Name: ______________________________ (   )   PDG: ______/ 16

ANDERSON JUNIOR COLLEGE

2017 JC2 Preliminary Examination

PHYSICS   Higher 2   9749/02

Paper 2 Structured Questions   **Tuesday 12 September 2017**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and PDG in the spaces provided above.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, glue or correction fluid.

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

Answer **all** questions.

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

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

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Significant Figure	
Total (80 marks)	

This document consists of **22** printed pages

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}
	$(1/(36\pi)) \times 10^{-9}$ 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	$\phi = -\dfrac{Gm}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
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.	$v = v_0 \cos \omega t$ $= \pm \omega\sqrt{x_o{}^2 - x^2}$
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	$V = \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to long straight wire	$B = \dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 In 2010, an iron cannon and some iron cannon balls were discovered offshore in the United Kingdom after sitting on the seabed for a few hundred years.

(a) An experiment is performed to determine the density ρ of an iron cannon ball. The average of the measurements, with their uncertainties, are shown in Fig 1.1.

Mass, m / kg	Diameter, d / cm
79.72 ± 0.01	26.7 ± 0.1

Fig 1.1

(i) Show that the density of iron, ρ is 7999 kg m^{-3}.

[1]

(ii) Calculate the actual uncertainty in ρ.

actual uncertainty in ρ =…………………….. kg m^{-3} [2]

(iii) State the value of ρ and its actual uncertainty to the appropriate number of significant figures.

ρ = ……………………±……………………kg m^{-3} [1]

(b) One possible way to raise the iron cannon from the seabed is to use a lifting bag, which may be attached to the iron cannon and then partially inflated with air, as shown in Fig. 1.2.

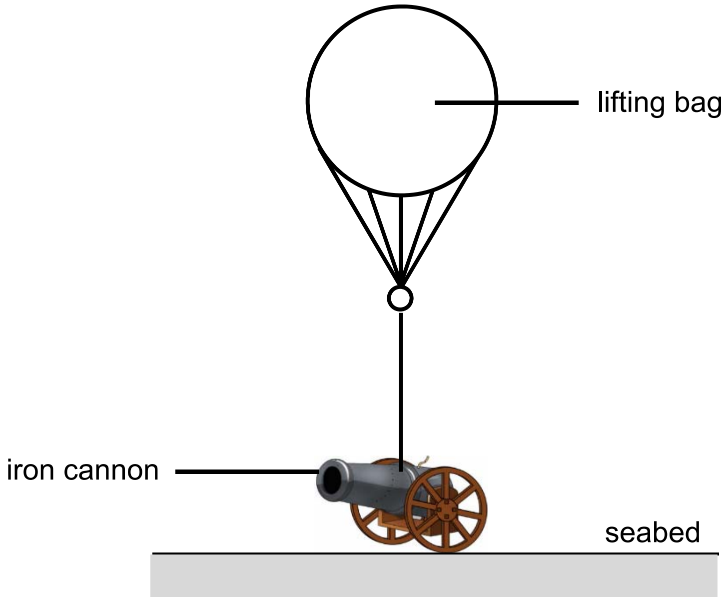

Fig. 1.2

(i) The submerged iron cannon of mass 800 kg is attached to a lifting bag of negligible volume and mass. Using the data in part **(a)(i)**, estimate the initial acceleration of the cannon when 0.70 m^3 of air is suddenly released into the bag. The density of the seawater is 1050 kg m^{-3}.

acceleration = …………………………… m s^{-2} [3]

(ii) Explain why air has to be released continuously from the lifting bag as the iron cannon rises from the seabed to the surface so that a constant speed of ascent is maintained.

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…………………………………………………………………………………………… [3]

2 **(a)** Gas, R, is trapped in a vessel by a column of liquid PQ as shown in Fig 2.1 below. Length of the liquid column can be increased by adding more liquid to PQ.

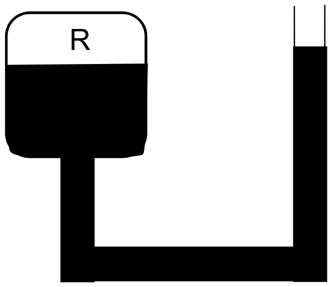

Fig 2.1

Using the kinetic theory, explain how the pressure of the gas R is increased,

(i) when the volume of R remain unchanged and its temperature increases.

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…………………………………………………………………………………………….[3]

(ii) when the temperature of R remain unchanged and its volume decreased slightly.

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

(b) There is about one hydrogen atom per cm^3 in outer space, where the temperature (in the shade) is about 3.5 K. The mass of a hydrogen atom is 1 *u*.

Calculate

(i) the rms speed of these atoms.

rms speed = …………………………….. $m\ s^{-1}$ [3]

(ii) the pressure exerted by these atoms.

pressure = ………………………………… Pa [3]

3 (a) A mass of 170 g oscillates with simple harmonic motion. Fig. 3.1 shows the variation with time *t* of the displacement *y* of the mass.

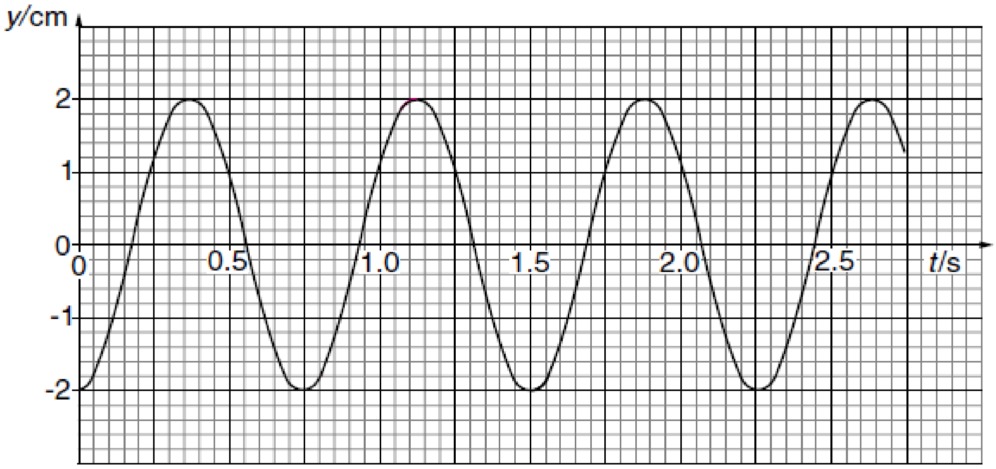

Fig. 3.1

(i) Explain what is meant by *simple harmonic motion*.

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…………………………………………………………………………………………… [2]

(ii) On Fig. 3.2, draw a graph showing the variation with displacement y of the potential energy E_p of the mass

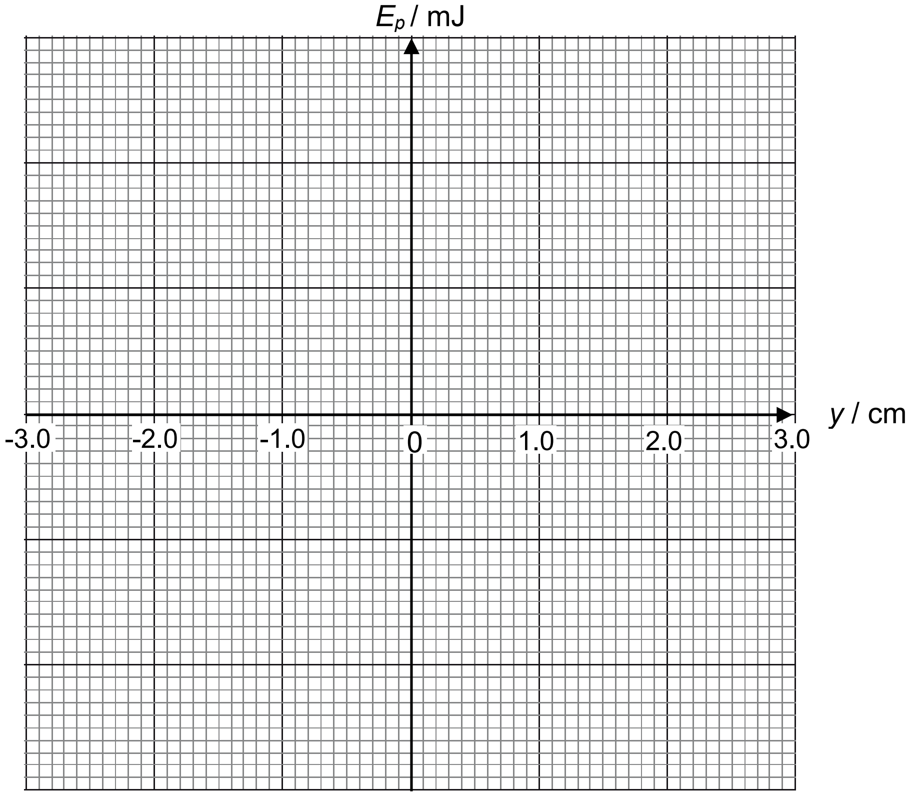

Fig. 3.2

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[3]

(b) The drums of an automatic washing machine are suspended from the casing by springs, at the top and bottom, as shown in Fig. 3.3. The inner drum rotates within the outer drum at variable speeds according to the washing programme.

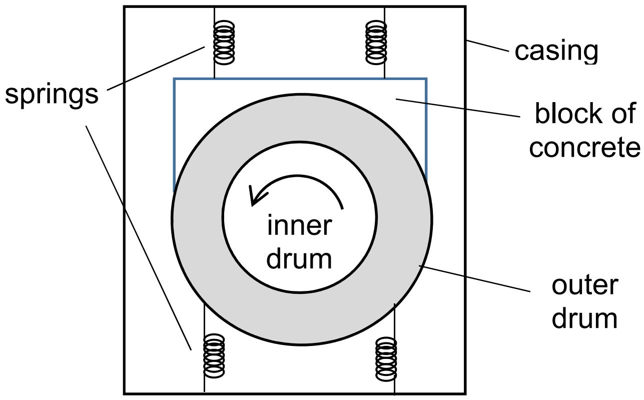

Fig. 3.3

The total mass of the drums is 20 kg. A block of concrete of mass 20 kg is added to the outer drum. The natural period of oscillation of the system is 1.6 s. The period of oscillation T of the system is given by $T = 2\pi\sqrt{\frac{M}{k}}$, where M is the total mass of the load in the system and k is the effective spring constant of the springs.

When the washing machine enters the spin part of the washing programme, it starts from rest and its rotational speed increases gradually. As the speed increases, the system is observed to oscillate with increasing amplitude which reaches a maximum value of 5.0 cm before decreasing again at higher speeds.

(i) Calculate the number of revolutions per second of the drum when the maximum amplitude of oscillation is observed.

number of revolutions per second = ………….......... [1]

(ii) Explain

1. why the system oscillates when the inner drum is rotated,

……………………………………………………………………………………..............

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

2. and why the amplitude reaches a maximum.

……………………………………………………………………………………..............

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

(iii) On Fig. 3.4, sketch a graph showing how the amplitude varies with frequency of rotation of the inner drum.

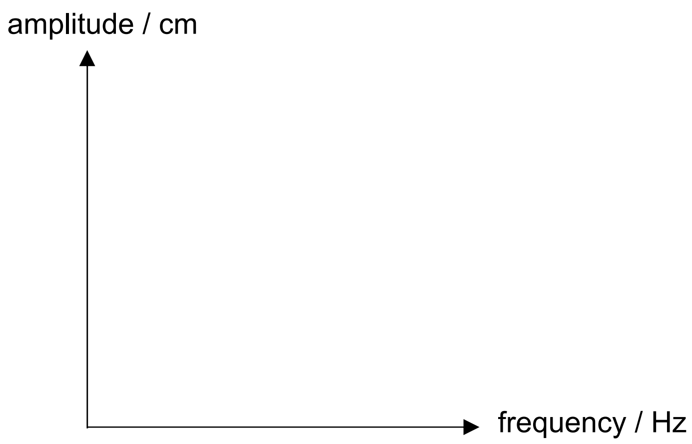

Fig. 3.4 [2]

(iv) State and explain one effect on the machine without the block of concrete fixed to the drum.

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

4 **(a)** A cell of e.m.f. E = 3.0 V and internal resistance r = 0.50 Ω is connected to three bulbs X, Y and Z as shown in the circuit of Fig. 4.1.

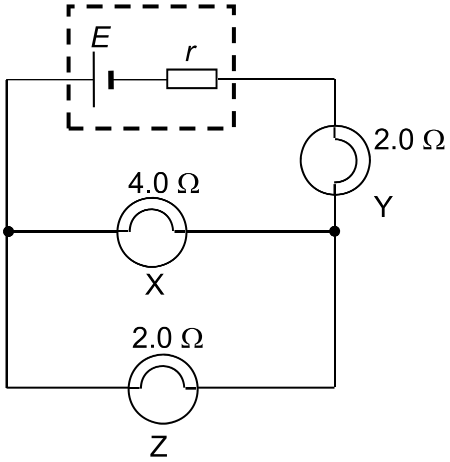

Fig. 4.1

(i) Calculate the effective resistance of the three bulbs in the circuit of Fig. 4.1.

effective resistance = ……………………………Ω [2]

(ii) List the light bulbs X, Y and Z in order of *increasing* brightness.

in order of increasing brightness: …………………………… [1]

(b) The circuit of Fig. 4.1 was connected to a potentiometer that is made up of a 6.0 V battery in series with a resistance R = 1.0 Ω and a uniform wire **AB** of length 100.0 cm and resistance 2.0 Ω (see Fig. 4.2).

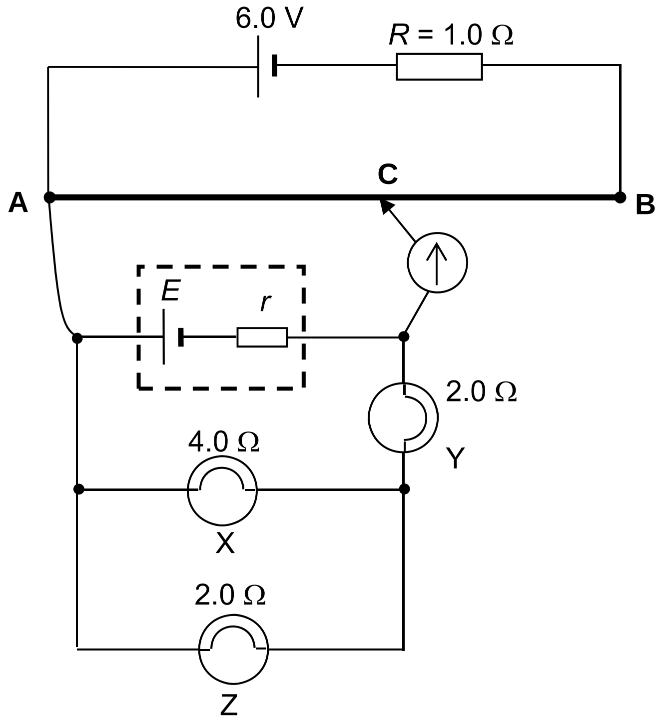

Fig. 4.2

(i) Show that the potential difference across **AB** is 4.0 V when the galvanometer shows null deflection

. [1]

(ii) Determine the balance length **AC**.

balance length **AC** = ……………………………cm [3]

(iii) Explain how, if at all, the balance length **AC** will be affected if bulb X is replaced by a bulb of lower resistance.

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5 **(a)** A current-carrying solenoid XY is placed near to a small coil, as shown in Fig. 5.1.

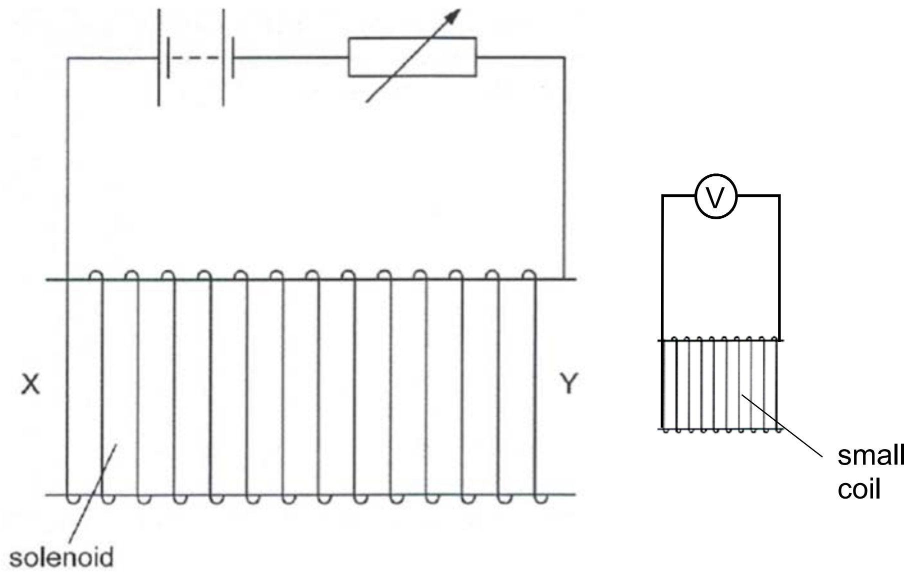

Fig. 5.1

The small coil is connected to a sensitive voltmeter.

(i) State the direction, XY or YX, of the magnetic field in the solenoid.

direction = ……………………………. [1]

(ii) The resistance of the variable resistor is changed so that the current in the solenoid increases.

1. State Faraday's law of electromagnetic induction and use it to explain why a reading is recorded on the voltmeter.

……………………………………………………………………………………..............

……………………………………………………………………………………..............

……………………………………………………………………………………..............

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

2. State Lenz's law and hence explain the direction of the induced current in the small coil.

On Fig. 5.1, mark the direction of this induced current.

……………………………………………………………………………………..........

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………………………………………………………………………………………[3]

(iii) The current in the solenoid is now made to vary as shown in Fig. 5.2.

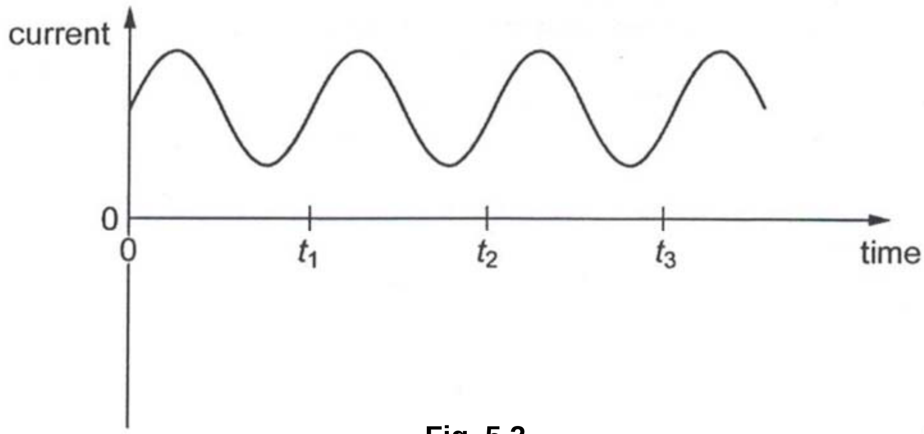

Fig. 5.2

On Fig. 5.3, show the variation with time of the e.m.f. induced in the small coil.

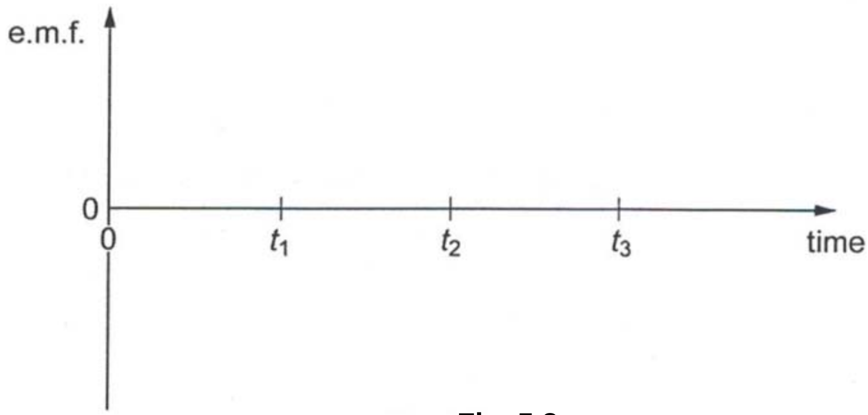

Fig. 5.3

[2]

(b) Fig. 5.4 is the circuit diagram for a half-wave rectifier.

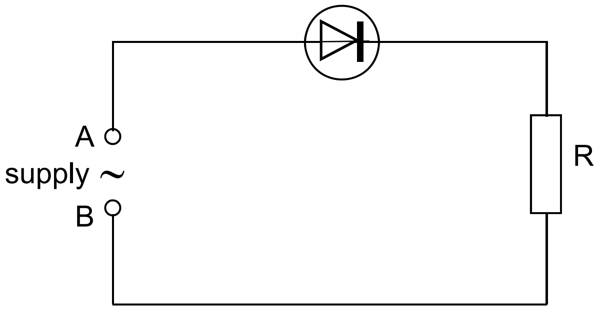

Fig. 5.4

The supply to the diode is rated as 50 Hz, 6.0 V, 1.5 W. Fig. 5.5 shows the trace of the variation with time of the potential at terminal A with respect to B when an oscilloscope is connected across the supply.

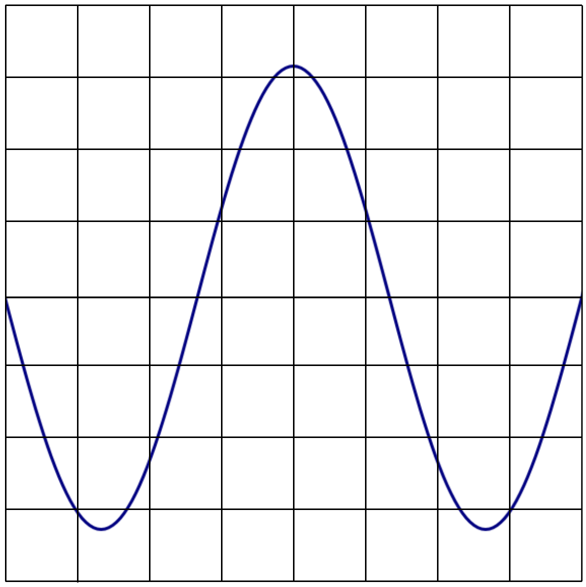

Fig. 5.5

(i) Determine the r.m.s. current the supply can provide when it is operating at 6.0 V.

r.m.s. current = ……………………………A [1]

(ii) On Fig. 5.6, draw a line to represent the corresponding trace seen on the oscilloscope across the load resistor R. [1]

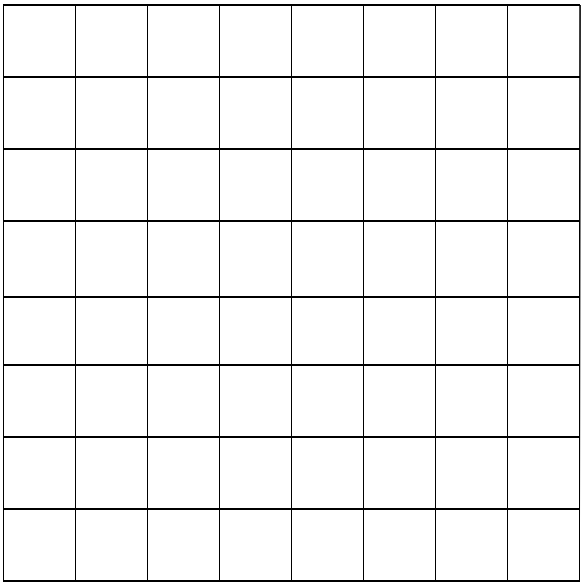

Fig. 5.6

6 **(a)** A parallel beam of electrons, all travelling at the same speed, is incident normally on a carbon film. The scattering of the electrons by the film is observed on a fluorescent screen, as illustrated in Fig. 6.1.

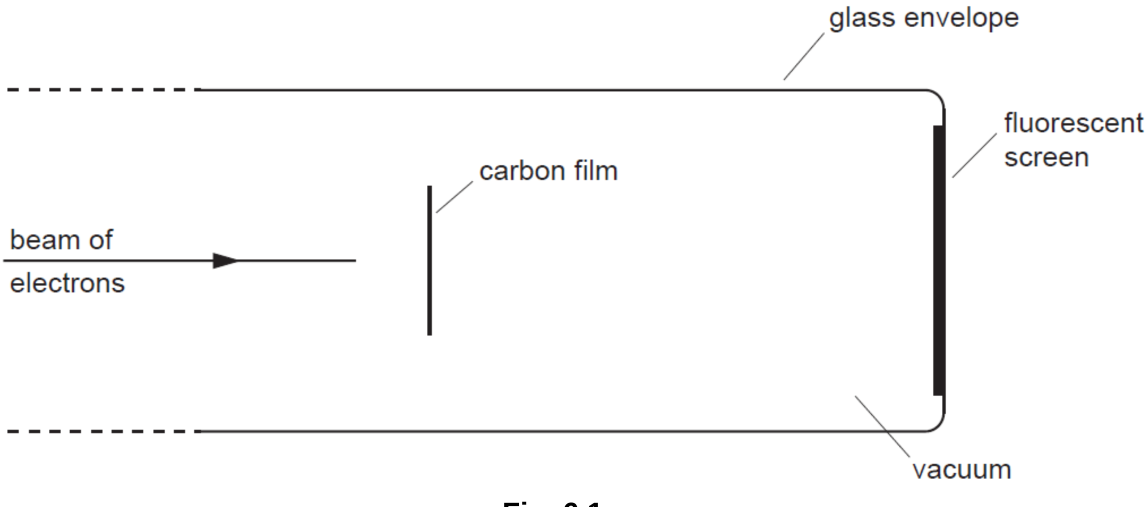

Fig. 6.1

(i) Assuming that the electrons behave as **particles**, predict what would be seen on the screen.

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(ii) In this experiment, the electrons do **not** behave as particles.

Describe briefly the pattern that is actually observed on the screen.

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…………………………………………………………………………………………..................

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

(b) The Heisenberg Uncertainty principle (HUP) for position and momentum can be written in the form

$$\Delta p \Delta x \geq h$$

where Δp is the uncertainty in momentum, Δx is the uncertainty in the position of a particle and h is the Planck constant.

(i) Calculate the uncertainty in momentum when an electron of mass 9.11×10^{-31} kg travelling at 3.00×10^{7} m s^{-1} passes through a narrow slit of width 1.00×10^{-10} m (comparable to the spacing of atoms in a crystal).

uncertainty in momentum = ... kg m s^{-1} [2]

(ii) Compare this uncertainty in momentum to the original momentum of the electron and state its significance.

…………………………………………………………………………………………..................

…………………………………………………………………………………………..................

…………………………………………………………………………………………..................

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

7 The article below is based on articles on the Internet.

Read the article and then answer the questions that follow.

Use of ultrasonic sound waves on biological cells

Ultrasonic sound waves (ultrasound) are produced and detected using an ultrasound transducer. Ultrasound transducers are capable of sending an ultrasound and then the same transducer can detect the sound and convert it to an electrical signal to be diagnosed.

To produce an ultrasound, a piezoelectric crystal has an alternating current running through it. The piezoelectric crystal grows and shrinks depending on the voltage applied across it. Running an alternating current through it causes it to vibrate at a high speed and to produce an ultrasound.

Ultrasound have frequencies outside the audible range of the human ear, that is, greater than about 20 kHz.

When an ultrasound passes through a medium, its wave energy is absorbed. The rate at which energy is absorbed by unit mass of the medium is known as the dose-rate. The dose-rate is measured in W kg^{-1}. The total energy absorbed by unit mass of the medium is known as absorbed dose. This is measured in J kg^{-1} or, as in this question, kJ kg^{-1}.

Under certain circumstances, biological cells may be destroyed by ultrasound. The effect on a group of cells is measured in terms of the survival fraction (*SF*).

$$SF = \frac{\text{number of cells surviving after exposure}}{\text{number of cells before exposure}}$$

For any particular absorbed dose, it is found that the survival fraction changes as the dose-rate increases. Fig. 7.1 shows the variation with dose-rate of the survival fraction for samples of cells in a liquid. The absorbed dose for each sample of cells was 240 kJ kg^{-1}.

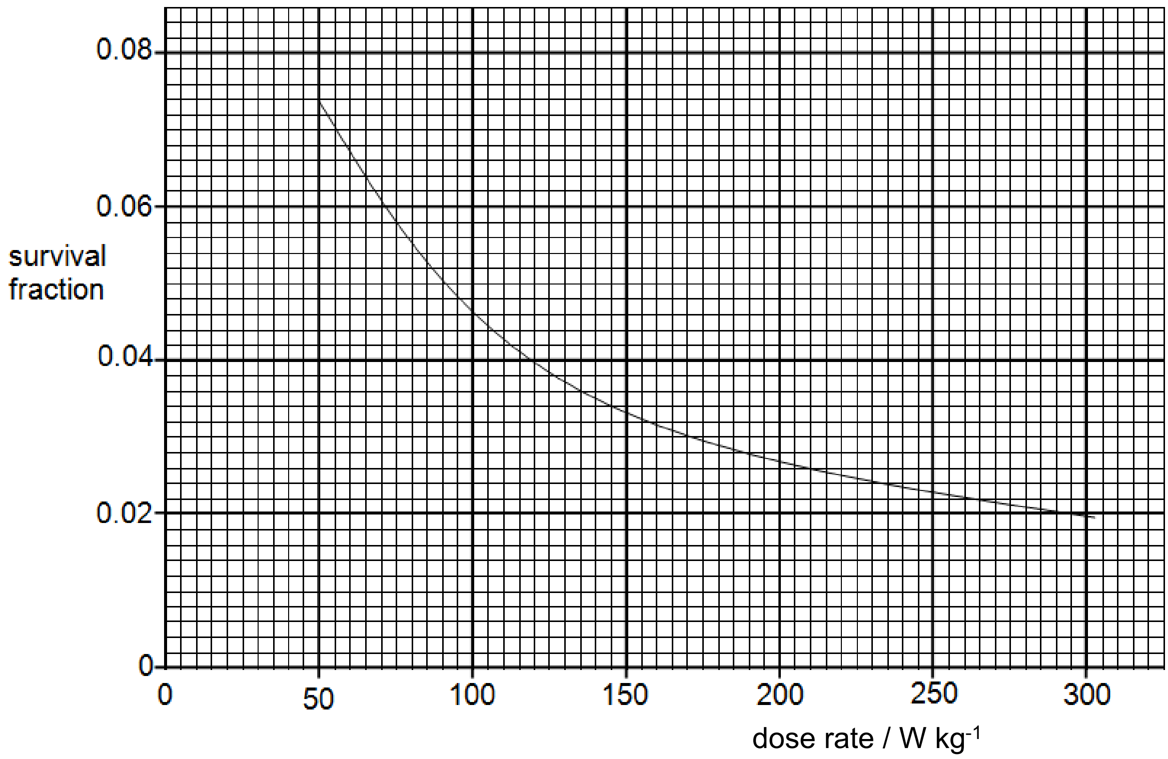

Fig. 7.1

(a) **(i)** State the transformation of energy that occurs in an ultrasound transducer.

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

(ii) State one difference between ultrasound and light.

……………………………………………………………………………………..................

……………………………………………………………………………………..................

……………………………………………………………………………………..................

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

(b) **(i)** Use Fig. 7.1 to state the survival fraction for a dose-rate of 200 W kg^{-1}.

survival fraction = ... [1]

(ii) Calculate the exposure time for an absorbed dose of 240 kJ kg^{-1} and at a dose-rate of 200 W kg^{-1}.

exposure time = …………………... s [2]

(c) Survival fraction depends not only on dose-rate but also on absorbed dose. Fig. 7.2 shows the variation with dose-rate of $\log_{10}(SF)$ for different values of absorbed dose.

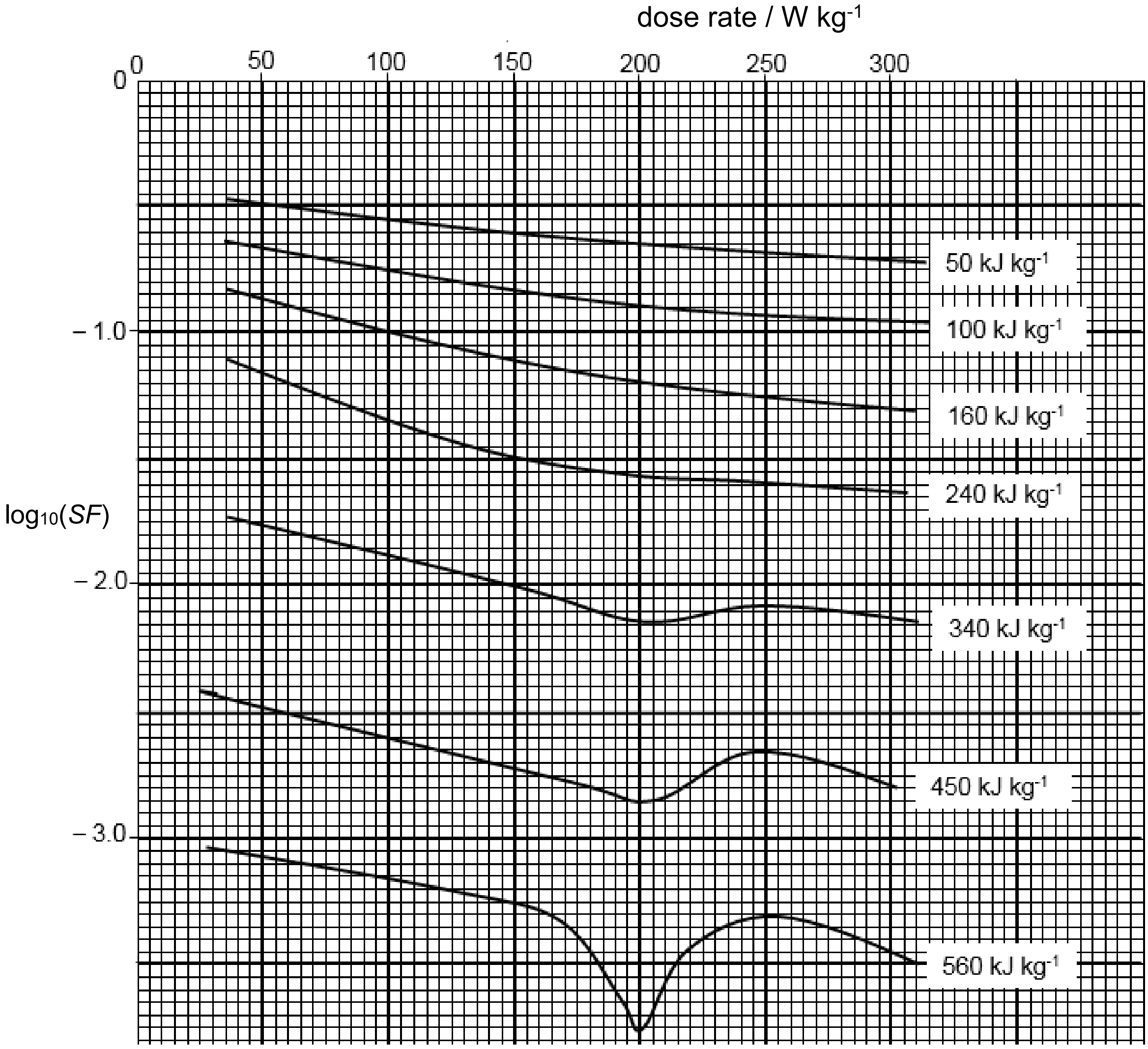

Fig. 7.2

The line with absorbed dose of 240 kJ kg^{-1} represents the data given in Fig. 7.1, but with survival fraction plotted on a logarithmic scale.

(i) Suggest why the survival fraction is plotted on a logarithmic scale.

…………………………………………………………………………………………..................

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

(ii) Use Fig. 7.2 to complete the table of Fig. 7.3 for a dose-rate of 200 W kg^{-1}.

absorbed dose / kJ kg^{-1}	$\log_{10}(SF)$
50	
100	
160	
240	
340	
450	
560	

Fig. 7.3

[3]

(iii) Use Fig. 7.3 to calculate the survival fraction for an absorbed dose of 160 kJ kg^{-1} at a dose-rate of 200 W kg^{-1}.

SF = …………………. [1]

(d) Use the table of Fig. 7.3 to plot, on the axes of Fig. 7.4, a graph to show how the variation with absorbed dose of $\log_{10}(SF)$ for the dose-rate of 200 W kg^{-1}. [3]

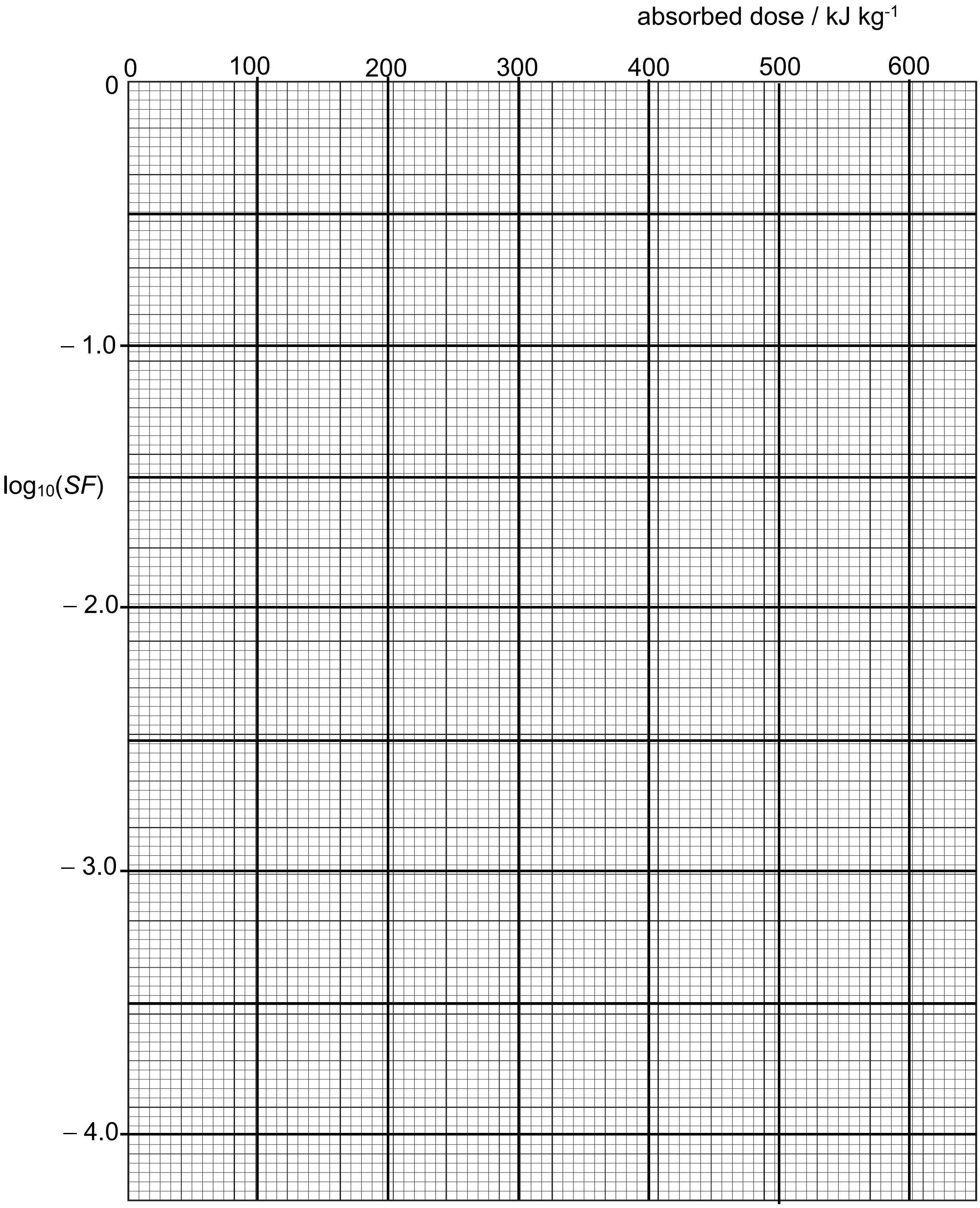

Fig. 7.4

[Turn Over

(e) Theory suggests that at a dose-rate of 200 W kg^{-1}, two separate effects may give rise to cell destruction. According to this theory, one of the effects becomes apparent only at higher absorbed doses. State the evidence provided for this theory by

(i) Fig. 7.2,

....

....[1]

(ii) Fig 7.4.

....

.... [2]

(f) The theory outlined in **(e)** suggests that the resultant survival fraction $(SF)_R$ due to two independent effects which have survival fractions $(SF)_1$ and $(SF)_2$ is given by the expression

$$(SF)_R = (SF)_1 \times (SF)_2$$

(i) Suggest how the graph in Fig. 7.4 may be used to determine $(SF)_R$ for an absorbed dose of 560 kJ kg^{-1}.

....

....

.... [1]

(ii) With reference to the graph in Fig. 7.4, discuss how it is possible to determine separate values of $(SF)_1$ and $(SF)_2$ for the absorbed dose of 560 kJ kg^{-1}.

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....

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....

....

.... [3]