



CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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9702/21

October/November 2021

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

speed of light in free space	$c = 3.00 \times 10^8 \text{ ms}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ ms}^{-2}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel	$C = C_1 + C_2 + \dots$
energy of charged capacitor	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

- 1 (a) Define *density*.

.....
 [1]

- (b) A smooth pebble, made from uniform rock, has the shape of an elongated sphere as shown in Fig. 1.1.

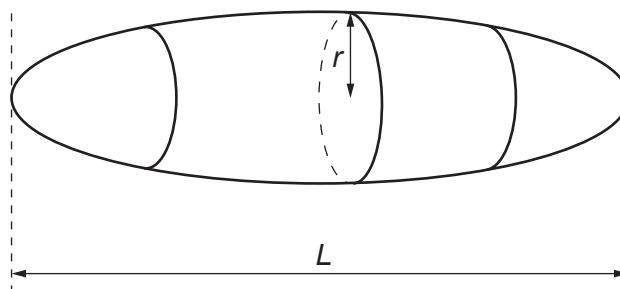


Fig. 1.1

The length of the pebble is L . The cross-section of the pebble, in the plane perpendicular to L , is circular with a maximum radius r .

A student investigating the density of the rock makes measurements to determine the values of L , r and the mass M of the pebble as follows:

$$\begin{aligned} L &= (0.1242 \pm 0.0001) \text{ m} \\ r &= (0.0420 \pm 0.0004) \text{ m} \\ M &= (1.072 \pm 0.001) \text{ kg.} \end{aligned}$$

- (i) State the name of a measuring instrument suitable for making this measurement of L .

..... [1]

- (ii) Determine the percentage uncertainty in the measurement of r .

percentage uncertainty = ... % [1]

- (c) The density ρ of the rock from which the pebble in (b) is composed is given by

$$\rho = \frac{Mr^n}{kL}$$

where n is an integer and k is a constant, with no units, that is equal to 2.094.

- (i) Use SI base units to show that n is equal to -2 .

[2]

- (ii) Calculate the percentage uncertainty in ρ .

percentage uncertainty = ... % [3]

- (iii) Determine ρ with its absolute uncertainty. Give your values to the appropriate number of significant figures.

$\rho = (\text{.....} \pm \text{.....}) \text{ kg m}^{-3}$ [3]

[Total: 11]

- 2 (a) Define *momentum*.

.....
 [1]

- (b) Two balls X and Y, of equal diameter but different masses 0.24 kg and 0.12 kg respectively, slide towards each other on a frictionless horizontal surface, as shown in Fig. 2.1.

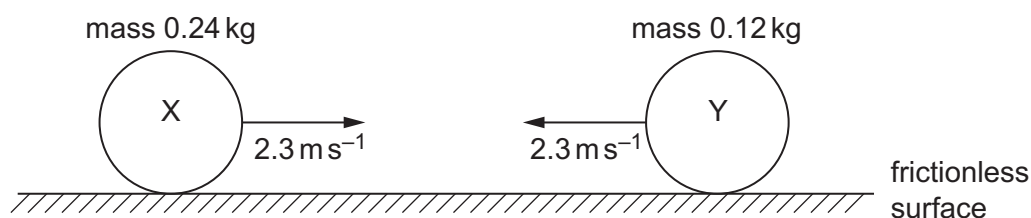


Fig. 2.1

Both balls have initial speed 2.3 ms^{-1} before they collide with each other. Fig. 2.2 shows the variation with time t of the force F_Y exerted on ball Y by ball X during the collision.

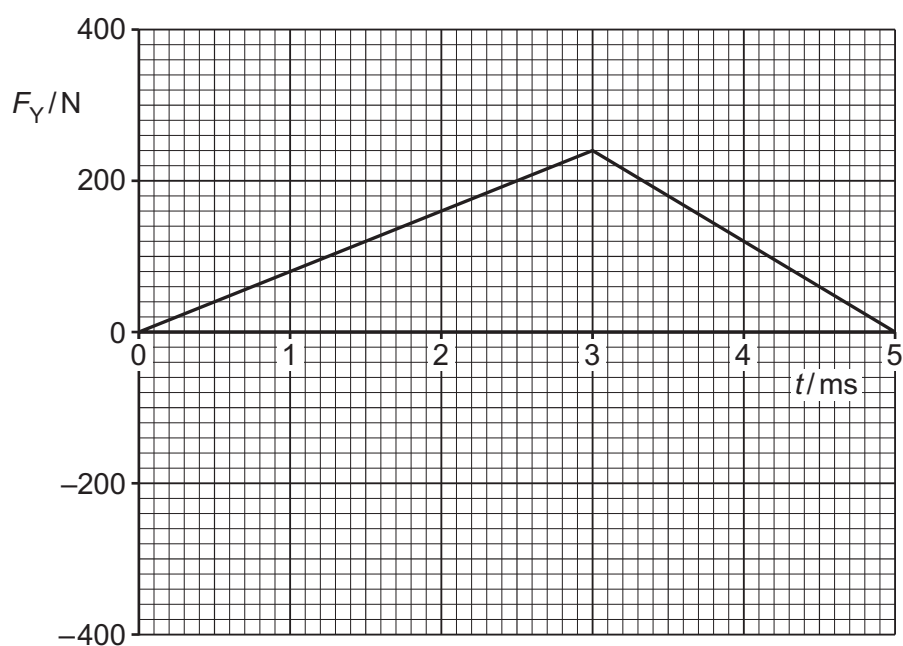


Fig. 2.2

- (i) Calculate the kinetic energy of ball X before the collision.

kinetic energy = ... J [3]

- (ii) The area enclosed by the lines and the time axis in Fig. 2.2 represents the change in momentum of ball Y during the collision.

Determine the magnitude of the change in momentum of ball Y.

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

- (iii) Calculate the magnitude of the velocity of ball Y after the collision.

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

- (c) On Fig. 2.3, sketch the variation with time t of the force F_X exerted on ball X by ball Y during the collision in (b).

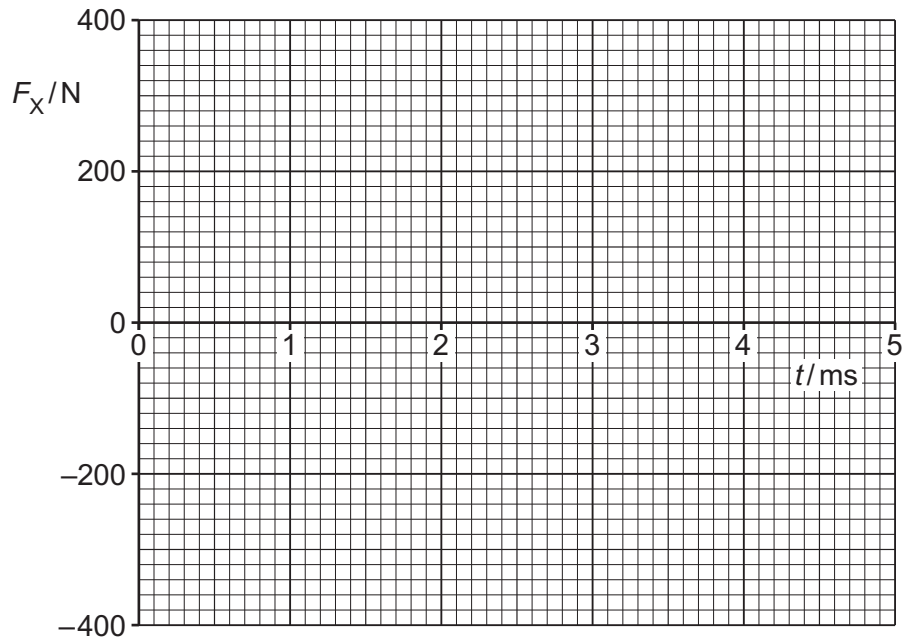


Fig. 2.3

[3]

[Total: 11]

- 3 (a) A uniform metal bar, initially unstretched, has sides of length w , x and y , as shown in Fig. 3.1.

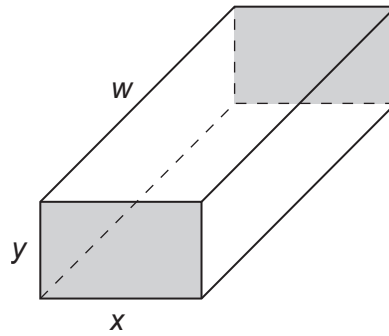


Fig. 3.1

The bar is now stretched by a tensile force F applied to the shaded ends. The changes in the lengths x and y are negligible. The bar now has sides of length x , y and z , as shown in Fig. 3.2.

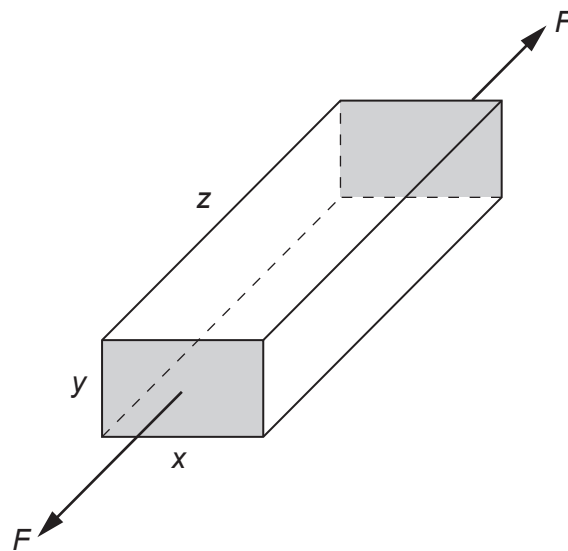


Fig. 3.2

Determine expressions, in terms of some or all of F , w , x , y and z , for:

- (i) the stress σ applied to the bar by the tensile force

$$\sigma = \dots\dots\dots [1]$$

- (ii) the strain ε in the bar due to the tensile force

$$\varepsilon = \dots\dots\dots [1]$$

- (iii) the Young modulus E of the metal from which the bar is made.

$$E = \dots\dots\dots [2]$$

- (b) A copper wire is stretched by a tensile force that gradually increases from 0 to 280 N. The variation with extension of the tensile force is shown in Fig. 3.3.

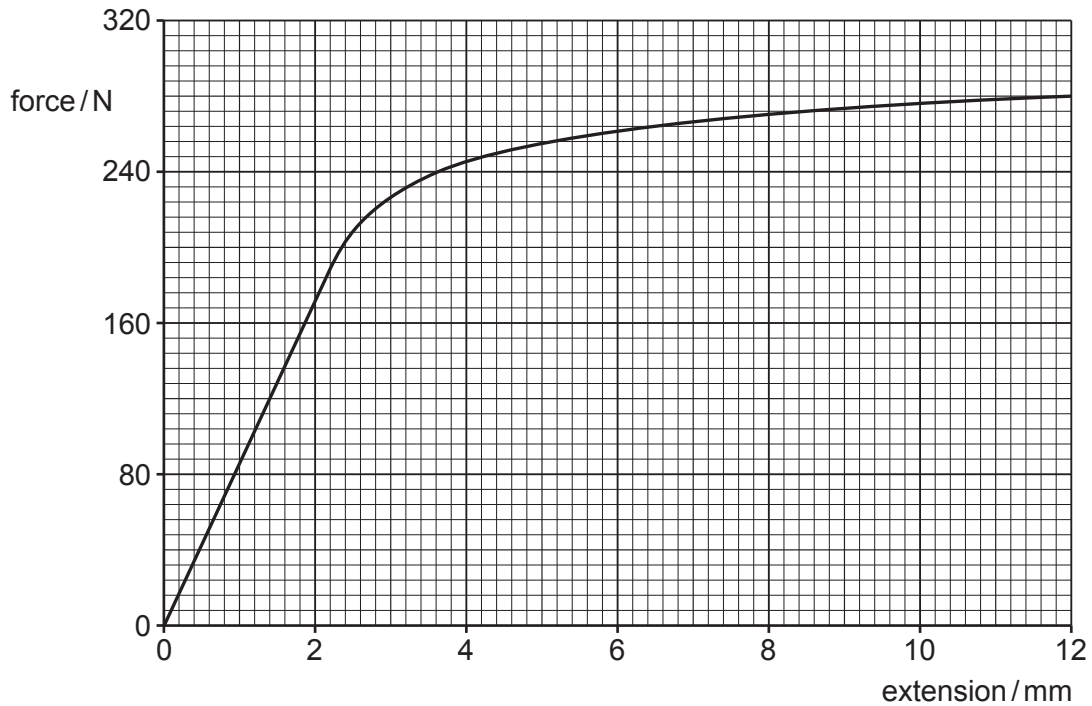


Fig. 3.3

- (i) State the maximum extension of the wire for which it obeys Hooke's law.

extension = ... mm [1]

- (ii) Use Fig. 3.3 to determine the strain energy in the wire when the tensile force is 120 N.

strain energy = ... J [3]

- (iii) Explain why the work done in stretching the wire to an extension of 12 mm is not equal to the energy recovered when the tensile force is removed.

.....

 [2]

[Total: 10]

- 4 (a) By reference to the direction of transfer of energy, state what is meant by a *longitudinal* wave.

.....
 [1]

- (b) A vehicle travels at constant speed around a wide circular track. It continuously sounds its horn, which emits a single note of frequency 1.2 kHz. An observer is a large distance away from the track, as shown in the view from above in Fig. 4.1.

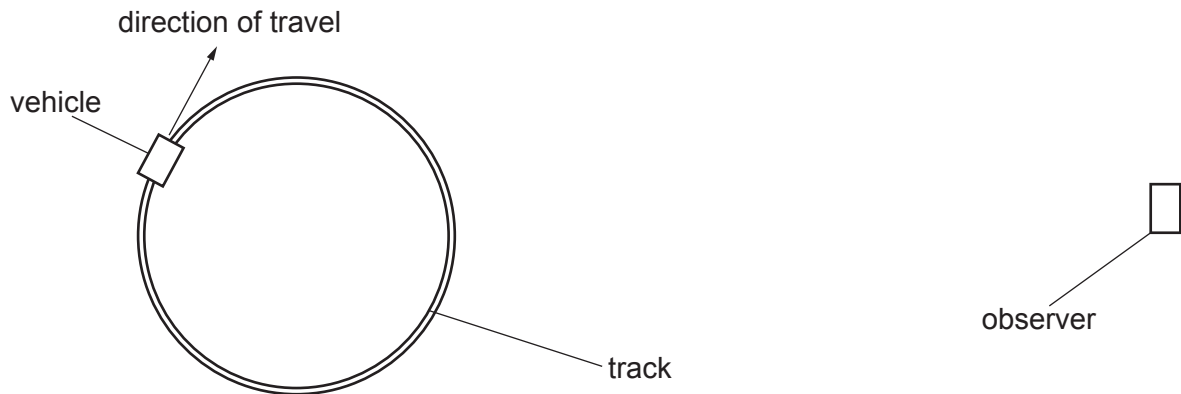


Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with time of the frequency f of the sound of the horn that is detected by the observer. The time taken for the vehicle to travel once around the track is T .

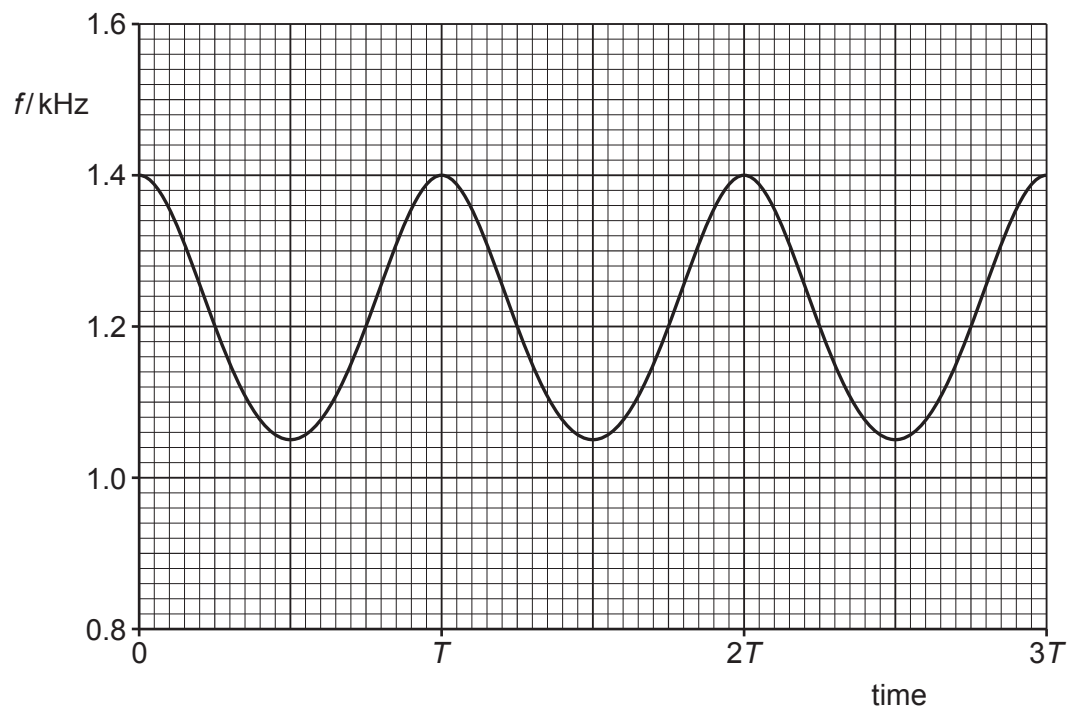


Fig. 4.2

- (i) Explain why the frequency of the sound detected by the observer is sometimes above and sometimes below 1.2 kHz.

.....

 [2]

- (ii) State the name of the phenomenon in (b)(i).

..... [1]

- (iii) On Fig. 4.1, mark with a letter X the position of the vehicle when it emitted the sound that is detected at time T . [1]

- (iv) On Fig. 4.1, mark with a letter Y the position of the vehicle when it emitted the sound that is detected at time $\frac{9T}{4}$. [1]

- (c) The speed of the sound in the air is 320 m s^{-1} .

Use Fig. 4.2 to determine the speed of the vehicle in (b).

speed = ... m s^{-1} [3]

[Total: 9]

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

.....

 [2]

- (b) The circuit shown in Fig. 5.1 contains a battery of electromotive force (e.m.f.) E and negligible internal resistance connected to four resistors R_1 , R_2 , R_3 and R_4 , each of resistance R .

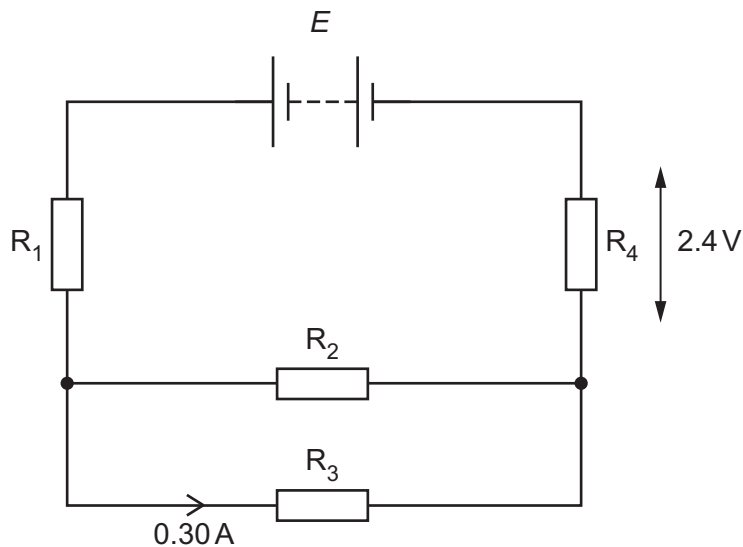


Fig. 5.1

The current in R_3 is 0.30 A and the potential difference (p.d.) across R_4 is 2.4 V .

- (i) Show that R is equal to $4.0\ \Omega$.

[2]

- (ii) Determine the e.m.f. E of the battery.

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

- (c) The battery in (b) is replaced with another battery of the same e.m.f. E but with an internal resistance that is not negligible.

State and explain the change, if any, in the total power produced by the battery.

.....

.....

..... [2]

- (d) The resistors in the circuit of Fig. 5.1 are made from nichrome wire of uniform radius $240\ \mu\text{m}$. The length of this wire needed to make each resistor is $0.67\ \text{m}$.

Calculate the resistivity of nichrome.

resistivity = ... Ωm [3]

[Total: 11]

- 6 (a) Complete Table 6.1 to show the masses (in terms of the unified atomic mass unit u) and charges (in terms of the elementary charge e) of α , β^+ and β^- particles.

Table 6.1

	mass / u	charge / e
α -particle		
β^+ particle		
β^- particle		

[4]

- (b) Carbon-14 is radioactive and decays by emission of β^- particles.

- (i) Nuclei do not contain β^- particles.

Explain the origin of the β^- particle that is emitted from the nucleus during β^- decay.

.....

 [1]

- (ii) State the change in the quark composition of a carbon-14 nucleus when it emits a β^- particle.

..... [1]

- (iii) Suggest why the β^- particles are emitted with a range of different energies.

.....

 [2]

[Total: 8]

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Data

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Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel	$C = C_1 + C_2 + \dots$
energy of charged capacitor	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
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Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

- 1 (a) A unit may be stated with a prefix that represents a power-of-ten multiple or submultiple.

Complete Table 1.1 to show the name and symbol of each prefix and the corresponding power-of-ten multiple or submultiple.

Table 1.1

prefix	power-of-ten multiple or submultiple
kilo (k)	10^3
tera (T)	
()	10^{-12}

[2]

- (b) In the following list, underline all the units that are SI base units.

ampere

coulomb

metre

newton

[1]

- (c) The potential difference V between the two ends of a uniform metal wire is given by

$$V = \frac{4\rho LI}{\pi d^2}$$

where d is the diameter of the wire,
 I is the current in the wire,
 L is the length of the wire,
 and ρ is the resistivity of the metal.

For a particular wire, the percentage uncertainties in the values of some of the above quantities are listed in Table 1.2.

Table 1.2

quantity	percentage uncertainty
d	$\pm 3.0\%$
I	$\pm 2.0\%$
L	$\pm 2.5\%$
V	$\pm 3.5\%$

The quantities listed in Table 1.2 have values that are used to calculate ρ as $4.1 \times 10^{-7} \Omega \text{ m}$.

For this value of ρ , calculate:

- (i) the percentage uncertainty

percentage uncertainty = ...% [2]

- (ii) the absolute uncertainty.

absolute uncertainty = ... $\Omega \text{ m}$ [1]

[Total: 6]

- 2 A charged oil drop is in a vacuum between two horizontal metal plates. A uniform electric field is produced between the plates by applying a potential difference of 1340V across them, as shown in Fig. 2.1.

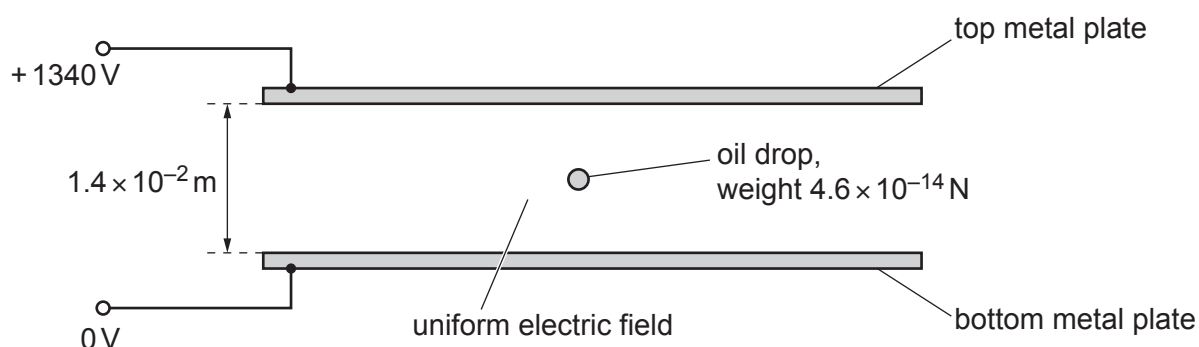


Fig. 2.1

The separation of the plates is $1.4 \times 10^{-2} \text{ m}$.

The oil drop of weight $4.6 \times 10^{-14} \text{ N}$ remains stationary at a point mid-way between the plates.

- (a) (i) Calculate the magnitude of the electric field strength.

electric field strength = ... NC^{-1} [2]

- (ii) Determine the magnitude and the sign of the charge on the oil drop.

magnitude of charge = ... C

sign of charge [3]

- (b) The electric potentials of the plates are instantaneously reversed so that the top plate is at a potential of 0V and the bottom plate is at a potential of +1340V. This change causes the oil drop to start moving downwards.

- (i) Compare the new pattern of the electric field lines between the plates with the original pattern.

.....
 [2]

- (ii) Determine the magnitude of the resultant force acting on the oil drop.

resultant force = ... N [1]

- (iii) Show that the magnitude of the acceleration of the oil drop is 20 m s^{-2} .

[2]

- (iv) Assume that the radius of the oil drop is negligible.

Use the information in **(b)(iii)** to calculate the time taken for the oil drop to move to the bottom metal plate from its initial position mid-way between the plates.

time = ... s [2]

- (c) The oil drop in **(b)** starts to move at time $t = 0$. The distance of the oil drop from the bottom plate is x .

On Fig. 2.2, sketch the variation with time t of distance x for the movement of the drop from its initial position until it hits the surface of the bottom plate. Numerical values of t are not required.

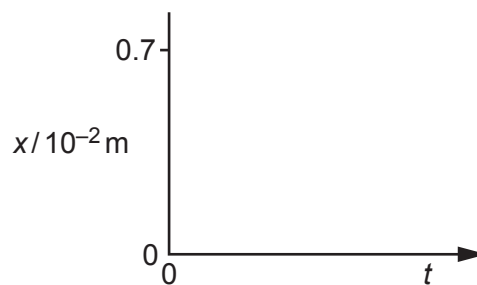


Fig. 2.2

[2]

[Total: 14]

- 3 (a) Define *power*.

.....
 [1]

- (b) A car of mass 1700 kg moves in a straight line along a slope that is at an angle θ to the horizontal, as shown in Fig. 3.1.

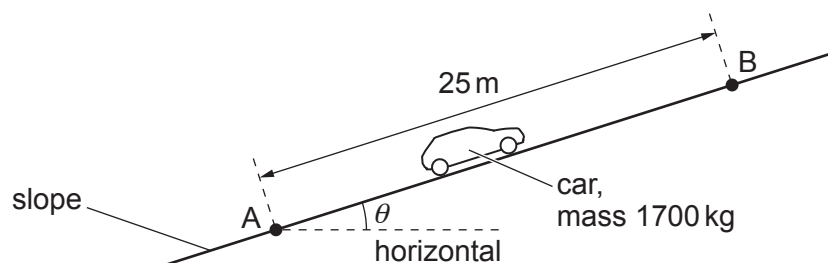


Fig. 3.1 (not to scale)

The car moves at constant velocity for a distance of 25 m from point A to point B.
 Air resistance and friction provide a total resistive force of 440 N that opposes the motion of the car.

For the movement of the car from A to B:

- (i) state the change in the kinetic energy

change in kinetic energy = ... J [1]

- (ii) calculate the work done against the total resistive force.

work done = ... J [1]

- (c) The movement of the car in (b) from A to B causes its gravitational potential energy to increase by $4.8 \times 10^4 \text{ J}$.

Calculate:

- (i) the increase in vertical height h of the car for its movement from A to B

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

- (ii) angle θ .

$$\theta = \dots\dots\dots^\circ \text{ [1]}$$

- (d) The engine of the car in (b) produces an output power of $1.7 \times 10^4 \text{ W}$ to move the car along the slope.

Calculate the time taken for the car to move from A to B.

$$\text{time} = \dots\dots\dots \text{ s [2]}$$

[Total: 8]

- 4 A child sits on the ground next to a remote-controlled toy car. At time $t = 0$, the car begins to move in a straight line directly away from the child. The variation with time t of the velocity of the car along this line is shown in Fig. 4.1.

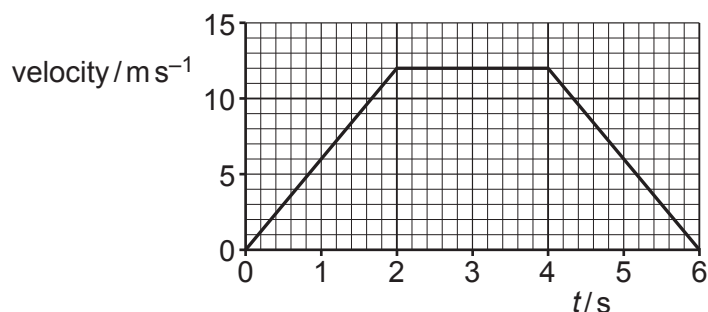


Fig. 4.1

The car's horn continually emits sound of frequency 925 Hz between time $t = 0$ and time $t = 6.0$ s. The speed of the sound in the air is 338 m s^{-1} .

- (a) Describe qualitatively the variation, if any, in the frequency of the sound heard, by the child, that was emitted from the car horn:

- (i) from time $t = 0$ to time $t = 2.0$ s

..... [1]

- (ii) from time $t = 4.0$ s to time $t = 6.0$ s.

..... [1]

- (b) Determine the frequency, to three significant figures, of the sound heard, by the child, that was emitted from the car horn at time $t = 3.0$ s.

frequency = ... Hz [2]

- (c) Determine the time taken for the sound emitted at time $t = 4.0$ s to travel to the child.

time taken = ... s [2]

[Total: 6]

- 5 A tube is initially fully submerged in water. The axis of the tube is kept vertical as the tube is slowly raised out of the water, as shown in Fig. 5.1.

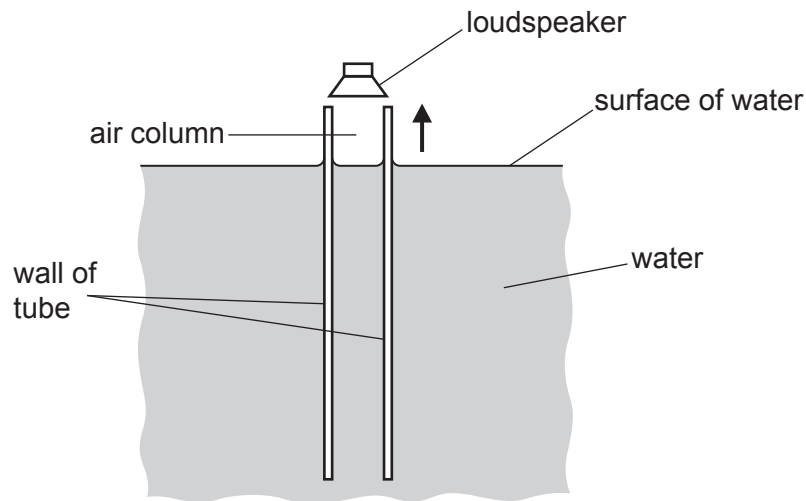


Fig. 5.1

A loudspeaker producing sound of frequency 530 Hz is positioned at the open top end of the tube as it is raised. The water surface inside the tube is always level with the water surface outside the tube. The speed of the sound in the air column in the tube is 340 m s^{-1} .

- (a) Describe a simple way that a student, without requiring any additional equipment, can detect when a stationary wave is formed in the air column as the tube is being raised.

.....
 [1]

- (b) Determine the height of the top end of the tube above the surface of the water when a stationary wave is first produced in the tube. Assume that an antinode is formed level with the top of the tube.

height = ... m [3]

- (c) Determine the distance moved by the tube between the positions at which the first and second stationary waves are formed.

distance = ... m [1]

[Total: 5]

- 6 A cell of electromotive force (e.m.f.) 0.48 V is connected to a metal wire X, as shown in Fig. 6.1.

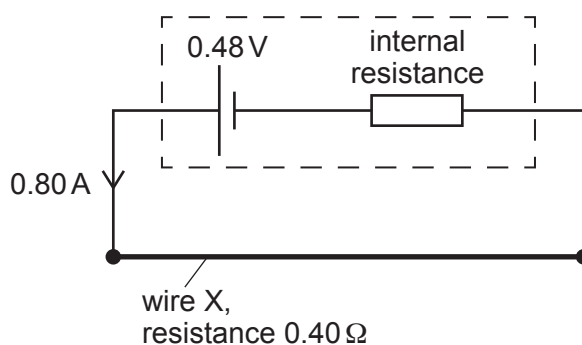


Fig. 6.1

The cell has internal resistance. The current in the cell is 0.80 A .

Wire X has length 3.0 m , cross-sectional area $1.3 \times 10^{-7}\text{ m}^2$ and resistance $0.40\ \Omega$.

- (a) Calculate the charge passing through the cell in a time of 7.5 minutes.

charge = ... C [2]

- (b) Calculate the percentage efficiency with which the cell supplies power to wire X.

efficiency = ... % [3]

- (c) There are 3.2×10^{22} free (conduction) electrons contained in the volume of wire X.

For wire X, calculate:

- (i) the number density n of the free electrons

$$n = \dots\dots\dots \text{m}^{-3} \quad [1]$$

- (ii) the average drift speed of the free electrons.

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

- (d) A wire Y has the same cross-sectional area as wire X and is made of the same metal. Wire Y is longer than wire X.

Wire X in the circuit is now replaced by wire Y. Assume that wire Y has the same temperature as wire X.

State and explain whether the average drift speed of the free electrons in wire Y is greater than, the same as, or less than that in wire X.

.....

.....

.....

.....

.....

..... [3]

[Total: 11]

- 7 A stationary nucleus P of mass 243u decays by emitting an α -particle of mass 4u to form a different nucleus Q, as illustrated in Fig. 7.1.

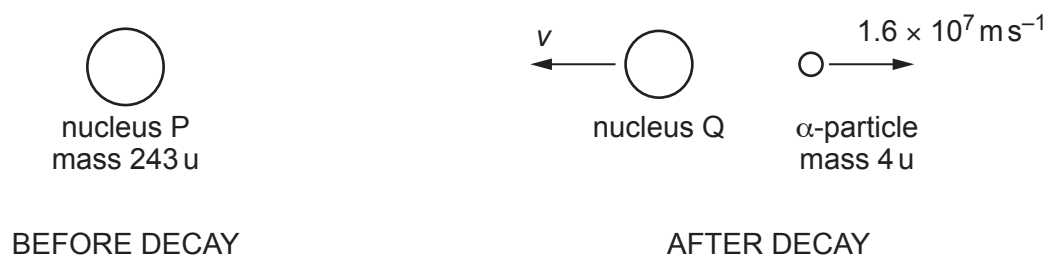


Fig. 7.1

The initial speed of the α -particle is $1.6 \times 10^7 \text{ ms}^{-1}$.

- (a) Use the principle of conservation of momentum to explain why the initial velocities of nucleus Q and the α -particle must be in opposite directions.

.....

 [2]

- (b) Determine the initial speed v of nucleus Q.

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

- (c) Calculate the initial kinetic energy, in MeV, of the α -particle.

kinetic energy = $\dots\dots\dots$ MeV [3]

(d) A graph of number of neutrons N against proton number Z is shown in Fig. 7.2.

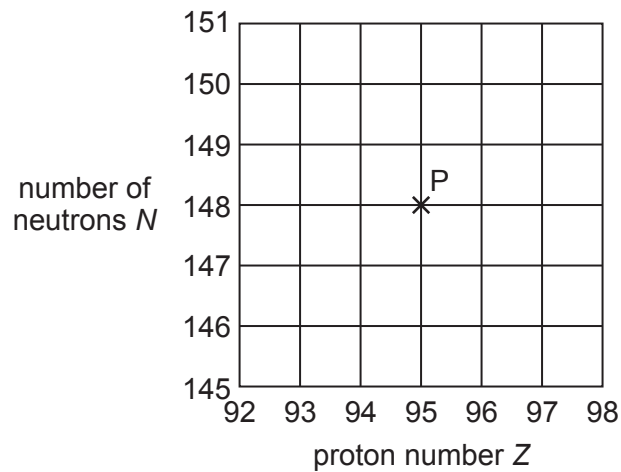


Fig. 7.2

The graph shows a cross that represents nucleus P.

A nucleus R has a nucleon number of 242 and is an isotope of nucleus P.

Nucleus R decays by emitting a β^- particle to form a different nucleus S.

(i) On Fig. 7.2, draw a cross to represent:

1. nucleus R (label this cross R)
2. nucleus S (label this cross S).

[2]

(ii) State the name of the other lepton, in addition to the β^- particle, that is emitted during the decay of nucleus R.

..... [1]

[Total: 10]

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9702/23

October/November 2021

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

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel	$C = C_1 + C_2 + \dots$
energy of charged capacitor	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

- 1 (a) A solid cylinder of weight 24 N is made of material of density 850 kg m^{-3} . The cylinder has a length of 0.18 m, as shown in Fig. 1.1.

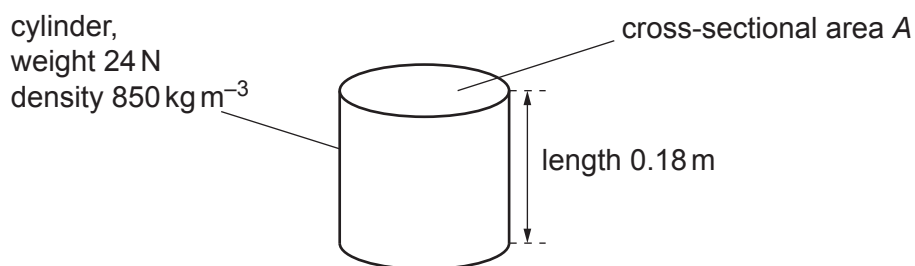


Fig. 1.1

Show that the cross-sectional area A of the cylinder is 0.016 m^2 .

[3]

- (b) The cylinder in (a) is attached by a spring to the bottom of a rigid container of liquid, as shown in Fig. 1.2.

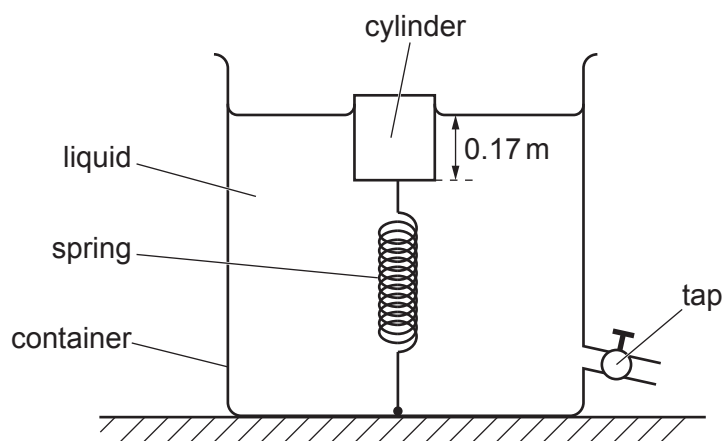


Fig. 1.2 (not to scale)

The cylinder is in equilibrium with its bottom face at a depth of 0.17 m below the surface of the liquid. The tension in the spring is 8.0 N.

- (i) Show that the upthrust acting on the cylinder due to the liquid is 32 N.

[1]

- (ii) Calculate the density of the liquid.

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

- (c) Fig. 1.3 shows the variation of the tension F with the length of the spring in (b).

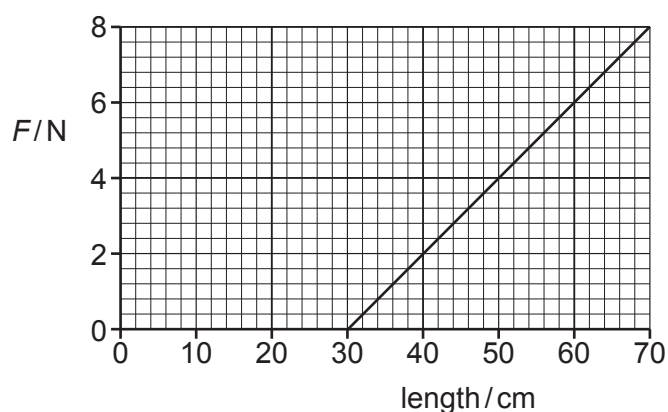


Fig. 1.3

- (i) The tap at the bottom of the container is opened so that a fixed amount of liquid flows out of the container. The cylinder moves downwards so that the tension in the spring changes from 8.0 N to 4.0 N.

Determine the change in the elastic potential energy of the spring.

change in elastic potential energy = ... J [3]

- (ii) More liquid is let out of the container until the upthrust on the cylinder becomes 24 N.

For the upthrust of 24 N, determine the length of the spring.

length = ... cm [1]

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

.....
 [1]

- (b) Use your answer in (a) to show that the SI base units of energy are $\text{kg m}^2 \text{s}^{-2}$.

[1]

- (c) A metal rod is heated at one end so that thermal energy flows to the other end.
 The thermal energy E that flows through the rod in time t is given by

$$E = \frac{cA(T_1 - T_2)t}{L}$$

where A is the cross-sectional area of the rod,
 T_1 and T_2 are the temperatures of the ends of the rod,
 L is the length of the rod,
 and c is a constant.

Determine the SI base units of c .

SI base units [3]

[Total: 5]

- 3 (a) Define *velocity*.

..... [1]

- (b) A remote-controlled toy aircraft is flying horizontally in a wind. Fig. 3.1 shows the velocity vectors, to scale, of the wind and of the aircraft in still air.

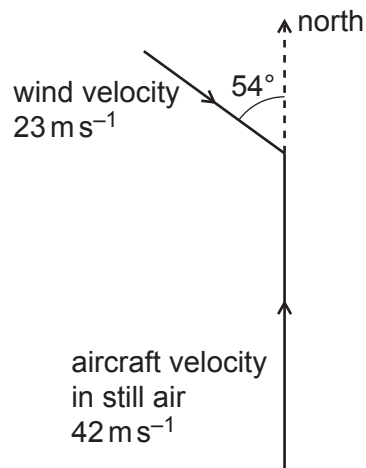


Fig. 3.1

The velocity of the aircraft in still air is 42 m s^{-1} to the north. The velocity of the wind is 23 m s^{-1} in a direction of 54° east of south.

Determine the magnitude of the resultant velocity of the aircraft.

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

- (c) The engine of the aircraft in (b) stops. The aircraft then glides towards the ground with a constant velocity at an angle θ to the horizontal, as illustrated in Fig. 3.2.

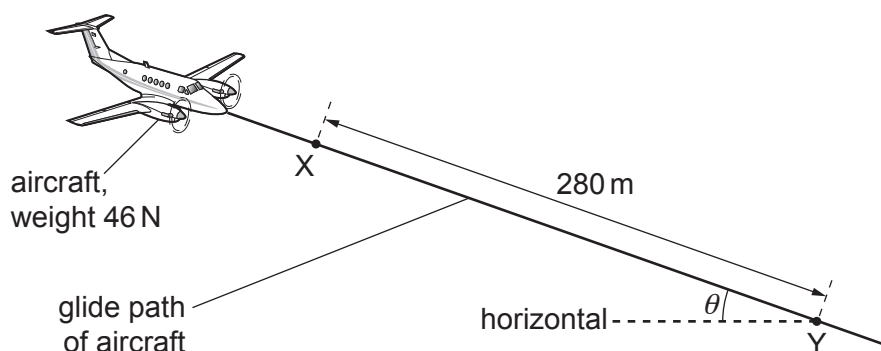


Fig. 3.2 (not to scale)

The aircraft has a weight of 46 N and travels a distance of 280 m from point X to point Y. The change in gravitational potential energy of the aircraft for its movement from X to Y is 6100 J.

Assume that there is now no wind.

- (i) Calculate angle θ .

$$\theta = \dots\dots\dots^\circ \quad [3]$$

- (ii) Calculate the magnitude of the force acting on the aircraft due to air resistance.

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

- (d) The aircraft in (c) travels from X to Y in a time of 14 s. Fig. 3.3 shows that, as the aircraft travels from X to Y, it moves directly towards an observer who is standing on the ground.

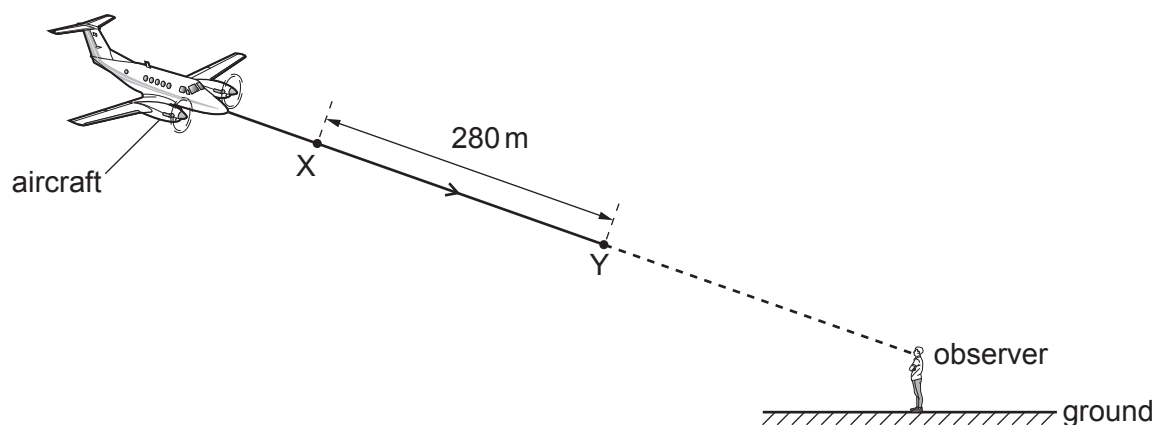


Fig. 3.3 (not to scale)

The aircraft emits sound as it travels from X to Y. The observer hears sound of frequency 450 Hz. The speed of the sound in the air is 340 m s^{-1} .

Calculate the frequency of the sound that is emitted by the aircraft.

frequency = ... Hz [3]

[Total: 11]

- 4 An α -particle moves in a straight line through a vacuum with a constant speed of $4.1 \times 10^6 \text{ m s}^{-1}$. The α -particle enters a uniform electric field at point A, as shown in Fig. 4.1.

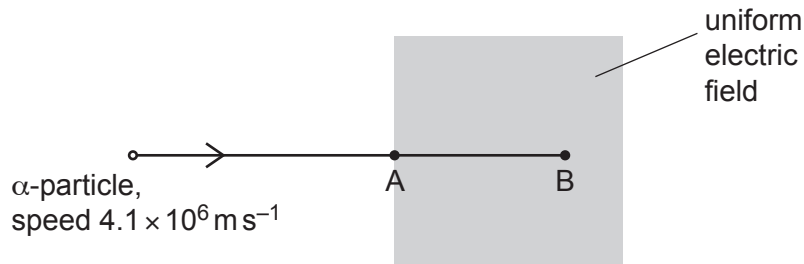


Fig. 4.1

The α -particle continues to move in the same straight line until it is brought to rest at point B by the electric field. The deceleration of the α -particle by the electric field is $2.7 \times 10^{14} \text{ m s}^{-2}$.

- (a) State the direction of the electric field.

..... [1]

- (b) Calculate the distance AB.

distance = ... m [2]

- (c) Calculate the electric field strength.

electric field strength = ... V m^{-1} [3]

- (d) The α -particle is at point A at time $t = 0$.

On Fig. 4.2, sketch the variation with time t of the momentum of the α -particle as it travels from point A to point B. Numerical values are not required.

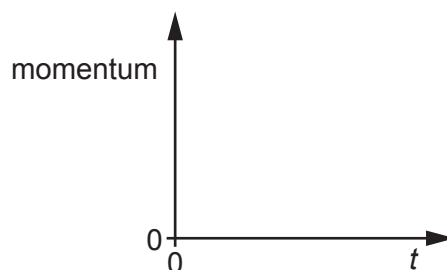


Fig. 4.2

[1]

- (e) State the name of the quantity that is represented by the gradient of the graph in (d).

..... [1]

- (f) A β^- particle now enters the electric field along the same initial path as the α -particle and with the same initial speed of $4.1 \times 10^6 \text{ ms}^{-1}$.

- (i) Calculate the kinetic energy, in J, of the β^- particle at point A.

kinetic energy = ... J [3]

- (ii) State and explain the differences between the electric force on the β^- particle in the electric field and the electric force on the α -particle in the electric field.

.....

 [3]

- (iii) The β^- particle is produced by the decay of a nucleus. State the name of another lepton that is produced at the same time as the β^- particle.

..... [1]

- 5 (a) For a progressive wave on a stretched string, state what is meant by *amplitude*.

.....
 [1]

- (b) Light from a laser has a wavelength of 690 nm in a vacuum.

Calculate the period of the light wave.

period = ... s [3]

- (c) A two-source interference experiment uses the arrangement shown in Fig. 5.1.

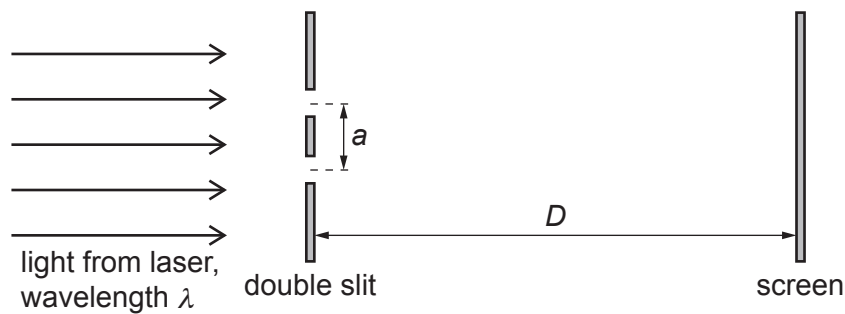


Fig. 5.1 (not to scale)

Light from a laser is incident normally on a double slit. A screen is parallel to the double slit.

Interference fringes are seen on the screen at distance D from the double slit. The separation of the centres of the slits is a . The light has wavelength λ .

The separation x of the centres of adjacent bright fringes is measured for different values of distance D .

The variation with D of x is shown in Fig. 5.2.

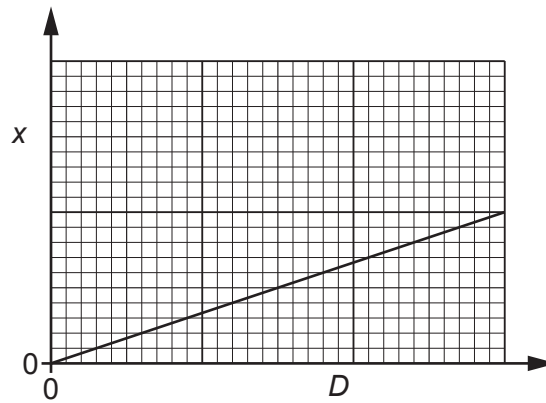


Fig. 5.2

The gradient of the graph is G .

- (i) Determine an expression, in terms of G and λ , for the separation a of the slits.

$$a = \dots\dots\dots [2]$$

- (ii) The experiment is repeated with slits of separation $2a$. The wavelength of the light is unchanged.

On Fig. 5.2, sketch a graph to show the results of this experiment. [2]

[Total: 8]

- 6 (a) A resistance wire of uniform cross-sectional area $3.3 \times 10^{-7} \text{ m}^2$ and length 2.0 m is made of metal of resistivity $5.0 \times 10^{-7} \Omega \text{ m}$.

Show that the resistance of the wire is 3.0Ω .

[2]

- (b) The ends of the resistance wire in (a) are connected to the terminals X and Y in the circuit shown in Fig. 6.1.

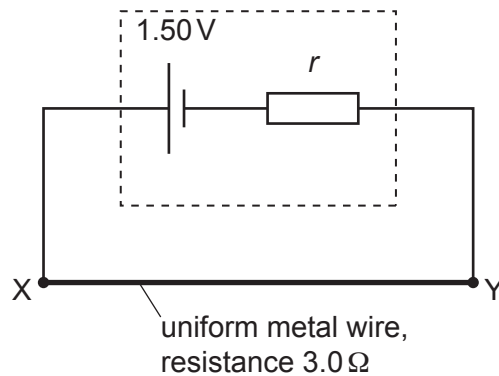


Fig. 6.1

The cell has an electromotive force (e.m.f.) of 1.50 V and internal resistance r . The potential difference between X and Y is 1.20 V .

Calculate:

- (i) the current in the circuit

current = ... A [1]

- (ii) the internal resistance r .

$r =$ Ω [2]

- (c) A galvanometer and a cell of e.m.f. E with negligible internal resistance are connected to the circuit in (b), as shown in Fig. 6.2.

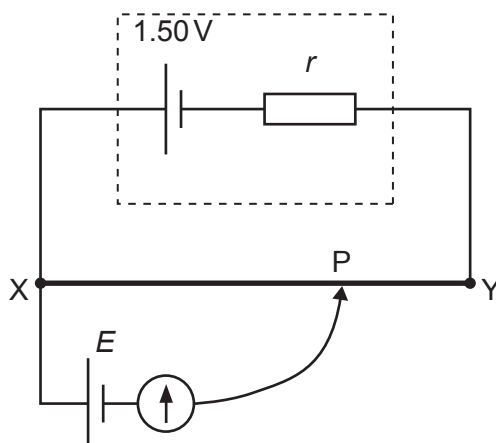


Fig. 6.2

The resistance wire between X and Y has a length of 2.0 m. The galvanometer has a reading of zero when the connection P is adjusted so that the length XP is 1.4 m.

Determine the e.m.f. E of the cell.

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

- (d) The circuit in Fig. 6.2 is modified by replacing the original resistance wire with a second resistance wire. The second wire has the same length as the original wire and is made of the same metal.

The second wire has a smaller cross-sectional area than the original wire.

Connection P is adjusted on the second wire so that the galvanometer has a reading of zero.

State and explain whether length XP for the second wire is shorter than, longer than or the same as length XP for the original wire when the galvanometer reading is zero.

.....

.....

.....

.....

..... [3]

[Total:10]

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