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9702/21

October/November 2012

1 hour

No Additional Materials are required.

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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO NOT WRITE IN ANY BARCODES.

Answer **all** questions.

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.

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Total	

This document consists of **16** printed pages.

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.

For
Examiner's
Use

- 1 (a) (i) Define *acceleration*.

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

- (ii) State Newton's first law of motion.

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

- (b) The variation with time t of vertical speed v of a parachutist falling from an aircraft is shown in Fig. 1.1.

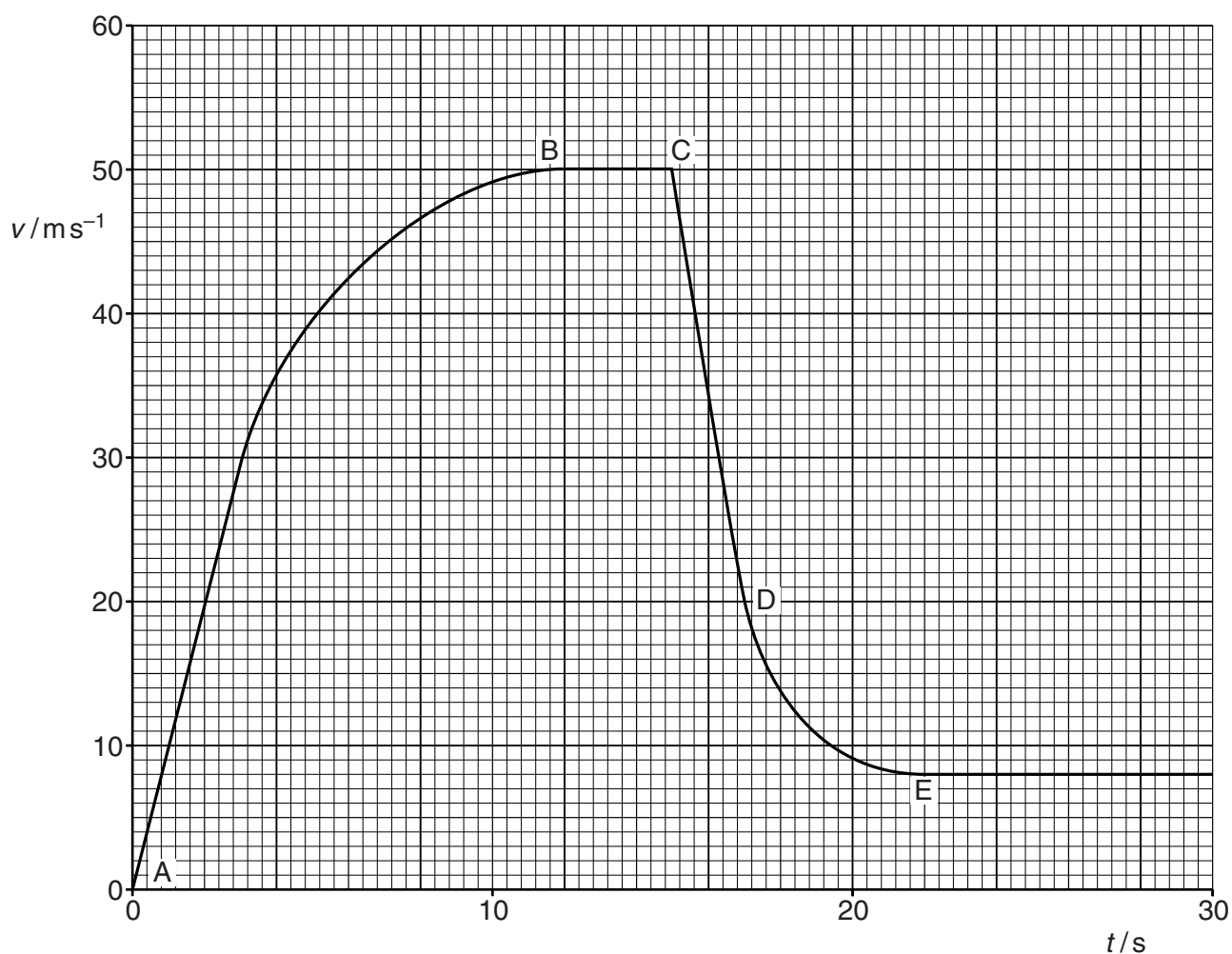


Fig. 1.1

- (i) Calculate the distance travelled by the parachutist in the first 3.0 s of the motion.

distance = ... m [2]

- (ii) Explain the variation of the resultant force acting on the parachutist from $t = 0$ (point A) to $t = 15$ s (point C).

.....

 [3]

- (iii) Describe the changes to the frictional force on the parachutist

1. at $t = 15$ s (point C),

.....

 [1]

2. between $t = 15$ s (point C) and $t = 22$ s (point E).

.....

 [1]

(iv) The mass of the parachutist is 95 kg.

Calculate, for the parachutist between $t = 15$ s (point C) and $t = 17$ s (point D),

1. the average acceleration,

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

2. the average frictional force.

frictional force = ... N [3]

For
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Use

Please turn over for Question 2.

- 2 (a) Define electrical *resistance*.

For
Examiner's
Use

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

- (b) A circuit is set up to measure the resistance R of a metal wire. The potential difference (p.d.) V across the wire and the current I in the wire are to be measured.

- (i) Draw a circuit diagram of the apparatus that could be used to make these measurements.

[3]

- (ii) Readings for p.d. V and the corresponding current I are obtained. These are shown in Fig. 2.1.

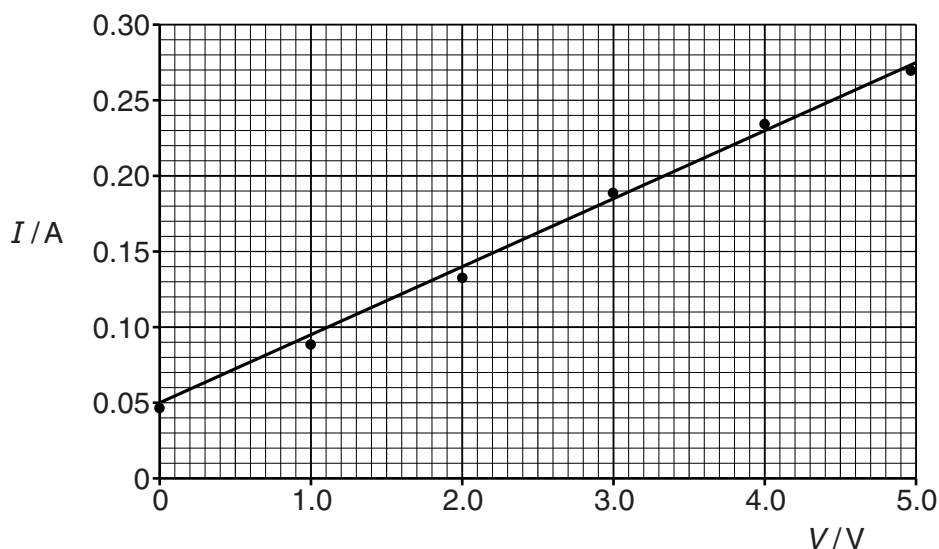


Fig. 2.1

Explain how Fig. 2.1 indicates that the readings are subject to

1. a systematic uncertainty,

.....
 [1]

2. random uncertainties.

.....
 [1]

(iii) Use data from Fig. 2.1 to determine R . Explain your working.

$R = \dots\dots\dots \Omega$ [3]

(c) In another experiment, a value of R is determined from the following data:

Current $I = 0.64 \pm 0.01$ A and p.d. $V = 6.8 \pm 0.1$ V.

Calculate the value of R , together with its uncertainty. Give your answer to an appropriate number of significant figures.

$R = \dots\dots\dots \pm \dots\dots\dots \Omega$ [3]

- 3 (a) Define *pressure*.

.....
 [1]

- (b) Explain, in terms of the air molecules, why the pressure at the top of a mountain is less than at sea level.

.....

 [3]

- (c) Fig. 3.1 shows a liquid in a cylindrical container.

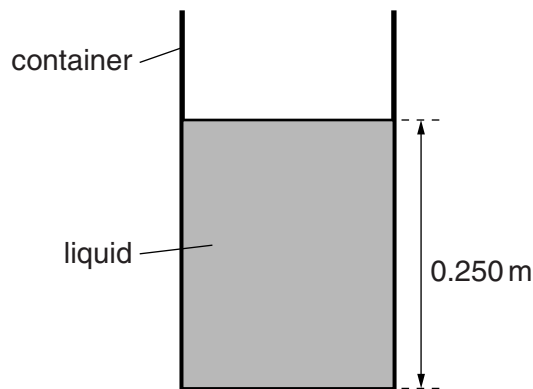


Fig. 3.1

The cross-sectional area of the container is 0.450 m^2 . The height of the column of liquid is 0.250 m and the density of the liquid is 13600 kg m^{-3} .

- (i) Calculate the weight of the column of liquid.

weight = ... N [3]

- (ii) Calculate the pressure on the base of the container caused by the weight of the liquid.

*For
Examiner's
Use*

pressure = ... Pa [1]

- (iii) Explain why the pressure exerted on the base of the container is different from the value calculated in (ii).

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

- 4 (a) Describe the diffraction of monochromatic light as it passes through a diffraction grating.

For
Examiner's
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.....

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..... [2]

- (b) White light is incident on a diffraction grating, as shown in Fig. 4.1.

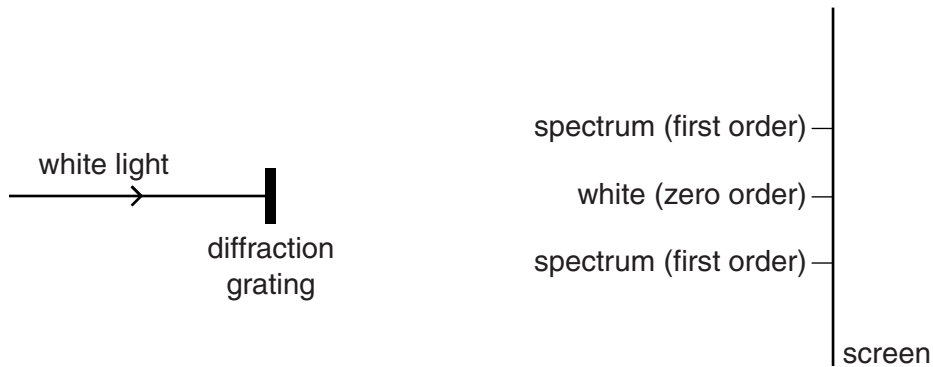


Fig. 4.1 (not to scale)

The diffraction pattern formed on the screen has white light, called zero order, and coloured spectra in other orders.

- (i) Describe how the principle of superposition is used to explain

1. white light at the zero order,

.....

.....

..... [2]

2. the difference in position of red and blue light in the first-order spectrum.

.....

.....

..... [2]

- (ii) Light of wavelength 625 nm produces a second-order maximum at an angle of 61.0° to the incident direction.
Determine the number of lines per metre of the diffraction grating.

For
Examiner's
Use

number of lines = ... m^{-1} [2]

- (iii) Calculate the wavelength of another part of the visible spectrum that gives a maximum for a different order at the same angle as in (ii).

wavelength = ... nm [2]

- 5 (a) Explain what is meant by *plastic deformation*.

.....
 [1]

- (b) A copper wire of uniform cross-sectional area $1.54 \times 10^{-6} \text{ m}^2$ and length 1.75 m has a breaking stress of $2.20 \times 10^8 \text{ Pa}$. The Young modulus of copper is $1.20 \times 10^{11} \text{ Pa}$.

- (i) Calculate the breaking force of the wire.

breaking force = ... N [2]

- (ii) A stress of $9.0 \times 10^7 \text{ Pa}$ is applied to the wire. Calculate the extension.

extension = ... m [2]

- (c) Explain why it is not appropriate to use the Young modulus to determine the extension when the breaking force is applied.

.....
 [1]

- 6 (a) Describe the structure of an atom of the nuclide $^{235}_{92}\text{U}$.

For
Examiner's
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.....

.....

.....

..... [2]

- (b) The deflection of α -particles by a thin metal foil is investigated with the arrangement shown in Fig. 6.1. All the apparatus is enclosed in a vacuum.

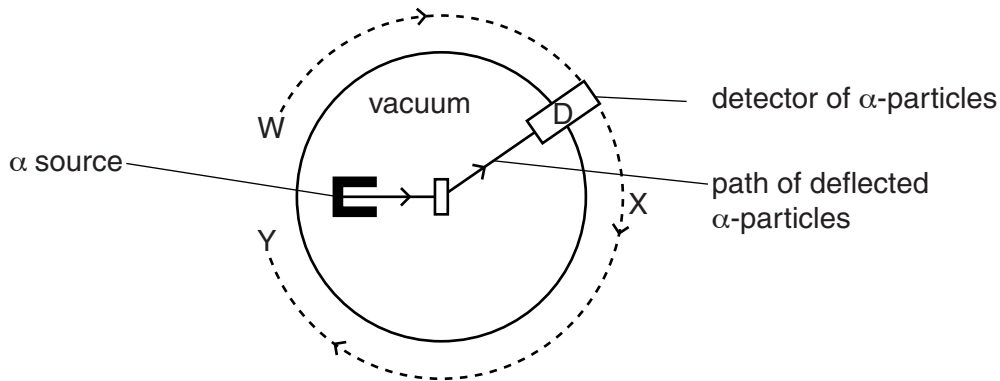


Fig. 6.1

The detector of α -particles, D, is moved around the path labelled WXY.

- (i) Explain why the apparatus is enclosed in a vacuum.

.....

..... [1]

- (ii) State and explain the readings detected by D when it is moved along WXY.

.....

.....

.....

.....

.....

..... [3]

Question 6 continues on page 16.

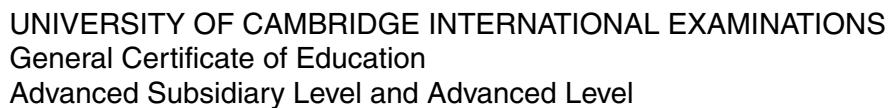
- (c) A beam of α -particles produces a current of 1.5 pA. Calculate the number of α -particles per second passing a point in the beam.

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number = ... s⁻¹ [3]

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$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

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For
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Use

- 1 (a) The drag force D on an object of cross-sectional area A , moving with a speed v through a fluid of density ρ , 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.

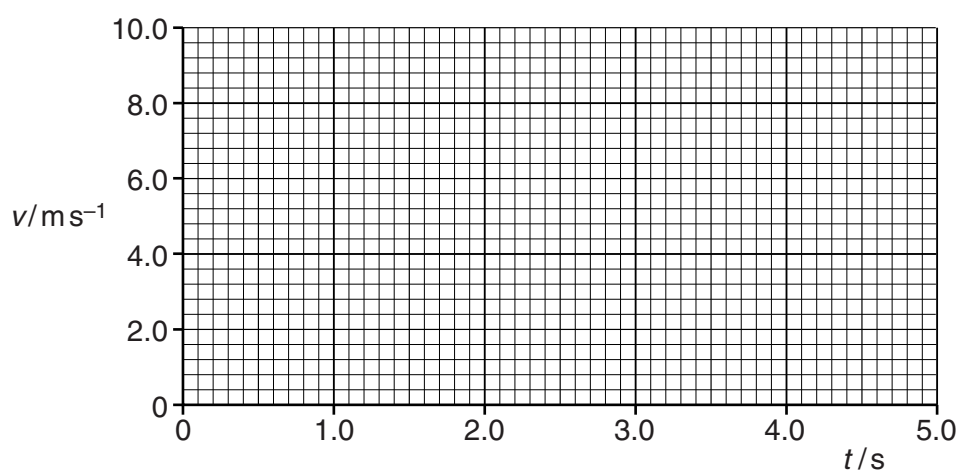


Fig. 1.1

[1]

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

velocity = ... ms^{-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).

For
Examiner's
Use

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

[1]

- (ii) The raindrop has mass $1.4 \times 10^{-5} \text{ kg}$ and cross-sectional area $7.1 \times 10^{-6} \text{ m}^2$. The density of the air is 1.2 kg 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 m 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.

For
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.....
..... [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) For the collision in (b) between the ball and the wall, state how the following apply:

1. Newton's third law,

.....
.....
.....
..... [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.

For
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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.

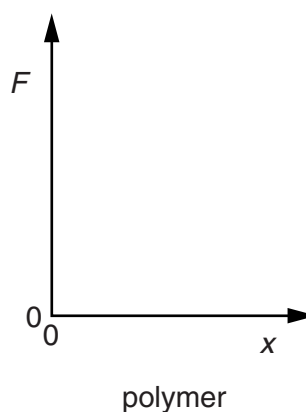
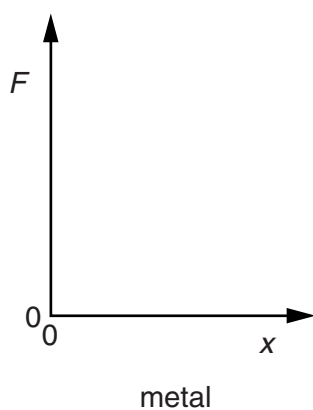


Fig. 3.1

[2]

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

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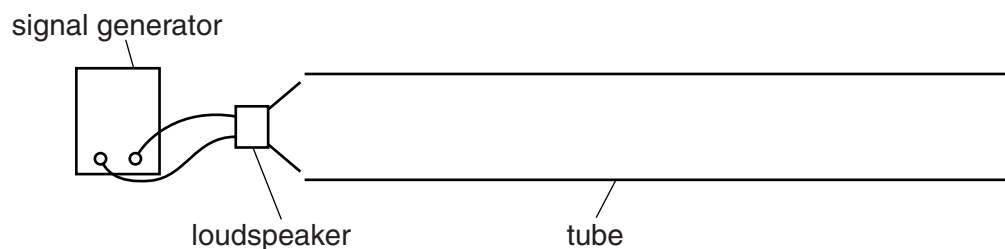


Fig. 4.1

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

.....

.....

.....

.....

..... [3]

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

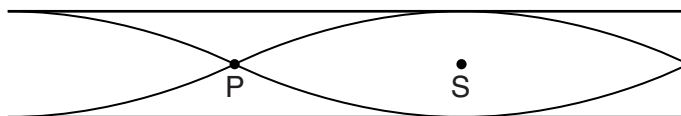


Fig. 4.2

- (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 ms^{-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.

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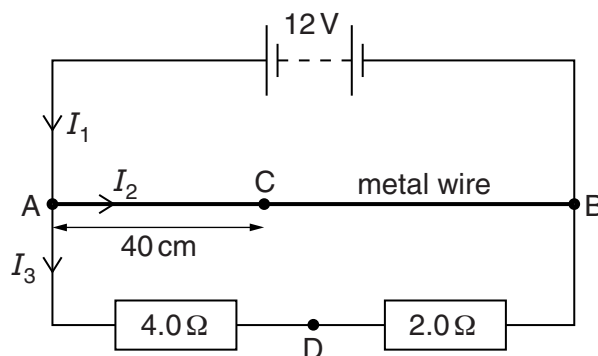


Fig. 5.1

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

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

..... [1]

- (ii) Calculate I_1 .

$I_1 = \dots\dots\dots$ A [3]

- (iii) Calculate the ratio x , where

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

$x = \dots\dots\dots$ [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. = $\dots\dots\dots$ 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.

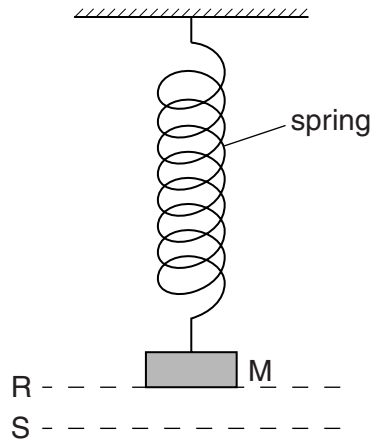


Fig. 6.1

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. For 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]

- (d) Describe and explain the energy changes from the time the object M in Fig. 6.1 is released to the time it first returns to R.

*For
Examiner's
Use*

.....

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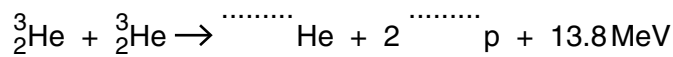
.....

.....[2]

Please turn over for Question 7.

- 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.

For
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Use



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

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

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

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

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

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

State

- (i) a possible type of radiation that may be produced,
..... [1]

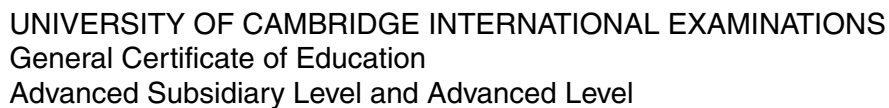
- (ii) why the energy of this radiation is less than the 13.8 MeV given in the equation.
..... [1]

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

number = ... s⁻¹ [2]

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

For
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- 1 (a) The spacing between two atoms in a crystal is $3.8 \times 10^{-10} \text{ m}$. State this distance in pm.

spacing = ... pm [1]

- (b) Calculate the time of one day in Ms.

time = ... Ms [1]

- (c) The distance from the Earth to the Sun is 0.15 Tm. Calculate the time in minutes for light to travel from the Sun to the Earth.

time = ... min [2]

- (d) Underline all the vector quantities in the list below.

distance energy momentum weight work [1]

- (e) The velocity vector diagram for an aircraft heading due north is shown to scale in Fig. 1.1. There is a wind blowing from the north-west.

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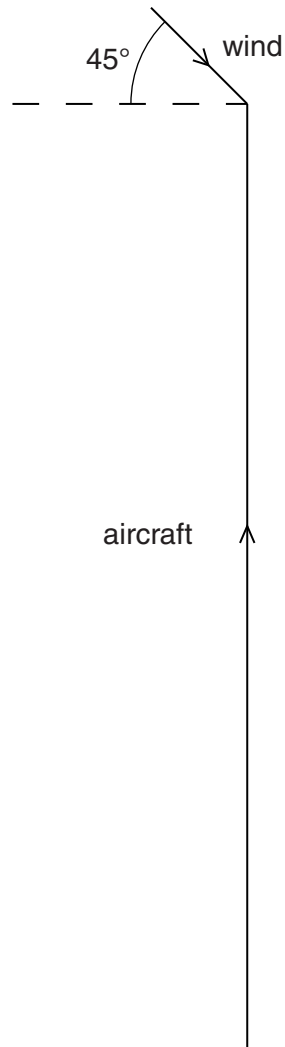


Fig. 1.1

The speed of the wind is 36 m s^{-1} and the speed of the aircraft is 250 m s^{-1} .

- (i) Draw an arrow on Fig. 1.1 to show the direction of the resultant velocity of the aircraft. [1]
- (ii) Determine the magnitude of the resultant velocity of the aircraft.

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

- 2 Two planks of wood AB and BC are inclined at an angle of 15° to the horizontal. The two wooden planks are joined at point B, as shown in Fig. 2.1.

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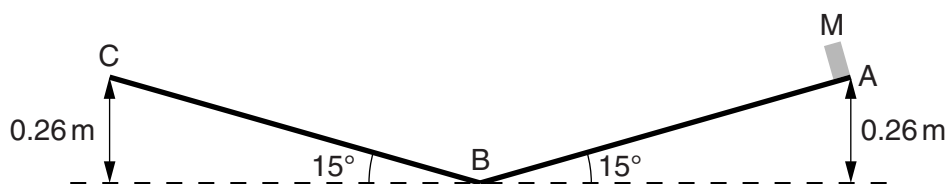


Fig. 2.1

A small block of metal M is released from rest at point A. It slides down the slope to B and up the opposite side to C. Points A and C are 0.26 m above B. Assume frictional forces are negligible.

- (a) (i) Describe and explain the acceleration of M as it travels from A to B and from B to C.

.....

.....

.....

..... [3]

- (ii) Calculate the time taken for M to travel from A to B.

time = ... s [3]

- (iii) Calculate the speed of M at B.

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

- (b) The plank BC is adjusted so that the angle it makes with the horizontal is 30° . M is released from rest at point A and slides down the slope to B. It then slides a distance along the plank from B towards C.

Use the law of conservation of energy to calculate this distance. Explain your working.

distance = ... m [2]

- 3 (a) Define *power*.

.....
 [1]

- (b) A cyclist travels along a horizontal road. The variation with time t of speed v is shown in Fig. 3.1.

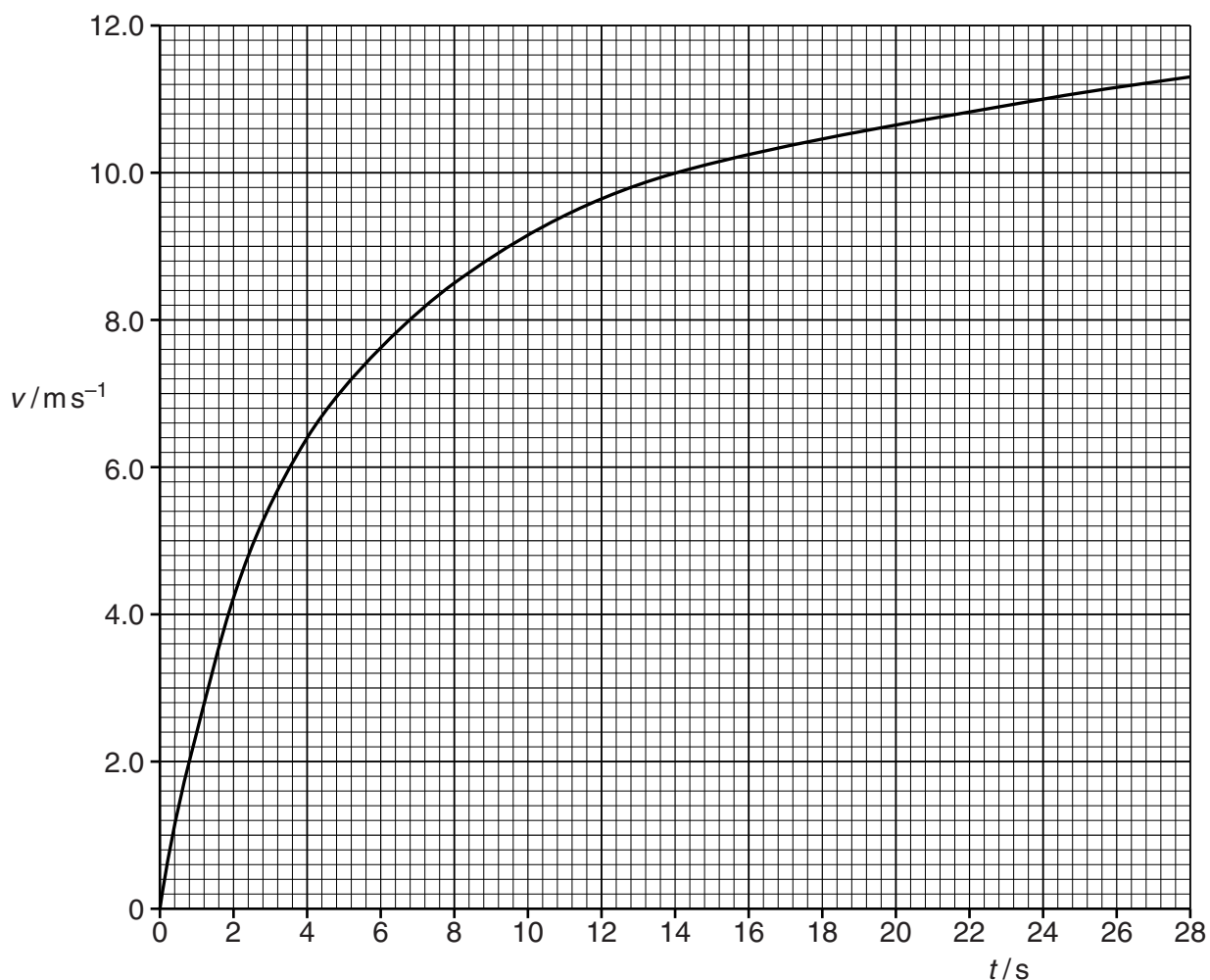


Fig. 3.1

The cyclist maintains a constant power and after some time reaches a constant speed of 12 ms^{-1} .

- (i) Describe and explain the motion of the cyclist.

.....

 [3]

- (ii) When the cyclist is moving at a constant speed of 12 m s^{-1} the resistive force is 48 N . Show that the power of the cyclist is about 600 W . Explain your working.

For
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Use

[2]

- (iii) Use Fig. 3.1 to show that the acceleration of the cyclist when his speed is 8.0 m s^{-1} is about 0.5 m s^{-2} .

[2]

- (iv) The total mass of the cyclist and bicycle is 80 kg . Calculate the resistive force R acting on the cyclist when his speed is 8.0 m s^{-1} . Use the value for the acceleration given in (iii).

$R = \dots\dots\dots \text{ N}$ [3]

- (v) Use the information given in (ii) and your answer to (iv) to show that, in this situation, the resistive force R is proportional to the speed v of the cyclist.

[1]

- 4 A circuit used to measure the power transfer from a battery is shown in Fig. 4.1. The power is transferred to a variable resistor of resistance R .

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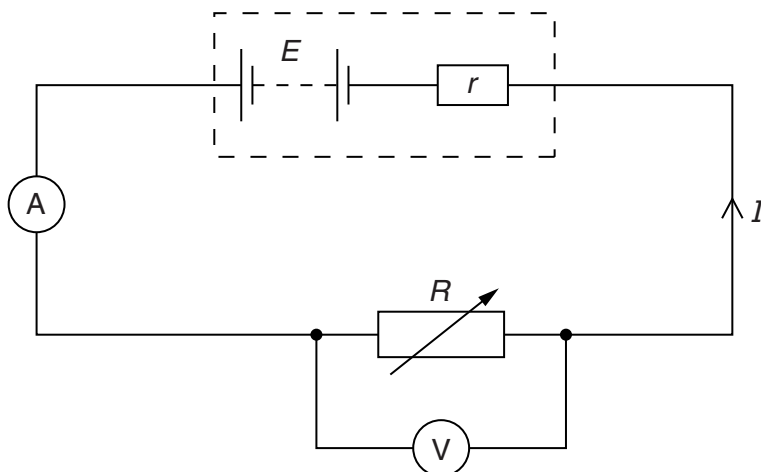


Fig. 4.1

The battery has an electromotive force (e.m.f.) E and an internal resistance r . There is a potential difference (p.d.) V across R . The current in the circuit is I .

- (a) By reference to the circuit shown in Fig. 4.1, distinguish between the definitions of e.m.f. and p.d.

.....

.....

.....

..... [3]

- (b) Using Kirchhoff's second law, determine an expression for the current I in the circuit.

[1]

- (c) The variation with current I of the p.d. V across R is shown in Fig. 4.2.

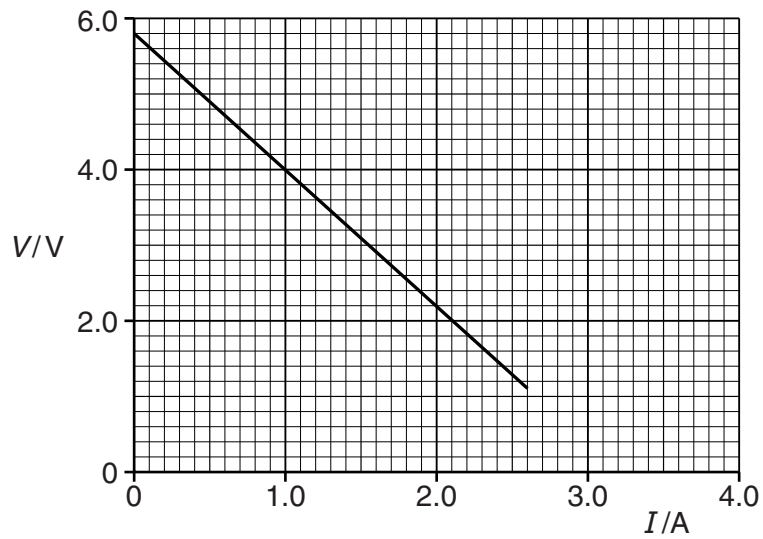


Fig. 4.2

Use Fig. 4.2 to determine

- (i) the e.m.f. E ,

$$E = \dots\dots\dots \text{ V [1]}$$

- (ii) the internal resistance r .

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

- (d) (i) Using data from Fig. 4.2, calculate the power transferred to R for a current of 1.6 A.

$$\text{power} = \dots\dots\dots \text{ W [2]}$$

- (ii) Use your answers from (c)(i) and (d)(i) to calculate the efficiency of the battery for a current of 1.6 A.

$$\text{efficiency} = \dots\dots\dots \% \text{ [2]}$$

- 5 (a) State one property of electromagnetic waves that is **not** common to other transverse waves.

..... [1]

- (b) The seven regions of the electromagnetic spectrum are represented by blocks labelled A to G in Fig. 5.1.

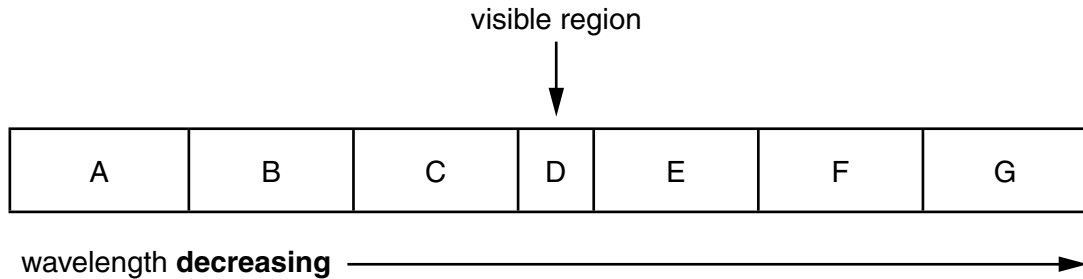


Fig. 5.1

A typical wavelength for the visible region D is 500 nm.

- (i) Name the principal radiations and give a typical wavelength for each of the regions B, E and F.

B: name: wavelength: m

E: name: wavelength: m

F: name: wavelength: m

[3]

- (ii) Calculate the frequency corresponding to a wavelength of 500 nm.

frequency = ... Hz [2]

- (c) All the waves in the spectrum shown in Fig. 5.1 can be polarised. Explain the meaning of the term *polarised*.

.....

 [2]

- 6 (a) β -radiation is emitted during the spontaneous radioactive decay of an unstable nucleus.

(i) State the nature of a β -particle.

..... [1]

(ii) State two properties of β -radiation.

1.

2. [2]

(iii) Explain the meaning of *spontaneous radioactive decay*.

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

- (b) The following equation represents the decay of a nucleus of hydrogen-3 by the emission of a β -particle.

Complete the equation.



- (c) The β -particle is emitted with an energy of $5.7 \times 10^3 \text{ eV}$.

Calculate the speed of the β -particle.

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

- (d) A different isotope of hydrogen is hydrogen-2 (deuterium). Describe the similarities and differences between the atoms of hydrogen-2 and hydrogen-3.

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

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