EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2022
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME								
CIVICS GROUP	2	1	-			REGISTRATION NUMBER		

PHYSICS

9749/03

Paper 3 Longer Structured Questions

August/September 2022

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
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.

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

For Examiner's Use		
1		10
2		5
3		13
4		8
5		4
6		10
7		10
Section B		
8	9	20
s.f.		
Total		80

This document consists of **27** printed pages and 1 blank page.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature,	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
electric current,	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** **(i)** State what is meant by *gravitational field strength*.

....

....

.... [1]

(ii) State Newton's law of gravitation and hence, show that the gravitational field strength g at a distance R from a point mass M is given by

$$g = \frac{GM}{R^2}$$

[3]

(b) A star is spherical in shape, has mass 6.2×10^{30} kg and radius 2.7×10^{4} m.

(i) Calculate the average density of the star.

average density = ………………………………… kg m^{-3} [2]

(ii) It is found that the density inside a star is non-uniform.

State and explain how the density is likely to vary with distance from the centre of the star.

....

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.... [2]

(iii) Find the minimum speed needed for a mass of 250 kg at the surface of the star to escape the effects of the gravitational field due to the star.

Show your working clearly.

speed = ………………………………… m s^{-1} [2]

[Total: 10]

2 **(a)** State what is meant by *simple harmonic motion*.

....

....

.... [1]

(b) In a particular video game, players control the movement of characters through obstacle courses. One particular obstacle features a rectangular wall which moves vertically up and down with simple harmonic motion, as shown in Fig. 2.1. The wall is tall such that the character cannot progress with the game by jumping over the wall. The bottom face of the wall touches the ground every 4.0 s, and rises to a maximum height of 1.4 m.

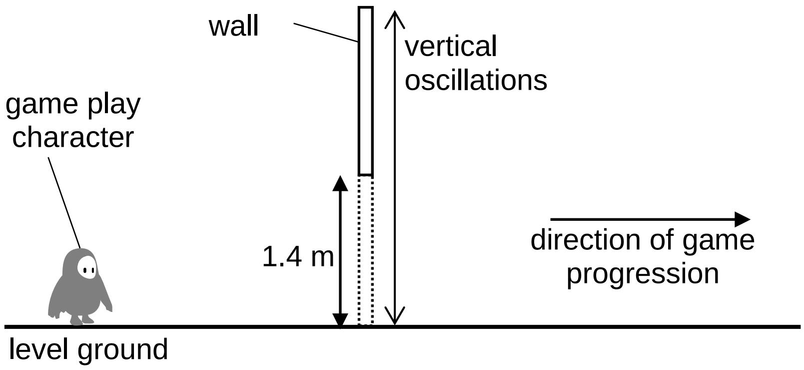

Fig. 2.1 (not to scale)

(i) Find the speed of the wall when the bottom face of the wall is 0.50 m above the ground.

speed = ... m s^{-1} [2]

(ii) The bottom face of the wall needs to be at least 0.55 m above the ground for the character to pass under successfully.

Find the duration of time that the character can pass under, in each cycle of simple harmonic motion.

time = ... s [2]

[Total: 5]

3 **(a)** Fig. 3.1 shows a set up that measures the specific latent heat of vaporization of pure water.

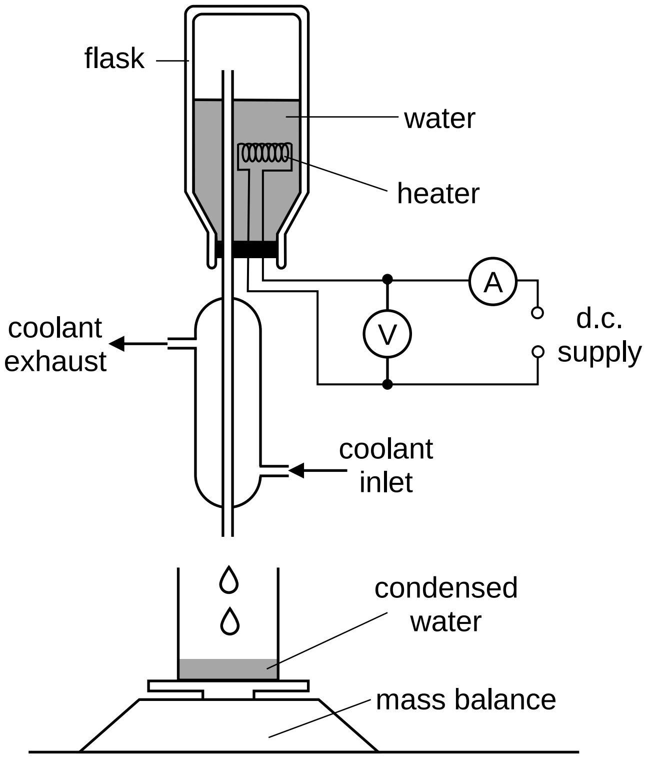

Fig. 3.1

The measurements in Fig 3.2 were made across 2 separate experiments each lasting for 1.5 minutes.

voltmeter reading / V	ammeter reading / A	mass of condensed water / g
78	5.0	16
60	4.0	10

Fig. 3.2

(i) Show that the specific latent heat of vaporization of water is 2.25×10^{6} J kg^{-1}.

[2]

(ii) The assumption when using the values provided in Fig 3.2 to determine the specific latent heat of vaporization of water is that the rate of heat loss from the system is constant.

Explain why the assumption is valid.

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....

.... [1]

(b) At a temperature of 100 °C and a pressure of 1.00×10^5 Pa, steam of mass 1.00 kg occupies a volume of 1.67 m^3. In comparison, liquid water of the same mass, at the same temperature and subject to the same external pressure, occupies a volume of 1.04×10^{-3} m^3.

1.00 kg of water undergoes phase change from liquid to gas at 100 °C and 1.00×10^5 Pa. Using **(a)(i)**, determine the

(i) heat supplied to the water,

heat supplied = ………………………………… J [2]

(ii) work done by the water,

work done = ………………………………… J [2]

(iii) increase in internal energy of the water.

increase in internal energy = ………………………………… J [1]

(iv) The total potential energy and total kinetic energy of all the molecules in 1.0 kg of liquid water at a temperature of 100 °C is 3.41×10^5 J and 2.58×10^5 J respectively.

Find the potential energy of all the molecules in 1.0 kg of gaseous water at the same temperature and at the same external pressure.

potential energy = …………………………………. J [2]

(v) Explain why energy has to be continuously supplied during the vaporization process.

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.... [3]

[Total: 13]

4 Fig. 4.1 shows the cross-sectional view of a long solenoid. A small copper disc spins via a copper axle which lies along the axis of the solenoid. The ends of the solenoid are connected in series with resistor *R* to a d.c. supply.

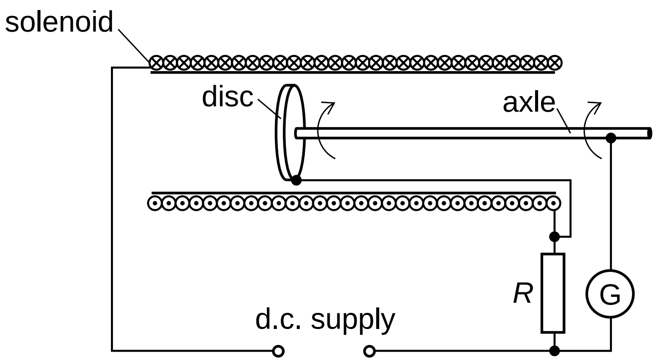

Fig. 4.1

The edge of the copper disc maintains electrical contact with resistor *R* by means of carbon brushes. A galvanometer connects the copper axle to the other end of resistor *R*.

(a) Using Faraday's law of electromagnetic induction,

(i) explain why an e.m.f. is generated between the axle and the rim of the disc when the copper disc rotates about the axle,

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.... [3]

(ii) show that the e.m.f. described in **(a)(i)** is given by

$$E = BAf$$

where B is the magnetic flux density inside the long solenoid,
A is the circular area of the copper disc, and
f is the frequency of revolution of the copper disc.

[2]

(b) **(i)** Using **(a)(ii)**, show with clear explanation that the resistance R when the galvanometer registers null deflection is given by

$$R = \mu_0 n A f$$

where n is the number of turns per unit length of the solenoid.

[1]

(ii) Hence, suggest the advantage in using this method for finding resistance.

....

.... [1]

(c) The copper disc has a radius of 0.20 m and is rotated at 5.0 revolutions each second. When the galvanometer meter registers null deflection, the current flowing through the resistor R of $10\ \Omega$ is found accurately to be 1.0 mA.

Determine B.

B = ... T [1]

[Total: 8]

5 **(a)** In Fig. 5.1, sketch the variation with frequency f of the stopping potential V_s when electromagnetic radiation is incident on a metal surface of work function energy 2.4 eV.

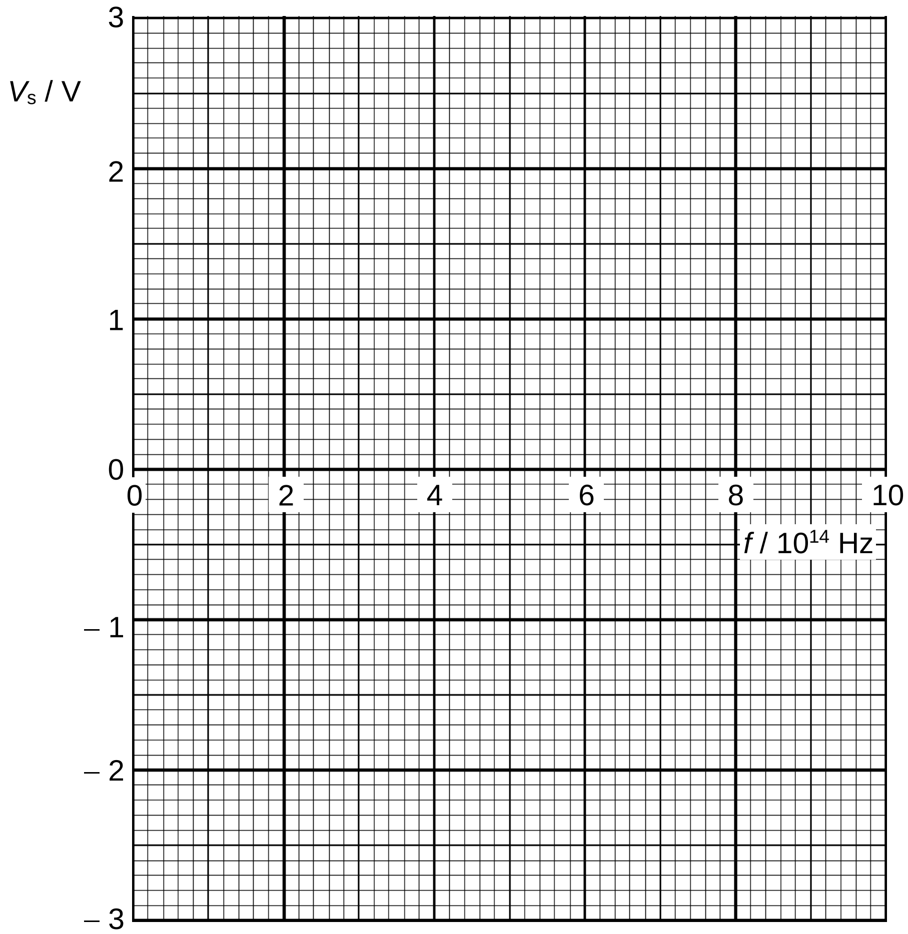

Fig. 5.1

[2]

(b) Fig. 5.2 shows an alternating supply, of frequency 25 Hz and rated at an output p.d. of 4.6 V, connected in series with an ideal diode and a resistor.

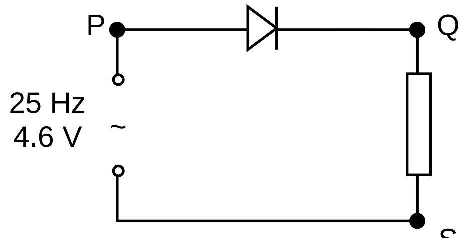

Fig. 5.2

(i) Calculate the maximum potential difference (p.d.) that is applied across the diode.

maximum p.d. = ………………………………….. V [1]

(ii) The waveform seen on the screen of the c.r.o. when the Y-plates are connected across points QS is shown on Fig. 5.3.

On the same figure Fig. 5.3, sketch the waveform that is seen on the screen of the c.r.o. when the Y-plates are connected across PQ instead.

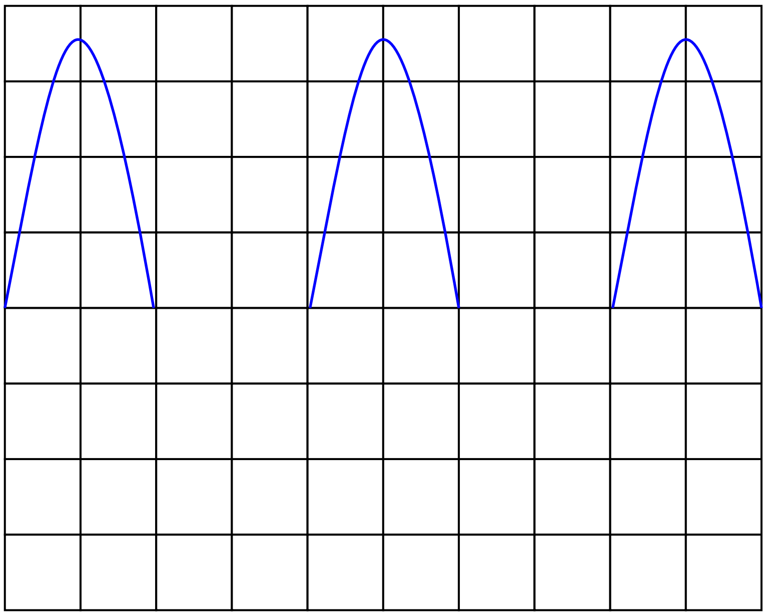

Fig. 5.3

[1]

[Total: 4]

6 Fig. 6.1 shows two parallel metal plates each of length 10 cm, at a distance of 4.0 cm apart, in a vacuum environment. A proton with speed 6.5×10^{5} m s^{-1} is emitted from a proton source.

The proton travels along a straight path exactly down the middle of the region between the parallel plates when there is no electric potential difference between the metal plates. It then strikes a screen where it shows up as a scintillation.

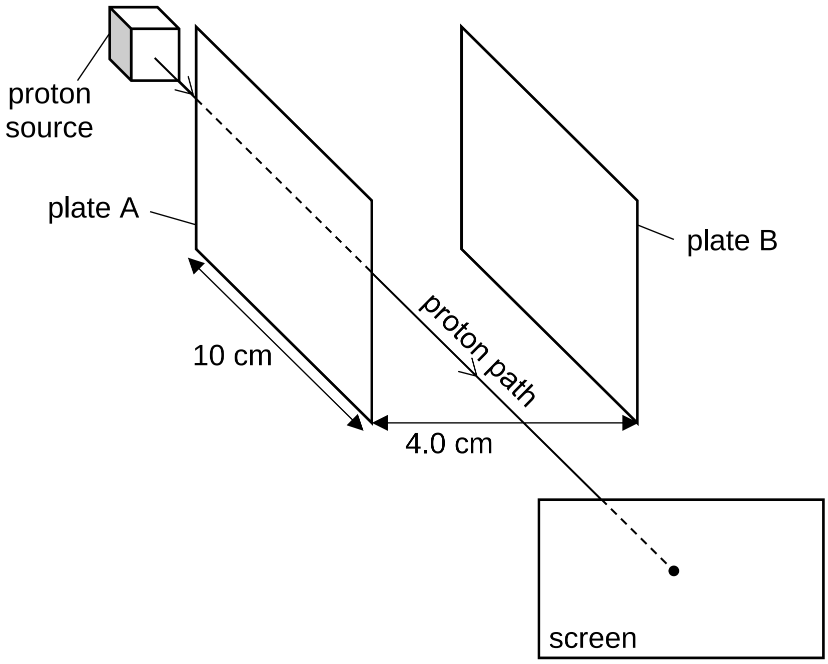

Fig. 6.1 (not to scale)

(a) When a potential of +250 V and – 250 V is applied to plates A and B respectively, a region of uniform electric field is set up between the metal plates.

(i) Determine the speed at which the proton emerges from the region of uniform electric field.

speed = ... m s^{-1} [4]

(ii) Calculate the electric potential at the point where the proton emerges from the region of uniform electric field.

potential = ………………………………… V [2]

(b) In Fig. 6.1, indicate with a cross (×) where the deflected proton is likely to hit the screen. [1]

(c) Suggest how the set up in Fig. 6.1 can be modified to be used as a velocity selector.

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.... [3]

[Total: 10]

7 **(a)** Explain what is meant by a *photon*.

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.... [1]

(b) **(i)** Determine the maximum and minimum energy of photons spanning the visible spectrum.

maximum photon energy = ………………………………….. eV

minimum photon energy = ………………………………….. eV [1]

(ii) White light is passed through hydrogen gas. The emerging beam is passed through a diffraction grating.

Explain why there are dark lines observed in the resulting absorption spectrum despite all of the wavelengths that are absorbed are subsequently re-emitted.

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.... [1]

(iii) Fig. 7.1 shows some of the energy levels present in the hydrogen atom.

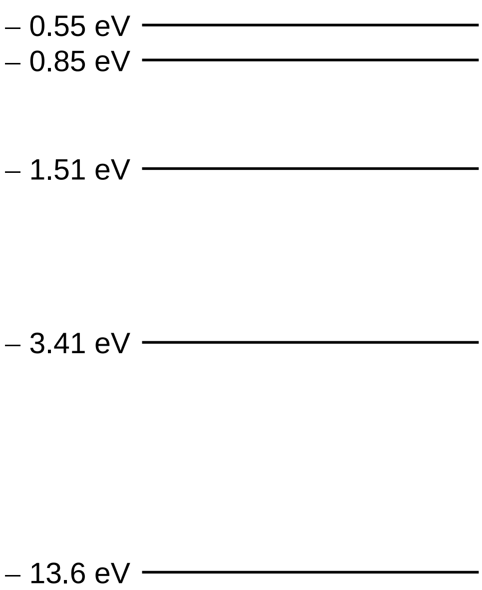

Fig. 7.1 (not to scale)

In Fig. 7.1, draw arrows to represent the electron promotion between energy levels that give rise to the dark lines observed in an absorption spectrum. [2]

(c) The hydrogen gas is now cooled to ground state.

(i) State and explain the changes, if any, to the resulting absorption spectrum.

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.... [2]

(ii) The white light source is switched off. An electron beam is accelerated from rest through potential difference *V* and made to pass through the cooled hydrogen gas. There are now three bright lines visible in the resulting emission spectrum.

1. Determine the minimum *V* for the above emission spectrum to occur.

minimum *V* = …………………………………. V [2]

2. Find the shortest wavelength of visible light emitted as part of the emission spectrum.

shortest wavelength = …………………………………. m [1]

[Total: 10]

Section B

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

8 **(a)** A helicopter hovers at a height of 200 m above the sea. It then releases an emitter which emits radio waves in all directions, from rest. As the emitter drops towards the sea, a receiver on the helicopter detects a series of distinct minima and maxima. The variation of the intensity detected by the receiver with distance *d* between emitter and receiver is shown in Fig. 8.1.

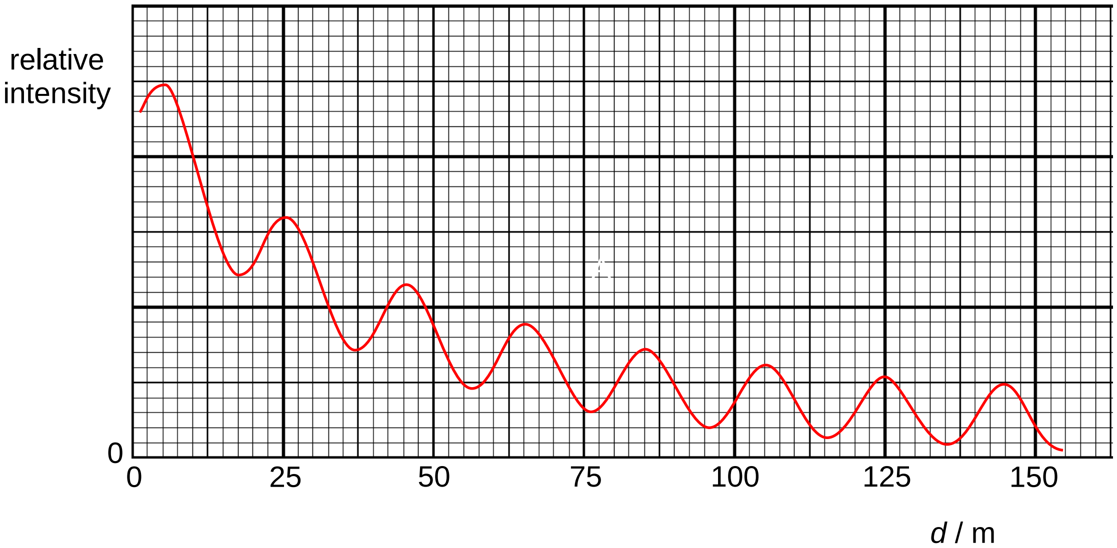

Fig. 8.1

(i) State the *principle of superposition*.

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.... [1]

(ii) Explain the following features of the graph in Fig. 8.1:

1. the formation of alternating minima and maxima,

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.... [3]

2. the intensity of the minima decreases with increasing *d*,

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.... [2]

(iii) Determine the wavelength of the radio wave.

wavelength = ... m [3]

(b) (i) Explain what is meant by *nuclear fission*.

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.... [1]

(ii) State what is *radioactive decay*.

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.... [1]

(iii) Describe the process of *nuclear fusion*.

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.... [1]

(c) When a uranium-235 nucleus $^{235}_{92}U$ is exposed to neutrons, it may absorb a neutron and then undergo fission. The percentage mass yield of the fission products varies with nucleon number as shown in Fig. 8.2.

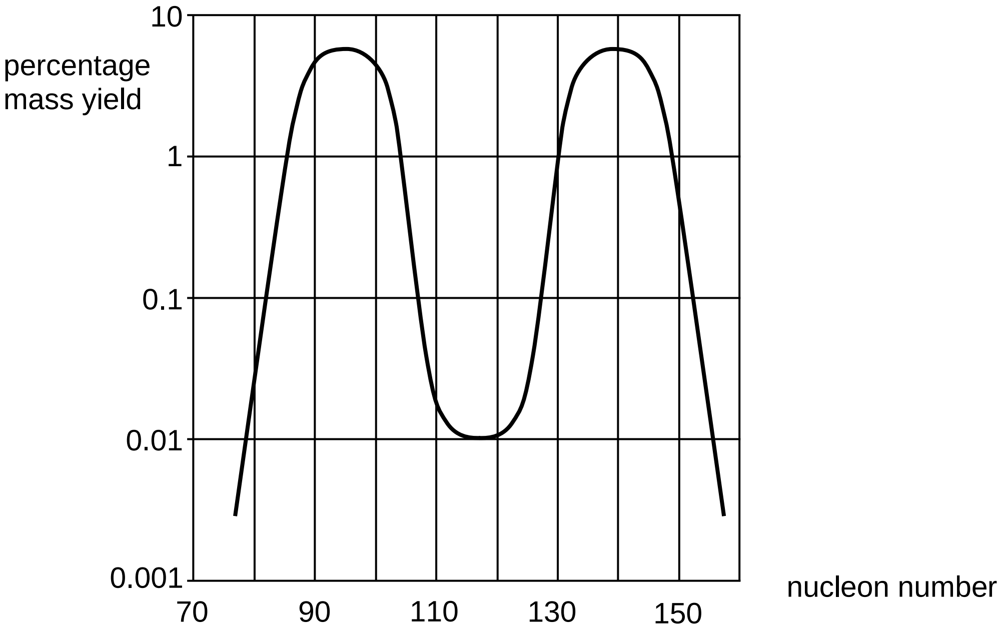

Fig. 8.2

(i) Suggest why the percentage mass yield is shown on a logarithm scale.

....

.... [1]

(ii) The nuclear process referenced in Fig. 8.2 results in two neutrons amongst the products.

Explain why the graph is symmetrical about the nucleon number 117.

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.... [3]

(d) In a particular fission reaction, one of the products is iodine-140 $^{140}_{53}\mathrm{I}$. A student suggests that the iodine-140 nucleus could decay by emitting either a neutron or a β^- particle.

Fig. 8.3 shows some relevant data:

		mass / *u*
electron	$^{0}_{-1}\mathrm{e}$	0.0006
neutron	$^{1}_{0}\mathrm{n}$	1.0087
iodine-139	$^{139}_{53}\mathrm{I}$	138.8969
xenon-140	$^{140}_{54}\mathrm{Xe}$	139.8919
iodine-140	$^{140}_{53}\mathrm{I}$	139.9019

Fig. 8.3

For the iodine-140 nucleus, write an equation representing the radioactive decay involving

(i) neutron emission

[1]

(ii) beta emission

[1]

(iii) Use Fig. 8.3 to show if the radioactive decay involving neutron emission is feasible.

....

.... [1]

(iv) Use Fig. 8.3 to show if the radioactive decay involving beta emission is feasible.

....

.... [1]

[Total: 20]

9 **(a)** Fig. 9.1 shows a metal wire held taut between a knife edge X and a smooth pulley P. The wire passes between opposing poles of permanent bar magnets.

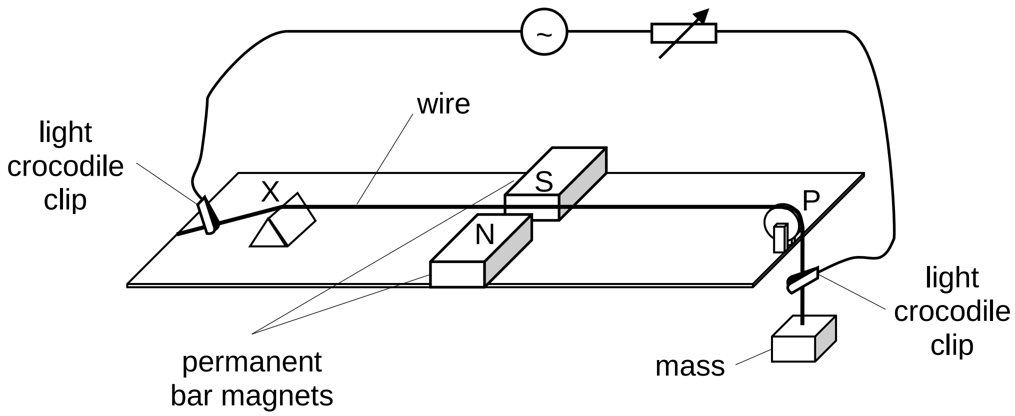

Fig. 9.1

(i) The wire vibrates when a sinusoidal alternating source is connected across the wire.

Explain how these vibrations are created.

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.... [2]

(ii) When the frequency of the alternating source is 50 Hz and the distance XP is 40 cm, a fundamental stationary wave is observed between XP.

1. Calculate the speed of the wave in the wire.

speed = ………………………………… m s^{-1} [1]

2. Explain, with reference to the formation of a stationary wave, what is meant by the speed calculated in **(a)(ii)1**.

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.... [4]

3. State and explain how the amplitude of the vibration would change if X is shifted closer to P.

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....

.... [2]

4. Determine the next 2 higher frequencies that will produce stationary waves when XP remains 40 cm apart.

frequencies = ………………. Hz, ………………. Hz, [1]

(b) The decay of a radioactive nuclei is random and spontaneous. In a radioactive decay, the activity of the atoms at time t is given by

$$A = A_0 \exp(-\lambda t)$$

where A_0 is the activity at the start of the decay and λ is the decay constant.

As part of monitoring of a particular disposal site where nuclear waste in the form of a particular radioactive isotope is disposed, the activity on-site is recorded on a yearly basis from 1990 through to 2003. A significant reduction in activity was recorded in 1998, as shown in Fig. 9.2.

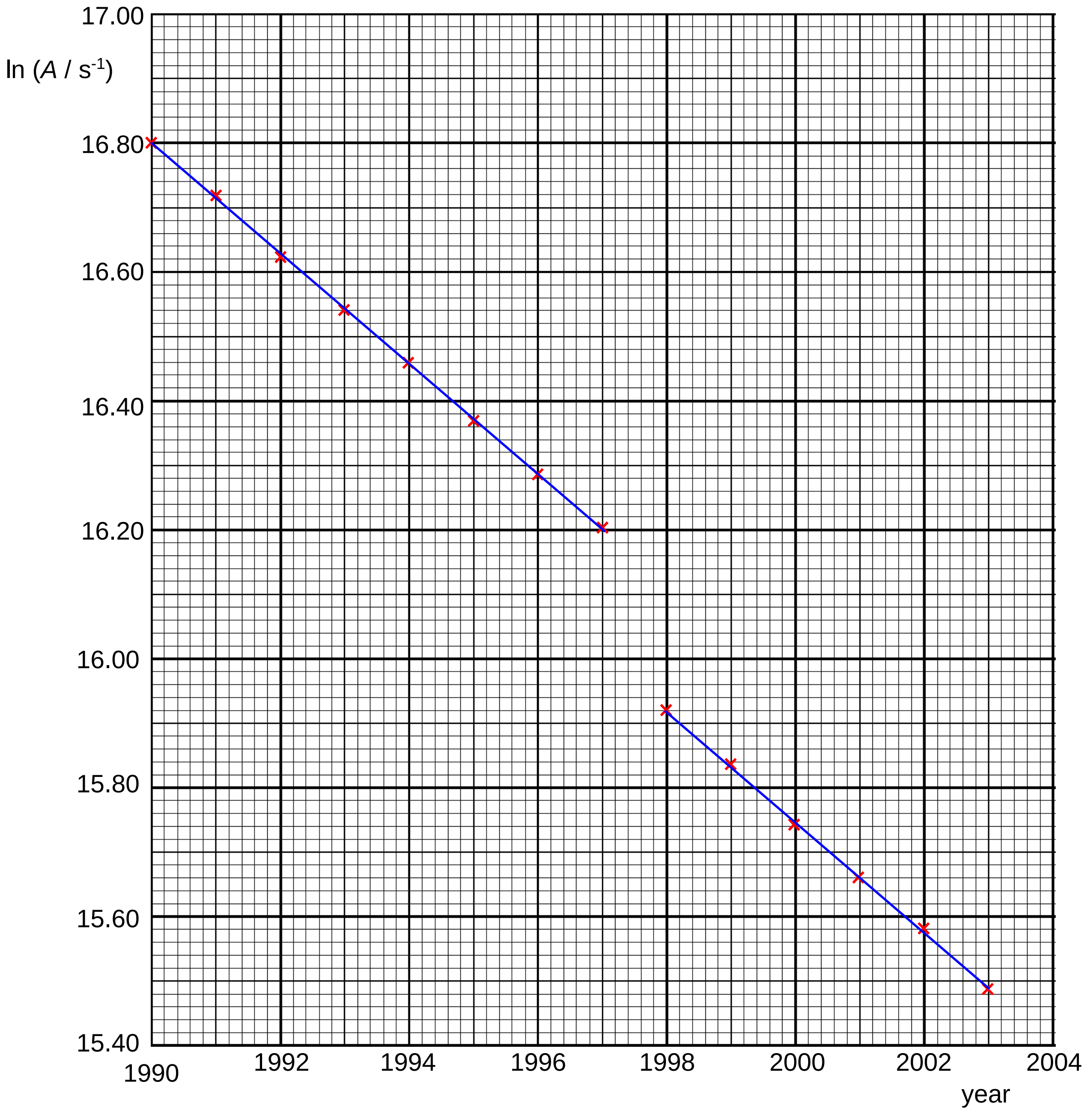

Fig. 9.2

(i) Use Fig. 9.2 to determine the decay constant λ of the radioactive isotope.

λ = ………………………………… s^{-1} [2]

(ii) Hence or otherwise, find the half-life of the radioactive isotope.

half-life = ………………………………… years [2]

(iii) Use Fig. 9.2 to show that the number of undecayed nuclei present in the year 1997 is 4.00×10^{15}.

(iv) It is alleged that some of the radioactive waste material was stolen between 1997 to 1998.

Estimate the number of radioactive nuclei that was stolen.

number = ………………………………… [2]

(v) Explain why the two sections of the graph before and after the alleged theft, are parallel.

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.... [2]

[Total: 20]