

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

PHYSICS

Paper 1 Multiple Choice

9749/01

24 September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THE INSTRUCTION FIRST

Write in soft pencil.

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

Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. 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.

Read the instructions on the Answer Sheet very carefully.

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.

The use of an approved scientific calculator is expected, where appropriate.

The OAS index number is in a 5-digit format.

The 5-digit format is as follows: **1st digit** and the **last four digits** of the Reg Number.

e.g. 2005011 becomes 25011

INSTRUCTIONS ON SHADING OF REGISTRATION NUMBER

1. Enter your NAME (as in step 1) TOP AND BOTTOM.

2. Enter the SUBJECT CODE. CHEMISTRY

3. Enter the TEST NAME. S.H.S. CHEMISTRY TEST

4. Enter the CLASS. O4 AS 545

5. Enter your CLASS NUMBER or INDEX NUMBER.

6. Now SHADE the corresponding number in the grid for EACH DIGIT of TEST NO.

	GRADE APPROPRIATE DIGITS									
DIGIT	0	1	2	3	4	5	6	7	8	9
0	<input type="checkbox"/>									
1	<input type="checkbox"/>									
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9	<input type="checkbox"/>									

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	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
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the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
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the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
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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	$\phi = -Gm/r$
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	$B = \frac{\mu_0 NI}{2r}$
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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 What is the order-of-magnitude of the mass of **twelve** one-dollar (\$1) Singapore coins?

- A 10^0 g B 10^1 g C 10^2 g D 10^3 g

2 A student takes measurements to calculate the density of a liquid in a beaker.

The height of the liquid is $0.20 \text{ m} \pm 2\%$.

The internal diameter of the beaker is $0.05 \text{ m} \pm 3\%$.

The mass of the liquid is $0.36 \text{ kg} \pm 10\%$.

What is the percentage uncertainty in the calculated density of the liquid?

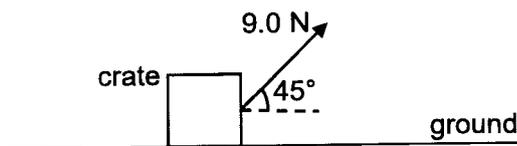
- A 2 % B 5 % C 15 % D 18 %

3 A student throws a stone upwards at an initial speed of 15.0 m s^{-1} .

What is the displacement of the stone after 2.00 s?

- A 1.12 m B 10.4 m C 11.5 m D 12.6 m

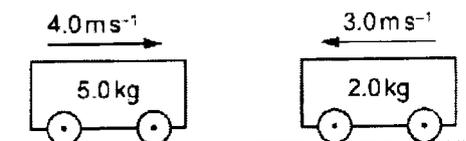
4 A student pulls a 2.0 kg crate with a force of 9.0 N directed at an angle 45° from the horizontal as shown in the diagram. A frictional force of 2.0 N acts between the crate and the ground.



What is the acceleration of the crate?

- A 2.2 m s^{-2} B 3.2 m s^{-2} C 3.5 m s^{-2} D 4.5 m s^{-2}

5 Two frictionless trolleys move along the same straight line towards one another. Their masses and velocities before collision are shown.



The trolleys collide and stick together.

What is the final kinetic energy of the trolleys after the collision?

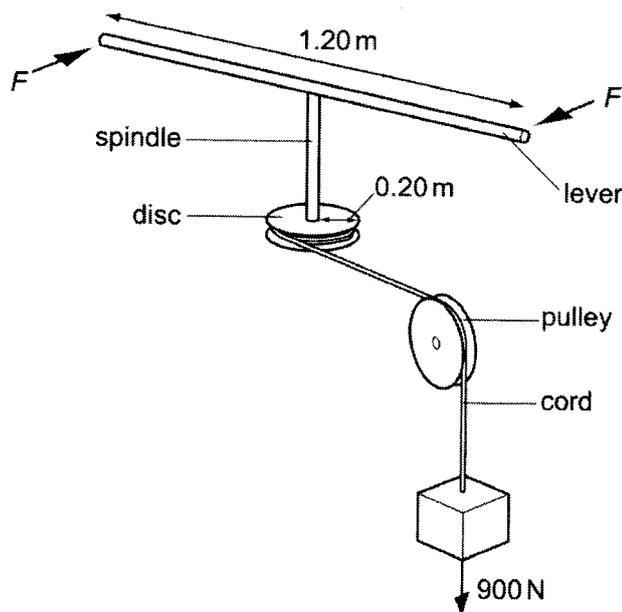
- A 0.71 J B 14 J C 31 J D 35 J

- 6 A spring hangs from the ceiling of a stationary train and a 1.2 kg mass is hung on the spring. The mass causes an extension of 2.4 cm on the spring when it is hung vertically.

What is the extension of the spring when the train accelerates horizontally at a rate of 5.0 m s^{-2} ?

- A 1.2 cm B 2.6 cm C 2.7 cm D 3.6 cm

- 7 A spindle is attached at one end to the centre of a lever 1.20 m long and at its other end to the centre of a disc of radius 0.20 m. A cord is wrapped round the disc, passes over a pulley and is attached to a 900 N weight.



What is the minimum force F , applied to each end of the lever, that could lift the weight?

- A 75 N B 150 N C 300 N D 950 N

- 8 A turbine at a hydroelectric power station is situated at a vertical distance 30 m below the level of the surface of a large lake. The water passes through the turbine at a rate of $5.7 \text{ m}^3 \text{ s}^{-1}$.

The overall efficiency of the turbine and generator system is 90%. The density of water is 1000 kg m^{-3} .

What is the useful power output of the power station?

- A 0.15 MW B 1.5 MW C 1.7 MW D 90 MW

- 9 A small coin of mass 10 g is placed on a horizontal rotating disc at a distance of 5.0 cm from the centre of the disc. The maximum frictional force between the coin and the disc is 0.20 N.

[Turn over

What is the largest angular velocity that the disc can have without coin slipping?

- A** 0.060 rad s⁻¹ **B** 1.0 rad s⁻¹ **C** 20 rad s⁻¹ **D** 400 rad s⁻¹

- 10** An astronaut of mass m in a spacecraft experiences a gravitational force $F = mg$ when stationary on the launchpad. The spacecraft is launched vertically upwards with an acceleration of $0.2g$.

What is the gravitational force on the astronaut immediately after launch?

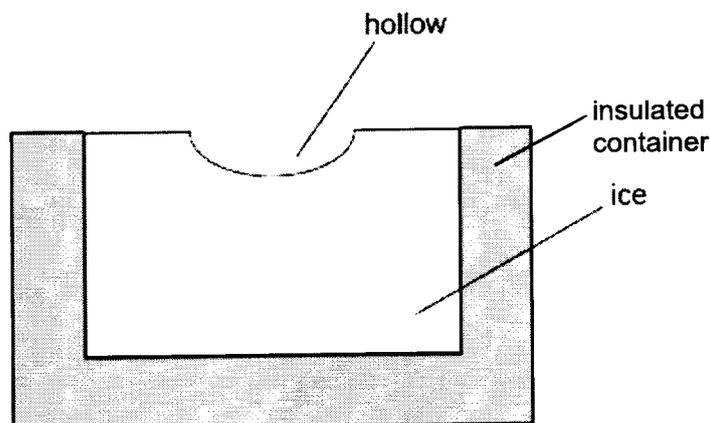
- A** $1.2mg$ **B** mg **C** $0.8mg$ **D** 0

- 11** The gravitational field strength at the surface of Neptune is approximately equal to the gravitational field strength at the surface of the Earth. The mass of Neptune is 17 times the mass of the Earth.

What is the value of the ratio $\frac{\text{radius of Neptune}}{\text{radius of Earth}}$?

- A** 0.059 **B** 0.24 **C** 4.1 **D** 17

- 12** A huge block of ice at 0°C with a hollow in its top surface is placed in an insulated container as illustrated.



A mass of 160 g of water at 100°C is poured into the hollow. The water has a specific heat capacity 4.20 kJ kg⁻¹ K⁻¹ and ice has a specific latent heat of fusion 336 kJ kg⁻¹.

After thermal equilibrium has been reached, the total mass of the water in the hollow is measured.

What is the mass of the water in the hollow assuming no thermal exchange with the surroundings?

- A** 100 g **B** 200 g **C** 260 g **D** 360 g

- 13** A system absorbs 80 J through heating while doing 100 J of external work.

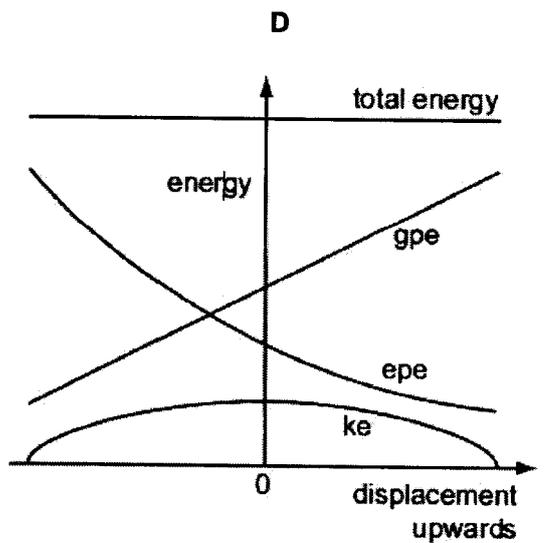
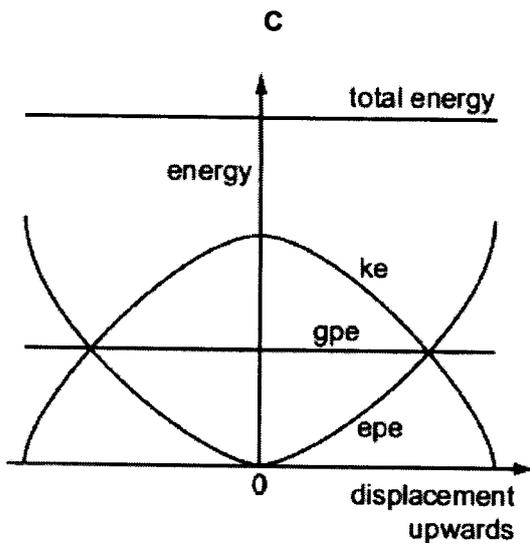
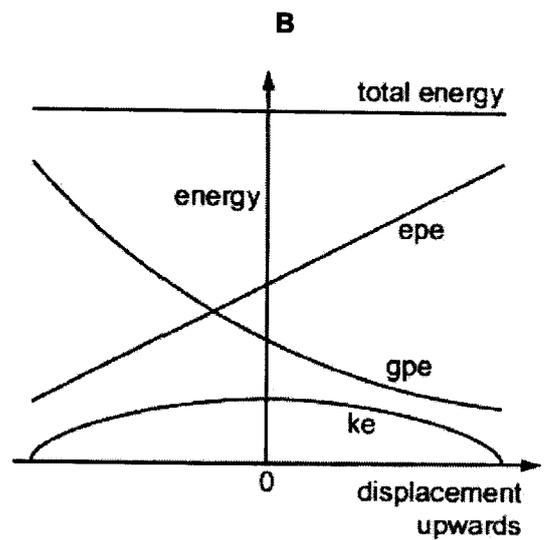
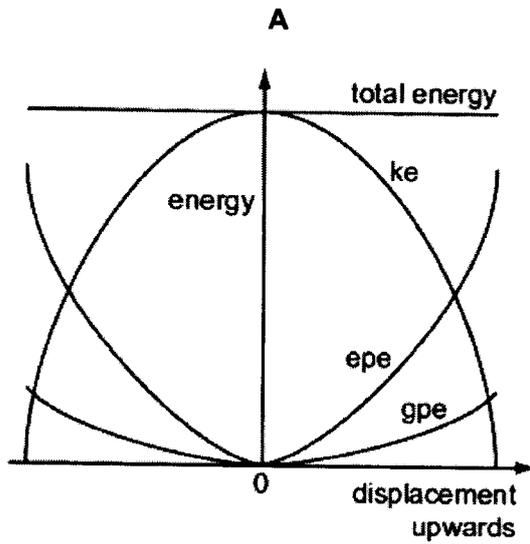
What is the change in internal energy of the system?

- A** -100 J **B** -20 J **C** +80 J **D** +180 J

- 14 A mass attached to a spring is undergoing simple harmonic oscillations vertically.

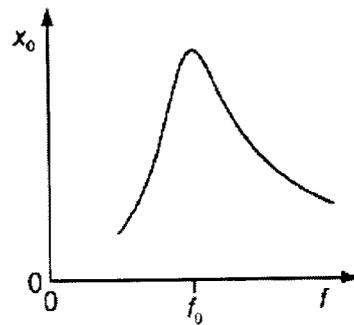
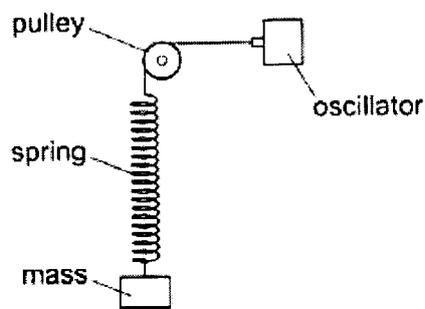
Interchange between kinetic energy (ke), gravitational potential energy (gpe) and elastic potential energy (epe) takes place.

Which graph shows the interchange of the energy?



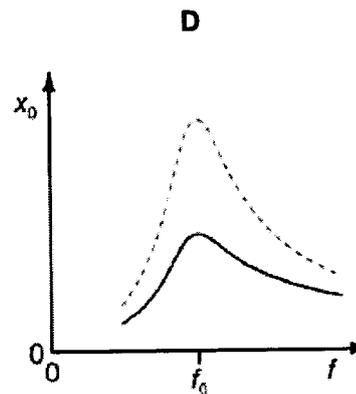
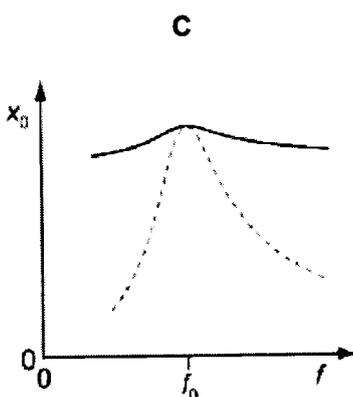
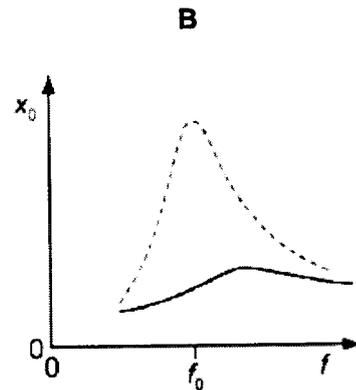
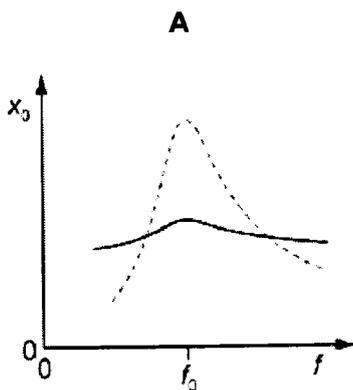
15 A mass, suspended from a helical spring, is made to oscillate.

The graph shows the variation with frequency f of the amplitude x_0 of vibration of the mass.

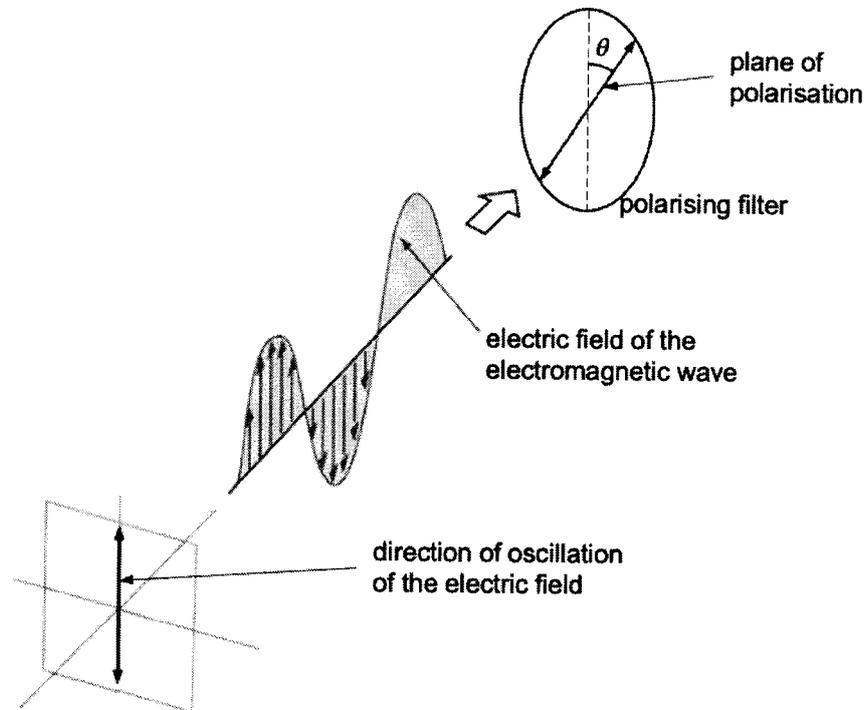


A sheet of cardboard of negligible mass is now fixed to the mass on the spring to cause light damping of the oscillations.

Which graph shows how x_0 will vary with f over the same frequency range? The dotted line represent the original curve.



- 16 A plane-polarised electromagnetic wave is incident on a polarising filter as shown below.



The electric field of the wave before reaching the filter is vertical and the magnitude E of the field is

$$E = E_0 \sin \sin (\omega t) .$$

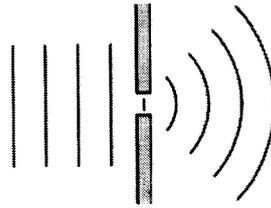
where E_0 is the amplitude and t is the time.

The plane of polarisation of the filter is at θ from the vertical.

What is the amplitude of the electric field emerging from the filter?

- A $E_0^2 \cos^2 \theta$
- B $E_0 \cos \theta$
- C $E_0 \sin \theta$
- D $E_0^2 \sin^2 \theta$

- 17 The diagram shows a water wave in a shallow tank. The wave is diffracted through a gap in a barrier and spreads. The wavelength of the wave is much smaller than the width of the gap.



The wavelength of the wave and the width of the gap are both changed by a small amount.

Which combination of changes **must** increase the amount of spreading due to diffraction?

	wavelength	width of gap
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

- 18 Light of wavelength 567 nm is incident normally on a diffraction grating. The grating has 400 lines per mm.
- What is the angle between the second-order and the third-order maxima?
- A** 13.1° **B** 13.9° **C** 15.9° **D** 27.0°
- 19 Two point charges are separated by a distance of 200 mm. The force of attraction between them is 180 μN .
- The distance between the point charges is increased to 600 mm.
- What is the new force of attraction?
- A** 20 μN **B** 45 μN **C** 60 μN **D** 90 μN
- 20 An alpha particle is moving towards a stationary gold nucleus. The alpha particle has a kinetic energy 9.0×10^{-13} J when it is a large distance from the gold nucleus.

The gold nucleus contains 79 protons.

What is the closest possible distance of approach of the alpha particle to the gold nucleus?

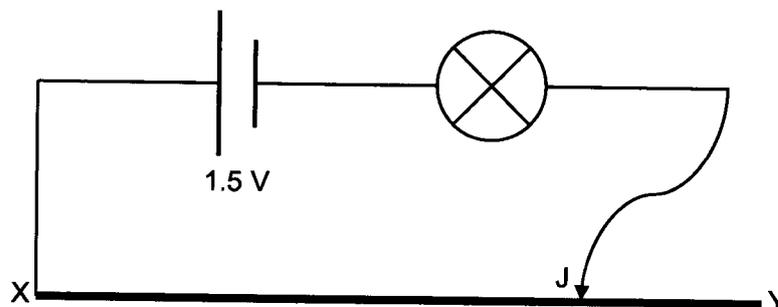
- A 2.5×10^{-16} m C 4.0×10^{-14} m
 B 2.0×10^{-14} m D 2.0×10^{-7} m

- 21 A copper wire of cross-sectional area 1.0 mm^2 carries a current of 0.30 A .

If the free electron density of copper is $8.5 \times 10^{28} \text{ m}^{-3}$, what is the drift velocity of the electrons in the copper wire?

- A $2.2 \times 10^{-5} \text{ m s}^{-1}$ C $2.2 \times 10^{-2} \text{ m s}^{-1}$
 B $2.2 \times 10^{-3} \text{ m s}^{-1}$ D $2.2 \times 10^{-1} \text{ m s}^{-1}$

- 22 A cell of e.m.f. 1.5 V of negligible internal resistance is connected in series with a lamp of resistance 10Ω which is in turn connected to a resistance wire XY of length 1.00 m with total resistance 20Ω via a movable jockey J.



When J is at X, the power of the lamp is P .

Assuming that the resistance of the lamp remains constant, what is the power of the lamp when the length XJ is 0.50 m ?

- A $0.13 P$ B $0.25 P$ C $0.50 P$ D $0.75 P$

- 23 A 150 mm long wire is at right angles to a uniform magnetic field and carries an electric current. When the current in the wire is increased by 4.0 A , the force acting on the wire increases by $3.6 \times 10^{-3} \text{ N}$.

What is the magnetic flux density of the field?

- A $6.0 \times 10^{-6} \text{ T}$ B $6.0 \times 10^{-3} \text{ T}$ C $1.7 \times 10^2 \text{ T}$ D $1.7 \times 10^5 \text{ T}$

- 24 A beam consists of ionised atoms of two isotopes of an element. When the beam enters a uniform magnetic field, the ions move in circular paths. The ions have the same charge and travel at the same speed when they enter the magnetic field.

Which statement is true?

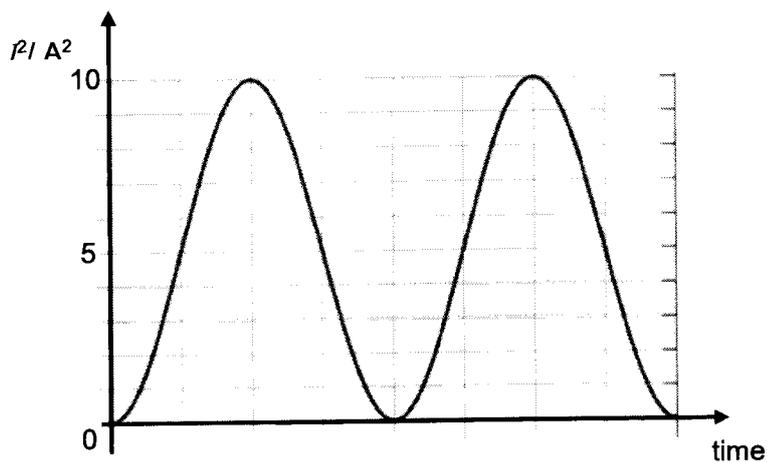
- A The force acting on an ion is different for each isotope.
 B The radius of the path followed by an ion is different for each isotope.
 C The kinetic energy of an ion increases for both isotopes.
 D The acceleration of an ion is the same for both isotopes.
- 25 A circular coil with a radius of 0.10 m has 200 turns. The coil rotates at 50 revolutions per second about an axis which is perpendicular to a uniform magnetic field and in the plane of the coil. The magnetic flux density of the field is 0.20 T.

The maximum induced e.m.f. E_0 is given by the expression

$$E_0 = \text{maximum magnetic flux linkage} \times \text{angular speed of the coil}$$

What is the maximum e.m.f. induced in the coil?

- A 63 V B 126 V C 195 V D 395 V
- 26 The alternating current from an a.c. mains supply varies sinusoidally. The graph shows how the square of the current I in a given resistor varies with time.



Which direct current in the same resistor would generate the same average power as that from the alternating current?

- A 2.2 A B 2.8 A C 3.2 A D 7.1 A
- 27 A metal has a work function of 2.3 eV.

Which of the following is the longest wavelength of electromagnetic radiation that can cause photoemission?

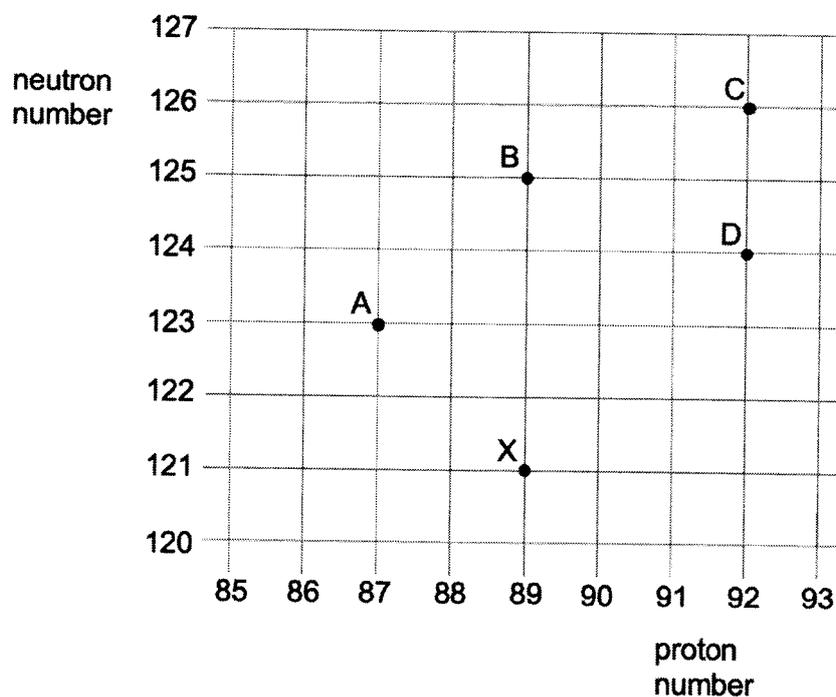
- A 460 nm B 500 nm C 540 nm D 590 nm

- 28 Electrons are accelerated through a potential difference and produce similar diffraction patterns as a wave of wavelength 2.0 pm.

What is the kinetic energy of one of the electrons?

- A 1.5×10^{-14} J C 6.0×10^{-14} J
B 3.0×10^{-14} J D 1.2×10^{-13} J

- 29 Which of the following nuclides will produce nuclide X by undergoing a series of decays to emit an alpha particle and two beta particles?



- 30 Antimony-124 undergoes radioactive decay, with a half-life of 60 days, to become tellurium-124. Tellurium-124 is stable.

Initially, a sample of antimony-124 contains no tellurium.

For this sample, after what period of time will the ratio of antimony-124 to tellurium-124 be $\frac{1}{2}$?

- A between 30 days and 60 days
B 60 days

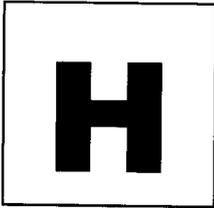
- C** between 60 days and 120 days
- D** 120 days

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NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

PHYSICS

Paper 2 Structured Questions

9749/02

**2 Sep 2025
2 hours**

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.

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

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

The use of an approved scientific calculator is expected, where appropriate.
Answers **all** questions.

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

For Examiner's Use

1	/ 8
2	/ 10
3	/ 6
4	/ 6
5	/ 10
6	/ 10
7	/ 10
8	/ 20
Total	/ 80

[Turn over

This document contains **24** printed pages and **0** blank pages.

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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

- 1 A small pellet of mass 8.00×10^{-3} kg is projected at an angle θ above the horizontal, as shown in Fig.1.1. The speed of projection is u .

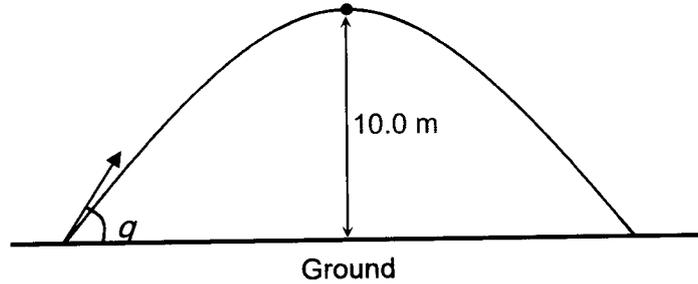


Fig. 1.1

The pellet reaches a maximum height of 10.0 m and travels at a speed of 5.00 m s^{-1} at maximum height.

(a) Air resistance is negligible.

- (i) Using energy conservation, show that the initial speed of projection is 14.9 m s^{-1} .

[1]

(ii) Calculate the angle of projection θ .

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

(iii) Determine the time taken by the pellet from launch to impact with the ground.

(iv) Determine the average rate of change of momentum of the pellet from the instant of projection to the instant before it hits the ground. time = s [2]

rate of change of momentum = N [1]

(b) Fig. 1.2. shows part of the graph (up to the maximum height) of the variation with time of the vertical displacement of the pellet when air resistance is not negligible.

Complete the graph from the maximum height to the instant the pellet hits the ground. Numerical values are not required. [2]

Vertical displacement

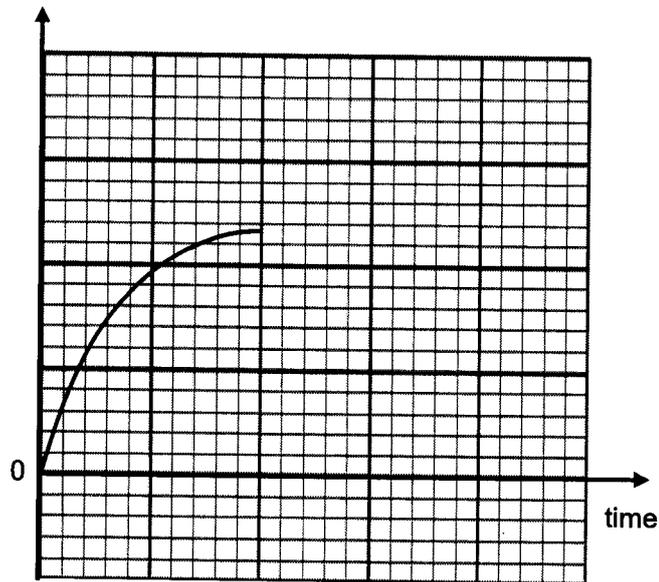


Fig. 1.2

[Total: 8]

[Turn over

- 2 (a) Momentum is conserved when two objects collide.

State the condition under which momentum is conserved.

.....
[1]

- (b) Fig. 2.1 shows the variation with time of the momentum of two colliding trucks A and B.

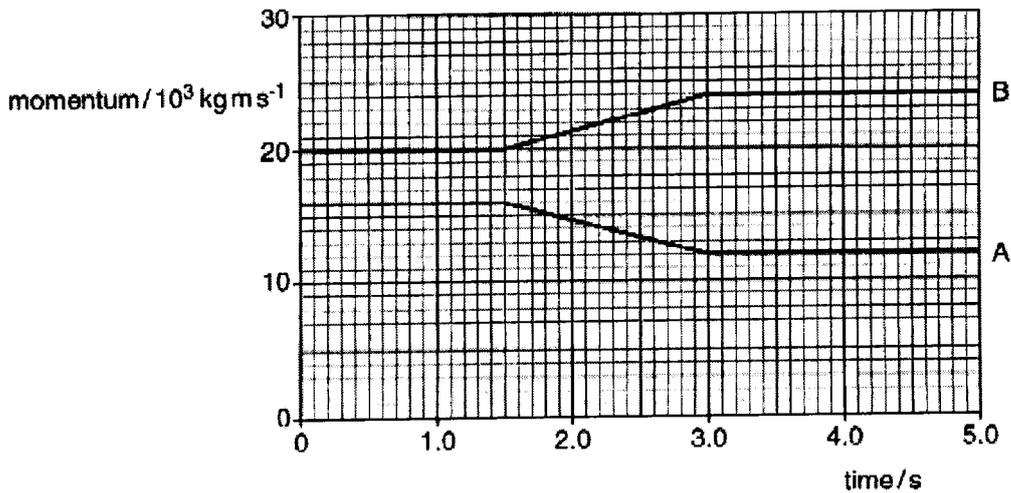


Fig. 2.1

The masses of trucks A and B are 2000 kg and 4000 kg respectively. The period of collision is between 1.5 s and 3.0 s.

- (i) Calculate the force acting on truck B during the collision

force = N [2]

- (ii) Explain using Newton's laws, the relationship between the gradients of both graphs during the collision.

.....

.....[2]

- (iii) Using the concepts of impulse and momentum, explain why the total momentum of the two trucks is conserved during collision.

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

.....[2]

- (iv) Calculate the change in the total kinetic energy of the trucks before and after the collision. State the type of collision.

change in kinetic energy = J [2]

type of collision:[1]

[Total: 10]

- 3 Fig. 3.1 shows a wheel that is being pulled over a kerb of height 0.080 m by a horizontal force F . The weight of the wheel is 700 N and the wheel has a radius of 0.60 m.

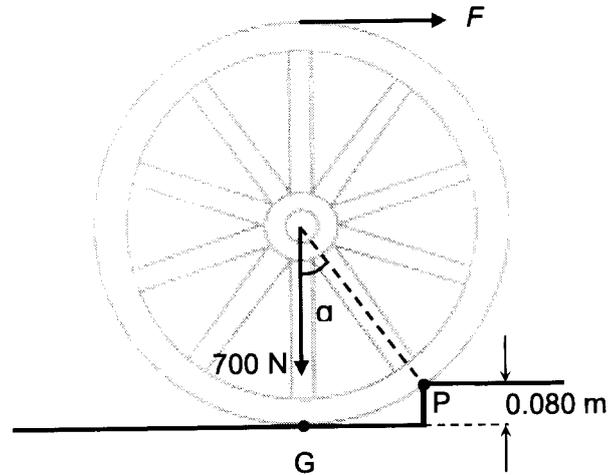


Fig. 3.1 (Not to scale)

At the instant shown, the wheel just loses contact with the ground at G.

- (a) Show that θ is 30° .

[1]

- (b) On Fig. 3.1, draw an arrow to represent the contact force exerted on the wheel at P.

[1]

- (c) Show that the minimum value of F is 190 N.

- (d) Hence, determine the magnitude of the contact force at P.

[1]

magnitude = N [3]

[Total: 6]

- 4 Binary star systems, consisting of two stars orbiting around each other, are very common.

Fig. 4.1 shows two stars of mass M and $2M$ in circular orbits about point C.

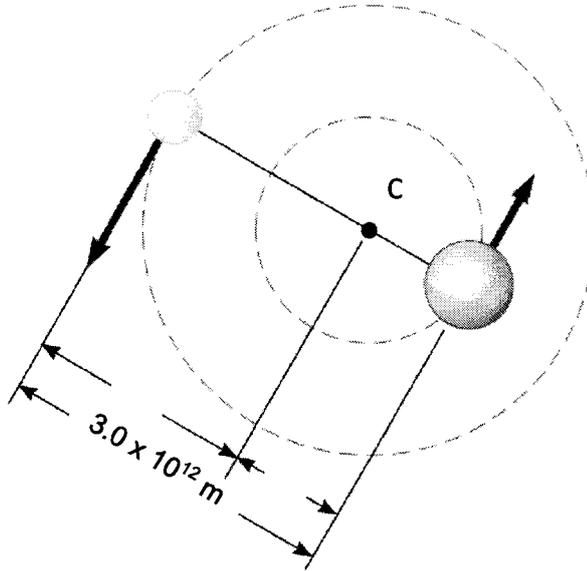


Fig. 4.1

The centre-to-centre separation between the two stars is 3.0×10^{12} m. Both stars have the same orbital period, and they are always located on opposite sides of C.

- (a) Explain how the gravitational force acting on one star is equal to the gravitational force acting on the other star.

.....
[1]

- (b) The orbital radius of M is r_1 and the orbital radius of $2M$ is r_2 . By considering the magnitude of the centripetal forces acting on the two stars, show that

$$\frac{r_1}{r_2} = 2$$

[1]

(c) Hence, or otherwise, determine the value of r_1 .

$r_1 = \dots\dots\dots$ m [2]

(d) M is 2.0×10^{30} kg.

Determine the orbital period T of the stars.

$T = \dots\dots\dots$ s [2]

[Total: 6]

[Turn over

5 (a) State **two** features of a stationary wave that distinguish it from a progressive wave.

- 1.
.....
.....
- 2.
.....

[2]

(b) A microwave emitter is placed in front of a large metal sheet in a vacuum as shown in Fig. 5.1.

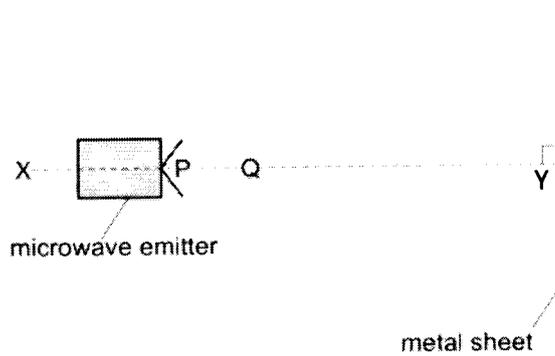


Fig. 5.1 (not to scale)

The line XY is perpendicular to the metal sheet. Distance between P and Q is 1.5 m.

(i) When the emitter is at position P, a stationary wave is formed between the emitter and the sheet.

Explain how the stationary wave is formed between P and Y.

-
.....
.....
.....

[2]

- (ii) A microwave receiver is placed between P and Y. At point P the receiver detects a maximum amplitude of the stationary wave.

The receiver is moved slowly from point P to point Q along the line PY. The receiver detects another 50 maximum amplitudes including the maximum amplitude at Q.

Determine the wavelength of the microwaves.

wavelength = m [2]

- (iii) Explain whether the number of maximum amplitudes detected between P and Q remains the same, decreases or increases for the following independent changes.

1. The frequency of the microwave is increased from (b)(ii) while the intensity remains the same.

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

2. The intensity of the microwaves is increased while the frequency of the microwaves remains the same as (b)(ii).

.....
.
.....

.....

[4]

[Total: 10]

6 (a) Define *magnetic flux density*.

.....
.....

.....

.....[2]

]

(b) A long, straight wire carries a current into the page, as shown in Fig. 6.1.



Fig. 6.1

On Fig. 6.1, draw field lines to represent the magnetic field around the wire due to the current.

[2]

- (c) Two long straight, current carrying wires, X and Y are carrying current. They are parallel and separated by a distance of 0.12 m. The current in wire X is 2.0 A and the current in wire Y is 3.0 A as shown in Fig. 6.2.

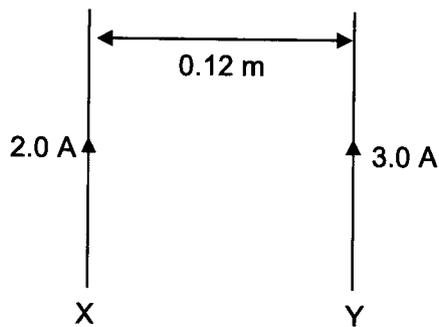


Fig. 6.2

- (i) Explain why the two wires exert a magnetic force on each other.

.....

.....

.....

.....[2]

[Turn over

- (ii) On Fig. 6.2, draw an arrow to show the direction of the magnetic force exerted on wire X. Label your arrow F. [1]
- (iii) Calculate the magnetic force per unit length on wire X.

force per unit length = N m⁻¹ [2]

- (iv) Wire X forms a circular loop centred at wire Y. Wire X carries a current in a clockwise direction and wire Y carries a current into the page, as shown in Fig. 6.3. Current in wire X and wire Y remain the same.

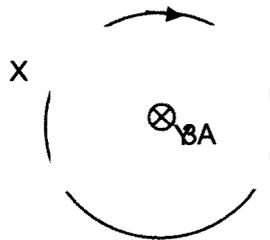


Fig. 6.3

The magnitudes of the currents in wire X and wire Y remain the same.

Explain why no force acts on wire Y.

.....

[1
]

[Total: 10]

- 7 Fig. 7.1 shows the variation with light intensity of the resistance of an LDR.

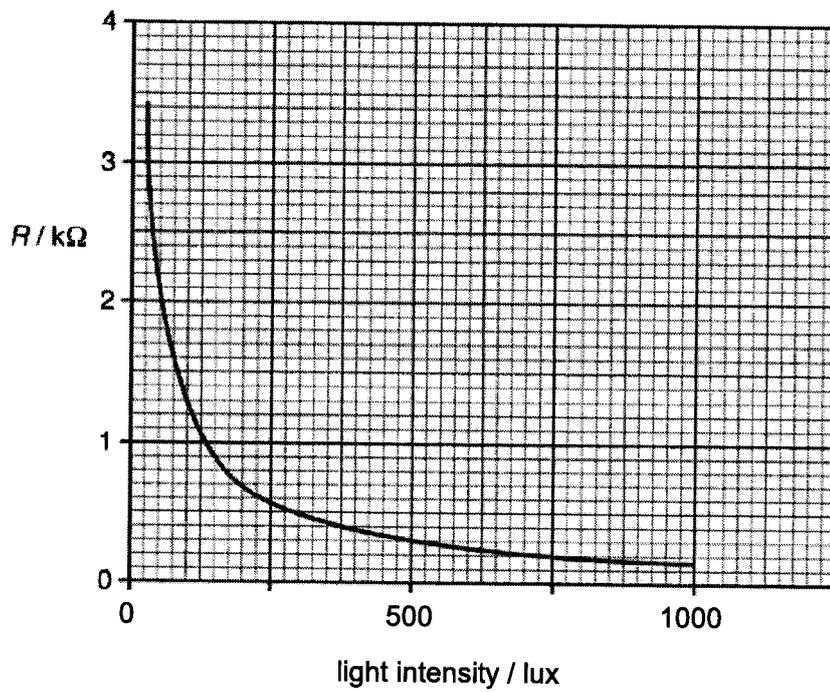


Fig. 7.1

- (a) State the resistance of the LDR when the light intensity is 500 lux.

resistance = Ω [1]

- (b) The LDR is to be used as a light sensor in a potential divider circuit shown in Fig. 7.2.

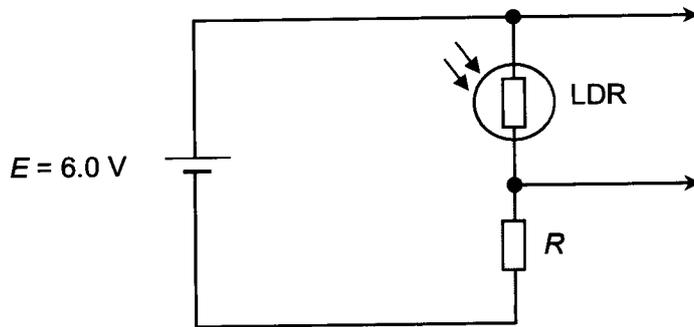


Fig. 7.2

It is required that the potential difference across the LDR be 2.4 V at a light intensity of 500 lux.

- (i) Calculate the value of the fixed resistor R to achieve this.

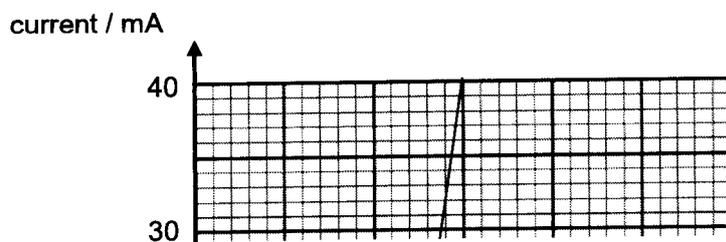
$R = \dots\dots\dots \Omega$ [2]

- (ii) Explain how the potential difference across the LDR changes if the light intensity incident on the LDR falls below 500 lux.

.....

[2]

- (c) Fig. 7.3 shows the I-V characteristics of an LED. The LED starts to conduct when the potential difference across it is 2.0 V.



Calculate the resistance at 3.0 V.

Resistance = Ω [1]

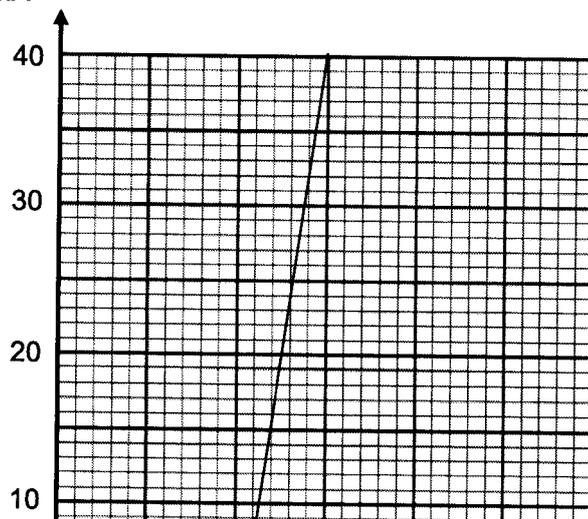
- (d) The LDR in Fig. 7.2 is now replaced with component X. Component X consists of the same LDR in parallel with the LED in (c).

The light intensity incident on the LDR remains constant at 500 lux. The resistance of the LDR follows Ohm's law when the intensity of light incident on it is constant.

On Fig. 7.4, draw the I-V characteristics of

- (i) the LDR. Label your line as L. [1]
- (ii) component X. Label your line as X. [1]

current / mA



[Turn over

(iii) Hence, determine the current from the 6.0 V battery.

current = A [2]

[Total: 10]

8 Read the passage and answer the questions that follow.

X-Rays

A modern X-ray tube is illustrated in Fig. 8.1. A heated cathode produces electrons, known as cathode ray, and these are accelerated by the potential difference between the cathode and anode. X-ray tubes used by dentists typically use potential differences of 60 kV. As the electrons hit the anode, X-rays are produced. Tungsten metal is an ideal material for the target, or anode, of an X-ray machine. In practice, only about 1 % of the energy of the electron beam produces X-rays. The rest is wasted as heat.

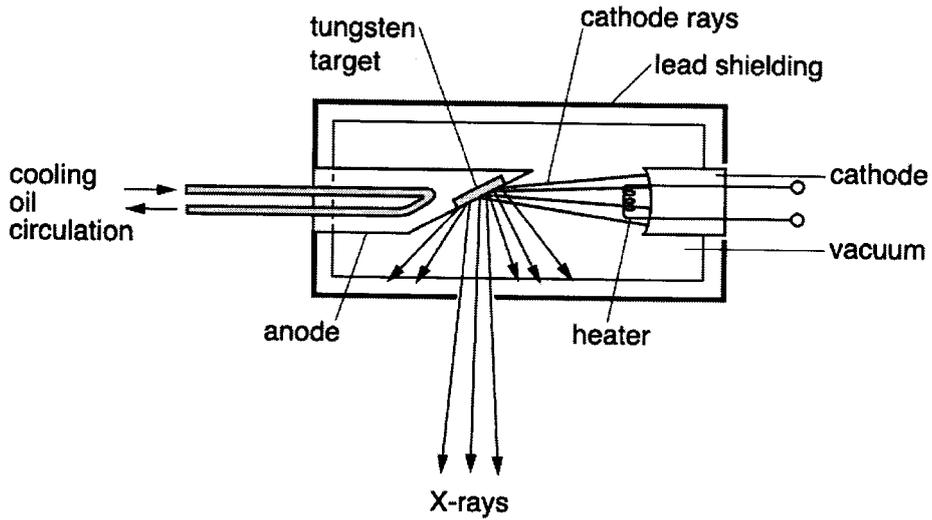


Fig. 8.1

The X-ray spectrum is both a continuous and a superimposed line spectrum, as shown in Fig. 8.2. Fig. 8.2a shows the X-ray spectrum and Fig. 8.2b shows how X-ray intensity varies with the wavelength. The wavelengths of the X-ray spectra are determined by the element from which the target is made.

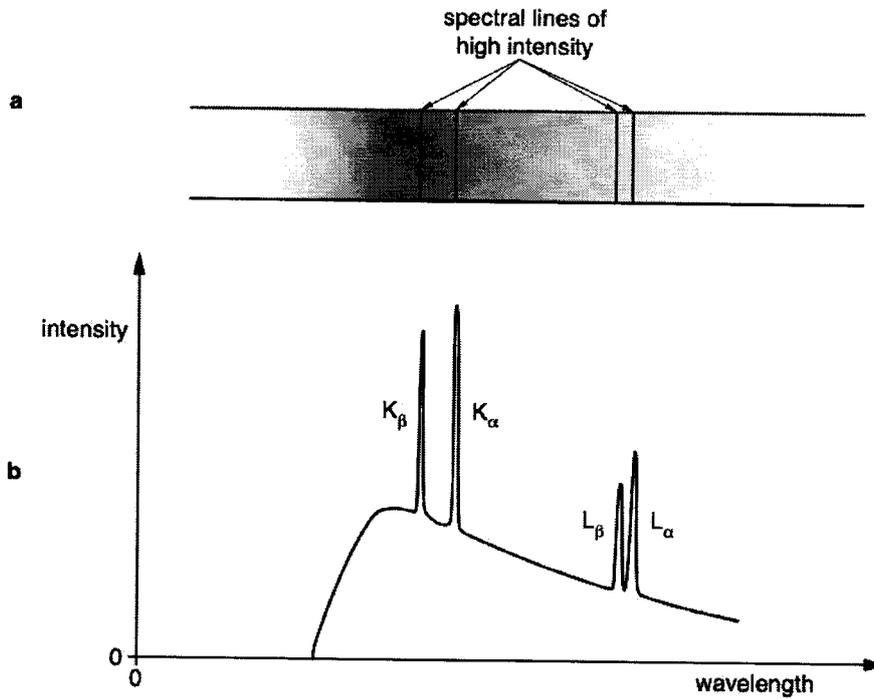


Fig. 8.2

Electrons in the tungsten atom have energy levels in a similar way to the energy levels for a hydrogen atom. Fig. 8.3 shows the logarithm of the energy E of some of the energy levels of electrons in the tungsten atom. E is measured in electron-volts (eV).

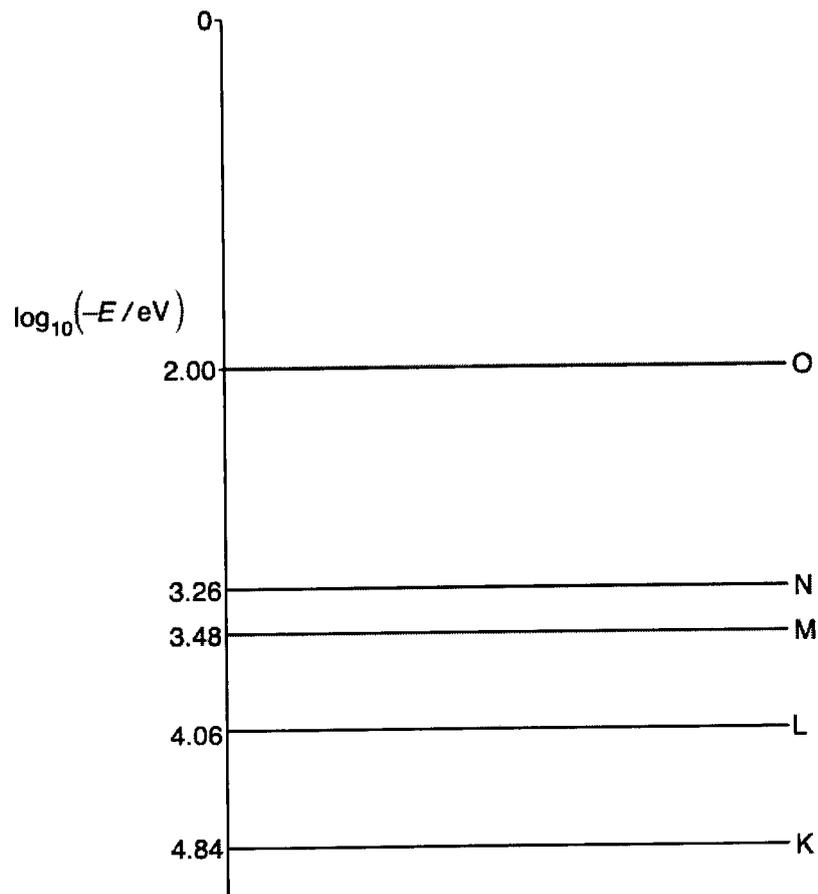


Fig. 8.3

Attenuation of X-ray

When X-ray passes through a medium, it is absorbed by the medium.

The intensity I of a beam of X-ray is related to the distance x it travels through a medium by the relationship:

$$I = I_0 e^{-\mu x}$$

where I_0 is the incident intensity and μ is the **total linear attenuation coefficient**, a constant which depends on the medium and the photon energy of the X-rays.

The decrease variation with distance of the intensity is shown in Fig. 8.4.

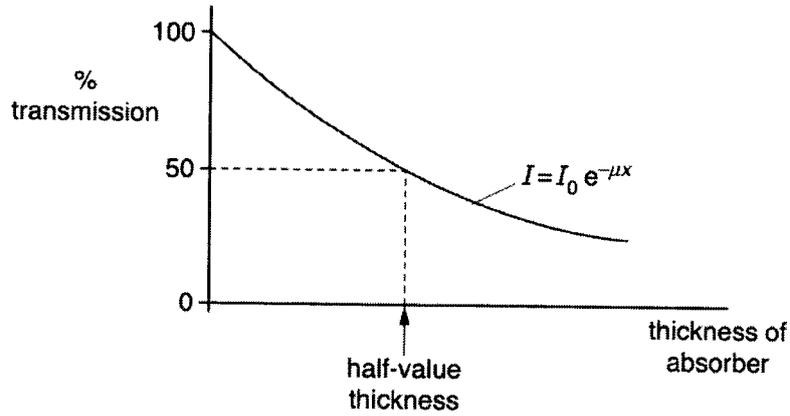


Fig. 8.4

The penetrating power, or quality, of a radiation can conveniently be described in terms of the thickness of material needed to reduce the intensity to half the original value. This is called the **half-value thickness (HVT)**, $\frac{x_{1/2}}$.

- (a) In the production of X-rays, electrons are emitted from the cathode and accelerated in an electric field. The electron energy is often described in terms of electron-volts.

Explain what is meant by the term *electron-volt*.

.....

 [2]

- (b) (i) When an electron strikes the target anode, it can emit energy in creating a single photon.

Determine the minimum wavelength for the X-ray spectrum used by dentist.

minimum wavelength = m [3]

- (ii) Suggest how the continuous spectrum of X-rays in Fig. 8.2 are produced.

.....

 [1]

- (c) An electron falling from the L to the K level gives rise to the K_α line. The photon energy of electrons falling from level L to level K depends on the element used for the target. The table in Fig. 8.5 shows the photon energy and the proton number Z for three elements.

element	proton number Z	K_α photon energy / keV
chromium	24	5.40
copper	29	8.03
silver	47	22.10
tungsten	74	

Fig. 8.5

In 1914 Henry G.J. Moseley discovered empirically that the wavelength λ of the K_α line is related to the proton number by the relationship:

$$\sqrt{\frac{1}{\lambda}} \propto Z$$

which is known as the Moseley's law.

- (i) Determine the K_α photon energy for the tungsten atom.

energy = keV [2]

- (ii) Determine quantitatively, without drawing a graph, whether Moseley's law is valid.

[3]

- (iii) Explain why the K_β line has a shorter wavelength than the K_α line.

.....

 [1]

- (d) Suggest and explain one feature of tungsten that makes it an ideal metal for the target of an X-ray machine.

.....

 [2]

- (e) A beam of X-rays is incident on a hand and the X-ray photograph is taken, as shown in Fig. 8.6.

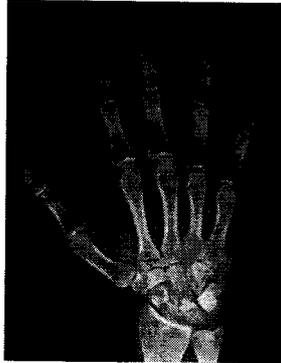


Fig. 8.6

- (i) The beam is attenuated as it passes through the bone. The total linear attenuation coefficient of the bone is 0.528 cm^{-1} .

1. Show that the penetrating power of the X-ray in human bone is 1.31 cm

[1]

2. Calculate the depth of bone required to reduce the intensity of the beam to 40.0% of its initial value.

depth of bone = cm [2]

- (ii) An identical beam of X-rays is also attenuated by 40% as it passes through 3.87 cm of human muscle.
 Calculate the total linear attenuation coefficient of human muscle.

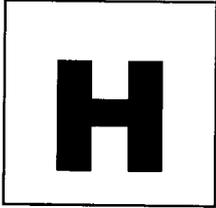
total linear attenuation coefficient = cm^{-1} [1]

[Turn over

- (iii) Briefly explain how these different values of attenuation coefficient help in the interpretation of X-ray pictures taken of human bodies.

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

[Total: 20]



NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

PHYSICS

Paper 3 Longer Structured Questions (Section A)

9749/03

19 Sep 2025
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your subject class, registration number and name in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use a HB pencil for any diagrams, graphs or rough working.

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

The use of an approved scientific calculator is expected, where appropriate.

Section A

Answer all questions.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

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

For Examiner's Use

Section A

1	/ 10
2	/ 10
3	/ 9
4	/ 11
5	/ 10
6	/ 10
Sub-Total	/ 60
Section B	/ 20
Total	/ 80

[Turn over

This document contains **19** printed pages and **1** 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	$\phi = -Gm/r$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

- 1 (a) Define *gravitational potential at a point*.

.....
 [1]

- (b) The Earth may be considered to be an isolated sphere of radius R with its mass M concentrated at its centre.

The variation of gravitational potential ϕ with distance x from the centre of the Earth is shown in Fig. 1.1.

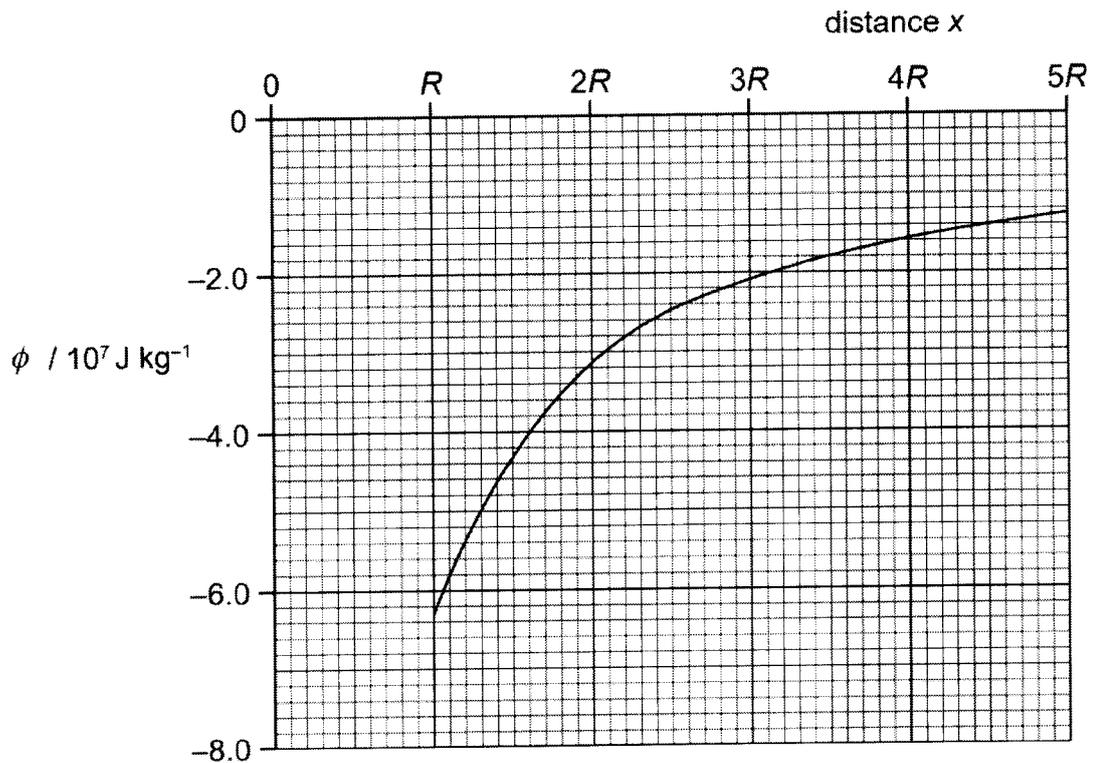


Fig. 1.1

The radius R of the Earth is $6.4 \times 10^6 \text{ m}$.

- (i) Show that the mass M of the Earth is $6.0 \times 10^{24} \text{ kg}$.

(ii) A meteorite is at rest at infinity. The meteorite travels from infinity towards the Earth.

When the meteorite is at a distance $2R$ above the Earth's surface, calculate

1. the speed of the meteorite,

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

2. the acceleration of the meteorite.

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

(iii) In practice, the Earth is not an isolated sphere because it is orbited by the Moon.

Suggest how the speed calculated in (ii)1. will change.

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

[Total: 10]

[Turn over

- 2 A cylinder that contains a fixed amount of an ideal gas is shown in Fig. 2.1.

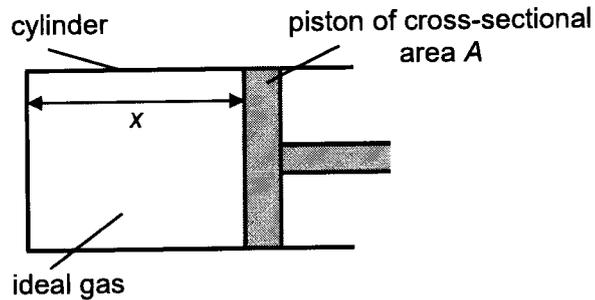


Fig. 2.1

The cylinder is tightly fitted with a piston, of cross-sectional area A . The piston moves freely in the horizontal direction, trapping the gas within a length x .

- (a) A gas molecule of mass m travels at a speed of u in the horizontal direction and collides elastically with the piston and the walls of the container.
- (i) State an expression, in terms of some or all of the symbols defined above, for the magnitude of the change in momentum during each collision.

change in momentum = [1]

- (ii) Hence, show that the average force exerted on the piston by the molecule is $\frac{mu^2}{x}$.

[1]

- (b) The gas in the cylinder undergoes a cycle of changes $A \rightarrow B \rightarrow C \rightarrow A$, as shown in Fig. 2.2.

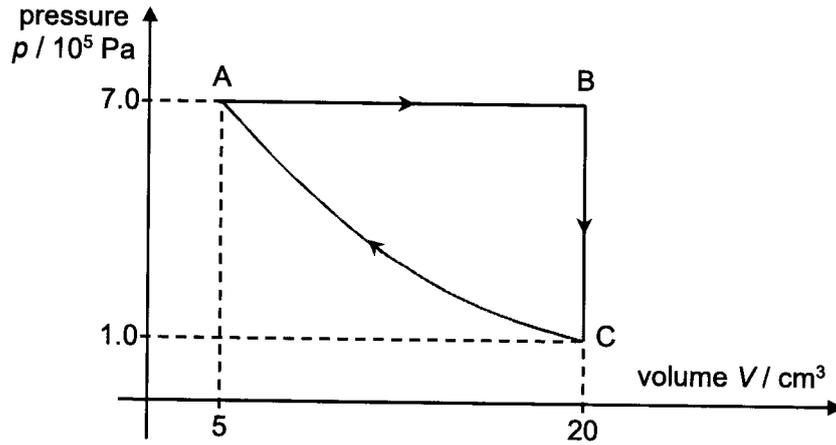


Fig. 2.2

(i) Calculate the work done by the gas during the change A → B.

work done by the gas = J [2]

(ii) Fig. 2.3 is a table of energy changes during one cycle. Complete Fig. 2.3.

section of cycle	heating supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A → B			
B → C	-30		
C → A	zero	3.7	

Fig. 4.2

[4]

(iii) The net work done by the gas is considered the useful work done of the cycle.

The efficiency of this cycle is given by

[Turn over

$$efficiency = \frac{useful\ work\ done}{total\ energy\ input} \times 100\%$$

Determine the efficiency of the cycle.

efficiency = % [2]

[Total: 10]

- 3 (a) State the *principle of superposition*.

.....

 [2]

- (b) Two coherent microwave sources X and Y of frequency 2.5×10^{10} Hz are a distance of 0.18 m apart in a vacuum, as shown in Fig. 3.1.

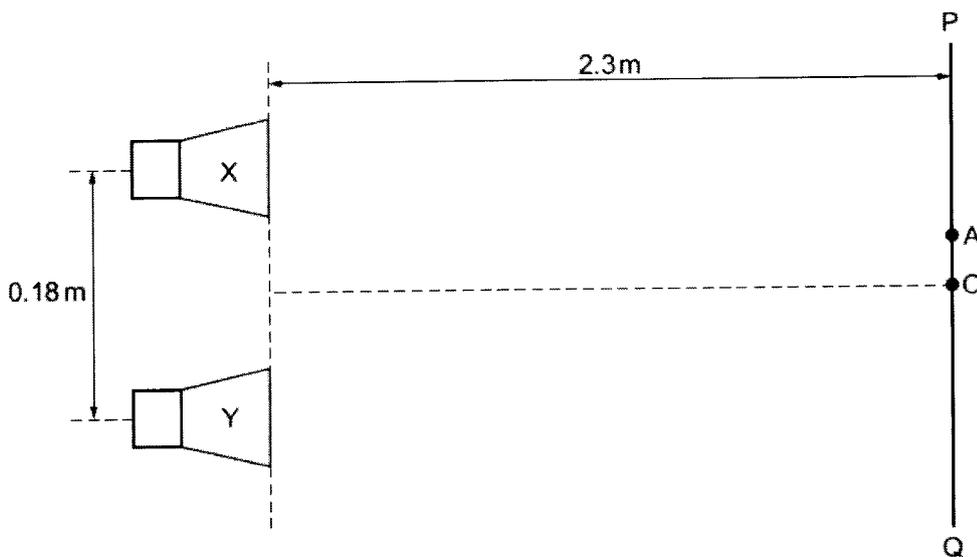


Fig. 3.1 (not to scale)

There is a phase difference of 180° between the waves emitted by the two sources.

A microwave detector moves along line PQ, which is parallel to the line joining the two sources and 2.3 m away from it.

Point O is along line PQ at a position that is equidistant from the two sources.
Point A is the first maximum intensity detected when the detector moves from O to A.

(i) Show that the wavelength of the microwaves is 0.012 m.

[1]

(ii) 1. Explain why zero intensity is detected at point O.

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

[2]

2. Determine the difference in the distances travelled by the microwaves from X to A and from Y to A.

difference = m [1]

(iii) Use the formula for the double-slit interference of light to calculate the distance between adjacent intensity maxima on line PQ.

distance = m [2]

[Turn over

- (iv) On Fig. 3.1, draw a cross (\times) to show the position of a point along line PQ closest to point O where the waves meet with a phase difference of 90° . Label this point B. [1]

[Total: 9]

- 4 (a) Define *electric field strength at a point*.

.....
 [1]

- (b) Two isolated non-conducting charged spheres X and Y are placed near to each other, as shown in Fig. 4.1.

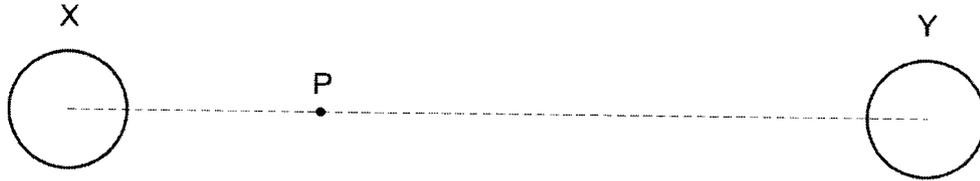


Fig. 4.1

P is a point on the line joining the centres of the spheres where the electric potential is zero.

- (i) Explain why it is **not** possible for the resultant electric field to be zero at point P.

.....

 [2]

- (ii) The magnitudes of the charges on spheres X and Y in Fig. 4.1 are Q and $2Q$ respectively. The spheres may be considered as point charges at their centres.

Point P is at a distance x from the centre of sphere X.

1. Show that the distance of point P from the centre of sphere Y is equal to $2x$.

[1]

2. Determine an expression, in terms of Q , x , π and the permittivity of free space ϵ_0 , for the resultant electric field strength E at point P due to the two spheres.

$E =$ [2]

[Turn over

(c) Fig. 4.2 shows a spark detector used to detect alpha particles.

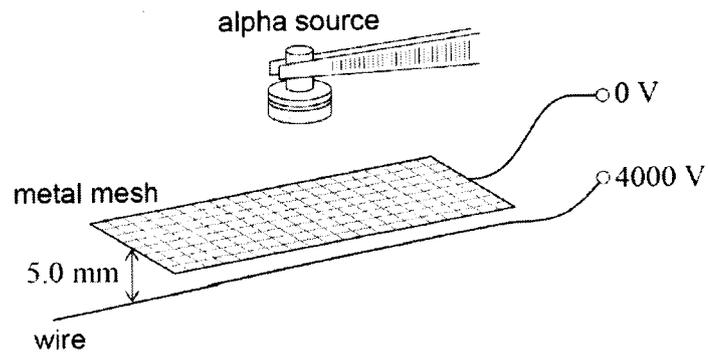


Fig. 4.2

The detector consists of a metal mesh placed 5.0 mm above a wire.
A potential difference of 4000 V is applied between the mesh and the wire.

Molecules in the air between the mesh and the wire are ionised by an alpha particle and a spark is produced.

- (i) Fig. 4.3 shows equipotential surfaces between the mesh and the wire.

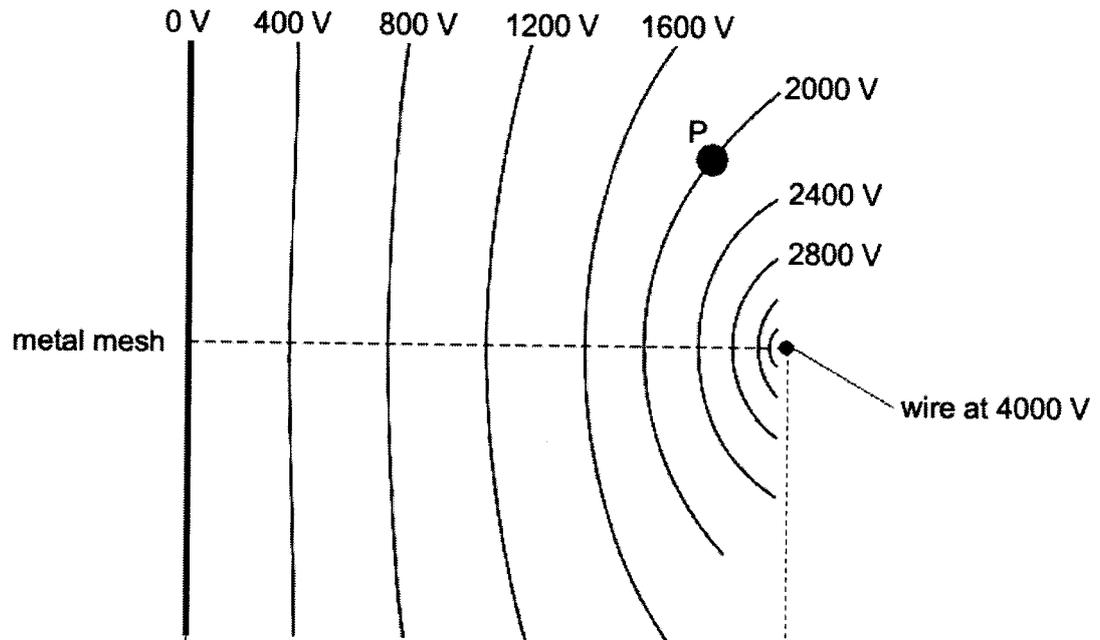


Fig. 4.3

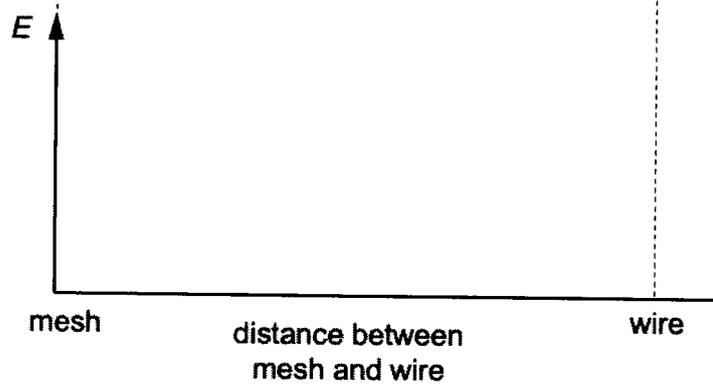


Fig. 4.4

Sketch on Fig. 4.4 the variation of the magnitude of the electric field strength E along the dashed line between the mesh and the wire in Fig. 4.3.

Values are not required on the E -axis.

[2]

[Turn over

- (ii) An alpha particle passes through the mesh. The alpha particle ionises an argon atom at point **P** on Fig. 4.3, releasing one electron.

The electron and the argon ion have no kinetic energy at point **P**.

The electron then travels to the wire and the argon ion (mass = 6.64×10^{-26} kg) travels to the mesh.

Calculate the ratio $\frac{\textit{speed of electron when it reaches the wire}}{\textit{speed of argon ion when it reaches the mesh}}$.

Assume that the air does not affect the motion of the electron or the argon ion.

ratio = [2]

- (iii) In practice, the air **does** affect the motion of the electron and the motion of argon ion.

Suggest qualitatively how the presence of the air between the mesh and the wire affects the ratio in (b)(ii).

.....

 [1]

[Total: 11]

- 5 (a) A metal rod is accelerated uniformly from rest in a uniform magnetic field as shown in Fig. 5.1.

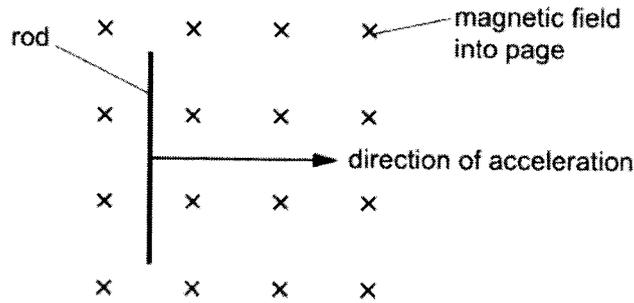


Fig. 5.1

The rod has length l and the flux density of the magnetic field is B .

An electromotive force (e.m.f.) is induced in the rod. The variation with time t of the induced e.m.f. E is shown in Fig. 5.2.

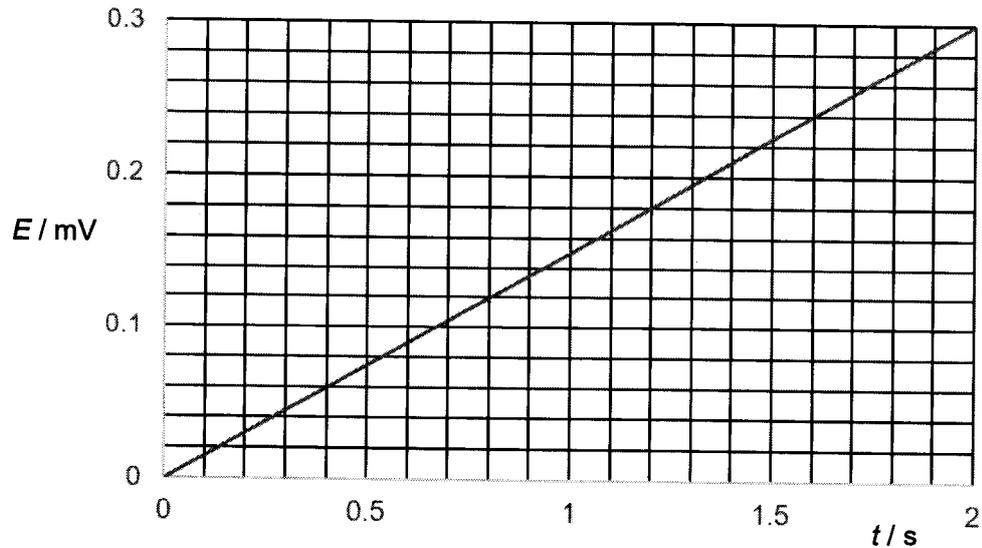


Fig. 5.2

- (i) Explain how Fig. 5.2 shows that the acceleration of the rod is uniform.

.....

 [2]

- (ii) The same metal rod in (a) is now placed on a pair of smooth conducting rails with a resistor R connected to the rails on a flat surface as shown in Fig. 5.3. The rod is pulled on the rails at a steady speed v from the left to the right.

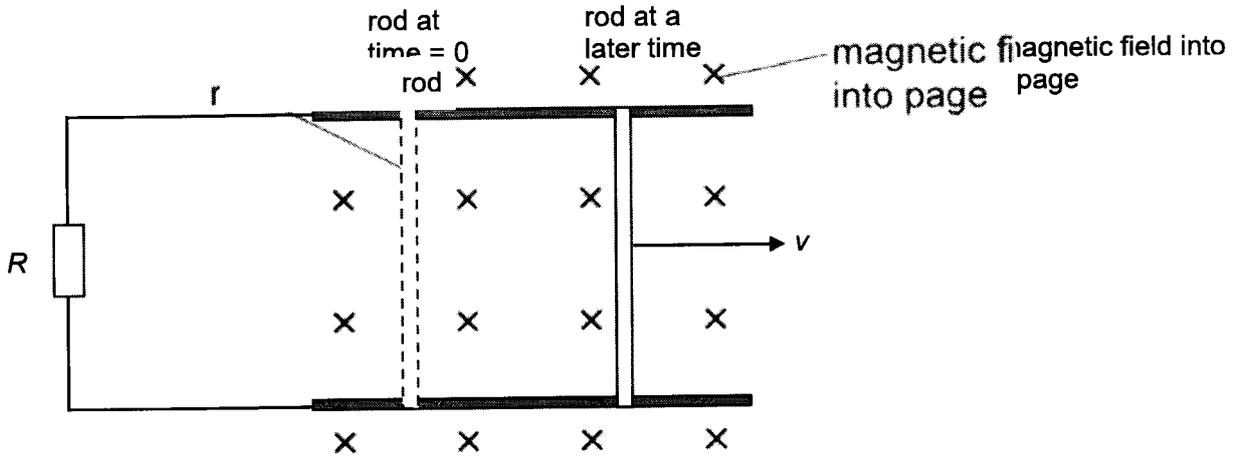


Fig. 5.3

Explain in terms of energy changes, why external work is needed to keep the speed of the rod constant.

.....

.....

.....

.....

..... [2]

- (b) An alternating current I in a resistor of resistance 400Ω varies with time t according to

$$I = 3.5 \sin(40\pi t)$$

where I is in A and t is in s.

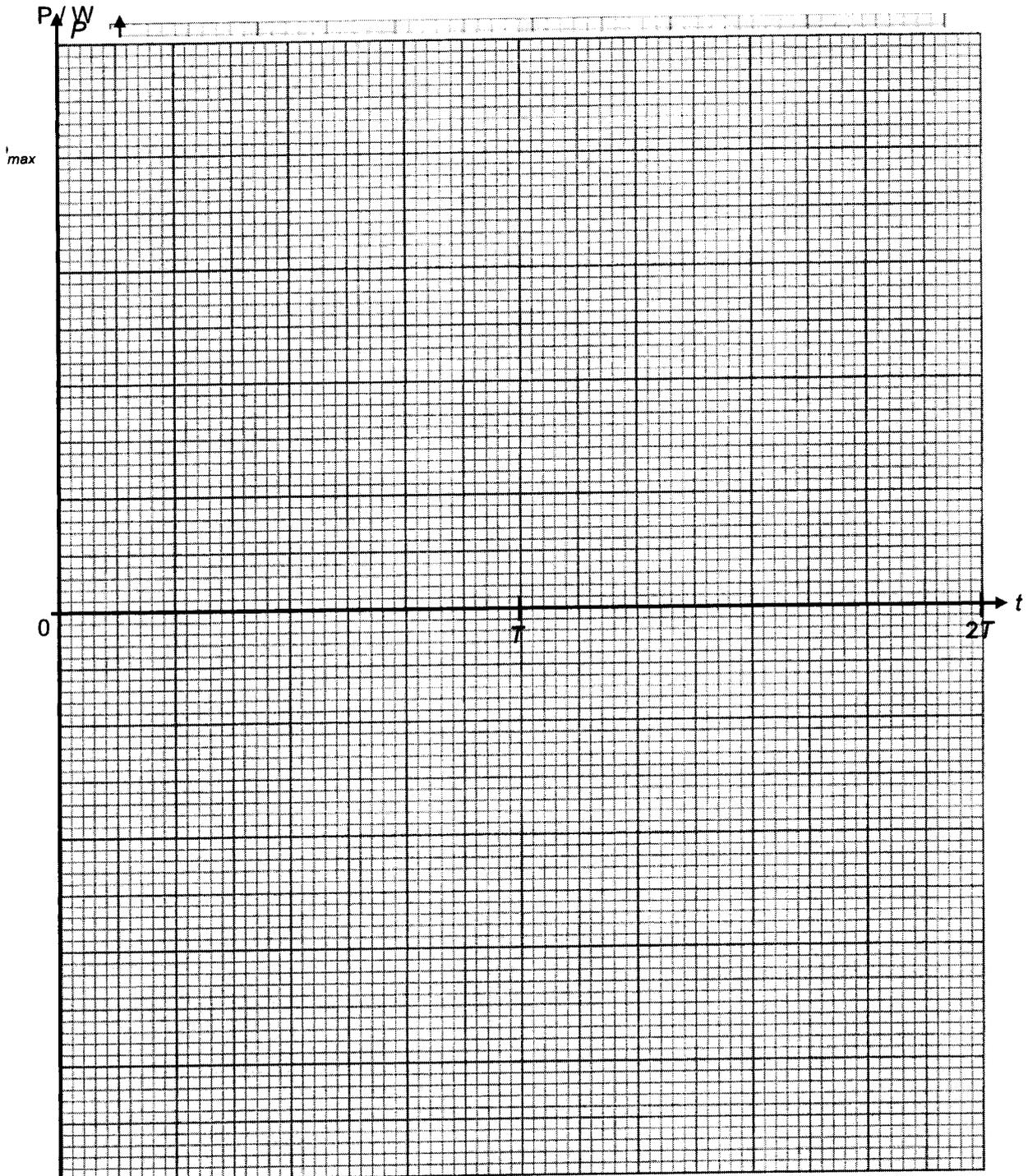
- (i) Calculate the period T period of the alternating current.

$$T = \dots\dots\dots \text{ s [1]}$$

- (ii) Calculate the mean power P transferred in the 400Ω resistor.

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

- (iii) On Fig. 5.4, show the variation with time t of the power P transferred in the resistor for two periods of the alternating current. P_{max} is the maximum power transferred in the resistor.



[3]

[Total: 10]

- 6 The energy E , in eV, of the electron energy levels in a hydrogen atom may be determined using the expression

$$E = -\frac{13.6}{n^2}$$

where n is the energy level.

- (a) (i) Calculate the energy, in eV, of energy level $n = 2$.

energy = eV [1]

- (ii) Explain why the energy of each energy level is negative.

.....
 [1]

- (b) A sample of low-pressure cool hydrogen gas is illuminated with monochromatic electromagnetic radiation of 103 nm. Some of the atoms are excited from the $n = 1$ level to the $n = 3$ level.

A spectrometer is placed near the sample of hydrogen gas, as shown in Fig. 6.1.

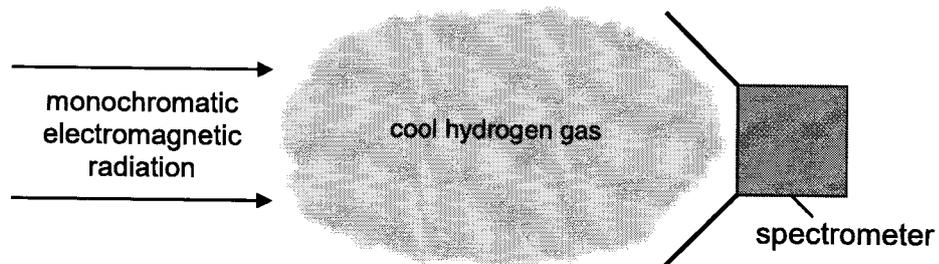


Fig. 6.1

Three wavelengths are detected by the spectrometer. One of the wavelengths is the incident radiation.

- (i) The hydrogen glows faintly. Only transitions from $n = 3$ level to the $n = 2$ level lead to emission of visible light photons.

Determine the wavelength of the visible light photons and state the colour of the glow.

wavelength = m

[Turn over

colour: [2]

(ii) Determine the third wavelength detected.

wavelength = m [2]

(iii) Explain why the number of photons measured over a duration for the wavelengths in (i) and (ii) is equal.

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

(iv) On Fig. 6.2, sketch the number of photons against wavelength graph of the spectrum detected over a duration.



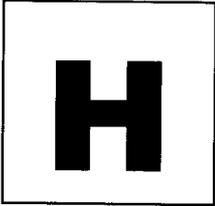
Fig. 6.2

[3]

[Total: 10]

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NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

PHYSICS

Paper 3 Longer Structured Questions (Section B)

9749/03

**19 Sep 2025
2 hours**

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your subject class, registration number and name in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use a HB pencil for any diagrams, graphs or rough working.

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

The use of an approved scientific calculator is expected, where appropriate.

Section B

Answer **one** questions only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

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

For Examiner's Use

Section B

7

/ 20

8

/ 20

[Turn over

This document contains **11** printed pages and **1** 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	$\phi = -Gm/r$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **one** question from this Section in the spaces provided.

- 7 (a) A cylindrical tube, containing some sand, floats upright in a liquid of density ρ , as shown in Fig. 7.1.

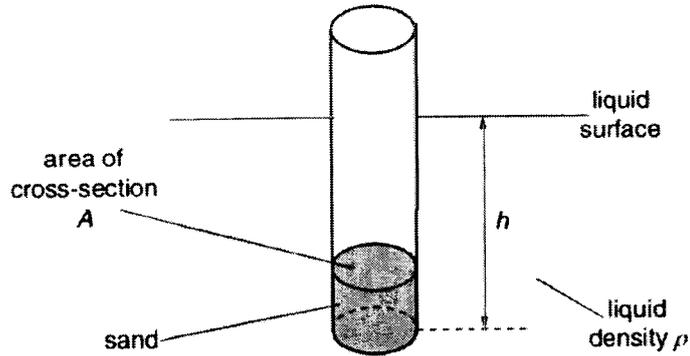


Fig. 7.1

The tube has cross-sectional area A . The total mass of the tube and sand is M . The tube floats in equilibrium with its base a distance h below the surface of the liquid.

- (i) By considering the pressure due to a fluid, show that $M = \rho hA$. Explain your working.

[2]

- (ii) The tube is now held stationary below the equilibrium floating position of the tube.

Show that, when released, the acceleration a of the tube is related to its displacement x from the equilibrium position by the equation:

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

where g is the acceleration of free fall. Explain your working.

- (b) A dipper oscillates at a frequency of 2.0 Hz in a ripple tank. Surface water waves ripple circularly out from the dipper with wavelength 1.0 cm as shown in Fig. 7.3.

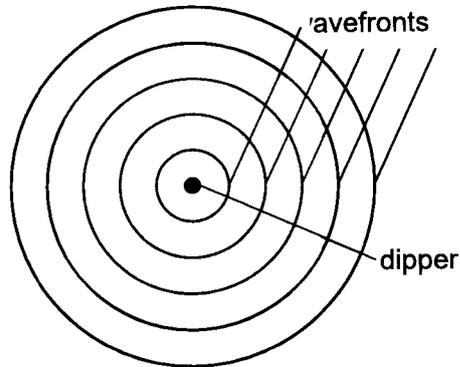


Fig. 7.3

- (i) Explain why the amplitude of the wave decreases with distance from the dipper.

.....

 [2]

- (ii) Show that the dipper and the water at a point 2.0 cm away from the dipper oscillate in phase.

- (iii) At a particular instance in time, the dipper is at its maximum negative displacement. X on Fig. 7.4 shows the variation with distance of the amplitude of the water wave.

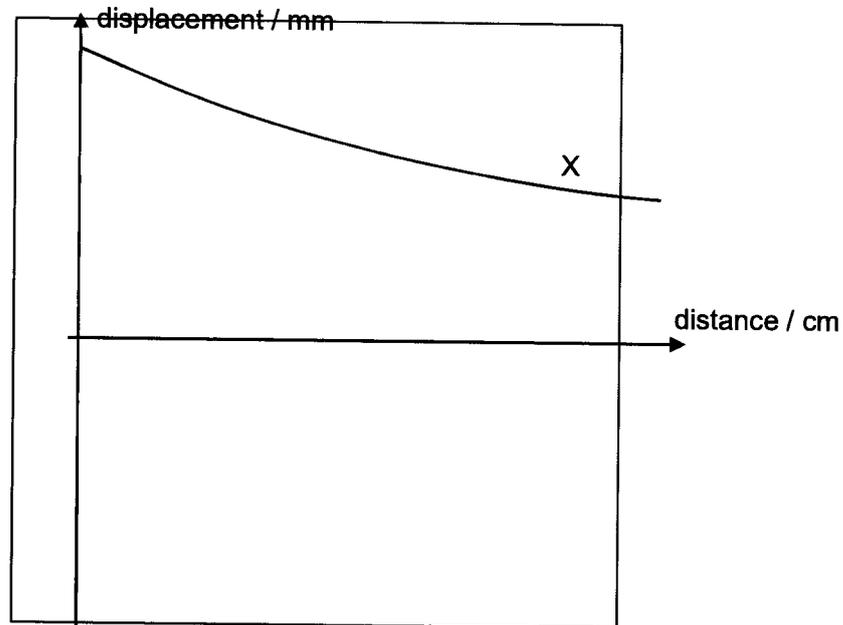


Fig. 7.4

On Fig. 7.4, sketch the displacement-distance graph of the water wave at this instance. [2]

- (iv) The dipper is at its maximum negative displacement when time = 0 s. On Fig. 7.5, sketch the displacement-time graph of the water at a point 3.0 cm away from the dipper.

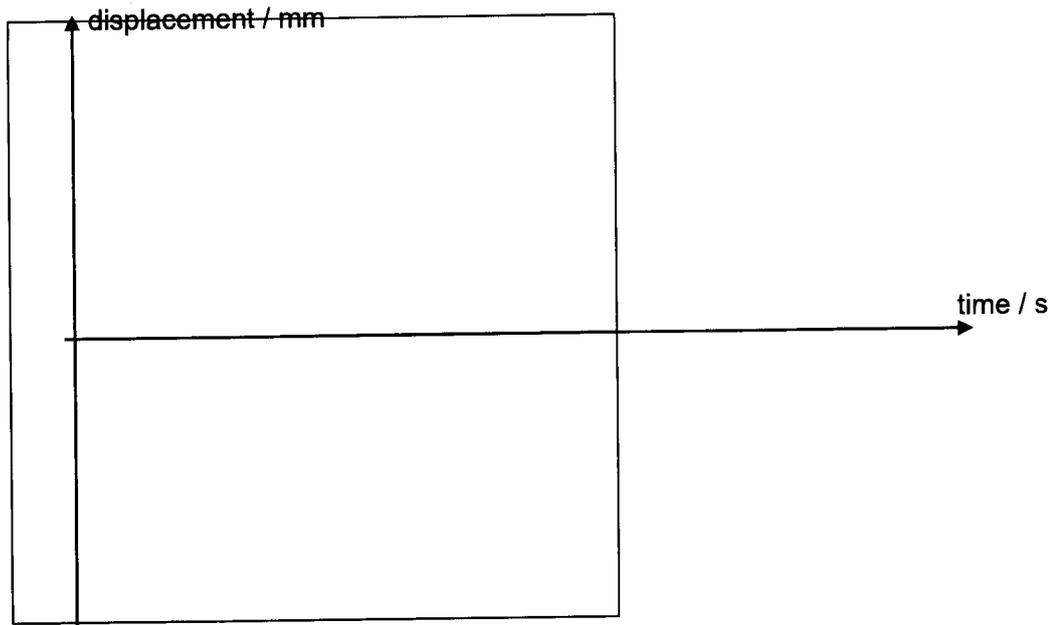


Fig. 7.5

[2]

[Total: 20]

- 8 (a) The masses of various nuclides and of various sub-atomic particles, are shown in Fig. 8.1.

nuclide or sub-atomic particles	proton number	mass / u
electron	n/a	0.000549
proton	n/a	1.007276
neutron	n/a	1.008664
helium-4	2	4.002603
thallium-205	81	204.974428
bismuth-209	83	208.980399
polonium-209	84	208.982430

Fig. 8.1

- (i) Bismuth-209 is radioactive.

Use the data in Fig. 8.1 to determine which type(s) of radiation (α or β) it is possible for bismuth-209 to emit. Explain your reasoning.

radiation emitted: [4]

(ii) Determine the binding energy per nucleon of bismuth-209.

binding energy per nucleon = MeV [4]

(b) A radiation detector is placed close to a radioactive source. The variation with time t of the measured count rate is shown in Fig. 8.2.

[Turn over

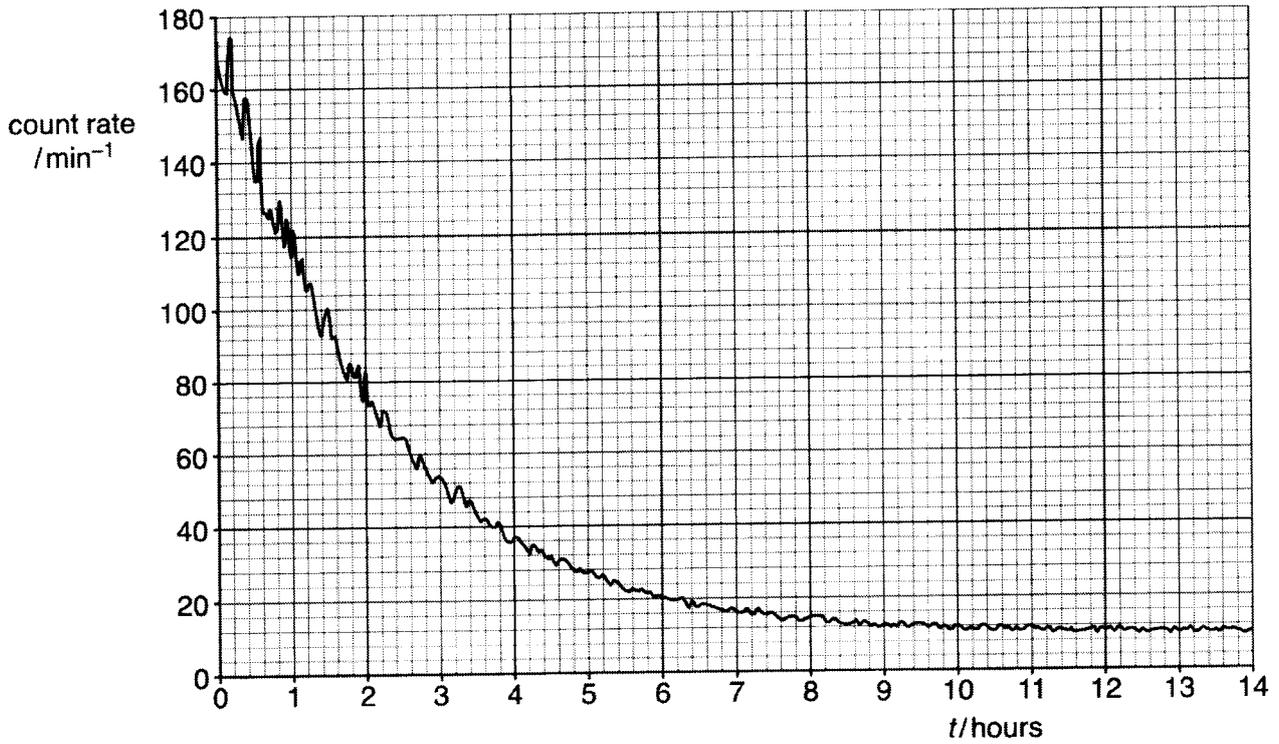


Fig. 8.2

(i) State the feature of Fig. 8.2 that indicates the random nature of radioactive decay.

.....

 [1]

(ii) State the background count rate recorded by the radiation detector.

background count rate = min⁻¹ [1]

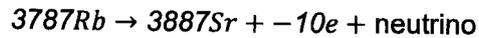
(iii) Use Fig. 8.2 to determine the half-life of the radioactive isotope in the source.

half-life = hours [3]

- (c) Samples of Moon rock were collected by Apollo astronauts.

Scientists measure the relative abundance of strontium isotopes in samples of Moon rock to determine the age of the rocks.

The isotope rubidium-87, found in Moon rock, is radioactive. It decays by beta emission. The nuclide decay equation is



- (i) The decay constant of rubidium-87 is $1.44 \times 10^{-11} \text{ yr}^{-1}$. Calculate, in years, the half-life of rubidium-87.

half-life = yr [1]

- (ii) When Moon rocks were formed about 4.0×10^9 years ago they contained rubidium-87, strontium-87 and strontium-86. The two strontium isotopes are stable. The rate at which strontium-87 atoms are created is equal to the rate of decay of the rubidium-87 atoms.

Use the half-life your answer in (c)(i), show that this rate has remained almost constant over the age of the rock.

- (iii) The ratio R of the strontium isotopes found in Moon rock is given by [2]

$$R = \frac{\text{number of atoms } {}^{87}_{38}\text{Sr}}{\text{number of atoms } {}^{86}_{38}\text{Sr}}$$

On Fig. 8.3, sketch a graph to show how the ratio R has varied with time since the rock samples formed.



Fig. 8.3

[2]

- (iv) Explain how a measure of the ratio R in (c)(iii) could be used to estimate the age of the Moon rock. State any additional information that would be required.

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

[Total: 20]

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