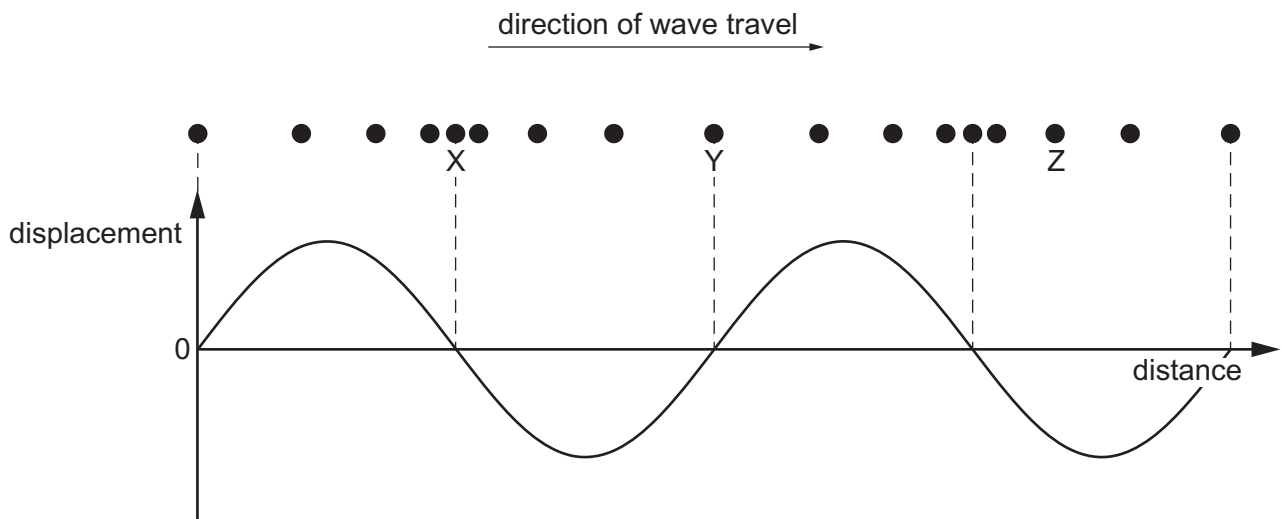


Fig. 4.1

Particle displacements to the right of their equilibrium positions are shown as positive on the graph and particle displacements to the left are shown as negative on the graph.

The period of the wave is T .

- (i) On Fig. 4.1, draw circles around two particles which are exactly one wavelength apart. [1]
- (ii) On Fig. 4.1, sketch a line on the graph to represent the displacements of the particles for the longitudinal wave at time $t_0 + \frac{T}{4}$. [3]
- (iii) State the direction of motion of particle Z at time $t_0 + \frac{T}{4}$.
 [1]
- (b) The frequency of the wave in (a) is 16 kHz. The distance between particles X and Y is 0.19 m. Calculate the speed of the wave as it travels through the medium.

speed = ... ms^{-1} [3]

- (c) A longitudinal sound wave is travelling through a solid. The initial intensity of the wave is I_0 . The frequency of the wave remains constant and the amplitude falls to half of its original value.

Determine, in terms of I_0 , the final intensity of the wave.

intensity = ... I_0 [2]

- (d) The sound wave in (c) now meets another sound wave travelling in the opposite direction.

- (i) State a condition necessary for these two waves to form a stationary wave.

..... [1]

- (ii) State **two** ways in which a stationary wave differs from a progressive wave.

1

.....

2

.....

[2]

[Total: 13]

- 5 (a) State Kirchhoff's second law.

.....

.....

..... [2]

- (b) Three identical cells, each of electromotive force (e.m.f.) 1.5 V and internal resistance $590\text{ m}\Omega$, are connected in parallel across a conductor, as shown in Fig. 5.1.

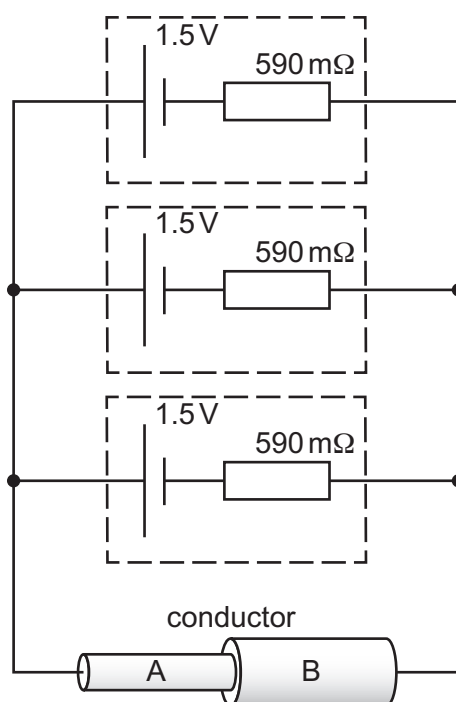


Fig. 5.1

The conductor is composed of two cylindrical sections A and B.
The total resistance of the circuit is $2.2\text{ }\Omega$.

- (i) Show that the resistance of the conductor is $2.0\text{ }\Omega$.

[2]

- (ii) Calculate the current in the conductor.

current = ... A [2]

- (c) The two cylindrical sections A and B of the conductor in Fig. 5.1 are made from the same material and have the same length.

The diameter of section A is 4.3 mm and the diameter of section B is 7.6 mm.

The resistance of section A is R_A and the resistance of section B is R_B .

- (i) Calculate the ratio $\frac{R_A}{R_B}$.

$\frac{R_A}{R_B} =$ [3]

- (ii) Calculate the ratio

$$\frac{\text{average drift speed of free electrons in section A}}{\text{average drift speed of free electrons in section B}}.$$

Explain your reasoning.

ratio = ... [2]

- (d) The circuit of Fig. 5.1 is altered by removing one of the cells.

State and explain the effect, if any, of this change on the potential difference across the conductor.

.....

.....

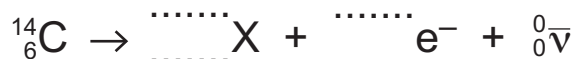
.....

.....

..... [3]

[Total: 14]

- 6 (a) The nuclide $^{14}_6\text{C}$ (carbon-14) is unstable and undergoes β^- decay, emitting a high-energy electron and an antineutrino to form a new nuclide X. The equation for this decay is shown.



Complete the equation.

[2]

- (b) (i) State the equation for β^- decay in terms of the fundamental particles involved.

[1]

- (ii) Use your equation from (b)(i) to show how charge is conserved in β^- decay.

[1]

- (c) Neutrinos were first proposed to exist more than 20 years before they were directly detected, in order to explain a particular experimental observation about β -decay.

- (i) State an observation about β -decay that is explained by the existence of neutrinos.

.....

 [1]

- (ii) Suggest how the existence of neutrinos explains the observation in (c)(i).

.....

 [1]

[Total: 6]

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