YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CG		INDEX NUMBER	

PHYSICS 9749/03

Paper 3 Longer Structured Questions **15 September 2021**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and class 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 or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

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

Section A
Answer **all** questions.

Section B
Answer any **one** question.

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 Examiner's Use	
Paper 3	
Section A	
1	**/3**
2	**/7**
3	**/6**
4	**/4**
5	**/10**
6	**/10**
7	**/11**
8	**/9**
Section B	
9	**/20**
10	**/20**
Penalty	
	/80

This document consists of **25** printed pages and **3** blank pages.

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}
			$(1/(36\pi)) \times 10^{-9}$ 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	=	$-\frac{Gm}{r}$
temperature,	T/K	=	$T/°C + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle C^2\rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm\, \omega \sqrt{(x_o^2 - x^2)}$
electric current,	I	=	$A\,n\,v\,q$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots\ldots$
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	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

Section A

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

1 Astronauts in space cannot weigh themselves by standing on a bathroom scale. Instead, they measure their mass by oscillating on a large spring. Typically, an astronaut attaches one end of a large spring to his belt and the other end of the spring is hooked to the wall of the space capsule. A fellow astronaut then pulls him away from the wall and releases him.

The period T of oscillation of the astronaut is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where m is the mass of the astronaut and k the force constant of the spring.

If $T = (3.20 \pm 0.01)$ s and $k = (250 \pm 5)$ N m^{-1}, express the mass of the astronaut and its associated uncertainty. Show your working clearly below.

mass = …………………………….. kg [3]

[Total: 3]

2 **(a)** A student throws a ball, at velocity *u*, towards a hoop, as shown in Fig. 2.1. The dotted curve represents the path the ball makes. It takes 1.1 s from the point of release to reach the hoop.

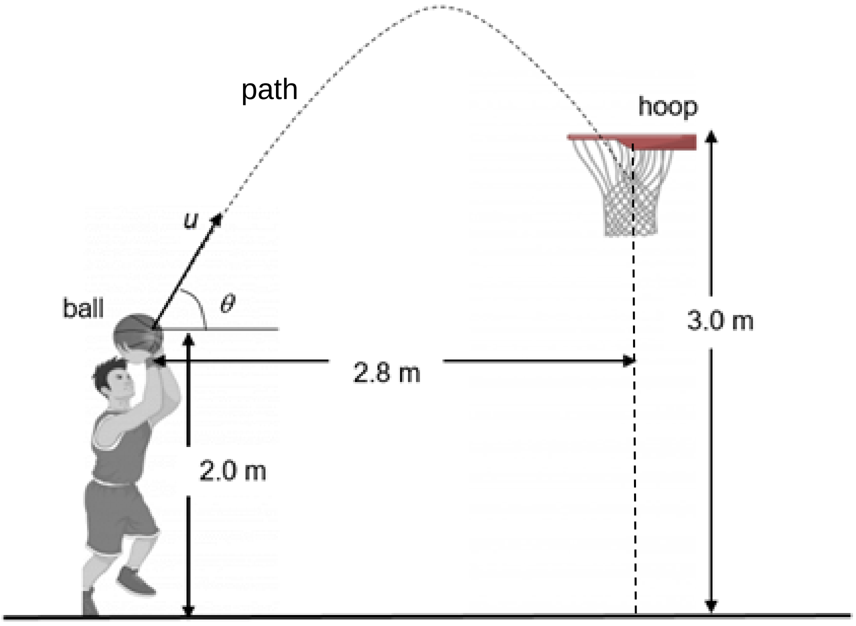


Fig. 2.1

(i) Determine the vertical component of the initial velocity.

vertical component of initial velocity = ……………………… m s^{-1} [2]

(ii) Determine the launch angle θ.

θ = ………………….. ° [3]

(b) The ball is now thrown in a medium of significant air resistance with the same initial speed and direction. Sketch the new path of the ball in Fig. 2.1.

[2]

[Total: 7]

3 A spring is supported so that it hangs vertically, as shown in Fig. 3.1.

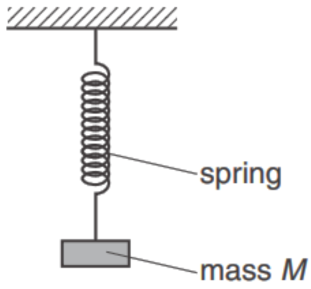


Fig. 3.1

Different masses are attached to the lower end of the spring. The extension x of the spring is measured for each mass M. The variation of M with x is shown in Fig. 3.2.

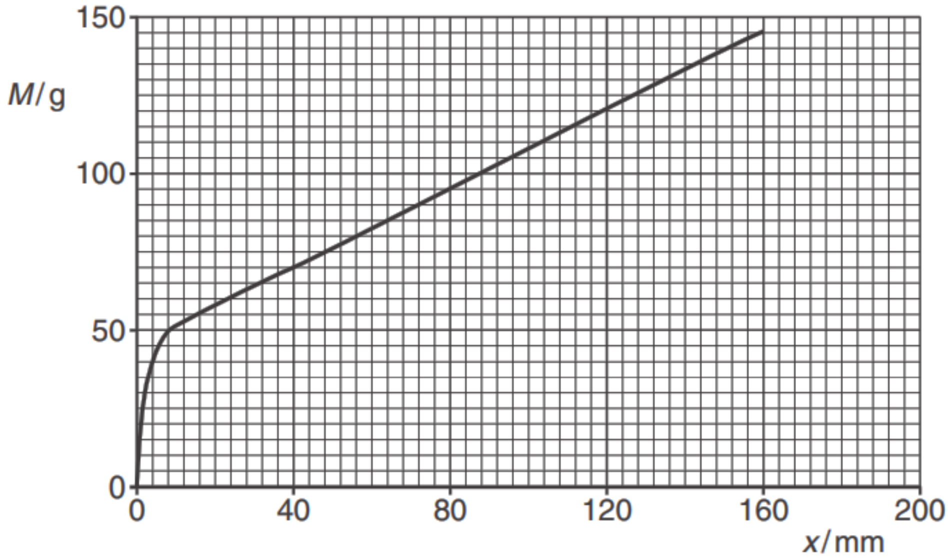


Fig. 3.2

(a) With reference to Fig. 3.2, state and explain whether the spring obeys Hooke's Law.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(b) Describe how to determine whether the spring is permanently deformed after the graph in Fig. 3.2 is obtained.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(c) Calculate the work done on the spring as it is extended from x = 40.0 mm to x = 160.0 mm.

Explain your working.

work done = ……………………. J [3]

[Total: 6]

4 Fig. 4.1 shows two bodies X and Y connected by a light inextensible cord that passes through a frictionless pulley. X starts from rest and moves up a rough plane inclined at 30° to the horizontal. The masses of X and Y are 4.0 kg and 5.0 kg respectively. Ignore effects of air resistance.

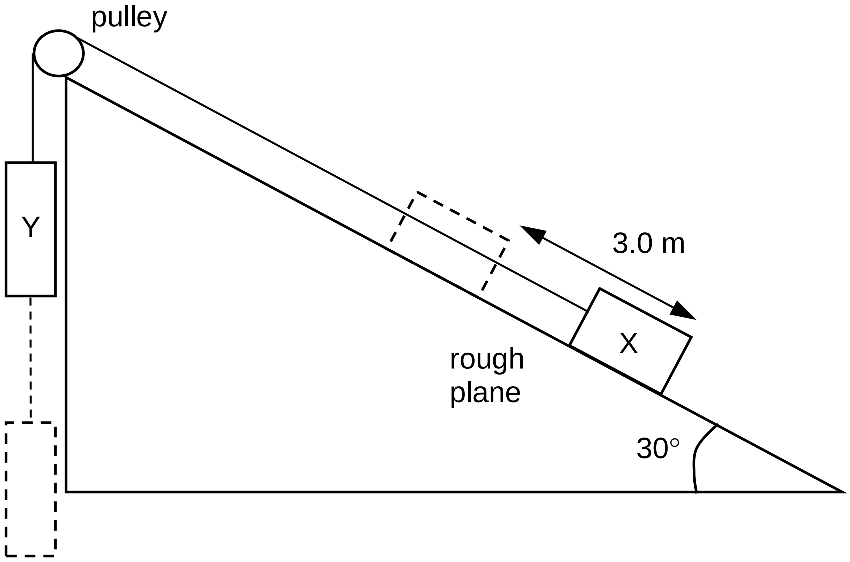


Fig. 4.1

Given that the average frictional force acting on X is 10.0 N, when X has travelled 3.0 m along the plane, determine

(a) the total kinetic energy of the system,

kinetic energy = …………………… J [3]

(b) the speed attained by Y.

speed = …………………… m s^{-1} [1]

[Total: 4]

5 A binary star consists of two stars A and B that orbit about a common centre P, a distance d from the centre of star A, as illustrated in Fig. 5.1.

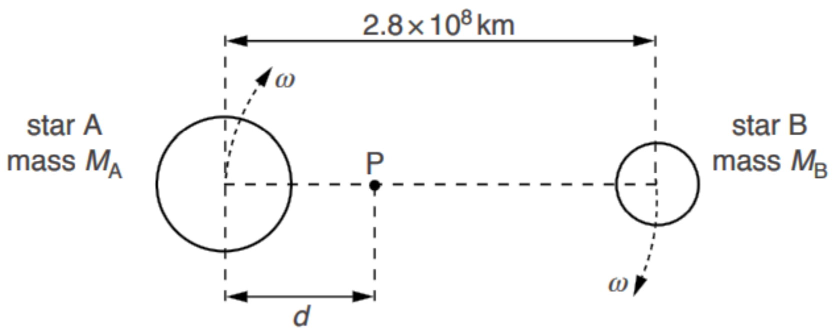


Fig. 5.1

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

....

....

....

.... [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed ω of the stars.

ω = ... rad s^{-1} [2]

(b) The separation of the centres of the stars is 2.8×10^8 km.

The mass of star A is M_A. The mass of star B is M_B.

The ratio of $\frac{M_A}{M_B}$ is 3.0.

(i) Determine the distance d.

d = ………………………… km [3]

(ii) Use your answers in **(a)(ii)** and **(b)(i)** to determine the mass M_B of star B. Explain your working.

M_B = ………………………… kg [3]

[Total: 10]

6 A cylindrical tube, seated at one end, has cross-sectional area A and contains some sand. The total mass of the tube and the sand is M.

The tube floats upright in a liquid of density ρ, as illustrated in Fig. 6.1.

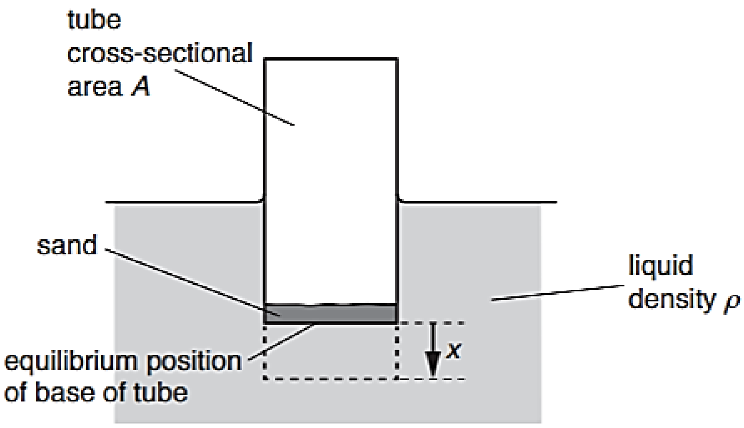


Fig. 6.1

The tube is pushed downwards by a distance of 3.0 cm into the liquid and then released.

(a) **(i)** State the two forces that act on the tube immediately after its release.

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

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

(ii) State and explain the direction of the resultant force acting on the tube immediately after its release.

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

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

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

(b) The acceleration a of the tube is given by the expression

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

where x is the vertical displacement of the tube from its equilibrium position.

Use the expression to explain why the tube undergoes simple harmonic oscillations in the liquid.

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

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

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

(c) The tube has a cross-sectional area A of 4.5 cm^2 and a total mass M of 0.17 kg.

The variation with time t of the vertical displacement x of the tube from its equilibrium position is shown in Fig. 6.2.

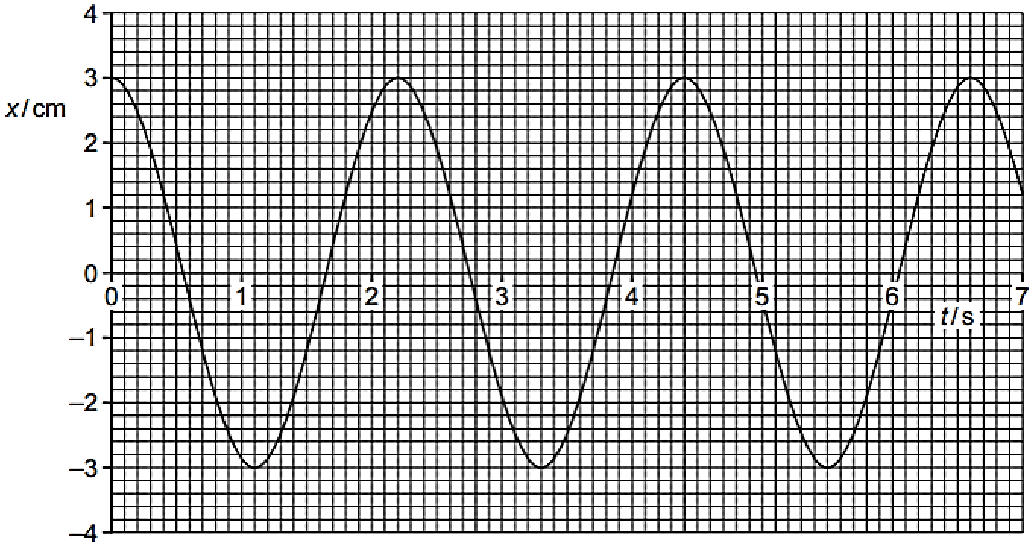


Fig. 6.2

(i) Use Fig. 6.2 to show that the angular frequency ω of oscillation of the tube is 2.9 rad s^{-1}.

[1]

(ii) Determine the density ρ of the liquid in which the tube is floating.

ρ = ………………….. kg m^{-3} [2]

(iii) Determine the speed of the tube as it passes through its equilibrium position.

speed = ……………………. m s^{-1} [2]

[Total: 10]

7 **(a)** Consider the electric field created by the charged parallel plates in Fig. 7.1

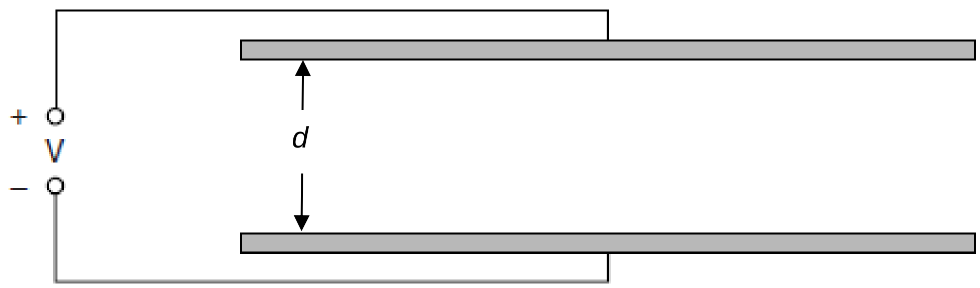


Fig. 7.1

These plates are separated by a distance d and there is a potential difference V between them. A small charge of $+Q$ is moved slowly from the negative plate up to the positive plate by applying a force F.

State an expression for the work W done on the charge

(i) in terms of V and Q,

W = ... [1]

(ii) in terms of F and d.

W = ... [1]

(b) Use your answers to **(a)(i)** and **(a)(ii)** to show that the electric field strength between the plates is equal to the potential gradient.

[2]

(c) Fig. 7.2 shows a side view of a U-shaped permanent magnet of mass 82.0 g resting on an electronic top-pan balance.

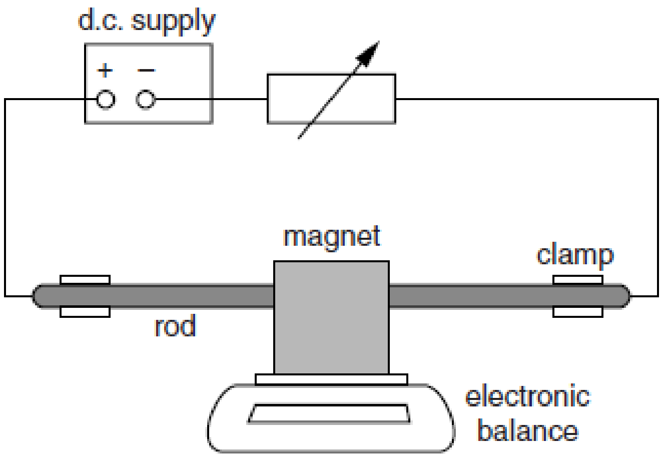


Fig. 7.2

An aluminium rod is clamped between the poles of the magnet so that the rod cannot move. The rod is connected in the circuit shown.

The d.c. supply is switched on. The reading on the balance increases to 82.4 g.

(i) Calculate the additional force exerted on the magnet when there is a current in the circuit.

additional force = ………………………… N [1]

(ii) Explain how this additional force originates.

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

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

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

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

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

(iii) Fig. 7.3 shows a plan view, from above, of the apparatus shown in Fig.7.2. The plan shows the aluminium rod fixed between the poles of the U-shaped magnet. The direction of current in the aluminium rod is from left to right.

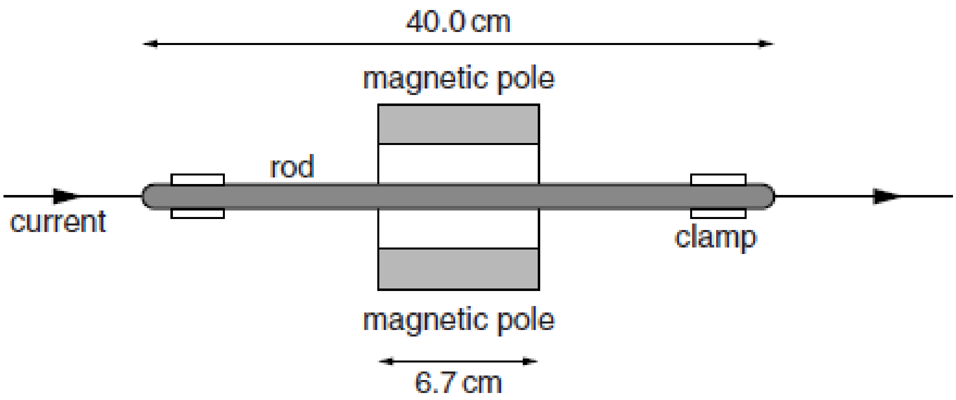


Fig. 7.3

1. On Fig. 7.3, draw an arrow to show the direction of the magnetic field between the poles that resulted in the increase in the balance reading. [1]

2. The aluminium rod is 40.0 cm long and the length of each magnetic pole is 6.7 cm. The magnetic flux density between the poles is 28.6 mT.

Calculate the current in the aluminium rod.

current = …………………….. A [2]

3. The connections to the d.c. supply are switched over so that the current is reversed. The reading on the electronic balance changes.

Determine the new reading on the electronic balance.

new reading = ……………………………. g [1]

[Total: 11]

8 **(a)** State what is meant by root mean square voltage.

....

.... [1]

(b) An alternating voltage of period 10 ms is being applied directly across a resistor of 25.0 Ω in a circuit. The variation with time t of voltage V is shown in Fig. 8.1.

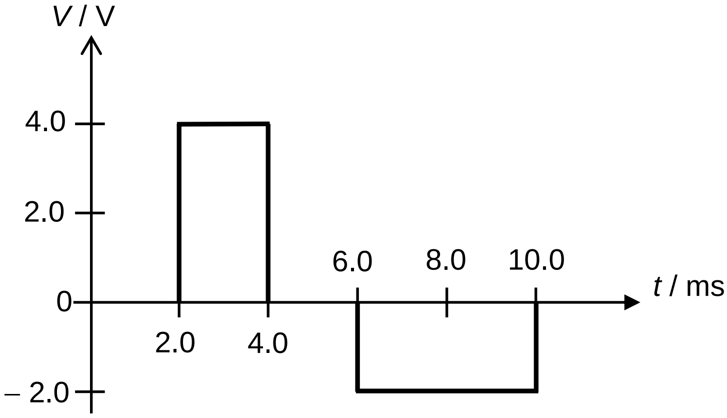


Fig. 8.1

Calculate the average power dissipated in the resistor.

average power = ………………….. W [3]

(c) Explain why it is necessary to use high voltages for the efficient transmission of electrical energy.

....

....

.... [2]

(d) A 50 Hz sinusoidal voltage input of 15 V is connected to the primary coil of an ideal transformer as shown in Fig. 8.2. The turns ratio of the transformer, $\frac{N_s}{N_p}$ is 70. The secondary coil is connected to a 2500 Ω resistor.

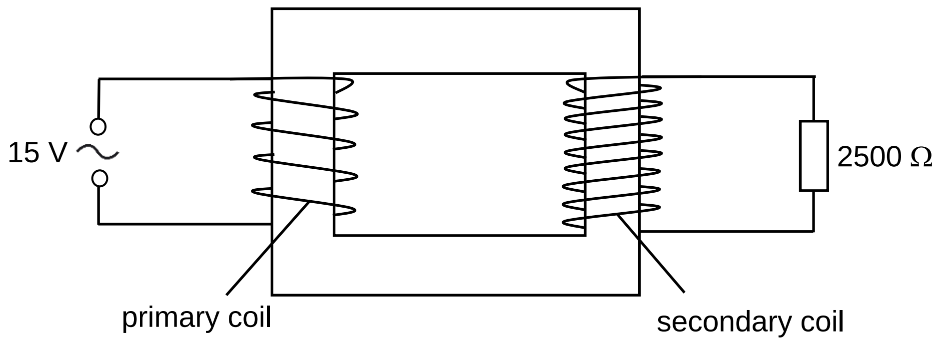


Fig. 8.2

(i) Calculate the r.m.s output voltage supplied to the 2500 Ω resistor.

r.m.s output voltage = ………………….. V [1]

(ii) In Fig. 8.3, sketch the variation with time *t* of the power *P* dissipated in the 2500 Ω resistor. Label all values on the axes.

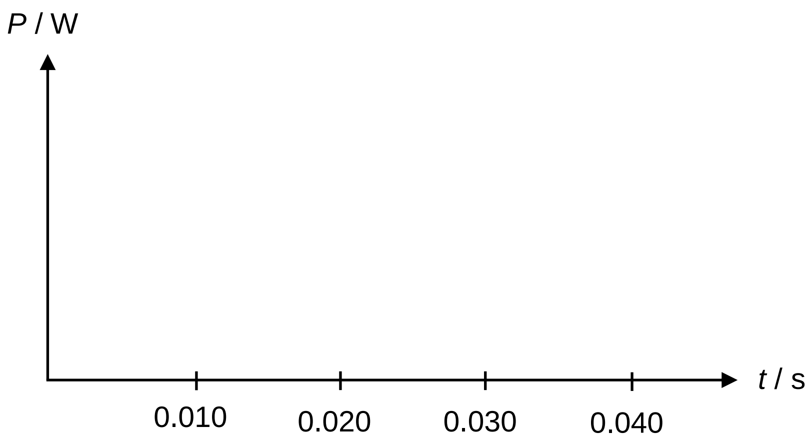


Fig. 8.3

[2]

[Total: 9]

Section B

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

9 **(a)** **(i)** Deduce the phase difference between the two waves shown in Fig. 9.1. State the unit for phase difference.

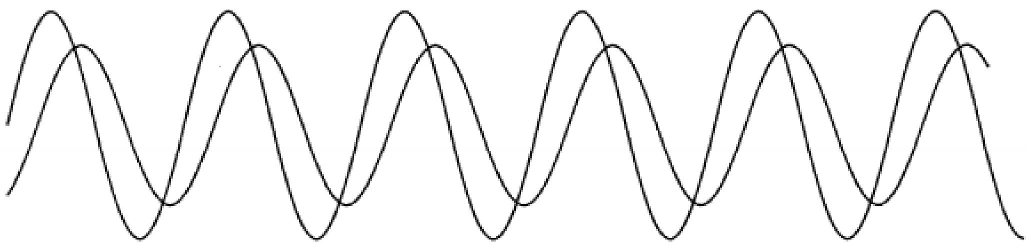


Fig. 9.1

phase difference ……………… unit …..…… [2]

(ii) Explain how you can tell that the two waves in Fig 9.1 are coherent.

…………………………………………………………………………………………………

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

(b) A beam of unpolarised light with intensity I_0 directed towards two ideal polarising filters.

Fig. 9.2 shows that the beam meets the first filter with its plane of polarisation vertical. The plane of polarisation of the second filter is at an angle of ϕ with respect to the vertical.

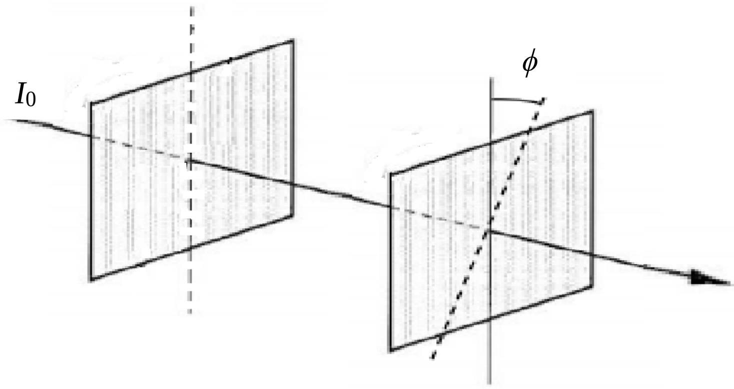


Fig. 9.2

In terms of I_0 and/or ϕ,

(i) state the intensity of the beam after it passes through the **first** polarising filter,

intensity = ………………….. [1]

(ii) determine the intensity of the beam after it passes through the **second** polarising filter.

intensity = ………………….. [1]

(iii) The planes of polarisation of the two filters are now aligned vertically.

The two filters are then rotated through 360° in opposite directions in their own plane at equal speeds as shown in Fig. 9.3.

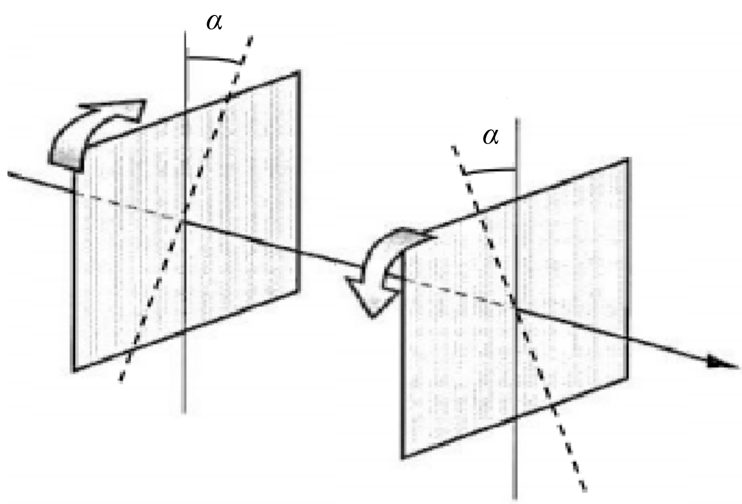
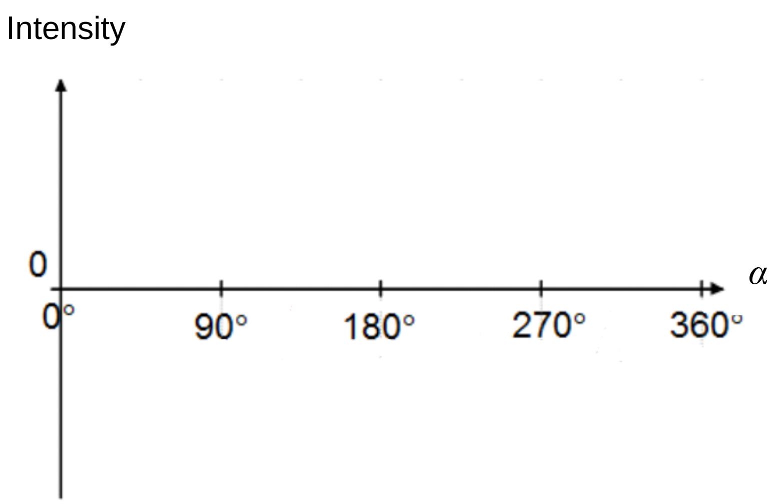


Fig. 9.3

Sketch how the intensity of light that emerged from the second polarising filter varies with the angle α that the polarisers turn through.



[3]

(c) Light of wavelength 590 nm passes through a rectangular slit of width 0.20 mm. The light is observed on a screen placed 0.75 m from the slit, as illustrated in Fig. 9.4.

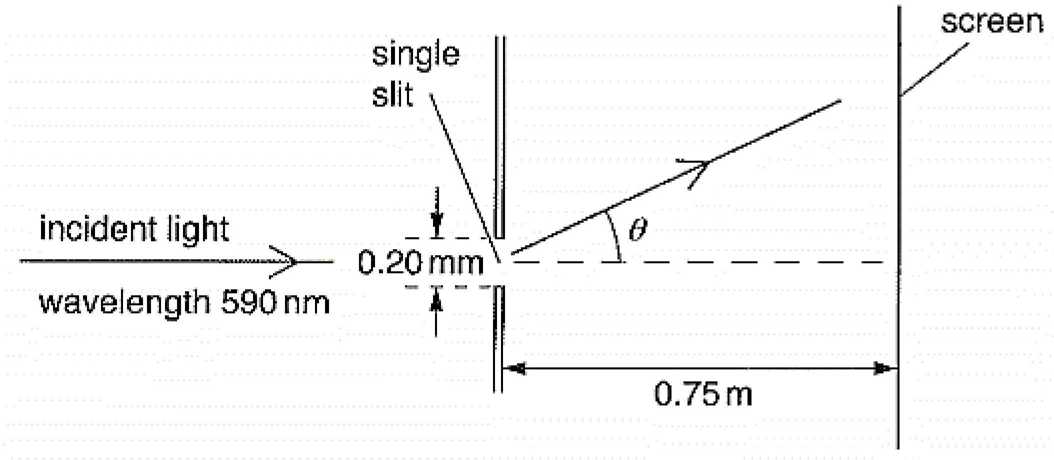


Fig. 9.4 (not drawn to scale)

Light passing through the slit is diffracted through an angle θ.

The variation of the intensity I of the light with the angle θ of the diffraction is shown in Fig. 9.5.

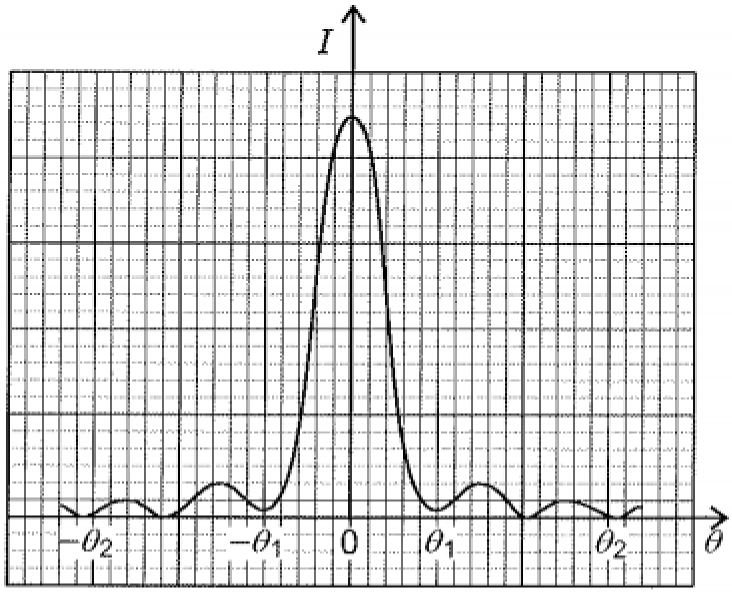


Fig. 9.5

(i) Determine the magnitude of the angle θ_1.

θ_1 = ……………………. rad [2]

(ii) Determine the magnitude of the angle θ_2.

θ_2 = ……………………. rad [1]

(iii) Calculate the width of the central maximum of the diffraction pattern.

width = ……….……………mm [2]

(iv) Determine the angle between two beams of light, each of wavelength 590 nm, incident on the slit such that their diffraction patterns are just resolved.

Explain your working.

angle = ……………….…….. rad [2]

(d) In an experiment to measure the wavelength of monochromatic light, a beam of the light was shone onto a double slit with a separation of 2.5 mm. The resulting interference pattern was viewed on a screen placed at a distance of 1.83 m from the double slit. The distance between adjacent maxima of the interference pattern was 0.45 mm.

(i) Calculate the wavelength of the light.

wavelength = ……………………… m [2]

(ii) Describe an experimental advantage and an experimental disadvantage of making the width of each slit larger, without altering the separation of the slits.

advantage……………………………………………………………………………………

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

disadvantage………………………………………………………………………………..

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

[Total: 20]

10 **(a)** The radioactive decay process is described as both spontaneous and random. Explain what is meant by

(i) *spontaneous* decay, and

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) *random* decay.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) A sample contains X nuclei of thallium-208 at time t. At time Δt later, the sample contains ($X - \Delta X$) nuclei of thallium-208.

Write down the expressions, in terms of X, ΔX, t and Δt, for

(i) the average activity of the sample in time Δt

[1]

(ii) the probability of decay of a thallium nucleus in time Δt

[1]

(iii) the decay constant λ for thallium-208

[1]

(c) A source of β-emission, which may be considered to be a point source radiating uniformly in all directions is situated 0.400 m away from a Geiger-Muller tube which has an effective area of 5.0 cm^2. The recorded count rate at a given time is 250 s^{-1}.

(i) Estimate a value for the activity of the source at this time.

activity of source = ……………….. s^{-1} [2]

(ii) Given that the half-life is 45 seconds, calculate a value for the number of radioactive atoms present in the sample 135 seconds before the measurement was made.

initial number of atoms = ……………….. [2]

(iii) Suggest and explain whether the answer in **(ii)** is an over-estimation or an under-estimation of the actual results obtained.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iv) Suggest why a magnetic material can be used to shield a person from the harmful effects of the β emissions.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(d) **(i)** Describe the physical process of nuclear fission.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) Explain why this process may release energy.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iii) Fig. 10.1 shows a portion of a graph indicating how the binding energy per nucleon of various nuclides varies with their nucleon numbers.

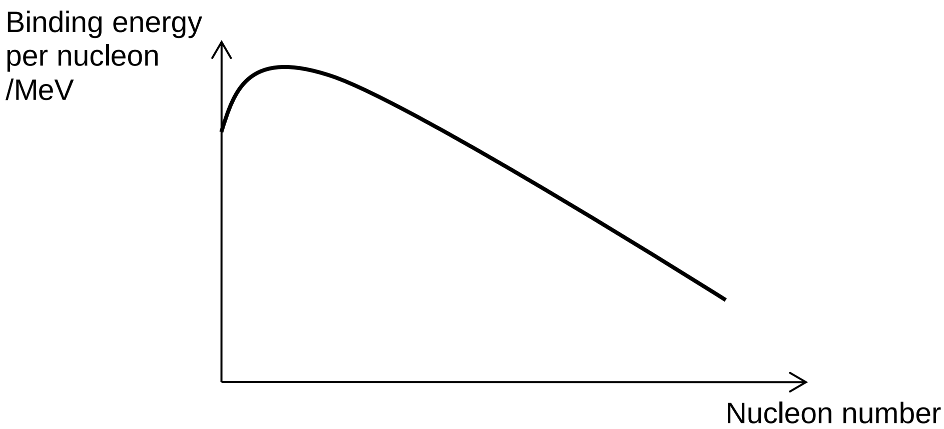


Fig. 10.1

1. Indicate on the graph with an "**X**", the position of the nucleon number and its associated binding energy per nucleon for a nucleus that is least stable. [1]

2. Give reasoning for your answer in **1**.

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(iv) When a nucleus of uranium-235 disintegrates into barium-141 and krypton-92, the loss in mass is 3.1×10^{-28} kg.

Calculate the number of uranium-235 nuclei that disintegrates in order to release 100 GeV of energy.

number of nuclei = ……………….. [2]

[Total: 20]

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