H2 PHYSICS

Exam papers with worked solutions

(Selected from Top JC)

SET B

PAPER 3

Compiled by

THE PHYSICS CAFE

READ THESE INSTRUCTIONS FIRST

Write your name and tutorial group on all the work you hand in.

Write in dark blue or black pen in the spaces provided on the Question Paper.
You may use a soft pencil for any diagrams, graphs or rough working
Do not use staples, paper clips, highlighters, glue or correction fluid

Section A
Answer **all** questions

Section B
Answer any **two** questions

You are advised to spend about an hour on each section.
The number of marks is given in brackets [ ] at the end of each question or part question.

This question paper consists of **19** printed pages.

PHYSICS DATA:

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

PHYSICS FORMULAE:

uniformly accelerated motion,	s	=	$u t + \frac{1}{2} a t^2$
	v^2	=	$u^2 + 2 a s$
work done on / by a gas,	W	=	$p \Delta V$
Hydrostatic pressure	P	=	$\rho g h$
gravitational potential,	ϕ	=	$-G m / r$
Displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
Velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^2 - x^2}$
resistors in series,	R	=	$R_1 + R_2 + ...$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + ...$
electric potential,	V	=	$Q / 4 \pi \varepsilon_0 r$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
Transmission coefficient	T	=	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in this section.

1 (a) When fire-fighters encourage victims to jump off a burning building, they would usually place a safety net below to catch the victims as they land. In a particular fire, the victim jumps horizontally off the window of the sixth storey. Assume that the window is 22.8 m from the ground and that the net was placed 1.0 m above ground level.

(i) Determine the duration the victim takes to fall to the safety net placed at the base of the building. [2]

Duration = …… s

(ii) At what speed did the fire-fighter expect the victim to jump out of the building if the safety net was 5.0 m away from the base of the building? [2]

Speed = …… m s^{-1}

(b) The safety net is elastic in nature and requires 50 N to depress 1.0 mm. Taking the average mass of a person to be 75 kg,

(i) Calculate the average depression of the net when the speed of the victim **first** reaches zero. [2]

Average depression = …… m

(ii) Determine the average force the net exerted on the victim to stop his fall. [2]

Average force = …… N

(c) With reference to your answers above suggest two factors manufacturers consider when they choose a particular material for making the safety net. [2]

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2 (a) Explain what is meant by two gases having the same internal energies. [2]

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(b) A monoatomic ideal gas has an initial volume of 0.00322 m^3 at a temperature of 300 K and at a pressure of1.0 x10^5 Pa. When heat is supplied at constant pressure, it expands to a final volume of 0.00550 m^3.

Calculate

(i) the final temperature of the gas. Express your answer in degree Celsius. [2]

Final temperature = …… °C

(ii) the work done by the gas. [2]

Work done by gas = …… J

(iii) the change in internal energy. [2]

Change in internal energy = …… J

(iv) the heat supplied to the system. [2]

Heat supplied = …… J

3 (a) Distinguish between potential difference and electromotive force.

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.....[3]

(b) Figure 3.1 below shows a potentiometer which shows a balance point at Z when switches S_1 and S_2 are **closed**.

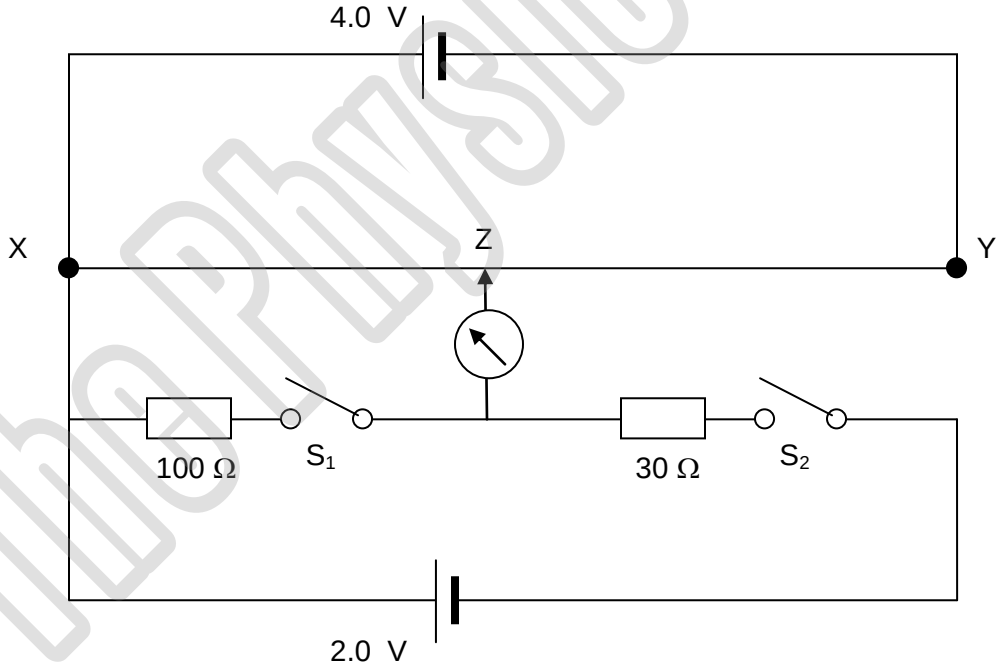

Figure 3.1

(i) Assuming that both cells have negligible resistance, find the potential difference across XZ.

V_{XZ} = ... V. [2]

(ii) Hence, find the balance length XZ, if wire XY is 100 cm long.

XZ = ... cm. [2]

(iii) Determine the new balance length XZ' when the switch S_2 is closed and S_1 is open.

XZ' = ... cm. [2]

(iv) Determine, for the new balance length XZ', the current through the 30Ω resistor when the switch S_2 is closed and S_1 is open.

I = ... A. [1]

4 A junction is formed between slices of p-type and of n-type semi-conductor material, as shown in Figure 4.1 below.

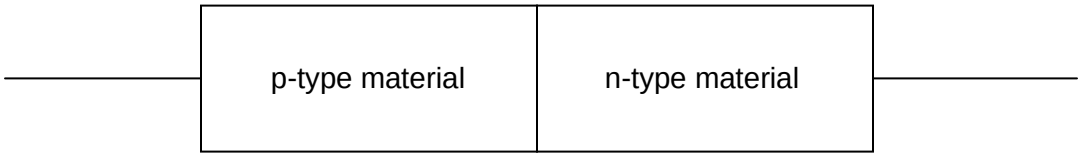

Figure 4.1

(a) On the figure above, draw an arrow to show the direction of movement of electrons as the two slices are brought into contact. [1]

(b) Describe the origin of the depletion region at the junction.

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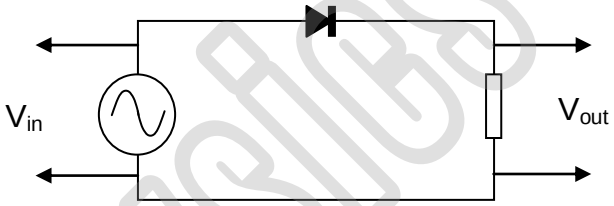
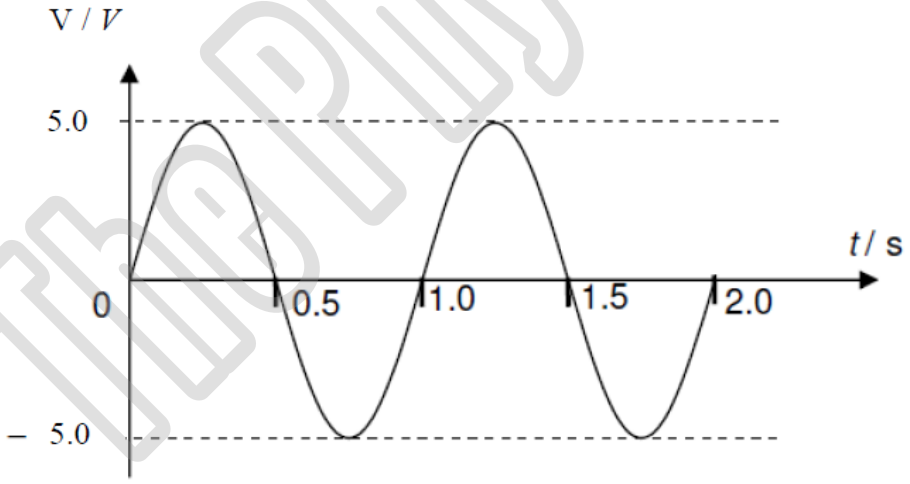
(c) On the figure above, draw the symbol for a battery connected so as to increase the width of the depletion region. [1]

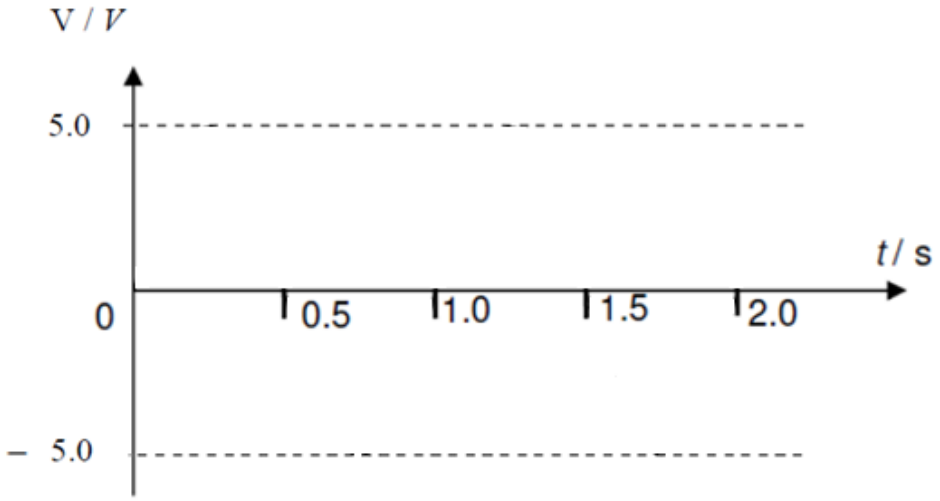
(d) An ohmic resistor is now connected in series to the semiconductor diode in the circuit below.



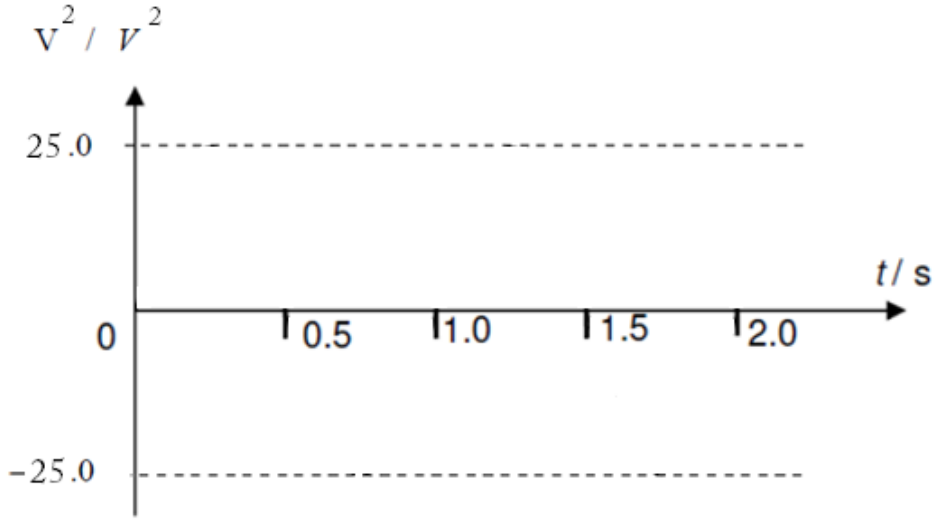
The input signal has the characteristics as shown in the figure below:



(i) Sketch the output signal across a resistor placed in series with the semiconductor. [1]



(ii) Sketch the V^2 / V^2 against the t / *s* graph for the output signal. [1]



(iii) Calculate the average value of the V^2 across the resistor.

$\langle V^2 \rangle$ = ... V^2 [1]

(iv) Hence, calculate the r.m.s. value of the potential difference across the resistor.

$V_{r.m.s.}$ = ... V [1]

Section B

Answer **two** questions in this section.

5 (a) The Earth takes 365 days to orbit around the Sun. The mass of the Sun is 1.989 x 10^{30} kg.

(i) Calculate the angular velocity of the Earth around the Sun. [2]

Angular velocity = …… rad s^{-1}

(ii) Calculate the distance between the Earth and the Sun. [2]

Distance = …… m

(iii) State the assumption made in your calculations. [1]

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(b) At the core of the Sun, two protons are combined to create helium-4 and energy in several steps:

1. Two protons combine to form a deuterium (hydrogen atom with one neutron), a positron (similar to electron, but with a positive charge) and a neutrino.
2. A proton and a deuterium atom combine to form a helium-3 atom (two protons with one neutron) and a gamma ray.
3. Two helium-3 atoms combine to form a helium-4 (two protons and two neutrons) and two protons.

Data needed:

Particle	**Atomic mass / u**
Proton	1.007276
Deuterium	2.01410178
Electron (-e)	0.000549

(i) Given that a neutrino has negligible mass, and a positron is identical to an electron except for its charge, calculate the energy released in the fusion of the two hydrogen atoms in the first step. Leave your answer in MeV. [4]

Energy released = …… MeV

(ii) Write the equation governing the fusion reaction in step 2. [2]

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(iii) State the aspect of the reaction in (ii) that shows the products are more stable than the reactants. [1]

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(iv) Suggest a reason why nuclear fusion requires such high pressure, even though the products are more stable than their reactants. [1]

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(c) The half life of ^{210}Po is about 2.9 years.

(i) If ^{210}Po decays to ^{206}Pb, state the name of the radioactive particle emitted. [1]

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(ii) Determine the decay constant of ^{210}Po in years^{-1}. [2]

Decay constant = …… $years^{-1}$

(iii) A lab is given a sample of 105 g of ^{210}Po. How many grams of ^{210}Po would be left after 10 years. [3]

Mass = …… g

(iv) In the nucleus, the strong nuclear force keeps the nucleons (neutrons and protons) together, overcoming the strong repulsive electrostatic force between protons. Suggest the mechanism by which the helium nucleus escapes the nucleus, overcoming the strong nuclear force. [1]

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6 (a) Figure 6.1 shows a displacement-distance graph for 2 waves **A** and **B**, of the same frequency and amplitude. Wave **A** is traveling to the right and wave **B** is traveling to the left.

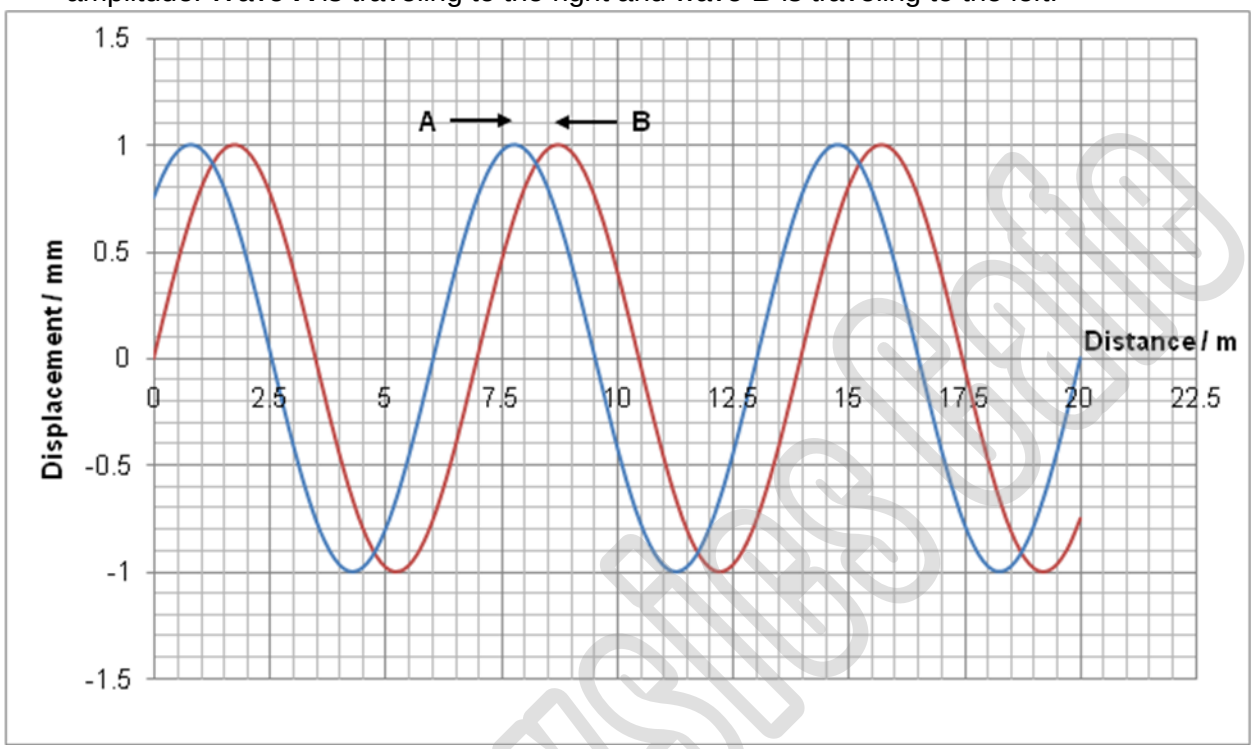

Figure 6.1

(i) State the Principle of Superposition. [2]

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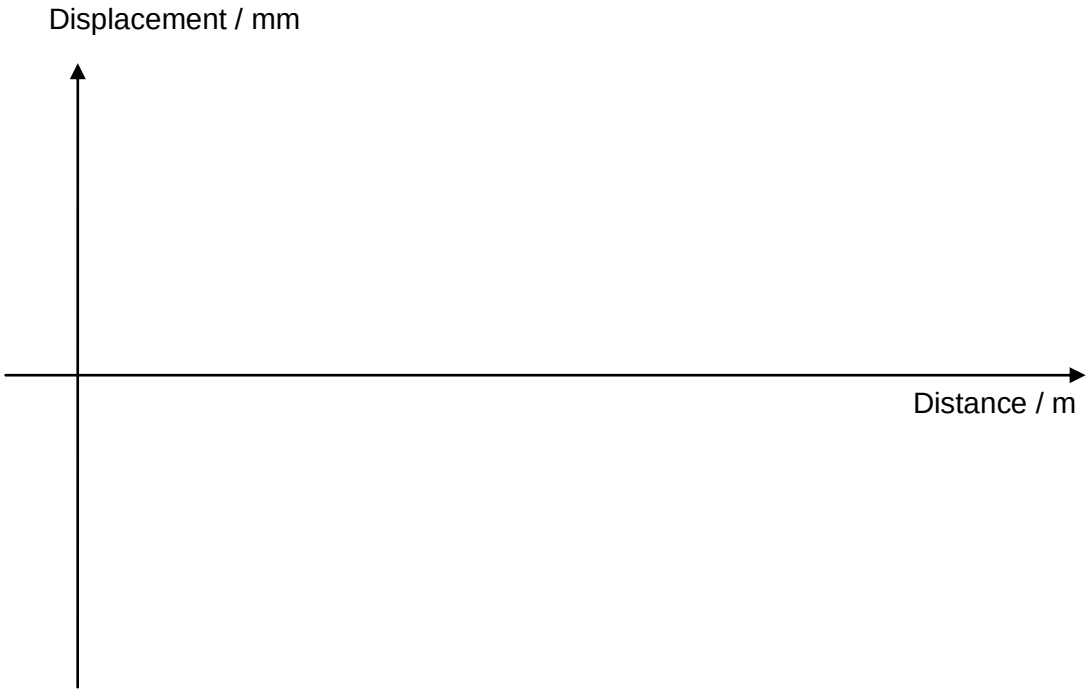
(ii) If the period of each wave is *T*, on the axes below, sketch the graphs of the resultant displacement of the two waves

1. at the instant shown (use a solid line and label graph as t_1).
2. at the instant shown + $\frac{1}{14}T$ (use a dotted line and label graph as t_2).
3. at the instant shown + $\frac{1}{14}T + \frac{1}{2}T$ (use a dotted line and label graph as t_3).

In each case, indicate clearly the maximum displacements and the positions at which they occur. [6]



(iii) Waves **A** and **B** are sound waves. Draw a graph to show the resultant pressure variation when the two waves superpose *at the instant shown* in Figure 6.1. Indicate clearly the regions of compression and rarefaction. Take vectors to the right as positive. [2]

(b) Figure 6.2 shows a Young's Double Slits experiment. A double-slit (S_1 and S_2) is placed in front of a narrow single slit **A** situated in front of a monochromatic light source. Slit **A** is equidistant from slits S_1 and S_2.

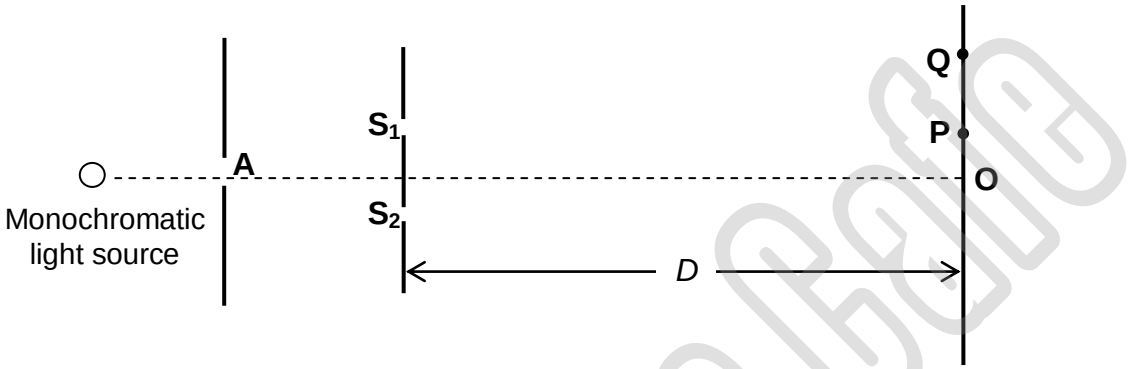


Figure 6.2

(i) Two-source interference fringes using light can only be obtained if light from the two sources is coherent. Explain

1. the meaning of the term *coherent*. [1]

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2. why, in practice, interference fringes can be seen only if light from a single slit is split into two. [2]

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(ii) Suggest a modification that can be made to the setup such that the single slit **A** is no longer required. [1]

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(iii) Point **Q** is the position of the second order dark fringe. State, in terms of the wavelength λ, the path difference between the waves that superpose at point **Q**. [1]

Path difference = …… λ

(iv) Slits $\mathbf{S_1}$ and $\mathbf{S_2}$ are a distance 0.38 mm apart. The distance D between the double slits ($\mathbf{S_1}$ and $\mathbf{S_2}$) and the screen is 1.20 m. The distance between **O** and **Q** is 4.3 mm. Calculate the wavelength of the monochromatic light. Express your answer in nm. [3]

Wavelength = ……nm

(v) Describe and explain the effect if one of the slits is covered with a thin sheet of transparent material of high refractive index. [2]

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7 A simple electric motor (Figure 7.1a) has a rectangular coil (Figure 7.1b) of 120 turns each with dimensions of 5 cm by 4 cm, and of total resistance 0.8 Ω. The strength of the radially symmetrical magnetic field in the region of the coil is 0.5 T.

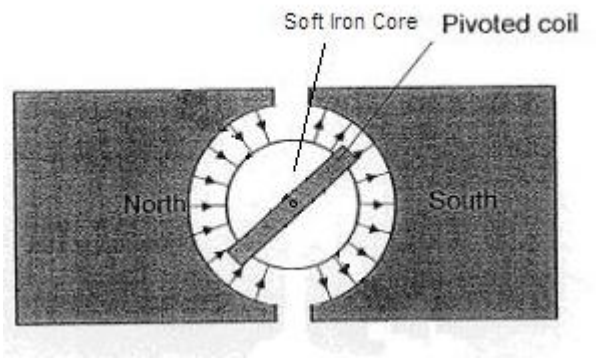

Figure 7.1a (Side View)

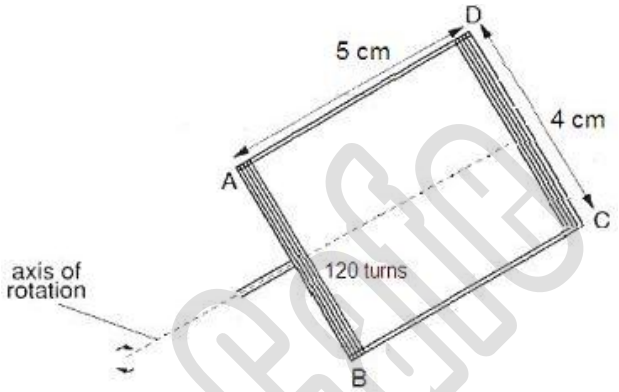

Figure 7.1b (Close-up view of the coil)

(a) (i) Define *magnetic field strength*. [2]

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(ii) Show that the maximum change in magnetic flux when the rectangular coil rotates through 180° is 240 mWb. [2]

It is connected to a 12 V d.c. supply of negligible internal resistance. Figure 7.2 shows the variation of current I with time t when the motor is switched on.

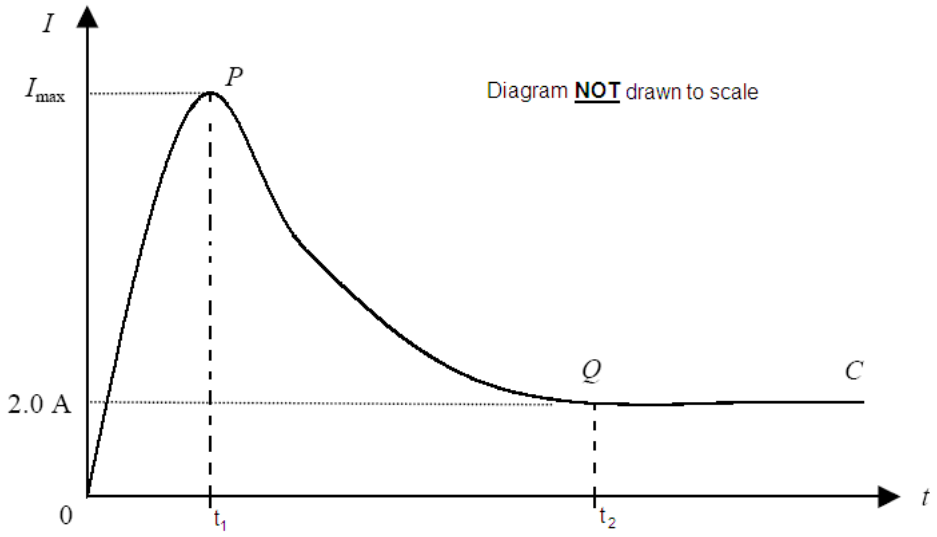

Figure 7.2

(b) (i) Estimate the maximum value of I_{max}. [2]

Estimated value of I_{max} =…….. A. [1]

(ii) Explain why this value is an estimate.

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.....[1]

(c) Explain why the current

(i) rises gradually from zero to its maximum value instead of rising immediately to its maximum value. [2]

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(ii) drops gradually from P to Q. [2]

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(iii) becomes steady along QC. [1]

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(d) What is the maximum moment acting on the coil due to the current in the coil when it is rotating at constant speed (i.e after $t = t_2$)? [3]

Maximum moment = ……Nm

(e) When the motor is switched on, the current is so large such that it may burn out the coil. It has been suggested that a resistor is placed in series with the coil to reduce the current in the circuit. Explain why this is method not practical. [2]

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(f) Figures 7.3.1 below shows two long, parallel vertical wires each carrying equal currents in the same direction. The wires pass through a horizontal sheet of card. Figure 7.3.2 shows a plan view of the wires looking down onto the card.

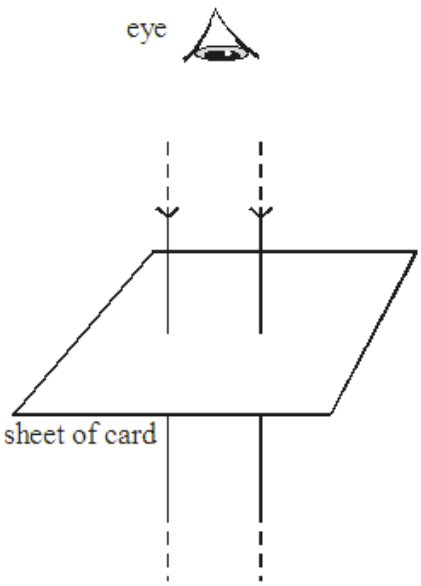

Figure 7.3.1

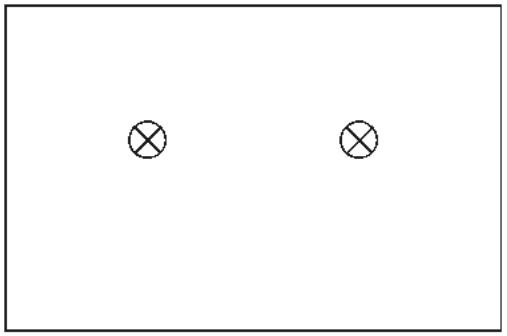

Figure 7.3.2

(i) Draw on Figure 7.3.2 the magnetic field pattern due to the currents in the wire. [2]

(ii) The card is removed and one of the two wires is free to move. Describe and explain the changes in the acceleration of the moveable wire. [2]

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END OF PAPER 3