



CANDIDATE
NAME

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NUMBER

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9702/21

October/November 2023

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 (a) Compare scalar and vector quantities.

.....

.....

..... [2]

- (b) The radius of a small sphere is determined from a measurement of the volume of the sphere. The sphere is submerged in water, displacing some of the water into a measuring cylinder as shown in Fig. 1.1.

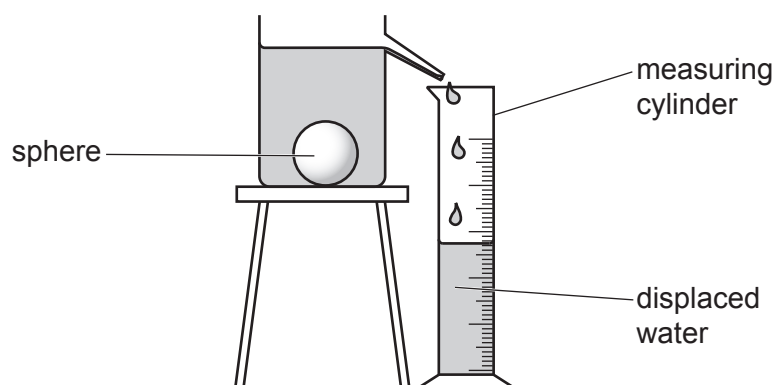


Fig. 1.1 (not to scale)

The measured volume of displaced water is $(28.0 \pm 0.5)\text{cm}^3$.

Calculate:

- (i) the radius, in cm, of the sphere

radius = ... cm [1]

- (ii) the percentage uncertainty in the radius of the sphere.

percentage uncertainty = ... % [2]

[Total: 5]

- 2 A hot-air balloon floats just above the ground. The balloon is stationary and is held in place by a vertical rope, as shown in Fig. 2.1.

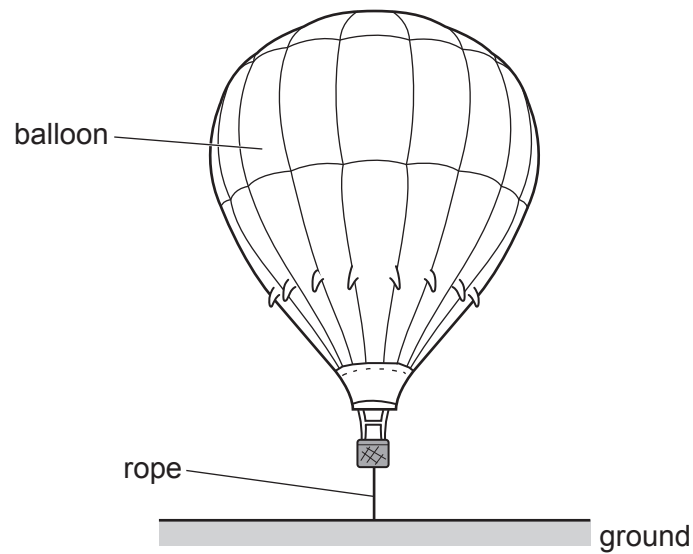


Fig. 2.1

The balloon has a weight W of $3.39 \times 10^4 \text{ N}$. The tension T in the rope is $4.00 \times 10^2 \text{ N}$.
Upthrust U acts on the balloon.
The density of the surrounding air is 1.23 kg m^{-3} .

- (a) (i) On Fig. 2.1, draw labelled arrows to show the directions of the three forces acting on the balloon. [2]
- (ii) Calculate the volume, to three significant figures, of the balloon.

volume = ... m^3 [3]

- (iii) The balloon is released from the rope.

Calculate the initial acceleration of the balloon.

acceleration = ... ms^{-2} [3]

- (b) The balloon is stationary at a height of 500 m above the ground. A tennis ball is released from rest and falls vertically from the balloon.

A passenger in the balloon uses the equation $v^2 = u^2 + 2as$ to calculate that the ball will be travelling at a speed of approximately 100 ms^{-1} when it hits the ground.

Explain why the actual speed of the ball will be much lower than 100 ms^{-1} when it hits the ground.

.....

 [3]

- (c) Before the balloon is released, the rope holding the balloon has a strain of 2.4×10^{-5} . The rope has an unstretched length of 2.5 m. The rope obeys Hooke's law.

- (i) Show that the extension of the rope is $6.0 \times 10^{-5} \text{ m}$.

[1]

- (ii) Calculate the elastic potential energy E_p of the rope.

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

- (iii) The rope holding the balloon is replaced with a new one of the same original length and cross-sectional area. The tension is unchanged and the new rope also obeys Hooke's law.

The new rope is made from a material of a lower Young modulus.

State and explain the effect of the lower Young modulus on the elastic potential energy of the rope.

.....

 [2]

[Total: 16]

- 3 A trolley A moves along a horizontal surface at a constant velocity towards another trolley B which is moving at a lower constant speed in the same direction. Fig. 3.1 shows the trolleys at time $t = 0$.



Fig. 3.1

Table 3.1 shows data for the trolleys.

Table 3.1

trolley	mass/kg	initial speed/ m s^{-1}
A	0.25	0.48
B	0.75	0.12

The two trolleys collide elastically and then separate. Resistive forces are negligible.

Fig. 3.2 shows the variation with time t of the velocity v for trolley B.

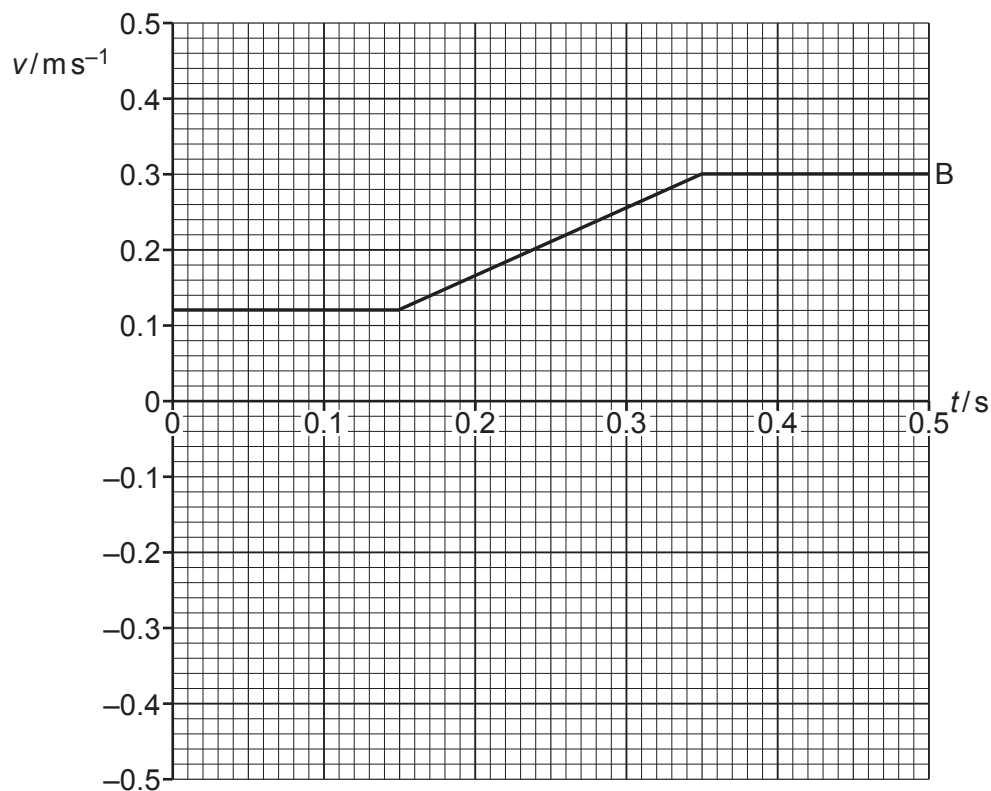


Fig. 3.2

- (a) State what is represented by the area under a velocity–time graph.

..... [1]

- (b) Use Table 3.1 and Fig. 3.2 to determine:

- (i) the acceleration of trolley B during the collision

acceleration of B = ... ms^{-2} [2]

- (ii) the magnitude and direction of the final velocity of trolley A.

magnitude = ... ms^{-1}

direction [3]

- (c) On Fig. 3.2, sketch the variation of the velocity of trolley A with time t from $t = 0$ to $t = 0.50\text{ s}$. [3]

[Total: 9]

- 4 (a) State the principle of superposition.

.....

 [2]

- (b) Coherent light is incident normally on two identical slits X and Y. The diffracted light emerging from the slits superposes to produce an interference pattern on a screen positioned at a distance of 1.9 m from the slits.

Fig. 4.1 shows the arrangement and the central part of the interference pattern of bright and dark fringes formed on the screen.

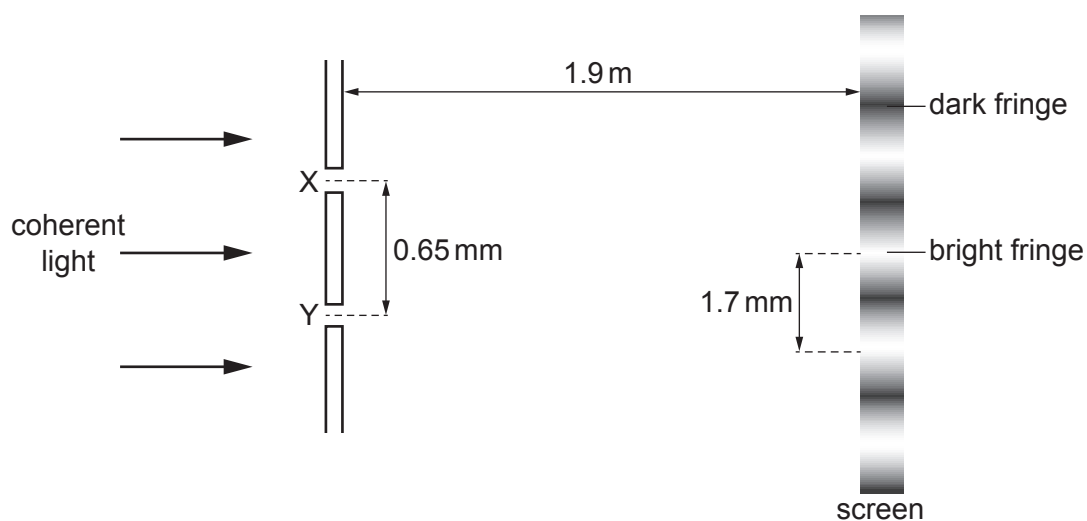


Fig. 4.1 (not to scale)

The separation of the slits is 0.65 mm. The distance between the centres of adjacent bright fringes is 1.7 mm.

Calculate the wavelength λ of the light.

$$\lambda = \dots\dots\dots \text{ m [3]}$$

- (c) Light waves from slits X and Y in (b) arrive at a point between adjacent bright fringes on the screen. Fig. 4.2 shows the variation of displacement with time for the waves arriving at the point where they meet.

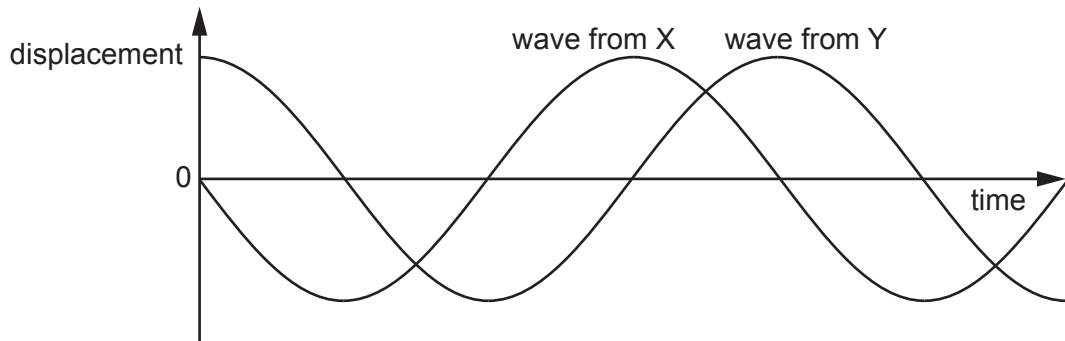


Fig. 4.2

A student makes two statements about the waves at this point:

Statement 1: 'The phase difference between the waves is 90° .'

Statement 2: 'The amplitude of the resultant wave is zero.'

- (i) Explain how statement 1 is correct.

.....

 [1]

- (ii) State and explain whether statement 2 is correct.

.....

 [1]

- (d) The width of each slit in (b) is decreased by the same amount. There is no change to the separation of the slits.

Describe and explain the effect, if any, of this change on the appearance of the interference pattern.

.....

 [2]

[Total: 9]

- 5 A train travels at a constant high speed along a straight horizontal track towards an observer standing adjacent to the track, as shown in Fig. 5.1.

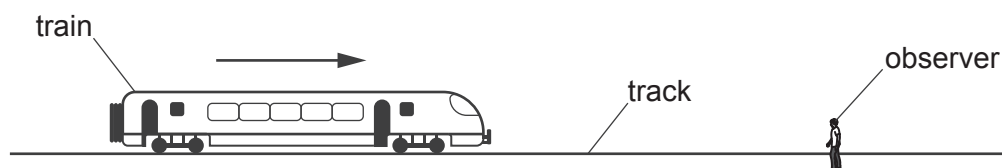


Fig. 5.1

The train sounds its horn continuously as it approaches the observer, from time $t = 0$ until it is well past the observer at time $t = t_2$. The train passes the observer at time $t = t_1$. The horn emits a sound wave of constant frequency f_s .

- (a) On Fig. 5.2, sketch the variation of the frequency of sound heard by the observer with time t , from time $t = 0$ to $t = t_2$.

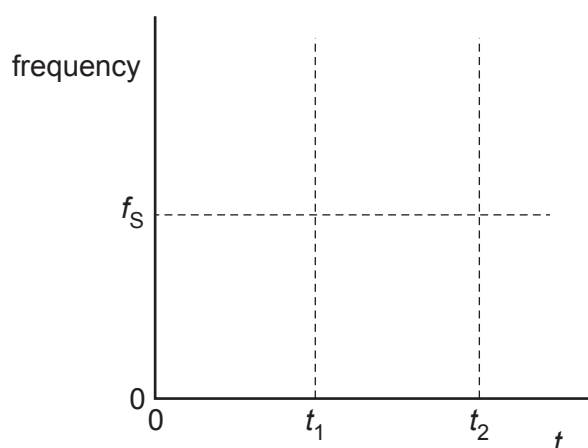


Fig. 5.2

[1]

- (b) At a particular time, the sound waves at the observer have an intensity of $4.7 \times 10^{-3} \text{ W m}^{-2}$. The waves at the observer are incident at right angles on a circular detector of radius 2.8 cm.

Calculate the power P of the waves incident on the detector.

$P = \dots\dots\dots \text{ W}$ [3]

[Total: 4]

- 6 A battery is connected in a circuit with a light-dependent resistor (LDR), two fixed resistors and a voltmeter, as shown in Fig. 6.1.

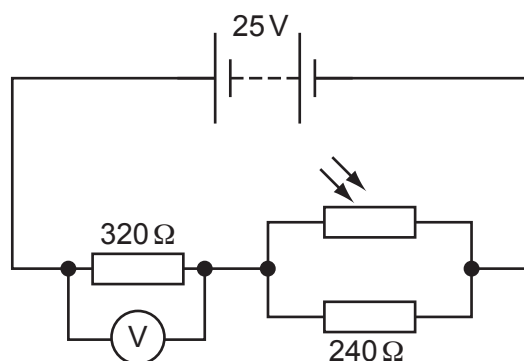


Fig. 6.1

The battery has an electromotive force (e.m.f.) of 25 V and negligible internal resistance. The resistors have resistances of 320 Ω and 240 Ω.

- (a) The voltmeter displays a reading of 16 V.
- (i) Show that the current in the battery is 0.050 A.

[1]

- (ii) Calculate the resistance of the LDR.

resistance = ... Ω [3]

(iii) Determine the ratio

$$\frac{\text{power dissipated in the LDR}}{\text{power dissipated in the } 240\,\Omega \text{ resistor}}$$

ratio = ... [2]

(b) The intensity of the light incident on the LDR increases.

State and explain what happens to the voltmeter reading.

.....

 [3]

[Total: 9]

- 7 (a) The results of the α -particle scattering experiment led to the development of the nuclear model for the atom.

State the results that suggested that most of the mass of the atom is concentrated in a very small region and most of the atom is empty space.

.....

.....

.....

..... [2]

- (b) State the composition of γ -radiation.

..... [1]

- (c) Table 7.1 lists the names of three particles and possible classifications for them.

Table 7.1

particle name	classification		
	baryon	hadron	lepton
neutrino			
neutron			
positron			

Complete Table 7.1 by placing ticks (✓) in the boxes to indicate the classifications that apply to each particle. [2]

- (d) The discovery of a particle with an unusual charge was an important step in the development of the theory of quarks. The particle is a hadron with a mass of 2.19×10^{-27} kg and a charge of $+2e$, where e is the elementary charge.

- (i) Calculate the mass, in u , of the particle. Give your answer to three significant figures.

mass = ... u [1]

- (ii) Determine a possible quark composition of a hadron with a charge of $+2e$.
Explain your reasoning.

[2]

[Total: 8]

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

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- 1 (a) In the following list, underline **all** quantities that are SI base quantities.

charge

electric current

force

time

[1]

- (b) Under certain conditions, the distance s moved in a straight line by an object in time t is given by

$$s = \frac{1}{2}at^2$$

where a is the acceleration of the object.

State **two** conditions under which the above expression applies to the motion of the object.

1

2 [2]

- (c) The variation with time t of the velocity v of a car that is moving in a straight line is shown in Fig. 1.1.

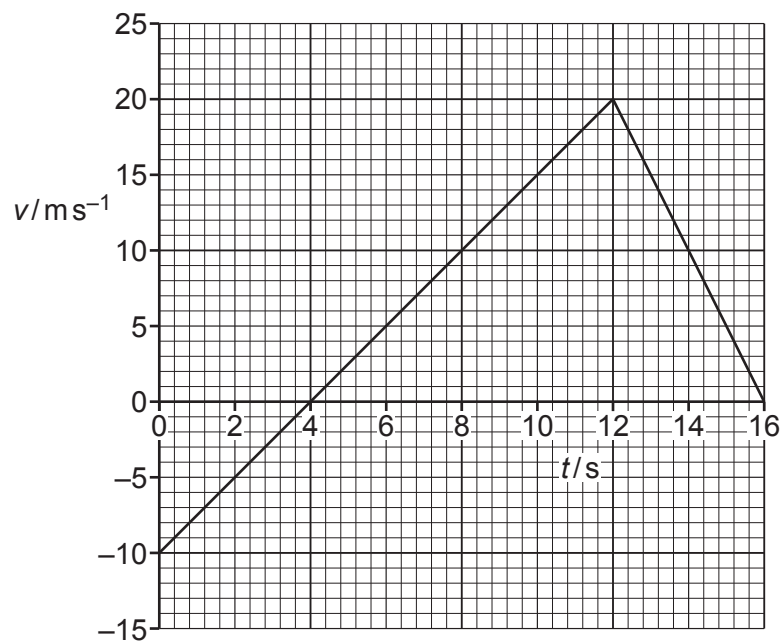


Fig. 1.1

- (i) Compare, qualitatively, the acceleration of the car at time $t = 8.0\text{ s}$ and at time $t = 14.0\text{ s}$ in terms of:

- magnitude

.....

.....

- direction.

.....

.....

[2]

- (ii) Determine the magnitude of the acceleration of the car at time $t = 4.0\text{ s}$.

acceleration = ... ms^{-2} [2]

- (iii) The car is at point X at time $t = 0$.

Determine the magnitude of the displacement of the car from X at time $t = 12.0\text{ s}$.

displacement = ... m [2]

[Total: 9]

- 2 A high-altitude balloon is stationary in still air. A solid sphere is suspended from the balloon by a string, as shown in Fig. 2.1.

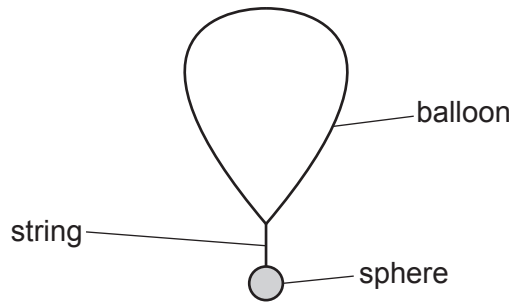


Fig. 2.1 (not to scale)

The volume of the balloon is 7.5 m^3 . The total weight of the balloon, string and sphere is 65 N . The upthrust acting on the string and sphere is negligible.

- (a) Calculate the density of the air surrounding the balloon.

density = ... kg m^{-3} [2]

- (b) The string breaks, releasing the sphere.

- (i) State the magnitude of the acceleration of the sphere immediately after the string breaks.

acceleration = ... ms^{-2} [1]

- (ii) State and explain the variation, if any, in the magnitude of the acceleration of the sphere when it is moving downwards **before** it reaches terminal (constant) velocity.

.....

.....

.....

.....

.....

.....

..... [3]

- (c) The sphere has a mass of 4.0 kg.

Calculate the total resistive force acting on the sphere at the instant when its acceleration is 1.9 m s^{-2} .

resistive force = ... N [2]

[Total: 8]

- 3 A vertical rod is fixed to the horizontal surface of a table, as shown in Fig. 3.1.

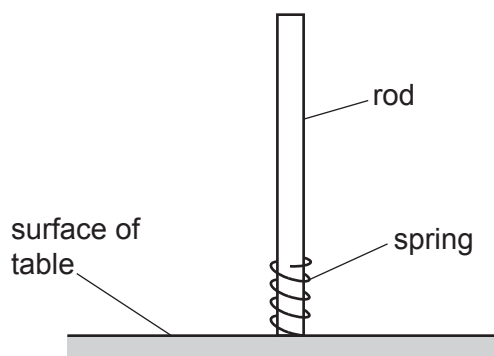


Fig. 3.1 (not to scale)

A spring of mass 7.5 g is able to slide along the full length of the rod.

The spring is first pushed against the surface of the table so that it has an initial compression of 2.1 cm. The spring is then suddenly released so that it leaves the surface of the table with a kinetic energy of 0.048 J and then moves up the rod.

Assume that the spring obeys Hooke's law and that the initial elastic potential energy of the compressed spring is equal to the kinetic energy of the spring as it leaves the surface of the table. Air resistance is negligible.

- (a) By using the initial elastic potential energy of the compressed spring, calculate its spring constant.

spring constant = ... Nm^{-1} [2]

- (b) Calculate the speed of the spring as it leaves the surface of the table.

speed = ... ms^{-1} [2]

- (c) The spring rises to its maximum height up the rod from the surface of the table. This causes the gravitational potential energy of the spring to increase by 0.039 J.
- (i) Calculate, for this movement of the spring, the increase in height of the spring after leaving the surface of the table.

increase in height = ... m [2]

- (ii) Calculate the average frictional force exerted by the rod on the spring as it rises.

average frictional force = ... N [2]

- (d) The rod is replaced by another rod that exerts negligible frictional force on the moving spring. The initial compression x of the spring is now varied in order to vary the maximum increase in height Δh of the spring after leaving the surface of the table. Assume that the spring obeys Hooke's law for all compressions.

On Fig. 3.2, sketch a graph to show the variation with x of Δh . Numerical values are not required.

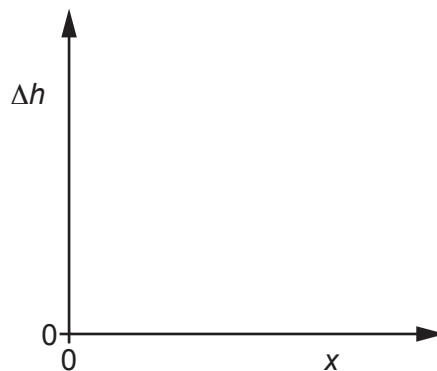


Fig. 3.2

[2]

[Total: 10]

- 4 (a) A ball Y moves along a horizontal frictionless surface and collides with a ball Z, as illustrated in the views from above in Fig. 4.1 and Fig. 4.2.

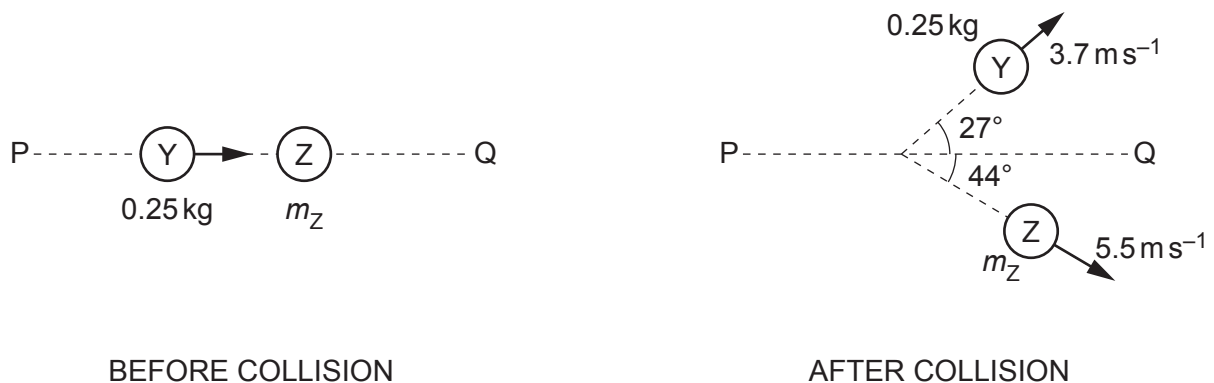


Fig. 4.1 (not to scale)

Fig. 4.2 (not to scale)

Ball Y has a mass of 0.25 kg and initially moves along a line PQ.
 Ball Z has a mass m_Z and is initially stationary.

After the collision, ball Y has a final velocity of 3.7 ms^{-1} at an angle of 27° to line PQ and ball Z has a final velocity of 5.5 ms^{-1} at an angle of 44° to line PQ.

- (i) Calculate the component of the final momentum of ball Y in the direction perpendicular to line PQ.

component of momentum = ... N s [2]

- (ii) By considering the component of the final momentum of each ball in the direction perpendicular to line PQ, calculate m_Z .

$m_Z = \dots \text{ kg}$ [1]

- (iii) During the collision, the average force exerted on Y by Z is F_Y and the average force exerted on Z by Y is F_Z .

Compare the magnitudes and directions of F_Y and F_Z . Numerical values are not required.

magnitudes:

directions:

[2]

- (b) Two blocks, A and B, move directly towards each other along a horizontal frictionless surface, as shown in the view from above in Fig. 4.3.



Fig. 4.3

The blocks collide perfectly elastically. Before the collision, block A has a speed of 4 ms^{-1} and block B has a speed of 6 ms^{-1} . After the collision, block B moves back along its original path with a speed of 2 ms^{-1} .

Calculate the speed of block A after the collision.

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

[Total: 6]

- 5 (a) A beam of vertically polarised light is incident normally on a polarising filter, as shown in Fig. 5.1.

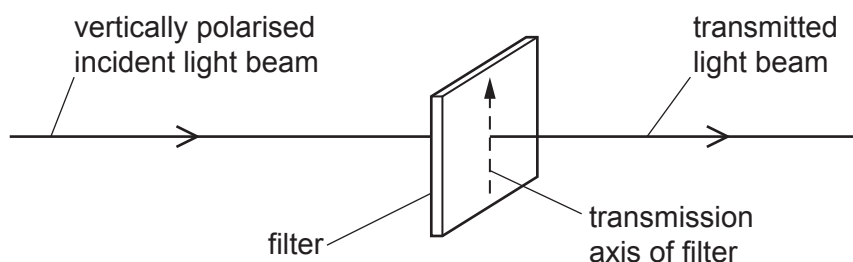


Fig. 5.1

- (i) The transmission axis of the filter is initially vertical. The filter is then rotated through an angle of 360° while the plane of the filter remains perpendicular to the beam.

On Fig. 5.2, sketch a graph to show the variation of the intensity of the light in the transmitted beam with the angle through which the transmission axis is rotated.

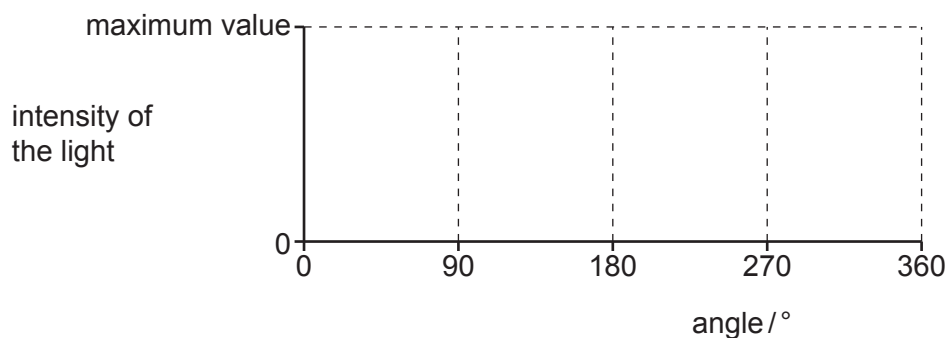


Fig. 5.2

[2]

- (ii) The intensity of the light in the incident beam is 7.6 W m^{-2} . When the transmission axis of the filter is at angle θ to the vertical, the light intensity of the transmitted beam is 4.2 W m^{-2} .

Calculate angle θ .

$$\theta = \dots\dots\dots^\circ \quad [2]$$

- (b) State what is meant by the diffraction of a wave.

.....

 [2]

- (c) A beam of light of wavelength $4.3 \times 10^{-7} \text{ m}$ is incident normally on a diffraction grating in air, as shown in Fig. 5.3.

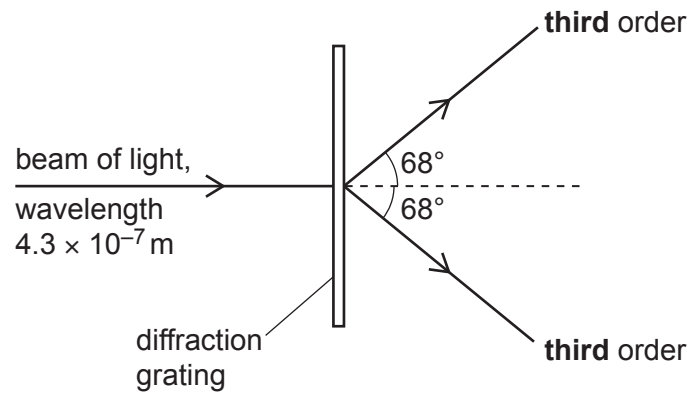


Fig. 5.3 (not to scale)

The **third**-order diffraction maximum of the light is at an angle of 68° to the direction of the incident light beam.

- (i) Calculate the line spacing d of the diffraction grating.

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

- (ii) Determine a different wavelength of **visible** light that will also produce a diffraction maximum at an angle of 68° .

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

[Total: 10]

- 6 (a) A metal wire has a resistance per unit length of $0.92 \Omega \text{m}^{-1}$. The wire has a uniform cross-sectional area of $5.3 \times 10^{-7} \text{m}^2$.

Calculate the resistivity of the metal of the wire.

resistivity = ... Ωm [2]

- (b) A battery of electromotive force (e.m.f.) E and negligible internal resistance is connected in series with a fixed resistor and a light-dependent resistor (LDR), as shown in Fig. 6.1.

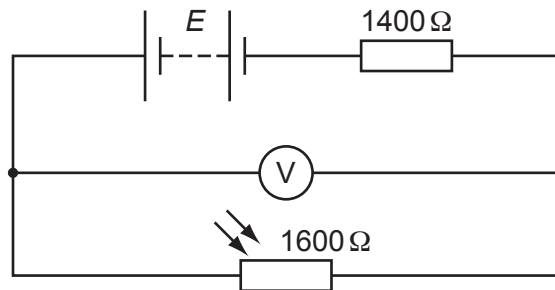


Fig. 6.1

The resistance of the fixed resistor is 1400Ω . The intensity of the light illuminating the LDR causes it to have a resistance of 1600Ω . A voltmeter connected across the LDR reads 6.4V .

- (i) Show that the current in the LDR is $4.0 \times 10^{-3} \text{A}$.

[1]

- (ii) Calculate the number of free electrons passing through the LDR in a time of 3.2 minutes.

number of free electrons = ... [2]

(iii) Calculate the e.m.f. E .

$$E = \dots\dots\dots \text{ V [2]}$$

(iv) Determine the ratio

$$\frac{\text{power dissipated in LDR}}{\text{power dissipated in fixed resistor}}.$$

$$\text{ratio} = \dots\dots\dots \text{ [2]}$$

(c) The environmental conditions change causing a decrease in the resistance of the LDR in (b). The temperature of the environment does not change.

State whether there is a decrease, increase or no change to:

(i) the intensity of the light illuminating the LDR

..... [1]

(ii) the current in the battery

..... [1]

(iii) the reading of the voltmeter.

..... [1]

[Total: 12]

- 7 (a) In the following list, underline **all** the particles that are **not** fundamental.

antineutrino baryon nucleon positron [1]

- (b) A nucleus of thorium-230 ($^{230}_{90}\text{Th}$) decays in stages, by emitting α -particles and β^- particles, to form a nucleus of lead-206 ($^{206}_{82}\text{Pb}$).

Determine the total number of α -particles and the total number of β^- particles that are emitted during the sequence of decays that form the nucleus of lead-206 from the nucleus of thorium-230.

number of α -particles = ...

number of β^- particles = ...

[2]

- (c) A meson has a charge of $-1e$, where e is the elementary charge. The quark composition of the meson includes a charm antiquark.

State and explain a possible flavour (type) of the other quark in the meson.

.....
 [2]

[Total: 5]

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9702/23

October/November 2023

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 **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) Table 1.1 lists some physical quantities. Complete the table by placing a tick (✓) next to the scalar quantities.

Table 1.1

acceleration	
charge	
momentum	
power	
upthrust	

[1]

- (b) A uniform cylinder has diameter D , length L and mass M .
The density ρ of the cylinder is given by

$$\rho = \frac{4M}{\pi D^2 L}.$$

Table 1.2 shows the data obtained from an experiment to determine the density of the cylinder.

Table 1.2

quantity	measurement	percentage uncertainty
D	$(26.2 \pm 0.1)\text{mm}$	%
L	$(162 \pm 1)\text{mm}$	%
M	$(247 \pm 1)\text{g}$	0.4%

- (i) Calculate the percentage uncertainties in D and L . Write your answers in Table 1.2.

[1]

- (ii) Calculate the density of the cylinder. Give your answer to three significant figures.

density = ... kg m^{-3} [2]

- (iii) Calculate the percentage uncertainty in the density.

percentage uncertainty = ...% [2]

[Total: 6]

- 2 A ball on horizontal ground is kicked towards a vertical wall. Fig. 2.1 shows the path of the ball.

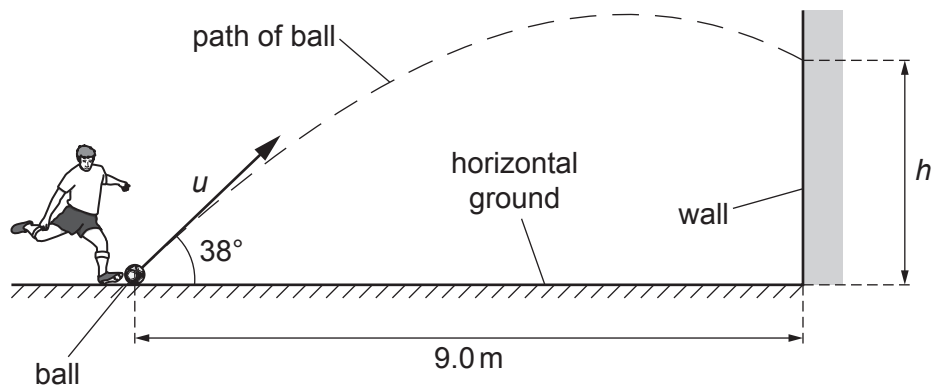


Fig. 2.1 (not to scale)

The ball has an initial velocity u at an angle of 38° to the ground. The ball travels a horizontal distance of 9.0 m before striking the wall at a height h above the ground. The horizontal component u_H of the initial velocity of the ball is 9.5 m s^{-1} .

Air resistance is negligible.

- (a) (i) Show that the time t for the ball to reach the wall is 0.95 s.

[1]

- (ii) Calculate the vertical component u_V of the initial velocity of the ball.

$$u_V = \dots\dots\dots \text{ m s}^{-1} \quad [2]$$

- (iii) Determine h .

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

- (b) The speed of the ball just after striking the wall is less than its speed just before striking the wall.

State what this indicates about the nature of the collision of the ball with the wall.

.....

..... [1]

[Total: 6]

- 3 (a) State the conditions for a system to be in equilibrium.

.....

.....

..... [2]

- (b) Fig. 3.1 shows an airship in flight. The airship is propelled by identical fans that can be angled to control the motion of the airship.

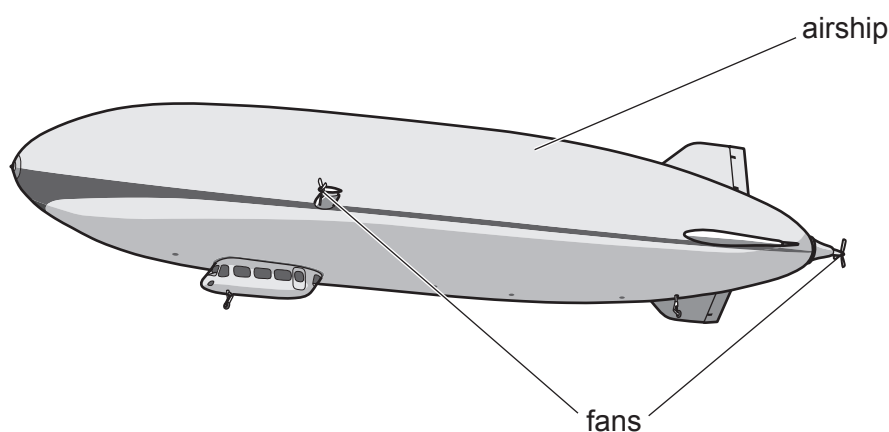


Fig. 3.1

The upthrust on the airship is 93 000 N.
The density of the surrounding air is 1.2 kg m^{-3} .

- (i) Calculate the volume of air displaced by the airship.

volume = ... m^3 [1]

- (ii) When fully loaded, the weight of the airship is greater than the upthrust.
To maintain horizontal flight, the fans provide a total vertical force of $3.0 \times 10^3 \text{ N}$ upwards on the airship.

Calculate the mass of the airship.

mass = ... kg [2]

- (c) At a certain time, the airship in (b) is stationary. The thrust force exerted by a fan on the airship is 2800 N.

To produce this force, a mass of 64 kg of air is propelled through the blades of the fan in a time of 0.50 s. Assume that this air is initially stationary at the entrance to the fan.

Calculate:

- (i) the change in momentum Δp of the air propelled through the fan blades in this time

$$\Delta p = \dots\dots\dots \text{ kg ms}^{-1} \quad [2]$$

- (ii) the speed of the air as it leaves the fan

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

- (iii) the total kinetic energy of this air due to its movement through the fan.

$$\text{kinetic energy} = \dots\dots\dots \text{ J} \quad [2]$$

[Total: 11]

- 4 Fig. 4.1 shows the variation with extension x of the tensile force F for two wires, G and H, made from the same material.

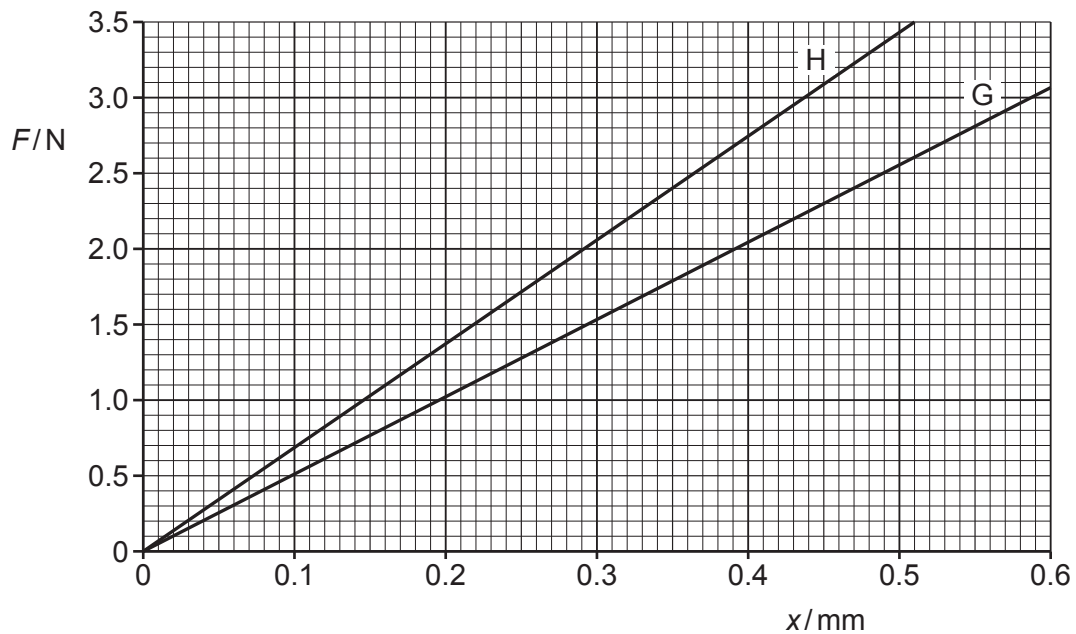


Fig. 4.1

The elastic limit has not been exceeded for G or H.

- (a) For the lines in Fig. 4.1:

- (i) state what is represented by the gradient

..... [1]

- (ii) explain why the area under the line represents the elastic potential energy of the wire.

.....

 [2]

- (b) Wires G and H are joined together end-to-end to form a composite wire of negligible weight. The composite wire hangs vertically from a fixed support.

A block of weight of 2.0 N is attached to the end of the wire, as shown in Fig. 4.2.

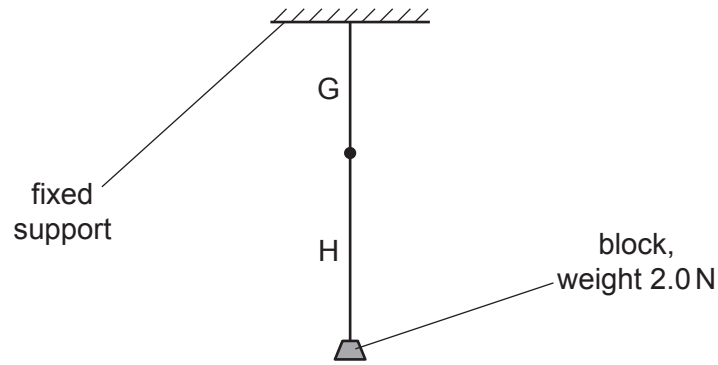


Fig. 4.2

(i) Use Fig. 4.1 to determine:

- the extension x_G of wire G

$$x_G = \dots\dots\dots \text{ mm}$$

- the extension x_H of wire H.

$$x_H = \dots\dots\dots \text{ mm}$$

[1]

(ii) Calculate the total elastic potential energy E_P of the composite wire due to the weight of the block.

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

(iii) The original length of wire G is L and the original length of wire H is $1.5L$.

Calculate the ratio

$$\frac{\text{cross-sectional area of wire G}}{\text{cross-sectional area of wire H}}.$$

$$\text{ratio} = \dots\dots\dots [3]$$

[Total: 9]

- 5 Two point sources, A and B, produce coherent electromagnetic waves. The waves from A and B are emitted in phase and have wavelength λ , as shown in Fig. 5.1.

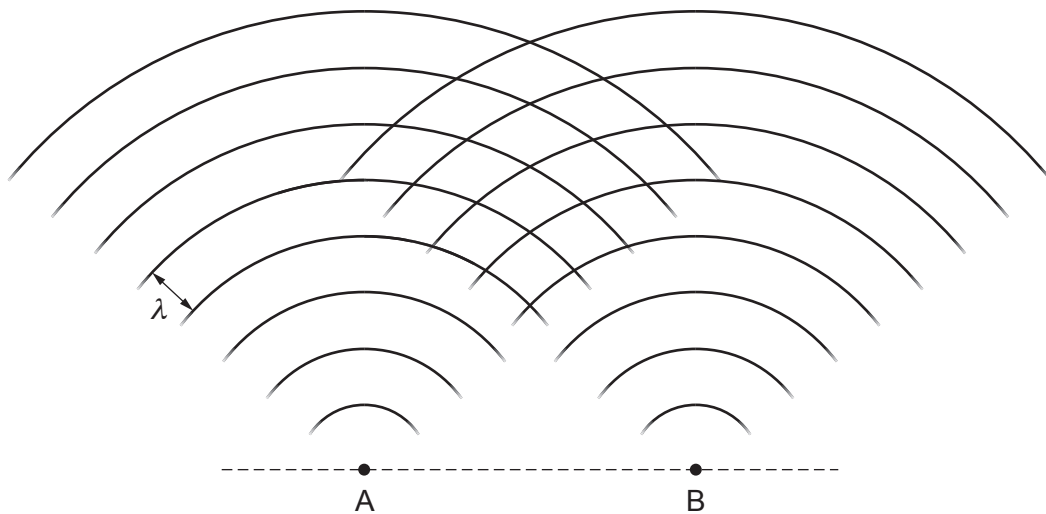


Fig. 5.1 (not to scale)

The lines on Fig. 5.1 represent wavefronts. All the points on a wavefront are in phase.

- (a) On Fig. 5.1, mark with a cross (×):

- (i) the position of an interference maximum (label this cross Y) [1]
- (ii) the position of an interference minimum (label this cross Z). [1]

- (b) The waves in air have a wavelength of 2.9×10^{-5} m.

An interference pattern is detected along a line parallel to AB and at a perpendicular distance of 140 m from AB. The spacing between adjacent interference maxima is 1.2 cm.

- (i) Calculate the separation a of the sources A and B.

$$a = \dots\dots\dots \text{ m } [3]$$

- (ii) State the principal region of the electromagnetic spectrum to which the waves belong.

..... [1]

[Total: 6]

- 6 A train travels at constant speed along a straight horizontal track towards an observer standing adjacent to the track, as shown in Fig. 6.1.

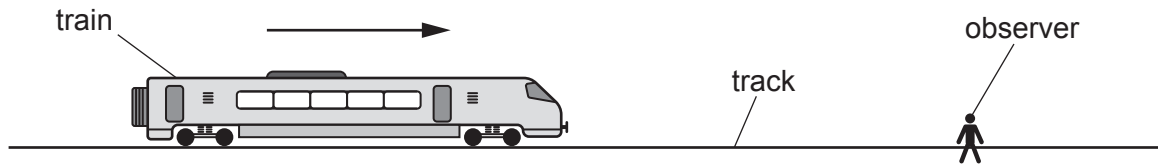


Fig. 6.1

The train sounds its horn continuously as it approaches the observer. The horn emits a sound of constant frequency 251 Hz. The frequency of sound heard by the observer is 291 Hz. The speed of sound in air is 340 m s^{-1} .

- (a) Calculate the speed of the train.

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

- (b) The train approaches and then passes the observer. The intensity I of the sound heard by the observer varies with the distance d of the horn from the observer.

When the horn is at a distance x_0 from the observer, the intensity I of the sound heard is I_0 and the amplitude A of the sound wave at the observer is A_0 .

Fig. 6.2 shows the variation with d/x_0 of I/I_0 as the train moves away from the observer.

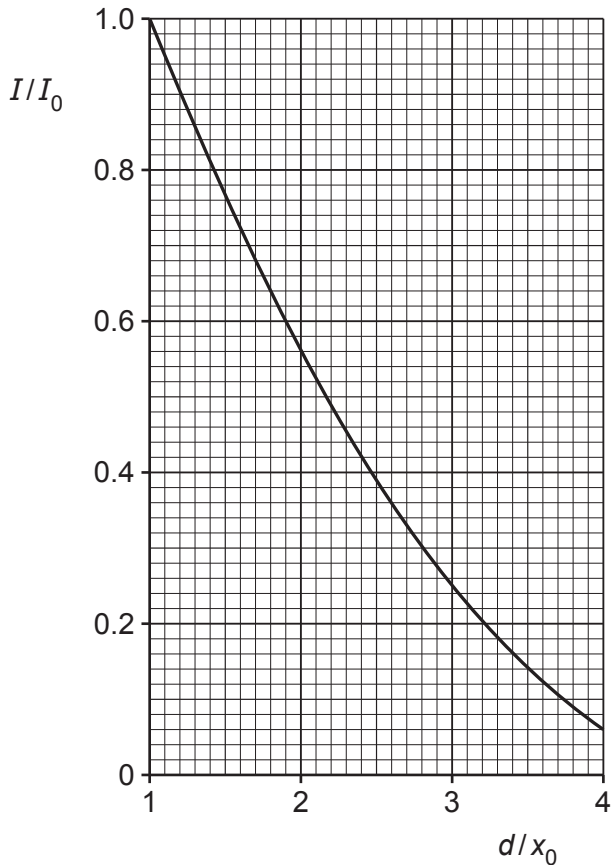


Fig. 6.2

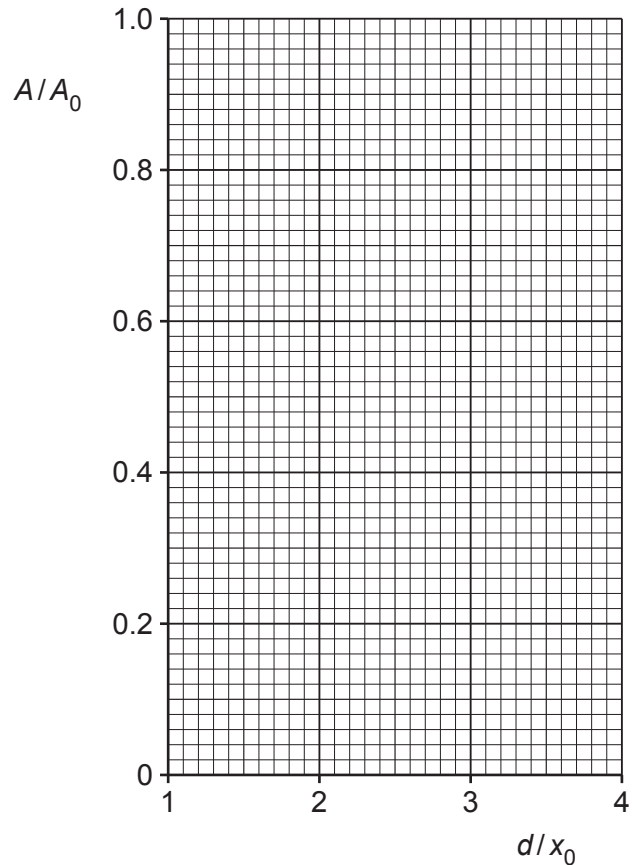


Fig. 6.3

- (i) State the relationship between amplitude A and intensity I for a progressive wave.

..... [1]

- (ii) On Fig. 6.3, sketch the variation with d/x_0 of A/A_0 . [2]

[Total: 5]

- 7 (a) State Ohm's law.

.....

 [2]

- (b) A battery of electromotive force (e.m.f.) 6.2V and negligible internal resistance is connected in a circuit to a uniform resistance wire, a voltmeter, a fixed resistor and a switch, as shown in Fig. 7.1.

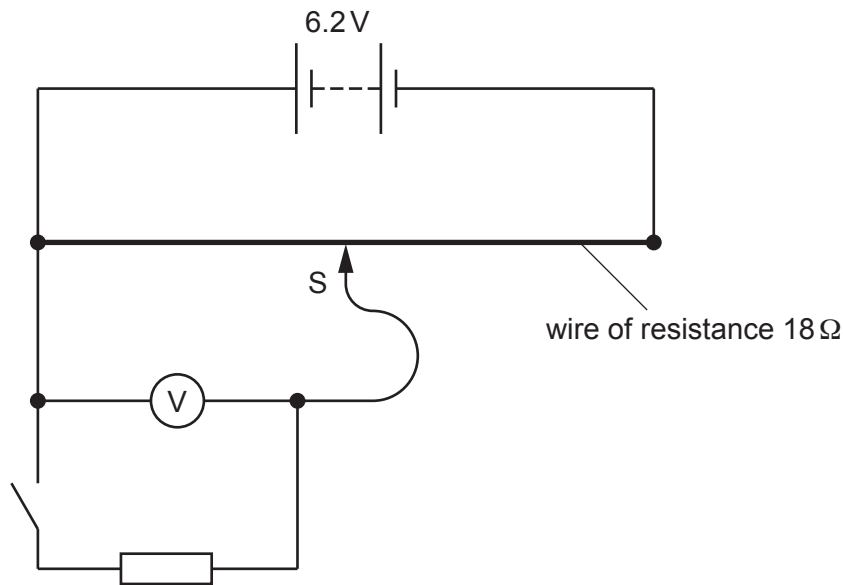


Fig. 7.1

The resistance wire has resistance 18Ω , length 0.94 m and cross-sectional area $7.2 \times 10^{-8}\text{ m}^2$. The slider S is positioned half-way along the length of the wire.

- (i) Calculate the resistivity ρ of the material of the resistance wire.

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

- (ii) The switch is open.
 State the reading on the voltmeter.

$$\text{voltmeter reading} = \dots\dots\dots \text{V} \quad [1]$$

- (iii) The switch is now closed.

State whether there is an increase, decrease or no change to:

- the current in the battery

.....

- the voltmeter reading.

.....

[2]

- (iv) The switch remains closed. The slider S is moved along the resistance wire so that the voltmeter reading is 3.1 V.

On Fig. 7.1, draw a cross (×) on the resistance wire to show a possible new position of the slider. [1]

- (c) The circuit in (b) is altered by changing the battery for one of a different e.m.f. The switch is open.

A student records the following data for the resistance wire:

current in the wire	0.93 A
mean drift speed of charge carriers	$1.3 \times 10^{-3} \text{ m s}^{-1}$
number density of charge carriers	$9.0 \times 10^{28} \text{ m}^{-3}$.

- (i) Determine the charge q of a charge carrier in the wire suggested by this data.

$q = \dots\dots\dots \text{ C}$ [2]

- (ii) With reference to the value of q , explain why the data recorded by the student cannot be correct.

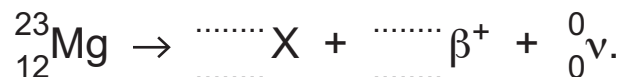
.....

..... [1]

[Total: 11]

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- 8 (a) The nuclide ${}^{23}_{12}\text{Mg}$ is an isotope of magnesium that undergoes β^+ decay to form a new nuclide X according to the equation



Four numbers are missing from the equation.

- (i) For the nuclide ${}^{23}_{12}\text{Mg}$, state what is represented by the numbers 23 and 12.

23 represents:

12 represents: [2]

- (ii) Complete the equation by inserting the missing numbers. [2]

- (iii) State the name of the group (class) of fundamental particles to which the positron and neutrino belong.

..... [1]

- (b) A radioactive source emits particles from its nuclei when it decays.

Fig. 8.1 shows, for the source, the variation with kinetic energy of the number of particles emitted.

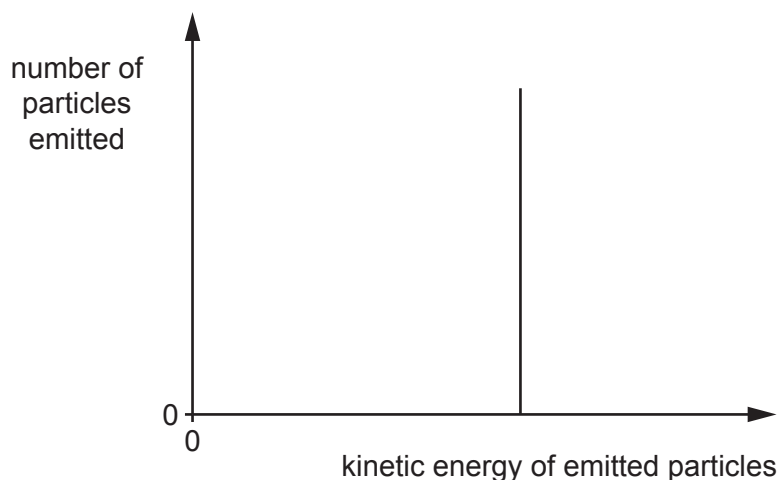


Fig. 8.1

State how Fig. 8.1 shows that these nuclei do **not** undergo beta-decay.

..... [1]

[Total: 6]

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