H

TEMASEK JUNIOR COLLEGE
2023 JC2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CG

PHYSICS 9749/03

Paper 3 Longer Structured Questions

13 September 2023

2 hours

Candidates answer on the Question Paper.

No additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, CG and subject tutor's name 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

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	
Section A	
1	
2	
3	
4	
5	
6	
Section B	
7	
8	
s.f.	
Total	

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} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} Js
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	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T/°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	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
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	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{ln2}{t_{1/2}}$

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

Section A

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

1 **(a)** With reference to electric field lines, explain why, for points outside an isolated charged spherical conductor, the charges on the sphere may be considered to act as a point charge at its centre.

....

....

.... [1]

(b) Two vertical metal plates in a vacuum have a separation of 4.0 cm. A potential difference of 2.0×10^2 V is applied between the plates. Fig. 1.1 shows a side view of this arrangement.

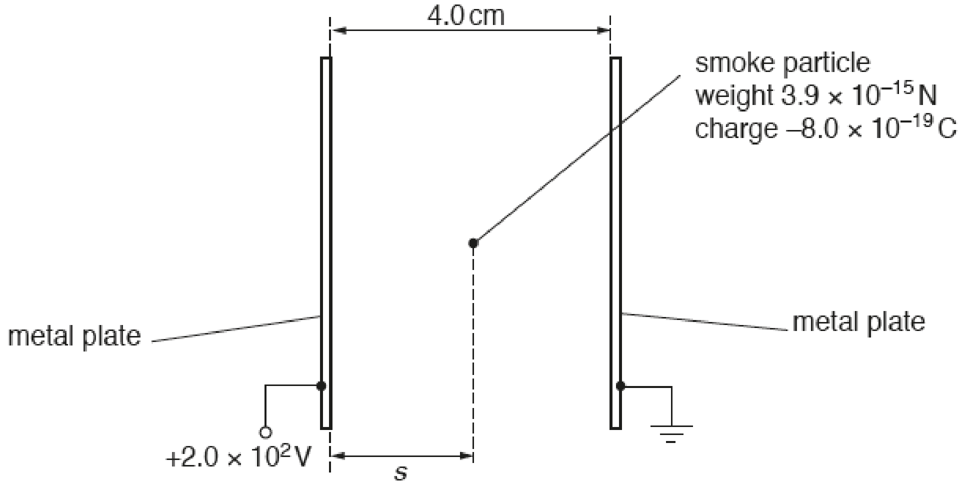

Fig. 1.1

An isolated smoke particle is in the uniform electric field between the plates. The particle has weight 3.9×10^{-15} N and charge -8.0×10^{-19} C.

(i) On Fig. 1.1, draw labelled arrows to show the directions of the two forces acting on the smoke particle. [1]

(ii) The resultant force acting on the smoke particle is *F*.

Determine

1. the magnitude of *F*,

F = ... N [3]

2. The angle of F to the horizontal.

angle = ... ° [1]

(c) **(i)** The electric field in **(b)** is switched on at time t = 0 when the particle is at a horizontal displacement s = 2.0 cm from the left-hand plate. At time t = 0 the horizontal velocity of the particle is zero. The particle is then moved by the electric field until it hits a plate at time t = T.

On Fig. 1.2, sketch the variation with time t of the horizontal displacement s of the particle from the left-hand plate.

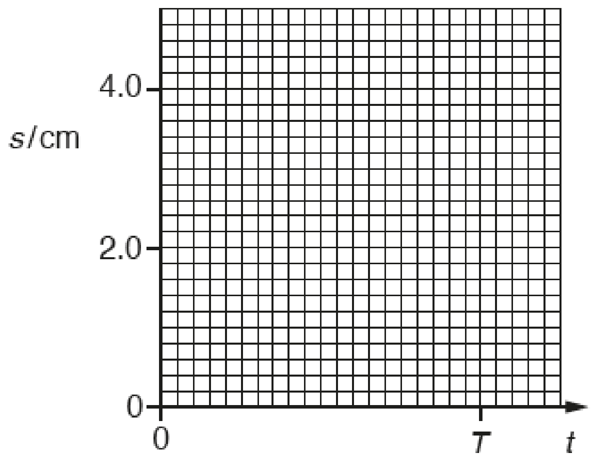

Fig. 1.2

[2]

(ii) Determine the time T.

T = ... s [2]

[Total: 10]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

2 **(a)** State the relationship between gravitational potential ϕ and gravitational field strength g.

....

.... [1]

(b) In a binary star system, star B of mass M and radius R and star A of mass $3M$ and radius $2R$ are separated at a distance D between their centres, as shown in Fig. 2.1.

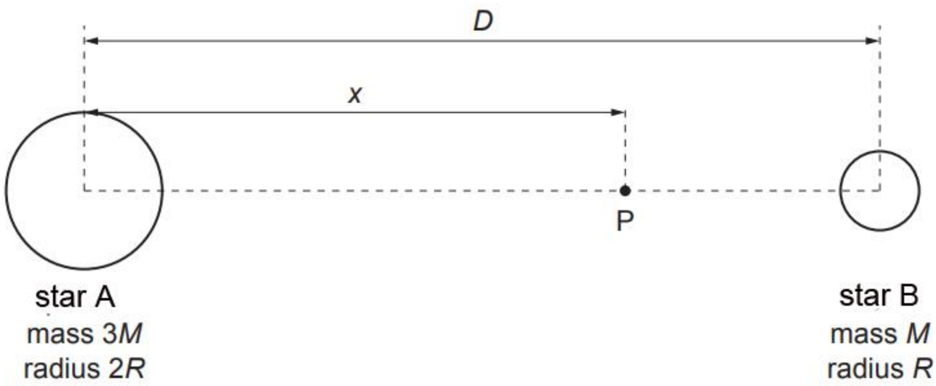

Fig. 2.1

Point P is a point along the line between the centres of the two stars, at a variable distance x from the centre star A.

The variation with x of the gravitational potential ϕ at point P, for points between the stars is shown in Fig. 2.2.

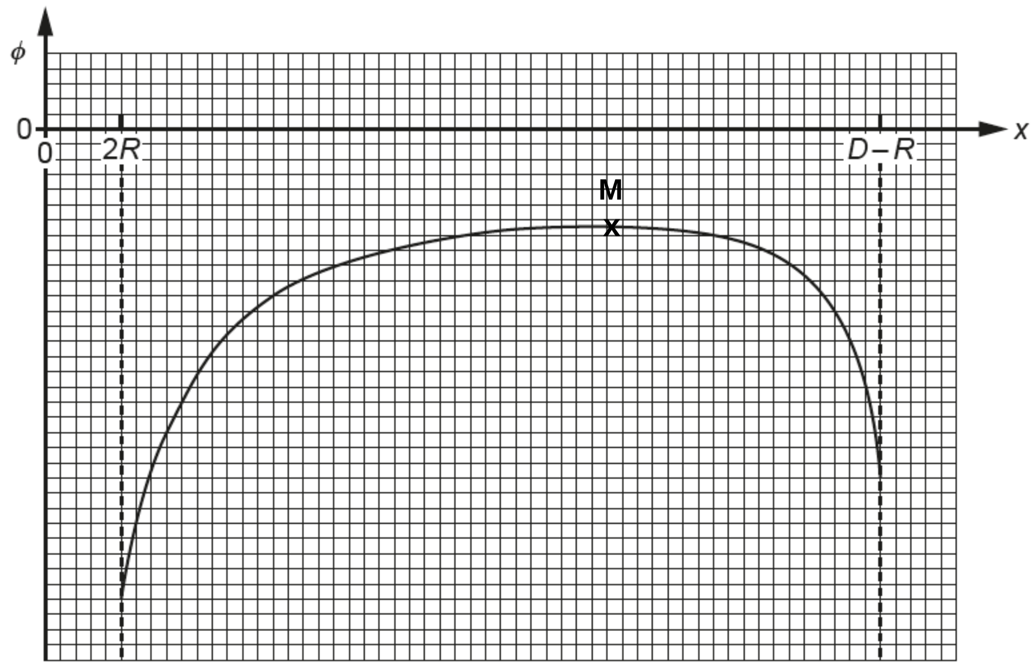

Fig. 2.2

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

(i) Deduce whether the gravitational field strength at the surface of star A is greater or less than the gravitational field strength at the surface of star B.

Show your workings, if any, in the spaces provided.

....

.... [2]

(ii) Explain the significance of the maximum point **M** on the graph.

....

....

.... [1]

(iii) On Fig. 2.3, sketch the variation with *x* of the gravitational field strength *g* at point P between $x = 2R$ and $x = D - R$. No numerical values is required.

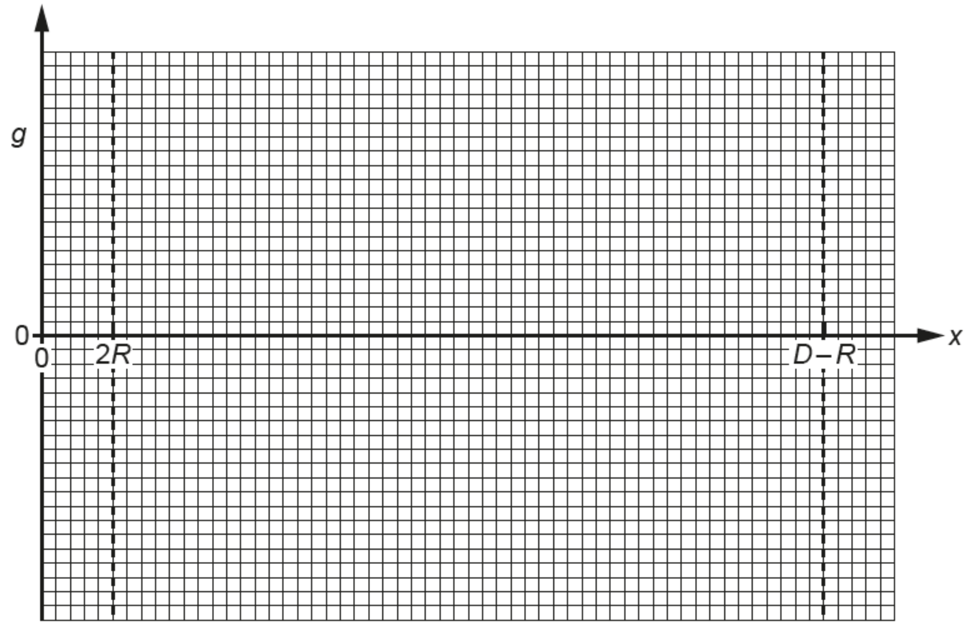

Fig. 2.3

[2]

(c) The stars in **(b)** are in circular orbits with the same angular speed ω and with the centres of both orbits at point C, a distance d from the centre of star A, as shown in Fig. 2.4.

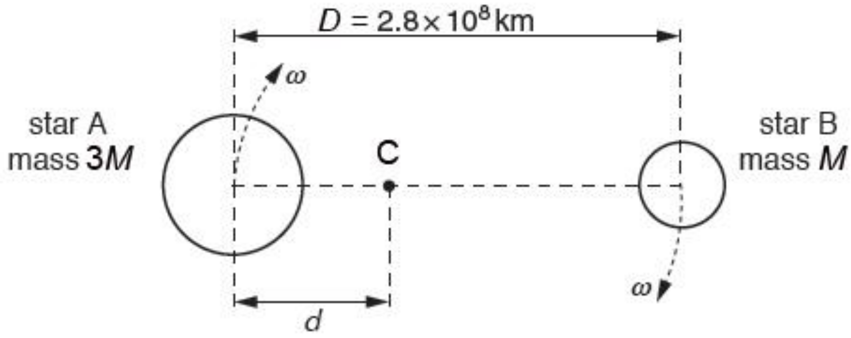

Fig. 2.4

(i) Explain why the centripetal force acting on both stars has the same magnitude.

....

....

.... [1]

(ii) Explain why both stars rotate with the same angular speed ω.

....

....

.... [1]

(ii) The separation D of the centres of the stars is 2.8×10^8 km.
Determine the distance d.

d = ... km [2]

[Total: 10]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

3 **(a)** The internal energy of an ideal gas is dependent on its state, and is given by the sum of the *random* kinetic energies of all its molecules.

(i) Explain why it is important to include the word *random* in this definition.

....

....

.... [1]

(ii) Explain why the potential energy of the molecules is not included in this definition.

....

....

.... [1]

(iii) The pressure p exerted by an ideal gas is given by the equation

$$p = \frac{1}{3}\rho < c^2 >$$

where ρ is the density of the gas.

Use this equation to derive an expression for the total internal energy U of n moles of an ideal gas at temperature T.

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

[2]

(iv) State two physical conditions under which a real gas will behave approximately as an ideal gas.

1. ....

....

2. ....

....

[2]

(b) A heat engine uses 10 moles of an ideal gas as a working substance. Fig. 3.1 shows the changes in pressure and volume of the gas during one cycle ABCA of operation of the engine.

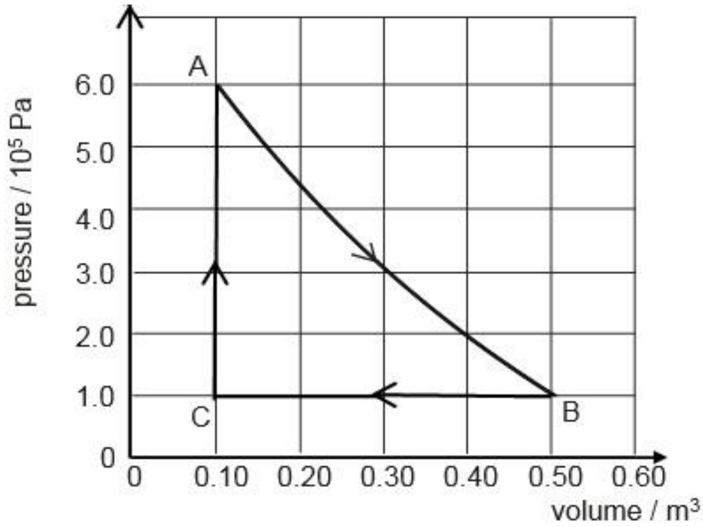

Fig. 3.1

(i) Using values from Fig. 3.1, calculate the temperature of the gas at point A.

temperature = ... K [2]

(ii) Show that the process A $\rightarrow$ B does not take place at a constant temperature.

Show your workings in the spaces provided.

....

.... [1]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

(iii) Use Fig. 3.1 to estimate the net work done by the gas during one cycle.

work done = ... J [2]

(iv) Hence, or otherwise, calculate the amount of heat absorbed by the gas during one cycle.

heat absorbed = ... J [1]

[Total: 12]

DO NOT WRITE IN THIS MARGIN

4 (a) A speaker emits sound waves uniformly in all directions. Fig. 4.1 shows the variation with time t of the displacement x of an air molecule at a point Q that is 120 cm from the speaker.

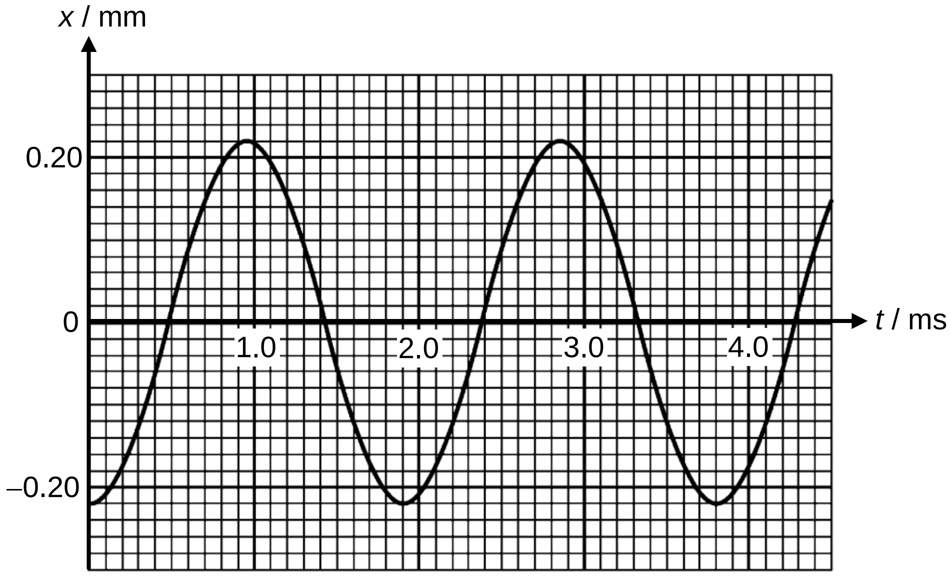

Fig. 4.1

(i) Use Fig. 4.1 to determine the frequency f of the sound waves,

f = ... Hz [2]

(ii) Determine the next earliest time after 1.5 ms when the motion of the air molecule at Q has a phase difference of $\frac{4}{5}\pi$ rad compared to its phase at 1.5 ms.

time = ... ms [2]

(iii) If the power of the speaker is reduced to 0.25 of its initial value, calculate the distance from the speaker that will have the same intensity as that at point Q.

distance = ... m [2]

(b) The wave arriving at point Q is progressive in nature. A stationary wave may be formed when two identical waves travelling in opposite directions superpose.

State the differences between the particles of a progressive wave and particles of a stationary wave in the following aspects:

(i) amplitude,

....

....

.... [1]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

(ii) phase.

....

....

.... [1]

[Total: 8]

5 **(a)** Interference fringes may be observed using a light-emitting laser to illuminate a double slit. The double slit acts as two sources of light.

(i) Explain the part played by diffraction in the production of the fringes.

....

....

....

....

.... [2]

(ii) Explain the reason why a double slit is used rather than two separate sources of light.

....

.... [1]

(ii) State two changes to the fringe pattern with when an identical beam of light passes through a diffraction grating which has the same separation between adjacent slits as the double slit.

1. ....

....

2. ....

....

[2]

(b) A laser emitting light of a single wavelength is used to illuminate slits S_1 and S_2, as shown in Fig. 5.1.

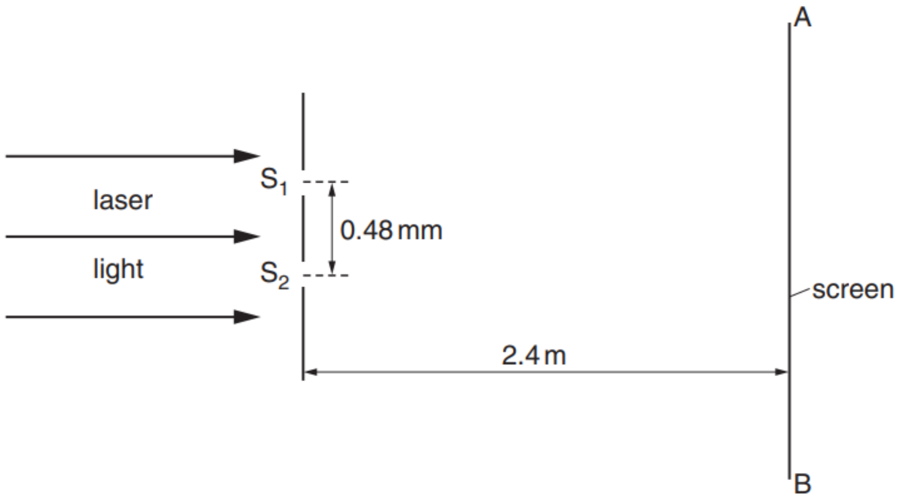

Fig. 5.1 (not to scale)

An interference pattern is observed on the screen AB. The separation of the slits is 0.48 mm. The slits are 2.4 m from AB. The distance on the screen across 16 fringes is 36 mm, as illustrated in Fig. 5.2.

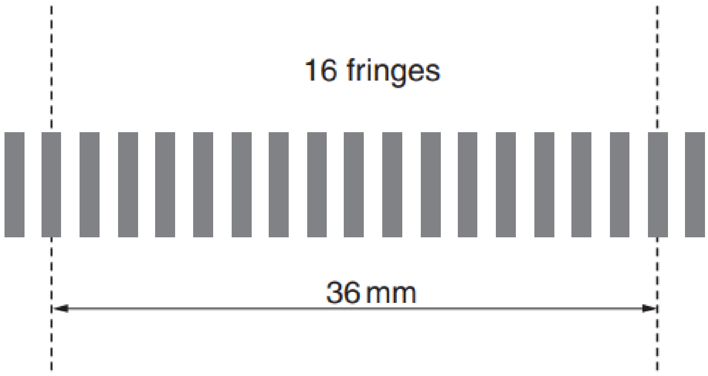

Fig. 5.2

Calculate the wavelength of the light emitted by the laser.

wavelength = ... m [3]

(c) Two dippers D_1 and D_2 are used to produce identical waves on the surface of water, as illustrated in Fig. 5.3.

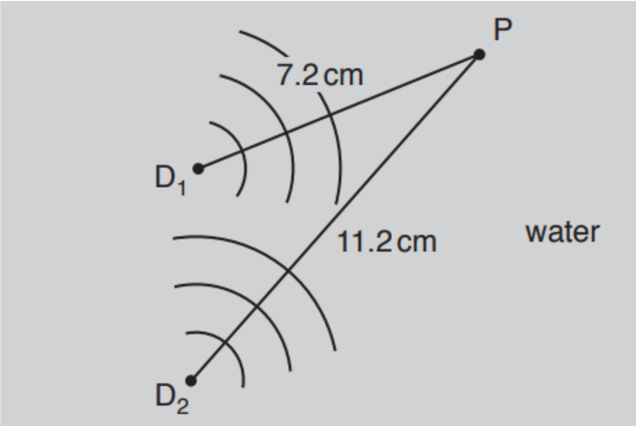

Fig. 5.3

Point P is 7.2 cm from D_1 and 11.2 cm from D_2. The wavelength of the waves is 1.6 cm. The phase difference between the waves produced at D_1 and D_2 is zero.

(i) State and explain what is observed at P.

....

....

....

....

.... [2]

(ii) State and explain the effect on the answer to **(c)(i)** if the apparatus is changed so that, separately,

1. the phase difference between the waves at D_1 and at D_2 is 180°,

....

....

.... [1]

2. the intensity of the wave from D_1 is less than the intensity of that from D_2.

....

....

.... [1]

[Total: 12]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

6 **(a)** A simple iron-cored transformer is illustrated in Fig. 5.1.

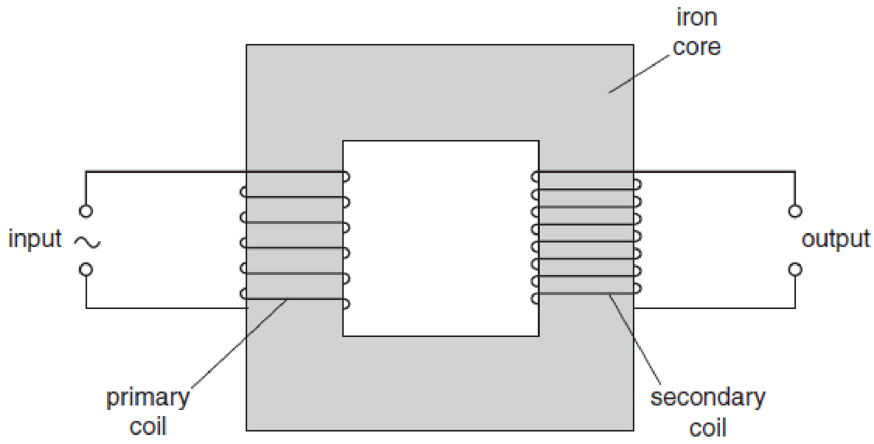

Fig. 5.1

(i) Explain why the primary and secondary coils are wound on a core made of iron.

....

.... [1]

(ii) Suggest why thermal energy is generated in the core when the transformer is in use.

....

....

....

....

....

....

.... [2]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

(b) A student is asked to design a circuit by which a direct voltage of peak value 9.0 V is obtained across a load from a 240 V alternating supply. The student uses a transformer that may be considered to be ideal and a rectifier incorporating an ideal diode.

The partially completed circuit diagram is shown in Fig. 5.2.

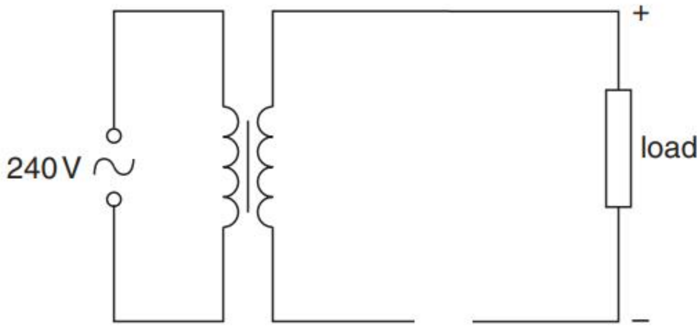

Fig. 5.2

(i) On Fig. 5.2, insert a symbol for the diode so as to produce the polarity across the load as shown on the diagram. [1]

(ii) Calculate the ratio

$$\frac{\text{number of turns in the secondary coil}}{\text{number of turns in the primary coil}}.$$

ratio = ... [3]

(iii) The load has a resistance of 4.5 Ω.

Calculate the mean power dissipated in the load.

mean power = ... W [2]

[Total: 9]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

Section B

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

7 A uniform magnetic field of flux density B makes an angle θ with a rectangular metal frame PQRS of area A, as shown in Fig. 7.1.

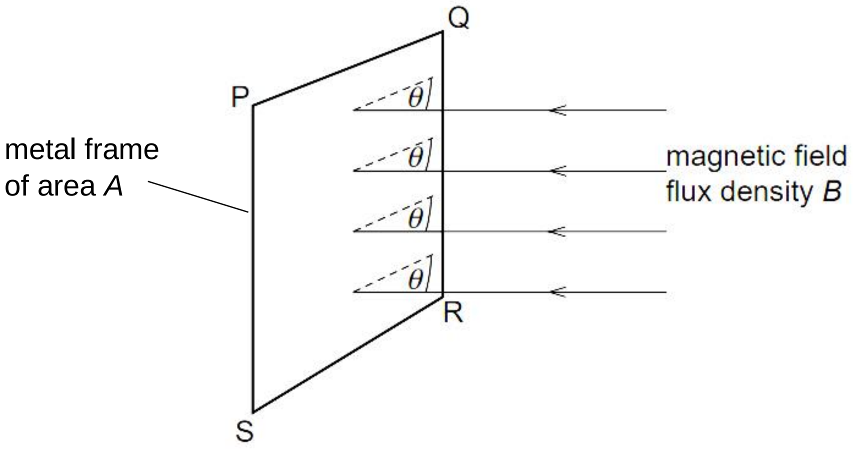

Fig. 7.1

(a) Distinguish between magnetic flux density and magnetic flux.

....

....

....

....

....

....

.... [3]

(b) Write an expression, in terms of A, B and θ, for the magnetic flux ϕ linking the frame PQRS.

.... [1]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

(c) The frame PQRS has width PQ = 52 cm and length QR = 95 cm. It is suspended by two non-conducting rods as shown in Fig. 7.2. The frame is rotated at a constant angular speed ω about the vertical axis through the rods.

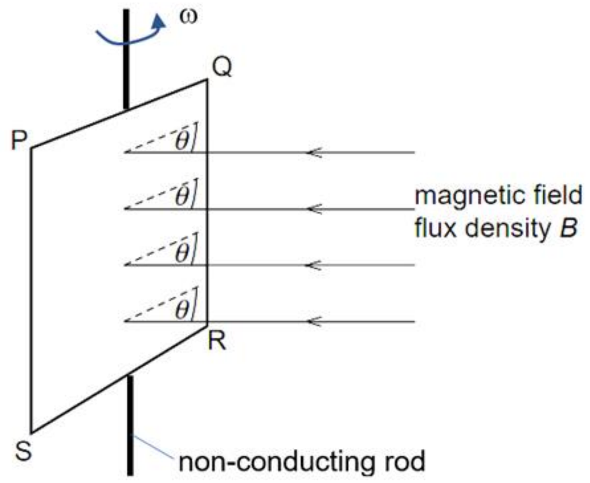

Fig. 7.2

The magnetic field density B is 1.8 T.

(i) Calculate the magnetic flux ϕ linking the metal frame when θ = 90°.

ϕ = ... Wb [2]

(ii) Explain, using the laws of electromagnetic induction, why there is an induced e.m.f. in the frame.

....

....

....

....

.... [2]

(iii) State the sides of the frame PQRS between which the e.m.f. is induced.

side .... and .... [1]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

(iv) The graph in Fig. 7.3 shows how the induced e.m.f. varies over one cycle of rotation of the coil.

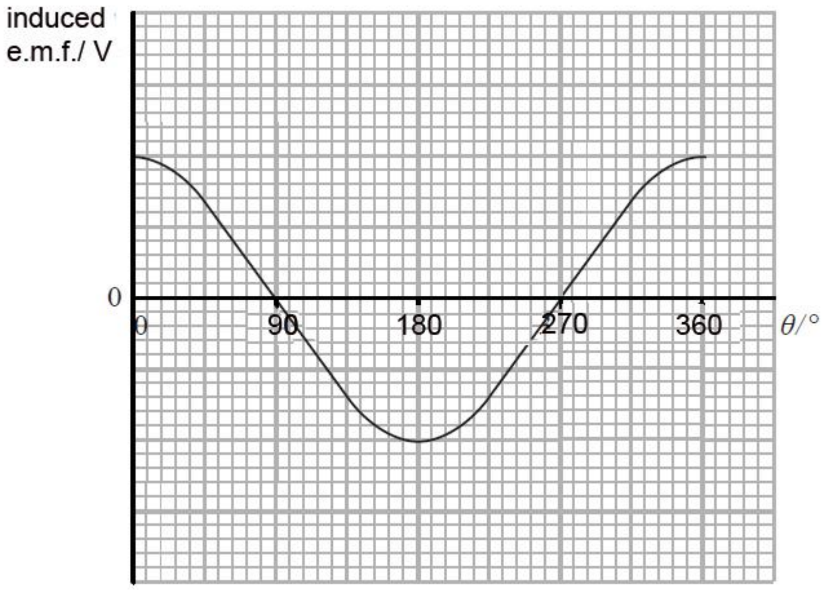

Fig. 7.3

1. Explain why the magnitude of the induced e.m.f. is maximum and zero at the values of θ shown in the graph.

....

....

....

....

....

....

....

.... [3]

2. Explain why the shape of the graph is sinusoidal.

....

....

....

....

.... [2]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

3. The angular speed ω is 4π rad s^{-1}.

Calculate the maximum value of the induced e.m.f. in the frame.

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

4. The resistance of the frame PQRS is 4.8 Ω.
Calculate the r.m.s current in the frame.

r.m.s current = ... A [2]

(vi) State and explain how the graph in Fig. 7.3 would differ if the frame rotated at a slower angular speed.

....

....

....

.... [2]

[Total: 20]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

8 **(a)** Cobalt-60, an isotope widely used in medicine, decays by emitting an electron (β^- decay) with a half-life of 5.272 years into an excited state of nickel-60, which then de-excites very quickly to the ground state of nickel-60 by emitting a number of gamma photons.

(i) Complete the nuclear equation for the Co-60 decay below.

$$^{60}_{.....}\mathrm{Co} \rightarrow\ ^{.....}_{28}\mathrm{Ni} +\ ^{.....}_{.....}\mathrm{e} + \gamma$$

[2]

(ii) Calculate the activity of 1.0 g of Cobalt-60.

activity = ... Bq [3]

(b) The emission spectrum of the gamma photons emitted by the de-excitation of nickel-60 is shown in Fig. 8.1.

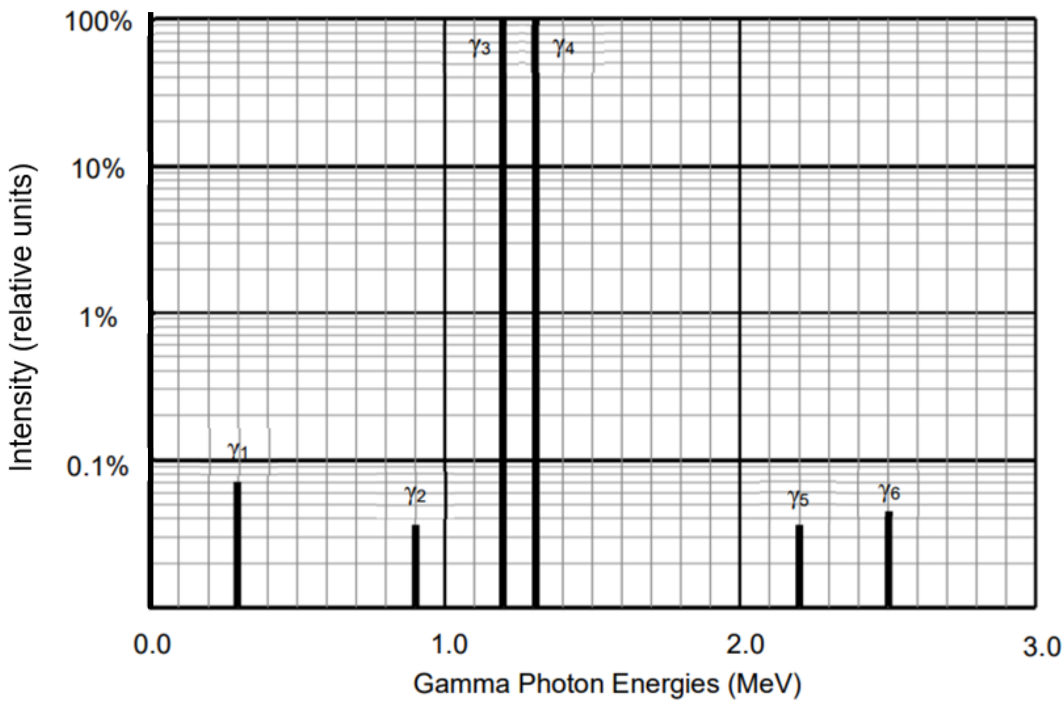

Fig. 8.1

(i) Explain what is meant by a *gamma photon*.

....

....

.... [2]

(ii) Explain why Fig. 8.1 provides evidence that the nucleus has discrete energy levels.

....

....

....

....

.... [2]

(iii) A few energy levels of the nucleus of nickel-60 are shown in Fig. 8.2.

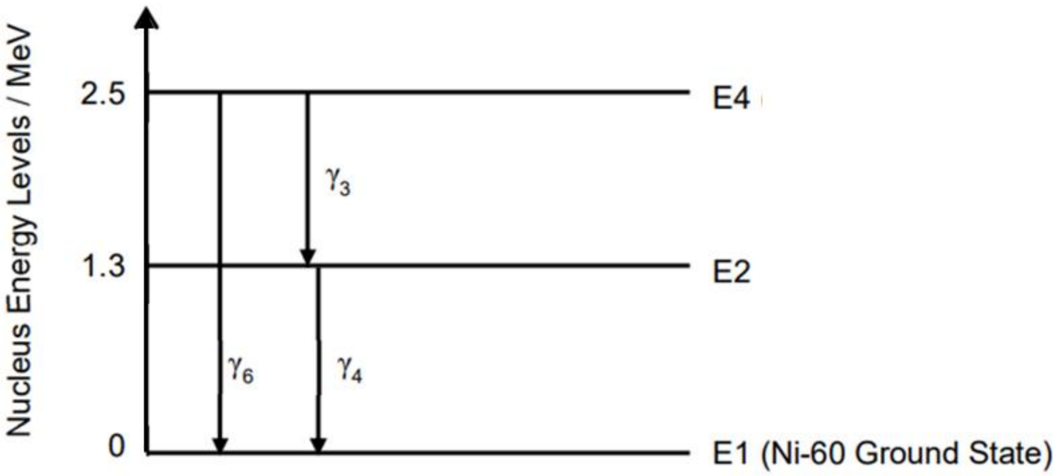

Fig. 8.2

1. There is a missing energy level E3 (between E2 and E4) in Fig. 8.2. With reference to Fig. 8.1, deduce the energy of this level. Draw and label the missing energy level E3 on Fig. 8.2.

energy of E3 level = ... MeV [2]

DO NOT WRITE IN THIS MARGIN

2. Hence sketch and label the transitions which correspond to the emission of γ_1, γ_2 and γ_5 photons on Fig. 8.2. [2]

3. The rest-mass of the Ni-60 nucleus at the ground state E1 is 59.93079 *u*. Calculate the mass, in *u*, of the Ni-60 nucleus at its excited state E4. Leave your answer to 7 s.f..

mass = ... *u* [3]

(c) Co-60 sources are often kept in lead containers. The interaction between the β^- particles and the lead atoms give rise to a continuous spectrum of X-ray radiation.

(i) Explain the origin of the **continuous** spectrum of X-ray.

....

....

....

....

....

.... [2]

(ii) Given that the maximum energy of the β particle is 0.30 MeV, calculate the cut-off wavelength of the continuous spectrum of X-ray.

wavelength = ... m [2]

[Total: 20]

DO NOT WRITE IN THIS MARGIN

DO NOT WRITE IN THIS MARGIN

BLANK PAGE