

CANDIDATE
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PHYSICS

9702/21

Paper 2 AS Structured Questions

October/November 2014

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.

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

This document consists of **15** printed pages and **1** blank page.

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 constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
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.,

$$v = v_0 \cos \omega t$$

$$v = \pm \omega \sqrt{(x_0^2 - x^2)}$$

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,

$$W = \frac{1}{2} QV$$

resistors in series,

$$R = R_1 + R_2 + \dots$$

resistors in parallel,

$$1/R = 1/R_1 + 1/R_2 + \dots$$

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) Mass, length and time are SI base quantities.
State two other base quantities.

1.

2.

[2]

- (b) A mass m is placed on the end of a spring that is hanging vertically, as shown in Fig. 1.1.

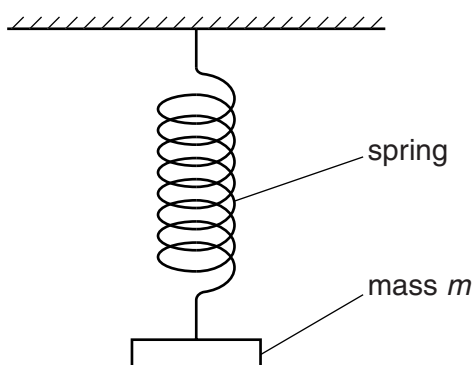


Fig. 1.1

The mass is made to oscillate vertically. The time period of the oscillations of the mass is T .

The period T is given by

$$T = C \sqrt{\frac{m}{k}}$$

where C is a constant and k is the spring constant.

Show that C has no units.

[3]

- 2 (a) Define *pressure*.

..... [1]

- (b) A cylinder is placed on a horizontal surface, as shown in Fig. 2.1.

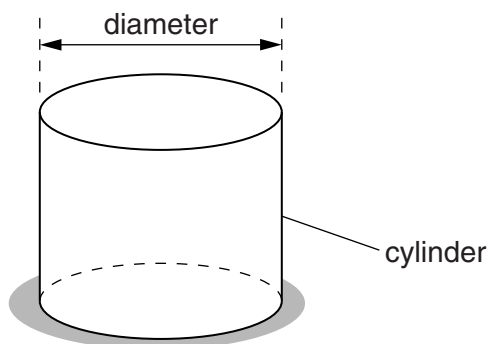


Fig. 2.1

The following measurements were made on the cylinder:

mass = 5.09 ± 0.01 kg
 diameter = 9.4 ± 0.1 cm.

- (i) Calculate the pressure produced by the cylinder on the surface.

pressure = ... Pa [3]

- (ii) Calculate the actual uncertainty in the pressure.

actual uncertainty = ... Pa [3]

- (iii) State the pressure, with its actual uncertainty.

pressure = ... $\pm$ Pa [1]

- 3 The resistance R of a uniform metal wire is measured for different lengths l of the wire. The variation with l of R is shown in Fig. 3.1.

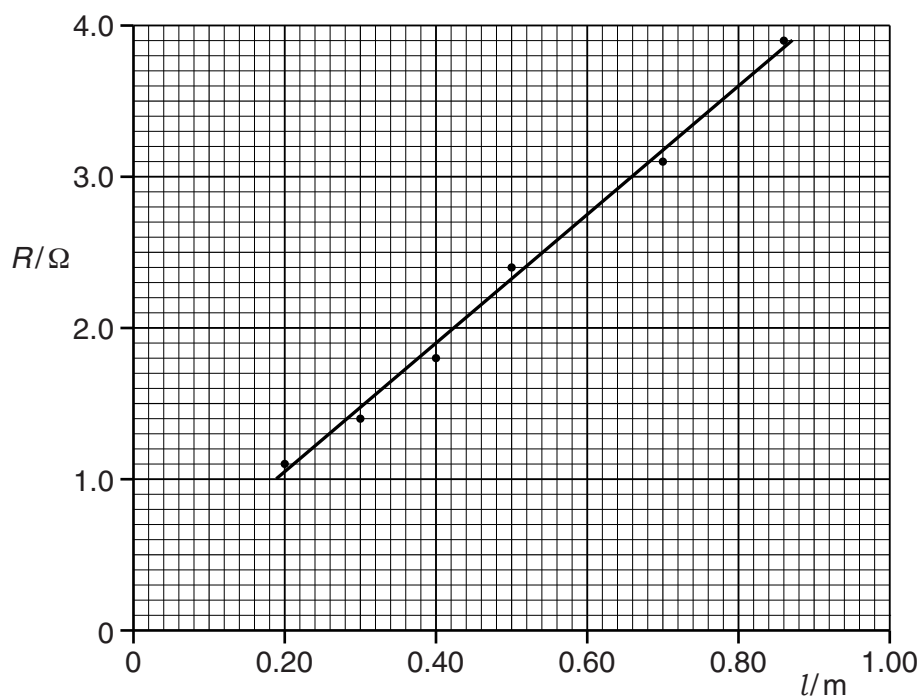


Fig. 3.1

- (a) The points shown in Fig. 3.1 do not lie on the best-fit line. Suggest a reason for this.

.....
 [1]

- (b) Determine the gradient of the line shown in Fig. 3.1.

gradient = ... [2]

- (c) The cross-sectional area of the wire is 0.12 mm^2 .

Use your answer in (b) to determine the resistivity of the metal of the wire.

resistivity = ... $\Omega \text{ m}$ [3]

- (d) The resistance R of different wires is measured. The wires are of the same metal and same length but have different cross-sectional areas A .

On Fig. 3.2, sketch a graph to show the variation with A of R .



Fig. 3.2

[2]

- 4 A trolley moves down a slope, as shown in Fig. 4.1.

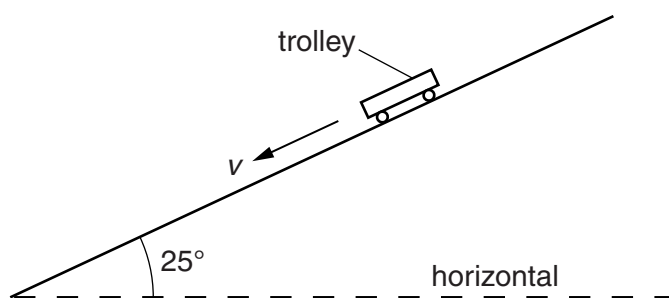


Fig. 4.1

The slope makes an angle of 25° with the horizontal. A constant resistive force F_R acts up the slope on the trolley.

At time $t = 0$, the trolley has velocity $v = 0.50 \text{ m s}^{-1}$ down the slope.

At time $t = 4.0 \text{ s}$, $v = 12 \text{ m s}^{-1}$ down the slope.

- (a) (i) Show that the acceleration of the trolley down the slope is approximately 3 m s^{-2} .

[2]

- (ii) Calculate the distance x moved by the trolley down the slope from time $t = 0$ to $t = 4.0 \text{ s}$.

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

- (iii) On Fig. 4.2, sketch the variation with time t of distance x moved by the trolley.

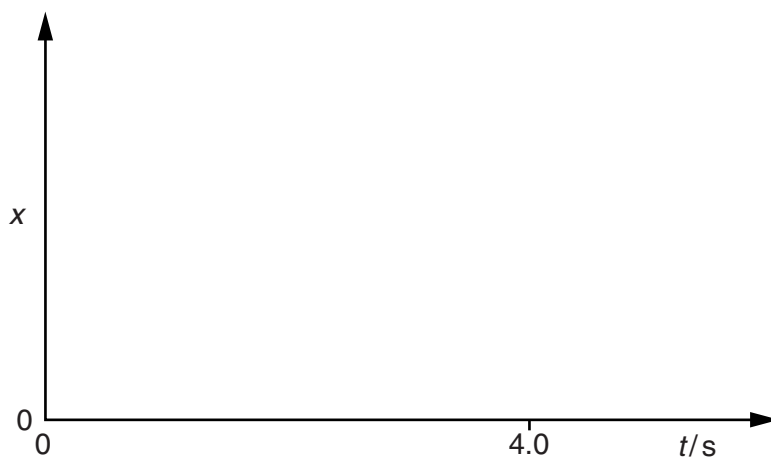


Fig. 4.2

[2]

(b) The mass of the trolley is 2.0 kg.

(i) Show that the component of the weight of the trolley down the slope is 8.3 N.

[1]

(ii) Calculate the resistive force F_R .

$F_R = \dots\dots\dots$ N [2]

- 5 A motor is used to move bricks vertically upwards, as shown in Fig. 5.1.

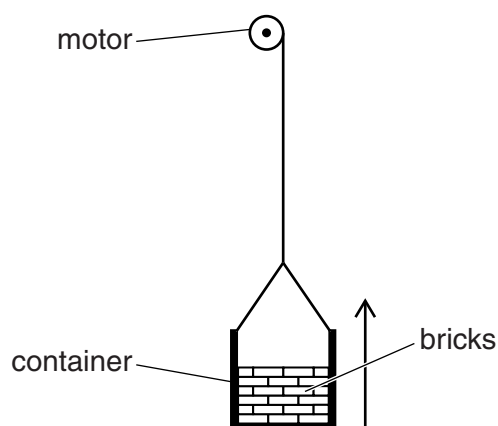


Fig. 5.1

The bricks start from rest and accelerate for 2.0 s. The bricks then travel at a constant speed of 0.64 ms^{-1} for 25 s. Finally the bricks are brought to rest in a further 3.0 s.

The total mass of the bricks is 25 kg.

- (a)** Determine the change in kinetic energy of the bricks

- (i)** in the first 2.0 s,

change in kinetic energy = ... J [2]

- (ii)** in the next 25 s,

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

- (iii)** in the final 3.0 s.

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

- (b) The bricks are in a container. The weight of the container and bricks is 350 N.

Calculate, for the lifting of the bricks and container when travelling at constant speed,

- (i) the gain in potential energy,

energy gain = ... J [3]

- (ii) the power required.

power = ... W [2]

- 6 Distinguish between *melting* and *evaporation*.

melting:

.....

.....

evaporation:

.....

.....

[4]

- 7 (a) A cell with internal resistance supplies a current. Explain why the terminal potential difference (p.d.) is less than the electromotive force (e.m.f.) of the cell.

.....

.....

..... [1]

- (b) A battery of e.m.f. 12 V and internal resistance $0.50\ \Omega$ is connected to a variable resistor X and a resistor Y of constant resistance, as shown in Fig. 7.1.

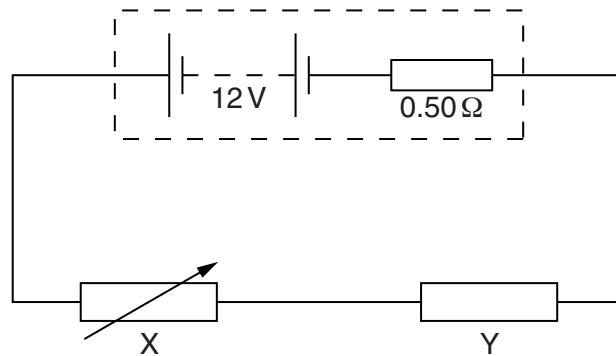


Fig. 7.1

The resistance R of X is increased from $2.0\ \Omega$ to $16\ \Omega$. The variation with R of the current I in the circuit is shown in Fig. 7.2.

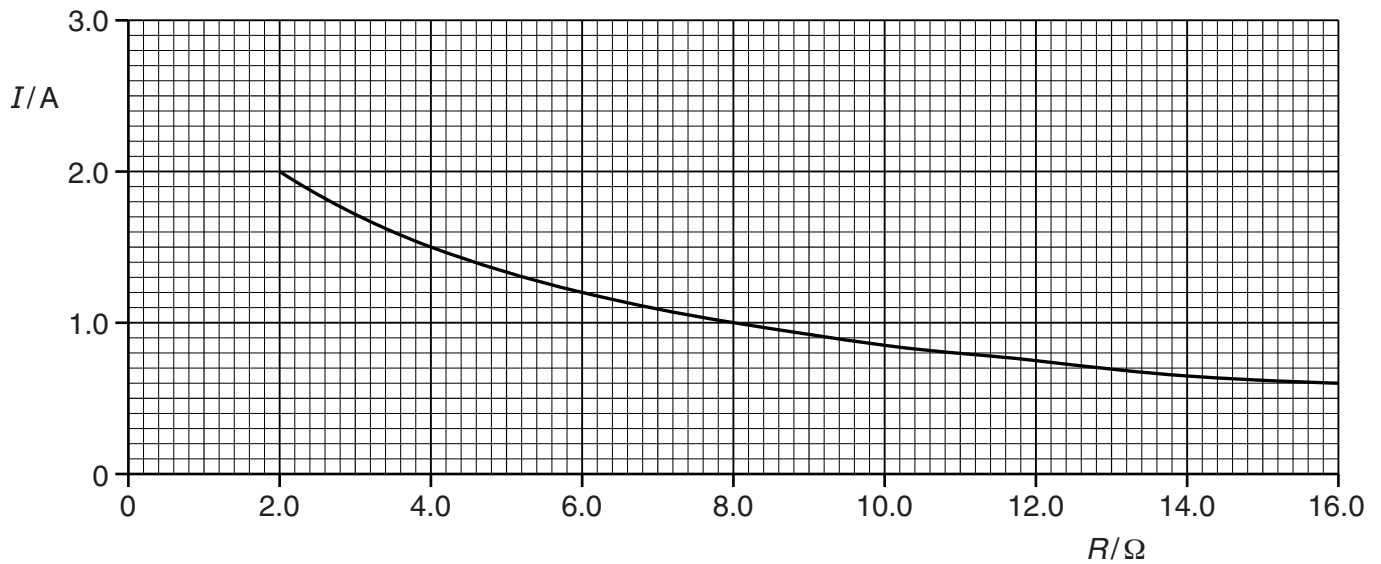


Fig. 7.2

Calculate, for $I = 1.2\text{ A}$,

(i) the p.d. across X,

p.d. = ... V [2]

(ii) the resistance of Y,

resistance = ... Ω [3]

(iii) the power dissipated in the battery.

power = ... W [2]

(c) Use Fig. 7.2 to explain the variation in the terminal p.d. of the battery as the resistance R of X is increased.

.....
 [1]

- 8 (a) Explain how stationary waves are formed.

.....

 [2]

- (b) The arrangement of apparatus used to determine the wavelength of a sound wave is shown in Fig. 8.1.

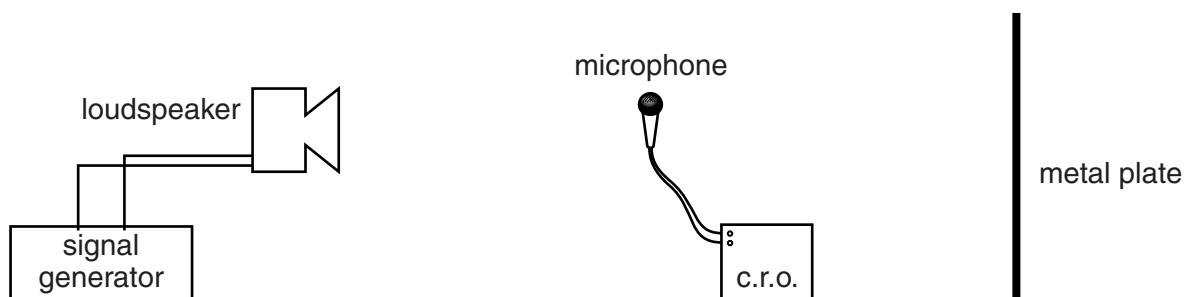


Fig. 8.1

The loudspeaker emits sound of one frequency. The microphone is connected to a cathode-ray oscilloscope (c.r.o.).

The waveform obtained on the c.r.o. for one position of the microphone is shown in Fig. 8.2.

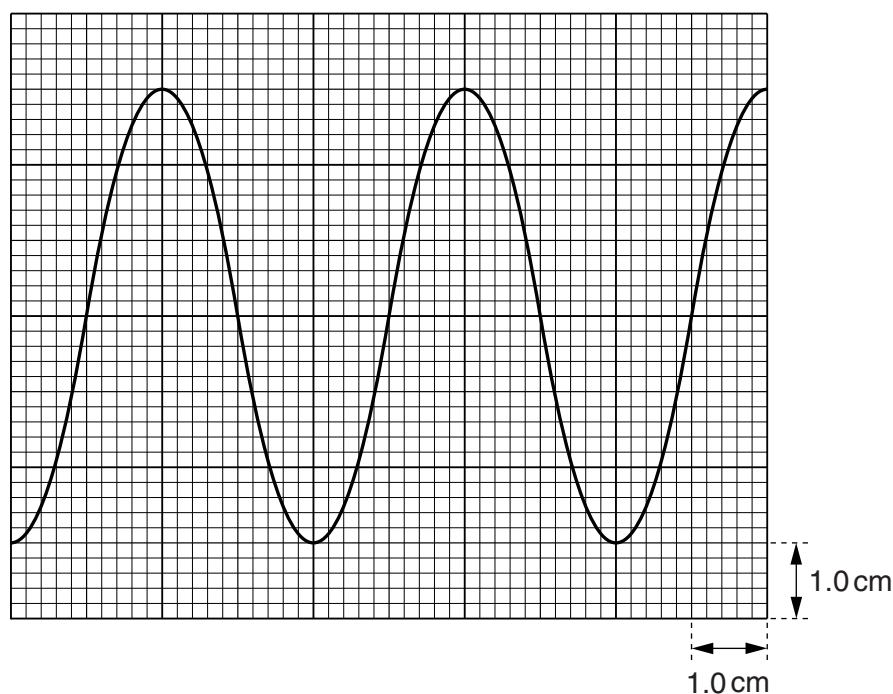


Fig. 8.2

The time-base setting of the c.r.o. is 0.20 ms cm^{-1} .

- (i) Use Fig. 8.2 to show that the frequency of the sound is approximately 1300 Hz.

[2]

- (ii) Explain how the apparatus is used to determine the wavelength of the sound.

.....

 [2]

- (iii) The wavelength of the sound wave is 0.26 m. Calculate the speed of sound in this experiment.

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

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capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \dots$
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energy of charged capacitor,	$W = \frac{1}{2} QV$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
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) The Young modulus of the metal of a wire is 1.8×10^{11} Pa. The wire is extended and the strain produced is 8.2×10^{-4} .
Calculate the stress in GPa.

stress = ...GPa [2]

- (b) An electromagnetic wave has frequency 12THz.

- (i) Calculate the wavelength in μm .

wavelength = ... μm [2]

- (ii) State the name of the region of the electromagnetic spectrum for this frequency.

.....[1]

- (c) An object B is on a horizontal surface. Two forces act on B in this horizontal plane. A vector diagram for these forces is shown to scale in Fig. 1.1.

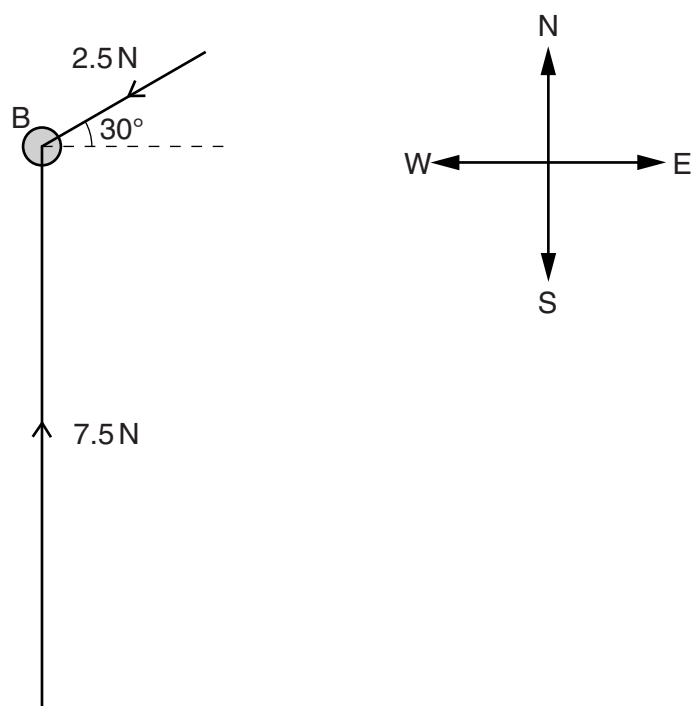


Fig. 1.1

A force of 7.5 N towards north and a force of 2.5 N from 30° north of east act on B.
The mass of B is 750 g.

- (i) On Fig. 1.1, draw an arrow to show the approximate direction of the resultant of these two forces. [1]

- (ii) 1. Show that the magnitude of the resultant force on B is 6.6 N.

[1]

2. Calculate the magnitude of the acceleration of B produced by this resultant force.

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

- (iii) Determine the angle between the direction of the acceleration and the direction of the 7.5 N force.

angle = ... ° [1]

- 2 A ball is thrown from A to B as shown in Fig. 2.1.

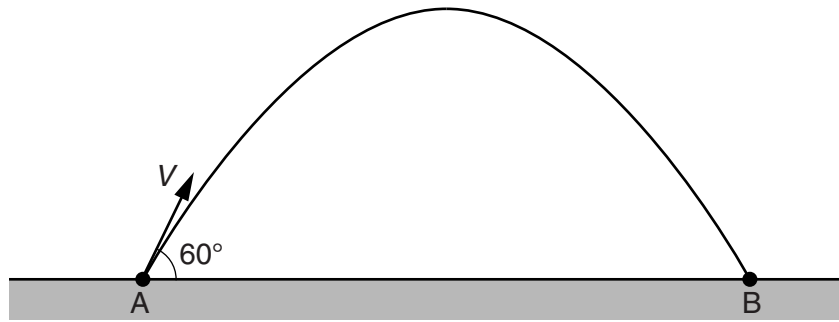


Fig. 2.1

The ball is thrown with an initial velocity V at 60° to the horizontal.

The variation with time t of the vertical component V_v of the velocity of the ball from $t = 0$ to $t = 0.60\text{ s}$ is shown in Fig. 2.2.

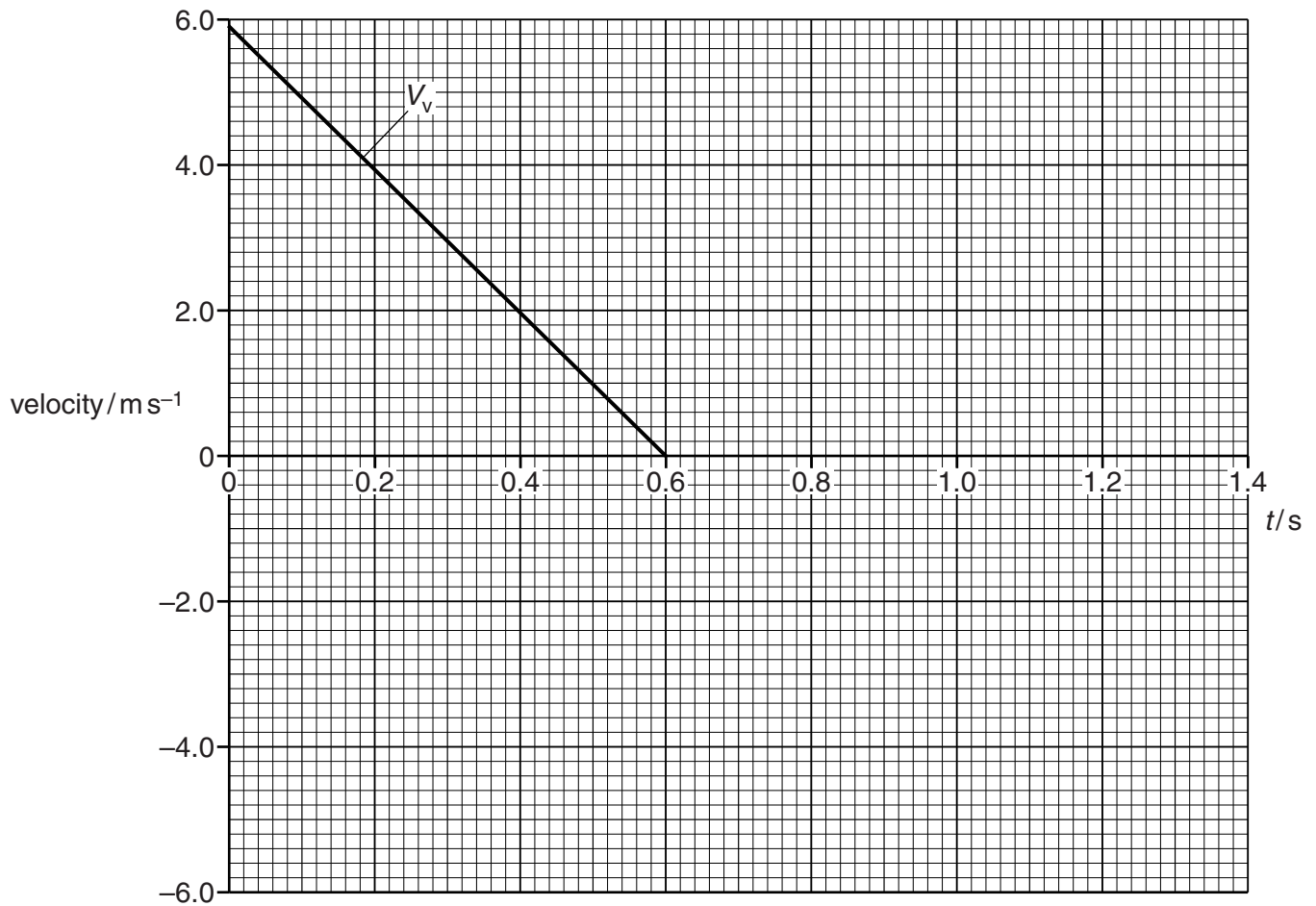


Fig. 2.2

Assume air resistance is negligible.

(a) (i) Complete Fig. 2.2 for the time until the ball reaches B. [2]

(ii) Calculate the maximum height reached by the ball.

height = ...m [2]

(iii) Calculate the horizontal component V_h of the velocity of the ball at time $t = 0$.

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

(iv) On Fig. 2.2, sketch the variation with t of V_h . **Label** this sketch V_h . [1]

(b) The ball has mass 0.65 kg.
Calculate, for the ball,

(i) the maximum kinetic energy,

maximum kinetic energy = ...J [3]

(ii) the maximum potential energy above the ground.

maximum potential energy = ...J [2]

- 3 (a) Define *electric field strength*.

.....
[1]

- (b) A sphere S has radius $1.2 \times 10^{-6} \text{ m}$ and density 930 kg m^{-3} .

Show that the weight of S is $6.6 \times 10^{-14} \text{ N}$.

[2]

- (c) Two horizontal metal plates are 14 mm apart in a vacuum. A potential difference (p.d.) of 1.9 kV is applied across the plates, as shown in Fig. 3.1.

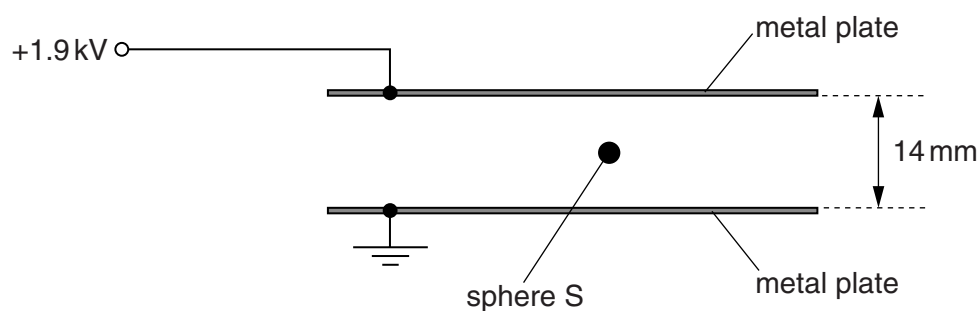


Fig. 3.1

A uniform electric field is produced between the plates.

The sphere S in (b) is charged and is held stationary between the plates by the electric field.

- (i) Calculate the electric field strength between the plates.

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

- (ii) Calculate the magnitude of the charge on S.

charge = ... C [2]

- (iii) The magnitude of the p.d. applied to the plates is increased.
Explain why S accelerates towards the top plate.

.....
.....[2]

4 (a) Compare the molecular motion of a liquid with

(i) a solid,

.....
[2]

(ii) a gas.

.....
[1]

(b) (i) A ductile material in the form of a wire is stretched up to its breaking point. On Fig. 4.1, sketch the variation with extension x of the stretching force F .

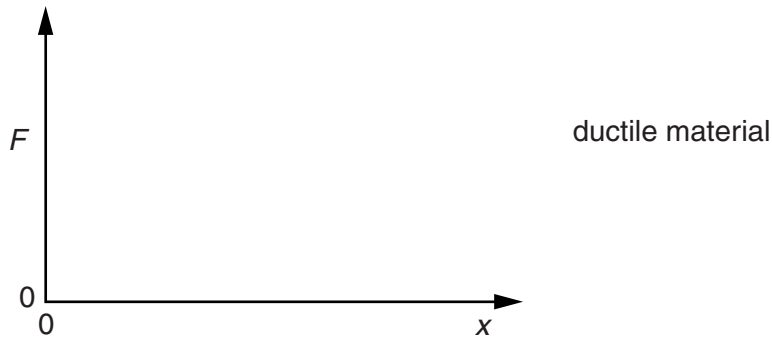


Fig. 4.1

[1]

(ii) On Fig. 4.2, sketch the variation with extension x of the stretching force F for a brittle material up to its breaking point.

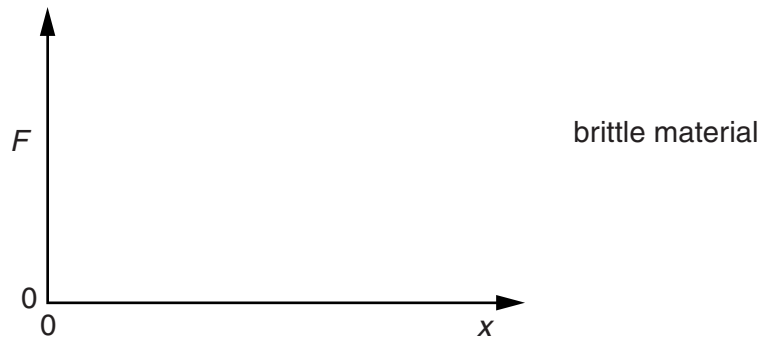


Fig. 4.2

[1]

(c) Describe a similarity and a difference between ductile and brittle materials.

similarity:

difference:

[2]

- 5 A battery of electromotive force (e.m.f.) 12V and internal resistance r is connected in series to two resistors, each of constant resistance X , as shown in Fig. 5.1.

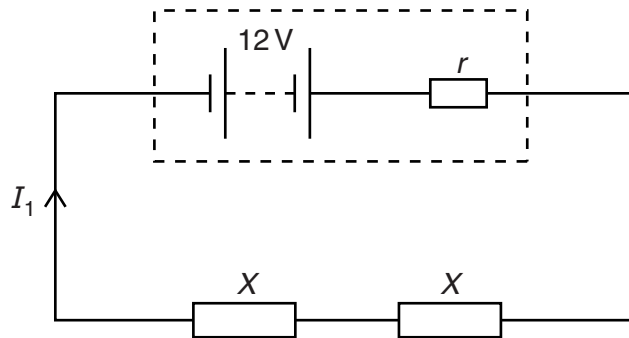


Fig. 5.1

The current I_1 supplied by the battery is 1.2 A.

The same battery is now connected to the same two resistors in parallel, as shown in Fig. 5.2.

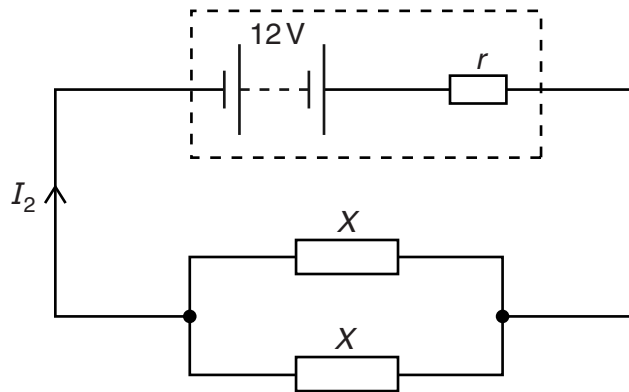


Fig. 5.2

The current I_2 supplied by the battery is 3.0 A.

- (a) (i) Show that the combined resistance of the two resistors, each of resistance X , is four times greater in Fig. 5.1 than in Fig. 5.2.

[2]

- (ii) Explain why I_2 is not four times greater than I_1 .

.....

[2]

(iii) Using Kirchhoff's second law, state equations, in terms of e.m.f., current, X and r , for

1. the circuit of Fig. 5.1,

.....

2. the circuit of Fig. 5.2.

.....

[2]

(iv) Use the equations in (iii) to calculate the resistance X .

$X = \dots\dots\dots \Omega$ [1]

(b) Calculate the ratio

$$\frac{\text{power transformed in one resistor of resistance } X \text{ in Fig. 5.1}}{\text{power transformed in one resistor of resistance } X \text{ in Fig. 5.2}}$$

ratio = ... [2]

(c) The resistors in Fig. 5.1 and Fig. 5.2 are replaced by identical 12V filament lamps.

Explain why the resistance of each lamp, when connected in series, is not the same as the resistance of each lamp when connected in parallel.

.....

.....

.....

..... [2]

- 6 (a) State one difference and one similarity between longitudinal and transverse waves.

difference:

.....

similarity:

.....

[2]

- (b) A laser is placed in front of two slits as shown in Fig. 6.1.

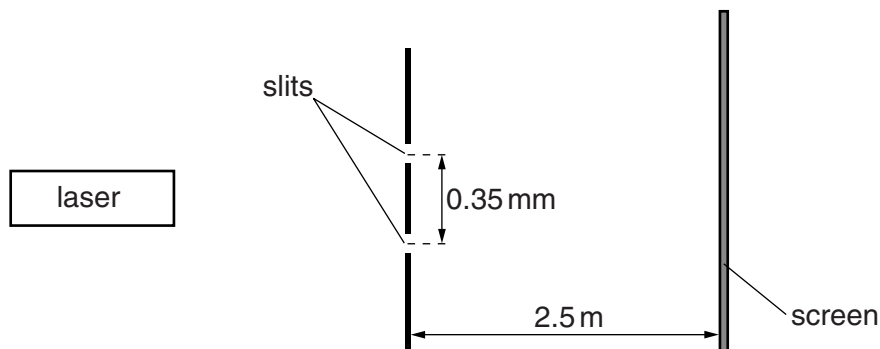


Fig. 6.1 (not to scale)

The laser emits light of wavelength 6.3×10^{-7} m.

The distance from the slits to the screen is 2.5 m. The separation of the slits is 0.35 mm.

An interference pattern of maxima and minima is observed on the screen.

- (i) Explain why an interference pattern is observed on the screen.

.....

.....

.....

.....[2]

- (ii) Calculate the distance between adjacent maxima.

distance = ...m [2]

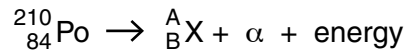
- (c) State and explain the effect, if any, on the distance between adjacent maxima when the laser is replaced by another laser emitting ultra-violet radiation.

.....

.....[1]

- 7 In the decay of a nucleus of $^{210}_{84}\text{Po}$, an α -particle is emitted with energy 5.3 MeV.

The emission is represented by the nuclear equation



- (a) (i) On Fig. 7.1, complete the number and name of the particle, or particles, represented by A and B in the nuclear equation.

	number	name of particle or particles
A		
B		

Fig. 7.1

[1]

- (ii) State the form of energy given to the α -particle in the decay of $^{210}_{84}\text{Po}$.

.....[1]

- (b) A sample of polonium $^{210}_{84}\text{Po}$ emits 7.1×10^{18} α -particles in one day.

Calculate the mean power output from the energy of the α -particles.

power = ... W [2]

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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 constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
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.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
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,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
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) The kilogram, metre and second are SI base units.

State two other base units.

1.

2.

[2]

- (b) Determine the SI base units of

(i) stress,

SI base units[2]

(ii) the Young modulus.

SI base units[1]

- 2 A microphone detects a musical note of frequency f . The microphone is connected to a cathode-ray oscilloscope (c.r.o.). The signal from the microphone is observed on the c.r.o. as illustrated in Fig. 2.1.

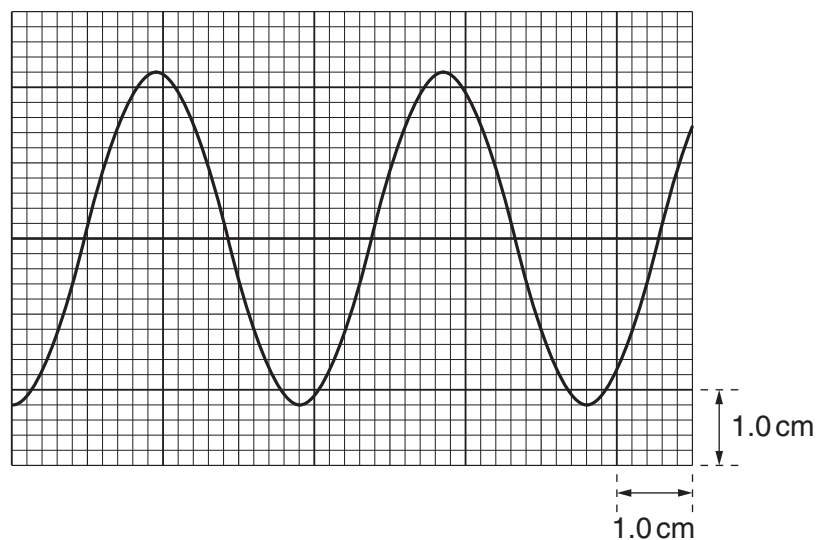


Fig. 2.1

The time-base setting of the c.r.o. is 0.50 ms cm^{-1} . The Y-plate setting is 2.5 mV cm^{-1} .

- (a) Use Fig. 2.1 to determine

- (i) the amplitude of the signal,

amplitude = ... mV [2]

- (ii) the frequency f ,

f = ... Hz [3]

- (iii) the actual uncertainty in f caused by reading the scale on the c.r.o.

actual uncertainty = ... Hz [2]

- (b) State f with its actual uncertainty.

f = ... $\pm$ Hz [1]

- 3 (a) Force is a vector quantity. State three other vector quantities.

1.

2.

3.

[2]

- (b) Three coplanar forces X , Y and Z act on an object, as shown in Fig. 3.1.

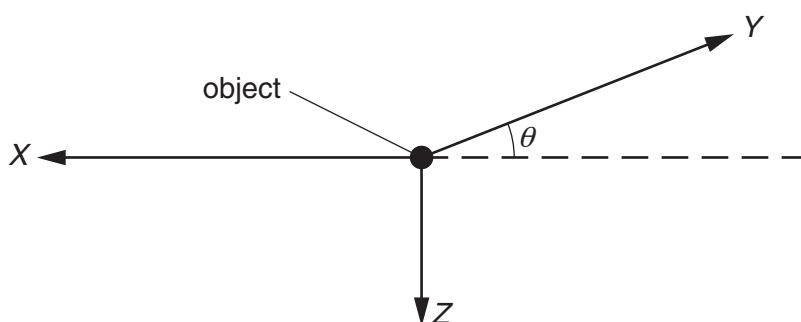


Fig. 3.1

The force Z is vertical and X is horizontal. The force Y is at an angle θ to the horizontal. The force Z is kept constant at 70 N.

In an experiment, the magnitude of force X is varied. The magnitude and direction of force Y are adjusted so that the object remains in equilibrium.

Fig. 3.2 shows the variation of the magnitude of force Y with the magnitude of force X .

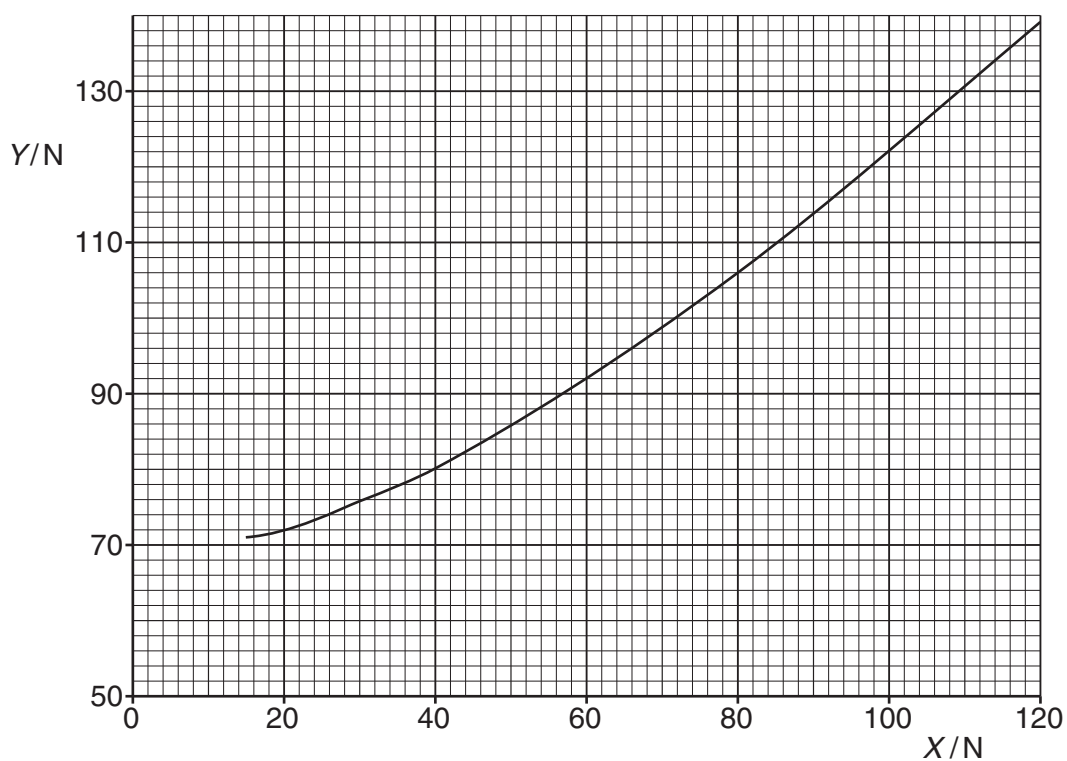


Fig. 3.2

- (i) Use Fig. 3.2 to estimate the magnitude of Y for $X = 0$.

$Y = \dots\dots\dots$ N [1]

- (ii) State and explain the value of θ for $X = 0$.

.....

 [2]

- (iii) The magnitude of X is increased to 160 N. Use resolution of forces to calculate the value of

1. angle θ ,

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

2. the magnitude of force Y .

$Y = \dots\dots\dots$ N [2]

- (c) The angle θ decreases as X increases. Explain why the object cannot be in equilibrium for $\theta = 0$.

.....

 [1]

- 4 (a) State the principle of conservation of momentum.

.....

.....

.....[2]

- (b) A ball X and a ball Y are travelling along the same straight line in the same direction, as shown in Fig. 4.1.



Fig. 4.1

Ball X has mass 400 g and horizontal velocity 0.65 m s^{-1} .
 Ball Y has mass 600 g and horizontal velocity 0.45 m s^{-1} .

Ball X catches up and collides with ball Y. After the collision, X has horizontal velocity 0.41 m s^{-1} and Y has horizontal velocity v , as shown in Fig. 4.2.

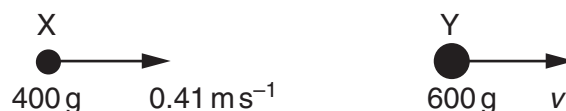


Fig. 4.2

Calculate

- (i) the total initial momentum of the two balls,

momentum = ... Ns [3]

- (ii) the velocity v ,

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

- (iii) the total initial kinetic energy of the two balls.

kinetic energy = ... J [3]

- (c) Explain how you would check whether the collision is elastic.

.....
[1]

- (d) Use Newton's third law to explain why, during the collision, the change in momentum of X is equal and opposite to the change in momentum of Y.

.....

[2]

- 5 Distinguish between *evaporation* and *boiling*.

evaporation:

.....

.....

boiling:

.....

.....

[4]

- 6 (a) A wire has length 100cm and diameter 0.38mm. The metal of the wire has resistivity $4.5 \times 10^{-7} \Omega \text{m}$.

Show that the resistance of the wire is 4.0Ω .

[3]

- (b) The ends B and D of the wire in (a) are connected to a cell X, as shown in Fig. 6.1.

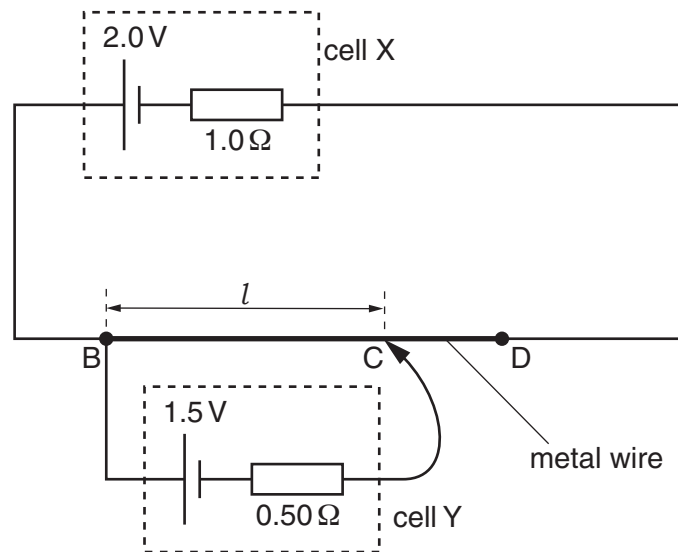


Fig. 6.1

The cell X has electromotive force (e.m.f.) 2.0V and internal resistance 1.0Ω .

A cell Y of e.m.f. 1.5V and internal resistance 0.50Ω is connected to the wire at points B and C, as shown in Fig. 6.1.

The point C is distance l from point B. The current in cell Y is zero.

Calculate

- (i) the current in cell X,

current = ... A [2]

(ii) the potential difference (p.d.) across the wire BD,

p.d. = ... V [1]

(iii) the distance l .

l = ... cm [2]

(c) The connection at C is moved so that l is increased. Explain why the e.m.f. of cell Y is less than its terminal p.d.

.....

[2]

- 7 (a) (i) Explain what is meant by a *progressive transverse wave*.

progressive:

.....

transverse:

.....

[2]

- (ii) Define frequency.

.....

.....[1]

- (b) The variation with distance x of displacement y for a transverse wave is shown in Fig. 7.1.

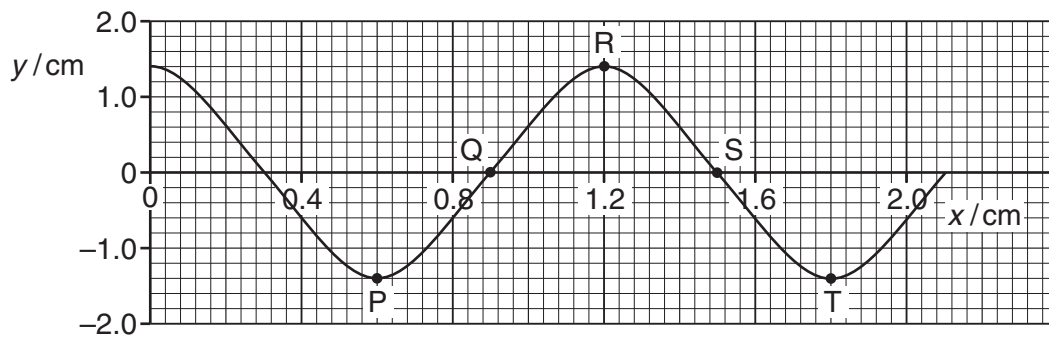


Fig. 7.1

On Fig. 7.1, five points are labelled.

Use Fig. 7.1 to state any two points having a phase difference of

- (i) zero,

.....[1]

- (ii) 270° .

.....[1]

- (c) The frequency of the wave in (b) is 15 Hz.

Calculate the speed of the wave in (b).

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

- (d) Two waves of the same frequency have amplitudes 1.4 cm and 2.1 cm.

Calculate the ratio

$$\frac{\text{intensity of wave of amplitude 1.4 cm}}{\text{intensity of wave of amplitude 2.1 cm}}$$

ratio = ... [2]

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