1 **(a)** The drag force $D$ on an object of cross-sectional area $A$, moving with a speed $v$ through a fluid of density $\rho$, is given by

$$D = \frac{1}{2} C\rho A v^2$$

where $C$ is a constant.

Show that $C$ has no unit.

[2]

**(b)** A raindrop falls vertically from rest. Assume that air resistance is negligible.

**(i)** On Fig. 1.1, sketch a graph to show the variation with time $t$ of the velocity $v$ of the raindrop for the first 1.0 s of the motion.

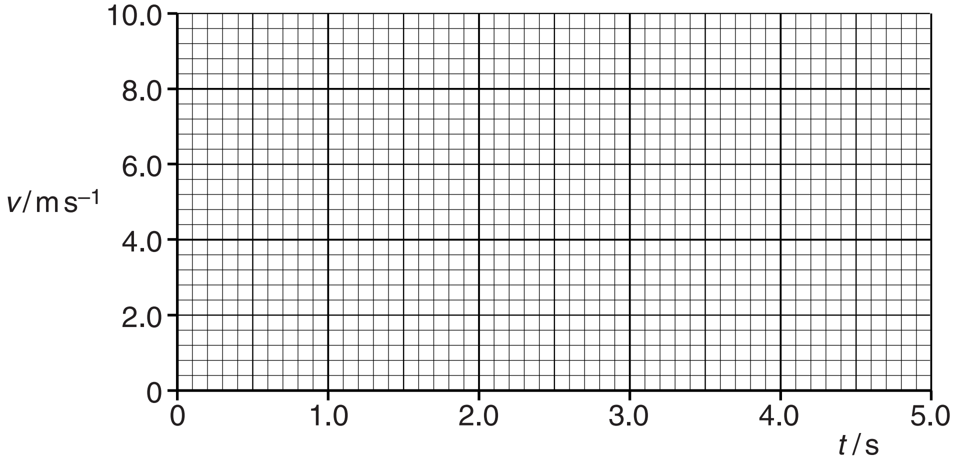


**Fig. 1.1**

[1]

**(ii)** Calculate the velocity of the raindrop after falling 1000 m.

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

**(c)** In practice, air resistance on raindrops is not negligible because there is a drag force. This drag force is given by the expression in **(a)**.

**(i)** State an equation relating the forces acting on the raindrop when it is falling at terminal velocity.

[1]

**(ii)** The raindrop has mass $1.4 \times 10^{-5}$ kg and cross-sectional area $7.1 \times 10^{-6}\,\text{m}^2$. The density of the air is $1.2\,\text{kg}\,\text{m}^{-3}$ and the initial velocity of the raindrop is zero. The value of $C$ is 0.60.

**1.** Show that the terminal velocity of the raindrop is about $7\,\text{m}\,\text{s}^{-1}$.

[2]

**2.** The raindrop reaches terminal velocity after falling approximately 10 m. On Fig. 1.1, sketch the variation with time $t$ of velocity $v$ for the raindrop. The sketch should include the first 5 s of the motion.

[2]

2 **(a)** State Newton's second law.

.............................................................................................................................................

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

**(b)** A ball of mass 65 g hits a wall with a velocity of 5.2 m $s^{-1}$ perpendicular to the wall. The ball rebounds perpendicularly from the wall with a speed of 3.7 m $s^{-1}$. The contact time of the ball with the wall is 7.5 ms.

Calculate, for the ball hitting the wall,

**(i)** the change in momentum,

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

**(ii)** the magnitude of the average force.

force = ............................................ N [1]

**(c)** **(i)** the collision in **(b)** between the ball and the wall, state how the following apply:

**1.** Newton's third law,

.............................................................................................................................................

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

**2.** the law of conservation of momentum.

.............................................................................................................................................

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

**(ii)** State, with a reason, whether the collision is elastic or inelastic.

.............................................................................................................................................

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

3 **(a)** With reference to the arrangement of atoms, distinguish between metals, polymers and amorphous solids.

metals: ..........................................................................................................................

..........................................................................................................................

polymers: ..........................................................................................................................

..........................................................................................................................

amorphous solids: ..........................................................................................................................

..........................................................................................................................
[3]

**(b)** On Fig. 3.1, sketch the variation with extension $x$ of force $F$ to distinguish between a metal and a polymer.

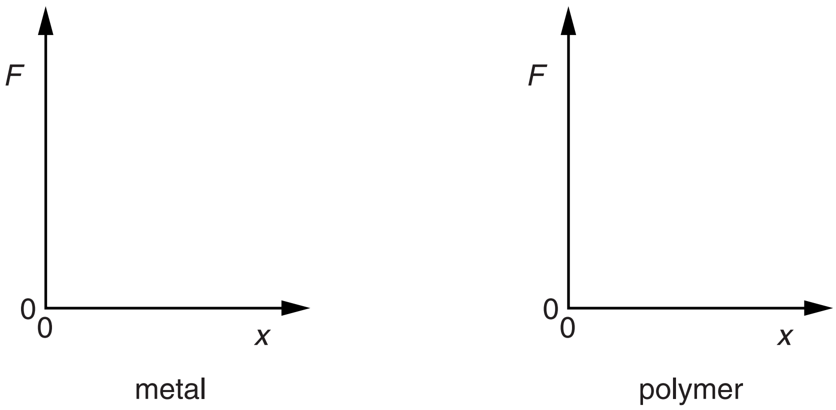


**Fig. 3.1**

[2]

4 Fig. 4.1 shows an arrangement for producing stationary waves in a tube that is closed at one end.

**Fig. 4.1**

**(a)** Explain how waves from the loudspeaker produce stationary waves in the tube.

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.......................................................................................................................................[3]

**(b)** One of the stationary waves that may be formed in the tube is represented in Fig. 4.2.

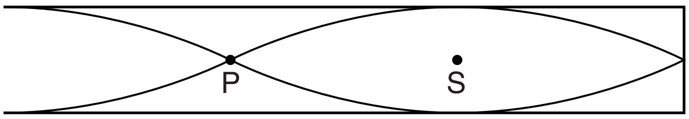


**Fig. 4.2**

**(i)** Describe the motion of the air particles in the tube at

**1.** point P,

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

**2.** point S.

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

**(ii)** The speed of sound in the tube is $330\,m\,s^{-1}$ and the frequency of the waves from the loudspeaker is 880 Hz. Calculate the length of the tube.

length = ............................................ m [3]

5 Fig. 5.1 shows a 12V power supply with negligible internal resistance connected to a uniform metal wire AB. The wire has length 1.00m and resistance 10Ω. Two resistors of resistance 4.0Ω and 2.0Ω are connected in series across the wire.

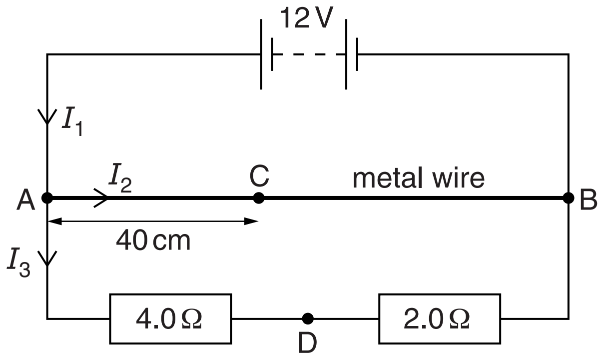


**Fig. 5.1**

Currents $I_1$, $I_2$ and $I_3$ in the circuit are as shown in Fig. 5.1.

**(a)** **(i)** Kirchhoff's first law to state a relationship between $I_1$, $I_2$ and $I_3$.

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

**(ii)** Calculate $I_1$.

$I_1$ = ............................................. A [3]

**(iii)** Calculate the ratio *x*, where

$$x = \frac{\text{power in metal wire}}{\text{power in series resistors}}.$$

*x* = ................................................ [3]

**(b)** Calculate the potential difference (p.d.) between the points C and D, as shown in Fig. 5.1. The distance AC is 40cm and D is the point between the two series resistors.

p.d. = ............................................. V [3]

**6** **(a)** State Hooke's law.

..........................................................................................................................................

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

**(b)** A spring is attached to a support and hangs vertically, as shown in Fig. 6.1. An object M of mass 0.41 kg is attached to the lower end of the spring. The spring extends until M is at rest at R.

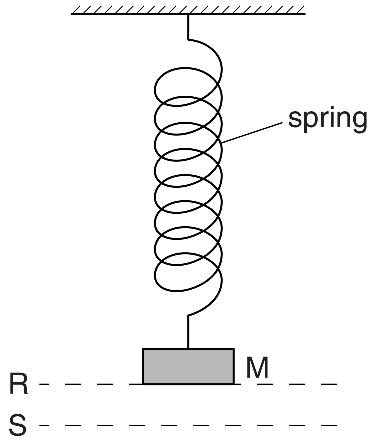


**Fig. 6.1**

The spring constant of the spring is $25\,N\,m^{-1}$. Show that the extension of the spring is about 0.16 m.

[2]

**(c)** The object M in Fig. 6.1 is pulled down a further 0.060 m to S and is then released. M, just as it is released,

**(i)** state the forces acting on M,

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

**(ii)** calculate the acceleration of M.

acceleration = ...................................... $m\,s^{-2}$ [3]

**7** A nuclear reaction between two helium nuclei produces a second isotope of helium, two protons and 13.8 MeV of energy. The reaction is represented by the following equation.

$$^{3}_{2}\text{He} + ^{3}_{2}\text{He} \rightarrow ^{\cdots\cdots}_{\cdots\cdots}\text{He} + 2\,^{\cdots\cdots}_{\cdots\cdots}\text{p} + 13.8\,\text{MeV}$$

**(a)** Complete the nuclear equation. [2]

**(b)** By reference to this reaction, explain the meaning of the term *isotope*.

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

**(c)** State the quantities that are conserved in this nuclear reaction.

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**(d)** Radiation is produced in this nuclear reaction.

State

**(i)** a possible type of radiation that may be produced,

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

**(ii)** why the energy of this radiation is less than the 13.8 MeV given in the equation.

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

**(e)** Calculate the minimum number of these reactions needed per second to produce power of 60 W.