Candidate Name: ______________________

Class	Adm No

H

millennia institute

2024 Preliminary Examination
Pre-University 3

H2 PHYSICS **9749/03**

Paper 3 Longer Structured Questions

Section A Booklet **16 September**

Candidates answer on the Question Paper. **2 hours**

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Do not turn over this page until you are told to do so.

Write your full name, class and Adm number 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, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

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

For Examiner's Use		
Section A		
1		**/ 10**
2		**/ 10**
3		**/ 10**
4		**/ 11**
5		**/ 9**
6		**/ 10**
Section B		
7		**/ 20**
8		**/ 20**
Presentation (overall)		
P3 Total		**/80**

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
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	$T/\text{K} = T/°\text{C} + 273.15$
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.	$x = x_0 \sin\omega t$
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	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** A bar magnet is suspended from a helical spring and one end of the magnet is situated in a coil of wire, as shown in Fig. 1.1. The coil is connected in series with a switch and a resistor. The switch is opened.

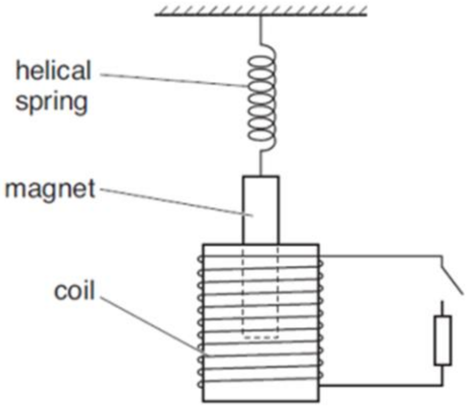

Fig. 1.1

The bar magnet is displaced vertically and then released. As the magnet passes through its rest position, a timer is started. The variation with time t of the vertical displacement of the magnet from its rest position is shown in Fig. 1.2. At t = 4.0 s, the switch is closed.

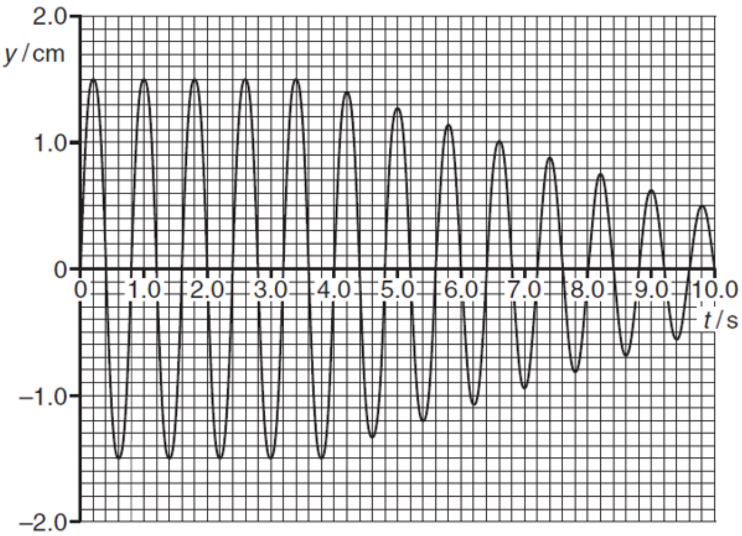

Fig. 1.2

(i) Use Fig. 1.2 to determine the frequency of oscillation of the magnet.

frequency = …………… Hz [2]

(ii) State Faraday's Law of electromagnetic induction.

…………………………………………………………………………………………………

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

(iii) Use the laws of electromagnetic induction to explain why the amplitude of oscillation decreases after the switch is closed.

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

(b) The set-up in **(a)** is modified by suspending the magnet above the coil and adding an alternating voltage supply source in series with the coil and resistor, as shown in Fig.1.3. The frequency of the voltage source is set at 0.50 Hz. The magnet was at rest initially and starts oscillating when the switch is closed.

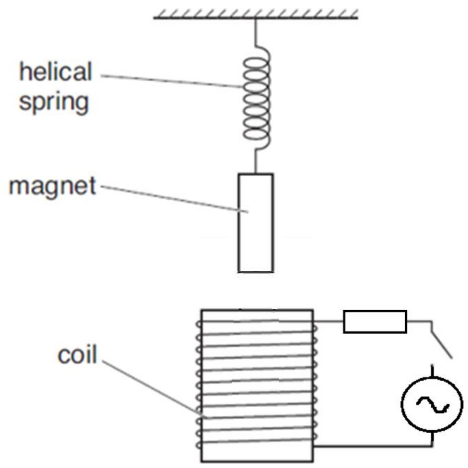


Fig. 1.3

(i) State the frequency of oscillation of the magnet.

frequency of oscillation = ………….. Hz [1]

(ii) The frequency of the voltage source is gradually increased to 5.0 Hz. State and explain what will be observed about the amplitude of oscillations of the magnet.

....

....

....

.... [2]

[Total: 10]

2 (a) Point source P, consisting of light with wavelength 630 nm, passes through a narrow slit and is incident on a screen at a distance of 2.4 m from the slit. Fig. 2.1 below shows the variation of intensity I of the light on the screen with distance x along the screen.

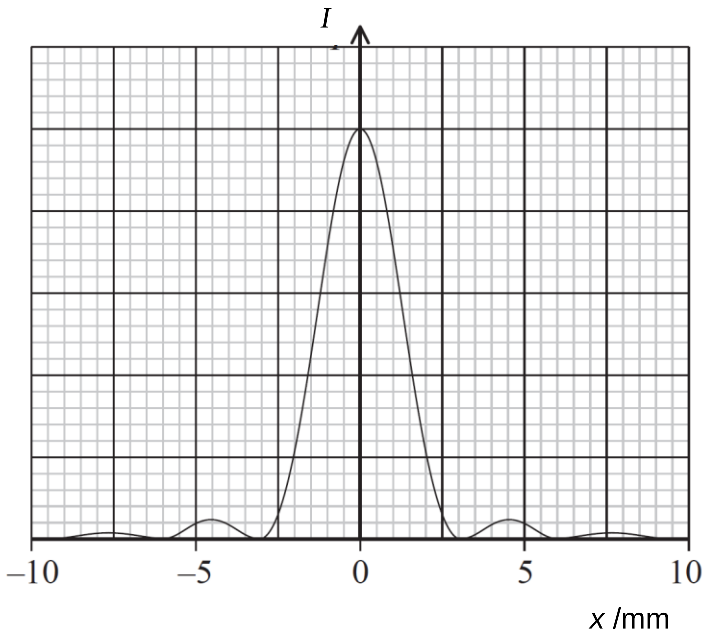


Fig. 2.1

(i) Use Fig. 2.1 to determine the width of the slit.

width = ... mm [2]

(ii) State the effect on the pattern on the screen in terms of width and intensity of central maximum if each of the following changes is made separately:

1. the width of the single slit is reduced,

....

....[2]

2. the red source is replaced with another source of violet light of the same intensity.

....

....[2]

(b) Light of wavelength 633 nm from a laser is directed normally at a diffraction grating, as illustrated in Fig. 2.2.

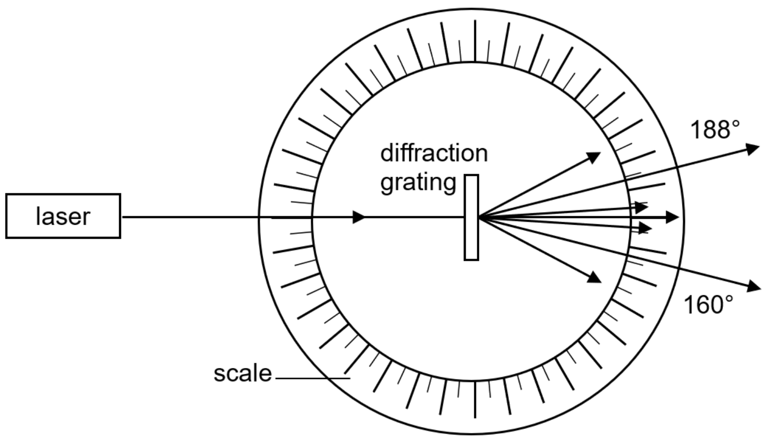


Fig. 2.2

The diffraction grating is situated at the centre of a circular scale, marked in degrees. The readings on the scale for the second order diffracted beams are 160° and 188°.

Calculate the number of lines per unit length of the slits in the diffraction grating.

number of lines per unit length = ……………………………… m^{-1} [4]

[Total: 10]

[Turn over

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

....

....[1]

(b) Fig. 3.1 shows a square ABCD of sides 2.0 cm. Three negative point charges of –1.2 μC are fixed at B, C and D.

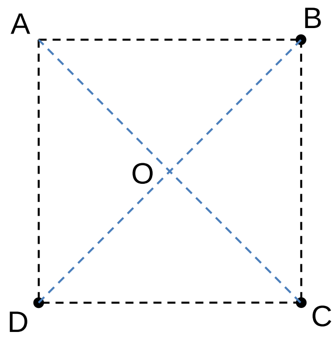


Fig. 3.1

(i) On Fig. 3.1, draw and label each of the forces acting on the charge at C due to the charges at B and D.

[1]

(ii) Determine the magnitude and direction of the resultant force acting on the charge at C due to the charges at B and D.

magnitude = …………………….N

direction = …………..…………… [3]

(iii) Determine the electric potential at the centre of the square, O, due to the three charges at B, C and D.

electric potential = …………..…………….V [3]

(iv) Determine the work done in bringing a positive charge of 1.2 μC from 100 m away to the centre of the square.

work done = …………..……………. J [2]

[Total: 10]

4 **(a)** State two ways to increase the magnetic field strength of a solenoid.

....

....

....[2]

(b) The magnetic flux density in a solenoid is measured using a current balance. The current balance is a U-shaped piece of stiff wire ABCDEF pivoted at BE, as shown in Fig. 4.1.

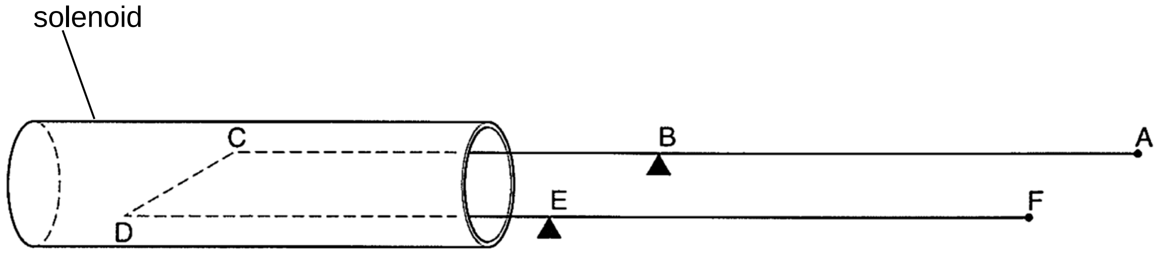


Fig. 4.1

When in use, there is a turning force on the stiff wire caused by a current in CD. CD has length 25 mm, CB and DE each have length 106 mm.

The stiff wire is first balanced when there is no current in it. A current of 4.9 A is then passed through CD and, in order to rebalance the stiff wire, a force of 5.7×10^{-4} N is applied at a distance of 77 mm from the pivot, as shown in Fig. 4.2. which is the side view of the balance.

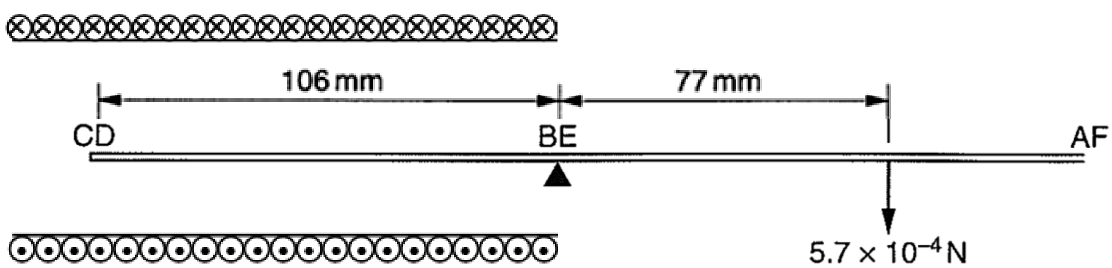


Fig. 4.2 (side view)

(i) On Fig. 4.1, indicate the direction of the current in CD. [1]

(ii) Calculate the magnetic flux density in the solenoid.

magnetic flux density = ...

full name of unit = ... [4]

(c) Fig. 4.3 shows a rectangular coil placed at the centre of a solenoid with its plane perpendicular to the axis of the solenoid.

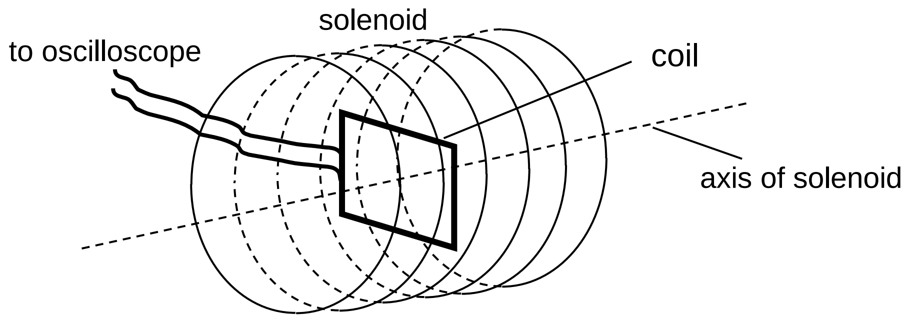


Fig. 4.3

The solenoid has 400 turns, a cross-sectional area of 0.0050 m^2 and a length of 50 cm. An alternating current of 50 Hz is passed through the solenoid. The rectangular coil has nine turns with dimensions of 0.010 m by 0.018 m. The ends of the coil are connected to a cathode ray oscilloscope.

Fig. 4.4 shows the variation with time of the current through the solenoid.

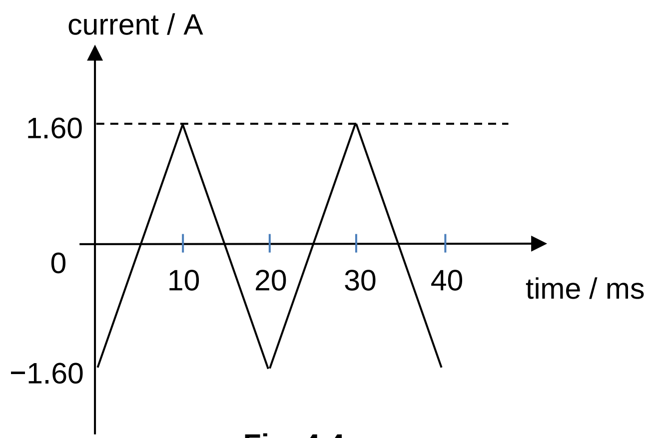


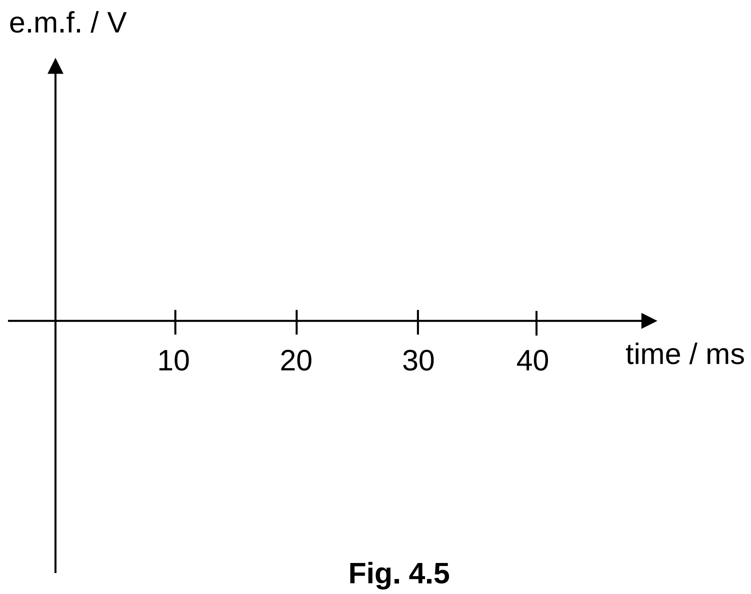
Fig. 4.4

(i) The flux density of the solenoid is given by $B = \mu_o nI$, where μ_o is the permeability of free space, n is the number of turns per unit length of the solenoid and I is the current through the solenoid.

Determine the magnitude of the e.m.f. induced in the coil.

e.m.f. = ... V [2]

(ii) On Fig. 4.5, sketch a labelled graph to show the variation with time of the induced e.m.f. in the coil over two cycles of current change.



[2]

Fig. 4.5

[Total: 11]

5 **(a)** Two resistors and two ideal diodes are connected to an AC supply as shown in Fig. 5.1. Ideal diodes have zero resistance when forward-biased and infinite resistance when reverse-biased.

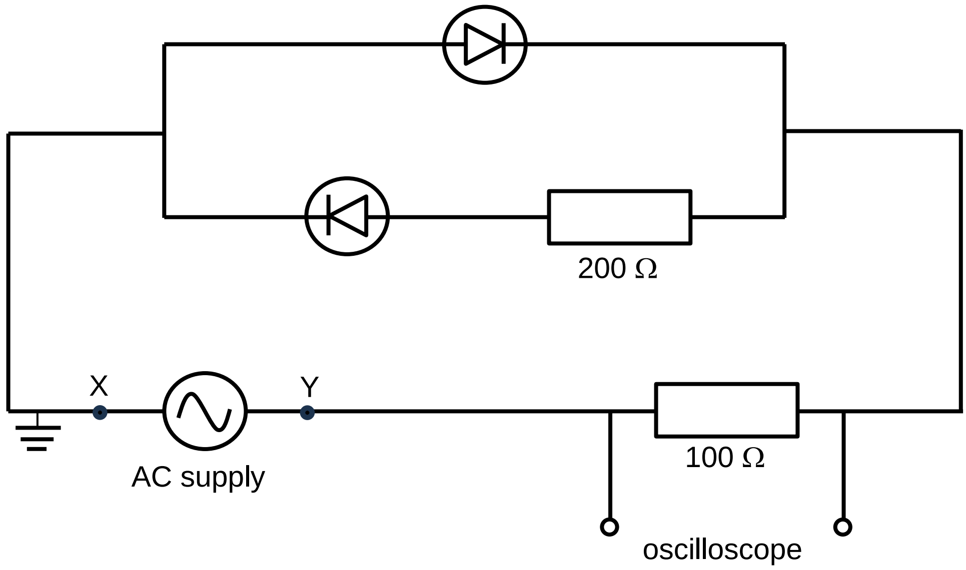


Fig. 5.1

Fig. 5.2 shows the variation with time of the potential of the AC supply at point Y.

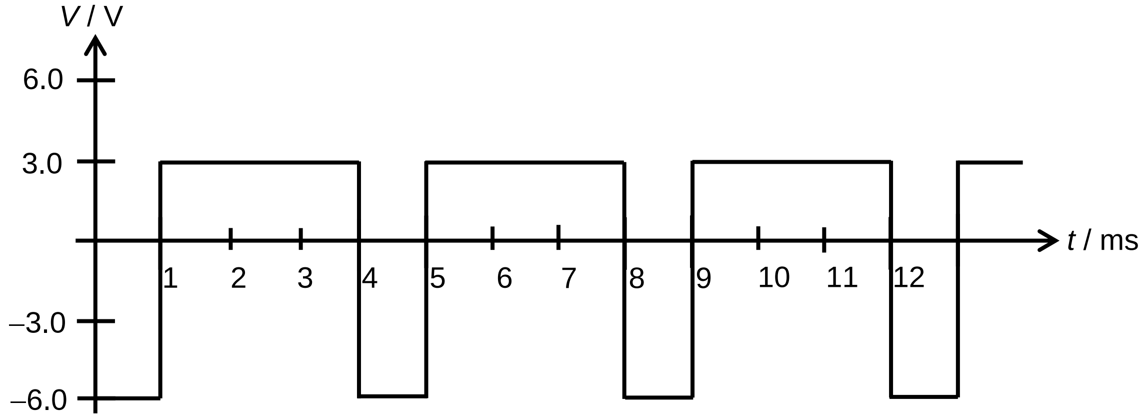
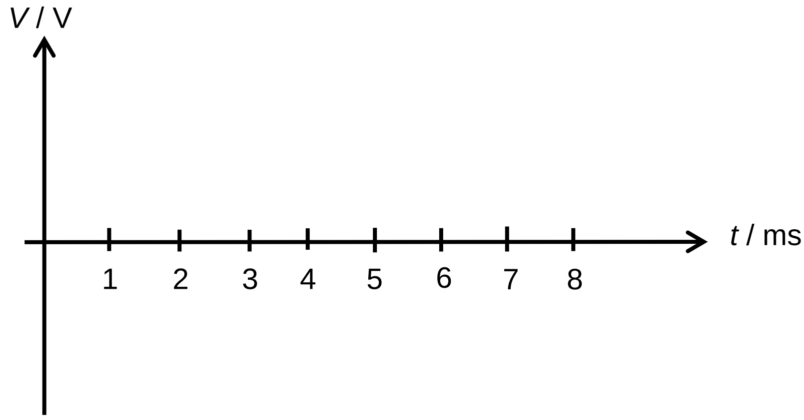


Fig. 5.2

(i) Determine the root-mean-square voltage of the AC supply.

root-mean-square voltage = ... V [2]

(ii) Sketch the variation with time of the voltage across the 100 Ω resistor for the first 8 seconds using the axes below.



[2]

(b) A transmission line that has a resistance per unit length of $4.50 \times 10^{-4}\ \Omega m^{-1}$ is to be used to transmit 5.00MW over 6.44×10^{5} m. The output voltage of the generator is 4.50 kV.

(i) A transformer is used to step up the voltage to 500 kV before transmission of power. Determine the turns ratio of the transformer.

turns ratio = ... [1]

(ii) Determine the power loss during transmission.

power loss = ... W [3]

(iii) Explain the advantage to step up the voltage before transmission of power.

....

.... [1]

[Total: 9]

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.

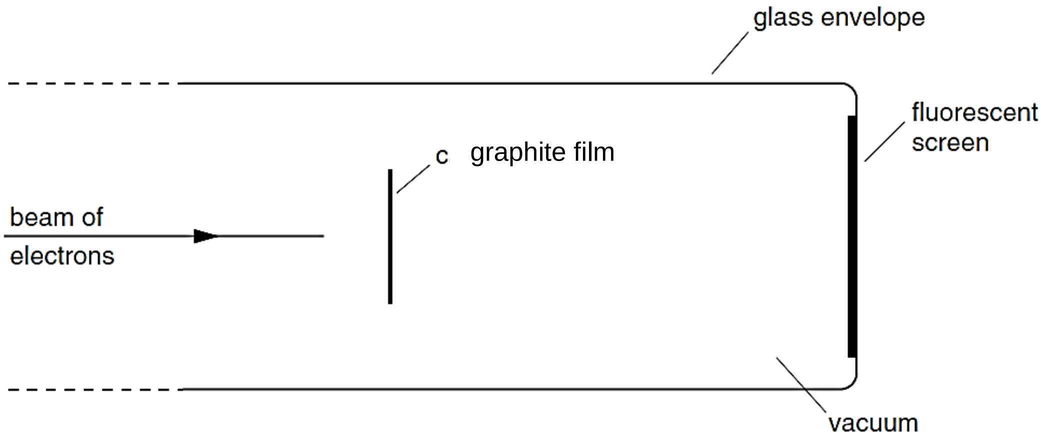


Fig. 6.1

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

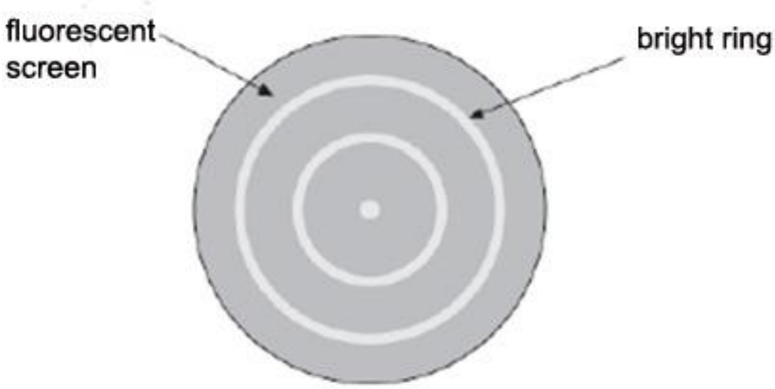


Fig. 6.2

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

....

....

....

....

.... [2]

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

λ =....................................... m [2]

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

....

....

....

....

....[2]

(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.

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[Total: 10]

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