Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME						CLASS	
CENTRE NUMBER	S	3	0	0	4	INDEX NUMBER	

PHYSICS **9749/03**

Paper 3 Longer Structured Questions

28 August 2024

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index 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 a half hours on Section A and half an hour on Section B.

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 Examiners' use only	
Section A	
1	/ 10
2	/ 12
3	/ 12
4	/ 14
5	/ 12
Total	/ 60
Section B	
6 / 7	/ 20
Grand Total	/ 80

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-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	=	$\rho g h$
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
temperature	T/K	=	T/°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	=	$\dfrac{3}{2}kT$
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	=	$\dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{\ln 2}{t_{½}}$

[Turn over

Section A

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

1 **(a)** **(i)** Define *linear momentum.*

………………………………………………………………………………………………

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

(ii) State the *principle of conservation of momentum*.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(b) Fig. 1.1 shows two spheres, A and B, with identical sizes but of different masses, connected by a light elastic string.

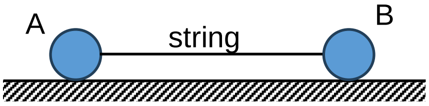

Fig. 1.1

The masses of A and B are 2.0 kg and 1.0 kg respectively. The two spheres are initially held at rest 0.90 m apart on a smooth horizontal surface with the string in tension. They are then simultaneously released. The string releases 12 J of energy as it contracts to its natural length.

(i) Determine the speeds acquired by each of the spheres.

speed of A = ……………………… $m\ s^{-1}$

speed of B = ……………………… $m\ s^{-1}$ [4]

For Examiner's Use

(ii) Determine the distance of the position of A from its initial position when the two spheres collide.

distance = ……………………… m [3]

[Total: 10]

For Examiner's Use

2 A fixed mass of monatomic ideal gas is being studied for its thermodynamic properties.

(a) State what is meant by an *ideal gas*.

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

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

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

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

(b) The gas is initially placed in a container of volume 2.3×10^4 cm^3 and at a pressure of 4.8×10^5 Pa. The temperature of the gas is 65 °C.

(i) Determine the number of atoms in the gas.

number = ……………………… [2]

(ii) Determine the internal energy of this gas at 65 °C.

internal energy = ……………………… J [2]

For Examiner's Use

(iii) The temperature is then increased to 75 °C.

Determine the ratio of

$$\frac{\text{root-mean-square (r.m.s.) speed of the gas molecules at 65 °C}}{\text{root-mean-square (r.m.s.) speed of the gas molecules at 75 °C}}.$$

ratio = ……………………… [2]

(c) The gas then undergoes a cycle of processes ABC as shown in Fig. 2.1.

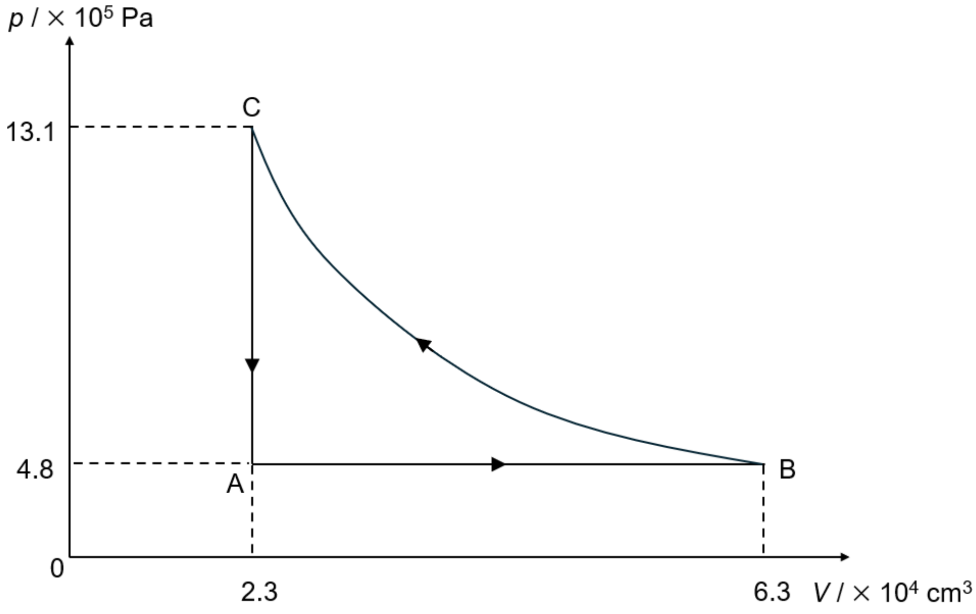

Fig. 2.1

During the isobaric process A→B, the gas expands from 2.3×10^4 cm^3 to 6.3×10^4 cm^3 at a constant pressure of 4.8×10^5 Pa.

During the isothermal process B→C, the gas contracts from 6.3×10^4 cm^3 to 2.3×10^4 cm^3 and the pressure increases to 13.1×10^5 Pa.

During the isovolumetric process C→A, the gas reduces in pressure to 4.8×10^5 Pa.

[Turn over

For Examiner's Use

(i) Explain why process B→C is isothermal.

………………………………………………………………………………………..

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

(ii) Complete Table 2.1. Show your working.

Table 2.1

process	work done on the gas / × 10^4 J	heat supplied to the gas / × 10^4 J	increase in internal energy / × 10^4 J
A → B			
B → C	3.05		0
C → A			−2.88

[3]

[Total: 12]

For Examiner's Use

3 A cylindrical tube, containing some sand, floats upright in a liquid of density ρ with its base at a depth of h below the liquid surface as shown in Fig. 3.1.

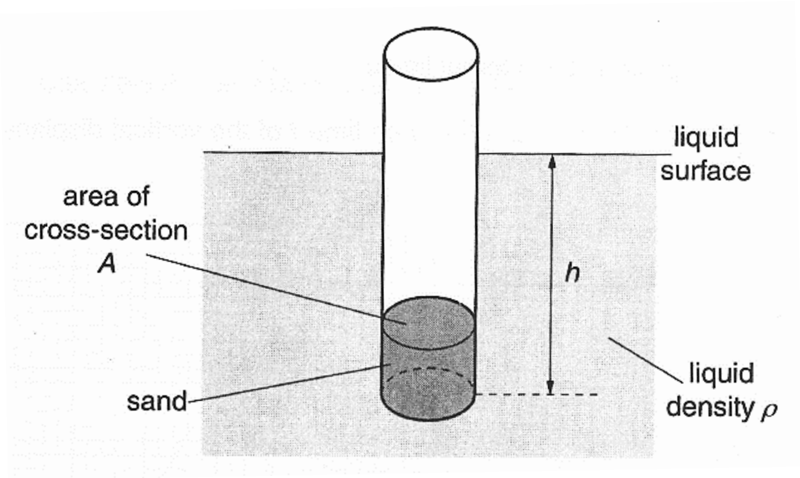

Fig. 3.1

The tube has a cross-sectional A and the total mass of the tube and the sand is M.

(a) By considering forces acting on the tube, explain why the tube is able to float.

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

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

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

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

For Examiner's Use

(b) The tube is displaced vertically downwards and then released.

Show that the acceleration *a* of the tube is given by

$$a = -\left(\frac{\rho A g}{M}\right)x\ ,$$

where *x* is the displacement from the depth *h* and *g* is the acceleration due to free fall. Explain your working.

[3]

(c) Explain why the expression in **(b)** suggests that the motion of the tube is simple harmonic.

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

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

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

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

For Examiner's Use

(d) The mass M is 120 g and the cross-section A of the tube is 5.5 cm^2.

Calculate the frequency of oscillation of the tube when it is in a liquid of density 1.2×10^3 kg m^{-3}.

frequency = ……………………… Hz [3]

(e) **(i)** On Fig. 6.2, sketch a graph to show the variation with displacement x of the velocity v of the tube.

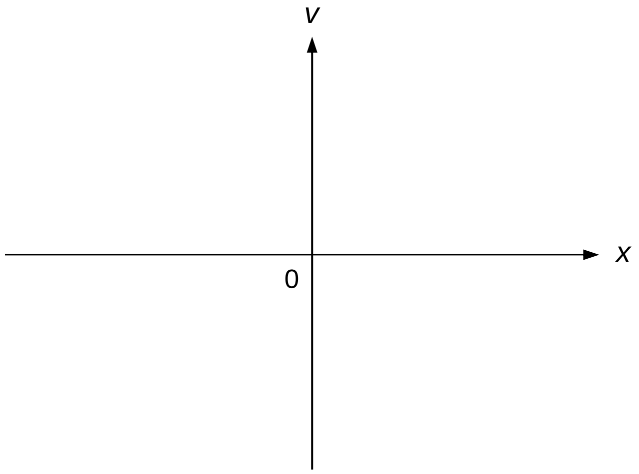

Fig. 6.2

[1]

(ii) If the viscosity of the fluid cannot be neglected, on Fig. 6.2, draw the variation with displacement x of the velocity v of the tube. [1]

[Total: 12]

[Turn over

For Examiner's Use

4 **(a)** **(i)** Explain what is meant by a *polarised wave*.

……………………………………………………………………………………………

……………………………………………………………………………………… [1]

(ii) A vertically polarised light of intensity I is incident on a polariser with its transmission axis at an angle of 40° from the vertical as shown in Fig. 4.1. The wave then passes through another polariser with its transmission axis at an angle of 40° from the vertical in the other direction.

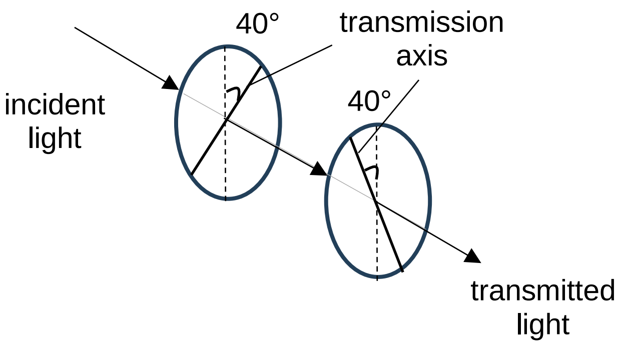

Fig. 4.1

Determine the intensity of the transmitted light in terms of I.

intensity = ……………………… I [2]

For Examiner's Use

(b) Fig. 4.2 shows a long tube, fitted with a tap at the bottom, filled with water. A tuning fork is sounded above the top of the tube as the water is allowed to run out of the tube.

Fig. 4.2 and Fig. 4.3 show the water levels when a loud sound is first heard and when it is next heard respectively.

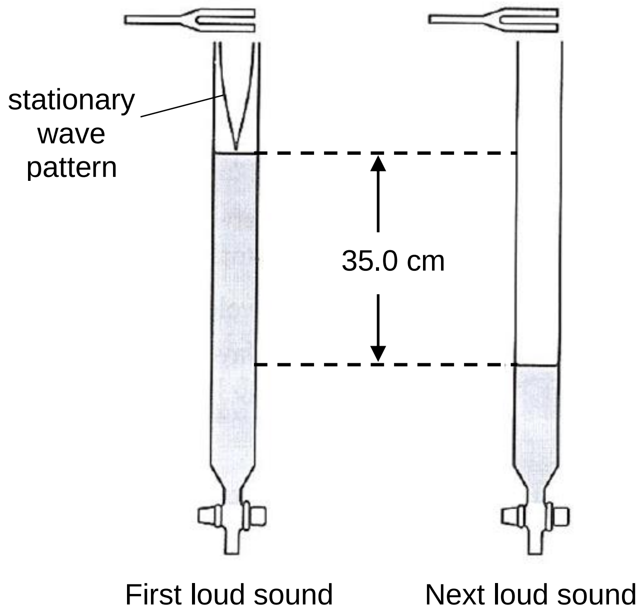

Fig. 4.2 **Fig. 4.3**

(i) Fig. 4.2 shows the stationary wave pattern produced in the tube.

1. Describe how the pattern illustrates a longitudinal wave.

....

....

....

.... [2]

2. On Fig. 4.3, sketch the stationary wave pattern set up in the tube. [1]

3. Indicate, with the letter N, the positions of any displacement nodes on the stationary wave in Fig. 4.3. [1]

For Examiner's Use

(ii) The speed of sound in the tube is 340 m s^{-1}. The water levels for the two positions differs by 35.0 cm.

Determine the frequency of the tuning fork.

frequency = ……………………… Hz [2]

(c) A diffraction grating, with 5.00×10^5 lines per metre, has a narrow beam of coherent light of wavelength 540 nm incident normally on it.

(i) Determine the number of maxima that are visible on a screen placed in front of the diffraction grating.

number = ……………………… [3]

For Examiner's Use

(ii) The incident beam is suspected to consist of two wavelengths of light, one at 542 nm and the other at 539 nm.

Given that the minimum angular separation of the maxima for which two wavelengths may be distinguished is 0.30°, determine whether the second order maxima of the two wavelengths of light could be observed as separate images.

……………………………………………………………………………………… [2]

[Total: 14]

For Examiner's Use

5 An electric field is set up between a pair of large parallel plates, P and Q which are 5.0 m apart. Plate P is at a potential of –1000 V and Q is at a potential of +1000 V.

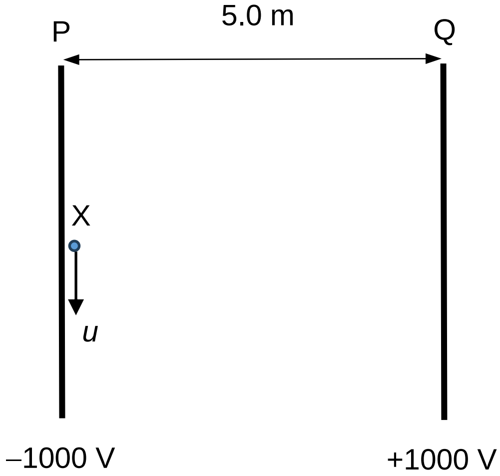

Fig. 5.1

A negatively charged particle, X of weight 4.9×10^{-4} N and charge 0.78 μC leaves plate P with a velocity *u* of magnitude 23 m s^{-1} along the vertical. The setup is assumed to be in an evacuated chamber.

(a) Determine the magnitude and direction of the electric force on particle X due to the electric field between the plates.

magnitude = ………………………. N [1]

direction = ………………………. [1]

For Examiner's Use

(b) **(i)** Draw a diagram to show the forces acting on particle X.

[1]

(ii) Hence, explain why the weight of particle X will affect its motion.

……………………………………………………………………………………..……

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

(c) Determine the speed of particle X just before it hits the surface of Q.

speed = ……………………… m s^{-1} [4]

For Examiner's Use

(d) Explain how the path taken by particle X between the plates can be considered as parabolic.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(e) Calculate the change in electric potential energy of particle X when it reaches the surface of Q from P.

change in electric potential energy = ……………………… J [2]

[Total: 12]

For Examiner's Use

Section B

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

6 (a) Define *magnetic flux density*.

....

....

....

.... [2]

(b) Ions in the atmosphere are affected by the magnetic field produced by long straight current-carrying cables carrying a large current. Fig. 6.1 shows a current-carrying cable carrying a current of 80 A towards the left. At point P, a distance 0.80 m from the cable, an ion travels directly towards the cable at a speed of 1.0×10^{3} m s^{-1} and follows the path shown in Fig. 6.1. The charge of the ion is $+1.6 \times 10^{-19}$ C. Ignore the effects of the Earth's magnetic field.

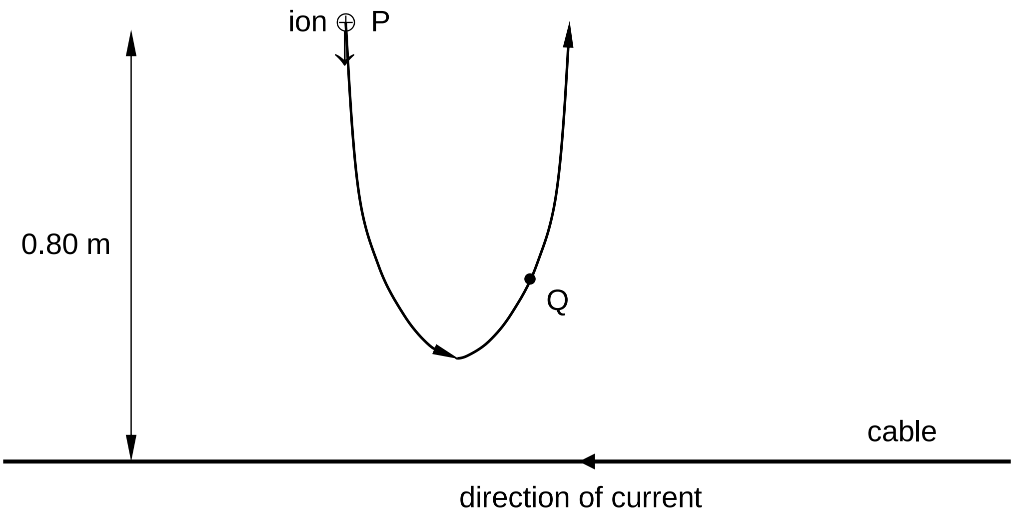

Fig. 6.1

(i) Calculate the force acting on the ion when it is at point P.

force = ... N [3]

[Turn over

For Examiner's Use

(ii) On Fig. 6.1, indicate the force acting on the ion when it is at point Q. Label the force *F*. [1]

(iii) Explain the shape of the path taken by the ion in Fig. 6.1.

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....

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....

....

.... [3]

(c) Fig. 6.2 shows a bar magnet being released from a height above a coil.

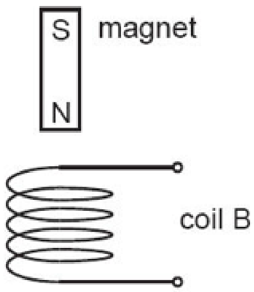

Fig. 6.2

The terminals of the coil are connected to a voltage sensor and datalogger which records the induced e.m.f. as the magnet falls through the coil.

For Examiner's Use

Fig. 6.3 shows the variation with time of the induced e.m.f.

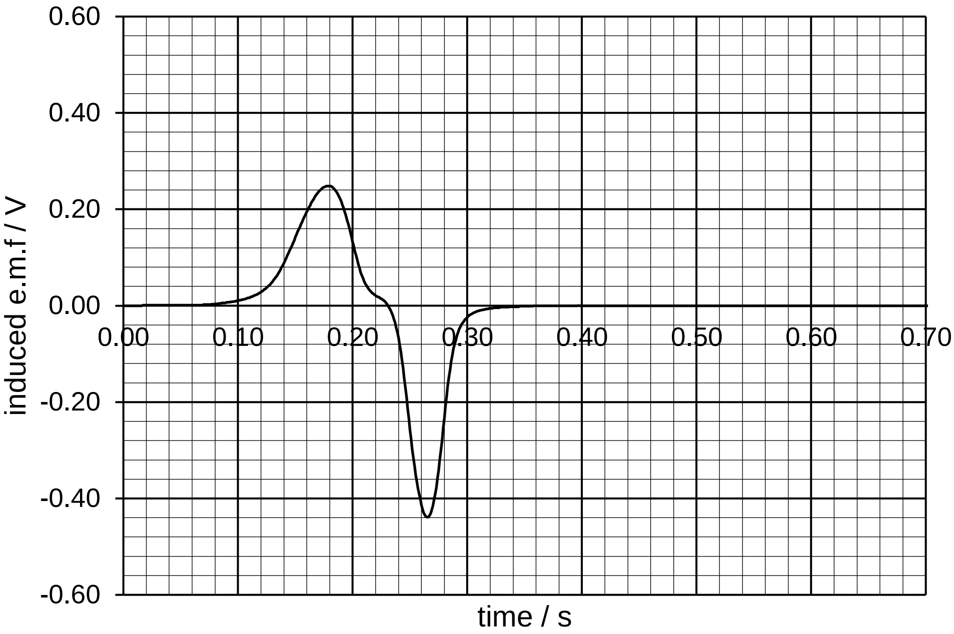

Fig. 6.3

(i) Using the laws of electromagnetic induction, explain the following features of the graph in Fig. 6.3.

1. The magnitude of the induced e.m.f. changes with time.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

2. The induced e.m.f. has opposite sign.

…………………………………………………………………………………………………

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

3. The magnitude of the maximum e.m.f. is different at 0.18 s and 0.26 s.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

[Turn over

For Examiner's Use

(ii) The coil in Fig. 6.2 is replaced with a longer coil of similar material such that the length is much longer than the magnet. The magnet is now released from the same height above the coil.

On Fig. 6.3, sketch a graph to show how the induced e.m.f would vary with time when the magnet falls through the longer coil. Label the graph L. [2]

(d) A sinusoidal alternating current source of frequency 50 Hz is connected to a resistor R of resistance 2.0 kΩ, an ideal diode and an oscilloscope, as shown in Fig. 6.4. The r.m.s. current through the resistor is 5.0 mA. Assume the oscilloscope has infinite resistance.

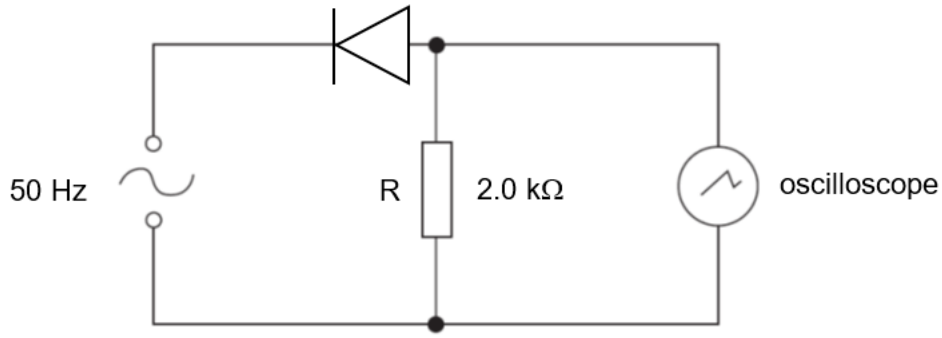

Fig. 6.4

(i) Calculate the peak value of the voltage across R.

peak voltage = ……………………… V [2]

For Examiner's Use

(ii) Fig. 6.5 represents the screen of the oscilloscope, each square being 1 cm × 1 cm. The time base of the oscilloscope is set at 5 ms cm^{-1} and the voltage sensitivity is 5.0 V cm^{-1}.

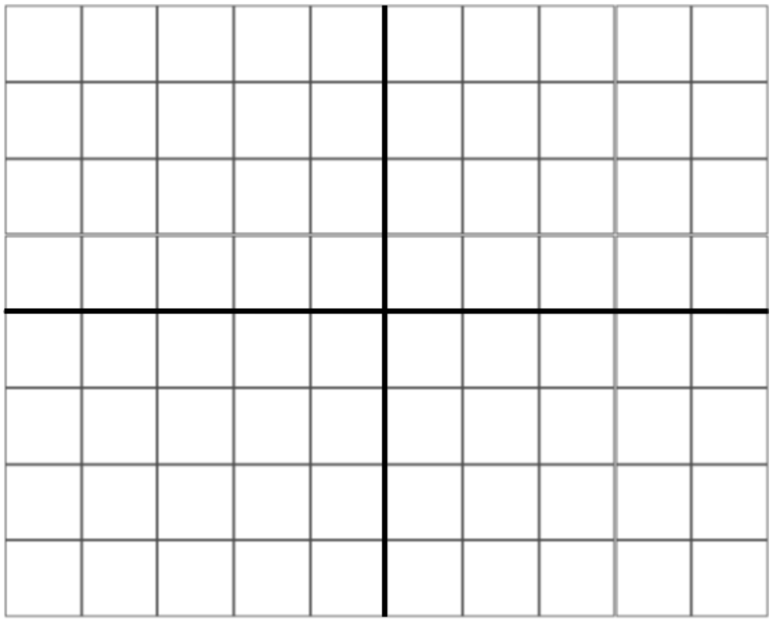

Fig. 6.5

On Fig. 6.5, sketch the signal seen on the screen of the oscilloscope. [2]

[Total: 20]

For Examiner's Use

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

....

....

.... [2]

(b) **(i)** Describe the appearance of a visible line emission spectrum.

....

.... [1]

(ii) Explain how the emission line spectra provides evidence for discrete energy levels in isolated atoms.

....

....

....

.... [2]

(c) The energy levels in eV of the electron in the hydrogen atom are given by

$$E = -\frac{13.6}{n^2},$$

where n = 1, 2, 3, …

(i) Explain what is meant by the ground state of an atom.

....

.... [1]

(ii) The electron in the hydrogen atom is in its ground state.

Calculate the energy in joules required to remove this electron from the atom.

energy = ... J [2]

For Examiner's Use

(d) The wavelengths λ of electromagnetic radiation emitted by hydrogen atoms when electrons move to level n = 2 from a higher level m is given by the formula

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{m^2}\right) \quad , \quad m = 3, 4, 5, \ldots$$

where R is a constant called Rydberg constant.

(i) Show that R is $1.09 \times 10^7\ \text{m}^{-1}$.

[3]

(ii) Calculate the longest wavelength of the photons emitted for electron transitions to level n = 2.

longest wavelength = ……………………… m [2]

(iii) State the region of the electromagnetic spectrum this wavelength belongs to.

……………………………………………………………………………………… [1]

For Examiner's Use

(e) De Broglie proposed that particles such as electrons exhibit wave behaviour and have an associated wavelength called the de Broglie wavelength. To explain the existence of discrete energy levels in an atom, de Broglie further proposed that electrons in an atom can only occupy orbits in which the circumference of the orbit is equal to whole number multiples of the electron wavelength. Hence, electrons can only possess specific energies associated with these allowed orbits.

(i) State an evidence that shows that electrons behave like waves.

.... [1]

(ii) A particular allowed orbit in the hydrogen atom has a radius 4.78×10^{-10} m. The circumference of this orbit is equal to three times the electron wavelength.

Determine the velocity v of an electron in this orbit.

v = ... m s^{-1} [3]

(iii) If the uncertainty in the position of an electron in this orbit is 0.0100 nm, determine the uncertainty in the electron's velocity.

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

[Total: 20]

End of Paper