

INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE
NAME

CLASS

INDEX NUMBER

PHYSICS

9749/01

Paper 1 Multiple Choice

14 September 2018

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

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

Write your name, class and index 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.

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



Data

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
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

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

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

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

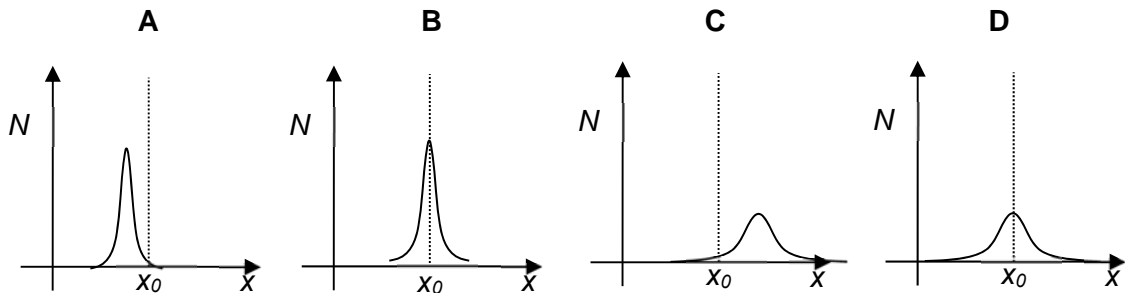
decay constant

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

- 1 In an experiment, a quantity x is measured many times.

Suppose N is the number of times of measurement which giving a value x and x_0 is the true value of the quantity.

Which of the following graphs best represents measurements of x that are precise but not accurate?

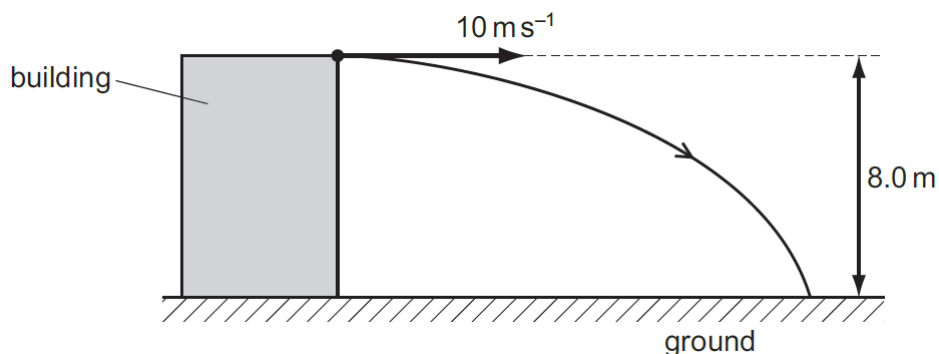


- 2 A capacitor is a device used to store electric charges. It consists of a pair of conducting plates. The capacitance C of a capacitor is defined as the ratio of the charge Q on either plate to the magnitude of the potential difference V between the plates, as depicted in the formula:

$$C = \frac{Q}{V}$$

Which of the following shows the SI base units for capacitance C ?

- A $A^2 s^4 m^{-2} kg^{-1}$ B $s^2 m^{-2} kg^{-1}$ C $A^2 m^{-2} kg^{-1}$ D $C^2 kg^{-1} m^{-2} s^2$
- 3 A boy throws a stone with a horizontal velocity of 10 m s^{-1} from the top of a building. The height of the building is 8.0 m . The stone travels along a curved path until it hits the ground, as shown in the diagram.



Neglecting air resistance, how long does it take the stone to reach the ground?

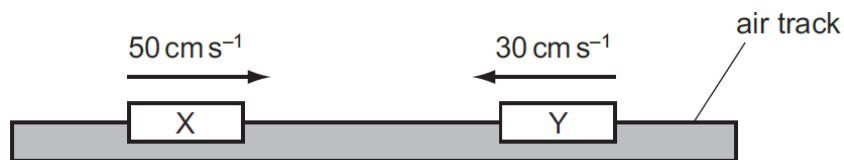
- A 0.61 s B 0.80 s C 1.3 s D 1.6 s

- 4 A firework rocket is fired vertically upwards. The fuel burns and produces a constant upwards force on the rocket. After 5 seconds, there is no fuel left. Air resistance is negligible.

What is the acceleration before and after 5 seconds?

	before 5 seconds	after 5 seconds
A	constant	constant
B	constant	zero
C	increasing	constant
D	increasing	zero

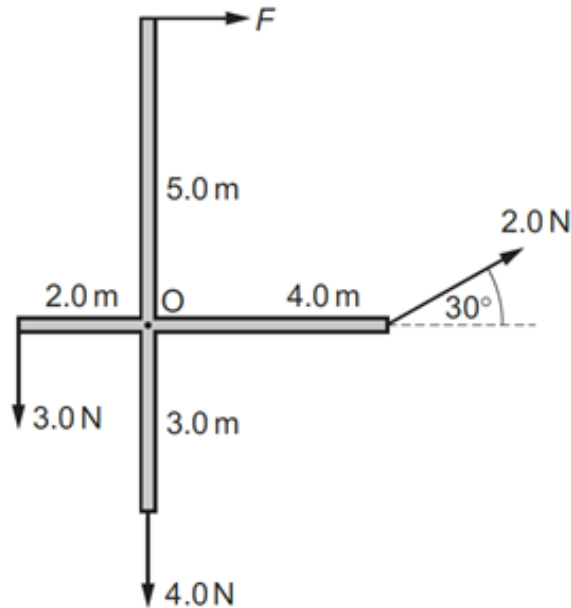
- 5 Two equal masses X and Y are moving towards each other on a frictionless air track as shown. The masses make an elastic collision.



Which row gives possible velocities for the two masses after the collision?

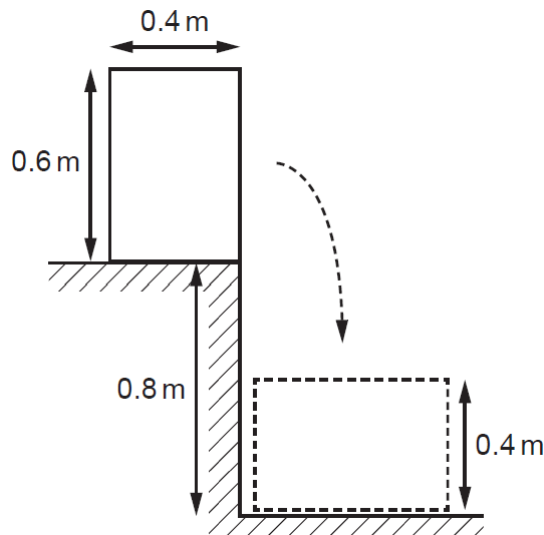
	velocity of X	velocity of Y
A	zero	20 cm s^{-1} to the right
B	10 cm s^{-1} to the right	10 cm s^{-1} to the right
C	20 cm s^{-1} to the left	zero
D	30 cm s^{-1} to the left	50 cm s^{-1} to the right

- 6 A cross-shaped structure, freely pivoted at O, has arms of lengths 5.0 m, 4.0 m, 3.0 m and 2.0 m. It is acted on by forces of 2.0 N, 3.0 N, 4.0 N and an unknown force F . The structure is in rotational equilibrium.



What is the magnitude of force F ?

- A 0.40 N B 2.0 N C 2.6 N D 4.4 N
- 7 A uniform solid block has weight 500 N, width 0.4 m and height 0.6 m. The block rests on the edge of a step of depth 0.8 m, as shown.

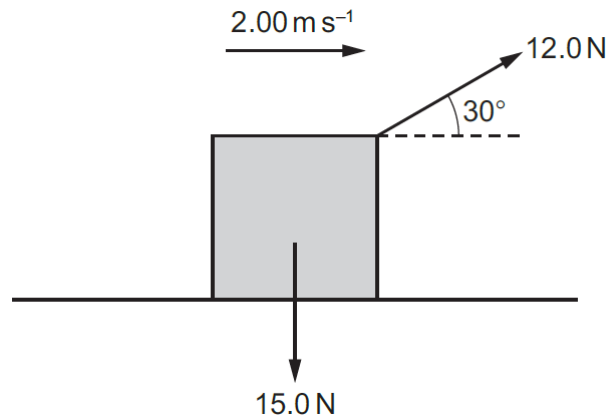


The block is knocked over the edge of the step and rotates through 90° before coming to rest with the 0.6 m edge horizontal.

What is the change in gravitational potential energy of the block?

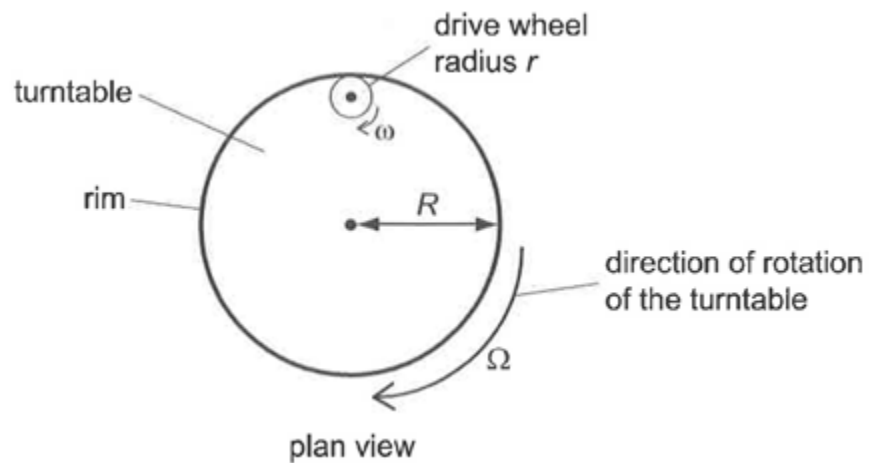
- A 300 J B 400 J C 450 J D 550 J

- 8 An object of weight 15.0 N is pulled along a horizontal surface at a constant velocity of 2.00 m s^{-1} . The force pulling the object is 12.0 N at 30° to the horizontal, as shown.



What is the power used to move the object?

- A 12.0 W B 20.8 W C 24.0 W D 30.0 W
- 9 A turntable has radius R . It is driven by a rubber drive wheel of radius r in contact with the inside of the rim of the turntable, as shown in the plan view diagram.



The turntable rotates with angular velocity Ω and the linear speed of a point on its rim is V . The drive wheel rotates with angular velocity ω and the linear speed of a point on its rim is v .

Which pair of equations show the relationship between the angular velocities and the linear speeds of the turntable and the wheel?

	angular velocities	linear speeds
A	$\Omega = \omega$	$V = v$
B	$\Omega = \omega$	$V = (r/R) v$
C	$\Omega = (r/R) \omega$	$V = v$
D	$\Omega = (R/r) \omega$	$V = (r/R) v$

- 10 A stationary object is released from a distance $6R$ from the centre of the Earth which has radius R and mass M .

Which one of the following expressions gives the speed of the object on hitting the Earth?

A $\sqrt{\frac{GM}{R}}$ B $\sqrt{\frac{GM}{5R}}$ C $\sqrt{\frac{5GM}{2R}}$ D $\sqrt{\frac{5GM}{3R}}$

- 11 A satellite is orbiting near the Moon's surface. The acceleration at the Moon's surface due to lunar gravity is $g/6$ and the Moon's radius is $R/4$ (where g is the acceleration of the Earth and R is the radius of the Earth).

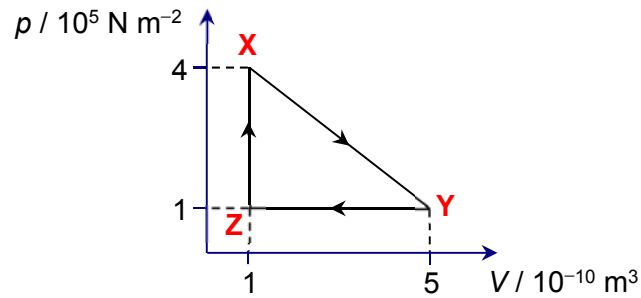
If a satellite orbiting near the Earth's surface has a period of T , what is the period of revolution of the Moon's satellite?

A $\frac{2}{3} T$ B $\sqrt{\frac{2}{3}} T$ C $\frac{4}{9} T$ D $\sqrt{\frac{3}{2}} T$

- 12 Two bodies X and Y are in good thermal contact and no net transfer of heat energy from one to the other is observed. Which one of the following statements is certainly correct?

- A The mean energies of their molecules are the same.
- B The total kinetic energies of their molecules are the same.
- C The materials have the same thermal conductivity.
- D Their internal energies are equal.

- 13 A mass of an ideal gas of volume V , at pressure p , undergoes a cycle of changes as shown in the graph.



Which combination is correct?

	work done by gas is negative	heat is
A	Y to Z	added
B	Y to Z	removed
C	X to Y	added
D	X to Y	removed

- 14 A particle oscillates with undamped simple harmonic motion. Which one of the following statements about the acceleration of the oscillating particle is true?

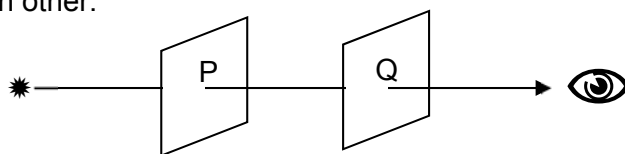
- A** It decreases as the potential energy increases.
- B** It is always in the opposite direction to its velocity.
- C** It is least when the speed is greatest.
- D** It is proportional to the frequency.

- 15 The least distance between two points of a progressive transverse wave which have a phase difference of $\frac{\pi}{3}$ rad is 0.050 m.

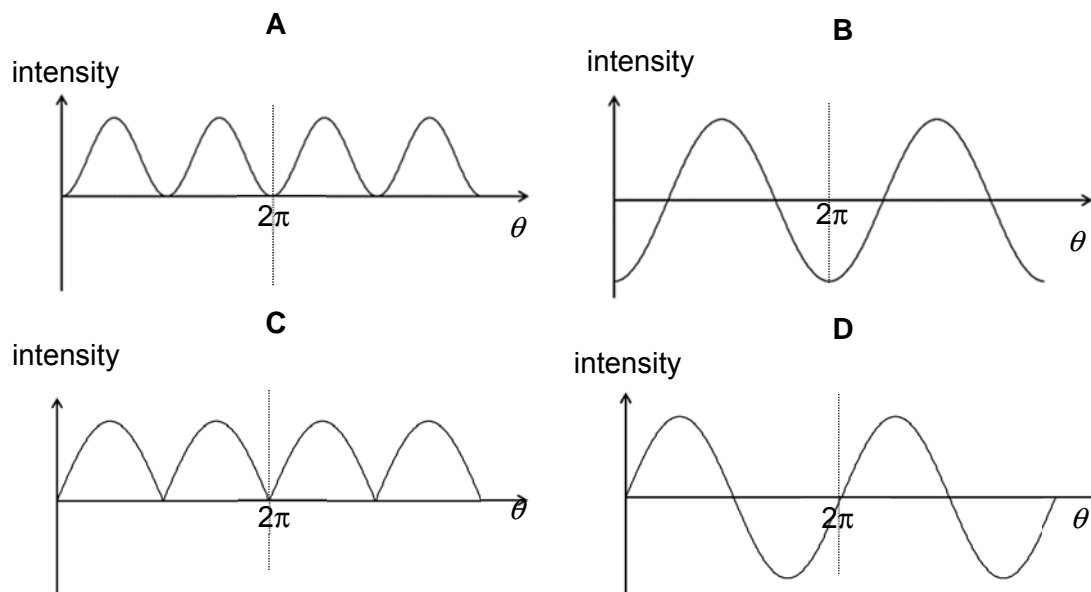
If the frequency of the wave is 500 Hz, what is the speed of the wave?

- A** 25 m s⁻¹ **B** 75 m s⁻¹ **C** 150 m s⁻¹ **D** 1666 m s⁻¹

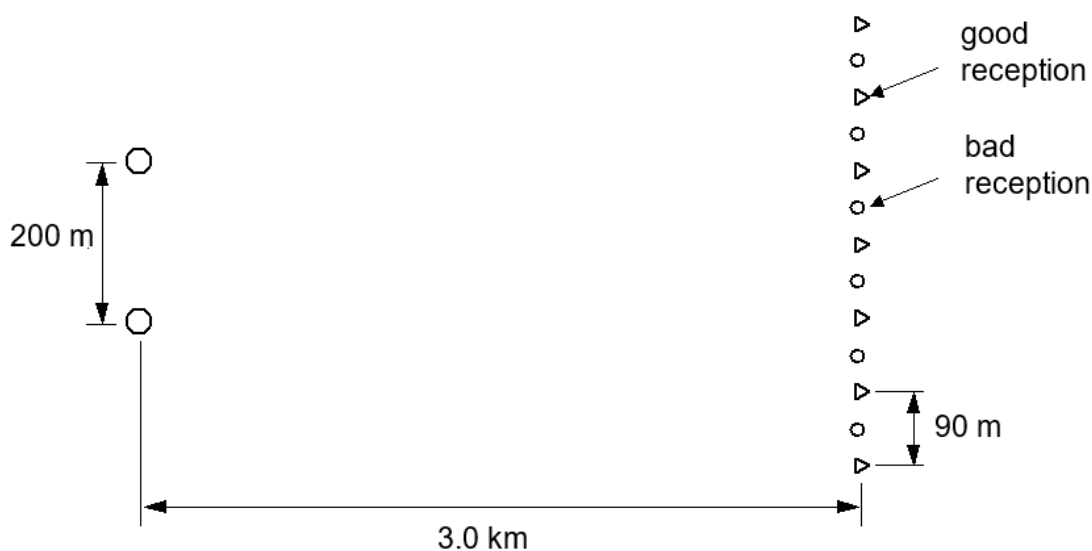
- 16 A light source is viewed through two pieces of polarizers with their axes initially at $\frac{1}{2}\pi$ rad from each other.



Which graph correctly shows the variation of intensity reaching the eye with angular displacement of the Q with respect to P when polarizer Q is rotated?



- 17 Two radio transmitters 200 m apart are transmitting on the same frequency as shown in the diagram below.

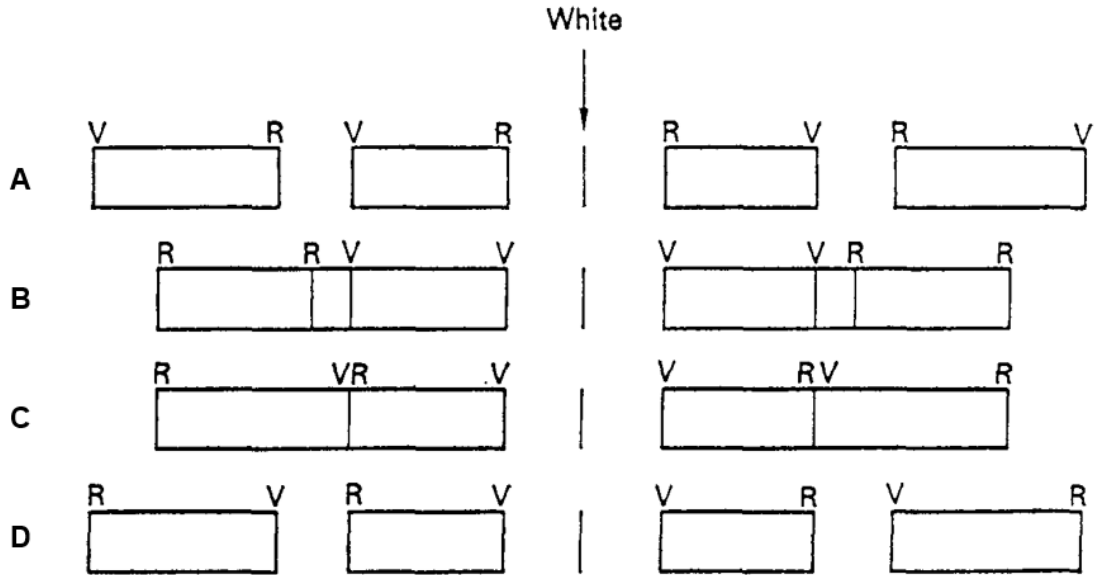


At a distance of 3.0 km away, it was found that there are series of good and poor areas of reception which are 90 m apart. Which one of the following is the wavelength of the radio wave?

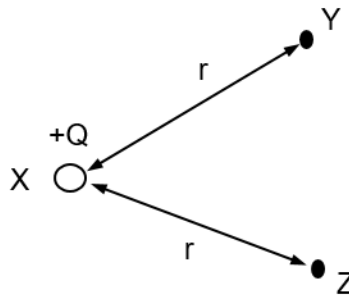
- A 0.17 m B 6.0 m C 670 m D 1350 m

- 18 A narrow shaft of white light (from violet 350 nm (V) to red 700 nm (R)) falls with normal incidence on a diffraction grating, and produces two orders of spectra on a distant screen.

Which of the following diagram shows the appearance of the spectra?



- 19 The figure below shows a particle of charge $+Q$ at X. The points Y and Z are equidistant from X.



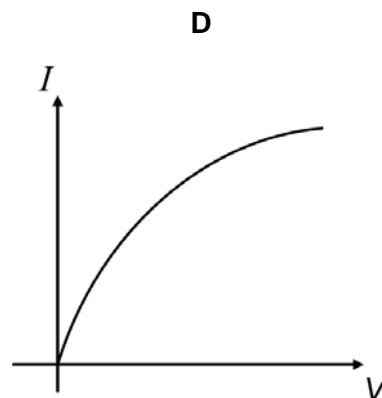
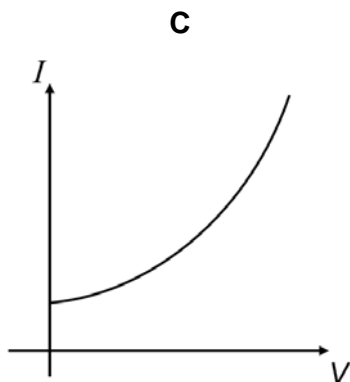
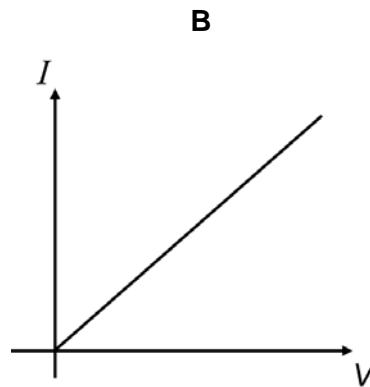
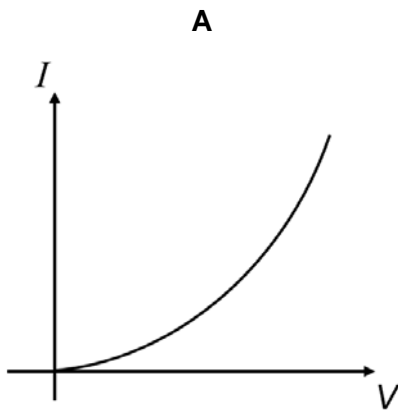
Which one of the following statements with reference to the above figure is **incorrect**?

- A No work is done in taking a charge from Y to Z.
- B The electric field strength at Z acts along ZX in the direction of Z to X.
- C The magnitude of the electric field strength at Y is equal to the magnitude of the electric field strength at Z.
- D The potentials at Y and Z are equal.

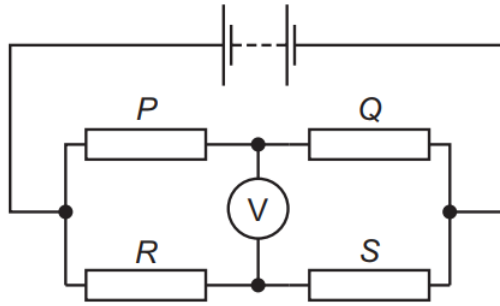
- 20 A potential difference of 12 V is applied across a resistor for a time interval of 5.0 s. The current flowing through the resistor is 3.0 A.

Which of the following statements is **incorrect**?

- A The resistance of the resistor is 4.0 Ω .
- B The energy dissipated in the resistor is 36 J.
- C The charge passing through the resistor is 15 C.
- D The potential difference across the resistor is 12 J C⁻¹.
- 21 Which of the following graphs best represents the relationship between the current I and applied p.d. V for a thermistor?



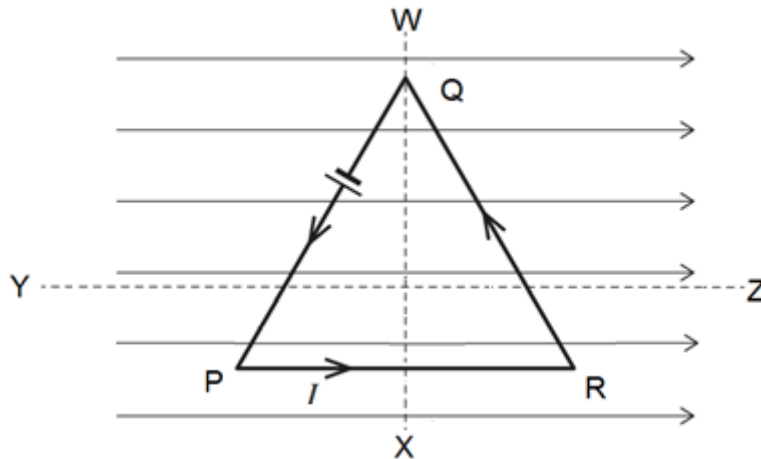
- 22 The circuit diagram shows four resistors of different resistances P , Q , R and S connected to a battery.



The voltmeter reading is zero.

Which equation is correct?

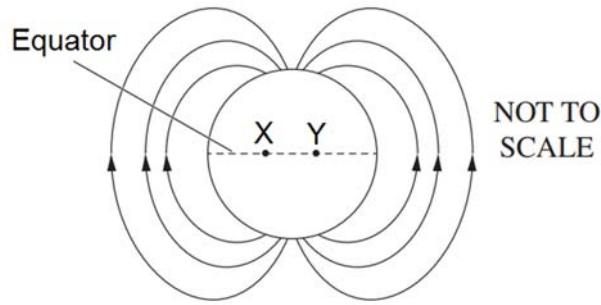
- A $P - Q = R - S$
- B $P - S = Q - R$
- C $PQ = RS$
- D $PS = QR$
- 23 A triangular piece of wire frame is placed in a magnetic field as shown below.



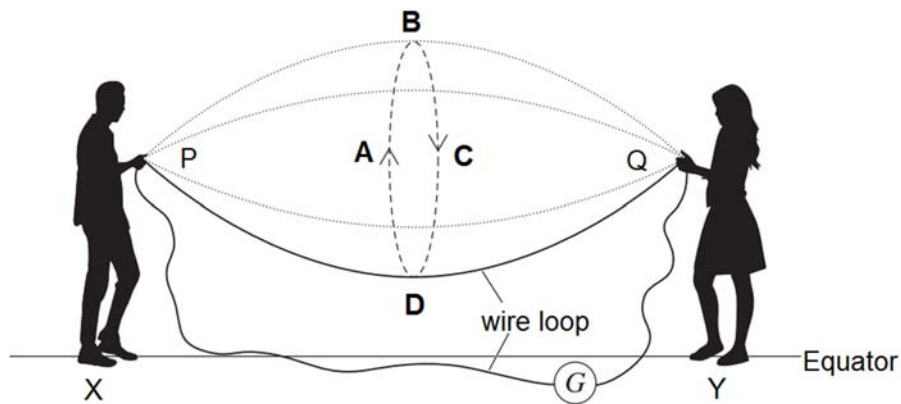
When a current I is supplied as shown, how does the wire frame rotate?

	Axis of rotation	Direction of movement
A	YZ	Q into page
B	YZ	Q out of page
C	WX	R into page
D	WX	R out of page

- 24 The Earth's magnetic field is shown in the following diagram.



Two students standing a few metres apart on the equator at points X and Y, where the Earth's magnetic field is parallel to the ground and acting into the page, hold a loop of copper wire between them. Part of the loop is rotated like a skipping rope as shown, while the other part remains motionless on the ground.



At which point **A**, **B**, **C** and **D** during the rotation of the wire does the maximum current flow in the direction from P to Q through the moving part of the wire?

- 25 A sinusoidal potential difference V_1 as shown in **Fig. A**, is applied across a resistor R and produces heat at a mean rate W .

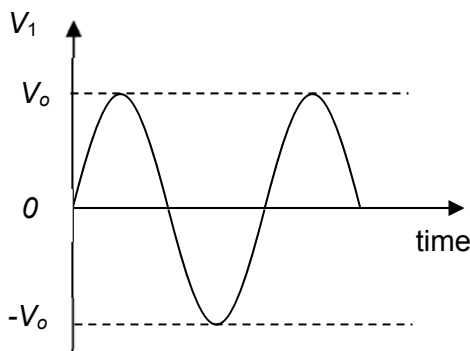


Fig. A

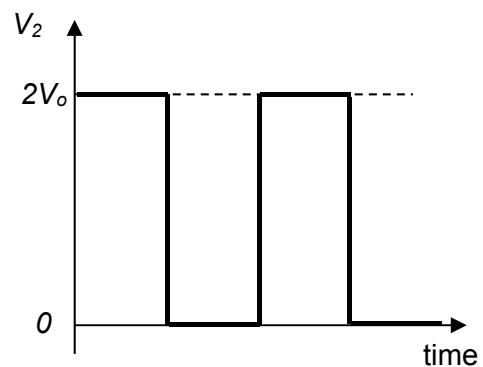


Fig. B

What is the mean rate of heat produced when another potential difference V_2 as shown in **Fig. B** is applied across the same resistor?

- A** $\frac{1}{2} W$ **B** $2 W$ **C** $4 W$ **D** $8 W$

- 26 An electric kettle has the following label:

Power : 2000 to 2400 W
 Voltage : 220 to 240V
 Frequency : 50 to 60 Hz

Which of the following is a probable expression of the current that passes through the kettle when used in Singapore?

- A $I = 8.33 \sin(315t)$ B $I = 10.9 \sin(315t)$
 C $I = 14.1 \sin(375t)$ D $I = 16.0 \sin(375t)$
- 27 A photon is emitted from a hydrogen atom by an electron transition between two energy levels. The energy levels have energies X and Y .

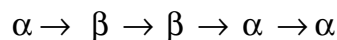
Which expression gives the momentum of this photon?

- A $\frac{(X-Y)}{h}$ B $\frac{(X-Y)}{c}$ C $\frac{(X-Y)}{hc}$ D $\frac{h(X-Y)}{c}$

- 28 A proton has a kinetic energy of 1.00 MeV.

If its momentum is measured with an uncertainty of 1.0 %, what is the minimum uncertainty in its position?

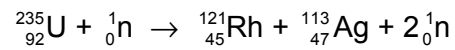
- A $1.22 \times 10^{-10} \text{ m}$ B $2.87 \times 10^{-12} \text{ m}$ C $9.08 \times 10^{-12} \text{ m}$ D $6.59 \times 10^{-15} \text{ m}$
- 29 ${}_{92}^{238}\text{U}$ decays through a series of transformations to a final stable nuclide. The particles emitted in the successive transformations are



Which nuclide is not produced during this series of transformations?

- A ${}_{88}^{228}\text{Ra}$ B ${}_{90}^{230}\text{Th}$ C ${}_{91}^{234}\text{Pa}$ D ${}_{92}^{234}\text{U}$

30 The equation



shows the fission of a uranium-235 nuclide by a slow-moving neutron into a rhodium-121 nuclide, a silver-113 nuclide and two neutrons.

binding energy per nucleon of ${}_{92}^{235}\text{U} = 7.59 \text{ MeV}$

binding energy per nucleon of ${}_{45}^{121}\text{Rh} = 8.26 \text{ MeV}$

binding energy per nucleon of ${}_{47}^{113}\text{Ag} = 8.52 \text{ MeV}$

What is the energy released during this fission process?

A 9.19 MeV

B 24.4 MeV

C 73.9 MeV

D 179 MeV

END OF PAPER

Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans
1	A	6	B	11	D	16	A	21	A	26	C
2	A	7	C	12	A	17	B	22	D	27	B
3	C	8	B	13	B	18	C	23	C	28	B
4	C	9	C	14	C	19	B	24	C	29	A
5	D	10	D	15	C	20	B	25	C	30	D

1 Ans: A
 Since it is precise, the spread of the values must be small.
 Since it is not accurate, it must deviate from the true value.

2 Ans: A
 Units of Q is $C = A s$
 Units of V is $J C^{-1} = kg m^2 s^{-2} / A s$

Hence units of C = $A^2 s^4 m^{-2} kg^{-1}$

3 Ans: C
 $s_y = u_y t + \frac{1}{2} a_y t^2$
 $-8.0 = 0 + \frac{1}{2} (-9.81)t^2$
 $t = 1.3 s$

4 Ans: C
 $F_n = ma$
 $U - W = ma$
 With the fuel burning, the mass and the weight of the rocket reduces. Hence, with increase in resultant force and decrease in mass of the rocket, acceleration of the rocket increases.

After 5 s, the mass remains constant. With the resultant force which is only comprised of weight, the acceleration remains constant.

5 Ans: D
 collision:
 $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$ where $m_1 = m_2$
 $u_1 + u_2 = v_1 + v_2$
 $(+50) + (-30) = v_1 + v_2$
 $v_1 + v_2 = 20$

elastic
 $u_1 - u_2 = v_2 - v_1$
 $(+50) - (-30) = v_2 - v_1$
 $v_2 - v_1 = 80$

	$v_1 + v_2$	$v_2 - v_1$
A	$0 + 20 = 20$	$20 - 0 = 20$
B	$10 + 10 = 20$	$10 - 10 = 0$
C	$(-20) + 0 = -20$	$0 - (-20) = 20$
D	$(-30) + (50) = 20$	$50 - (-30) = 80$

6 Ans: B
 Rotational equilibrium: $\Sigma M = 0$

Since 4.0 N force is passing through the pivot, it does not create any moment.
 Clockwise moment about O = Anticlockwise moment about O
 $F \times 5.0 = 2.0 \sin 30^\circ \times 4.0 + 3.0 \times 2.0$
 $F = 2.0 N$

7 Ans: C
 $\Delta GPE = mg\Delta h$ where $\Delta h =$ difference in height of CG
 $= 500 \times (1.1 - 0.2)$

$$= 450 \text{ J}$$

8 Ans: **B**

$$\begin{aligned} P &= Fv \\ &= 12.0 \cos 30^\circ \times 2.00 \\ &= 20.8 \text{ W} \end{aligned}$$

9 Ans: **C**

Since the drive wheel and the turntable are in contact, they should be moving with the same speed, i.e. $V = v$

Therefore, $R\Omega = r\omega$

$$\Omega = (r/R)\omega$$

10 Ans: **D**

By conservation of energy,

$$KE_i + GPE_i = KE_f + GPE_f$$

$$0 + \left(-\frac{GMm}{6R} \right) = \frac{1}{2}mv^2 + \left(-\frac{GMm}{R} \right)$$

$$v = \sqrt{\frac{5GM}{3R}}$$

11 Ans: **D**

$$F_c = ma_c$$

$$mg = mr\omega^2$$

When satellite is orbiting near the Moon's surface,

$$m \frac{g}{6} = m \left(\frac{R}{4} \right) \left(\frac{2\pi}{T_M} \right)^2 \quad \text{--- (1)}$$

When satellite is orbiting near the Earth's surface

$$mg = mR \left(\frac{2\pi}{T} \right)^2 \quad \text{--- (2)}$$

$$\frac{(1)}{(2)} : \frac{m \frac{g}{6}}{mg} = \frac{m \left(\frac{R}{4} \right) \left(\frac{2\pi}{T_M} \right)^2}{mR \left(\frac{2\pi}{T} \right)^2}$$

$$\left(\frac{T_M}{T} \right)^2 = \frac{6}{4}$$

$$T_M = \sqrt{\frac{3}{2}} T$$

12 Ans: **A**

Since there is no net transfer of heat energy from one to the other, bodies X and Y are in thermal equilibrium, i.e. same temperature. Their mean KE, given by $3/2 kT$ must be the same.

The internal energies and the total kinetic energies of bodies X and Y depends on both their temperature and the number of molecules.

Thermal equilibrium does not depend on thermal conductivity of the material of bodies X and Y.

13 Ans: **B**

Work done on gas is positive during compression, hence work done by gas is negative during compression (Y to Z).

For ideal gas, $U = 3/2 pV$. Hence the internal energy of the ideal gas decreases with constant pressure but decreasing volume.

With work done on gas being positive, the heat is transferred out of the gas, i.e. heat is removed.

- 14** Ans: **C**
A It **increases** as the potential energy increases.
B It is always in the opposite direction to its **displacement**.
C True
D It is proportional to the **square** of the frequency.

- 15** Ans: **C**

$$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$$

$$\frac{\pi/3}{2\pi} = \frac{0.050}{\lambda}$$

$$\lambda = 0.30 \text{ m}$$

$$v = f\lambda = 500 \times 0.30$$

$$= 150 \text{ m s}^{-1}$$

- 16** Ans: **A**

According to Malu's law
 $I = I_0 \cos^2 \theta$
 With the axes initially 90° from each other,
 $I = I_0 \cos^2(90 - \theta) = I_0 \sin^2(\theta)$
 The graph follows a sine square function.

- 17** Ans: **B**

Since $a \ll D$, this scenario can be approximated to a Young's double slit experiment.

$$x = \frac{\lambda D}{a}$$

$$90 = \frac{\lambda \times 3000}{200}$$

$$\lambda = 6.0 \text{ m}$$

- 18** Ans: **C**

$d \sin \theta = n\lambda$
 Violet light has a shorter wavelength than red light, thus it will be diffracted less from the normal than red light

Second order of violet light: $d \sin \theta_v = 2 \times 350 \times 10^{-9} = 700 \times 10^{-9}$

First order of red light: $d \sin \theta_r = 1 \times 700 \times 10^{-9} = 700 \times 10^{-9}$

For the same d , second order of violet light has the same angle of diffraction as that of red light of $700 \times 10^{-9} \text{ m}$

- 19** Ans: **B**

A: Since Y and Z is the same distance from charge Q, the potential at both point is the same. Having no potential difference, no work is done to taking a charge from Y to Z.

B: Electric field radiate outwards from the positive charge, hence the field strength acts in a direction from X to Z.

C: Since Y and Z is the same distance from charge Q, the magnitude of the electric field strength at both points is the same.

D: Since Y and Z is the same distance from charge Q, the potential at both point is the same.

- 20** Ans: **B**

A: $R = V/I = 12/3.0 = 4.0 \Omega$

B: $E = VIt = 12 \times 3.0 \times 5.0 = 180 \text{ J}$

C: $Q = It = 3.0 \times 5.0 = 15 \text{ C}$

D: Since potential is also defined as work done per unit charge, $[V] = V = \text{J C}^{-1}$.

- 21** Ans: **A**

As V increases, I increases more than proportional. Thus resistance decreases.

22 Ans: **D**

For the voltmeter to record zero voltage, the ratio of the resistance $P/Q = R/S$

23 Ans: **C**

Current along PR is parallel to the magnetic field and so there is no magnetic force on PR .

The current along QP has a component flowing vertically downwards and perpendicular to the magnetic field. Using Fleming's LHR, the force acts on wire QP out of the page.

The current along RQ has a component flowing vertically upwards and perpendicular to the magnetic field. Using Fleming's LHR, the force acts on wire RQ into the page.

Considering the two forces on the triangular wire QPR , the triangle rotates about the axis **WX** with R pointing into the page.

24 Ans: **C**

For the current to flow from P to Q , the motion of the copper wire must be **vertically downwards** accordingly to Fleming's Right Hand Rule. [The first finger (Earth's magnetic field) is pointing into the page while the middle finger points from P to Q , the thumb, i.e. the motion of wire, points down. For maximum current, the rate of cutting of the Earth's magnetic flux lines must be maximum. This occurs at the instant when the wire is moving perpendicular to the field lines.

25 Ans: **C**

$$\text{Fig A, Mean Power, } W = \frac{V_{rms}^2}{R} = \frac{\left(\frac{V_0}{\sqrt{2}}\right)^2}{R} = \frac{V_0^2}{2R}$$

$$\begin{aligned} \text{Fig B, } V_{rms} &= \sqrt{\frac{\text{area under the } V^2 - t \text{ curve over a period}}{T}} \\ &= \sqrt{\frac{(2V_0)^2 \frac{1}{2}T + 0}{T}} = \sqrt{2}V_0 \end{aligned}$$

$$\text{Mean power, } P_B = \frac{V_{rms}^2}{R} = \frac{(\sqrt{2}V_0)^2}{R} = \frac{2V_0^2}{R} = 4W$$

26 Ans: **C**

$$\langle P \rangle = V_{rms} I_{rms}$$

$$(I_{rms})_{min} = 2000 / 240 = 8.33 \text{ A}$$

$$(I_0)_{min} = 8.33 \times \sqrt{2} = 11.8 \text{ A}$$

$$(I_{rms})_{max} = 2400 / 220 = 10.9 \text{ A}$$

$$(I_0)_{max} = 10.9 \times \sqrt{2} = 15.4 \text{ A}$$

$$\omega = 2\pi f$$

$$\omega_{min} = 2\pi \times 50 = 314$$

$$\omega_{max} = 2\pi \times 60 = 377$$

Probable current, $I = 14.1 \sin(375t)$

27 Ans: **B**

$$E_p = \Delta E$$

$$\frac{hc}{\lambda} = X - Y$$

De Broglie's momentum

$$p = \frac{h}{\lambda} = \frac{X - Y}{c}$$

28

Ans: B

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

$$1.00 \times 10^6 \times 1.6 \times 10^{-19} = \frac{p^2}{2 \times 1.67 \times 10^{-27}}$$

$$p = 2.312 \times 10^{-20} \text{ kg m s}^{-1}$$

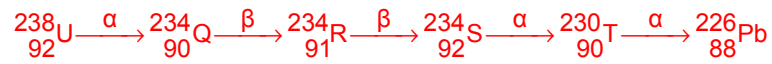
$$\Delta p = 0.01 \times 2.312 \times 10^{-20} = 2.312 \times 10^{-22}$$

$$\Delta p \Delta x = h$$

$$\Delta x = 2.87 \times 10^{-12} \text{ m}$$

29

Ans: A

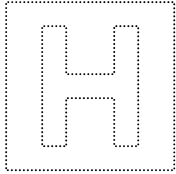


${}_{88}^{228}\text{Ra}$ is not produced during this series of transformations.

30

Ans: D

$$\begin{aligned} \text{Energy releases} &= \text{BE of products} - \text{BE of reactants} \\ &= 121(8.26) + 112(8.52) - 235(7.59) \\ &= 179 \text{ MeV} \end{aligned}$$



INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

PHYSICS

9749/02

Paper 2 Structured Questions

29 August 2018

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.
Please write down your answers in the spaces provided.

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

Marks will be deducted for using inappropriate number of significant figures or wrong value of g .

For Examiner's Use	
1	14
2	10
3	10
4	6
5	9
6	11
7	20
Penalty	
P2 Total	80

This document consists of **21** printed pages and **1** blank page.



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

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

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

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

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

For
Examiner's
Use

- 1 A spring is attached at one end to a fixed point and hangs vertically with a cube attached to the other end. The cube is initially held so that the spring has zero extension, as shown in Fig. 1.1.

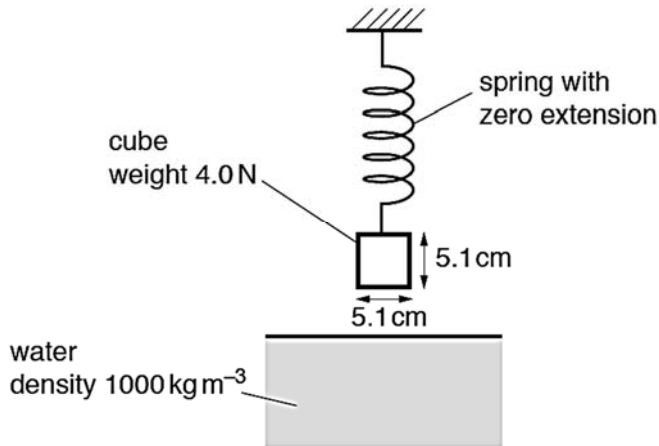


Fig. 1.1

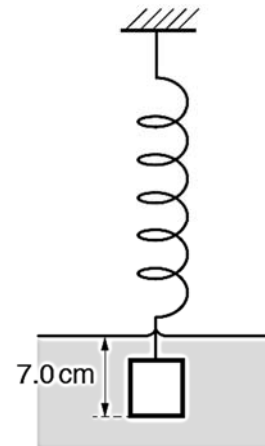


Fig. 1.2

The cube has weight 4.0 N and sides of length 5.1 cm. The cube is released and sinks into water as the spring extends. The cube reaches equilibrium with its base at a depth of 7.0 cm below the water surface, as shown in Fig. 1.2. The density of water is 1000 kg m^{-3} .

- (a) (i) Calculate the difference in the pressure exerted by the water on the bottom face and on the top face of the cube.

difference in pressure = Pa [2]

- (ii) Use your answer in (a)(i) to show that the upthrust on the cube is 1.3 N. Explain your working.

[2]

- (iii) Calculate the force exerted on the spring by the cube when it is in equilibrium in the water.

force = N [2]

- (iv) The spring obeys Hooke's law and has a spring constant of 30 N m^{-1} .

Determine the initial height above the water surface of the base of the cube before it was released.

height above surface = cm [2]

- (b) The cube in the water is released from the spring.

- (i) State Newton's second law of motion.

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

- (ii) Determine the initial acceleration of the cube.

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

- (iii) Describe and explain the variation, if any, of the acceleration of the cube as it sinks further into the water.

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

- 2 Fig. 2.1 shows a simplified heat engine which consists of an insulated cylinder fitted with a perfectly fitting frictionless piston. The cylinder contains a fixed mass of an ideal gas and a heater. When heat is supplied to the gas, it can expand and does work by pushing the piston.

For
Examiner's
Use

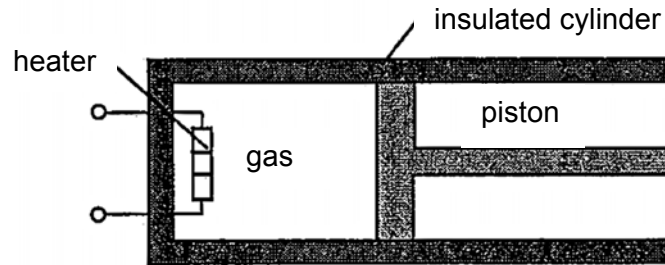


Fig. 2.1

- (a) Explain in terms of the motion of the molecules in the gas, how work can be done by the heated gas to move the piston.

.....

.....

.....

.....

..... [2]

- (b) The efficiency of a heat engine is given by the following equation

$$\text{efficiency} = \frac{\text{useful mechanical work done}}{\text{input heat supplied}}$$

- (i) In practice, attaining 100% efficiency is impossible. Suggest two possible reasons.

.....

.....

.....

..... [2]

- (ii) Two experiments are performed on the heat engine in Fig. 2.1.

For
Examiner's
Use

Experiment 1

The heater provides 150 J of thermal energy with the piston held in a fixed position. The temperature rise of the gas is 30 K.

Experiment 2

The heater again supplies 150 J of thermal energy with the piston free to move so that the gas expands at a constant pressure of 1.0×10^5 Pa and does some useful work W . In this case, the temperature rise is 18 K and the efficiency is 40%.

1. Explain why there is a difference in the temperature rise in each case.

.....

.....

.....

..... [2]

2. In the first experiment, calculate the gain in internal energy of the gas.

gain in internal energy = J [1]

3. In the second experiment, calculate the work done W by the expanding gas.

work done = J [2]

4. In the second experiment, calculate the gain in internal energy of the gas.

gain in internal energy = J [1]

3 (a) State the principle of superposition.

.....

 [2]

(b) A ship at X is equidistant from two shore-based radio transmitters P and Q. The stations are 60 km apart, and each behaves as a point source of electromagnetic waves which radiate circular wavefronts. Both transmitters operate with a frequency of 1.0 MHz and radiate signals of equal amplitude.

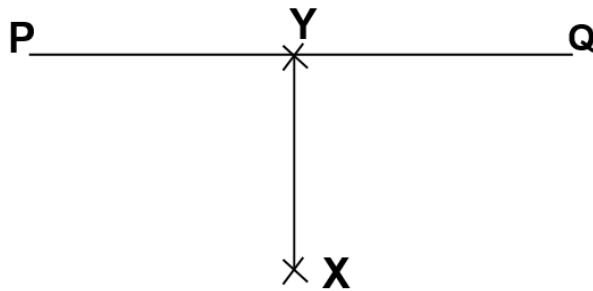


Fig. 3.1

(i) When the ship is at position X as shown in Fig. 3.1, the ship detects zero signal amplitude. State what can be deduced about the signals from P and Q.

.....
 [1]

(ii) The ship moves in a straight line from X to Y. Explain why, throughout the journey, the amplitude of the signal detected by the ship is zero.

.....

 [2]

- (iii) The ship moves in the direction **YQ** until the signal detected has an amplitude twice that from either transmitter alone. Determine the distance that the ship has moved. Explain your answer.

*For
Examiner's
Use*

distance = m [3]

- (iv) When the ship sails from **Y** to the harbour alongside transmitter **Q** the detected signal rises and falls in amplitude. Calculate how many dips in intensity will be passed.

number = [2]

- 4 In order to investigate the variation of the current I in a variable resistor with the potential difference V across it, a student set up the following circuit.

For
Examiner's
Use

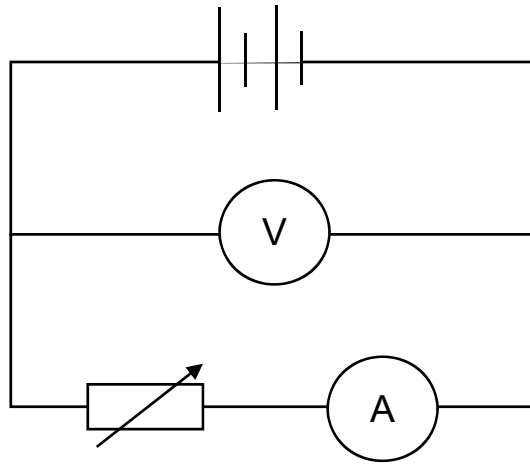


Fig. 4.1

The variation of V with I is shown below.

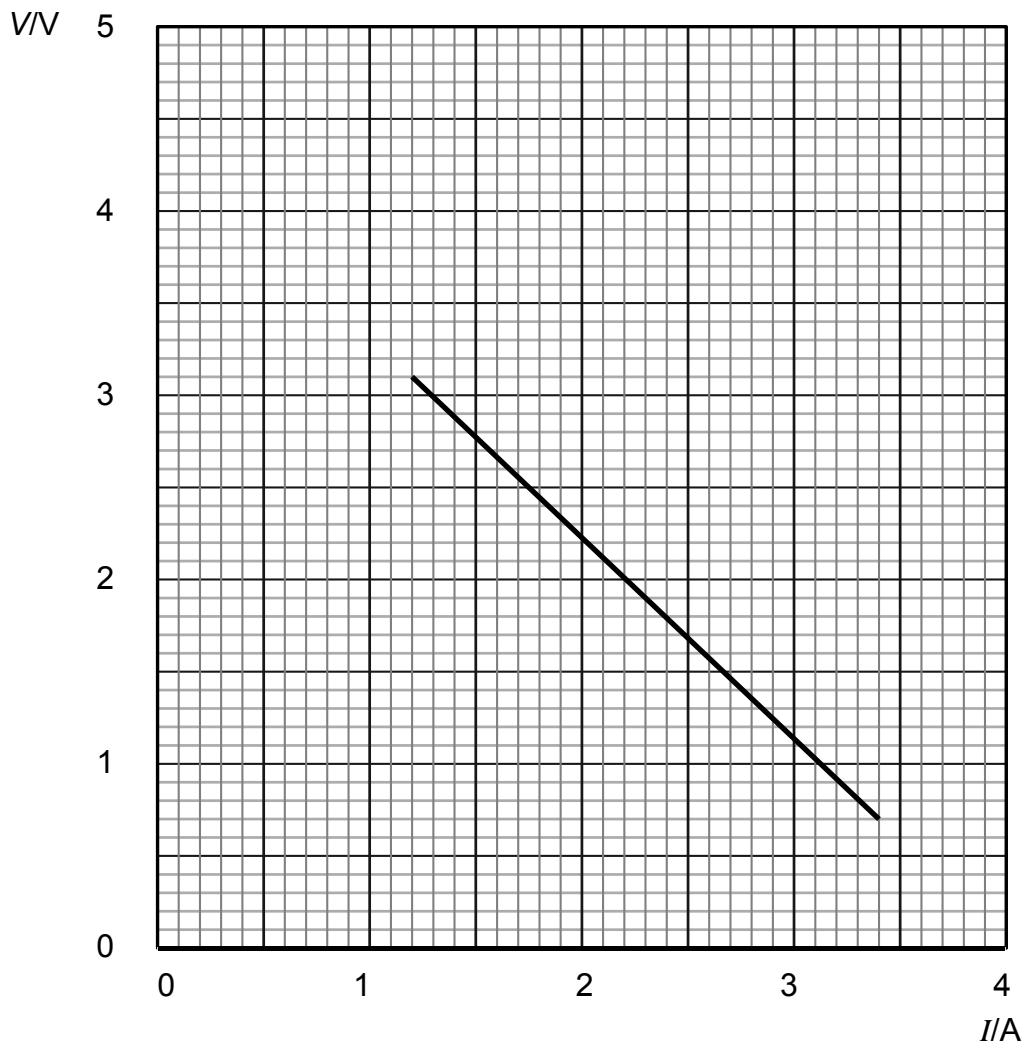


Fig. 4.2

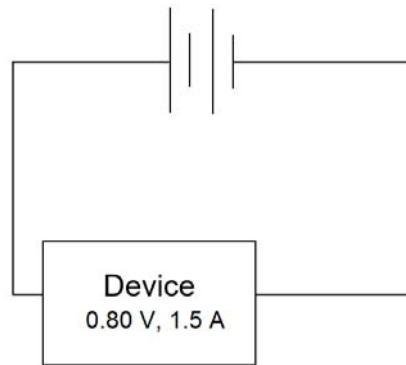
- (a) (i) With reference to the graph, explain why the internal resistance of the battery is not negligible.

.....
 [1]

- (ii) Show that the e.m.f of the battery and its internal resistance is 4.4 V and 1.1 Ω respectively.

[2]

- (b) The battery in (a) is to be used as the power source for an electrical device. The device is rated as 0.80 V, 1.5 A.
 Complete the circuit below to show how the battery may be connected so that the device operates normally. Calculate the value of any other component you may use.



[3]

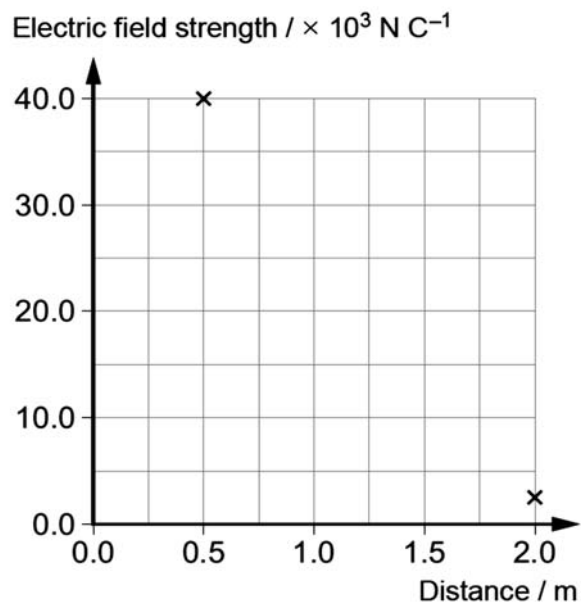
5 A small sphere has a charge $q = +1.11 \times 10^{-6} \text{ C}$.

(a) Determine the number of electrons that have been removed from the sphere.

number = [2]

(b) On the grids below, sketch curves between 0.5 m and 2.0 m from the centre of the sphere for the electric field strength.

The points at 0.5 m and 2.0 m are already shown.



[2]

For
Examiner's
Use

- (c) A second identical sphere also has a charge of $+1.11 \times 10^{-6} \text{ C}$. It is brought from a distant point to a distance 1.2 m from the first sphere as shown in Fig. 5.1.

For
Examiner's
Use



Fig. 5.1
(not to scale)

- (i) Determine the work done required to do this.

work done = J [2]

- (ii) Determine the magnitude and direction of the electric field strength at the point between the two spheres that is 0.70 m from the left-hand side sphere.

electric field strength = N C^{-1}

direction = [3]

- 6 (a) Electromagnetic radiation is incident on a negatively charged zinc plate. Electrons are emitted from the surface of the plate when a weak intensity ultraviolet source is used. Electrons are not emitted at all when an intense visible light from a lamp is used.

Explain these observations.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

- (b) The **maximum** wavelength of the electromagnetic radiation incident on the surface of a metal which causes electrons to be emitted is 2.9×10^{-7} m. Calculate the maximum kinetic energy of electrons emitted from the surface of the metal when each incident photon has energy of 5.1 eV.

maximum kinetic energy = J [3]

- (c) Electromagnetic radiation of constant wavelength is incident on a metal plate. Photoelectrons are emitted from the metal plate. Fig. 6.1 shows an arrangement used to determine the maximum kinetic energy of electrons emitted from a metal plate.

For
Examiner's
Use

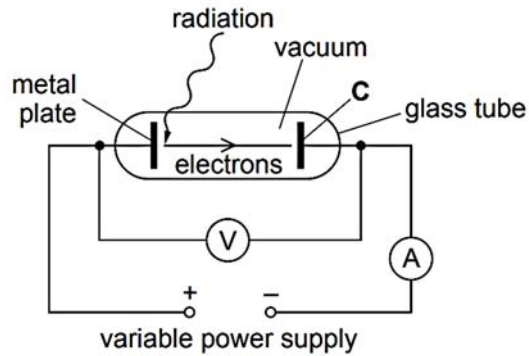


Fig. 6.1

The metal plate and the electrode **C** are both in a vacuum. The electrode **C** is connected to the negative terminal of the variable power supply. Fig. 6.2 shows the variation of current I in the circuit as the potential difference V between the metal plate and **C** is increased from 0 V to 3.0 V.

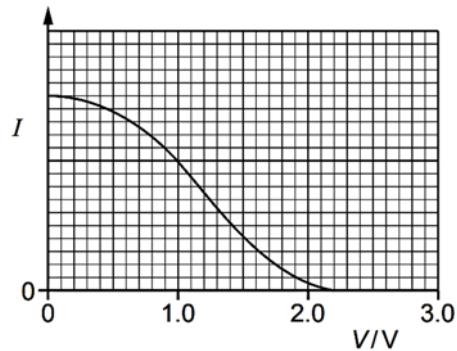


Fig. 6.2

- (i) Explain why the current decreases as V increases.

.....

 [2]

- (ii) Using Fig 6.2, determine the maximum kinetic energy of the emitted electrons. Explain your working.

.....

 [2]

- 7 Read the following article and then answer the questions that follow.

Powering the world's energy needs through nuclear fission

Nuclear power plants are a type of power plant that use the process of nuclear fission in order to generate electricity. They do this by using nuclear reactors in combination with the Rankine cycle, where the heat generated by the reactor converts water into steam, which spins a turbine and a generator.

The large amount of energy released in a nuclear fission reaction, together with the emission of more than one neutron, has made it possible for neutron-induced fission to be used as a source of useful energy. For most nuclear reactor, the uranium fuel is assembled in such a way that a controlled fission chain reaction can be achieved. When a neutron is captured by a Uranium-235 nucleus, it causes the nucleus to fission. On average, 2.5 neutrons are emitted in these fission reactions. When the conditions are suitable, a chain reaction can occur as shown in Fig. 7.1. If the chain reaction is controlled in the reactor, a source of continuous power may be created.

The induced fission reaction of Uranium-235 may be represented by a nuclear equation of the form

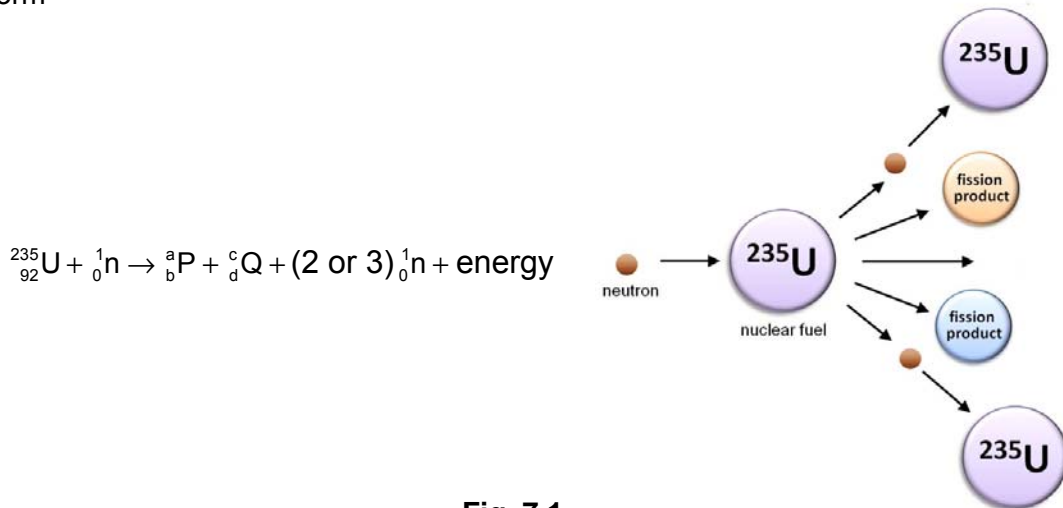


Fig. 7.1

Usually when any two nuclei are fissioned, the fission products may not be the same. If a large sample of Uranium-235 is fissioned, many different fission products will be produced. The percentage amount of each fission product in the fissioned material is referred to as percentage yield.

In 2016, nuclear plants have managed to supply 2477 TWh of electricity worldwide. That was the fourth consecutive year that the global nuclear generation has risen. Nuclear energy generated via nuclear reactions generate heat to produce steam, which is used to generate electricity. The efficiency of a nuclear power plant is determined similarly to other heat engines, since technically the plant is a large heat engine. The amount of electric power produced for each unit of thermal power gives the plant its thermal efficiency. Typical nuclear power plants achieve efficiency of 35%. In addition, nuclear power plants had an average capacity factor of 92.3 percent which is relatively much higher than other electrical systems, meaning they operated at full power on 336 out of 365 days per year.

- (a) Suggest why there is a need for the fission process in the nuclear reactor to be controlled.

For
Examiner's
Use

.....

 [2]

- (b) Fig. 7.2 shows the variation of the energy release E during each stage of the chain reaction with its stage number n .

(Stage $n = 1$ represents the stage where the energy is released when the first neutron interacts with first Uranium nucleus and releases 2 or 3 neutrons.

Stages $n = 2, 3, \dots$ represent the stages where the energy is released when the neutrons from previous stage interacts with other Uranium nuclei and releases 2 or 3 more neutrons for each reaction)

$\lg(E/\text{MeV})$

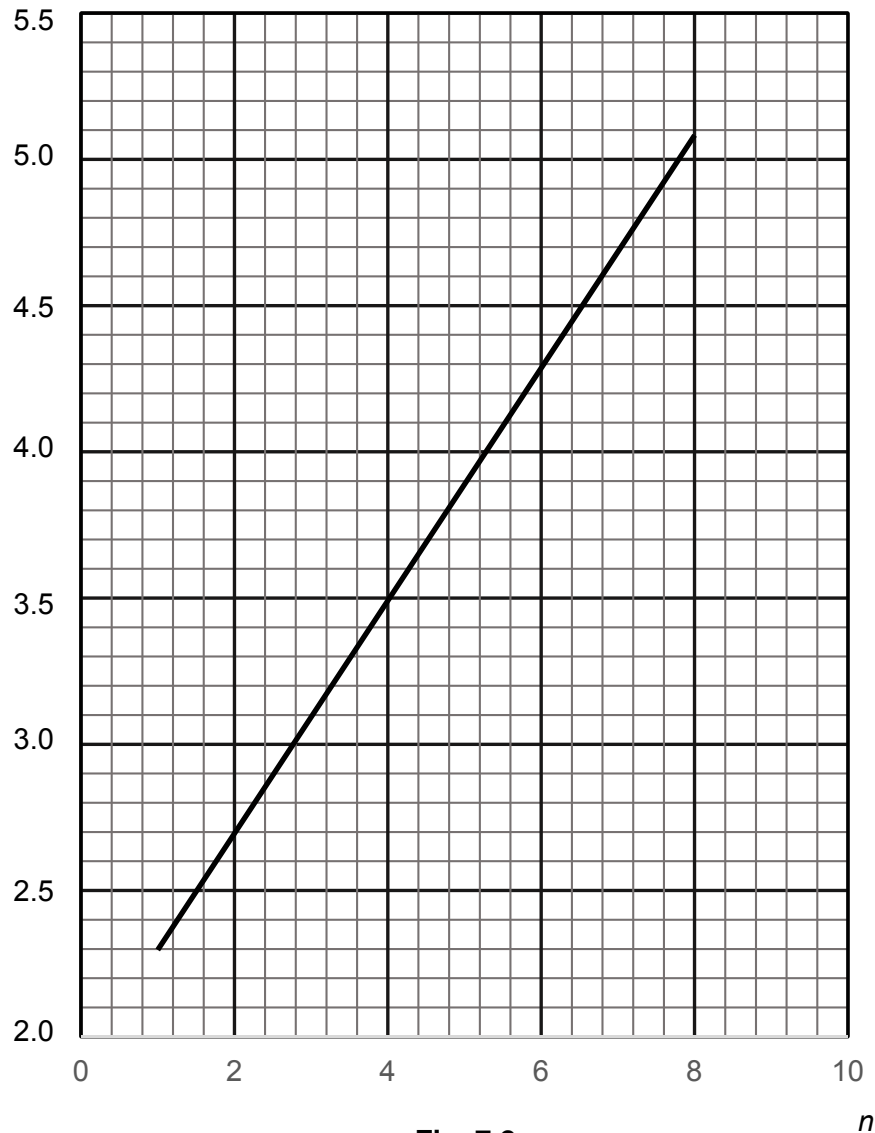


Fig. 7.2

- (i) The total energy released per chain E would thus increase with the number n of stage that the fission has proceed till and is given by

$$E = a^{n-1}b$$

where a is the average number of neutrons emitted per fission reaction and b is a constant.

Use Fig. 7.2 to determine the value of b .
Show your working clearly.

For
Examiner's
Use

$$b = \dots\dots\dots \text{MeV [3]}$$

- (ii) Suggest what is represented by the value of b .

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

- (c) The variation with nucleon number of the percentage yield of different products is illustrated in Fig. 7.3.

For
Examiner's
Use

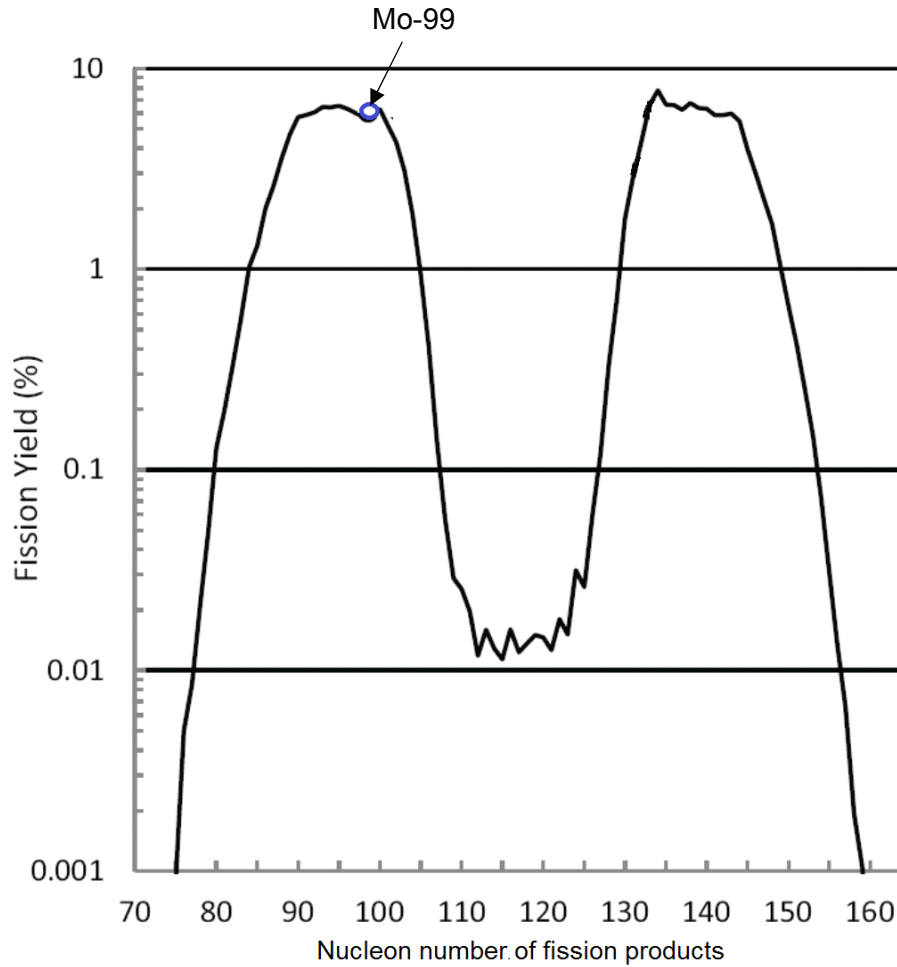


Fig. 7.3

- (i) State the proton number of the other fission product for the fission of one uranium if one of the products is $^{89}_{36}\text{Kr}$.

proton number = [1]

- (ii) Suggest why the percentage yield is shown on a logarithmic scale.

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

(iii) Show that the percentage yield of Mo-99 is about 400 times more than those having masses equal to each other.

[2]

(d) (i) The energy released during one fission reaction of a uranium nuclei occurs partly as kinetic energy of the fission products (167 MeV) and of the neutrons.

Suggest one other mechanism by which energy is released in the fission reaction.

..... [1]

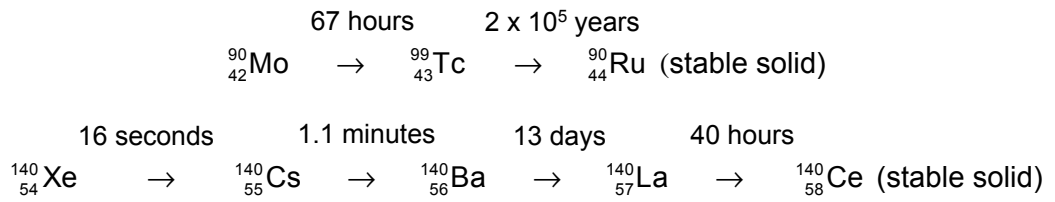
(ii) Determine the amount of heat required to generate the electrical energy worldwide in 2016.

energy = J [2]

(iii) Determine the rate at which uranium is consumed to generate the amount of heat required in 2016.

amount required = kg s⁻¹ [3]

- (e) The fission products are usually radioactive and give rise to a series of radioactive decay products. Each decay product has its own half-life. Two such fission products with their decay products and half-lives are shown below.



Consider equal amounts of these two products.
Suggest why there are very different problems for the storage of this nuclear waste.

.....

.....

.....

..... [2]

- (f) Despite the advantages of nuclear power, it is unlikely that our world will be purely powered by nuclear energy.
Suggest two reasons, aside from the danger from nuclear waste and cost, for this.

.....

.....

.....

.....

..... [2]

End of Paper 2

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1 (a)(i)

$$p = \rho gh$$

$$= 1000 \times 9.81 \times 7.0 \times 10^{-2} \text{ or } 1000 \times 9.81 \times 1.9 \times 10^{-2} \quad [C1]$$

$$\Delta p = \rho g \Delta h$$

$$= 1000 \times 9.81 \times (7.0 \times 10^{-2} - 1.9 \times 10^{-2})$$

$$500 \text{ Pa} \quad [A1]$$

1 (a)(ii)

Upthrust is the upward force by the water due to the difference in the pressure between the top and the bottom surface of the object. [B1]

$$U = \Delta p \times A$$

$$U = 500 \times (5.1 \times 10^{-2})^2 \quad [M1]$$

$$= 1.3 \text{ N} \quad [A0]$$

1 (a)(iii)

$$F_n = 0$$

$$T + U = W$$

$$T + 1.3 = 4.0 \quad [C1]$$

$$T = 2.7 \text{ N} \quad [A1]$$

1 (a)(iv)

$$T = kx$$

$$2.7 = 30 \times x$$

$$x = 0.090 \text{ m} \quad [C1]$$

$$\text{height above surface} = 0.090 - 0.070$$

$$= 0.020 \text{ m} = 2.0 \text{ cm} \quad [A1]$$

1 (b)(i)

Newton's second law of motion state that the rate of change of momentum of an object is directly proportional to the resultant force acting on it [B1] and the change in momentum occurs in the direction of the resultant force [B1].

1 (b)(ii)

$$F_n = ma$$

$$4.0 - 1.3 = \frac{4.0}{9.81} \times a \quad [C1]$$

$$a = 6.6 \text{ m s}^{-2} \quad [A1]$$

1 (b)(iii)

As the cube accelerates, its velocity increases and hence the viscous force acting on the cube (by water) increases (and then becomes constant when reach terminal velocity) [M1]. With weight and upthrust being constant, net force and acceleration decreases (to zero) [A1].

2 (a)

When the gas is heated, the molecules **gain kinetic energy**. As the molecules move faster, they also **collide with the piston more frequently**. [B1]

The **change of momentum** experienced by the molecules upon collision with the wall, causes an impact **force on the piston wall pushing it to the right** thereby doing work in causing the gas to **expand**. [B1]

Credit was given for those who gave $W = P\Delta V$ but they need to explain how the pressure originate from the collision of the gas particles on the wall and that the volume increases.

2 (b)(i)

Any two possible answers [B1x2]

2018 JC2 H2 Physics Prelims Exam Solution (9749 Paper 2)

1. There can be work done against friction due to the piston rubbing against the wall which dissipates the supplied energy.
2. The heat generated does not totally transfer into mechanical work done as some is given to raise the internal energy of the gas.
3. The wall of the vessel is not a perfect insulator and it might conduct some of the heat away from the vessel resulting in smaller work done.
4. The gas is not ideal. So the collision is not elastic.
5. The wire conducts some of the heat energy from the heater.

2 (b)(ii)1.

In the first experiment, **the piston is fixed and so no work is done**. All the 150 J goes into increasing the internal energy of the gas. [B1]

In the second experiment, the piston is free to move and so work is done by the gas. Because there is **work done by the gas, there is less thermal energy** available to increase the internal energy and so **the temperature rise for the second experiment is less**. [B1]

Using 1st law of thermodynamics

$$\text{Expt 1 : } \Delta U = Q + 0$$

$$\text{Expt 2 : } \Delta U' = Q - W \quad (Q \text{ is } 150 \text{ J for both})$$

Thus, the rise in internal energy (and temperature) for Expt 2 is less.

2 (b)(ii)2.

$$\begin{aligned} \Delta U &= Q + W \\ &= 150 + 0 \\ &= 150 \text{ J} \quad [\text{A1}] \end{aligned}$$

2 (b)(ii)3.

efficiency = Work / heat energy supplied

$$40/100 = W / 150 \quad [\text{C1}]$$

$$W = 60 \text{ J} \quad [\text{A1}]$$

Deduct one mark for negative answer

2 (b)(ii)4.

$$\begin{aligned} \Delta U &= Q + W \\ &= 150 + (-60) \\ &= 90 \text{ J} \quad [\text{A1}] \end{aligned}$$

Allow ECF

3 (a)

The principle of superposition states that when two or more waves meet at a point [B1], the resultant displacement at that point is equal to the vector sum of the displacements of the individual waves at that point. [B1]

3 (b)(i)

It means that the signals from P and Q reaching the point are in antiphase. [A1] (accept completely or 180° or π out of phase.)

3 (b)(ii)

Along the line joining X and Y, any point Z along XY will be such that the distance PZ equals the distance QZ. Thus the path difference PZ – QZ will be zero. [B1]

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The phase difference of the two signals reaching point Z will be due to the phase difference between the transmitter P and Q which is π out of phase.

Thus the waves from P and Q meet point Z in antiphase and the resultant displacement is **always zero** [B1] and the signal detected by the ship is zero.

3 (b)(iii)

$$\lambda \text{ wavelength of wave} = v / f = (3.0 \times 10^8 \text{ m s}^{-1}) / (1.0 \times 10^6 \text{ Hz}) = 300 \text{ m}$$

[M1]

When the ship detects an amplitude that is twice, it reaches a point of constructive interference. [M1]

$$\begin{aligned} \text{Distance between destructive interference to constructive interference} &= \lambda/4 \\ &= 75 \text{ m} \end{aligned} \text{ [A1]}$$

3 (b)(iv)

Distance from mid point to Q = 30 km.

$$\text{Distance between two nodes} = \lambda/2 = 150 \text{ m}$$

$$\text{Number of dips} = 30000 / 150 = 200$$

4 (a)(i)

As the graph shows a significant drop in the p.d across the variable resistance as current changes, it shows that the variation of p.d in internal resistance is significant

4 (a)(ii)

$$\text{Using } V = E - Ir$$

$$\text{Thus, when } I = 0, V = E$$

[B1]

$$\text{When extending the graph, the line cut } 4.4 \text{ V, } E = 4.4 \text{ V}$$

$$\text{Gradient of graph} = -r$$

$$\text{Thus } -r = (3.1 - 0.7) / (1.2 - 3.4) = -1.1$$

[B1]

$$r = 1.1$$

4 (b)

When device is operating in normal condition,

$$\text{Resistance of device} = 0.53 \Omega \quad \text{[B1]}$$

$$\text{Effective resistance of circuit needed} = 4.4 / 1.5 = 2.93 \quad \text{[B1]}$$

$$\text{Additional resistance required} = 2.93 - 0.53 - 1.1 = 1.3 \Omega$$

[Draw an additional 1.3 Ω of resistor in series with the emf and device] [A1]

5 (a)

Number of electrons removed = total charge / charge of 1 electron

$$= \frac{1.11 \times 10^{-6}}{1.6 \times 10^{-19}} \quad \text{[C1]}$$

$$= 6.94 \times 10^{12} \quad \text{[A1]}$$

5 (b)

(a) Values for graph

Distance/ m	$E / \times 10^3 \text{ V}$
0.50	40.0
1.00	10.0
1.50	4.44
2.00	2.50

Correct points [B1]

Shape for curve with decreasing magnitude with increasing distance. [B1]

5 (c)(i)

$$\text{Work done} = q\Delta V = \frac{q^2}{4\pi\epsilon_0} \left(\frac{1}{1.2} - 0 \right)$$

$$= (1.11 \times 10^{-6})^2 (9.0 \times 10^9) (0.833) \quad [M1]$$

$$= 9.24 \times 10^{-3} \text{ J} \quad [A1]$$

5 (c)(ii)

$$\text{Field strength due to charge of right} = \frac{q}{4\pi\epsilon_0(0.5)^2} \text{ points to the left.}$$

$$\text{Field strength due to charge of left} = \frac{q}{4\pi\epsilon_0(0.7)^2} \text{ points to the right.}$$

$$\begin{aligned} \text{Resultant field strength} &= \frac{q}{4\pi\epsilon_0(0.5)^2} - \frac{q}{4\pi\epsilon_0(0.7)^2} \quad [C1] \\ &= 1.96 \times 10^4 \text{ V m}^{-1} [A1] \end{aligned}$$

Direction towards the left [A1] (accept negative sign if student states rightward as convention).

6 (a)

The photoemission of electrons from the zinc plate is due to the fact that the electromagnetic radiation incident on the plate exhibit a **particle nature** as opposed to wave nature. They propagate as **photons**.

Electrons are emitted from the zinc plate only when the photons each has energy that **exceed the work function** (minimum energy for photoelectron emission) of the metal through a **one-to-one interaction** between the photons and electrons.

Electrons are emitted from the metal surface because the energy of the uv photon **exceed the work function** of the metal

or

the frequency of the uv radiation (ultraviolet rays) **exceed the threshold frequency** (minimum frequency for photoelectron emission),

The emission of electrons is **independent of the intensity** as changing the intensity merely changes the rate of the incident photons and it does not alter their energy. Thus, a weak intensity uv radiation can cause photoelectron emission but an intense visible light may not cause photoelectron emission.

6 (b)

$$\text{Work function } \phi = \frac{hc}{\lambda_0} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^8)}{2.9 \times 10^{-7}}$$

$$= 6.86 \times 10^{-19} \text{ J} \quad [C1]$$

Energy of photon $E = 5.1 \text{ eV}$

$$= (5.1)(1.60 \times 10^{-19})$$

$$= 8.16 \times 10^{-19} \text{ J} \quad [C1]$$

$$E = \phi + \text{Max KE}$$

$$\text{Max KE} = E - \phi$$

$$= (8.16 - 6.86) \times 10^{-19}$$

$$= 1.3 \times 10^{-19} \text{ J} \quad [A1]$$

6 (c)(i)

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Because the electrode C is connected to the negative terminal, the electrons are **repelled** by it [B1] (ie the electric force acts opposite to the initial electron flow).

As V increases, fewer electrons per unit time reach C and hence the current I decreases. [B1]

6 (c)(ii)

The electrons are emitted with a **range of KE**.

When the **opposing potential** is raised to the point (**stopping potential**) where the **current is just zero**, it is an indication that the most energetic electron is stopped on its track just short of touching C. [B1]

By COE,

Loss in Max KE = Gain in EPE

$$= (\text{Stopping potential})(\text{charge})$$

$$= V e$$

$$= \mathbf{2.2 \text{ eV}}$$

$$= \mathbf{3.36 \times 10^{-19} \text{ J}}$$
 (max KE of e) [B1]

7 (a)

As nuclear fission takes place very quickly and the number of neutrons emitted will be very large as the stages proceed on [1] (resulting in a chain reaction) and hence leading to a very large amount of energy in a short time, which may cause an explosion if not controlled [1]

7 (b)(i)

$$E = a^{n-1} b \rightarrow \lg E = (n-1)\lg(a) + \lg(b)$$

Thus the intercept of the graph is $\lg(b) - \lg(a)$ [M1]

$$\text{Gradient of graph, } \lg(a) = (4.6 - 2.7) / (6.8 - 2.0) = 0.3958$$

$$4.6 = (0.3958)(6.8) + c$$

$$c = 1.908 \quad [M1]$$

$$\text{therefore } \lg(b) - \lg(a) = 1.908$$

$$\lg(b) = 2.30$$

$$b = 200 \text{ MeV} \quad [A1]$$

7 (b)(ii)

Energy release due to one nuclear fission reaction of uranium

7 (c)(i)

$$92 - 36 = 56$$

7 (c)(ii)

The range of percentage yield is very large and hence in order to show the variation of the values in a single graph, a logarithmic scale is used.

7 (c)(iii)

Percentage yield of having 135 and 99 = 6

If the Uranium produces two nuclei with the same masses, mass of each nuclide = $236/2 = 118$

Percentage yield of masses equal = 0.015

Therefore, the ratio = $6/0.015$

$$= 400$$

7 (d)(i)

Gamma (photon) radiation.

7 (d)(ii)

$$2477 \text{ TWh} = 2477 \times 10^{12} \times 3600$$

$$= 8.92 \times 10^{18} \text{ J} \quad [C1]$$

Since the efficiency is 35%,
The amount of heat required
 $= 100/35 \times 8.92 \times 10^{18} = 2.55 \times 10^{19} \text{ J}$ [A1]

7 (d)(iii)
Power required $= (2.55 \times 10^{19}) / (336 \times 24 \times 60 \times 60)$
 $= 8.78 \times 10^{11} \text{ W}$ [B1]

Number of reactions needed in one second
 $= (8.78 \times 10^{11}) / (167 \times 10^6 \times 1.6 \times 10^{-19})$
 $= 3.28 \times 10^{22}$ [B1]

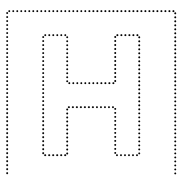
Amount required (mass per s)
 $= 3.28 \times 10^{22} \times 235u$
 $= 3.28 \times 10^{22} \times 235(1.66 \times 10^{-27})$
 $= 1.28 \times 10^{-2} \text{ kg s}^{-1}$ [A1]

7 (e)
The decay chain of Mo has a relatively longer half life and poses a health hazard if it is not stored properly over an extended period of time. And so it has to be securely shielded (or encapsulated) and stored in a safe and isolated place for a longer period of time.

The decay chain of Xe has much shorter half life and so the time it spends in isolated storage is much less and it can be 'disposed off' safely after a few days. However, due to its high activity at the initial stage, the shielding provided must be sufficiently 'thick' to contain its radiation.

7 (f)

- Like fossil fuel, there is finite amount of uranium available for nuclear reactor plants to meet the increasing needs for energy supply. They are not renewable and so when the supply drops, alternative energy sources will be required. Its usage is not sustainable in the long run.
- Despite raising the safety standards of nuclear reactor plants, it is still subjected to potential natural disaster (eg earthquake and tsunami). In the event of such disruption, nuclear meltdown can occur.
- Nuclear plants generate lots of heat due to the poor efficiency of heat engines. Its contribution to global warming is substantial and it can lead to climate changes.
- For certain countries where land is scarce (eg Singapore), setting up a nuclear reactor plant would not be feasible as there needs to be a minimum safe distance between populated areas and the nuclear site in case of a nuclear meltdown.



INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
 in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

PHYSICS

9749/03

Paper 3 Longer Structured Questions

12 September 2018

Candidates answer on the Question Paper.
 No Additional Materials are required.

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.

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

You may use a soft 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.

Section A

Answer **all** questions.

Section B

Answer only **one** question.

At the end of the examination, fasten all your work securely together.

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

For Examiner's Use	
Section A	
1	11
2	10
3	7
4	8
5	7
6	10
7	7
Section B	
8	20
9	20
Significant Figures	
P3 Total	80

This document consists of **25** printed pages and **1** blank page.



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,

$$s = ut + \frac{1}{2}at^2$$

work done on/by a gas,

$$v^2 = u^2 + 2as$$

hydrostatic pressure,

$$W = p\Delta V$$

gravitational potential,

$$p = \rho gh$$

temperature,

$$\Phi = -\frac{GM}{r}$$

pressure of an ideal gas

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

mean translational kinetic energy of an ideal gas molecule

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

displacement of particle in s.h.m.

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

velocity of particle in s.h.m.

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

$$v = v_0 \cos \omega t \\ = \pm \omega \sqrt{(x_0^2 - x^2)}$$

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,

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

Section A

Answer **all** the questions in this section.

- 1 A man travels on a toboggan down a slope covered with snow from point A to point B. The path is illustrated in Fig. 1.1.

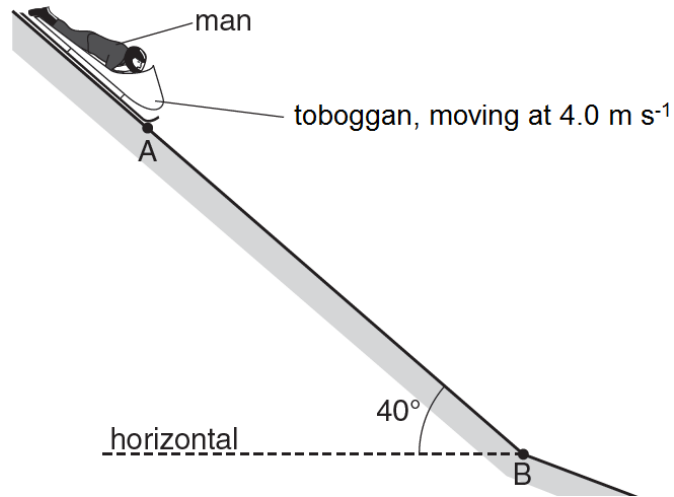


Fig. 1.1 (not to scale)

The slope AB makes an angle of 40° with the horizontal. Friction is **not negligible**.

The man and toboggan have a combined mass of 95 kg.

The mass starts with a speed of 4.0 m s^{-1} down the slope at A and has constant acceleration between A and B. The mass takes 17.0 s to reach B. His speed is 37.0 m s^{-1} at B.

- (a) (i) Calculate the distance moved from A to B.

distance = m [2]

- (ii) The actual uncertainty in each measurement of the speed of the mass is $\pm 0.1 \text{ m s}^{-1}$. The percentage uncertainty in the time taken to move from A to B is $\pm 0.6\%$.

For
Examiner's
Use

Calculate the percentage uncertainty in the distance moved from A to B.

percentage uncertainty = % [2]

- (iii) Use your answers in (a)(i) and (a)(ii) to determine the value of distance moved from A to B, with its actual uncertainty, to an appropriate number of significant figures.

distance = \pm m [1]

- (b) For the man and toboggan moving from A to B,

- (i) calculate the change in kinetic energy

change in kinetic energy = J [2]

- (ii) calculate the change in potential energy

change in potential energy = J [2]

- (iii) hence determine the average frictional force that acts on the toboggan between A and B.

frictional force = N [2]

- 2 (a) State Newton's law of gravitation.

For
Examiner's
Use

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

- (b) Some of the planets in the Solar System have several moons (satellites) that have circular orbits about the planet.
The planet and each of its moons may be considered to be point masses.

Show that the radius x of the moon's orbit is related to the period T of the orbit by the expression

$$GM = \frac{4\pi^2 x^3}{T^2}$$

where G is the gravitational constant and M is the mass of the planet. Explain your working.

[3]

- (c) The planet Neptune has eight moons, each in a circular orbit of radius x and period T . The variation with T^2 of x^3 for some of the moons is shown in Fig. 2.1.

For
Examiner's
Use

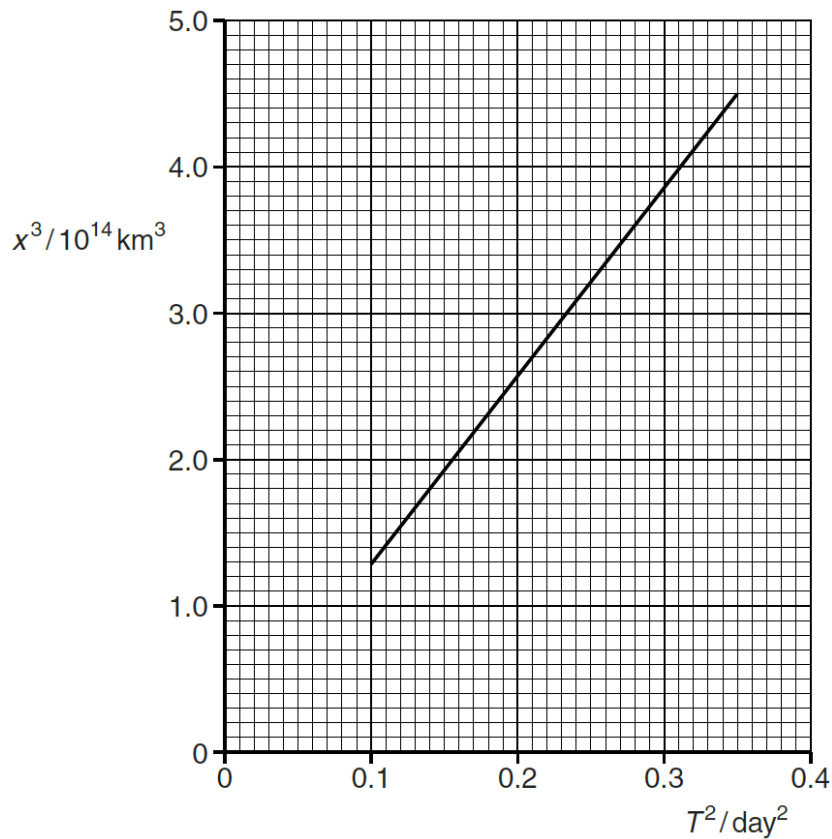


Fig. 2.1

- (i) Show that the gradient of the line in Fig. 2.1 is $1.7 \times 10^{14} \text{ m}^3 \text{ s}^{-2}$.

[1]

- (ii) Hence determine the mass of Neptune.

mass = kg [2]

- (d) The mass of the planet Uranus is smaller than that of the planet Neptune. On Fig. 2.1, sketch the variation with T^2 of x^3 for the moons of Uranus.

[2]

- 3 (a) An ideal gas is assumed to consist of atoms or molecules that behaves as hard, identical spheres that are in continuous motion and undergo elastic collisions.

State two further assumptions of the kinetic theory of gases.

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

- (b) Helium-4 (${}^4_2\text{He}$) may be assumed to be an ideal gas.

(i) Show that the mass of one atom of helium-4 is 6.6×10^{-27} kg.

[1]

(ii) Determine the internal energy of 1.2 mole of helium-4 gas at a temperature of 27 °C.

internal energy = J [1]

- (iii) Determine the root-mean-square (r.m.s.) speed of a helium-4 atom at a temperature of 27 °C.

For
Examiner's
Use

root-mean-square speed = m s⁻¹ [2]

- (iv) The above r.m.s. speed for helium is less than the escape speed for particles on the Earth's surface and yet there are still some helium atoms that escape the Earth's atmosphere. Explain.

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

- 4 (a) Distinguish between free oscillations and forced oscillations.

free oscillations:

.....

forced oscillations:

..... [2]

- (b) A trolley is held on a horizontal surface by means of two stretched springs, as shown in Fig. 4.1.

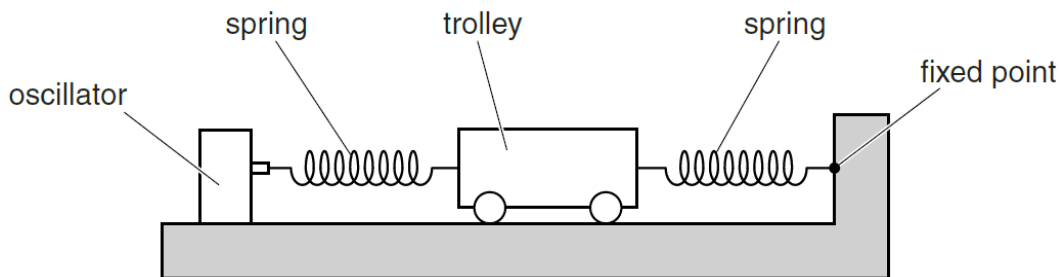


Fig. 4.1

One spring is attached to a fixed point. The other spring is attached to an oscillator that causes horizontal oscillations of the trolley.

The oscillator vibrates with a constant amplitude of vibration. The frequency of vibration of the oscillator is gradually increased from a very low value.

The variation with frequency f of the amplitude x_0 of vibration of the trolley is shown in Fig. 4.2.

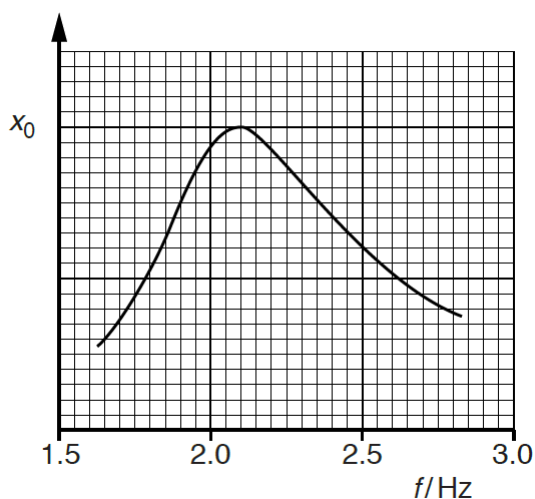


Fig. 4.2

Use Fig. 4.2 to state and explain

(i) the value of the natural frequency of vibration of the trolley,

.....

.....

.....

.....

.....

.....

..... [3]

(ii) whether there are any frictional forces acting on the trolley.

.....

..... [1]

(c) The oscillator in (b) is now stopped.

The trolley is given a horizontal displacement of 4.7 cm along the line of the springs. The trolley is then released.

Use information from Fig. 4.2 to estimate the maximum speed of the trolley.

speed = m s⁻¹ [2]

5 Fig. 5.1 shows a demonstration of a *stationary wave* on a string.

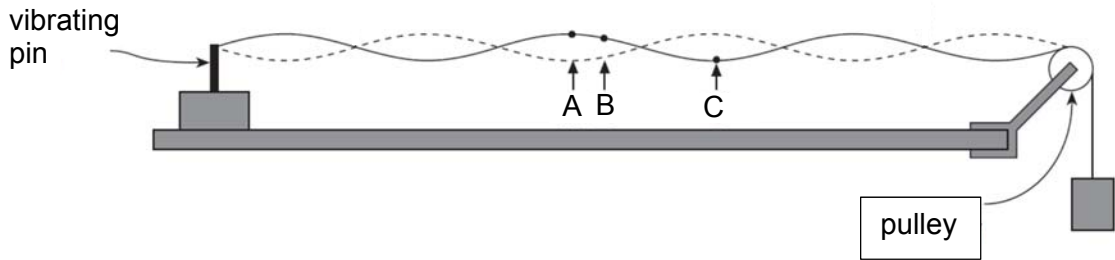


Fig. 5.1

(a) (i) State whether the following pairs of points on the string are vibrating *in phase*, *in antiphase*, or neither in phase nor in antiphase.

A and B

A and C [2]

(ii) Describe briefly how you could check this experimentally.

.....

 [1]

(b) (i) Progressive waves transfer energy through the medium; stationary waves do not do this. Describe the difference in term of the amplitude of the wave between progressive and stationary waves.

.....

 [2]

- (ii) Explain how, in the set-up as shown in Fig. 5.1, the stationary wave can be thought of as arising from progressive waves.

*For
Examiner's
Use*

.....

.....

.....

.....

..... [2]

- 6 (a) The resistivity of copper is $1.7 \times 10^{-8} \Omega \text{ m}$. Show that the resistance of a copper wire of length 1.5 m and cross-sectional area of $3.2 \times 10^{-9} \text{ m}^2$ is about 8.0Ω .

[1]

- (b) The copper wire in (a) is used to connect a circuit as shown in Fig. 6.1. Cell A has an e.m.f of 12.0 V and internal resistance 1.0Ω . A 2.0Ω resistance is used and connected in series with cell A.

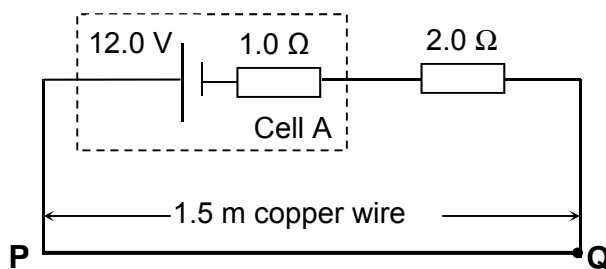


Fig. 6.1

Determine the drift velocity of the electrons flowing in the copper if the number of electrons per unit volume is $8.5 \times 10^{28} \text{ m}^{-3}$.

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

- (c) Cell B, a galvanometer and resistor of 4.0Ω is now placed in parallel together with the circuit and is shown in Fig. 6.2.

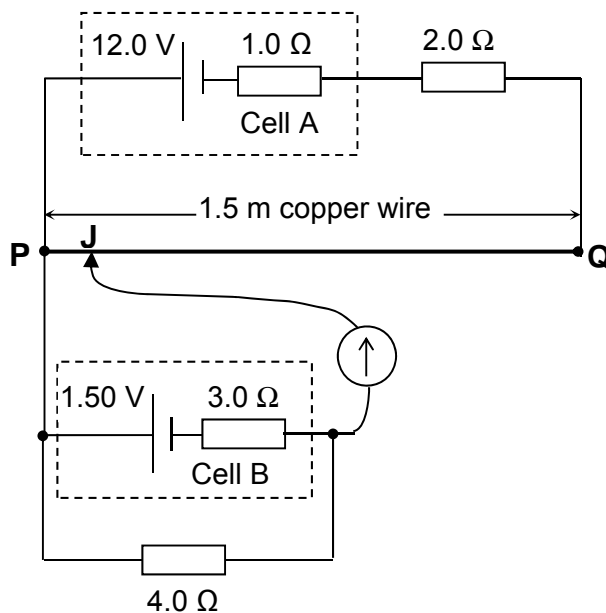


Fig. 6.2

(i) Show that the potential difference across the copper wire is 8.7 V.

[1]

(ii) Calculate the balance length PJ, in which the galvanometer will show zero reading.

PJ = m [3]

(iii) The balance point is found to be too near P resulting in high fractional error in the determination of balance length.

Suggest and explain how the circuit can be modified, without changing Cell B, to improve the accuracy.

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

(d) PJ is now increased.

Indicate the direction in Fig. 6.2 how the current will flow, if any, through the galvanometer. [1]

- 7 (a) A radiation detector is placed close to a radioactive source. The detector does not surround the source. Radiation is emitted in all directions and, as a result, the activity of the source and the measured count rate are different.

Suggest **two** other reasons why the activity and the measured count rate may be different.

.....

.....

.....

.....

..... [2]

- (b) The variation with time t of the measured count rate in (a) is shown in Fig. 7.1.

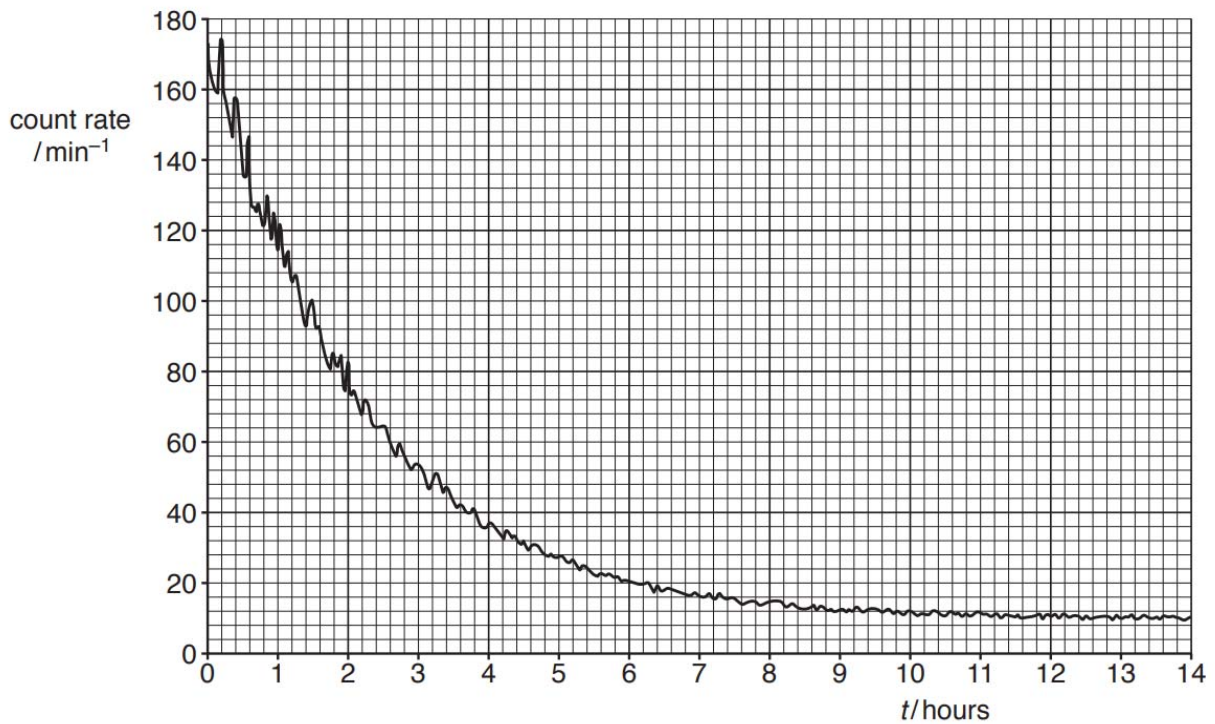


Fig. 7.1

- (i) State the feature of Fig. 7.1 that indicates the random nature of radioactive decay.

.....

..... [1]

(ii) Use Fig. 7.1 to determine the half-life of the radioactive isotope in the source.

half life = s [3]

(c) The readings in (b) were obtained at room temperature.

A second sample of this isotope is heated to a temperature of 500°C.

The initial count rate at time $t = 0$ is the same as that in (b).

The variation with time t of the measured count rate from the heated source is determined.

State, with a reason, the difference, if any, in the half-life.

.....

..... [1]

18
Section B

Answer **one** question in this section in the spaces provided.

- 8 (a)** Define the *tesla*.

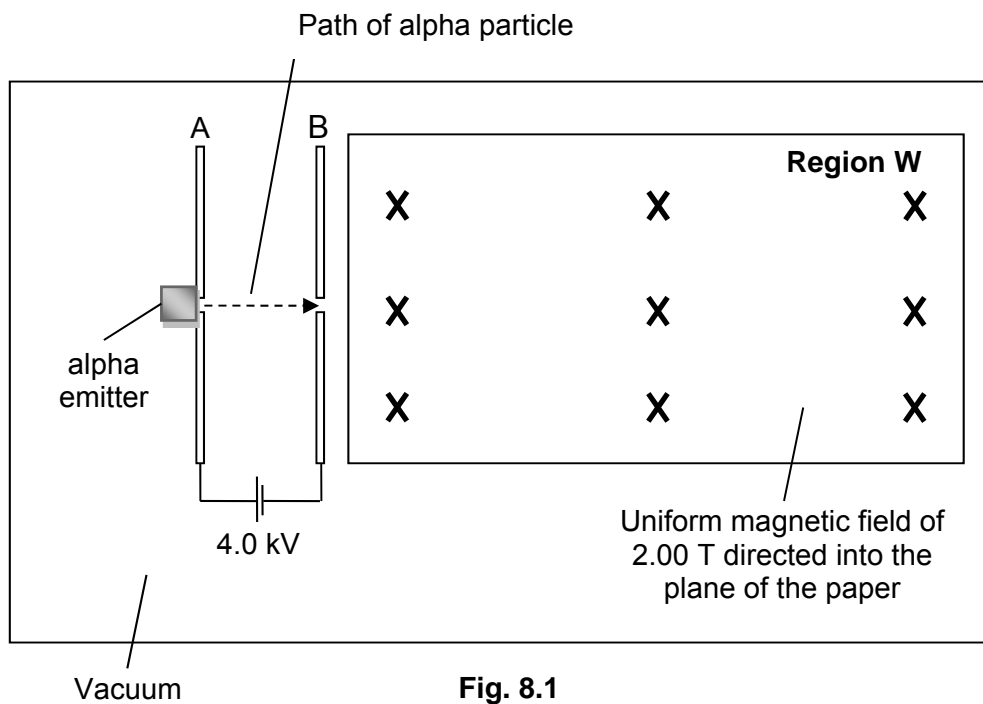
.....

.....

.....

[2]

- (b)** Fig. 8.1 shows an arrangement used to accelerate an initially stationary alpha particle and make it travel in a uniform magnetic field.



- (i)** On Fig. 8.1, draw a possible trajectory of the alpha particle in the uniform magnetic field.
- [1]
- (ii)** Explain whether the force experienced by the alpha particle due to the magnetic field changes its kinetic energy.

.....

.....

.....

.....

.....

.....

[3]

- (iii) Show that the alpha particle will attain a speed of $6.21 \times 10^5 \text{ m s}^{-1}$ when it reaches the slit opening of plate B.

[1]

- (iv) Determine the electric field that needs to be applied in **Region W** for the alpha particle to pass through the uniform magnetic field undeflected.

magnitude = V m^{-1} [2]

direction = [1]

- (c) Suppose that the arrangement in Fig. 8.1 is now modified so that the alpha particle enters the uniform magnetic field at an angle of 30° to the horizontal as shown in Fig. 8.2 below.

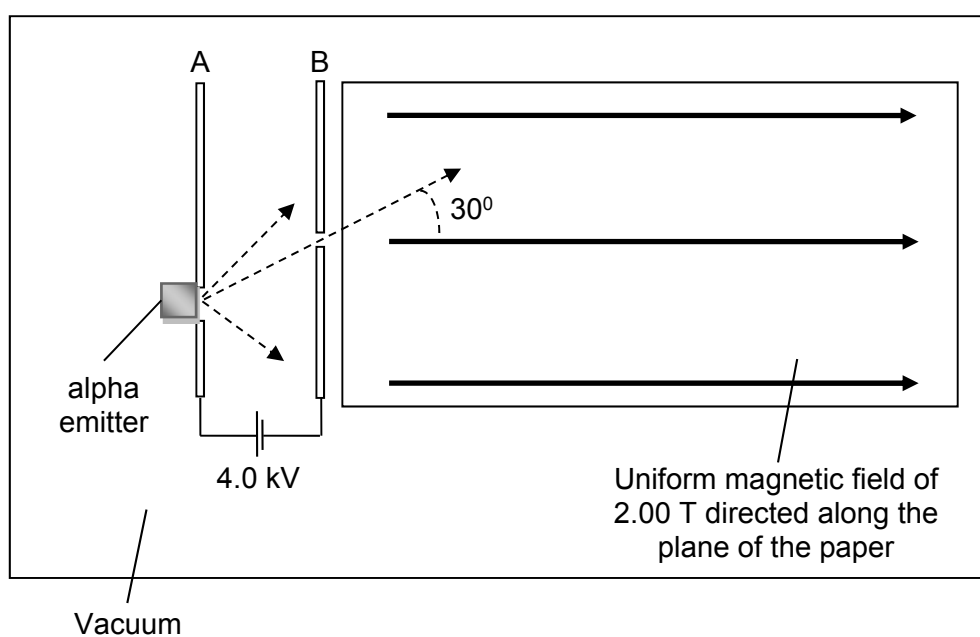


Fig 8.2

The path of the alpha particle can be described as a helix as shown in Fig. 8.3.

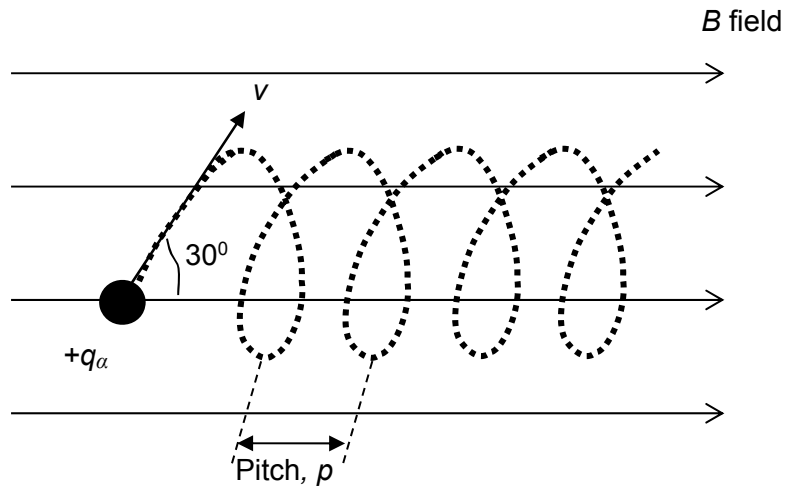


Fig. 8.3 (not to scale)

- (i) Calculate the radius r of the helical path.

radius = m [2]

- (ii) Show that the period, T of the helical path can be expressed as:

$$T = \frac{2\pi m_\alpha}{q_\alpha B}$$

where m_α and q_α is the mass and charge of the alpha particle respectively.

[1]

(iii) Calculate the pitch, p

pitch = m [3]

(iv) Describe and explain how the helical path will change if a positron, ${}_{+1}^0\text{e}^+$ (i.e. a particle with the mass of an electron and charge $+1.6 \times 10^{-19}$ C) with the same initial velocity was to be used in the experiment instead. You may quote relevant equations to substantiate your answer.

.....
.....
.....
..... [4]

9 (a) (i) Define the *magnetic flux*.

.....
 [1]

(ii) State the *laws of electromagnetic induction*.

.....

 [2]

(b) The variation of the magnetic flux density B beyond one end of a large bar magnet with distance is shown in Fig. 9.1.

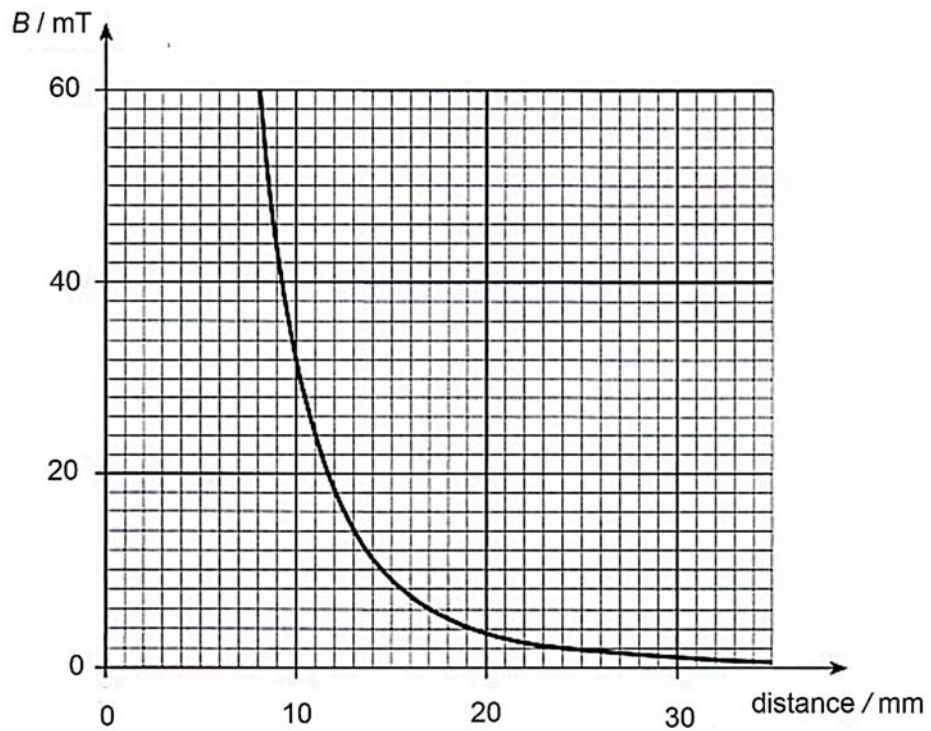


Fig. 9.1

A circular coil of wire with 50 turns and cross-sectional area 16 cm^2 is placed a few centimetres beyond the end of the above stated bar magnet. The axis of the coil is aligned with the axis of the magnet.

- (i) Calculate the magnetic flux linkage through the coil when it is 30.0 mm and when it is 10.0 mm from the end of the magnet respectively.

magnetic flux linkage at 30.0 mm = Wb

magnetic flux linkage at 10.0 mm = Wb [3]

- (ii) The coil of wire is moved towards the magnet from the 30.0 mm position to the 10.0 mm position so that a steady e.m.f. of 0.80 mV is induced in it. Calculate the average speed of the movement of the coil.

average speed = mm s⁻¹ [2]

- (iii) Describe how the speed of the coil would need to change when moving from the 30.0 mm position to the 10.0 mm position so as to maintain a steady e.m.f..

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

- (c) An a.c. generator consists of a rectangular coil of 800 turns with the dimensions $5.0 \text{ cm} \times 8.0 \text{ cm}$ in a uniform magnetic field of magnitude 0.50 T . The coil has a resistance of 0.60Ω and it is connected to an external load of resistance 11.4Ω in a complete circuit. The coil is rotating at a constant speed of 240 revolutions per minute.

- (i) Calculate the maximum voltage produced by this generator.

maximum voltage = V [2]

- (ii) State the relationship between the induced voltage V and the magnetic flux linkage Φ .

[1]

- (iii) Fig. 9.2 shows the variation of the induced voltage V in the coil with time.

Draw on Fig. 9.2, the corresponding variation of the magnetic flux linkage Φ with time.

[2]

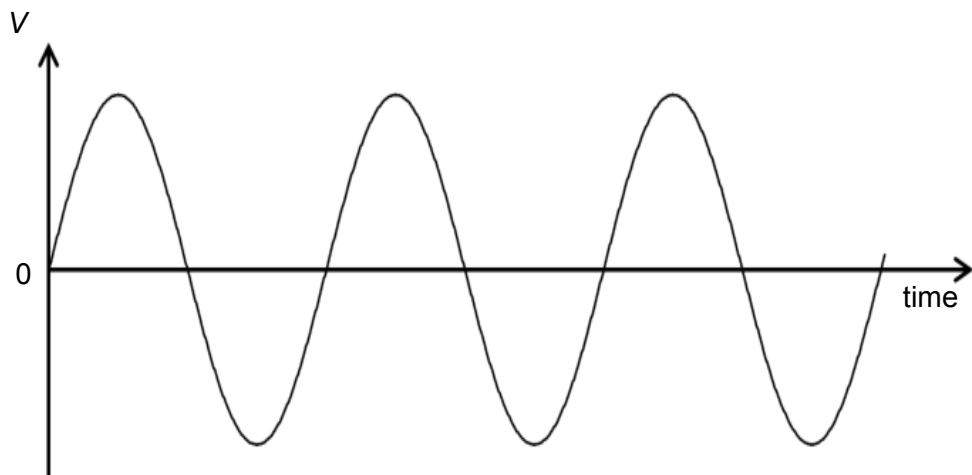


Fig. 9.2

(iv) Calculate the maximum current through the external load.

current = A [1]

(v) Explain the terms

(1) *root-mean-square* (r.m.s.) value

.....
.....

(2) *r.m.s. current*.

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

(vi) Calculate the r.m.s. current through the external load.

r.m.s current = A [1]

(vii) Calculate the average power through the external load.

average power = W [1]

END OF PAPER

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1 (a)(i)

$$\begin{aligned}
 s &= \frac{1}{2} (u + v) t \\
 &= \frac{1}{2} (4.0 + 37.0)(17.0) && [C1] \\
 &= 348.51 \\
 &\approx 349 \text{ m} && [A1]
 \end{aligned}$$

1 (a)(ii)

$$\begin{aligned}
 \Delta t &= 0.6 / 100 \times 17 = 0.1 \text{ s} \\
 s_{\max} &= \frac{1}{2} (4.1 + 37.1)(17.1) = 352.26 \\
 s_{\min} &= \frac{1}{2} (3.9 + 36.9)(16.9) = 344.76 \\
 2\Delta s &= s_{\max} - s_{\min} = 352.26 - 344.76 = 7.4 && [C1] \\
 \Delta s &= 3.7 \approx 4 \\
 \frac{\Delta s}{s} \times 100\% &= \frac{4}{348.51} \times 100\% = 1.1\% && [A1]
 \end{aligned}$$

Alternatively

$$\begin{aligned}
 s &= \frac{1}{2} (u + v) t \\
 \frac{\Delta s}{s} &= \frac{\Delta(u + v)}{(u + v)} + \frac{\Delta t}{t} && [C1]
 \end{aligned}$$

$$\frac{\Delta s}{s} \times 100\% = \left(\frac{0.1 + 0.1}{4.0 + 36.0} \right) \times 100\% + 0.6\%$$

$$\frac{\Delta s}{s} \times 100\% = 1.1\% \quad [A1]$$

1 (a)(iii)

$$\begin{aligned}
 \frac{\Delta s}{s} \times 100\% &= 1.1\% \\
 \Delta s &= 0.011 \times 349 \\
 \Delta s &= 3.84 \approx 4 \text{ m} \\
 s &= (349 \pm 4) \text{ m} && [B1]
 \end{aligned}$$

1 (b)(i)

$$\begin{aligned}
 \Delta KE &= \frac{1}{2} mv^2 - \frac{1}{2} mu^2 \\
 &= \frac{1}{2} \times 95 \times [(37.0)^2 - (4.0)^2] && [C1] \\
 &= 64300 \text{ J} && [A1]
 \end{aligned}$$

1 (b)(ii)

$$\begin{aligned}
 \Delta GPE &= \Delta mgh \\
 &= 95 \times 9.81 \times -349 \sin 40^\circ && [C1] \\
 &= -209000 \text{ J} && [A1]
 \end{aligned}$$

1 (b)(iii)

$$\begin{aligned}
 GPE_i + KE_i + W_{\text{friction}} &= GPE_f + KE_f \\
 \text{Work done by friction} &= \Delta GPE - \Delta KE \\
 &= -209100 + 64300 \text{ J} \\
 &= -144800 && [C1] \\
 f \times 349 \cos 180^\circ &= -144800 \\
 f &= 415 \text{ N} && [A1]
 \end{aligned}$$

2 (a)

Newton's law of gravitation states that the attractive gravitational force between two point masses [A1] is directly proportional to the product of the masses and inversely proportional to the square of their separation [M1].

2 (b)

The gravitational force acting on the moon provides the centripetal force. [B1]

$$F_c = ma_c$$

$$\frac{GMm}{x^2} = m\omega^2 \quad [M1]$$

$$\text{Since } \omega = \frac{2\pi}{T}$$

$$\frac{GMm}{x^2} = m\omega^2 = m\left(\frac{2\pi}{T}\right)^2 \quad [M1]$$

$$GM = \frac{4\pi^2 x^3}{T^2} \quad [A0]$$

2 (c)(i)

$$\text{gradient} = \frac{(4.5 \times 10^{14} - 1.3 \times 10^{14}) \times (1000)^3}{(0.35 - 0.10) \times (24 \times 60 \times 60)^2} \quad [M1]$$

$$= 1.71 \times 10^{14} \text{ m}^3 \text{ s}^{-2} \quad [A0]$$

2 (c)(ii)

$$GM = \frac{4\pi^2 x^3}{T^2}$$

$$6.67 \times 10^{-11} \times M = 4\pi^2 \times 1.71 \times 10^{14} \quad [C1]$$

$$M = 1.02 \times 10^{26} \text{ kg} \quad [A1]$$

2 (d)

The gradient of the graph is equal to $\frac{GM}{4\pi^2}$. Since the mass of planet Uranus is smaller than that of planet Neptune, the graph for Uranus is one with smaller gradient [B1] with the same zero-y-intercept [B1].

3 (a)

Any 2 assumptions [B1x2]

- Large number of particles.
- The time of collisions is negligible compared to the time between the collisions.
- Negligible intermolecular forces (except during collisions)
- Total volume of the gas particles are negligible compared to volume of the containing vessel.
- Average separation of gas particles is very large compared to the size of particle. Negligible microscopic PE.
- The gas particles moves randomly in all directions.

3 (b)(i)

$$\text{Mass of 1 mole of helium-4 gas} = 4.0 \times 10^{-3} \text{ kg}$$

$$\text{Mass of 1 atom} = 4.0 \times 10^{-3} / 6.02 \times 10^{23} \\ = 6.6 \times 10^{-27} \text{ kg} \quad [A1]$$

Alternatively

$$\text{Mass of one atom} = 4u = 4 \times (1.66 \times 10^{-27}) \\ = 6.6 \times 10^{-27} \text{ kg}$$

Mass the 2 electrons is negligible and so can be ignored.

No marks if 4xmass of proton. He-4 has 2 protons and 2 neutrons

3 (b)(ii)

$$\text{Internal Energy } U = \frac{3}{2}nRT = \frac{3}{2}(1.2)(8.31)(273 + 27) \\ = 4.5 \times 10^3 \text{ J} \quad [\text{A1}]$$

$$\text{Alternatively, can use } \frac{3}{2}NkT = \frac{3}{2}(nN_a)kT$$

3 (b)(iii)

$$\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT \quad [\text{C1}] \\ \frac{1}{2}(6.6 \times 10^{-27})\langle c^2 \rangle = \frac{3}{2}(1.38 \times 10^{-23})(300) \quad [\text{C1}] \\ \text{r.m.s. speed} = 1.4 \times 10^3 \text{ m s}^{-1} \quad [\text{A0}]$$

Alternatively,

Mean KE = Internal E / (no. of atoms)

$$\frac{1}{2}m\langle c^2 \rangle = \frac{4.49 \times 10^3}{6.023 \times 10^{23}} = 7.45 \times 10^{-21} \quad [\text{C1}] \\ \frac{1}{2}(6.64 \times 10^{-27})\langle c^2 \rangle = \frac{4.49 \times 10^3}{6.023 \times 10^{23}} = 7.45 \times 10^{-21} \quad [\text{C1}] \\ \text{r.m.s. speed} = 1.5 \times 10^3 \text{ m s}^{-1} \quad [\text{A0}]$$

3 (b)(iv)

The r.m.s. speed is a **singular representation of the effective speed** that determines the internal energy of the gas. It is a sort of an 'average' speed.

(MUST put inverted comma for the term 'average' as it denotes a proxy value and not the actual average speed. FYI, the average velocity is zero as the motion is random, Average speed is not the same as rms speed as the distribution of the speed does not follow a normal distribution).

Statistically, that means there are some particles that have speeds greater (or less) than the r.m.s. speed. Thus, some helium particles that have **with speed greater than the escape speed will escape** the Earth's atmosphere. [B1]

4 (a)

free oscillation: oscillation in which a body oscillates without any loss of energy or without resistive forces or without external forces applied. [B1]

forced oscillation: oscillation in which a body is made to vibrate by an external periodic force or continuous energy is transferred to the vibrating body. [B1]

4 (b)(i)

Resonance can be used as the driving frequency of the oscillator matches the natural frequency of the vibration of the trolley. [B1]

It can be observed where the **amplitude** of the vibration is the **maximum**. [B1]

From Fig. 4.2, frequency is 2.1 Hz (allow 2.08 to 2.12 Hz).

[B1]

4 (b)(ii)

The peak of the graph is not very sharp or the amplitude of the vibration is finite, so frictional forces are present. [B1]

4 (c)

$$v_0 = \omega x_0 \\ = 2\pi \times 2.1 \times 4.7 \times 10^{-2} \quad [\text{C1}] \\ = 0.62 \text{ m s}^{-1} \quad [\text{A1}]$$

5 (a)

A and B: in phase [A1]

A and C: in antiphase (accept completely or 180° or π out of phase.) [A1]5 (b)

Use stroboscope (B1) and adjust flash frequency for slow motion/ expect to see A moving up as C moves down etc.

Or use a video camera and replay in slow motion/ expect to see A moving up as C moves down etc.

5 (c)(i)The amplitude of the wave is constant for progressive wave [B1] but varies from 0 at the the node to $2A$ at the antinode for stationary wave. {B1}5 (c)(ii)

Reflection give rise to waves propagating in both directions [B1].

Interference between these progressive waves of the same amplitude, frequency and speed moving in opposite direction gives rise to stationary wave. {B1}

6 (a)

$$R = \frac{\rho l}{A} = \frac{1.7 \times 10^{-8} \times 1.5}{3.2 \times 10^{-9}} \quad [M1]$$

$$= 8.0 \Omega \quad [A0]$$

6 (b)

$$E = IR$$

$$12 = I \times (1.0 + 2.0 + 8.0)$$

$$I = 1.091 \text{ A} \quad [C1]$$

$$I = nAqv$$

$$1.091 = (8.5 \times 10^{28}) (3.2 \times 10^{-9}) (1.6 \times 10^{-19}) v$$

$$v = 0.025 \text{ m s}^{-1} \quad [A1]$$

6 (c)(i)

Using potential divider equation,

$$V_{PQ} = \frac{R_{RQ}}{R_{total}} = \frac{8.0}{8.0 + 1.0 + 2.0} \times 12.0 \quad [M1]$$

$$= 8.7 \text{ V} \quad [A0]$$

6 (c)(ii)

$$\text{terminal pd of B} = \frac{R}{R+r} \times E = \frac{4.0}{4.0+3.0} \times 12.0$$

$$= 0.857 \text{ V} \quad [C1]$$

$$\frac{V_{PJ}}{V_{PQ}} = \frac{I_{PJ}}{I_{PQ}}$$

Since terminal pd of B = V_{PJ}

$$\frac{0.857}{8.7} = \frac{I_{PJ}}{1.5} \quad [C1]$$

$$I_{PJ} = 0.148 \text{ A} \quad [A1]$$

6 (c)(iii)

To improve accuracy, the modification is either to

1. make the potential difference of PJ larger by increasing the resistance of the 4.0Ω resistor [B1].

However this amendment has minimal effect due to the small value of e.m.f. of cell B
Only award 1 mark.

2. make the potential difference per unit length of PQ smaller [M1] to increase the length of PQ needed at balance length by decreasing the e.m.f. of cell A or reducing the resistance of the wire through increasing its cross-sectional area, decreasing length or resistivity or increasing the resistance of the 2.0Ω resistor [A1]

6 (d)

From galvanometer towards J

7 (a)

- Emission from radioactive daughter products
- Self absorption in source
- Absorption in air before reaching detector
- Detector not sensitive to all radiations
- Window/detector may absorb some radiations
- Dead-time of the counter
- Background radiation

Any two

7 (b)(i)

Curve is not smooth

Or

Curve fluctuates/is jagged

7 (b)(i)

Evidence of background radiation taken account [B1]

Half life determine twice [B1]

Half life = 1.5h (accepting a range of 1.4-1.6 [A1])

7 (c)

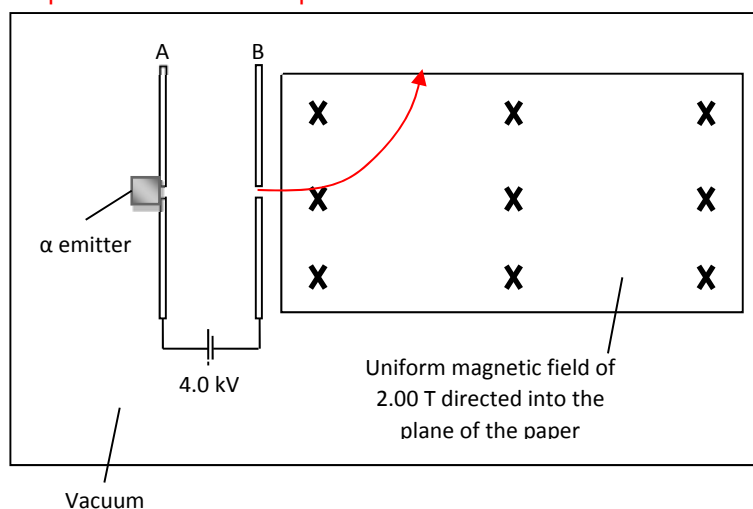
Half life has no change as radioactive is spontaneous/is not affected by external factor

8 (a)

One tesla is defined as the amount of magnetic flux density of a uniform magnetic field when a magnetic force per unit current per unit length of 1 newton per ampere per metre acts on a straight wire placed perpendicular to the magnetic field.

8 (b)(i)

Award [B1] if student's answer shows evidence of a circular path and particle is deflected upwards.



8 (b)(ii)

The magnetic force acting on the α -particle is always directed at right angles to the velocity of the particle. [B1]

The resulting acceleration is directed at right angles to the velocity of the particle and thus will not alter the speed but merely changes its direction. [B1] **OR** The magnetic force hence does not do work on the particle. [B1]

The kinetic energy of the particle thus does not change. [B1]

8 (b)(iii)

$$\frac{1}{2}mv^2 = qV$$

$$v = \sqrt{\frac{2(2 \times 1.6 \times 10^{-19})(4000)}{6.644 \times 10^{-27}}} \quad [\text{M1}]$$

$$= 6.207 \times 10^5 \text{ m s}^{-1} \quad [\text{A0}]$$

8 (b)(iv)

$$F_B = F_E$$

$$qvB = qE$$

$$E = vB$$

$$= (6.207 \times 10^5)(2.00) \quad [\text{M1}]$$

$$= 1.24 \times 10^6 \text{ V m}^{-1} \quad [\text{A1}]$$

E Field is directed downwards [B1]

8 (c)(i)

$$\begin{aligned}
 F_B &= F_c \\
 qvB &= \frac{mv^2}{r} \\
 r &= \frac{mv}{qB} \\
 &= \frac{6.644 \times 10^{-27} (6.207 \times 10^5) \sin 30^\circ}{(2 \times 1.6 \times 10^{-19})(2.00)} \quad [\text{M1}] \\
 &= 3.22 \times 10^{-3} \text{ m} \quad [\text{A1}]
 \end{aligned}$$

8 (c)(ii)

Magnetic force on charged particle provides the centripetal force.

$$\begin{aligned}
 q_\alpha v_y B &= m_\alpha v_y \omega \\
 q_\alpha B &= m_\alpha \left(\frac{2\pi}{T} \right) \quad [\text{M1}] \\
 T &= \frac{2\pi m_\alpha}{q_\alpha B} \quad (\text{shown})
 \end{aligned}$$

8 (c)(iii)

$$\begin{aligned}
 T &= \frac{2\pi m_\alpha}{q_\alpha B} \\
 &= \frac{2\pi (6.644 \times 10^{-27})}{(2 \times 1.6 \times 10^{-19})(2.00)} \\
 &= 6.522 \times 10^{-8} \text{ s} \quad [\text{M1}]
 \end{aligned}$$

Pitch, $p = v_x T$

$$\begin{aligned}
 &= (6.207 \times 10^5) \cos 30^\circ \times 6.522 \times 10^{-8} \quad [\text{M1}] \\
 &= 0.0351 \text{ m} \quad [\text{A1}]
 \end{aligned}$$

8 (c)(iv)

Since $q_{\text{positron}} = \frac{1}{2} q_\alpha$, $m_{\text{positron}} \ll m_\alpha$

$$\begin{aligned}
 \frac{m_{\text{positron}}}{q_{\text{positron}}} &= \frac{9.11 \times 10^{-31}}{1.6 \times 10^{-19}} = 5.69 \times 10^{-12} \\
 \frac{m_{\text{alpha}}}{q_{\text{alpha}}} &= \frac{6.644 \times 10^{-27}}{2 \times 1.6 \times 10^{-19}} = 2.07 \times 10^{-8}
 \end{aligned}$$

Thus, $(m/q)_{\text{positron}} < (m/q)_{\text{alpha}}$ [M1]

For a positron, the period, $T = \frac{2\pi m}{qB}$ will decrease for the same magnetic field [A1]

Since radius is also proportional to the ratio (m/q) for the same B and speed, the radius $r = \frac{mv}{qB}$ for positron will also decrease. [A1]

Pitch is proportional to the period for the same horizontal speed $p = v_x T$, thus the pitch will decrease. [A1]

9 (a)(i)

Magnetic flux through the surface is defined as the product of the magnetic flux density B **perpendicular** to the surface and the area A of the surface. [B1]

Or

Magnetic flux is the product of the magnetic flux density and the area **normal** to the lines of flux. [B1]

9 (a)(ii)

Faraday's law of electromagnetic induction states that the magnitude of the induced e.m.f. across a conductor is directly proportional to the rate of change of magnetic flux linkage (or the rate of cutting of magnetic flux). [B1]

Lenz's Law states that the induced e.m.f in a closed circuit will produce effects that oppose the magnetic flux change that causes it.

OR

Lenz's Law states that the induced current in a closed circuit will flow in such a way as to oppose the change that causes it.

[B1]

9 (b)(i).

Magnetic flux linkage $\Phi = NBA$ [C1]

At 30.0 mm position,

$$\begin{aligned}\Phi_1 &= (50)(1.0 \times 10^{-3})(16.0 \times 10^{-4}) \\ &= 8.0 \times 10^{-5} \text{ Wb}\end{aligned}$$
 [A1]

At 10.0 mm position,

$$\begin{aligned}\Phi_2 &= (50)(32.0 \times 10^{-3})(16.0 \times 10^{-4}) \\ &= 2.56 \times 10^{-3} \text{ Wb}\end{aligned}$$
 [A1]

9 (b)(ii)

From Faraday's law,

$$E = \left| \frac{\Delta\Phi}{\Delta t} \right|$$
 [M1]

$$0.80 \times 10^{-3} = \frac{2.56 \times 10^{-3} - 8.0 \times 10^{-5}}{\Delta t}$$

time take $\Delta t = 3.10 \text{ s}$

average speed = $(30.0 - 10.0) / 3.10$

$$= 6.45 \text{ mm s}^{-1}$$

$$= 6.5 \text{ mm s}^{-1} \text{ (2s.f.)}$$
 [A1]

9 (b)(iii)

$$E = \frac{dN\phi}{dt} = \frac{dNBA}{dt} = NA \left(\frac{dB}{dt} \right)$$

$$E = NA \left(\frac{dB}{dt} \right) = NA \left(\frac{dB}{dx/v} \right) = NA \left(\frac{dB}{dx} \right) v$$

Consider the coil moving at constant speed towards the end of the bar magnet. The induced emf in the coil will increase as the B-x gradient increases.

From the above, it can be seen that to maintain the same induced e.m.f., the rate of change (or rise) of magnetic flux linkage in the coil must be steady. The instantaneous velocity of the coil should therefore be inversely proportional to the B-x gradient. So, when approaching the magnet and the B-x gradient rises sharply, to mitigate the rise, the speed of the coil must decrease gradually. The combined effect is to make the magnetic flux linkage to rise at a steady rate resulting in a steady emf. See graphs on right.

At the 30.0 mm position, since the B-x slope is gradual, the speed of the coil must be large initially [B1]

When the coil approaches the magnet, the B-x gradient increases at an increasing rate wrt x. Thus, to maintain the same emf, the **speed of the coil must decrease at a decreasing rate** when moving from 30.0 mm position to the 10.0 mm position. [B1]

9 (c)(i)

For a rotating coil, $E = NBA\omega \sin(\omega t)$

For e.m.f. to be maximum, $\sin(\omega t) = 1$.

Hence, max e.m.f. $E_0 = NBA(2\pi f)$

$$= (800)(0.50)(5.0 \times 10^{-2} \times 8.0 \times 10^{-2})(2\pi)(240/60) \text{ [M1]}$$

$$= 40.2 \text{ V}$$

$$= 40 \text{ V}$$

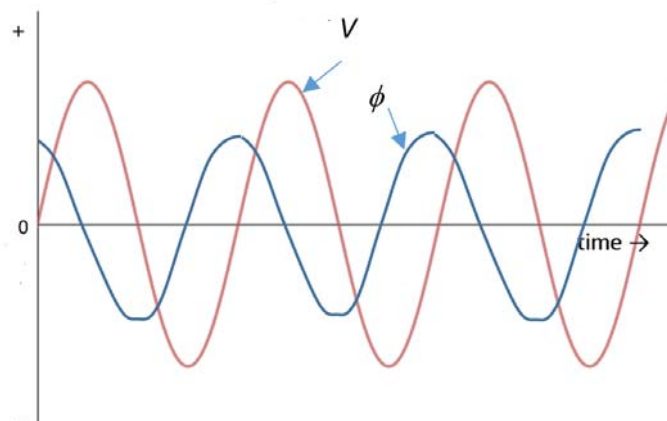
[A1]

9 (c)(ii)

$$V = -\frac{d\Phi}{dt} \quad \text{[B1]}$$

Do not award mark if the negative sign is omitted.

9 (c)(iii)



Both graphs have same frequency (period) [B1]
 A phase difference of 90° with V lagging ϕ . [B1]

9(c)(iv)

$$I_o = \frac{V_o}{R} = \frac{40}{12} = 3.3 \text{ A [A1]}$$

9 (c)(v)

The term r.m.s. value refers to the square root of the mean squared values. [B1]

The r.m.s. current is equivalent to that of a steady direct current which would dissipate energy in a given resistance at the same rate as the alternating current (same heating effect) [B1]

9 (c)(vi)

$$I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{3.35}{\sqrt{2}} = 2.37 \text{ A} \\ = 2.4 \text{ A [2 s.f.]} \quad \quad \quad \text{[A1]}$$

9 (c)(vii)

$$\text{Average power} = I_{rms}^2 R = (2.37)^2 (11.4) = 64.0 \text{ W} \\ = 64 \text{ W (2 s.f.)} \quad \quad \quad \text{[A1]}$$