



UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education
Advanced Subsidiary Level and Advanced Level

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PHYSICS

9702/21

Paper 2 AS Structured Questions

October/November 2009

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 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.

For Examiner's Use

1	
2	
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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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
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 The volume of fuel in the tank of a car is monitored using a meter as illustrated in Fig. 1.1.

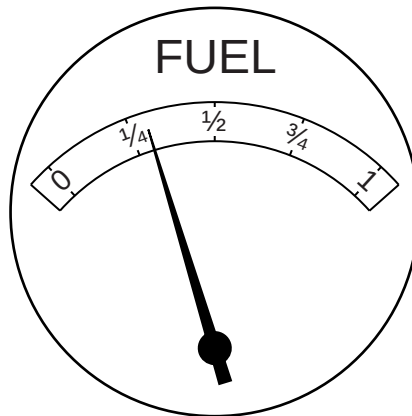


Fig. 1.1

The meter has an analogue scale. The meter reading for different volumes of fuel in the tank is shown in Fig. 1.2.

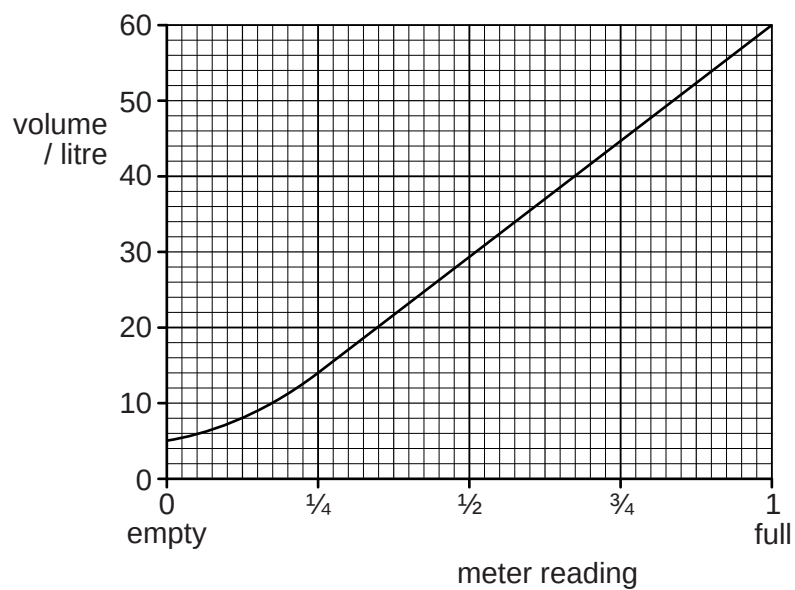


Fig. 1.2

The meter is calibrated in terms of the fraction of the tank that remains filled with fuel.

- (a)** The car uses 1.0 litre of fuel when travelling 14 km. The car starts a journey with a full tank of fuel.

- (i)** Calculate the volume of fuel remaining in the tank after a journey of 210 km.

volume = ... litres [2]

- (ii)** Use your answer to **(i)** and Fig. 1.2 to determine the change in the meter reading during the 210 km journey.

from *full* to [1]

- (b)** There is a systematic error in the meter.

- (i)** State the feature of Fig. 1.2 that indicates that there is a systematic error.

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

- (ii)** Suggest why, for this meter, it is an advantage to have this systematic error.

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

2 A sky-diver jumps from a high-altitude balloon.

(a) Explain briefly why the acceleration of the sky-diver

(i) decreases with time,

.....

 [2]

(ii) is 9.8 m s^{-2} at the start of the jump.

.....
 [1]

(b) The variation with time t of the vertical speed v of the sky-diver is shown in Fig. 2.1.

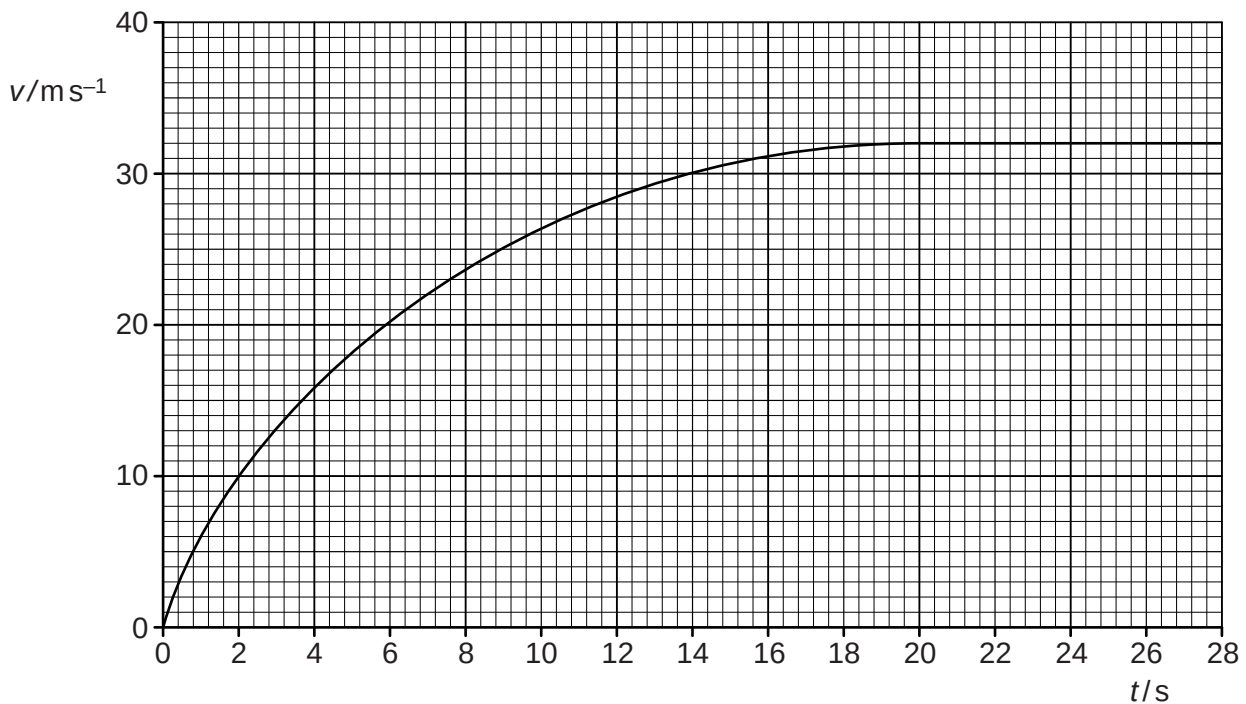


Fig. 2.1

Use Fig. 2.1 to determine the magnitude of the acceleration of the sky-diver at time $t = 6.0$ s.

For
Examiner's
Use

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

(c) The sky-diver and his equipment have a total mass of 90 kg.

(i) Calculate, for the sky-diver and his equipment,

1. the total weight,

weight = ... N [1]

2. the accelerating force at time $t = 6.0$ s.

force = ... N [1]

(ii) Use your answers in (i) to determine the total resistive force acting on the sky-diver at time $t = 6.0$ s.

force = ... N [1]

- 3 A stationary nucleus of mass 220u undergoes radioactive decay to produce a nucleus D of mass 216u and an α -particle of mass 4u , as illustrated in Fig. 3.1.

For
Examiner's
Use

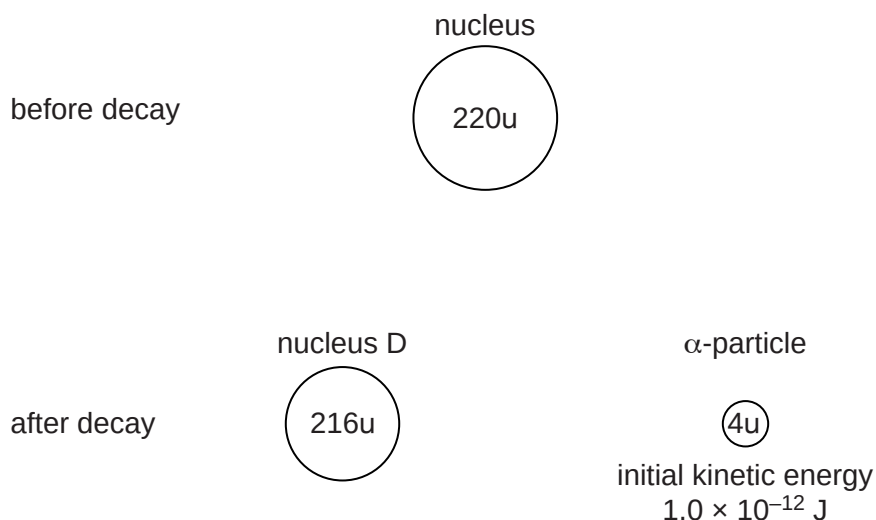


Fig. 3.1

The initial kinetic energy of the α -particle is $1.0 \times 10^{-12} \text{ J}$.

- (a) (i) State the law of conservation of linear momentum.

.....

 [2]

- (ii) Explain why the initial velocities of the nucleus D and the α -particle must be in opposite directions.

.....

 [2]

- (b) (i) Show that the initial speed of the α -particle is $1.7 \times 10^7 \text{ m s}^{-1}$.

[2]

- (ii) Calculate the initial speed of nucleus D.

For
Examiner's
Use

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

- (c) The range in air of the emitted α -particle is 4.5 cm.
Calculate the average deceleration of the α -particle as it is stopped by the air.

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

- 4 A uniform wire has length L and area of cross-section A . The wire is fixed at one end so that it hangs vertically with a load attached to its free end, as shown in Fig. 4.1.

For
Examiner's
Use

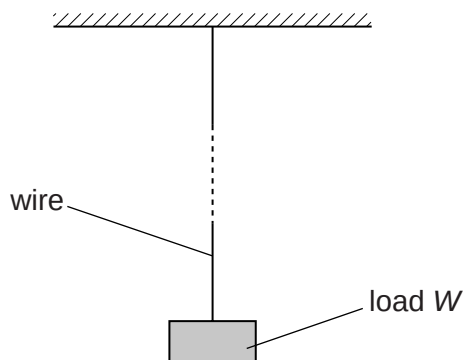


Fig. 4.1

When the load of magnitude W is attached to the wire, it extends by an amount e . The elastic limit of the wire is not exceeded.

The material of the wire has resistivity ρ .

- (a) (i) Explain what is meant by extends *elastically*.

.....

 [2]

- (ii) Write down expressions, in terms of L , A , W , ρ and e for

1. the resistance R of the unstretched wire,

$$R = \dots\dots\dots [1]$$

2. the Young modulus E of the wire.

$$E = \dots\dots\dots [1]$$

(b) A steel wire has resistance $0.44\ \Omega$. Steel has resistivity $9.2 \times 10^{-8}\ \Omega\text{m}$.

A load of 34 N hung from the end of the wire causes an extension of $7.7 \times 10^{-4}\text{ m}$.

Using your answers in **(a)(ii)**, calculate the Young modulus E of steel.

For
Examiner's
Use

$E =$ Pa [3]

- 5 (a) State what is meant by a *progressive wave*.

For
Examiner's
Use

.....

.....

..... [2]

- (b) The variation with distance x along a progressive wave of a quantity y , at a particular time, is shown in Fig. 5.1.

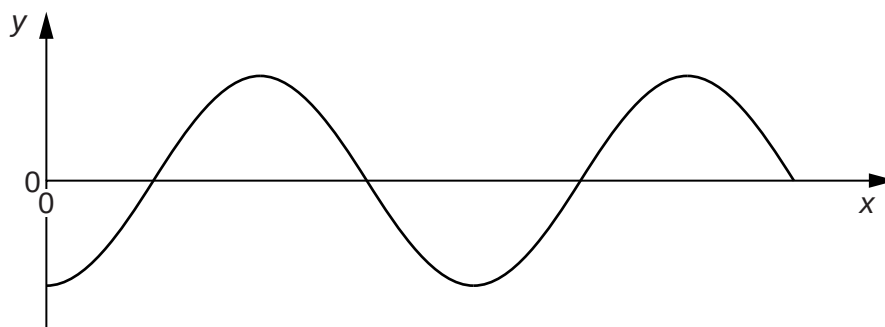


Fig. 5.1

- (i) State what the quantity y could represent.

.....

..... [1]

- (ii) Distinguish between the quantity y for

1. a transverse wave,

.....

..... [1]

2. a longitudinal wave.

.....

..... [1]

- (c) The wave nature of light may be demonstrated using the phenomena of diffraction and interference.

For
Examiner's
Use

Outline how diffraction and how interference may be demonstrated using light. In each case, draw a fully labelled diagram of the apparatus that is used and describe what is observed.

diffraction

.....

.....

.....

interference

.....

.....

.....

[6]

- 6 A cell has electromotive force (e.m.f.) E and internal resistance r . It is connected in series with a variable resistor R , as shown in Fig. 6.1.

For
Examiner's
Use

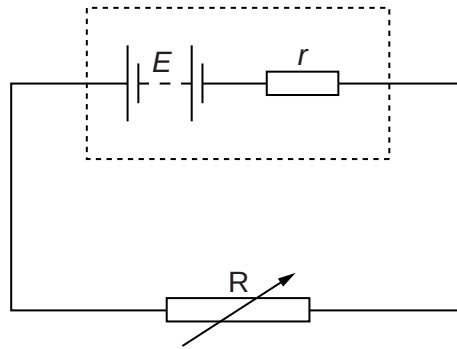


Fig. 6.1

- (a) Define electromotive force (e.m.f.).

.....

.....

..... [2]

- (b) The variable resistor R has resistance X . Show that

$$\frac{\text{power dissipated in resistor } R}{\text{power produced in cell}} = \frac{X}{X + r}.$$

[3]

- (c) The variation with resistance X of the power P_R dissipated in R is shown in Fig. 6.2.

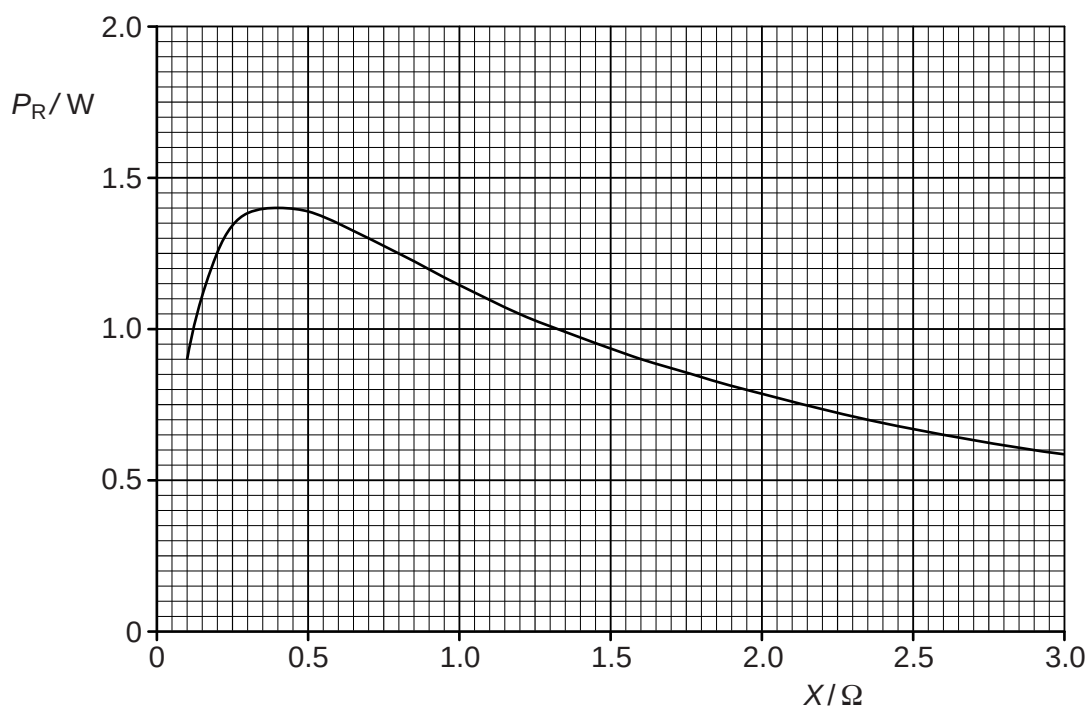


Fig. 6.2

- (i) Use Fig. 6.2 to state, for maximum power dissipation in resistor R , the magnitude of this power and the resistance of R .

maximum power = ... W

resistance = ... Ω
[2]

- (ii) The cell has e.m.f. 1.5V.
Use your answers in (i) to calculate the internal resistance of the cell.

internal resistance = ... Ω [3]

- (d) In Fig. 6.2, it can be seen that, for larger values of X , the power dissipation decreases. Use the relationship in (b) to suggest one advantage, despite the lower power output, of using the cell in a circuit where the resistance X is larger than the internal resistance of the cell.

.....

..... [1]

- 7 An α -particle A approaches and passes by a stationary gold nucleus N. The path is illustrated in Fig. 7.1.

For
Examiner's
Use

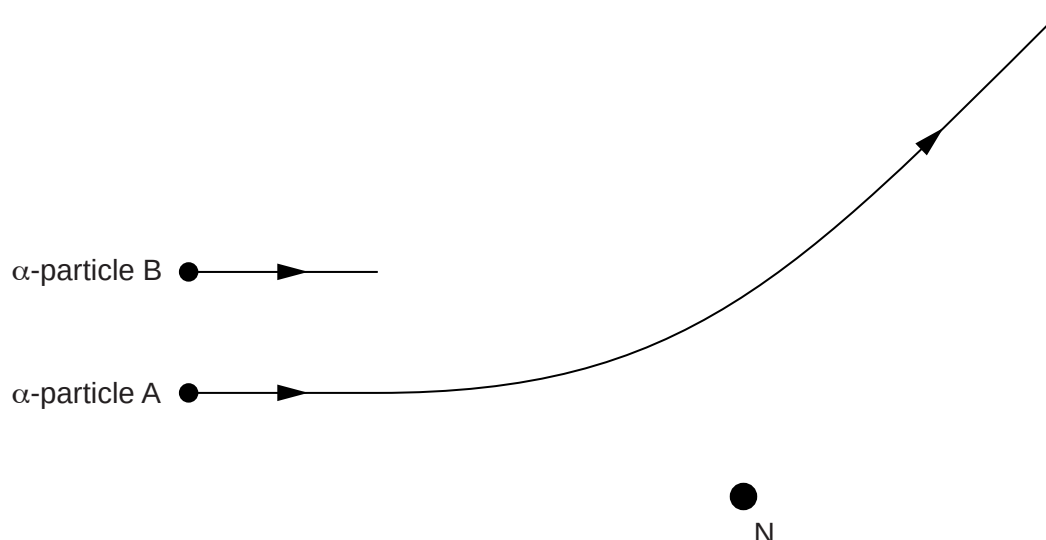


Fig. 7.1

- (a) On Fig. 7.1, mark the angle of deviation D of this α -particle as a result of passing the nucleus N. [1]
- (b) A second α -particle B has the same initial direction and energy as α -particle A. On Fig. 7.1, complete the path of α -particle B as it approaches and passes by the nucleus N. [2]
- (c) State what can be inferred about atoms from the observation that very few α -particles experience large deviations.

.....

.....

..... [2]

- (d) The nucleus N could be one of several different isotopes of gold.

Suggest, with an explanation, whether different isotopes of gold would give rise to different deviations of a particular α -particle.

.....

.....

..... [2]

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decay constant,

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

For
Examiner's
Use

- 1** A simple pendulum may be used to determine a value for the acceleration of free fall g . Measurements are made of the length L of the pendulum and the period T of oscillation.

The values obtained, with their uncertainties, are as shown.

$$T = (1.93 \pm 0.03) \text{ s}$$

$$L = (92 \pm 1) \text{ cm}$$

- (a)** Calculate the percentage uncertainty in the measurement of

- (i)** the period T ,

uncertainty = ... % [1]

- (ii)** the length L .

uncertainty = ... % [1]

- (b) The relationship between T , L and g is given by

$$g = \frac{4\pi^2 L}{T^2}.$$

For
Examiner's
Use

Using your answers in (a), calculate the percentage uncertainty in the value of g .

uncertainty = ... % [1]

- (c) The values of L and T are used to calculate a value of g as 9.751 ms^{-2} .

- (i) By reference to the measurements of L and T , suggest why it would not be correct to quote the value of g as 9.751 ms^{-2} .

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

- (ii) Use your answer in (b) to determine the absolute uncertainty in g .

Hence state the value of g , with its uncertainty, to an appropriate number of significant figures.

$g = \dots \pm \dots \text{ ms}^{-2}$ [2]

- 2 (a) (i) State one **similarity** between the processes of evaporation and boiling.

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

- (ii) State two **differences** between the processes of evaporation and boiling.

1.
.....
2.
..... [4]

- (b) Titanium metal has a density of 4.5 g cm^{-3} .

A cube of titanium of mass 48 g contains 6.0×10^{23} atoms.

- (i) Calculate the volume of the cube.

volume = ... cm^3 [1]

(ii) Estimate

For
Examiner's
Use

1. the volume occupied by each atom in the cube,

volume = ... cm^3 [1]

2. the separation of the atoms in the cube.

separation = ... cm [1]

- 3 A small ball is thrown horizontally with a speed of 4.0 m s^{-1} . It falls through a vertical height of 1.96 m before bouncing off a horizontal plate, as illustrated in Fig. 3.1.

For
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Use

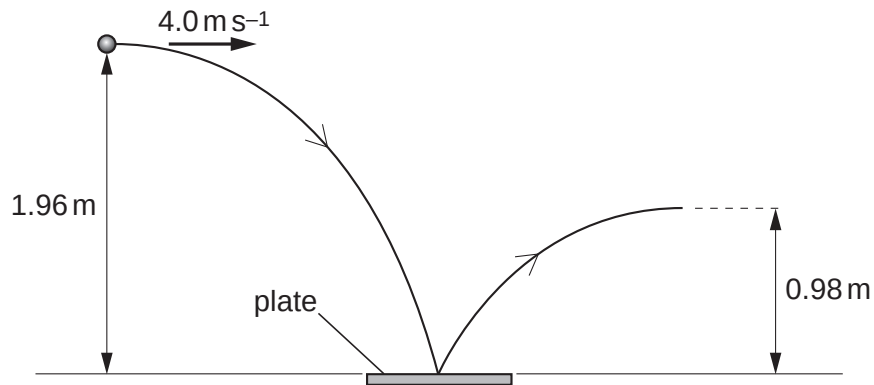


Fig. 3.1

Air resistance is negligible.

- (a) For the ball, as it hits the horizontal plate,

- (i) state the magnitude of the horizontal component of its velocity,

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

- (ii) show that the vertical component of the velocity is 6.2 m s^{-1} .

[1]

- (b) The components of the velocity in (a) are both vectors.

Complete Fig. 3.2 to draw a vector diagram, to scale, to determine the velocity of the ball as it hits the horizontal plate.

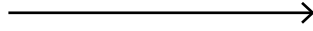


Fig. 3.2

velocity = ... ms^{-1}

at $^{\circ}$ to the vertical
[3]

- (c) After bouncing on the plate, the ball rises to a vertical height of 0.98 m.

- (i) Calculate the vertical component of the velocity of the ball as it leaves the plate.

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

For
Examiner's
Use

- (ii) The ball of mass 34 g is in contact with the plate for a time of 0.12 s.

Use your answer in (c)(i) and the data in (a)(ii) to calculate, for the ball as it bounces on the plate,

1. the change in momentum,

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

2. the magnitude of the average force exerted by the plate on the ball due to this momentum change.

force = ... N [2]

For
Examiner's
Use

- 4 (a) Explain what is meant by *strain energy* (*elastic potential energy*).

For
Examiner's
Use

.....

.....

..... [2]

- (b) A spring that obeys Hooke's law has a spring constant k .

Show that the energy E stored in the spring when it has been extended elastically by an amount x is given by

$$E = \frac{1}{2}kx^2.$$

[3]

- (c) A light spring of unextended length 14.2 cm is suspended vertically from a fixed point, as illustrated in Fig. 4.1.

For
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Use

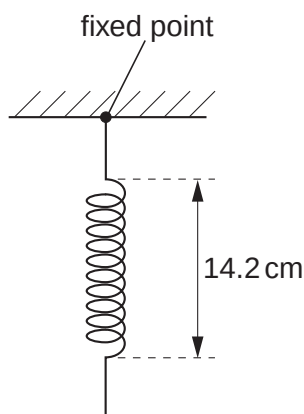


Fig. 4.1

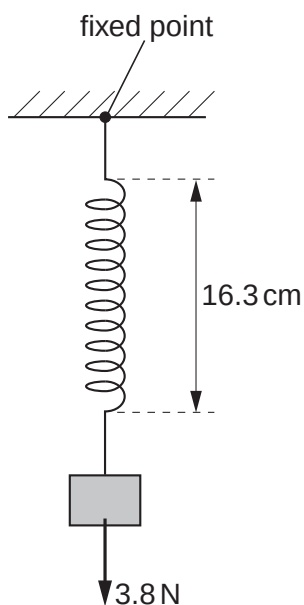


Fig. 4.2

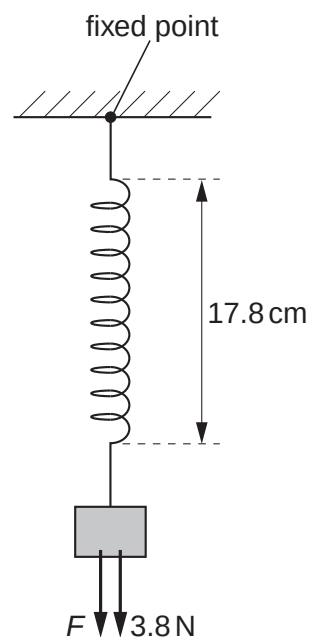


Fig. 4.3

A mass of weight 3.8 N is hung from the end of the spring, as shown in Fig. 4.2. The length of the spring is now 16.3 cm.

An additional force F then extends the spring so that its length becomes 17.8 cm, as shown in Fig. 4.3.

The spring obeys Hooke's law and the elastic limit of the spring is not exceeded.

- (i) Show that the spring constant of the spring is 1.8 N cm^{-1} .

[1]

(ii) For the extension of the spring from a length of 16.3 cm to a length of 17.8 cm,

1. calculate the change in the gravitational potential energy of the mass on the spring,

change in energy = ... J [2]

2. show that the change in elastic potential energy of the spring is 0.077 J,

[1]

3. determine the work done by the force F .

work done = ... J [1]

- 5 A uniform string is held between a fixed point P and a variable-frequency oscillator, as shown in Fig. 5.1.

For
Examiner's
Use

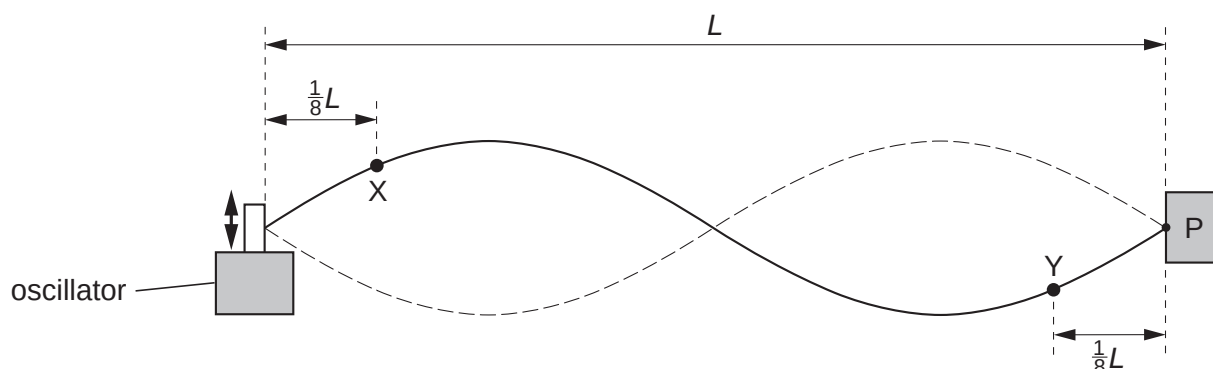


Fig. 5.1

The distance between point P and the oscillator is L .

The frequency of the oscillator is adjusted so that the stationary wave shown in Fig. 5.1 is formed.

Points X and Y are two points on the string.

Point X is a distance $\frac{1}{8}L$ from the end of the string attached to the oscillator. It vibrates with frequency f and amplitude A .

Point Y is a distance $\frac{1}{8}L$ from the end P of the string.

(a) For the vibrations of point Y, state

(i) the frequency (in terms of f),

frequency = ... [1]

(ii) the amplitude (in terms of A).

amplitude = ... [1]

(b) State the phase difference between the vibrations of point X and point Y.

phase difference = ... [1]

- (c) (i) State, in terms of f and L , the speed of the wave on the string.

speed = ... [1]

- (ii) The wave on the string is a stationary wave.

Explain, by reference to the formation of a stationary wave, what is meant by the speed stated in (i).

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

For
Examiner's
Use

- 6 (a) Two resistors, each of resistance R , are connected first in series and then in parallel.

Show that the ratio

$$\frac{\text{combined resistance of resistors connected in series}}{\text{combined resistance of resistors connected in parallel}}$$

is equal to 4.

For
Examiner's
Use

[1]

- (b) The variation with potential difference V of the current I in a lamp is shown in Fig. 6.1.

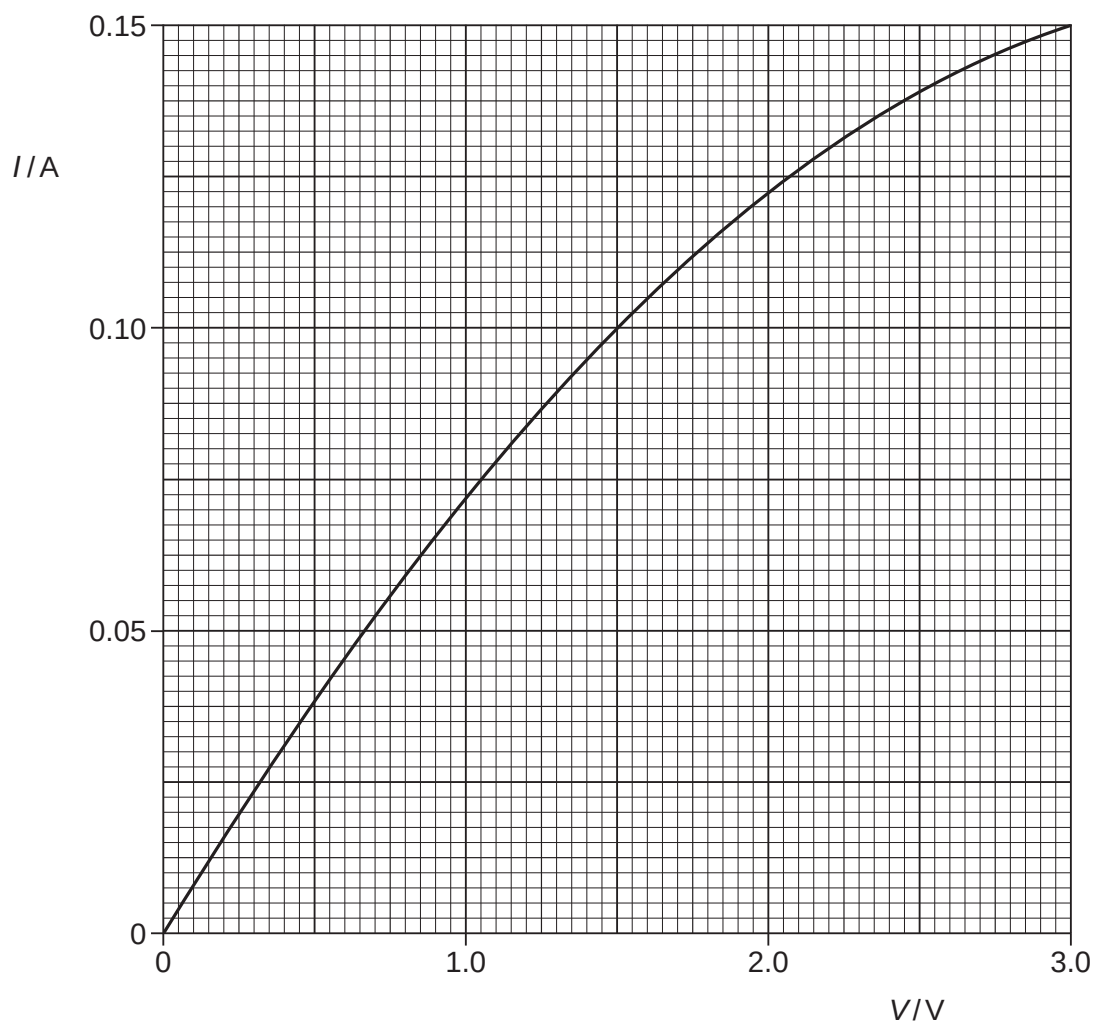


Fig. 6.1

Calculate the resistance of the lamp for a potential difference across the lamp of 1.5V.

For
Examiner's
Use

resistance = ... Ω [2]

- (c) Two lamps, each having the I - V characteristic shown in Fig. 6.1, are connected first in series and then in parallel with a battery of e.m.f. 3.0V and negligible internal resistance.

Complete the table of Fig. 6.2 for the lamps connected to the battery.

	p.d. across each lamp/V	resistance of each lamp/ Ω	combined resistance of lamps/ Ω
lamps connected in series			
lamps connected in parallel			

Fig. 6.2

[4]

- (d) (i) Use data from the completed Fig. 6.2 to calculate the ratio

$$\frac{\text{combined resistance of lamps connected in series}}{\text{combined resistance of lamps connected in parallel}}$$

ratio = ... [1]

- (ii) The ratios in (a) and (d)(i) are not equal.

By reference to Fig. 6.1, state and explain qualitatively the change in the resistance of a lamp as the potential difference is changed.

.....

 [3]

- 7 Tungsten-184 ($^{184}_{74}\text{W}$) and tungsten-185 ($^{185}_{74}\text{W}$) are two isotopes of tungsten.

Tungsten-184 is stable but tungsten-185 undergoes β -decay to form rhenium (Re).

- (a) Explain what is meant by *isotopes*.

.....

.....

.....

..... [2]

- (b) The β -decay of nuclei of tungsten-185 is spontaneous and random.

State what is meant by

- (i) *spontaneous* decay,

.....

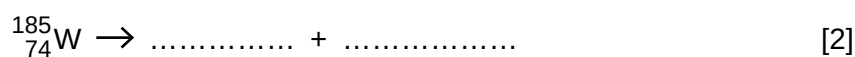
..... [1]

- (ii) *random* decay.

.....

..... [1]

- (c) Complete the nuclear equation for the β -decay of a tungsten-185 nucleus.



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