Name: ______________________________ Class: _____________

JURONG PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination 2023

PHYSICS **9749/03**
Higher 2 **18 September 2023**

Paper 3 Longer Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
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 **one** question only.

You are advised to spend about one and 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	
1	/ 10
2	/ 8
3	/ 8
4	/ 9
5	/ 6
6	/ 11
7	/ 8
8	/ 20
9	/ 20
Total	/ 80

This document consists of **24** printed pages.

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	$\phi = -\frac{GM}{r}$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
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.	$x = x_0 \sin \omega t$
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,	$R = R_1 + R_2 + ...$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + ...$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** questions in the spaces provided

1 A golf ball is hit from point A on the ground and moves through the air to point B. The path is illustrated in Fig. 1.1.

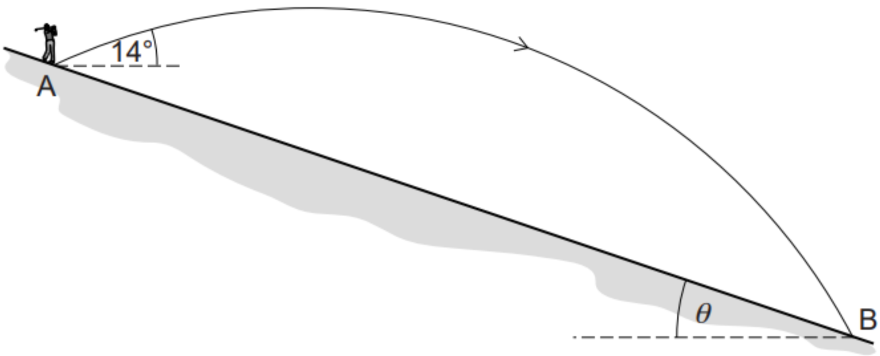

Fig. 1.1

The ground slopes downhill with a constant gradient. The ball has an initial speed of 67 m s^{-1} at an angle of 14° to the horizontal. The ball hits the ground at B after 4.9 s.

(a) Ignoring air resistance, calculate

(i) the horizontal and vertical components of the ball's velocity at A,

horizontal component at A = ……………….............. m s^{-1} [1]

vertical component at A = ……………….............. m s^{-1} [1]

(ii) the horizontal displacement from A to B,

horizontal displacement = ……………….............. m [1]

(iii) the vertical displacement from A to B,

vertical displacement = ……………….............. m [2]

(iv) the angle of the slope to the horizontal, θ.

angle θ = ……………….............. ° [2]

(b) In a real situation, air resistance provides a force on the ball in the opposite direction to its motion.

(i) On Fig. 1.1, sketch a likely path of the ball hit from A when air resistance is taken into account. [1]

(ii) Give reasons for the shape you have drawn in **(b)(i)** for

1. the path of the ball at the start,

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………………………… [1]

2. the angle at which the ball hits the ground.

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………………………………………………… [1]

2 **(a)** A satellite of mass 500 kg moves in a circular orbit at constant speed around the Earth, at a radius *r* of 9.0×10^{6} m, with a period *T*. The satellite is then moved such that it proceeds to orbit around the Earth at a new radius of 1.0×10^{7} m.

The mass of the Earth is 5.97×10^{24} kg and may be assumed to be a point mass at the centre of the Earth.

(i) Determine *T*.

T = ... s [2]

(ii) Determine the work done required in moving the satellite to its new orbit.

work done = ... J [2]

(b) **(i)** Explain why a geostationary satellite must orbit in the equatorial plane.

....

....

....

....

.... [3]

(ii) Explain why geostationary satellites are often used for telecommunication.

....

....

.... [1]

3 **(a)** **(i)** Explain what is meant by the *internal energy* of a system.

....

....

.... [1]

(ii) Write the equation representing the first law of thermodynamics, stating the meaning of each of the symbols clearly.

....

....

....

.... [2]

(iii) Explain why the heat capacity of a fixed mass of gas at constant pressure is greater than its heat capacity at constant volume.

....

....

....

....

....

.... [3]

(b) A styrofoam cup of negligible heat capacity contains 500 g of water at 90 °C. 100 g of ice at 0 °C is then added to the water.

Data for the specific latent heat of fusion and specific heat capacity of water are shown in Fig. 3.1.

specific latent heat of fusion of water / J kg^{-1}	3.34×10^5
specific heat capacity of water / J kg^{-1} K^{-1}	4200

Fig. 3.1

Determine the equilibrium temperature of the mixture, assuming no heat loss to the surroundings.

equilibrium temperature = ... °C [2]

4 Fig. 4.1 shows a block of mass 0.400 kg attached to a light spring with spring constant of 18.5 N m^{-1} at its equilibrium position. By pulling the block to the lowest point and then releasing it, the block undergoes simple harmonic motion.

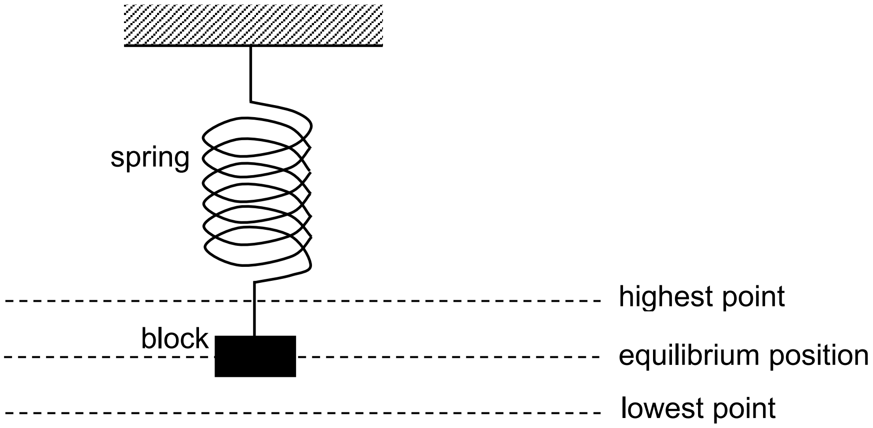

Fig. 4.1

(a) Explain what is meant by *simple harmonic motion*.

....

....

.... [1]

(b) The period T of the oscillations is given by the expression

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

where m is the mass of the block and k is the spring constant of the spring.

(i) Given that the block has a speed of 1.40 m s^{-1} when passing the equilibrium position, determine the amplitude of the oscillations.

amplitude = ... m [2]

(ii) Calculate the maximum tension in the spring during the oscillations.

maximum tension = ... N [3]

(c) (i) On Fig. 4.2, sketch a graph to show the variation with displacement x of the velocity v of the block. Label the graph with appropriate numerical values.

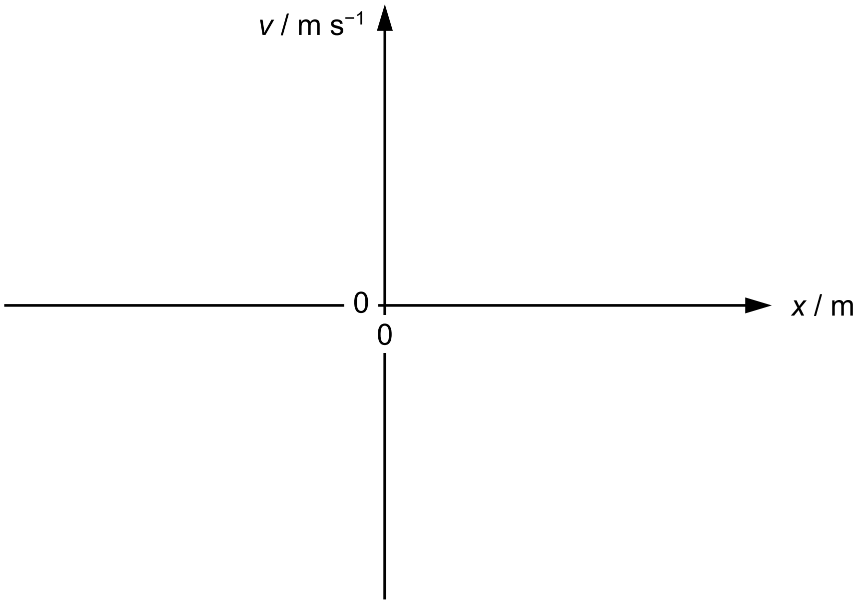

Fig. 4.2

[2]

(ii) The block is now replaced with one of mass larger than 0.400 kg and pulled down by the same amplitude calculated in **(b)(i)**.

On Fig. 4.2, sketch a second graph to show the variation with displacement x of the velocity v of the block with the larger mass.

Label the second graph **Z**. [1]

5 **(a)** A copper wire of diameter 1.8 mm has a current of 17 mA flowing through it.

(i) The density of copper is 8.9×10^{3} kg m^{-3} and its molar mass is 63.5 g mol^{-1}.

Assuming that copper has one conduction electron per atom, show that the number density of charge carriers in the copper wire is 8.4×10^{28} m^{-3}.

[2]

(i) Hence determine the drift velocity *v* of the charge carriers.

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

(b) One segment of the copper wire in **(a)** is found to be thinner compared to the rest of the wire.

State and explain how the drift velocity of charge carriers will change when they flow into the thinner segment.

....

....

.... [2]

6 **(a)** State *Faraday's law of electromagnetic induction*.

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

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

(b) A long solenoid of length 1.6 m is wound evenly with 400 turns of insulated wire. The solenoid has a circular cross-section of diameter 4.0 cm.

A coil Y having 80 turns of wire is wounded tightly around the centre of the solenoid, as illustrated in Fig. 6.1.

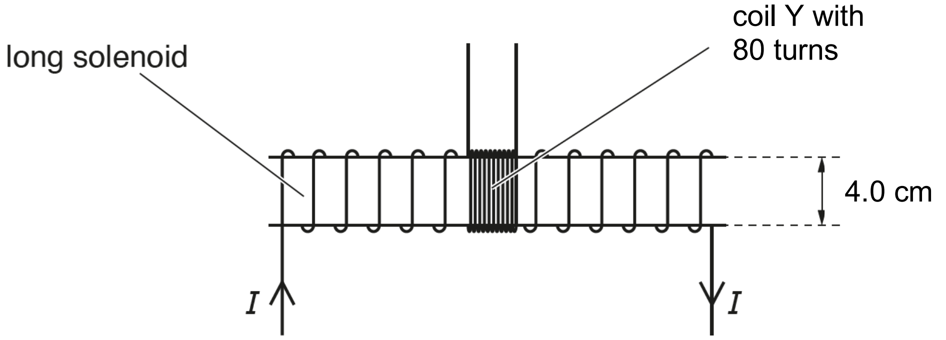

Fig. 6.1

(i) A current I of 3.8 A flows in the solenoid.

Calculate the magnetic flux linkage through coil Y.

magnetic flux linkage = ………………………… Wb [3]

(ii) The current I in the solenoid in **(b)(i)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil Y.

mean e.m.f. = …………………………… V [2]

(iii) The current I in the solenoid in **(b)(ii)** varies with time t as shown in Fig. 6.2.

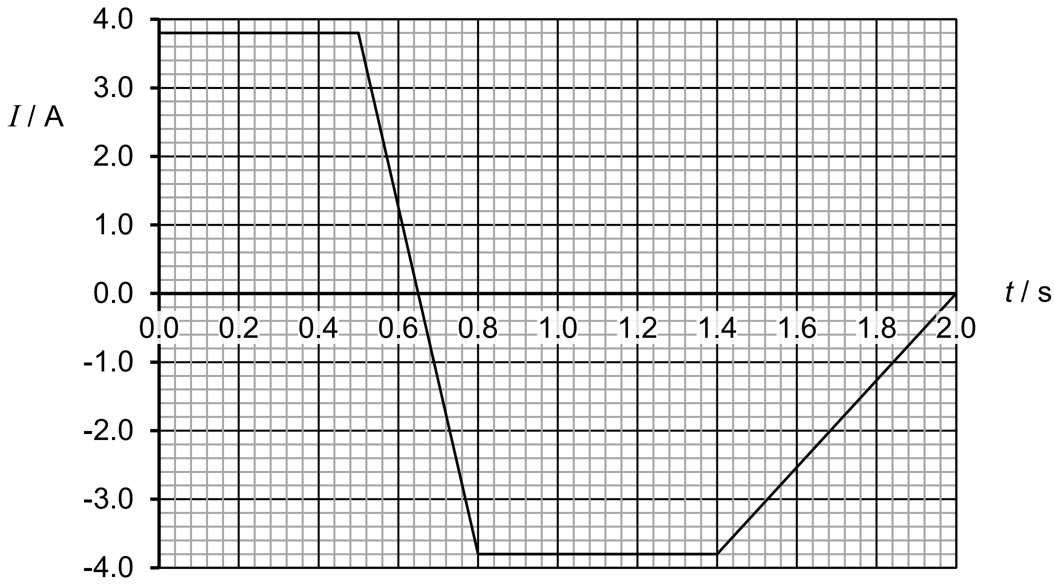

Fig. 6.2

Use your answer to **(b)(ii)** to sketch, on Fig. 6.3, the variation with time t of the e.m.f. E induced in coil Y.

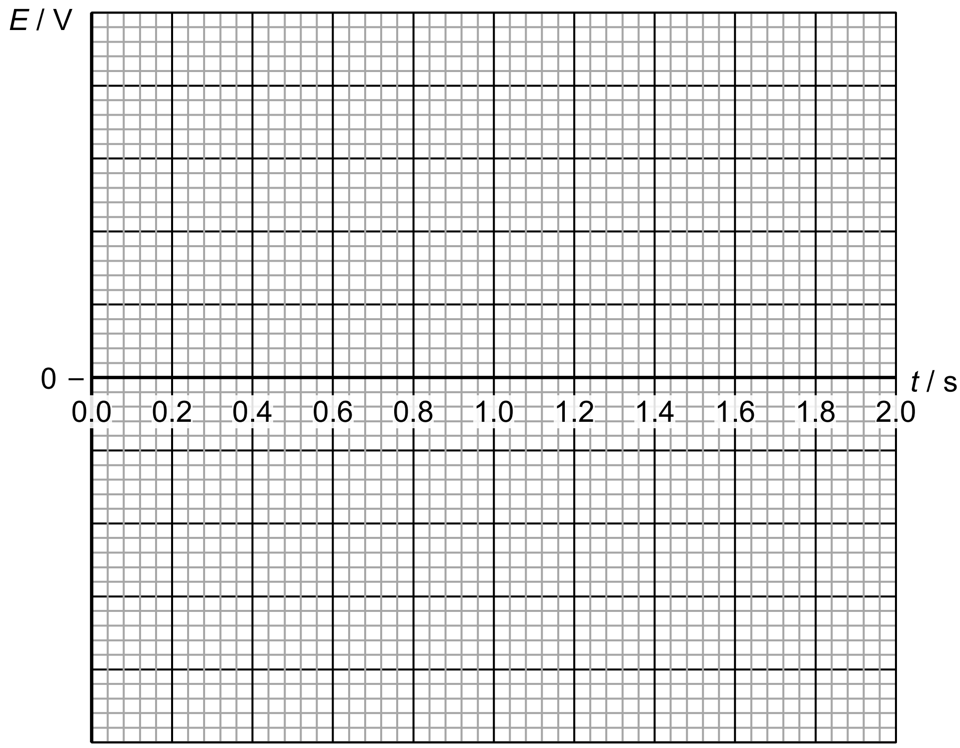

Fig. 6.3

[3]

(iv) An iron core is inserted into the solenoid and then held stationary within the solenoid.

State and explain the effect, if any, on the change in Fig. 6.3.

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

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

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

.... [2]

7 **(a)** The variation with time t of the current I for a sinusoidally alternating voltage supply of peak value of 240 V is shown in Fig. 7.1.

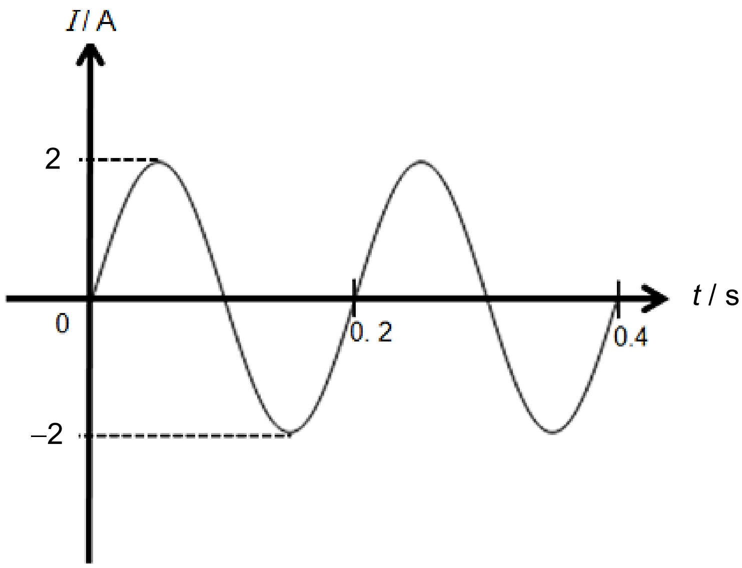

Fig. 7.1

(i) Determine the root-mean-square value of the current.

current = ... A [2]

(ii) Determine the mean power supplied.

mean power = ... W [2]

(b) A transformer has 500 turns in the primary coil and 10 turns in the secondary coil. The alternating voltage supply in **(a)** is connected to the primary coil.

(i) Determine the peak values of the voltage and current in the secondary coil.

State an assumption made.

voltage in secondary coil = ... V

current in secondary coil = ... A [2]

Assumption: ………………………………………………………………………………..

.... [1]

(ii) Suggest one use for such a current from the secondary coil of the transformer.

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

.... [1]

Section B

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

8 **(a)** A horizontal string is stretched between two fixed points A and B. A vibrator is used to oscillate the string and produce an observable stationary wave.

At one instant, the moving string is straight, as shown in Fig. 8.1.

Fig. 8.1

The dots in Fig. 8.1 represent the positions of the nodes on the string. Point P on the string is moving downwards.

The wave on the string has a speed of 35 m s^{-1} and a period of 0.040 s.

(i) Explain how the stationary wave is formed on the string.

....

....

....

.... [2]

(ii) On Fig. 8.1, sketch a line to show a possible position of the string a quarter of a cycle later than the position shown in Fig. 8.1. [1]

(iii) Determine the horizontal distance from A to B.

distance = ... m [2]

(iv) A particle on the string has zero displacement at time t = 0. From time t = 0 to time t = 0.060 s, the particle moves through a total distance of 72 mm.

Calculate the amplitude of oscillation of the particle.

amplitude = ... mm [2]

(b) Light from a laser is used to produce an interference pattern on a screen as shown in Fig. 8.2.

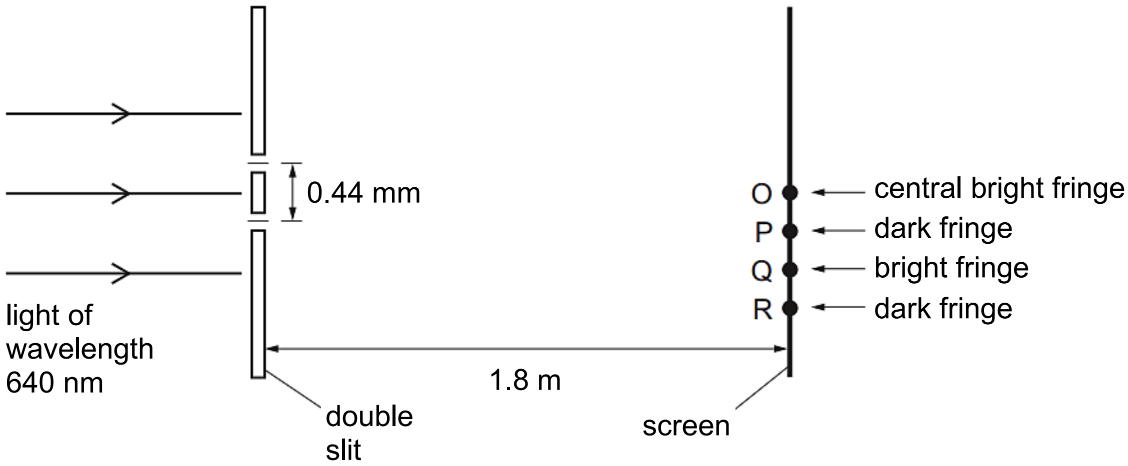

Fig. 8.2 (not to scale)

The light of wavelength 640 nm is incident normally on two slits that have a separation of 0.44 mm. The double slit is parallel to the screen. The perpendicular distance between the double slit and the screen is 1.8 m.

The central bright fringe on the screen is formed at point O. The next dark fringe below point O is formed at point P. The next bright fringe and the next dark fringe below point P are formed at points Q and R respectively.

(i) The light waves from the two slits are coherent.

State what is meant by coherent.

.... [1]

(ii) For the two light waves superposing at R, calculate

1. the difference in their path lengths from the slits,

path difference = ... nm [1]

2. their phase difference.

phase difference = ………………………… ° [1]

(iii) Determine the distance OR.

distance OR = ………………………… m [2]

(iv) The intensity of the light incident on the double slit is increased without changing the frequency.

Describe how the appearance of the fringes after this change is different from, and similar to, their appearance before the change.

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……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(v) The light of wavelength 640 nm is now replaced by blue light from a laser.

State and explain the change, if any, that must be made to the separation of the two slits so that the fringe separation on the screen is the same as it was for light of wavelength 640 nm.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(c) A diffraction grating is used with different wavelengths of visible light. The angle θ of the fourth-order maximum from the zero-order (central) maximum is measured for each wavelength.

The variation with wavelength λ of $\sin\theta$ is shown in Fig. 8.3.

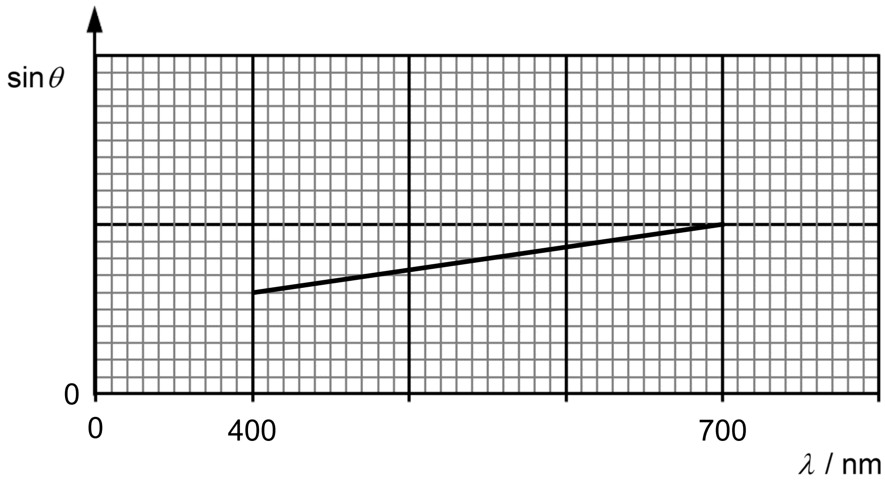

Fig. 8.3

(i) The gradient of the graph is G.

Determine an expression, in terms of G, for the distance d between the centres of two adjacent slits in the diffraction grating.

d = ... [1]

(ii) On Fig. 8.3, sketch a graph to show the results that would be obtained for the second-order maxima. [2]

9 (a) Explain what is meant by the *half-life* of a nuclide.

....

.... [1]

(b) Bismuth-214 ($^{214}_{83}Bi$) has an unusual decay pattern. Sometimes it decays by emission of an α-particle into thallium (Tl) and sometimes by emission of a β^--particle into polonium (Po).

(i) Complete the nuclear equations for these two decays of $^{214}_{83}Bi$.

<u>α-decay</u>:

$^{214}_{83}Bi \rightarrow Tl +$

<u>β^--decay</u>:

$^{214}_{83}Bi \rightarrow Po +$

[2]

(ii) Data for the α-decay of $^{214}_{83}Bi$ to form Tl are given in Fig. 9.1.

nucleus	mass of nucleus / *u*
Bi	213.9987
Tl	209.9901
α	4.0015

Fig. 9.1

Use the data in Fig. 9.1 to calculate the energy released during the decay.

energy released = ... J [3]

(iii) The two decay patterns of $^{214}_{83}\text{Bi}$ each give rise to γ-ray photons.

Suggest why photons from these two decays have different energies.

....

....

....

.... [2]

(c) (i) On Fig. 9.2, sketch a labelled graph (without numerical values) to show how starting with only $^{214}_{83}\text{Bi}$ nuclei, the activity of the $^{214}_{83}\text{Bi}$ changes with time. Label the graph Bi. [1]

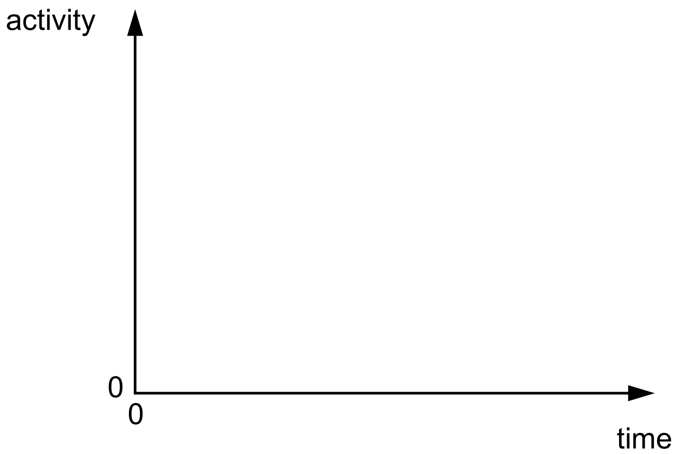

Fig. 9.2

(ii) The thalium (Tl) produced is also radioactive and has a shorter half-life than that of $^{214}_{83}\text{Bi}$.

On the same axes in Fig. 9.2, sketch another graph to show how the activity of the Tl changes with time. Label the graph Tl. [1]

(d) A sample of $^{214}_{83}\text{Bi}$ has mass 2.0 μg at time t = 0 s.

(i) Show that the sample contains approximately 5.6×10^{15} atoms.

[1]

(ii) The activity at t = 0 s is 3.3×10^{12} Bq.

Calculate the decay constant.

decay constant = ………………………….. s^{-1} [2]

(iii) Calculate the half-life.

half-life = ………………………….. s [1]

(iv) Calculate the time taken for the activity to fall to 3.3×10^{6} Bq.

time = ………………………….. s [2]

(e) The $^{214}_{83}Bi$ sample is stored in a non-radioactive lead container with thin walls of thickness 1 mm. Background radiation is negligible.

Suggest why, although the lead container provides adequate shielding for the α and β^{-}-emissions, some X-ray radiation may be detected outside the lead container.

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

End of paper