Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2020 Preliminary Examination

PHYSICS **9749/03**
Higher 2

23 September 2020
Paper 3 Longer Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use 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 and **circle the question number** on the cover page.

You are advised to spend one and a half hours 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.

***This booklet only contains Section A.**

For Examiner's Use		
Section A	**1**	/ 8
	2	/ 10
	3	/ 10
	4	/ 10
	5	/ 10
	6	/ 12
Section B (circle 1 question)	**7**	/ 20
	8	/ 20
Deduction		
Total		/ 80

This document consists of **18** printed 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	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
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	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 Body A of mass *m* and speed u_1 makes an elastic head-on collision with body B of mass 2*m* and speed u_2 as shown in Fig. 1.1.

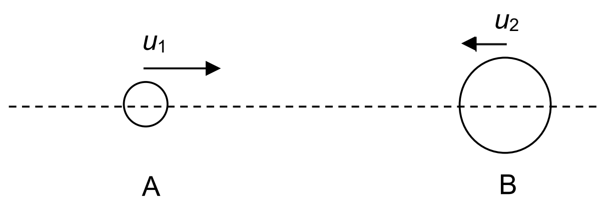

Fig. 1.1

(a) Describe the subsequent motion of the two bodies knowing that

(i) the collision is head-on,

....

.... [1]

(ii) the collision is elastic.

....

.... [1]

(b) Given that the speeds u_1 is 4.0 m s^{-1} and u_2 is 2.0 m s^{-1}, determine the velocity of each body after the collision.

velocity of A = ... m s^{-1}

velocity of B = ... m s^{-1} [4]

(c) Bodies A and B are steel ball bearings. If their motions occur in a vertical plane as shown in Fig. 1.2, with u_1 directed downwards and u_2 upwards, the principle of conservation of momentum can still be applied in analysing the collision between them.

Fig. 1.3 shows a similar scenario, but with a piece of styrofoam of negligible mass attached to the top of body B.

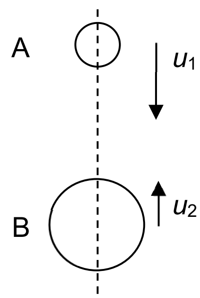

Fig. 1.2

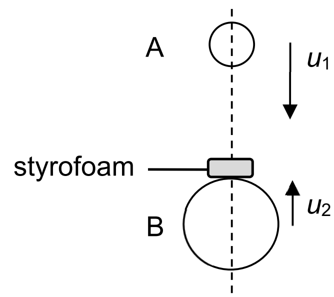

Fig. 1.3

Explain why the principle of conservation of momentum cannot be applied in analysing the collision in Fig. 1.3.

....

....

....

.... [2]

2 **(a)** Fig. 2.1 also shows two equipotential lines around Star X.

The gravitational potentials at points Q and R are -3.0×10^{12} J kg^{-1} and -1.0×10^{12} J kg^{-1} respectively.

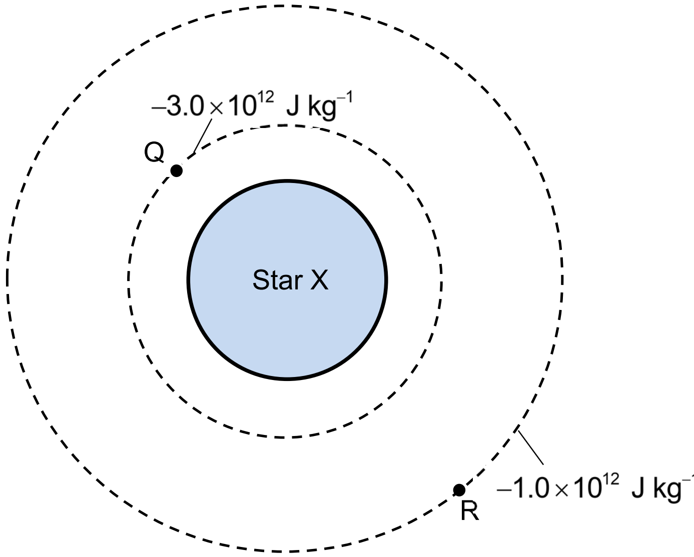

Fig. 2.1

(i) Explain why the gravitational potential at a point is always negative.

....

....

....

....

.... [2]

(ii) The gravitational potential at point Q which is 0.98×10^{7} km from the centre of Star X is -3.0×10^{12} J kg^{-1}.

What is meant by the above statement?

....

....

.... [1]

(iii) Calculate the distance from the centre of star X to point R.

distance = ... km [2]

(iv) Calculate the work done by an external force in bringing a body of mass 1200 kg from points R to Q.

work done = ... J [2]

(b) Star Y forms part of a binary star system with Star Z. Both stars orbit about a common centre C as shown in Fig. 2.2.

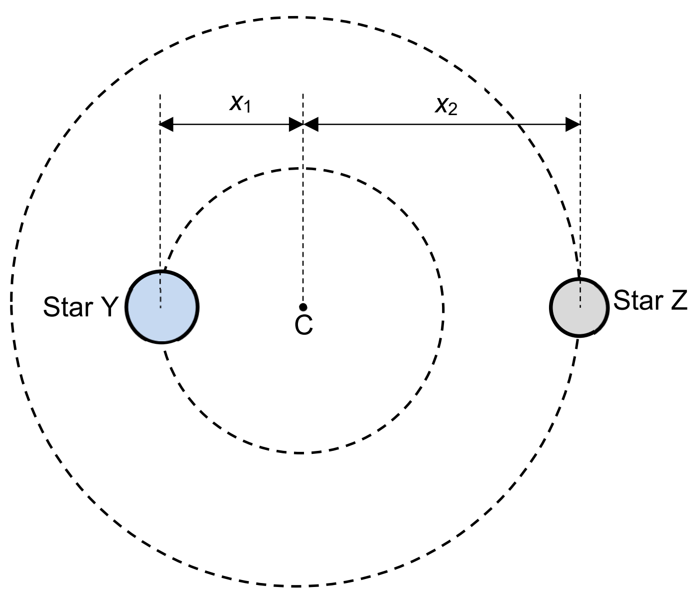

Fig. 2.2

The following data are given:

mass of Star Y $= 2.62 \times 10^{30}$ kg
mass of Star Z $= 1.45 \times 10^{28}$ kg

(i) The orbital radii of Stars Y and Z are x_1 and x_2 respectively.

Determine the ratio $\frac{x_1}{x_2}$.

$\frac{x_1}{x_2} =$ .... [2]

(ii) Explain why both stars must rotate with the same angular velocity about C.

....

....

.... [1]

3 **(a)** Gravitational fields, electric fields and magnetic fields are examples of fields of force.

State the direction of the force acting on the body with respect to the field it is in for each of the following scenarios.

(i) The Moon in the gravitational field of the Earth.

.... [1]

(ii) An electron released from rest in the electric field of a positive point charge.

.... [1]

(iii) An electron moving at an angle to a uniform magnetic field.

.... [1]

(b) An isolated point charge S in a vacuum produces electric potential *V* at distance *r* from S. Fig. 3.1 shows the variation with *r* of *V*.

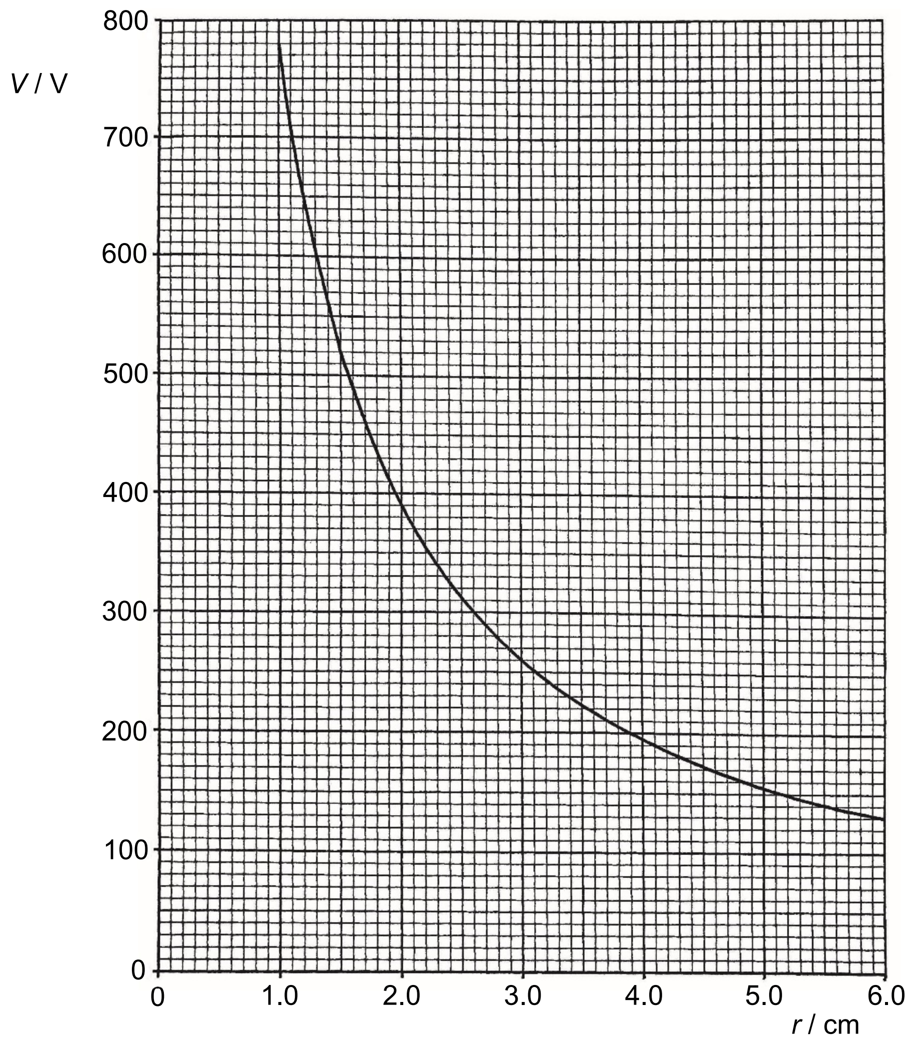

Fig. 3.1

(i) Show that the charge of S is 8.7×10^{-10} C .

[1]

(ii) An electron is projected radially from $r = 2.0$ cm with a speed of 8.4×10^{6} m s^{-1} away from S.

Using Fig. 3.1, determine the maximum distance of the electron from S.

maximum distance = ... cm [2]

(iii) A negative point charge T is now placed at a fixed distance $r = 6.0$ cm from S. The charge of T is -8.7×10^{-10} C .

1. Sketch on Fig. 3.3, the variation with distance *r* from S of the electric force *F* on an electron when it is between S and T.

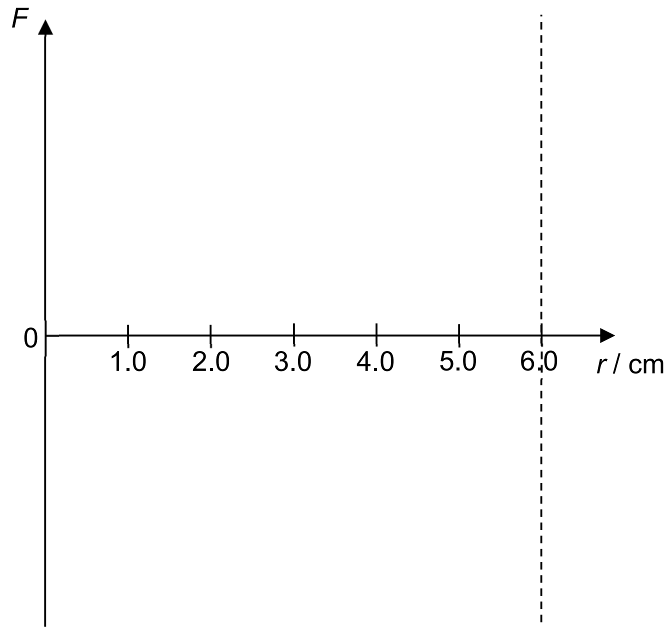

Fig. 3.3

[2]

2. If the electron in **(b)(ii)** is again projected from $r = 2.0$ cm with the same speed towards T, explain how the maximum distance of the electron from S will change.

....

....

.... [2]

4 **(a)** Distinguish between electromotive force (e.m.f.) and potential difference (p.d.).

....

....

.... [1]

(b) A battery of e.m.f. E_1 and internal resistance r_1 is connected in series with a variable resistor R as shown in Fig. 4.1.

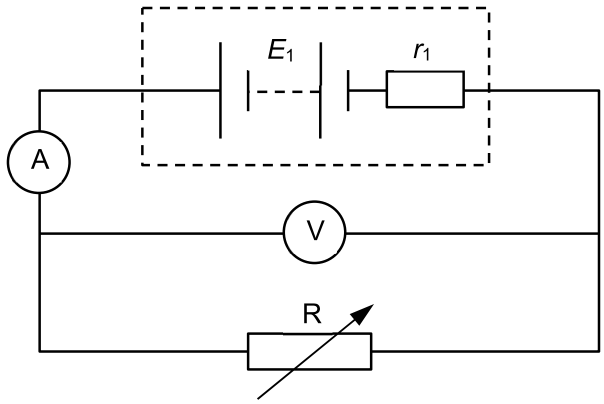

Fig. 4.1

Readings from the ammeter and the voltmeter are taken as the resistance of R is varied. Fig. 4.2 shows the variation with the voltmeter reading V of the ammeter reading I.

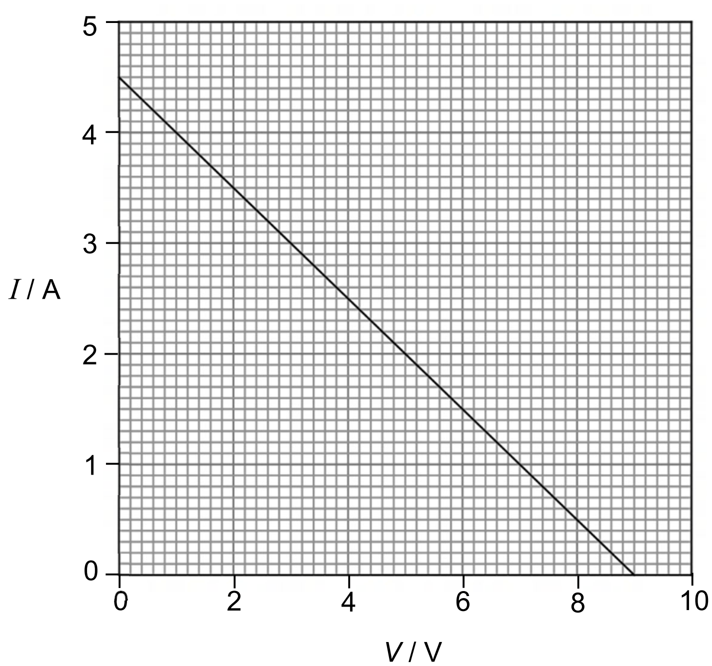

Fig. 4.2

Use Fig 4.2 to determine for the battery,

(i) its e.m.f. E_1,

E_1 = ... V [1]

(ii) its internal resistance r_1.

r_1 = ... Ω [2]

(c) The ammeter and voltmeter are removed and the variable resistor R is set at 4.0 Ω.

A uniform resistance wire XY, a cell C, a switch S, a 5.0 Ω resistor and a galvanometer are connected to the circuit of Fig 4.1, as shown in Fig 4.3. J is a movable electrical connection.

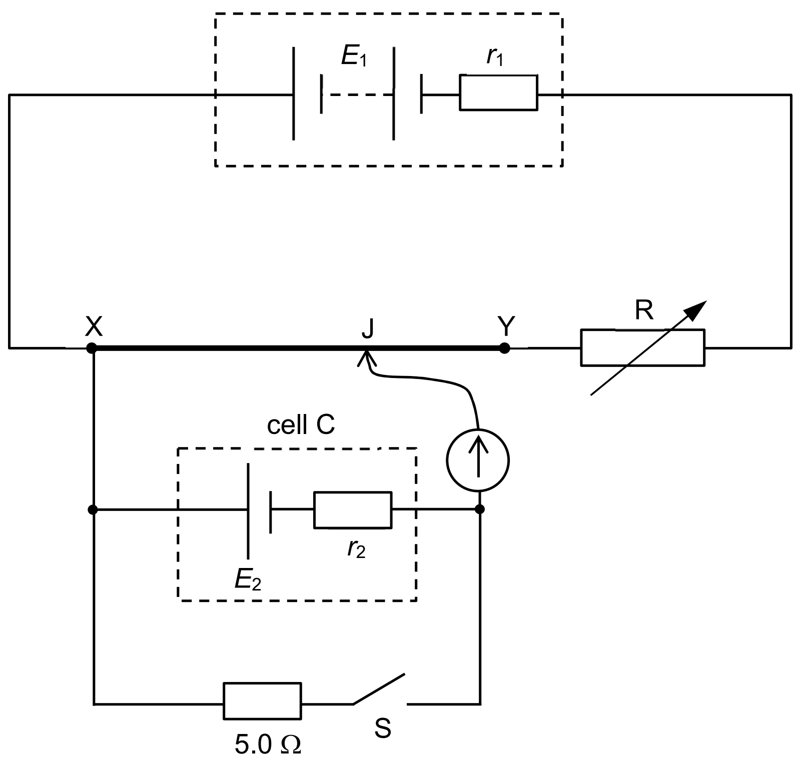

Fig 4.3

The wire XY has length 1.0 m and resistance 4.0 Ω. Cell C has an e.m.f. E_2 and internal resistance r_2.

With switch S opened, the galvanometer shows null deflection when XJ is 0.75 m.
With switch S closed, the galvanometer shows null deflection when XJ is 0.30 m.

(i) Calculate for Cell C,

1. its e.m.f. E_2,

E_2 = ... V [2]

2. its internal resistance r_2.

r_2 .... Ω [2]

(ii) Another uniform resistance wire PQ is connected across XY as shown in Fig. 4.4. The wire PQ has length 1.0 m and resistance 8.0 Ω. With switch S opened, a new balance length XJ' is found.

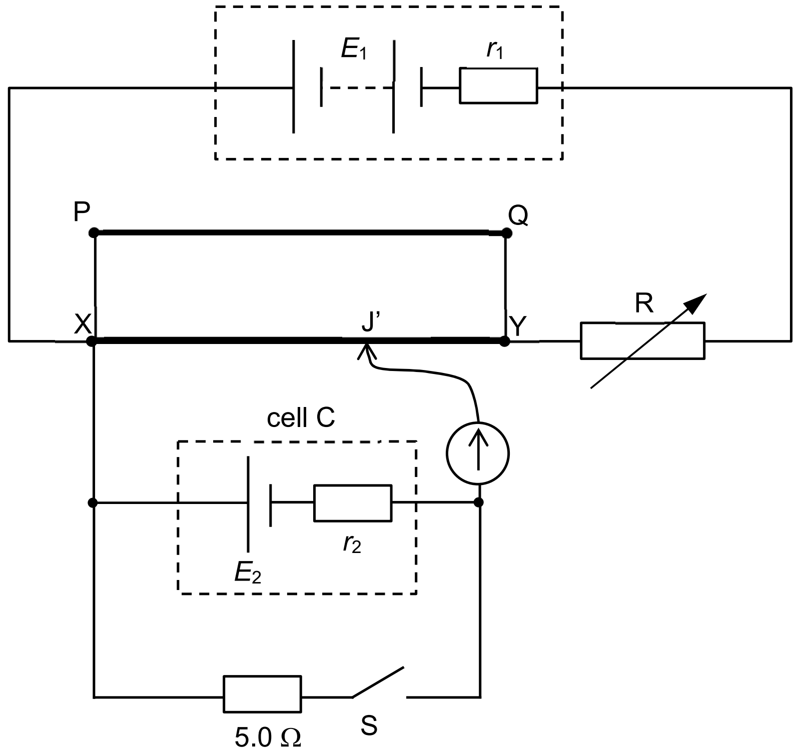

Fig. 4.4

State and explain if XJ' is smaller or larger than 0.75 m.

....

....

....

.... [2]

5 Fig. 5.1 shows two identical circular coils X and Y that are fixed in position. The planes of both coils are parallel and their centres lie along a common axis PQ.

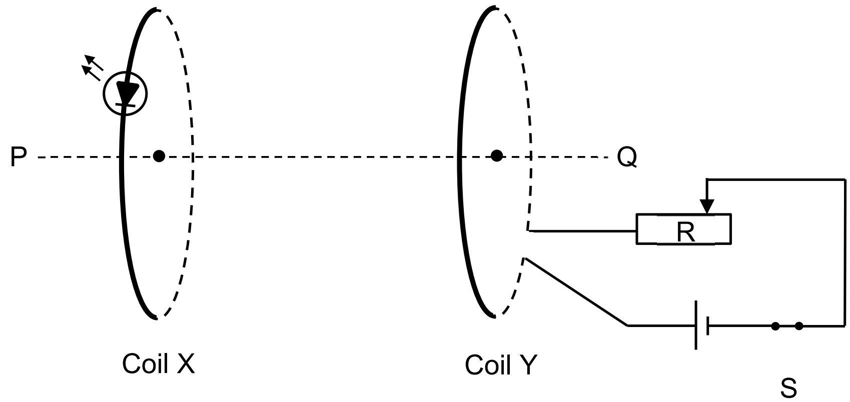

Fig. 5.1

Coil Y is connected to a cell, a switch S and a variable resistor R. S is closed and R is set to its maximum value.

A light emitting diode (LED) is connected to coil X and it is not lit up.

(a) Based on the laws of electromagnetic induction, describe and explain what would be observed about the LED when the following changes are made independently:

(i) S is opened.

....

....

....

....

....

.... [3]

(ii) The resistance of R is decreased.

....

....

....

....

....

.... [3]

(b) The cell is now replaced by an alternating voltage source. The sinusoidal current flowing through coil Y is represented by the equation $I_Y = I_0 \sin(100\pi t)$. Current flowing in the clockwise direction, when the coils are viewed from Q, is taken as positive.

(i) On the axes of Fig. 5.2, sketch at least 2 cycles of the variation with time *t* of the current I_Y flowing through coil Y.

Indicate relevant values on the horizontal axis.

Fig. 5.2

[2]

(ii) On the axes of Fig. 5.3, sketch at least 2 cycles of the variation with time *t* of the current I_X flowing through coil X.

Indicate relevant values on the horizontal axis.

Fig. 5.3

[2]

6 **(a)** To produce X-rays, a metal target inside an X-ray tube is bombarded with high speed electrons that have been accelerated over a large potential difference.

Fig. 6.1 shows the variation with wavelength of the emitted radiation from the tube of the X-ray intensity. It consists of a continuous spectrum with two sharp peaks, labelled K_α and K_β. The X-ray spectrum cuts off at a minimum wavelength of λ_0.

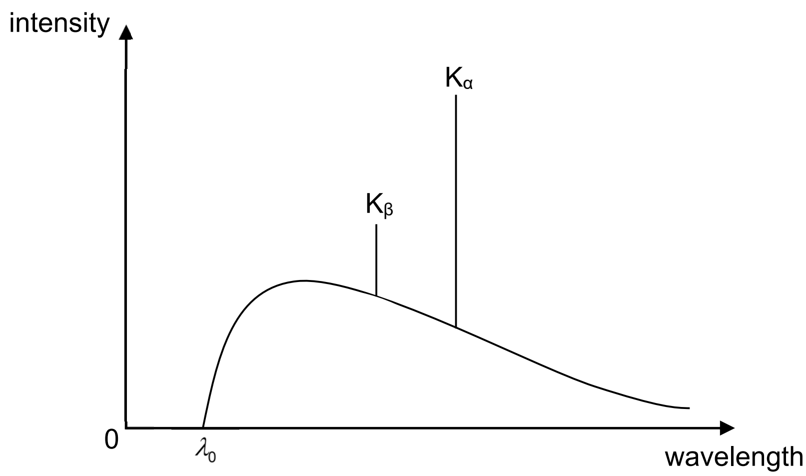

Fig. 6.1

(i) Explain the formation of the continuous spectrum.

....

....

....

....

....

.... [3]

(ii) Determine λ_0 if the electrons are accelerated over a potential difference of 50 kV.

λ_0 = ... m [2]

(iii) Besides the K_α and K_β peaks, two other peaks L_α and L_β can also be observed on the X-ray spectrum in Fig 6.1.

The L_α and L_β peaks are due to photons produced from electronic transitions within the metal atoms from energy levels n = 3 to n = 2, and n = 4 to n = 2 respectively.

Sketch the L_α and L_β peaks on Fig. 6.1. Label the two peaks clearly. [2]

(b) In a photoelectric experiment, a metal target in a vacuum tube is bombarded with electromagnetic radiation.

Fig. 6.2 shows the variation with the frequency *f* of the incident radiation of the stopping potential V_S.

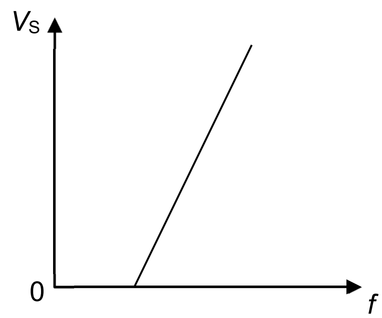

Fig. 6.2

(i) Determine, with clear explanations, the gradient of the graph.

gradient = ... [2]

(ii) When potassium was used as the metal target, it was found that no photocurrent was generated when the frequency of the incident electromagnetic radiation was below 5.55×10^{14} Hz.

Determine the work function energy of potassium.

work function energy = ... eV [2]

(iii) On Fig. 6.2, sketch a graph to represent the variation with *f* of V_S if tungsten was used as the metal target instead. The work function energy of tungsten is 4.50 eV. [1]

End of Paper 3 Section A