TEMASEK JUNIOR COLLEGE
2021 JC2 Preliminary Examination
Higher 2

NAME

CG

PHYSICS

Paper 3 Longer Structured Questions

9749/03

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

14 September 2021

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and civics group in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only

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

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

For Examiner's Use	
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3	
4	
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6	
7	
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s.f.	
Total	

This booklet consists of **23** printed pages and **1** blank page.

Data

speed of light in free space	c	$= 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$
permeability of free space	μ_o	$= 4\pi \times 10^{-7}\ \mathrm{H\ m^{-1}}$
permittivity of free space	ε_o	$= 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$ or $(1/(36\pi)) \times 10^{-9}\ \mathrm{F\ m^{-1}}$
elementary charge	e	$= 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant	h	$= 6.63 \times 10^{-34}\ \mathrm{Js}$
unified atomic mass constant	u	$= 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	m_e	$= 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton	m_p	$= 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant	R	$= 8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$
the Avogadro constant	N_A	$= 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant	k	$= 1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}}$
gravitational constant	G	$= 6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}}$
acceleration of free fall	g	$= 9.81\ \mathrm{m\ s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\mathrm{K} = T/^{\circ}\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_o \sin\omega t$
velocity of particle in s.h.m.	$v = v_o \cos\omega t$
	$= \pm\omega\sqrt{(x_o^{\ 2} - x^2)}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_o \sin\omega t$
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	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$

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Section A

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

1 **(a)** 0.050 moles of ideal gas is contained in a cylinder fitted with a piston. The piston moves slowly outwards, resulting in the variation of pressure shown in Fig. 1.1.

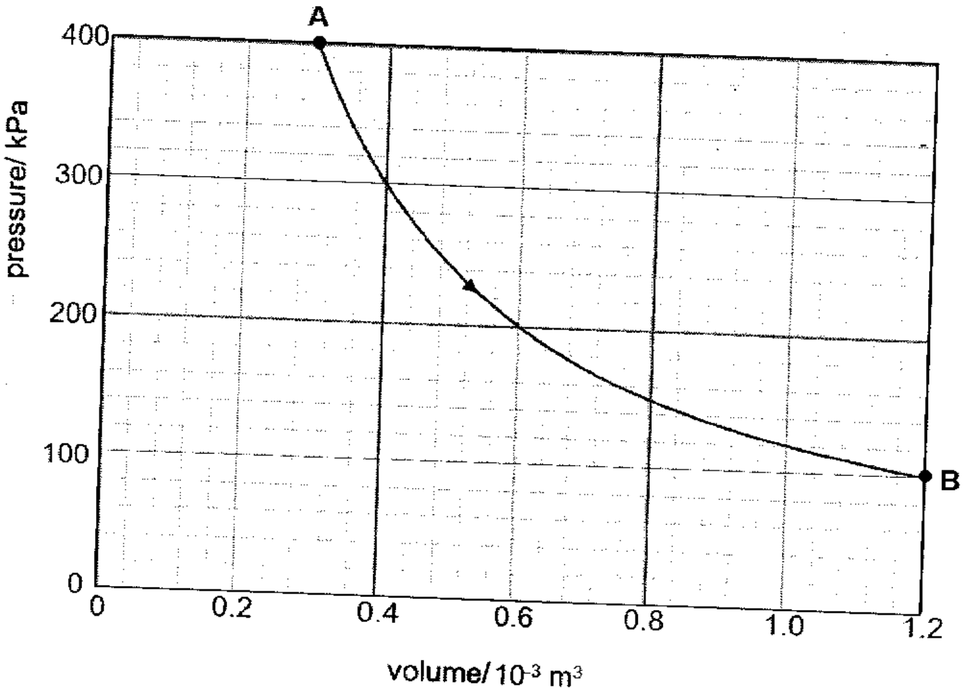

Fig. 1.1

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(i) The temperature of the gas does not change from A to B.

Calculate this temperature.

temperature = ... K [2]

(ii) Calculate the total kinetic energy of the gas molecules in the cylinder.

kinetic energy = ... J [1]

[Turn over

(iii) Estimate the amount of work done by the gas as it expands from A to B.

work done = ... J [2]

(iv) State and explain, using the first law of thermodynamics, whether heat flows into the gas during the process from A to B.

....

....

....

....

.... [2]

(b) An experiment is conducted to investigate how gas pressure varies with temperature.

Two identical sealed glass flasks P and Q are filled with the same amount of ideal gas at the same atmospheric pressure initially. Both flasks are heated from 27°C to 157°C. The pressure in flask P increases as expected, but the pressure in flask Q remains unchanged because some gas leak out of flask Q.

Calculate the ratio

$$\frac{\text{amount of gas in flask Q}}{\text{amount of gas in flask P}} \text{ at } 157°\text{C}.$$

ratio = ... [3]

[Total: 10]

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2 Fig. 2.1 shows a box with a piece of plasticine attached outside it. A light spring is attached to the box and the box is initially at rest. After some time, the plasticine detaches and falls, as shown in Fig. 2.2.

The box in Fig. 2.2 starts to oscillate in simple harmonic motion.

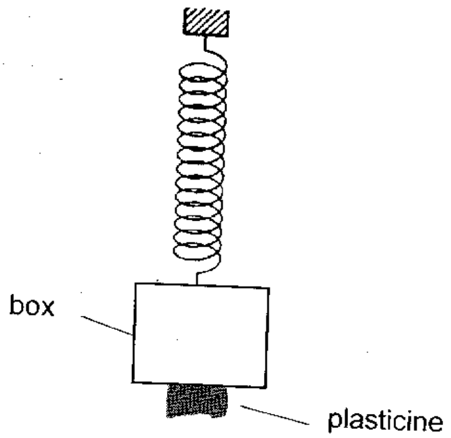

Fig. 2.1

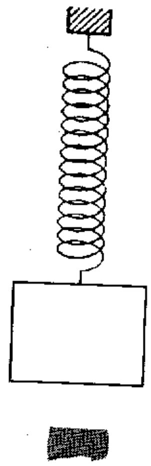

Fig. 2.2

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(a) Explain why the box in Fig. 2.2 starts to oscillate.

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.... [3]

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(b) The mass of the plasticine is 20.0 g and the mass of the box is 100.0 g.

(i) Show that the magnitude of the maximum acceleration of the box's oscillation in Fig. 2.2 is 1.96 m s^{-2}.

[2]

(ii) The box in Fig. 2.2 moves a distance 5.00 cm from its lowest position to its highest position. Calculate the period of the oscillation.

period = ... s [3]

(c) The box in Fig. 2.2 continues to oscillate after the plasticine detaches. The box is at its lowest position at time t = 0.0 s.

On Fig. 2.3, sketch the variation with time t of the displacement x of the box for at least two cycles of its oscillation.

Assume negligible air resistance.

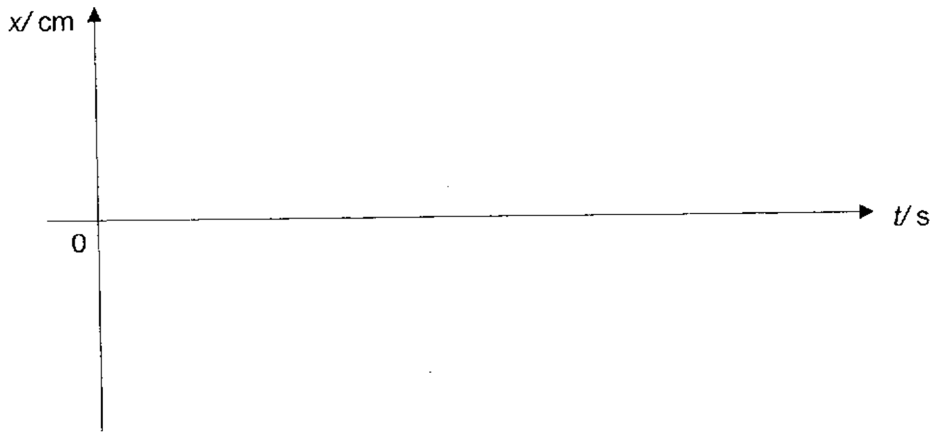

Fig. 2.4

[2]

[Total: 10]

3 (a) Define *electric potential* at a point.

....

....

.... [1]

(b) Two spherical conductors of radii r_1 and r_2 are separated by a distance *much larger* than the radius of either sphere. Initially, the charges on the spheres are q_1 and q_2 and the potentials are V_1 and V_2 respectively, as shown in Fig. 3.1.

Fig. 3.1 (not to scale)

The spheres are then connected by a conducting wire as shown in Fig. 3.2.

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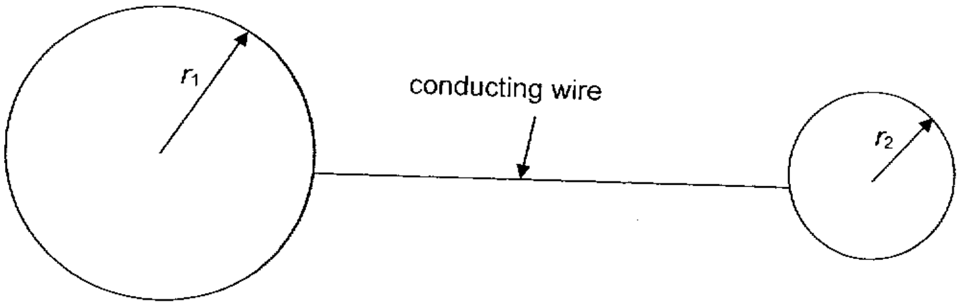

Fig. 3.2 (not to scale)

(i) State and explain what happen to the potentials of the spheres upon connecting them with the conducting wire.

....

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.... [2]

(ii) Derive an expression for the electric potential V at the surface of the larger sphere, after the wire is connected, in terms of V_1, V_2, r_1 and r_2.

State one assumption made in your derivation.

Assumption:

....

.... [3]

(c) Three identical small spheres A, B and C, each carrying equal charge $+q$, are connected to three light non-conducting strings as shown in Fig. 3.3. Spheres A and C are deflected at the same angle θ with the vertical and the length of the strings connected to both spheres is L.

The three spheres lie on the same horizontal axis.

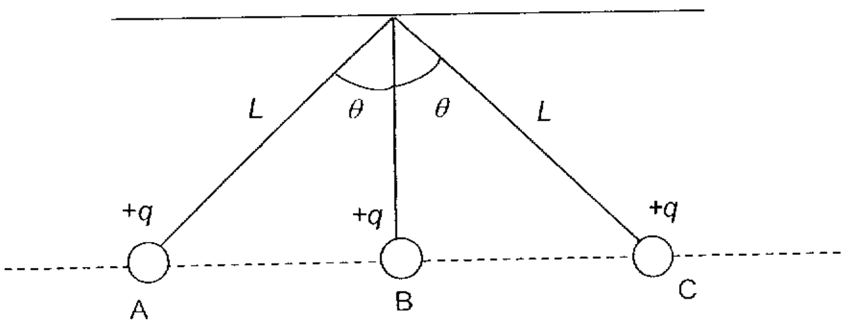

Fig. 3.3 (not to scale)

(i) Write down an expression for the electric force F acting on A in terms of q, θ and L.

[2]

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(ii) Derive an expression for the tension T in the string supporting A in terms of q, θ and L.

[2]

(iii) The charge on sphere B is increased. State the change, if any, in the positions of each of the spheres immediately after.

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.... [2]

[Total: 12]

4 A transmission line is used to deliver power in a high voltage a.c. transmission system.

Fig. 4.1 shows the variation with time t of the voltage V across the transmission line.

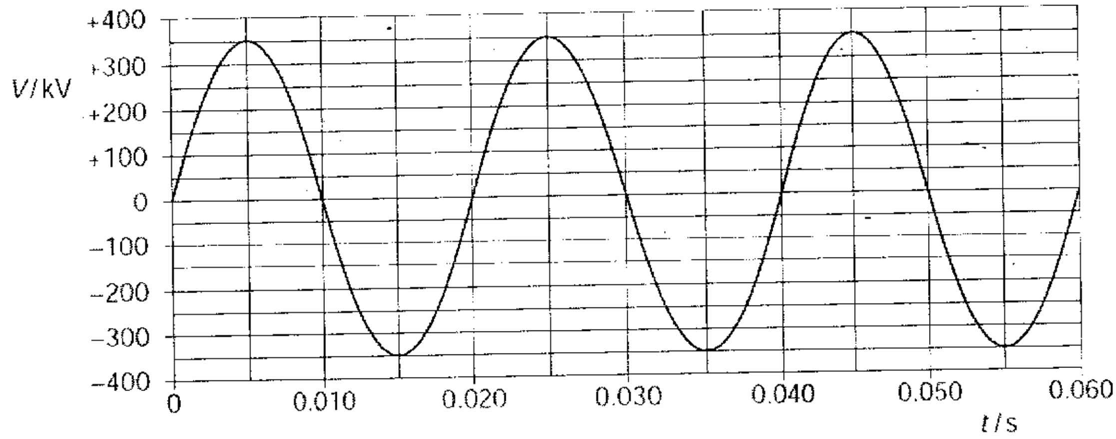

Fig. 4.1

Fig. 4.2 shows the variation with time t of the current I in the transmission line.

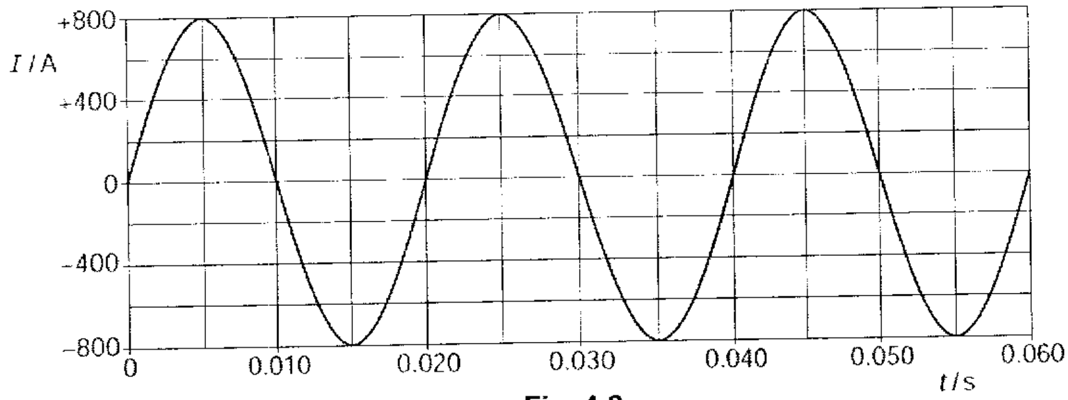

Fig. 4.2

(a) Determine the power delivered by the transmission line at

(i) $t = 0.015$ s,

power = ... W [1]

(ii) $t = 0.030$ s.

power = ... W [1]

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(b) Using information from Fig. 4.1 and Fig. 4.2, sketch a graph on the axes of Fig. 4.3 to show the variation with time t of the power P delivered by the transmission line. Indicate the value of the maximum power on Fig. 4.3.

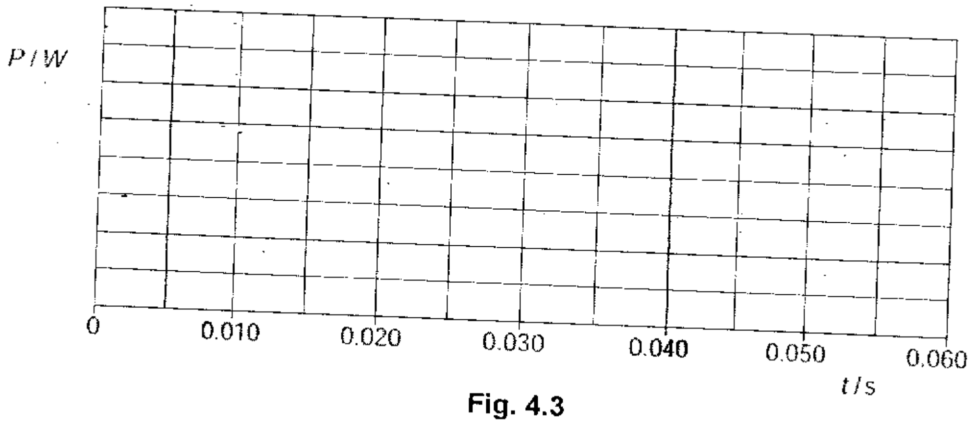

Fig. 4.3

[2]

(c) It is suggested that this transmission line is also used in a high voltage direct current (HVDC) transmission system delivering a current of 800 A at a constant voltage of 350 kV.

Show, with some workings, that the average power delivered by the HVDC transmission line would be greater than that delivered by the line when transmitting the a.c..

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.... [2]

(d) The a.c. transmission line passes through an ideal transformer of step-down ratio 20:1. Explain the change, if any, to the peak value of the current of the a.c.. You may show your workings in the spaces below.

....

.... [2]

[Total: 8]

[Turn over

5 **(a)** State Faraday's law of electromagnetic induction.

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.... [1]

(b) Fig 5.1 shows a system used by an engineer to determine the constant rate of revolution of a rotating cylinder.

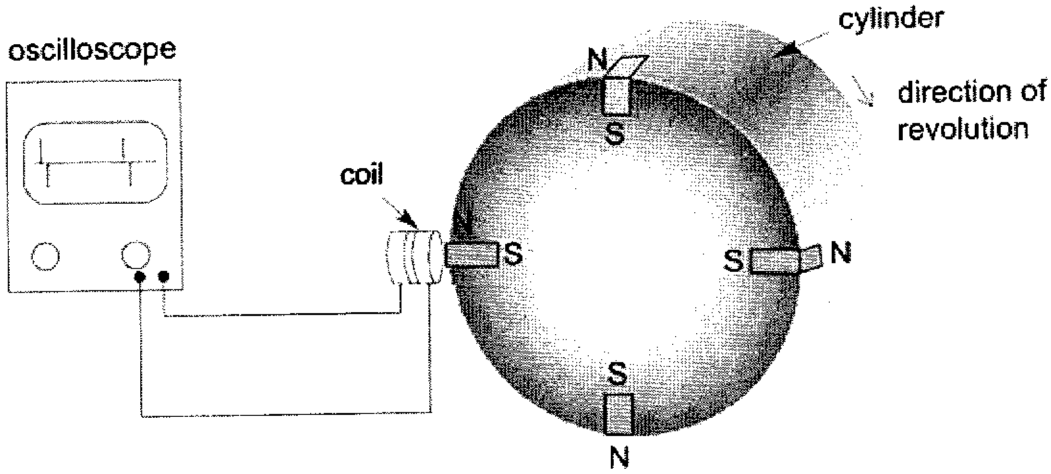

Fig. 5.1

Four small bar magnets are embedded in the cylinder as shown. The North-pole of each magnet is on the exterior of the cylinder. As the cylinder rotates, a voltage is produced between the terminals of a coil placed close to the cylinder.

The voltage produced is monitored using a cathode ray oscilloscope (c.r.o.). The waveform displayed on the c.r.o. is shown in Fig 5.2.

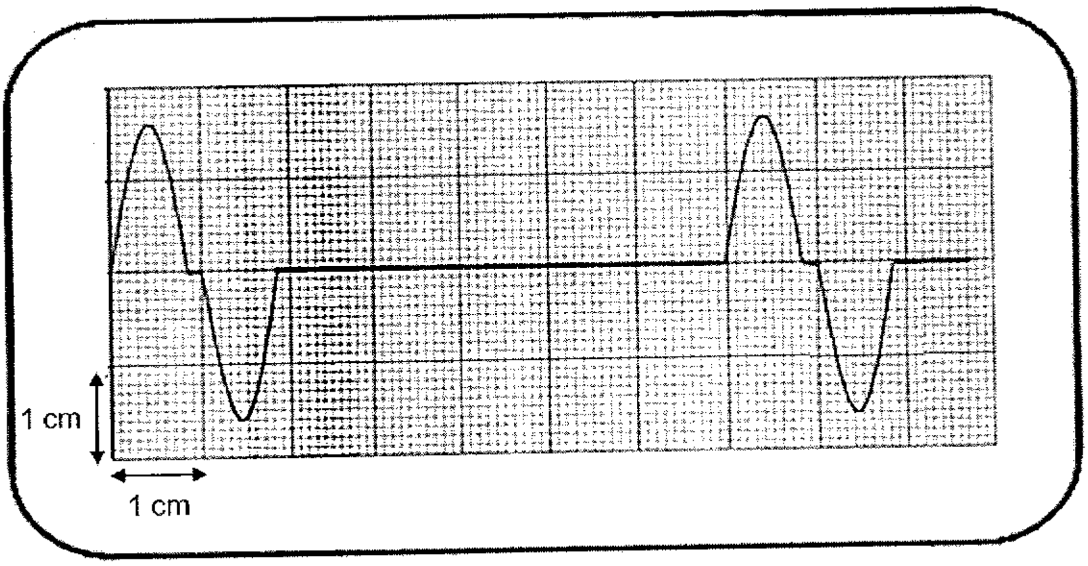

Fig. 5.2 (not to scale)

Given:

Y-plate sensitivity = 5.0 mV cm^{-1}
Time-base setting = 10 ms cm^{-1}

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(i) Using the laws of electromagnetic induction, explain the shape of the waveform obtained in Fig. 5.2.

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.... [2]

(ii) Determine the number of revolutions made by the cylinder in one minute.

number of revolutions = ... [3]

(iii) Determine the maximum rate of change of magnetic flux linkage of the coil.

maximum rate of change of flux linkage = ... $Wb\ s^{-1}$ [1]

(iv) Describe and explain the changes, if any, to the waveform displayed in Fig. 5.2 when the rate of revolution of the cylinder is doubled.

....

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.... [3]

[Total: 10]

[Turn over

6 (a) The wave properties of electrons can be demonstrated using electron diffraction. The arrangement used includes a parallel beam of electrons accelerated by a potential difference in a glass envelope as shown in Fig. 6.1. A graphite film is placed perpendicularly to the path of the electron beam.

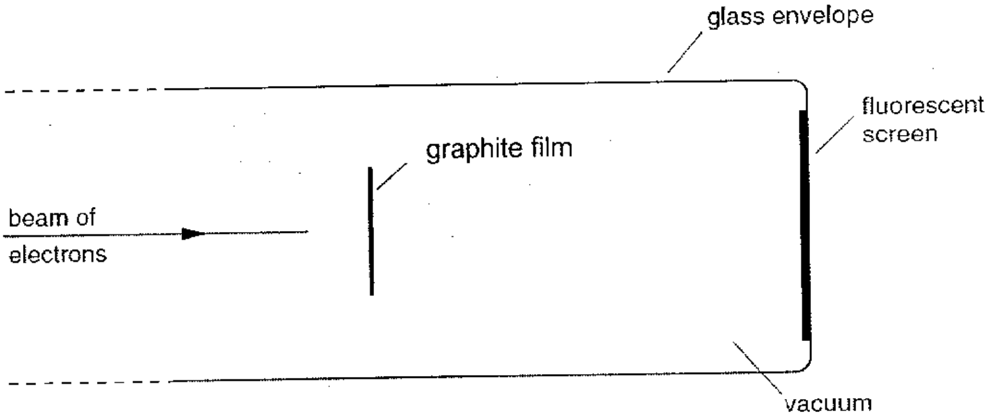

Fig. 6.1

The electrons incident on a fluorescent screen create a pattern consisting of bright and dark rings, as shown in Fig. 6.2.

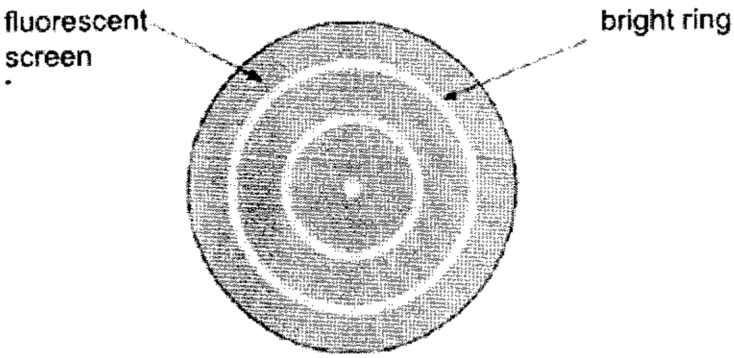

Fig. 6.2

(i) Identify two key features in Fig. 6.2 and explain how they provide evidence for the wave nature of electrons.

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.... [2]

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(ii) Electrons of mass m are accelerated in a vacuum through a potential difference V of 250 V.

1. Show that the associated wavelength λ of the electrons can be expressed as

$$\lambda = \frac{h}{\sqrt{2meV}}.$$

[2]

2. Hence, calculate the wavelength λ of the electrons.

λ = ... m [2]

(iii) Describe and explain how the observed pattern in Fig. 6.2 changes as the potential difference V is increased.

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(b) The wave properties of matter do not seem to affect us noticeably in everyday life.

When a 80 kg man walks in a straight line at 2.0 m s^{-1} and passes through a doorway of width 1.2 m, he is not obviously deflected from his path.

Show, using Heisenberg's Uncertainty Principle and some appropriate workings, that the deflection of the man is negligible. You may take the width of the doorway as the uncertainty in position of the man.

--- [2]

[Total: 10]

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Section B

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

7 **(a)** A progressive wave transfers energy. A stationary wave **does not** transfer energy. State **two other** differences between progressive waves and stationary waves.

1. ....

....

....

2. ....

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....

[2]

(b) Fig. 7.1 shows a progressive wave travelling from left to right along a stretched string at a speed of 0.40 m s^{-1}. The diagram shows the string at time t = 0 s.

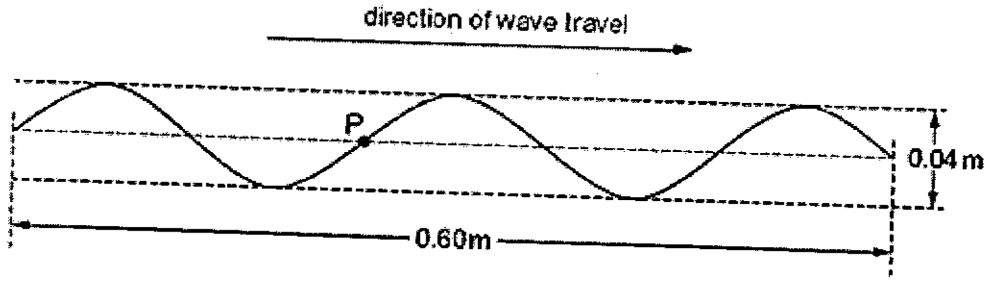

Fig. 7.1

Sketch, on the grid in Fig 7.2, the variation with time of the displacement of point **P** on the string between t = 0 s and t = 0.9 s. Show your workings in the space below the grid.

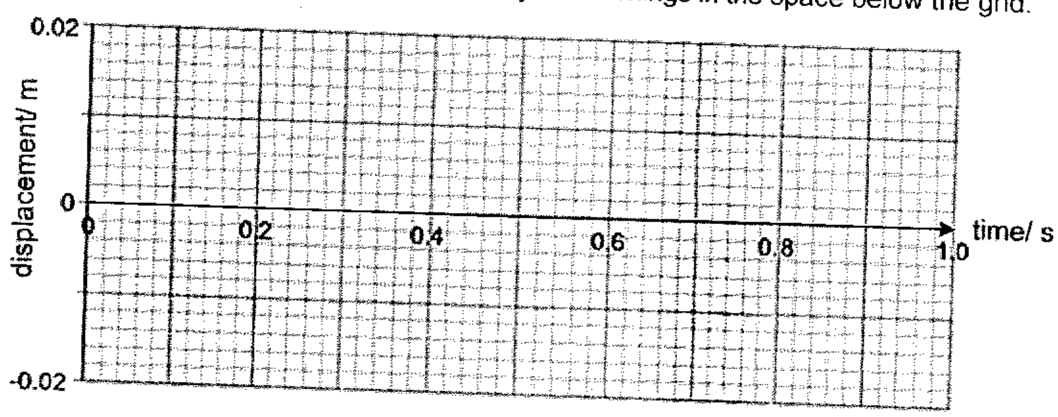

Fig. 7.2

[3]

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(c) A stationary wave is formed on a stretched string between two fixed points A and B.

The variation with distance x along the string of the displacement y of particles of the string for the wave at time $t = 0$ s is shown on Fig. 7.3.

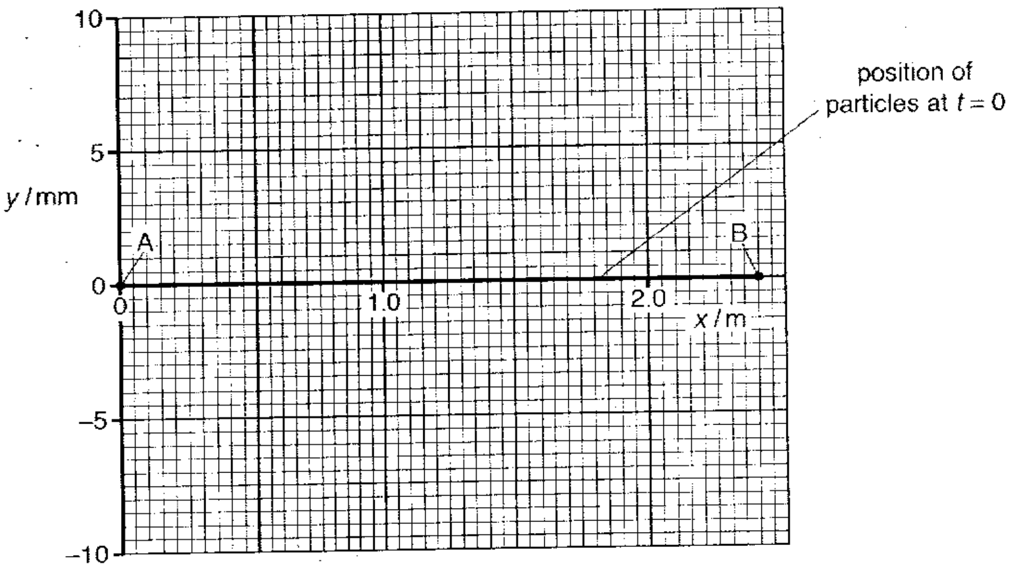

Fig. 7.3

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The wave has a period of 20 ms and a wavelength of 1.2 m. The maximum amplitude of the particles of the string is 5.0 mm.

(i) On Fig. 7.3, draw a line to represent the position of the string at $t = 5.0$ ms. [2]

(ii) State the phase difference between the particles of the string at $x = 0.40$ m and at $x = 0.80$ m.

phase difference = ... rad [1]

(iii) State and explain the change in the kinetic energy of a particle at an antinode between $t = 0$ and $t = 5.0$ ms. A numerical value is not required.

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.... [2]

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(d) Fig. 7.4 shows two emitters A and B, placed 2.00 m apart, emitting radio waves of same frequency and same phase which interfere with one another to produce lines of constructive and destructive interference.

The Automated Guided Vehicle (AGV) is a device that detects radio waves and searches for lines of constructive interference. When placed equidistant from both emitters, the AGV will automatically adjust its position so that it is always aligned along the centre-line.

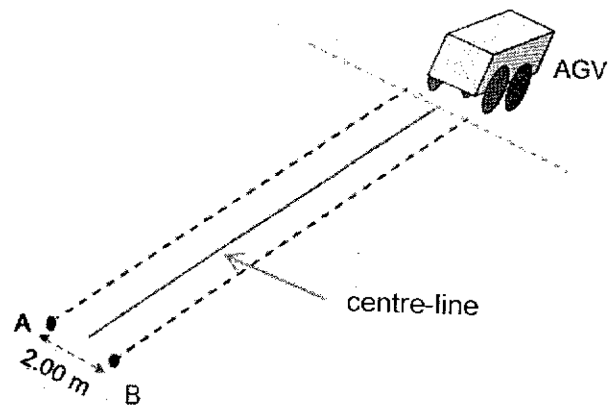

Fig 7.4 (not to scale)

(i) Explain why the centre-line is a line of constructive interference.

....

....

.... [1]

(ii) During one such operation, the AGV strays off from the centre-line as shown in Fig. 7.5.

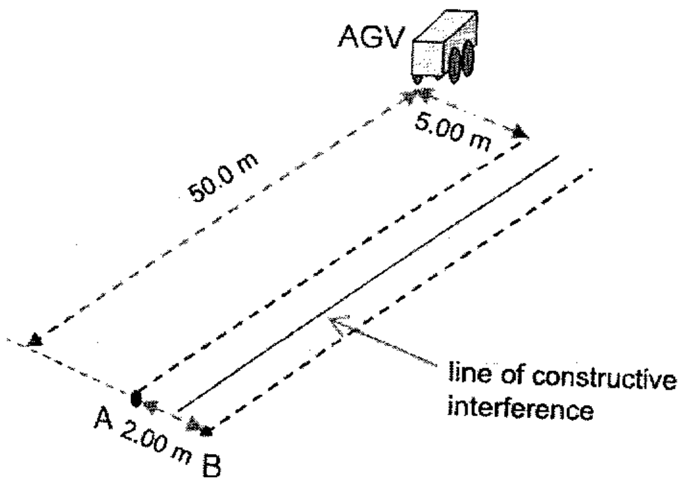

Fig 7.5 (not to scale)

Fig. 7.6 shows the separate radio signals X and Y detected by the receiver on the AGV.

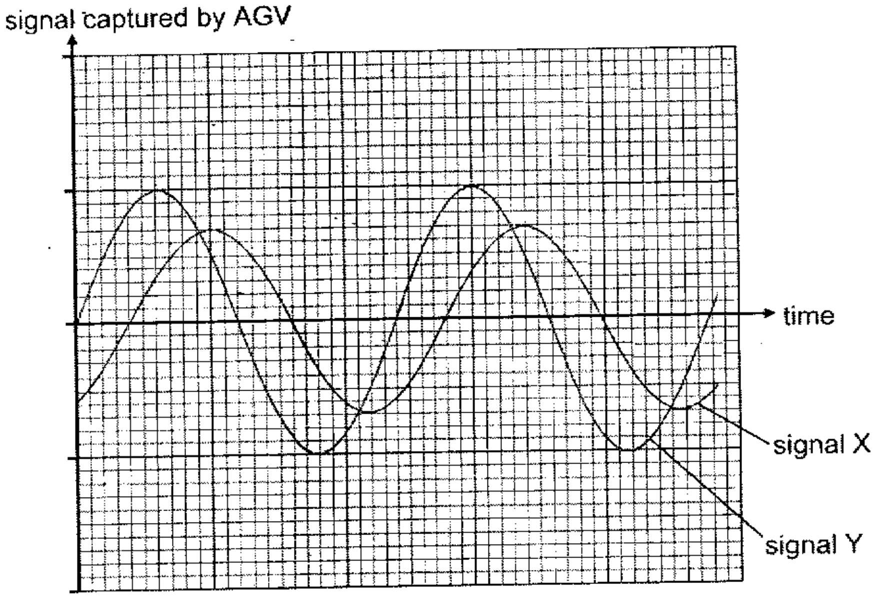

Fig 7.6

1. State and explain whether the source of signal X is from emitter A or B.

....

....

.... [2]

2. Calculate the phase difference between signals X and Y.

phase difference = ... rad [1]

3. Assuming the path difference is less than one wavelength, determine the frequency of the radio waves.

frequency = ... Hz [4]

4. Sketch on Fig. 7.6 the resultant signal detected by the AGV as a result of interference. [2]

[Total: 20]

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8 (a) The world's largest nuclear fusion reactor experiment ITER is currently under construction in southern France. An electrically charged hydrogen gas will be heated to extremely high temperature, when fusion begins to take place. The binding energy per nucleon changes after the reaction. The fusion reaction involves isotopes of hydrogen, deuterium (^2_1H) and tritium (^3_1H) and the release of energy.

$$^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + \text{X}$$

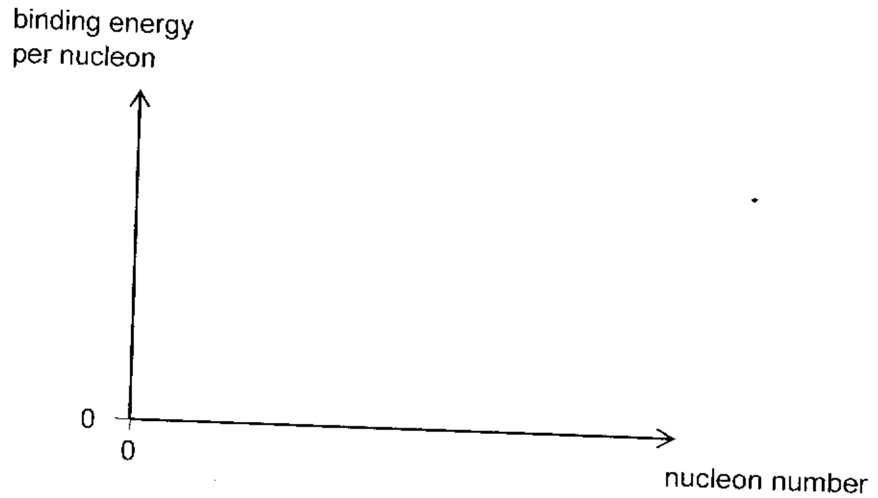
(i) Explain what is meant by *binding energy* of a nucleus.

....

....

.... [2]

(ii) On Fig. 8.1, sketch a graph to show the variation with nucleon number of the binding energy per nucleon.



[1]

Fig. 8.1

(iii) Explain why fusion of nuclei having high nucleon numbers is not associated with a release of energy.

....

....

.... [2]

(iv) State what is particle X.

.... [1]

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(v) Suggest an advantage of nuclear fusion as a source of energy production.

-- [1]

(vi) Calculate the amount of energy produced by 15 kg of appropriate mixture of the isotopes of hydrogen. The following data are provided:

	Mass
${}^{2}_{1}H$	2.0141 u
${}^{3}_{1}H$	3.0160 u
${}^{4}_{2}He$	4.0026 u
${}^{1}_{1}H$	1.0073 u
${}^{1}_{0}n$	1.0087 u
${}^{-1}_{0}e$	0.0005 u

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energy = ------------------------------ J [4]

(b) (i) "Uranium-238 is an *alpha-emitter* of *half life* 4.5×10^{9} years."

Explain what is meant by the terms in italics in the above statement.

-- [2]

(ii) An alpha-emitting Uranium-238 radioactive source is placed inside an ionization chamber. It produces an ionization current of 2.4×10^{-6} A. If each alpha particle produces on average 2.0×10^{5} ion pairs, determine the activity of the source. (Assume that the ions are singly-charged and that all ions are collected.)

activity = ... Bq [3]

(iii) The abundance of Uranium-238 in naturally-occurring uranium minerals on Earth is 99.28%. This means that there are 99.28 atoms of Uranium-238 for every 100 atoms of all uranium isotopes. The abundance of Uranium-235 is 0.72%. The decay constant of Uranium-238 is 15.5×10^{-11} year^{-1} and the decay constant of Uranium-235 is 98.5×10^{-11} year^{-1}.

In the early twentieth century, Rutherford assumed that at the time of the formation of the Earth's crust, an equal amount of each isotope was present. Making this assumption, determine the age of the Earth.

age = ... years [4]

[Total: 20]

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Solutions to 2021 Physics H2P3 Prelim

1 (a)(i) For a fixed mass of ideal gas, pV is proportional to T.

Using $p_A V_A = nRT$ — C1

$$T = \frac{400\text{x}0.30}{0.050\text{x}8.31} = 289\ \text{K}$$ A1

(a)(ii) Kinetic energy = 3/2 nRT = (3/2)(0.050)(8.31)(289)

= 180 J — A1

(a)(iii) Work done by the gas = area under the graph

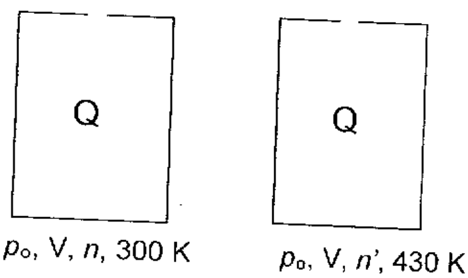
= (8.5 big squares)($100\text{X}10^{3}$)($0.20\text{X}10^{-3}$) — M1

= 170 J (allow 160-180J) — A1

(a)(iv) Since temperature of the ideal gas is constant, increase in internal energy ΔU = 0. As the gas expands from A to B, work done on the gas W is negative.

Using first law of thermodynamics, ΔU = Q + W, the heat supplied to the gas Q is positive. Hence, heat flows into the gas. — M1 A1

(b)



Initial temperature = 27 + 273 = 300 K
Final temperature = 157 + 273 = 430 K — C1

$$p_o V = nR \times 300$$
$$p_o V = n'R \times 430$$ M1

$$\frac{n'}{n} = \frac{300}{430} = 0.698$$ A1

2(a) The box is initially at rest. The tension in the spring initially balances the total weight of the box and the plasticine. When the plasticine falls, the tension is greater than the weight of the box. There is a restoring force/ resultant force upwards, towards an equilibrium position. B1 B1

When the extension of the spring is reduced, the weight is greater than the tension in the spring. There is a restoring force/ resultant force downwards, towards an equilibrium position. B1

Hence, the box oscillates about an equilibrium position.

2(b)(i) F = (0.02)(9.81)

$$a = \frac{F}{m} = \frac{(0.02)(9.81)}{0.100}$$ M1

$$= 1.96 \text{ m s}^{-2}$$ A1

2(b)(ii) $|a| = \omega^2 x_o$

$x_o = 2.50$ cm

$$\omega^2 = \frac{a}{x_o} = \frac{1.962}{2.5 \times 10^{-2}}$$ M1

$$\omega = \sqrt{\frac{1.962}{2.5 \times 10^{-2}}} = 8.8589 \text{ rad s}^{-1}$$

$$T = \frac{2\pi}{\omega}$$ M1

$$= \frac{2\pi}{8.8589}$$

$$= 0.709 \text{ s}$$ A1

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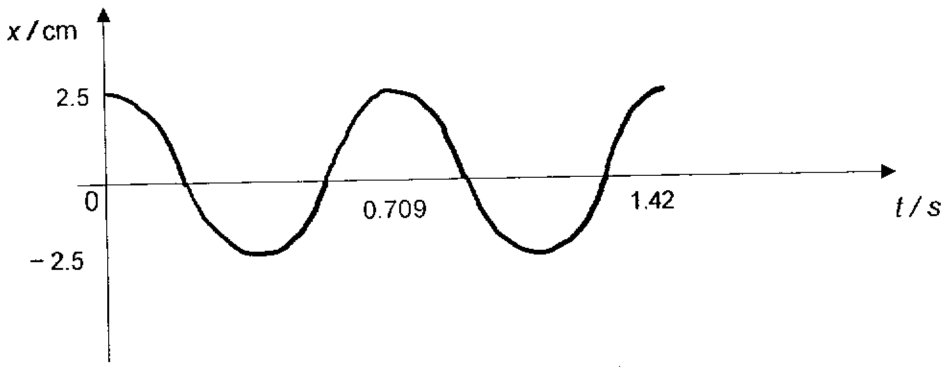
2(c)



B1 cosine variation

B1 label correct period and amplitude values

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[Turn over

3 (a) Electric potential at a point is defined as the work done per unit positive charge by an external agent in bringing a charged body from infinity to that point. B1

(b) (i) The charges in the 2 spheres will re-distribute themselves between the spheres. B1

Both spheres eventually reach the same potential. B1

(ii) $q_1 + q_2 = q_1' + q_2'$ M1

$V_1\, 4\pi\varepsilon_o\, r_1 + V_2\ 4\pi\varepsilon_o\, r_2 = V\, 4\pi\varepsilon_o\, (r_1 + r_2)$

$V = (V_1\, r_1 + V_2\, r_2) / (r_1 + r_2)$ A1

Assumption:

The spheres are treated as point charges.

Or no leakage of charge to the surrounding B1

(c) (i) $q^2 / 4\pi\varepsilon_o\, (L\sin\theta)^2 + [q^2 / 4\pi\varepsilon_o\, (2L\sin\theta)^2]$ M1

$= 5q^2 / (16\pi\varepsilon_o L^2 \sin^2\theta)$

$= 1.12 \times 10^{10}\, q^2 / (L \sin\theta)^2$ A1

(ii) $T \sin\theta = 5q^2 / 16\pi\varepsilon_o L^2 \sin^2\theta$ M1

$T = 5q^2 / 16\pi\varepsilon_o L^2 \sin^3\theta$

$= 1.12 \times 10^{10}\, q^2 / (L^2 \sin^3\theta)$ A1

(iii) Spheres A and C are deflected <u>equally</u> to higher positions as the angle θ is increased by the same amount for A and C as the force is increased. B1

Sphere B remains stationary. B1

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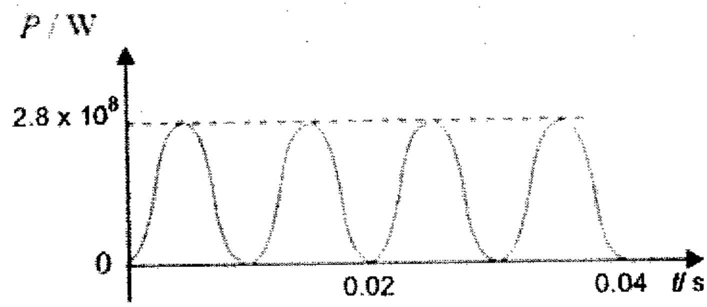
4 (a) Use P = VI

1. 2.8×10^8 (W) A1
2. 0.0 W A1

(b)



A $\sin^2$ graph with correct curvature drawn - 1 mark B1

Peak power at t = 0.005, 0.015, 0.025 s etc and Zero power at t = 0.010, 0.020, 0.030 s etc B1

(c) DC power = 800x350k = 2.8×10^8 W M1

AC average power = ½ peak power = 1.4×10^8 W, M1

so less average power than DC

(d) M1

V_s = 350k/20 = 17.5 kV

Ideal transformer, so power is unchanged,

$2.8 \times 10^8 = 17.5\ \text{kV} \times I_s$

secondary peak current = I_s = 16 kA

The secondary peak current by a factor of 20, or increased to 16 kA. B1

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5 (a) The **magnitude** of the electromotive force (e.m.f.) induced **in a circuit/conductor** is directly proportional to the rate of change of magnetic flux linkage experienced by it. B1

(b)(i) -Since cylinder is rotating with **constant angular velocity**, the rate of change of magnetic flux linkage is constant. **By Faraday's Law**, the magnitude of the maximum induced emf/**peak voltage** for either direction is the **same.** B1

-There is an **increase** in magnetic flux linkage as **magnet approaches** the coil. And there is a **decrease** in magnetic flux linkage as magnet **leaves** the coil. **By Lenz's law**, emf is induced in **opposite** directions. B1

(b)(ii) Time between 2 magnets passing coil is approximately 70 ms. B1

Time for 1 revolution = 4 x 70 = 280 ms B1

number of revolutions per minute = 60 / 0.280 = 214. A1

(b)(iii) Max rate of change of flux linkage = peak voltage = 1.6×5.0 mV = 8.0×10^{-3} Wb s^{-1} A1

(c) Since rate of revolution is doubled, the rate of change of magnetic flux linkage is doubled.

New waveform displayed on CRO:

- Narrower/sharper and higher peaks, as **peak voltage is doubled** B1
- Positive and negative peaks are **closer together** B1

B1

[Turn over

- **4 more sets of waveforms**, closer together as period of the waveform is halved

6 (a) (i) The spread of the electron beam to form bright rings due to diffraction, B1

The presence of dark regions between bright rings indicate that destructive interference is taking place B1

(ii) 1. $KE = eV = p^2/2m$ M1

$$\lambda = \frac{h}{p}$$

$$= \frac{h}{\sqrt{2meV}}$$ M1

A0

2. $$\lambda = \frac{h}{\sqrt{2meV}}$$

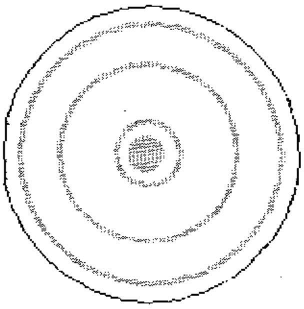
$$= \frac{6.63\times10^{-34}}{\sqrt{2(9.11\times10^{-31})(1.60\times10^{-19})(250)}}$$ M1

$= 7.77 \times 10^{-12}$ m A1

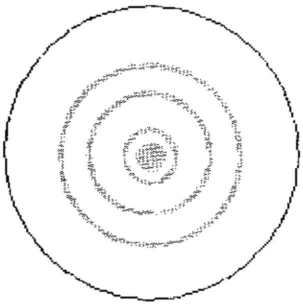
(iii) As velocity increases, the de Broglie wavelength decreases since $\lambda \prec \frac{1}{\sqrt{V}}$. B1

Since $d\sin\theta = n\lambda$, the angles at which the maxima are produced decrease. The rings become smaller/closer together. B1

Low accelerating voltage



High accelerating voltage



(b) $\Delta p \Delta x \gtrsim h$

$\Delta p\ (1.2) \gtrsim 6.63 \times 10^{-34}$

$\Delta p \gtrsim 5.53 \times 10^{-34}$ kg m s^{-1} M1

p = 80 x 2.0 = 160 kg m s^{-1}

Hence, the uncertainty in his momentum is negligible as compared to his linear momentum. B1

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$$\tan\theta = \frac{\Delta p}{p} = \frac{5.53\times10^{-34}}{160} = 3.46\times10^{-36} \approx 0$$

Hence, the angle of deflection is negligible.

7 (a) Any 2 below — B2

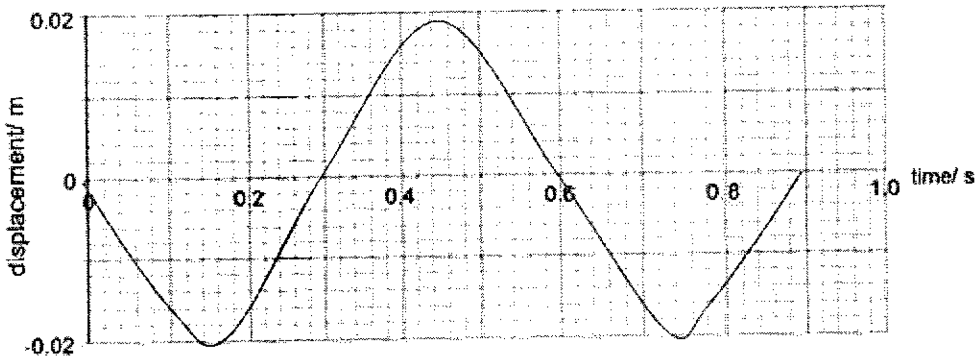
progressive: all particles have same amplitude
stationary: amplitude varies from maximum at antinode to minimum/zero amplitude at node

progressive: adjacent particles are not in phase
stationary: between adjacent nodes, wave particles are in phase
opposite side of a node, wave particles are anti-phase/π rad out of phase

progressive: 1 wavelength is distance between two adjacent particles in phase
stationary: 1wavelength is 2x distance between adjacent nodes or antinodes

(b)

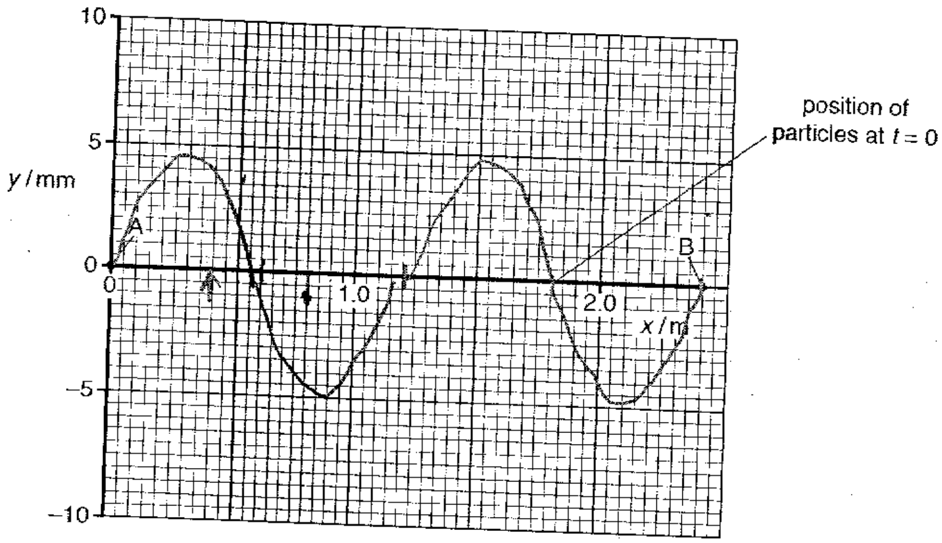
Sinusoidal of correct period and amplitude 0.020 m drawn from t = 0 to t = 0.9 s



Workings: λ = 0.60/2.5 = 0.24 m
T = 0.60 [s] correct period at 0.60 s — B1
Correct amplitude = 0.02 m — B1
Graph at correct phase ($-\sin \omega t$) — B1

(c)(i) 5 ms = ¼ of period, so stationary wave at maximum displacement
Note: **draw a line** – does not literally mean draw a straight line, it may be a curve/waveform

[Turn over



Correct amplitude (5.0 mm) and correct wavelength 1.2 m — B1
Correct zero displacement/nodes at 0.0, 0.60 m, 1.2 m, 1.8 m, 2.4 m) — B1

(c)(ii) π rad
(Particles on opposite side of a node are antiphase) — A1

(c)(iii) at t = 0 s particle has maximum kinetic energy as particle is moving — B1
at t = 5.0 ms no kinetic energy as particle is stationary
so decrease in kinetic energy (between t = 0 and t = 5.0 ms) — B1

Comment: Do not mix up the two terms: displacement and amplitude, e.g. an antinode particle has maximum amplitude but its displacement can vary from x = 0 to $x = x_0$. It is in s.h.m.

(d)(i) Path difference between the two sources is zero or meet in phase at any point on the centre line, so waves undergo constructive difference. — B1

(ii)1 Signal is from B. — A1
The intensity of signal is lower as the signal travels further spreads over a larger surface area as it is further from the AGV. — M1

2 phase difference = $4/24 \times 2\pi = \pi/3$ rad or 1.05 rad — B1

3
Dist. from A to AGV = $\sqrt{7.00^2 + 50.00^2}$ = 50.49 m

Dist. from B to AGV = $\sqrt{5.00^2 + 50.00^2}$ = 50.25 m — C1

$\frac{\Delta x}{\lambda} = \frac{\Delta \phi}{2\pi} = \frac{\pi}{3(2\pi)}$ since $\Delta\phi = \pi/3.0$ from graph

$$\Delta x = \frac{\lambda}{6}$$

Path Difference = $\frac{\lambda}{6}$

= 50.49 − 50.25 = 0.24 m — C1

λ = 1.4 m — C1

f = c / λ = 3.0 x 10^8/ 1.4

= 2.1 x 10^8 Hz — A1

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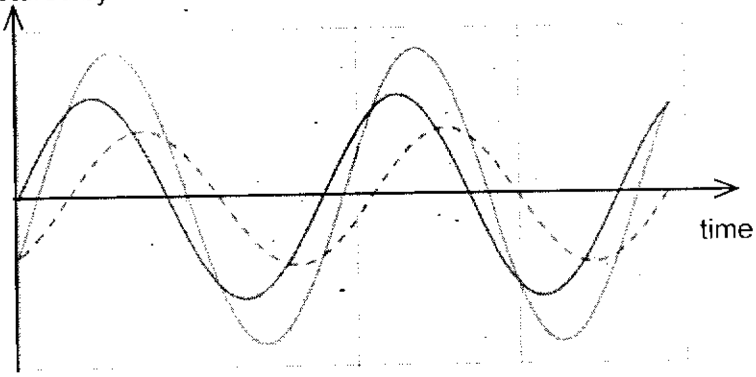
4 signal captured by AGV



B 1- For shape

B1- For accuracy of graph as given by crosses

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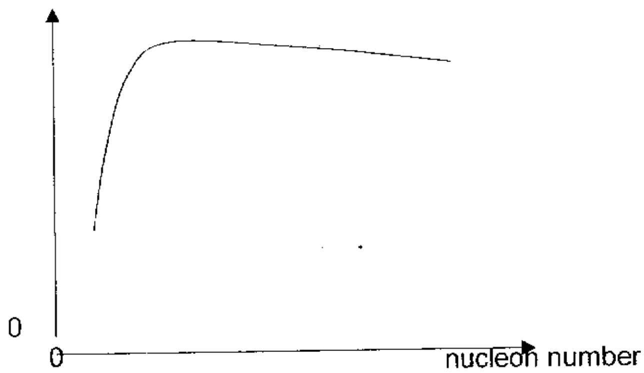
8(a)(i) Binding energy of a nucleus is the energy released when the nucleus is formed from its separate protons and neutrons. B1 B1

(a)(ii) B1

Steeper for lower nucleon number



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(a)(iii) Nuclear fusion of high nucleon number nucleus form less stable nucleus with lower binding energy per nucleon. B1

Less energy per nucleon to separate the nucleus. Therefore, energy is not released in fusion of nuclei with higher nucleon number. B1

(a)(iv) Neutron B1

(a)(v) The products/ daughter nuclei are safe, non-radioactivity nuclei.
The reactants are readily available (from water).
The energy produced per event is greater than nuclear fission.
Any 1 B1

(a)(vi) $Mass_{(reactants)} - Mass_{(products)}$
= (2.0141 u + 3.0160 u) – (4.0026 u +1.0087 u)

[Turn over

$= 3.1208 \times 10^{-29}$ kg — M1

$E = mc^2$
$= (3.1208 \times 10^{-29})(3\times10^{8})^2$
$= 2.8087 \times 10^{-12}$ J — M1

No. of reactions $= \dfrac{15}{5u}$

Total energy released $= \left(\dfrac{15}{5(1.66\times10^{-27})}\right)(2.8086\times10^{-12})$ — M1
$= 5.1 \times 10^{15}$ J — A1

(bi) An alpha emitter means a <u>helium ion is released</u> from the parent nucleus, with a reduction of 2 protons and 2 neutrons in the parent nucleus. — B1

Half life is the <u>average time taken</u> for the number of nuclei to reduce to <u>half the original number of nuclei</u>. — B1

Accept: Activity

(b)(ii) Activity, $|A| = \dfrac{dN}{dt}$

$I = \dfrac{dQ}{dt} = \dfrac{dN(2)(2\times10^5)(1.6\times10^{-19})}{dt}$ — M1

$\dfrac{dN}{dt} = \dfrac{2.4\times10^{-6}}{2(2\times10^5)(1.6\times10^{-19})}$ — M1
$= 3.8\times10^7$ Bq — A1

(b)(iii) Let the number of Uranium-238 nuclei be N_1
Let the number of Uranium-235 nuclei be N_2

$N_1 = N_o e^{-\lambda_1 t}$
$\dfrac{99.82}{100} N = N_o e^{-(15.5\times10^{-11})t}$ — M1

$N_2 = N_o e^{-\lambda_2 t}$
$\dfrac{0.72}{100} N = N_o e^{-(98.5\times10^{-11})t}$ — M1

Since N_o is the same,

$\dfrac{99.82}{0.72} = e^{(-15.5\times10^{-11}t-(-98.5\times10^{-11}t))}$ — M1

$\dfrac{99.82}{0.72} = e^{83\times10^{-11}t}$

$t = 5.9 \times 10^9$ years — A1

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