



EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY YEAR EXAMINATIONS 2025
General Certificate of Education Advanced Level
Higher 2

CANDIDATE
NAME

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CIVICS
GROUP

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REGISTRATION
NUMBER

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PHYSICS

9749/01

Multiple Choice Questions

September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected where appropriate.
Answer **all** questions.

There are **thirty** questions in this section.
For each question there are four possible answers **A, B, C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil**
on the separate Answer Sheet.

Each correct answer will score one mark.
A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **21** printed pages and **3** blank 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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
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,

$$W = p\Delta V$$

hydrostatic pressure,

$$p = \rho gh$$

gravitational potential,

$$\phi = -\frac{Gm}{r}$$

temperature,

$$T / \text{K} = T / ^\circ\text{C} + 273.15$$

pressure of an ideal gas,

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

mean translational kinetic energy of an ideal gas molecule

$$E = \frac{3}{2}kT$$

displacement of particle in s.h.m.

$$x = x_0 \sin \omega t$$

velocity of particle in s.h.m.

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

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

electric current,

$$I = Anvq$$

resistors in series,

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

resistors in parallel,

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

electric potential,

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current/voltage,

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long straight wire

$$B = \frac{\mu_0 I}{2\pi d}$$

magnetic flux density due to a flat circular coil

$$B = \frac{\mu_0 NI}{2r}$$

magnetic flux density due to a long solenoid

$$B = \mu_0 nI$$

radioactive decay,

$$x = x_0 \exp(-\lambda t)$$

decay constant

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

Section A – Multiple Choice Questions

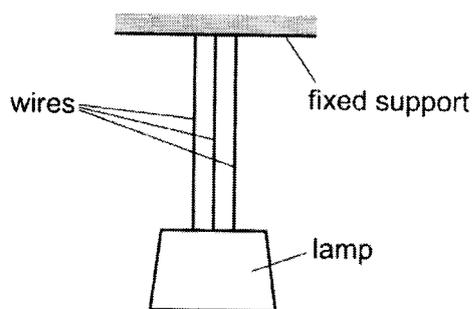
- 1 A copper pipe has a true diameter of 42.03 mm.
A builder measures the diameter of the pipe five times using digital calipers. The measurements are shown in the table.

diameter / mm
48.12
47.99
48.01
48.00
46.80

What describes the builder's measurements?

- A accurate and precise
B accurate but not precise
C not precise and not accurate
D precise but not accurate
- 2 A person, travelling on a motorway a total distance of 200 km, travels the first 90 km at an average speed of 80 km h^{-1} .
Which average speed must be obtained for the rest of the journey if the person is to reach the destination in a total time of 2 hours 0 minutes?
- A 110 km h^{-1} B 120 km h^{-1} C 122 km h^{-1} D 126 km h^{-1}

- 3 A lamp is suspended in equilibrium from a fixed support by three long identical wires.



The weight of the lamp causes each wire to have an extension of 0.40 cm. The height h of the lamp above the floor is measured.

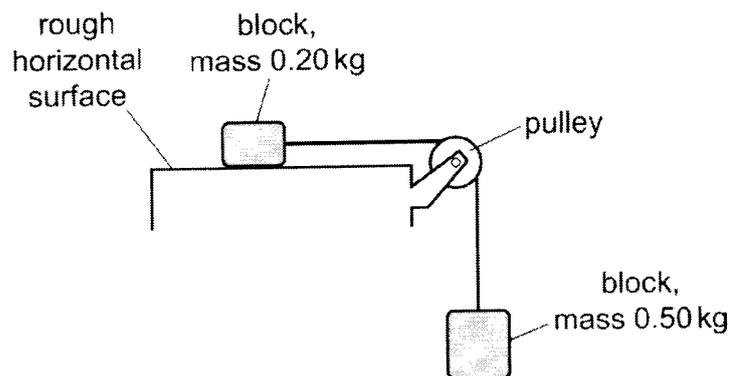
The middle wire suddenly breaks and the lamp falls a small distance as the extensions of the remaining two wires increase. The wires obey Hooke's law.

When the lamp is in equilibrium, the height h of the lamp above the floor is measured again.

What is the difference between the two values of h ?

- A 0.20 cm B 0.27 cm C 0.40 cm D 0.60 cm

- 4 Two blocks, of mass 0.20 kg and 0.50 kg, are connected by a light inextensible string that passes over a frictionless pulley.



The blocks are initially held stationary. The block of mass 0.20 kg rests on a rough horizontal surface.

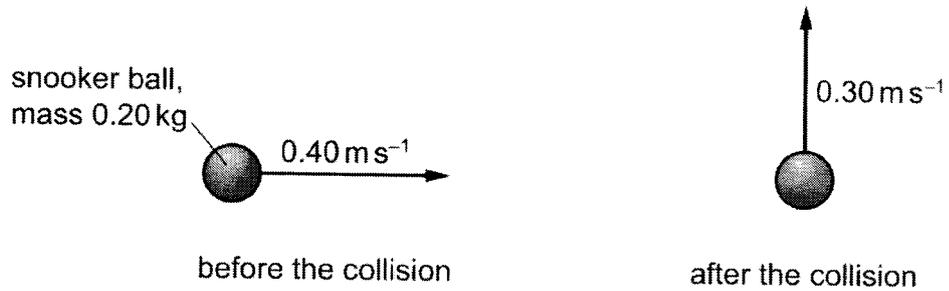
The block of mass 0.50 kg is suspended in air. Air resistance is negligible.

When the blocks are released, the kinetic frictional force between the block of mass 0.20 kg and the rough surface is 3.5 N.

What is the magnitude of the acceleration of the masses?

- A 2.0 m s^{-2}
- B 2.8 m s^{-2}
- C 3.9 m s^{-2}
- D 7.0 m s^{-2}

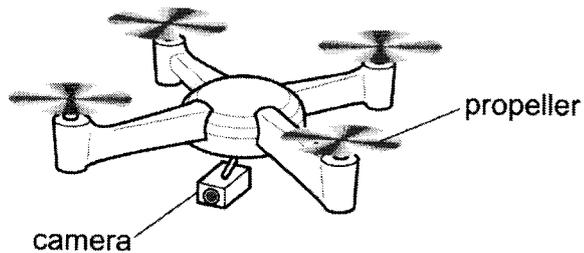
- 5 A snooker ball of mass 0.20 kg has a collision so that its direction of movement changes by an angle of 90° , as shown.



The ball has a speed of 0.40 m s^{-1} before the collision and a speed of 0.30 m s^{-1} after the collision.

What is the **magnitude** of the change in momentum of the snooker ball?

- A $0.020 \text{ kg m s}^{-1}$
 B 0.10 kg m s^{-1}
 C 0.14 kg m s^{-1}
 D 0.50 kg m s^{-1}
- 6 A camera drone of mass 1.20 kg hovers at a fixed point above the ground. The drone has four propellers.



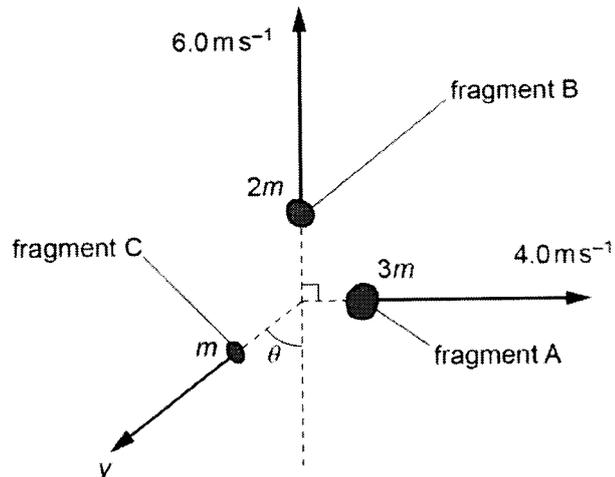
In a time of 1.00 s , each propeller pushes a mass of 0.400 kg of air vertically downwards.

Assume that the air above the propellers is stationary.

What is the speed of the air leaving each propeller?

- A 0.750 m s^{-1} B 3.00 m s^{-1} C 7.36 m s^{-1} D 29.4 m s^{-1}

- 7 A firework is initially stationary. It explodes into three fragments A, B and C that move in a horizontal plane, as shown in the view from above.



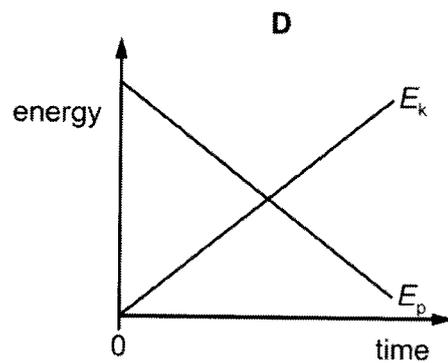
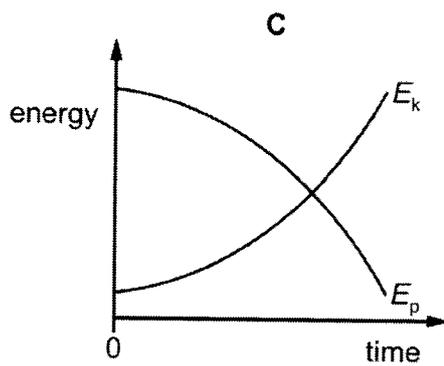
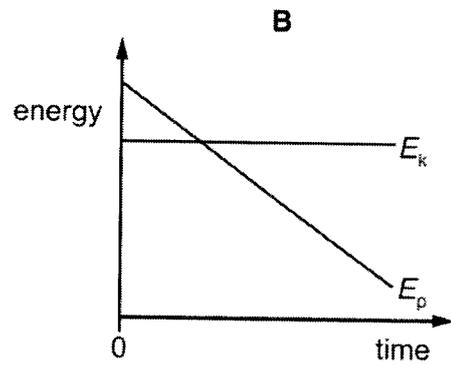
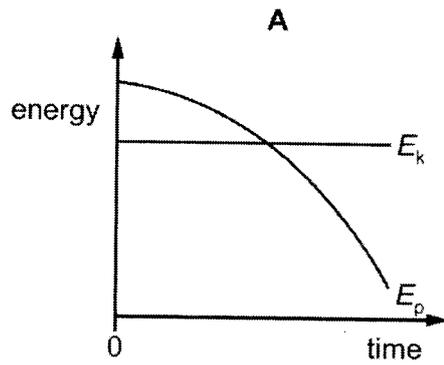
Fragment A has a mass of $3m$ and moves away from the explosion at a speed of 4.0 m s^{-1} .
 Fragment B has a mass of $2m$ and moves away from the explosion at a speed of 6.0 m s^{-1} at right angle to the direction of A.
 Fragment C has a mass of m and moves away from the explosion at a speed v and at an angle θ as shown.

What is the angle θ ?

- A** 30° **B** 45° **C** 60° **D** 70°

- 8 A steel ball is falling at constant speed in oil.

Which graph shows the variation with time of the gravitational potential energy E_p and the kinetic energy E_k of the ball?

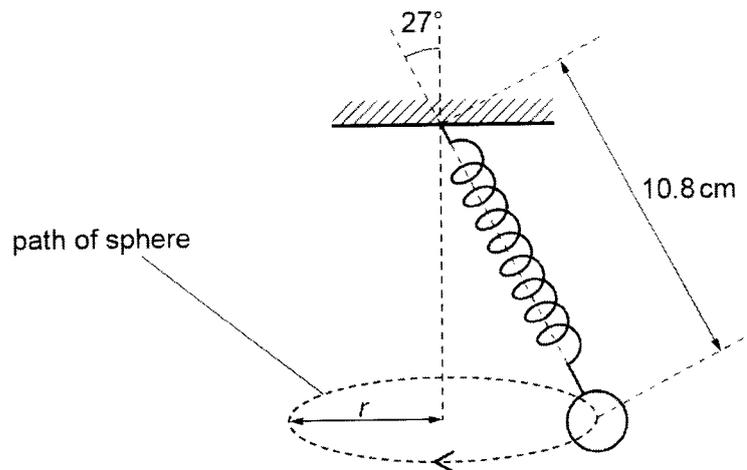


- 9 A vehicle of mass 1000 kg travels at a constant velocity of 6.5 m s^{-1} up a 45° incline. The input power to the engine of the car is 80 kW. The efficiency of the engine is 60%.

What is the resistive force on the car?

- A 450 N B 5400 N C 7400 N D 14 kN

- 10 A steel sphere is set in motion so that it is moving in a horizontal circle at constant speed with a radius r , as shown below.



The distance from the centre of the sphere to the top of the spring is 10.8 cm and the spring is tilted at 27° from the vertical.

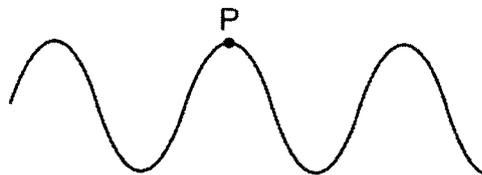
What is the period of the circular motion of the sphere?

- A 0.62 s
 B 7.9 s
 C 6.2 s
 D 79 s

- 11 Two satellites, A and B, orbiting around Earth have the same kinetic energy. Satellite A has a larger mass than satellite B. Which of the following statements is correct?
- A Satellite A has the same total energy as satellite B.
 - B Satellite A has a smaller orbital radius than satellite B.
 - C Satellite A has a smaller period than satellite B.
 - D Satellite A has a larger angular velocity than satellite B.
- 12 For the construction of a thermometer, what is an essential requirement of a thermometric substance?
- A It remains liquid over the entire range of temperatures to be measured.
 - B It has a property that varies linearly with temperature.
 - C It has a property that varies with temperature.
 - D It obeys the equation of state.

- 13 A transverse water wave has a frequency of 1.50 Hz, a wavelength of 0.240 m and an amplitude of 0.120 m.

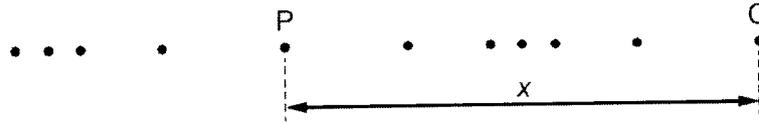
P is a water particle that is initially at the peak of the wave, as shown.



What is the total vertical distance travelled by P in a time of 0.75 s?

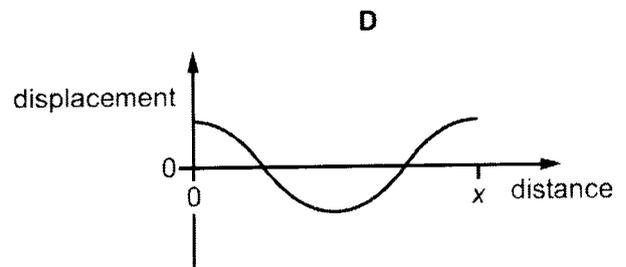
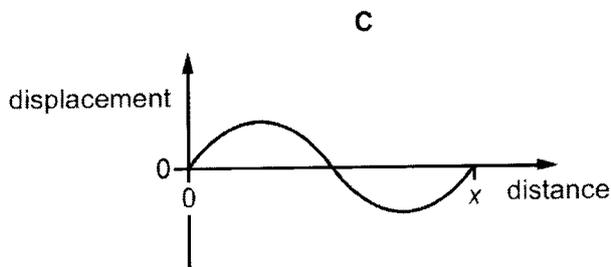
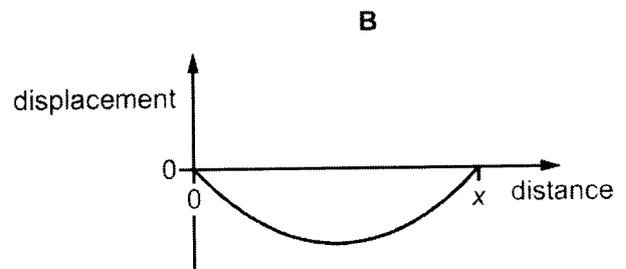
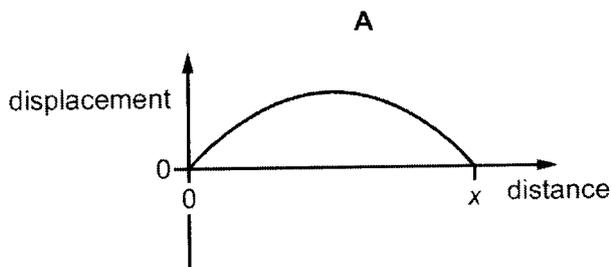
- A 35.1 mm B 84.9 mm C 325 mm D 515 mm

- 14 A progressive longitudinal sound wave moves through air. The diagram shows the positions of the air particles along part of the wave at one instant.



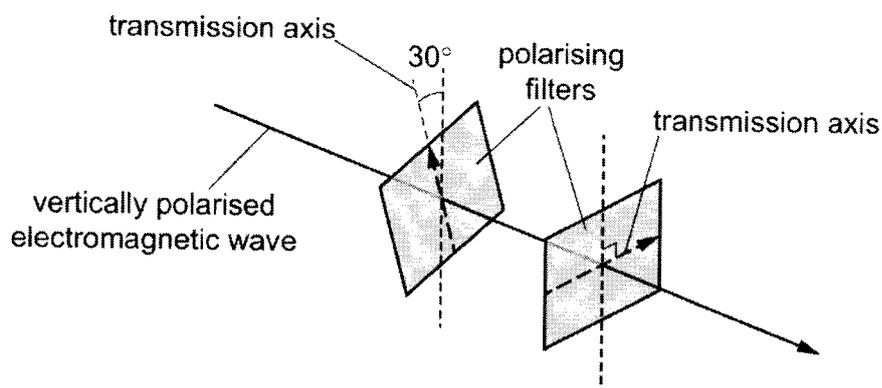
Point Q is a distance x from point P.

Which graph shows the variation of the displacement of the air particles with distance from P along the wave?



- 15 A vertically polarised electromagnetic wave of intensity I_0 is incident normally on a polarizing filter. The transmission axis of the filter is at an angle of 30° to the vertical.

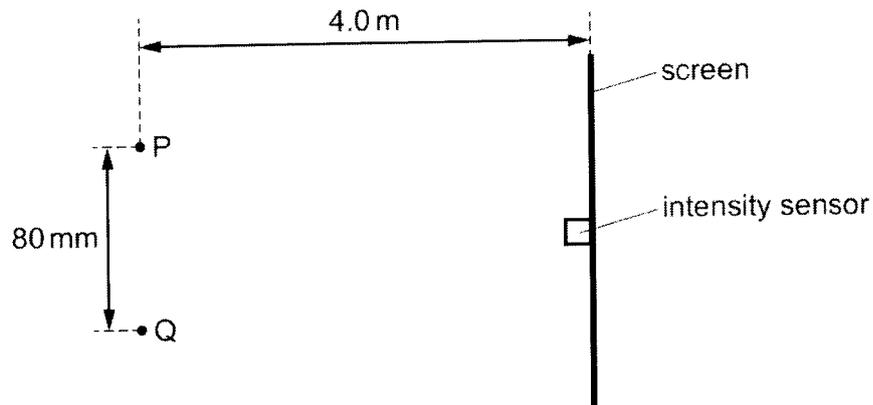
The transmitted wave from the first filter is then incident normally on a second polarising filter. The transmission axis of this filter is at an angle of 90° to the vertical.



What is the intensity of the wave after passing through the second filter?

- A 0 B $0.063 I_0$ C $0.19 I_0$ D $0.56 I_0$
- 16 Waves P and Q have the same amplitude. The waves meet in phase at point X and interfere to give a resultant wave with intensity I .
- The amplitude of wave P is doubled.
- What is the new intensity of the resultant wave at X, in terms of I ?
- A $0.44I$ B $1.5I$ C $2.3I$ D $3.0I$

- 17 A source of coherent light is incident on two slits, P and Q, which are placed 80 mm apart. The light has a single frequency of 1.5×10^{12} Hz. The light from the slits meets on a screen that is a distance of 4.0 m from the slits. The screen is parallel to a line joining the slits.



not to scale

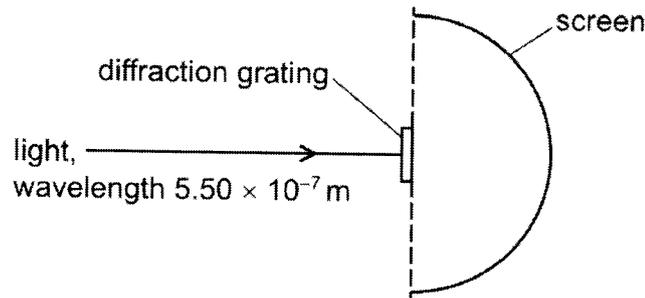
An intensity sensor is placed on the screen at the midpoint of the interference pattern such that the intensity reading is a maximum. The intensity sensor is moved along the screen.

The sensor travels through two intensity minima, two intensity maxima and stops in the middle of the third intensity minimum.

Which distance does the sensor move through?

- A 4.0 mm B 10 mm C 25 mm D 50 mm

- 18 Light of wavelength $5.50 \times 10^{-7} \text{ m}$ from a laser is incident normally on a diffraction grating. The diffracted light is incident on a semicircular screen, as shown in the view from above.



view from above

A total of 9 bright dots are formed on the screen.

The grating is at the centre of the semicircle. The lines of the grating are vertical. The separation between adjacent lines in the grating is d .

What is a possible value of d ?

- A** $2.25 \times 10^{-6} \text{ m}$ **B** $2.80 \times 10^{-6} \text{ m}$ **C** $4.40 \times 10^{-6} \text{ m}$ **D** $4.95 \times 10^{-6} \text{ m}$
- 19 A double star is at a distance of 20 light years from the Earth. A telescope with a diameter of 3.0 m is used to view the star.
- A light year is the distance light travels in a vacuum in one year.
- What is the approximate minimum separation between the two stars of the double star that can be detected by the telescope?
- A** $5.0 \times 10^8 \text{ m}$ **B** $1.0 \times 10^9 \text{ m}$ **C** $3.5 \times 10^{10} \text{ m}$ **D** $3.5 \times 10^{11} \text{ m}$

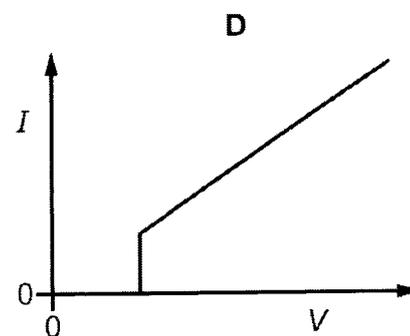
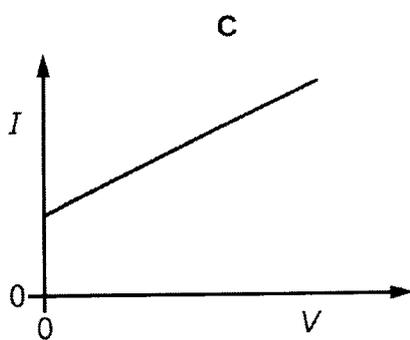
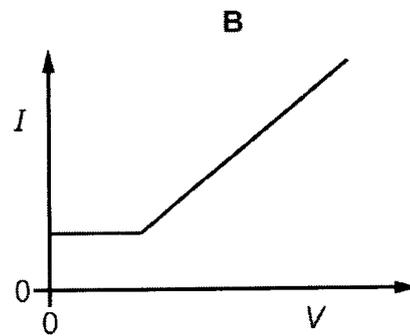
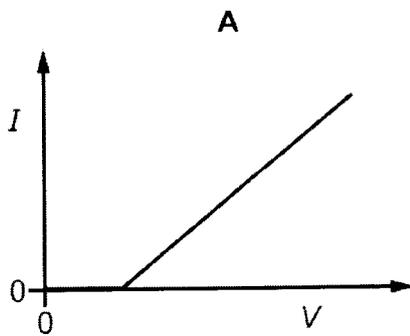
- 20 A long wire of radius 1.5 mm and length 2.0 m carries a steady current 5.0 A. There are approximately 1.5×10^{24} mobile electrons in the wire.

What is the drift velocity of the electrons in the wire?

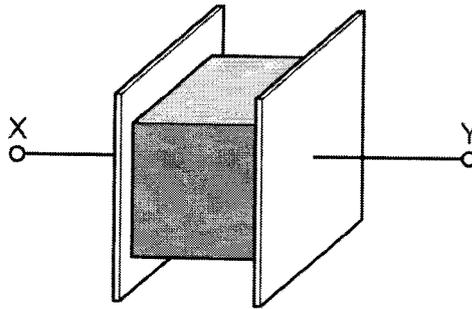
- A $4.2 \times 10^{-5} \text{ m s}^{-1}$ B $7.2 \times 10^{-5} \text{ m s}^{-1}$ C $7.2 \times 10^{-3} \text{ m s}^{-1}$ D 2.9 m s^{-1}

- 21 A fixed resistor and a diode are combined by connecting them in series. The total potential difference V across the combination is varied and the corresponding current I is measured.

Which graph could represent the variation of I with V ?



- 22 The resistance of a metal cube is measured by placing it between two parallel plates, as shown.

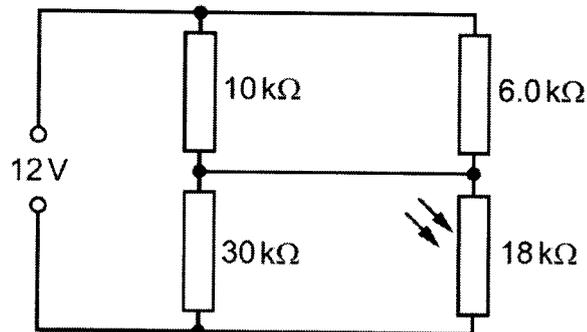


The cube has volume V and is made of a material with resistivity ρ . The connections to the cube have negligible resistance.

Which expression gives the electrical resistance of the metal cube between X and Y?

- A $\rho V^{\frac{1}{3}}$ B $\rho V^{\frac{2}{3}}$ C $\frac{\rho}{V^{\frac{1}{3}}}$ D $\frac{\rho}{V^{\frac{2}{3}}}$

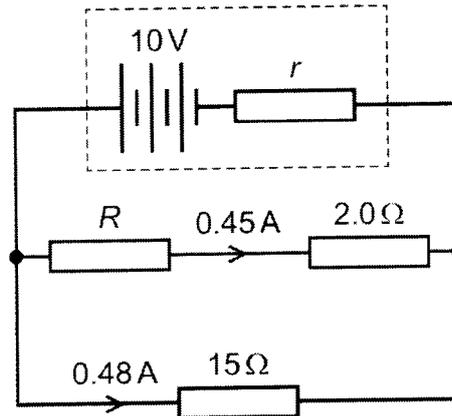
- 23 The diagram shows a circuit with a light-dependent resistor (LDR).



What is the effective resistance of the circuit?

- A 15 kΩ B 24 kΩ C 40 kΩ D 64 kΩ

- 24 A battery of electromotive force (e.m.f.) 10 V and internal resistance r is connected to three resistors of resistances R , 2.0Ω and 15Ω , as shown. A current of 0.45 A is in the resistor of resistance 2.0Ω and a current of 0.48 A is in the resistor of resistance 15Ω .

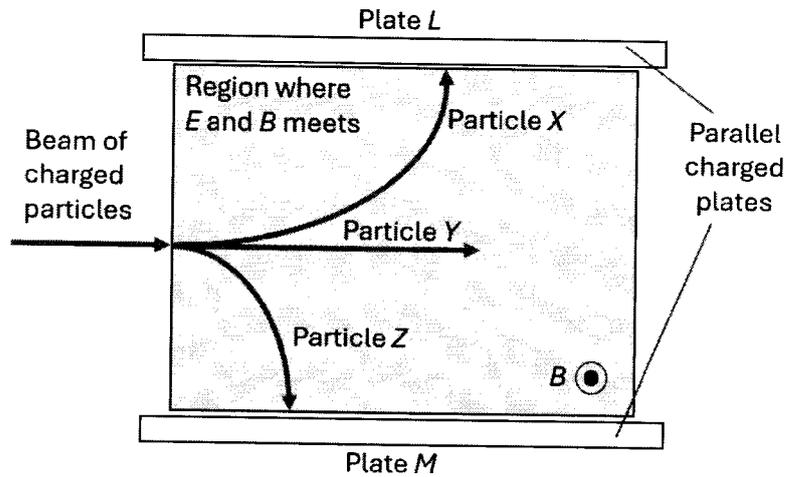


What are the values of r and R ?

	r/Ω	R/Ω
A	3.0	14
B	3.0	20
C	5.8	14
D	5.8	20

- 25 A beam of charged particles enters a region where a uniform electric field E setup by Plate L and Plate M is perpendicular to a uniform magnetic field B . Magnetic field B is directed out of the paper. The particles enter this region horizontally from the left.

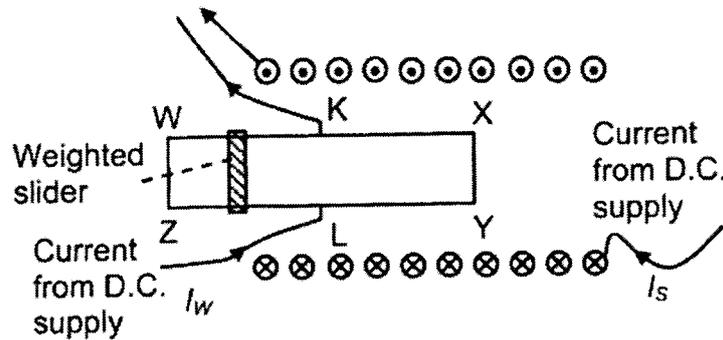
The path of particle X , Y and Z are illustrated in the diagram below.



Which of the statement can be concluded from the observation?

- A The velocity of particle Y is larger than $\frac{E}{B}$.
- B Plate L has a lower potential than plate M .
- C Particle X , Y and Z have the same polarity.
- D Particle Z has a larger mass than particle X and Y .

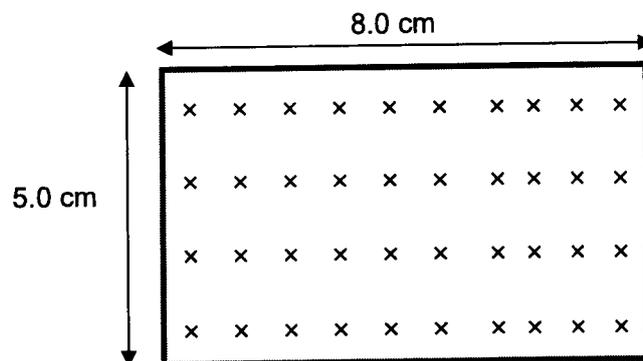
- 26 The figure below (not drawn to scale) shows the plan view of a weightless wire frame WXYZ being supported by two knife-edge at K and L. A current I_w flows through the frame. Section KXYL of the frame is placed inside a solenoid. A current of I_s flows through the coils of the solenoid. The wire frame is balanced in a horizontal position with a weighted slider.



Current I_s is increased.

Which of the following will enable the wire frame to be balanced in a horizontal position again.

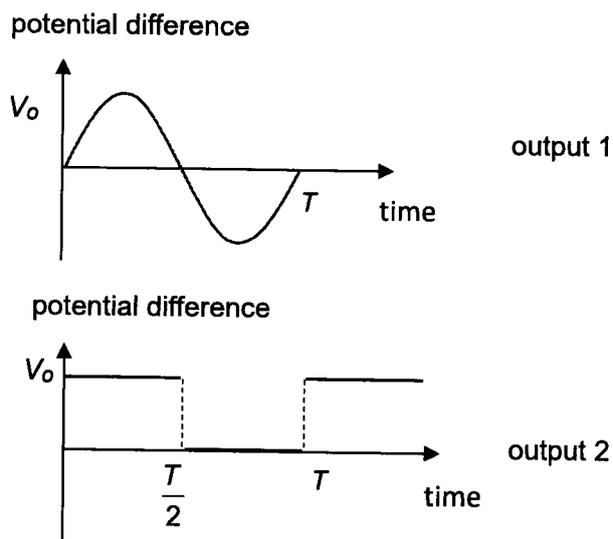
- A Increase the current I_w .
 - B Reverse the direction of current I_w .
 - C Move the weighted slider closer to WZ.
 - D Increase the number of turns on the solenoid.
- 27 A rectangular coil of length 5.0 cm and breadth 8.0 cm consists of 50 turns. It is placed in a uniform magnetic field of flux density 0.40 T such that the plane of the coil is perpendicular to the magnetic field and is directed into the page. The magnetic field is then uniformly reduced to zero in 0.20 s.



Which statement correctly describes the magnitude of the induced electromotive force (e.m.f.) and the direction of the induced current in the coil?

- A Induced e.m.f. of 0.40 V and direction of current is clockwise
- B Induced e.m.f. of 0.40 V and direction of current is anti-clockwise
- C Induced e.m.f. of 0.80 V and direction of current is clockwise
- D Induced e.m.f. of 0.80 V and direction of current is anti-clockwise

- 28 The outputs from the two sources are shown in the graphs below.



What is the ratio of $\frac{\text{root mean squared voltage from output 1}}{\text{root mean squared voltage from output 2}}$?

- A** 0.50 **B** 0.71 **C** 1 **D** 2
- 29 Which of the following explains why there are no X-ray frequencies in the line spectrum of hydrogen?
- A** Hydrogen nuclei do not contain neutrons.
B Hydrogen cannot be raised to a sufficiently high temperature.
C The cut-off frequency cannot be reached.
D The ionisation energy of a hydrogen atom is too low.
- 30 Which statement regarding alpha-particle scattering experiment can be concluded?
- A** Protons and electrons have equal but opposite charges.
B Protons have a much larger mass than electrons.
C The nucleus contains most of the mass of the atom.
D The nucleus of an atom contains protons and neutrons.

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PHYSICS
 Structured Questions

9749/02

September 2025

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
 The use of an approved scientific calculator is expected where appropriate.
 Answer **all** questions.

Write in dark blue or black pen on both sides of the paper.
 You may use an HB pencil for any diagrams or graphs.
 Do not use paper clips, highlighters, glue or correction fluid.
 The number of marks is given in brackets [] at the end of each question
 or part question.

For Examiner's Use	
Q1	6
Q2	11
Q3	5
Q4	7
Q5	9
Q6	8
Q7	6
Q8	8
Q9	20
s.f.	
P2 Total	80

This document consists of **24** 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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
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,	$m_p = 1.67 \times 10^{-27} \text{ kg}$
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the Avogadro constant,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
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Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature,	$T / K = T / ^\circ\text{C} + 273.15$
pressure of an ideal gas,	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

- 1 A student proposes that the speed v of a sound wave through a gas of pressure P and density ρ is given by the equation

$$v = \sqrt{\frac{kP}{3\rho}}$$

where k is a constant with no unit.

An experiment is performed to determine the value of k . The data from the experiment are shown in Table 1.1.

Table 1.1

quantity	value	
v	$3.3 \times 10^2 \text{ m s}^{-1}$	percentage uncertainty = $\pm 8\%$
P	$9.9 \times 10^4 \text{ Pa}$	fractional uncertainty = ± 0.07
ρ	1.29 kg m^{-3}	absolute uncertainty = 0.09 kg m^{-3}

- (a) Use data from Table 1.1 to calculate k .

$$k = \dots\dots\dots [1]$$

- (b) Use your answer in (a) and data from Table 1.1 to determine the value of k , with its absolute uncertainty, to an appropriate number of significant figures.

$$k = \dots\dots\dots \pm \dots\dots\dots [3]$$

- (c) It is proposed in that in the presence of wind, the actual speed u of the sound wave of frequency f is

$$u = v + fA$$

Derive the unit for A .

unit = [2]

[Total: 6]

- 2 (a) An Olympic diver stands on a platform above a pool of water, as shown in Fig. 2.1.

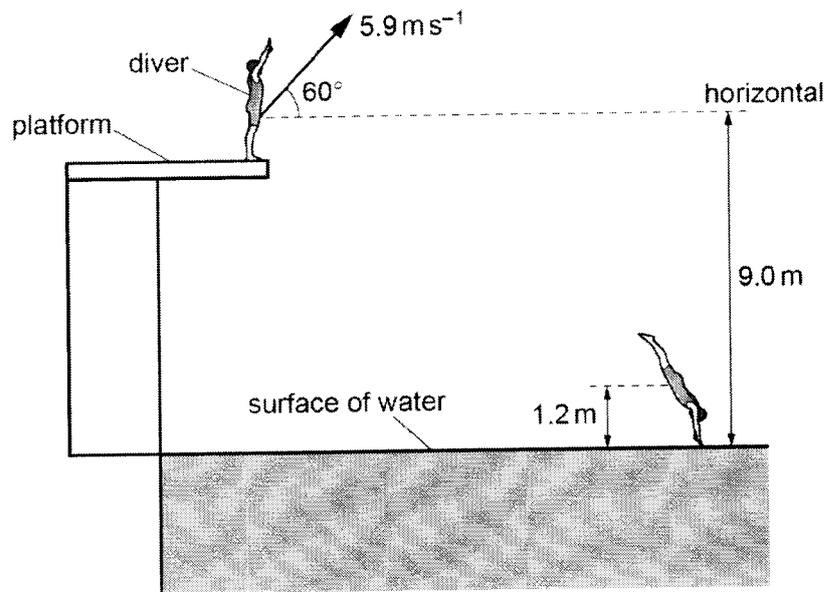


Fig. 2.1 (not to scale)

When the diver is on the platform his centre of gravity is a vertical height of 9.0 m above the surface of the water. The diver jumps from the platform with a velocity of 5.9 m s^{-1} at an angle of 60° to the horizontal.

Air resistance is negligible.

When the diver hits the surface of the water, his centre of gravity is a vertical height of 1.2 m above the surface of the water.

- (i) Calculate the time it takes him to hit the surface of the water.

time = s [2]

- (ii) Calculate the angle from the water surface when he hits the surface of the water.

angle = ° [3]

- (b) The diver in (a) enters the water.

- (i) Explain the why the resultant force acting on the diver in decreases in the water as he moves downwards.

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

- (ii) The diver has a volume of $7.5 \times 10^{-2} \text{ m}^3$. The density of the water is $1.0 \times 10^3 \text{ kg m}^{-3}$.

Show that the upthrust acting on the diver when he is entirely underwater is 740 N.

[1]

- (iii) At a particular instant when the diver is entirely underwater his horizontal velocity is zero. The viscous drag force acting on him at this instant is 950 N vertically upwards. The diver has a mass of 78 kg.

Determine the magnitude and direction of the acceleration of the diver.

acceleration = m s^{-2}

direction

[3]

[Total: 11]

3 (a) State the principle of moments.

.....

 [2]

(b) A uniform rod of weight 1000 N rests at angle of 30° to the ground. It is in equilibrium when supported by tension T which acts 47° from the horizontal, as shown in Fig. 3.1.

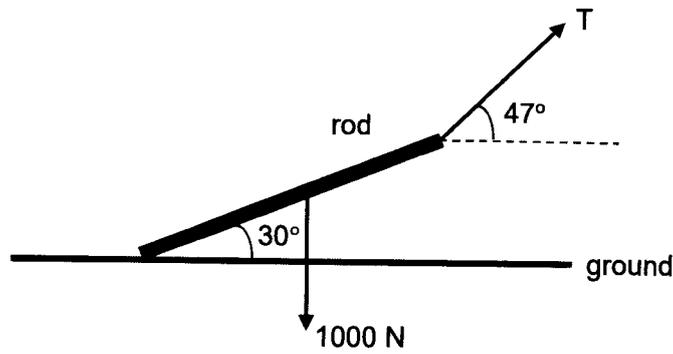


Fig. 3.1

Calculate the tension T .

$T = \dots\dots\dots$ N [3]

[Total: 5]

[Turn over

- 4 In Fig. 4.1 below, a trolley of mass 0.50 kg moves with a velocity 2.0 m s^{-1} towards a stationary pendulum bob of mass 0.20 kg , which is hung on a light string at a distance of 1.5 m from the ceiling. The trolley collides elastically with the pendulum bob and the pendulum bob then swings upwards.

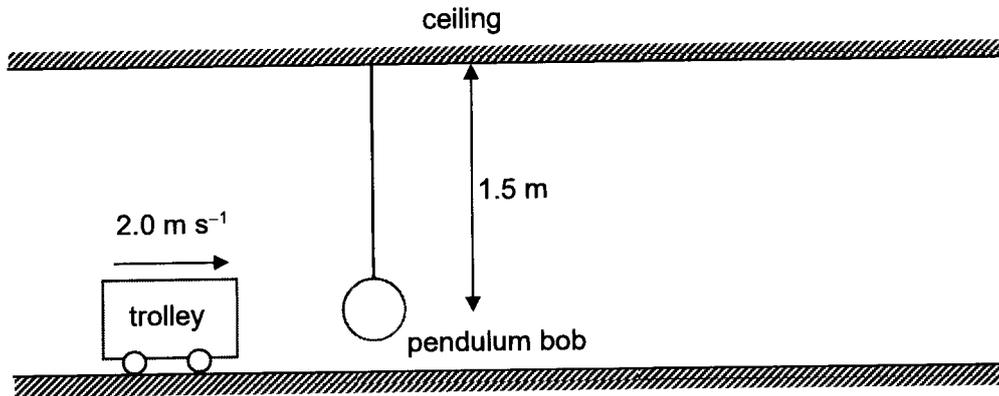


Fig. 4.1

- (a) Calculate the speed of the pendulum bob immediately after the collision.

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

- (b) Calculate the maximum angle, measured from the vertical, through which the pendulum bob swings.

maximum angle = ° [3]

- (c) Use the principle of conservation of linear momentum to explain why the momentum of the bob is not conserved as it swings upwards after the collision.

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

[Total: 7]

5 (a) State what is meant by *angular velocity*.

.....
 [1]

(b) A spring is used to project a toy car along a track from point X, round a vertical loop, to point Y, as illustrated in Fig. 5.1.

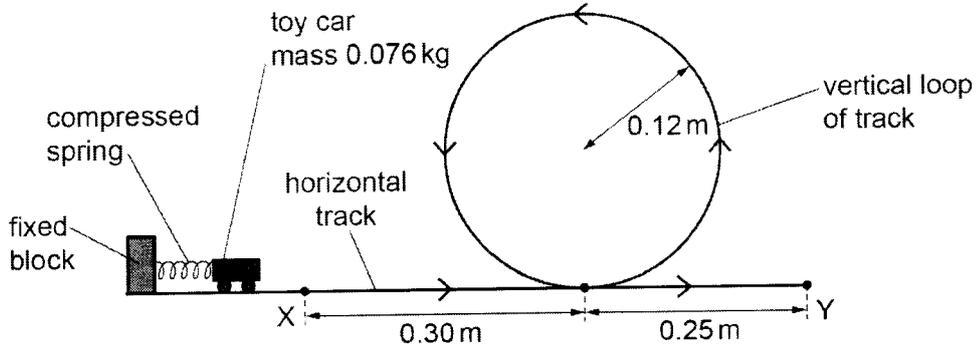


Fig. 5.1

The spring is initially given a compression of 16 cm. The car of mass 0.076 kg is held against one end of the compressed spring. When the spring is released, it projects the car forward. The car leaves the spring at point X with kinetic energy that is equal to the initial elastic potential energy of the compressed spring.

Assume that friction and air resistance are negligible.

(i) Calculate the minimum speed needed at the top of the circular path so that the toy car does not fall off the track.

minimum speed = m s⁻¹ [3]

- (ii) Calculate the value of the spring constant needed for the toy car to have the speed found in (b)(i) when it is at the top of the path.

spring constant = N m⁻¹ [3]

- (c) In practice, a resistive force due to friction and air resistance acts on the car so that its kinetic energy at Y is 0.23 J less than its kinetic energy at X.

Determine the average resistive force acting on the car for its movement from X to Y.

average resistive force = N [2]

[Total: 9]

- 6 A sphere of mass 1.6×10^{-10} kg has a charge of $+0.27$ nC. The sphere is in a uniform electric field that acts vertically upwards, as shown in the side view in Fig. 6.1.

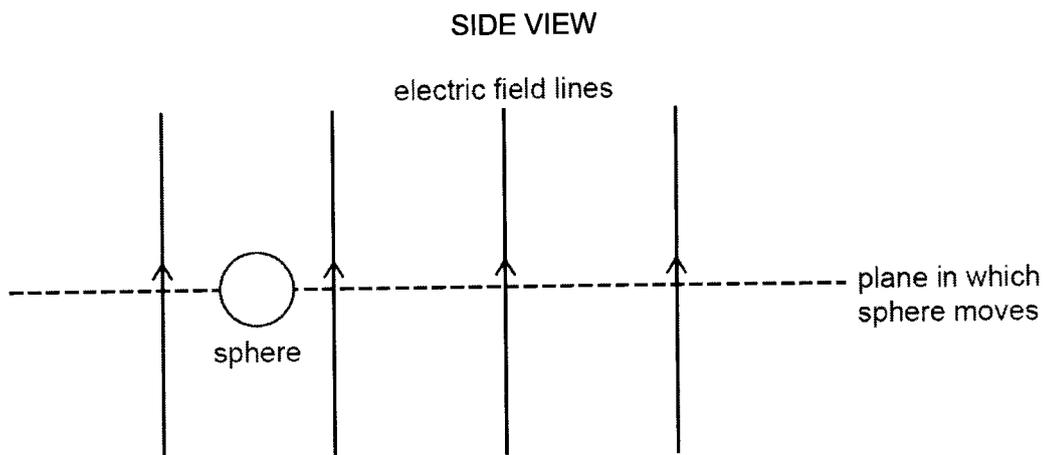


Fig. 6.1

The force exerted on the sphere by the electric field causes the sphere to remain at a fixed vertical height in a horizontal plane.

There is a uniform magnetic field in the region of the electric field. The sphere moves at a speed of 0.78 m s^{-1} in the horizontal plane. The magnetic field causes the sphere to move in a circular path of radius 3.4 m , as shown in the view from above in Fig. 6.2.

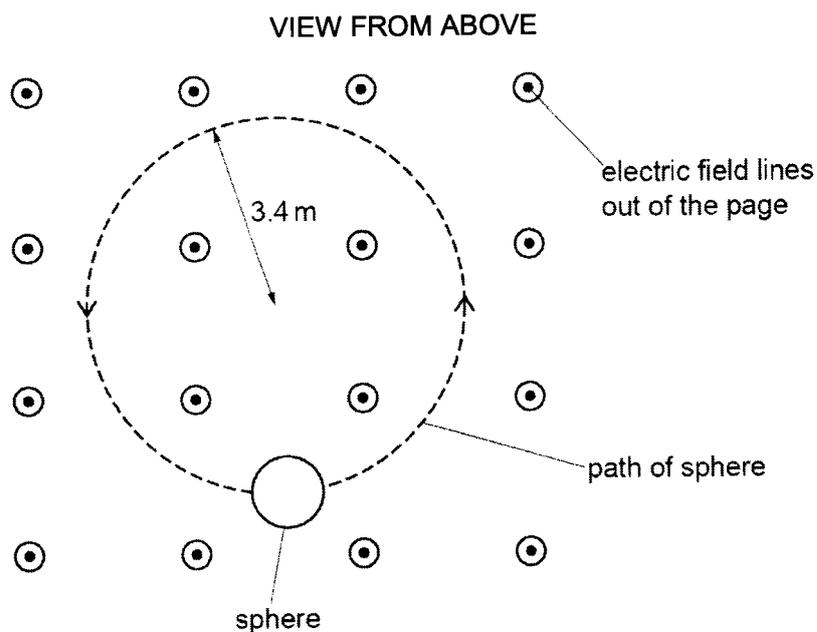


Fig. 6.2

(a) (i) State the direction of the uniform magnetic field from the SIDE VIEW in Fig. 6.1.

..... [1]

(ii) Explain why the sphere moves at constant speed in the circular path.

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

(b) Calculate the strength of the uniform electric field.

electric field strength = N C^{-1} [2]

(c) By considering the magnetic force on the sphere, show that the flux density of the uniform magnetic field is 0.14 T.

[3]

[Total: 8]

7 Fig. 7.1 shows the lowest four energy levels of an electron in an isolated atom.

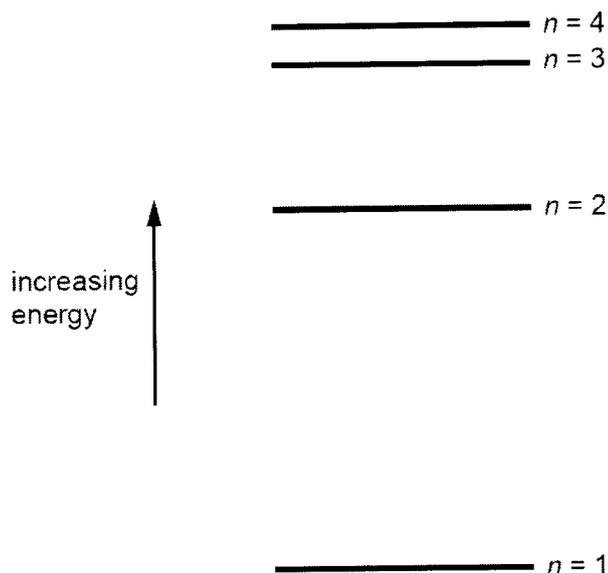


Fig. 7.1 (drawn to scale)

Fig. 7.2 shows the lines in the emission spectrum of the atom that correspond to the transitions of the electron from $n = 3$ to $n = 1$ and from $n = 4$ to $n = 1$.

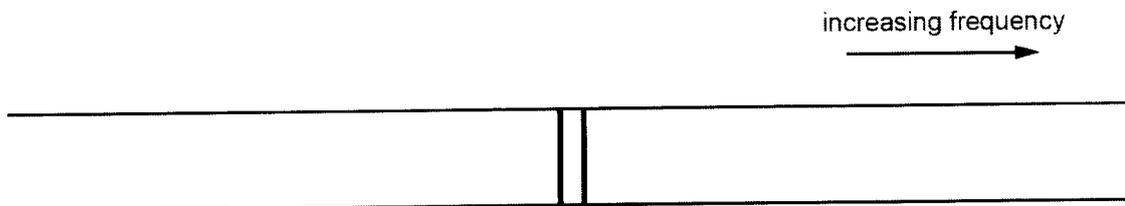


Fig. 7.2

(a) Explain, with reference to photons, why there is a single frequency of electromagnetic radiation that corresponds to each of these transitions.

.....

 [2]

(b) (i) On Fig. 7.2, draw a line that corresponds to the transition of the electron from $n = 2$ to $n = 1$.

Label this line A. [1]

(ii) On Fig. 7.2, draw a line that corresponds to the transition of the electron from $n = 3$ to $n = 2$.

Label this line B. [1]

- (c) The frequency of radiation represented by line A is f_A .
The frequency of radiation represented by line B is f_B .
The energy of the ground state ($n = 1$) is E_1 .

Determine an expression, in terms of f_A , f_B , E_1 and the Planck constant h , for the energy E_3 of the energy level $n = 3$.

$$E_3 = \dots\dots\dots [2]$$

[Total: 6]

- 8 The maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is determined for different wavelengths λ of the electromagnetic radiation incident on the surface.

The variation with $\frac{1}{\lambda}$ of E_{MAX} is shown in Fig. 8.1.

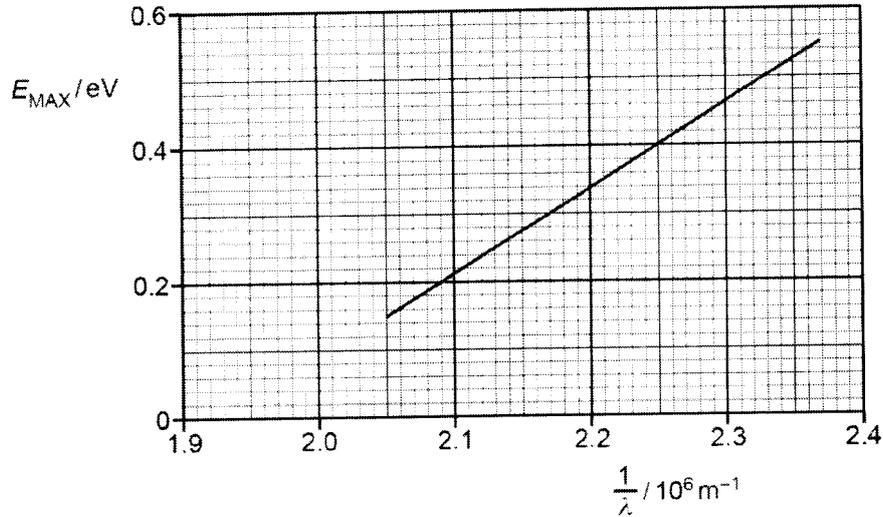


Fig. 8.1

- (a) Use the gradient of the line on Fig. 8.1 to determine a value for the Planck constant h .

Explain your working.

$h = \dots\dots\dots \text{ J s [3]}$

- (b) The electromagnetic radiation is now incident on a metal with a larger work function energy than the metal in (a).

On Fig. 8.1, sketch the variation with $\frac{1}{\lambda}$ of E_{MAX} . Label this line X. [1]

- (c) The work function energy in eV for some metals is given in Table 8.1.

Table 8.1

metal	work function / eV
tungsten	4.49
magnesium	3.68
potassium	2.40

Determine the metal used in the experiment. Show your working.

.....
 [3]

- (d) The intensity of the electromagnetic radiation for one particular frequency is increased. State and explain the change, if any, in the rate of emission of photoelectrons.

.....
 [1]

[Total: 8]

- 9 In 2022, the European Space Agency (ESA) launched the Solar Orbiter, a spacecraft designed to study the Sun's surface and its radiation. The spacecraft operates in an elliptical orbit, with its closest approach (perihelion) at 0.28 AU (1 AU = 1.5×10^{11} m) from the Sun on 15 March 2023. The Solar Orbiter observed a significant solar flare, during which its distance from the Sun varied slightly, affecting the power received by its solar panels.

The Sun emits electromagnetic waves where the power output is approximately 3.8×10^{26} W from these waves, excluding other high-energy particles. The Solar Orbiter's solar panels capture this radiation to power its instruments, with the power received depending on the intensity, panel area, and efficiency.

Radiation pressure P_r due to electromagnetic waves is given by:

$$P_r = \left(\frac{I}{c} + R \right)$$

where I is the intensity, c is the speed of light and R is the reflectivity. $R = 0$ for perfect absorption and $R = 1$ for perfect reflection.

The Sun also emits high-energy particles, including alpha particles from nuclear fusion, contributing to radiation pressure on the spacecraft.

The Solar Orbiter's radiation detector measures alpha particle flux from short-lived isotopes produced in solar flares, such as Nitrogen-13, which undergoes alpha decay with a half-life of 20 minutes and beta-plus decay with a half-life of 10 minutes. Beta-plus decay is a process where a proton in a nucleus transforms into a neutron, releasing a positron ${}^0_{+1}e$ and a neutrino. For a given sample size, the probability of an alpha decay is 1% and beta-plus decay is 99%.

During the solar flare, the Solar Orbiter's distance from the Sun varied from 0.28 AU to 0.30 AU over 10 hours due to its orbital motion. Data for the Solar Orbiter is provided in Table 9.1.

Table 9.1

parameter	value
distance from Sun	0.28 AU
solar panel area	6.5 m ²
efficiency of solar panels	28%
radiation detector sensitivity	1.2×10^4 counts s ⁻¹ GBq ⁻¹

Table 9.2 shows the percentage contribution of radiation pressure at perihelion.

Table 9.2

source	percentage contribution (%)
electromagnetic waves	99.8
alpha particles	0.15
other particles (Beta, Protons)	0.050

- (a) (i) Show that the intensity of solar radiation at the Solar Orbiter's perihelion due to electromagnetic waves is $1.7 \times 10^4 \text{ W m}^{-2}$.

intensity = W m^{-2} [2]

- (ii) Determine the power output by the Solar Orbiter's solar panels at perihelion due to electromagnetic waves, accounting for their efficiency. Assume that there is perfect absorption.

power output = W [2]

- (b) Radiation pressure is the force per unit area from momentum transfer by electromagnetic waves or particles.

- (i) Show that the radiation pressure exerted by alpha particles on the Solar Orbiter's solar panels at perihelion is $8.5 \times 10^{-8} \text{ Pa}$. Assume that there is perfect absorption.

[1]

- (ii) Show that kinetic energy

$$E_k = \frac{p^2}{2m}$$

where p and m refer to the momentum and mass respectively.

[2]

- (iii) Alpha particles from solar flares typically have energies of 5.0 MeV upon reaching the Solar Orbiter's solar panels. Use the value in **(b)(i)** and the expression in **(b)(ii)**, determine the rate at which alpha particles are incident on the panels.

rate = particles s⁻¹ [3]

- (c) At one point in time, the radiation detector measures a count rate of 3.6×10^5 counts s^{-1} due to Nitrogen-13 decay during a solar flare. Calculate the activity of the Nitrogen-13 source in GBq.

activity = GBq [2]

- (d) A sample of 2.2×10^{-11} kg of Nitrogen-13 is collected for a study.

- (i) Calculate the decay constants λ_α and λ_β of Nitrogen-13 undergoing alpha decay and beta decay respectively.

$\lambda_\alpha = \dots \text{min}^{-1}$ [1]

$\lambda_\beta = \dots \text{min}^{-1}$ [1]

- (ii) Show that the effective decay constant λ_{eff} of Nitrogen-13 is $6.9 \times 10^{-2} \text{min}^{-1}$. [1]

- (iii) Using the value in (d)(ii), calculate the number of Nitrogen-13 nuclei remaining after 15 minutes.

number of nuclei = [3]

- (iv) $^{13}_7\text{N}$ decays to form a stable isotope $^{13}_6\text{C}$. Write the nuclear equation for this decay process.

..... [1]

- (e) Suggest why the Solar Orbiter's power output from its solar panels varies significantly during its orbit around the Sun.

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

[Total: 20]



CANDIDATE
 NAME

CIVICS
 GROUP

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REGISTRATION
 NUMBER

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PHYSICS

Longer Structured Questions

9749/03

September 2025

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
 The use of an approved scientific calculator is expected where appropriate.

Section A

Answer **all** questions.

Section B

Answer **one** question only.

Write in dark blue or black pen on both sides of the paper.
 You may use an HB pencil for any diagrams or graphs.
 Do not use paper clips, highlighters, glue or correction fluid.
 The number of marks is given in brackets [] at the end of each question
 or part question.

For Examiner's Use	
Section A	
Q1	13
Q2	12
Q3	9
Q4	15
Q5	11
Section B	
Q6	20
Q7	20
s.f.	
P3 Total	80

This document consists of **25** printed pages and **3** blank 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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
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,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
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magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer all the questions in this section in the spaces provided.

- 1 A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 1.1.

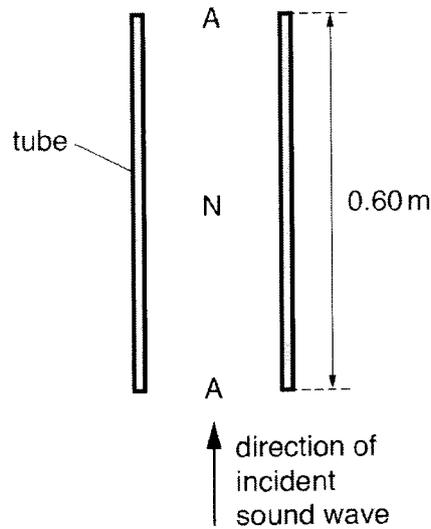


Fig. 1.1

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

- (a) Explain how the stationary wave is formed from the incident sound wave.

.....

.....

.....

.....

.....

..... [3]

- (b) (i) On Fig. 1.2, sketch a graph to show the variation of the amplitude of the stationary wave with height h above the bottom of the tube.

[2]

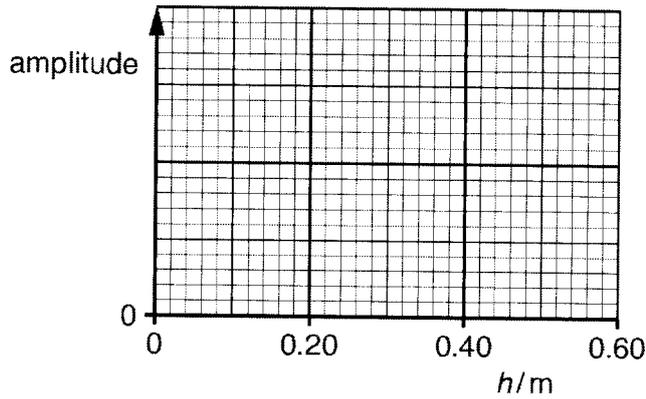


Fig. 1.2

- (ii) On Fig. 1.3, sketch a graph to show the variation of the intensity of the stationary wave with height h above the bottom of the tube.

[1]

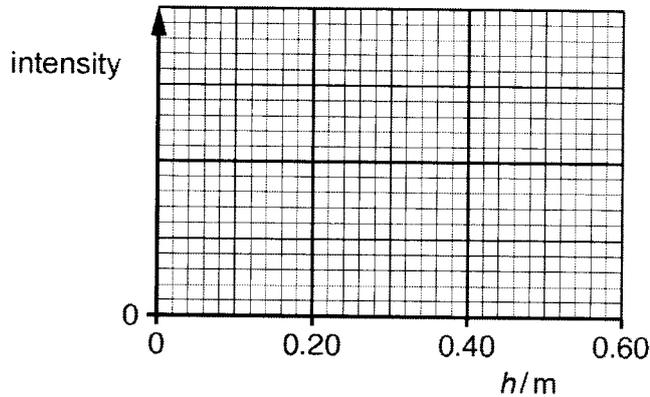


Fig. 1.3

- (c) For the stationary wave, state:

- (i) the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube.

..... [1]

- (ii) the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ° [1]

- (iii) the phase difference between the oscillations of a particle at the top of the tube and a particle at the bottom of the tube.

phase difference = ° [1]

- (d) The speed of the sound wave is 340 m s^{-1} .

Calculate the frequency of the sound wave.

frequency = Hz [2]

- (e) The frequency of the sound wave is gradually increased until a stationary wave is next formed.

- (i) Determine the frequency of this stationary wave.

frequency = Hz [1]

- (ii) The microphone is initially placed at the bottom of the tube and moved upwards.

Determine the shortest distance from bottom of the tube when the microphone detects a displacement node.

distance = m [1]

[Total: 13]

2 (a) A piece of resistance wire PQ of length 120 cm and diameter 1.1 mm has resistivity $1.1 \times 10^{-6} \Omega \text{ m}$.

(i) Show that the resistance of the wire PQ is 1.4Ω .

[1]

(ii) Wire PQ is now connected to a circuit as shown in Fig. 2.1 below. A voltmeter is connected to point X and Y, where X is the mid-point between PQ.

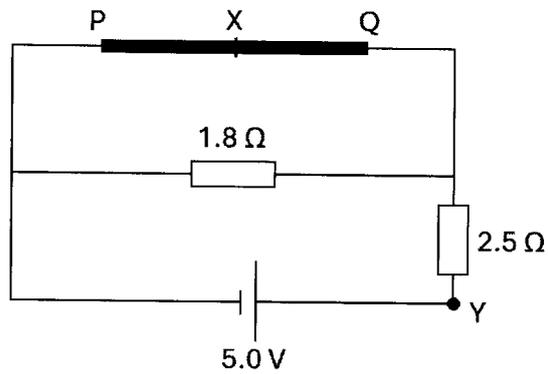


Fig. 2.1

Determine the reading on the voltmeter.

voltmeter reading = V [3]

- (b) Two long straight parallel wires A and B carrying currents I_A and I_B respectively are positioned 5.0 cm apart as shown in Fig. 2.2. Currents I_A and I_B are directed along the same direction.

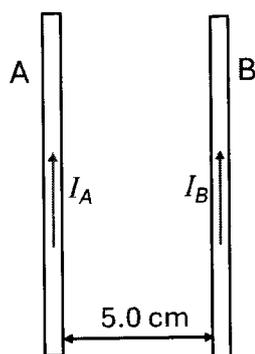


Fig. 2.2

- (i) Explain why the two wires are attracted to one another.

.....

 [2]

- (ii) The currents are now replaced with alternating currents.

I_A is represented by the equation:

$$I_A = -3.0 \cos(200\pi t)$$

I_B is represented by the graph shown in Fig. 2.3.

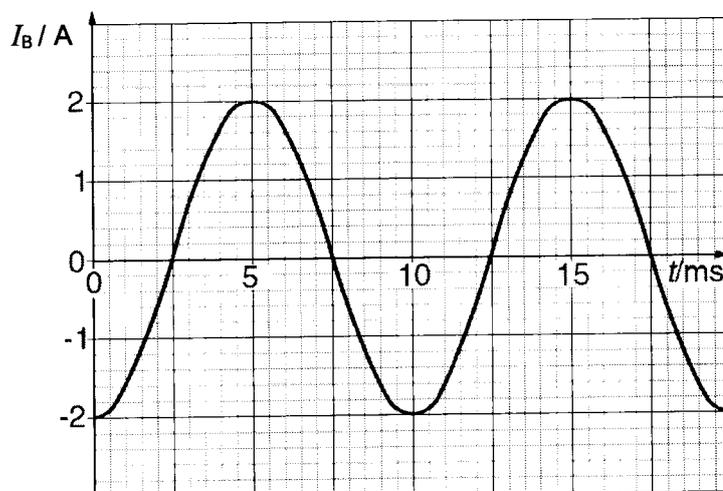


Fig. 2.3

1. Determine the instantaneous force per unit length acting on wire A when $t = 6.5$ ms.

force per unit length = N m^{-1} [3]

2. A diode is connected in series to wire A such it is reversed biased.

Sketch in in Fig. 3.2 the graph of the attractive force per unit length acting on wire A against time t from $t = 0$ ms to $t = 15$ ms. Numerical value of the force per unit length is not required.

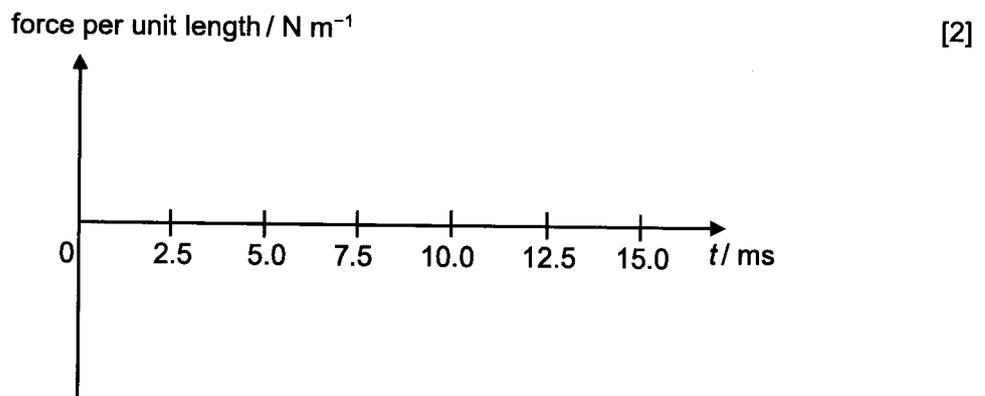


Fig. 3.2

3. The diode in (b)(ii)2. remains connected.

Determine the mean power dissipated across wire A given that the resistance of wire A is 15Ω .

mean power = W [1]

[Total: 12]

- 3 (a) The variation with pressure p of the volume V of a fixed mass of an ideal gas is shown in Fig. 3.1.

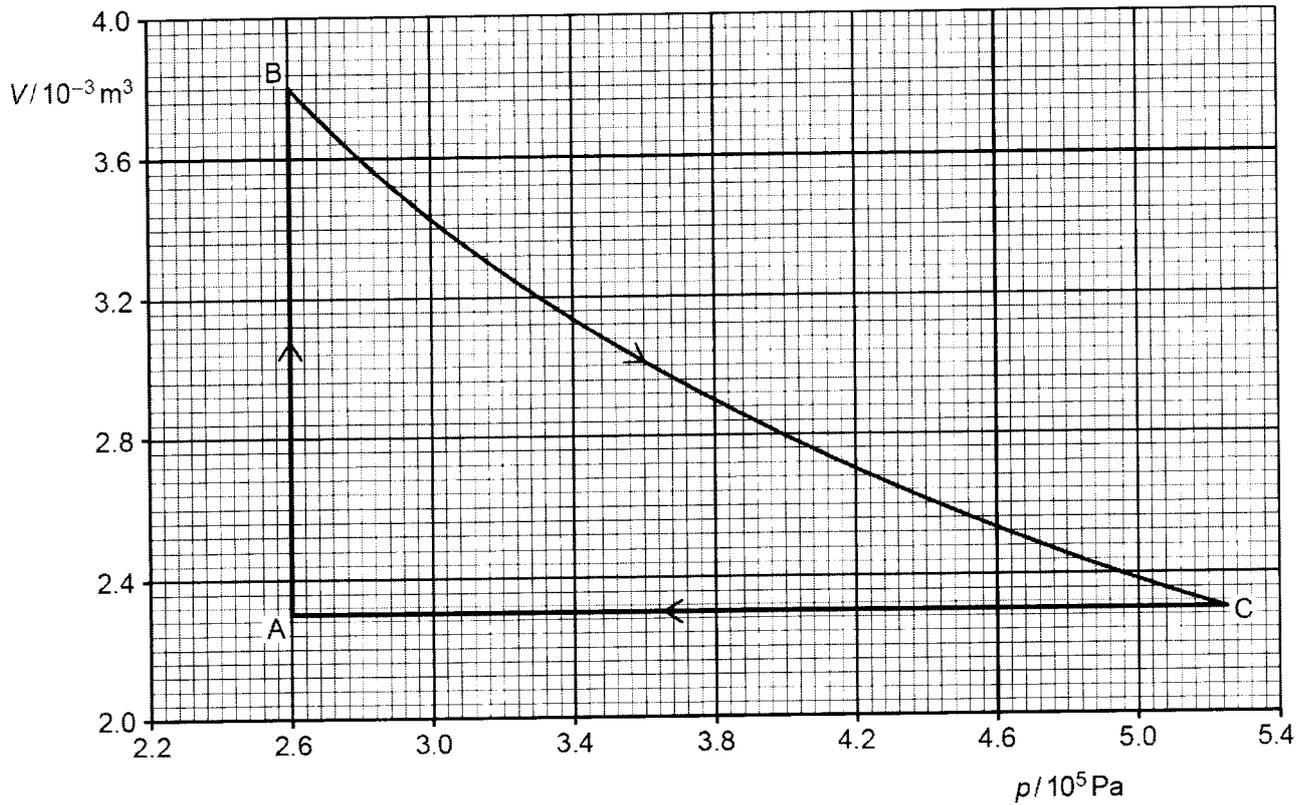


Fig. 3.1

The gas undergoes a cycle of changes A to B to C to A.

During the change A to B, the volume of the gas increases from $2.30 \times 10^{-3} \text{ m}^3$ to $3.80 \times 10^{-3} \text{ m}^3$.

- (i) Show that the magnitude of the work done during the change A to B is 390 J.

[1]

- (ii) State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

.....

.....

..... [2]

(b) During the change A to B, 1370 J of thermal energy is transferred to the gas.

During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

Use these data and the information in (a) to complete Table 3.1.

Table 3.1

change	thermal energy supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A to B			
B to C			
C to A			

[4]

(c) Use the first law of thermodynamics to explain why the specific latent heat of vaporisation is greater than the specific latent heat of fusion for a particular substance.

.....

.....

.....

.....

[2]

[Total: 9]

- 4 (a) A heavy aluminium disc has a radius of 0.36 m. The disc rotates with the wheels of a vehicle and forms part of an electromagnetic braking system on the vehicle.

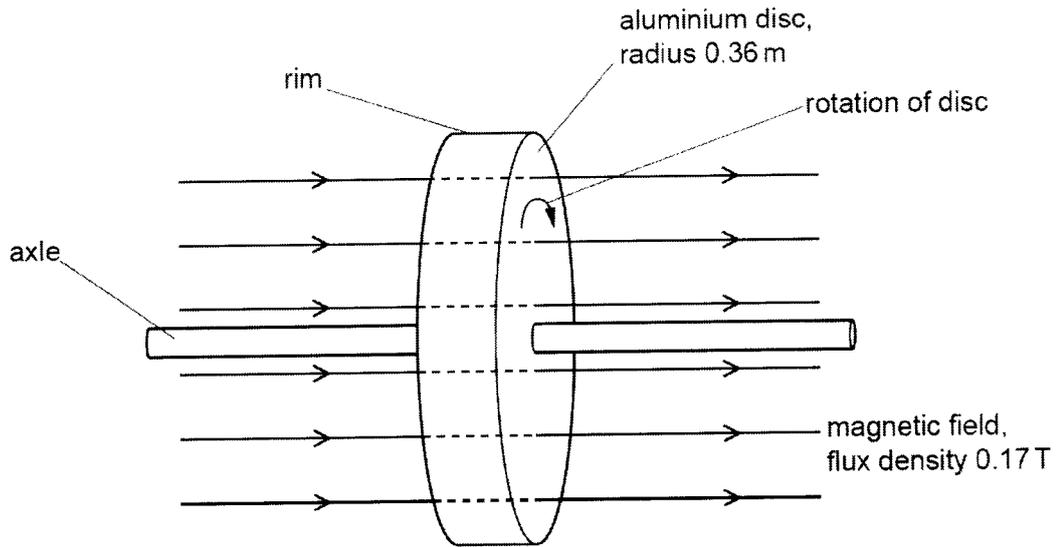


Fig. 4.1

In order to activate the braking system, a uniform magnetic field of flux density 0.17 T is switched on. This magnetic field is perpendicular to the plane of rotation of the disc, as shown in Fig. 4.1.

- (i) Define magnetic flux linkage.

.....

 [2]

- (ii) The disc is rotating at a rate of 25 revolutions per second.

Calculate the magnitude of the electromotive force (e.m.f.) induced between the axle and the rim of the disc.

e.m.f. = V [3]

- (iii) The axle and the rim are connected to an external circuit that enables the energy of the rotation of the disc to be stored for future use. The direction of rotation is shown in Fig. 4.1.

Use Lenz's law of electromagnetic induction to determine whether the current in the disc is from the rim to the axle or from the axle to the rim. Explain your reasoning.

.....

.....

.....

.....

..... [3]

(b) A metal ring is suspended from a fixed point P by means of a thread, as shown in Fig. 4.2.

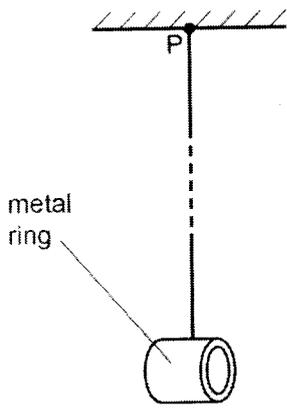


Fig. 4.2

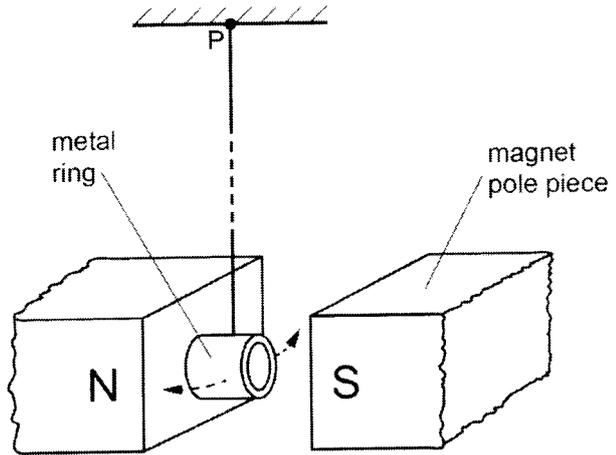


Fig. 4.3

The ring is displaced a distance d and then released. The ring completes many oscillations before coming to rest.

The poles of a magnet are now placed near to the ring so that the ring hangs midway between the poles of the magnet, as shown in Fig. 4.3.

(i) The ring is again displaced a distance d and then released.

Explain why the ring completes fewer oscillations before coming to rest.

.....

.....

.....

.....

.....

.....

..... [4]

(ii) The ring in (b) is now cut so that it has the shape shown in Fig. 4.4.

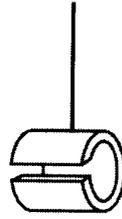


Fig. 4.4

Explain why, when the procedure in (b) is repeated, the cut ring completes more oscillations than the complete ring when oscillating between the poles of the magnet.

.....

.....

.....

.....

..... [3]

[Total: 15]

5 (a) (i) State what is meant by nuclear binding energy.

.....

 [2]

(ii) On Fig. 5.1, sketch a line to show the variation with nucleon number A of the binding energy per nucleon E of a nucleus.

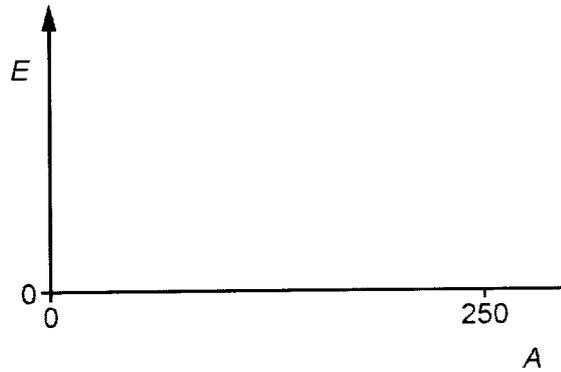
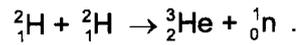


Fig. 5.1

[1]

(b) In one type of nuclear process, deuterium (${}^2_1\text{H}$) undergoes the reaction



(i) State the name of this type of nuclear process.

..... [1]

(ii) Explain, with reference to your line in (a)(ii), why this reaction results in the release of energy.

.....

 [2]

(c) Table 5.1 shows the masses of the particles involved in the reaction in (b).

Table 5.1

particle	mass/u
${}^1_0\text{n}$	1.008 665
${}^2_1\text{H}$	2.014 102
${}^3_2\text{He}$	3.016 029

Calculate the energy released when 1.00 mol of deuterium undergoes the reaction.

energy = J [5]

[Total: 11]

SECTION B

Answer any ONE of the two questions.

- 6 A cylindrical tube, sealed at one end, has cross-sectional area A and contains some sand. The total mass of the tube and the sand is M .

The tube floats upright in a liquid of density ρ , as illustrated in Fig. 6.1.

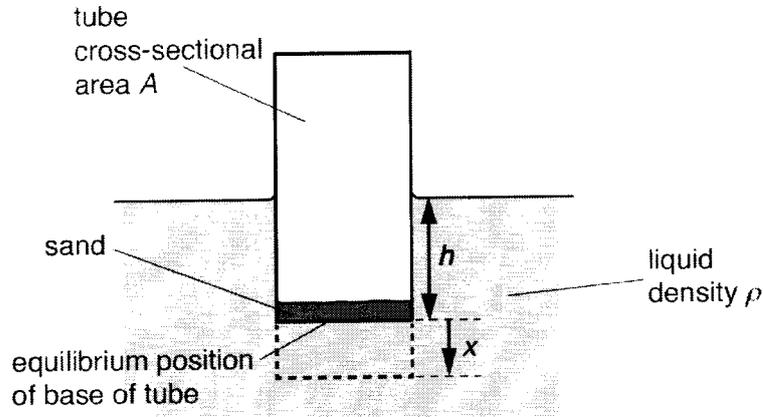


Fig. 6.1

At equilibrium, the tube has a depth h submerged under water. The tube is pushed a short distance downwards into the liquid and then released.

- (a) State and explain, by considering the forces acting on the tube, the direction of the resultant force acting on the tube immediately after its release.

.....

.....

..... [2]

- (b) Show that the acceleration a of the tube is given by the expression

$$a = -\left(\frac{A\rho g}{M}\right)x$$

where x is the vertical displacement of the tube from its equilibrium position.

[3]

- (c) Use the expression in (b) to explain why the tube undergoes simple harmonic oscillations in the liquid.

.....

.....

..... [2]

(d) A student conducted an experiment and obtained the following measurements:

$$\begin{aligned} M &= 0.17 \text{ kg} \\ A &= 4.5 \times 10^{-4} \text{ m}^2 \\ \text{period of oscillation} &= 1.3 \text{ s} \end{aligned}$$

(i) Determine the angular frequency ω of the oscillations.

$$\omega = \dots\dots\dots \text{ rad s}^{-1} \text{ [2]}$$

(ii) Determine the density ρ of the liquid in which the tube is floating.

$$\rho = \dots\dots\dots \text{ kg m}^{-3} \text{ [3]}$$

(iii) 1. Show that total energy of the oscillation is given by

$$\frac{1}{2} M \omega^2 x_o^2$$

where x_o represents the amplitude of the oscillation.

[3]

2. Hence determine the total energy of the oscillation when the amplitude of the oscillation is 0.20 m.

total energy = J [1]

- (iv) During each complete oscillation the total energy of the system decreases by 8.0% of the total energy at the start of that oscillation.

Determine the decrease in total energy, in mJ, of the system by the end of the first 6 complete oscillations.

energy lost = mJ [2]

- (v) The variation with time of the depth h for undamped oscillation is shown in Fig. 6.2.

h

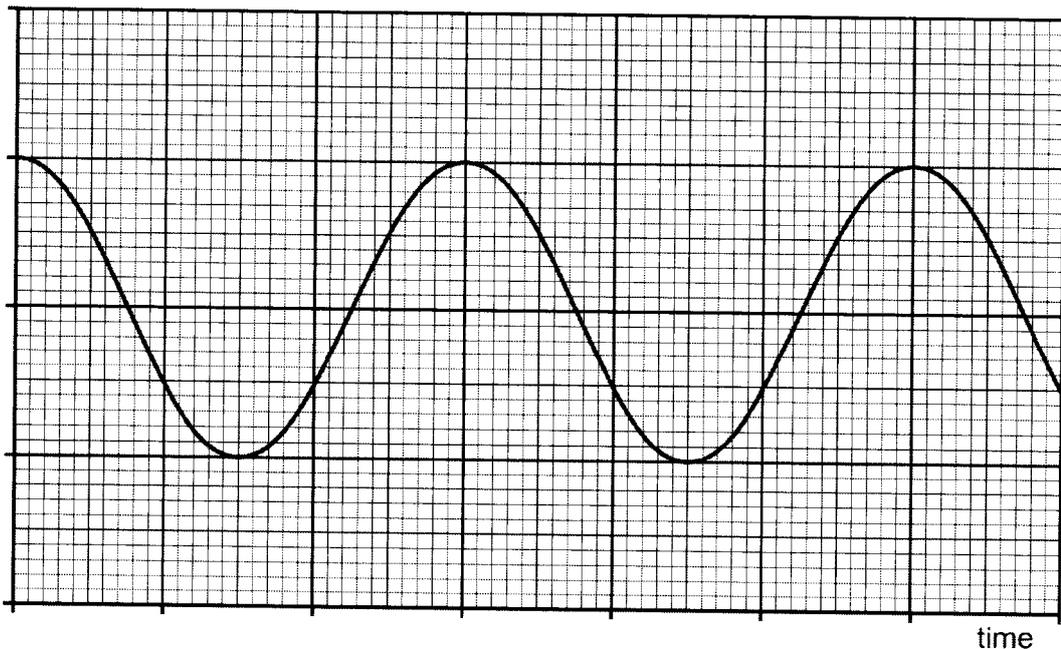


Fig. 6.2

On Fig. 6.2, draw a line to show light damping of the oscillations. Numerical values are not required

[2]

[Total: 20]

7 (a) (i) Define *gravitational potential at a point*.

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

(ii) Explain why the gravitational potential is negative.

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

(b) An isolated uniform spherical planet has gravitational potential ϕ at its surface.

A particle of mass m is projected vertically upwards from the surface. The particle is given just enough kinetic energy to travel to an infinite distance away from the planet, escaping from the gravitational pull of the planet, without any additional work being done on it.

Show that the speed v at which the particle is projected upwards from the surface of the planet is given by

$$v = \sqrt{-2\phi} .$$

[3]

- (c) The Moon may be considered to be an isolated uniform sphere of mass 7.3×10^{22} kg and radius 1.7×10^6 m.

Calculate the gravitational potential at the surface of the Moon.

gravitational potential = J kg⁻¹ [2]

- (d) A particle is moving upwards at the surface of the Moon.

Use the expression in (b) and your answer in (c) and to determine the minimum speed of this particle that will result in it escaping from the gravitational pull of the Moon.

speed = m s⁻¹ [1]

- (e) Hydrogen may be assumed to be an ideal gas.

The mass of a hydrogen molecule is 3.34×10^{-27} kg.

Calculate the root-mean-square (r.m.s.) speed of a hydrogen molecule in hydrogen gas that is at a temperature of 400 K.

r.m.s. speed = m s⁻¹ [3]

- (f) The surface of the Moon reaches temperatures of approximately 400 K when in direct sunlight.

With reference to your answer to (d) and (e), suggest why it is still possible for the Moon to not have an atmosphere consisting of hydrogen.

.....
 [1]

- (g) Fig. 7.1 shows the path of a comet of mass 2.20×10^{14} kg as it passes around a star of mass 1.99×10^{30} kg.

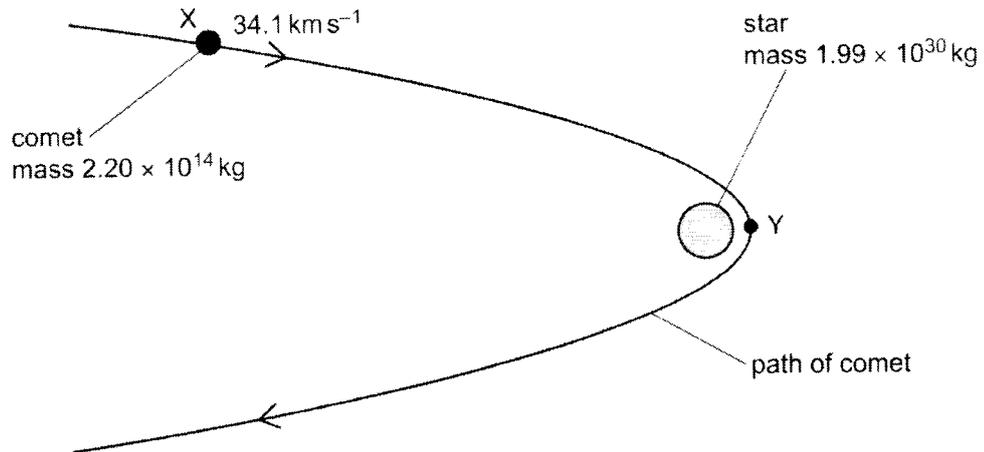


Fig. 7.1

At point X, the comet is 8.44×10^{11} m from the centre of the star and is moving at a speed of 34.1 km s^{-1} .

At point Y, the comet passes its point of closest approach to the star. At this point, the comet is a distance of 6.38×10^{10} m from the centre of the star.

Both the comet and the star can be considered as point masses at their centres.

- (i) Determine the speed, in km s^{-1} , of the comet at point Y.

speed = km s^{-1} [4]

- (ii) A second comet passes point X with the same speed as the original comet and travelling in the same direction. This comet is gradually losing mass. The mass of this comet when it passes point X is the same as the mass of the original comet.

Suggest, with a reason, how the path of the second comet compares with the path shown in Fig. 7.1.

.....

.....[1]

- (iii) A third comet passes point X in the same direction as the original comet but with a greater speed. Sketch a possible path for this comet starting at X in Fig. 7.1 and label this path P.

[1]

[Total: 20]

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