NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CLASS		TUTOR'S NAME	
CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS 9749/03

Paper 3 Longer Structured Questions **13 September 2024**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number 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 a HB pencil for any diagrams, graphs or rough working.
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 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	
Section A	
1	**/ 9**
2	**/ 8**
3	**/ 12**
4	**/ 9**
5	**/ 12**
6	**/ 10**
Section B	
7	**/ 20**
8	**/ 20**
Total	**/ 80**

This document consists of **23** 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 gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
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	=	$x_0 \sin \omega t$
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 the spaces provided.

1 **(a)** **(i)** Define *impulse*.

....

....[1]

(ii) State the principle of *conservation of linear momentum*.

....

....

....[2]

(b) Two isolated objects, X and Y travel along the same straight line with speeds 3.5 m s^{-1} and 2.0 m s^{-1} respectively as shown in Fig. 1.1. The objects collide elastically and continue to travel along the same straight line after the collision.

Fig. 1.1

Object X has a mass of 0.5 kg and object Y has a mass of 0.25 kg.

The variation with time of the force exerted by object X on object Y during the collision is shown in Fig. 1.2.

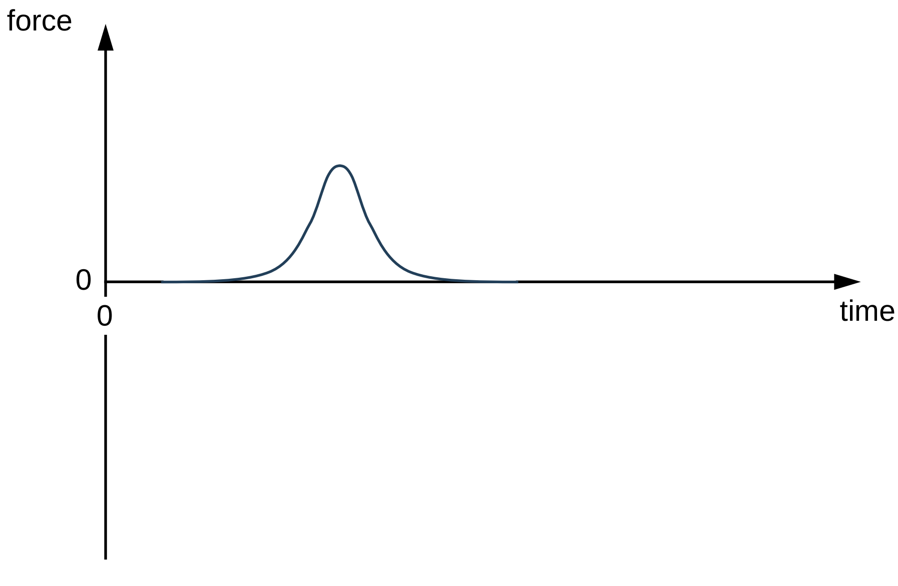

Fig. 1.2

(i) Sketch on Fig. 1.2 the variation with time of the force exerted by object Y on object X during the collision. Label this line *F*. [1]

(ii) State and explain whether, during the collision it is possible for both objects to be at rest simultaneously.

....

....

....[2]

(iii) The area under the graph given in Fig. 1.2 is 0.50 N s. Use the information in **(b)** to calculate the velocity of object Y after the collision.

velocity of object Y = ... m s^{-1} [3]

[Total: 9]

2 **(a)** A student performs an experiment to determine the specific latent heat of fusion of ice. The student has two sets of apparatus next to each other on the laboratory bench, as shown in Fig. 2.1 and Fig. 2.2.

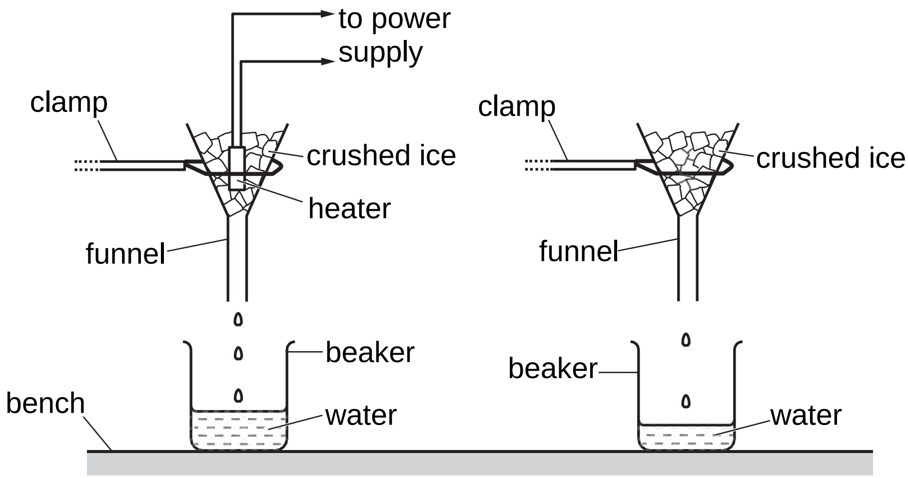

Fig. 2.1 **Fig. 2.2**

Both funnels are identical and have the same mass of crushed ice at 0 °C.

The current in the heater is 5.0 A and the potential difference across it is 12 V.

Fig. 2.3 shows the variation of mass of water *m* collected in each beaker with time *t*.

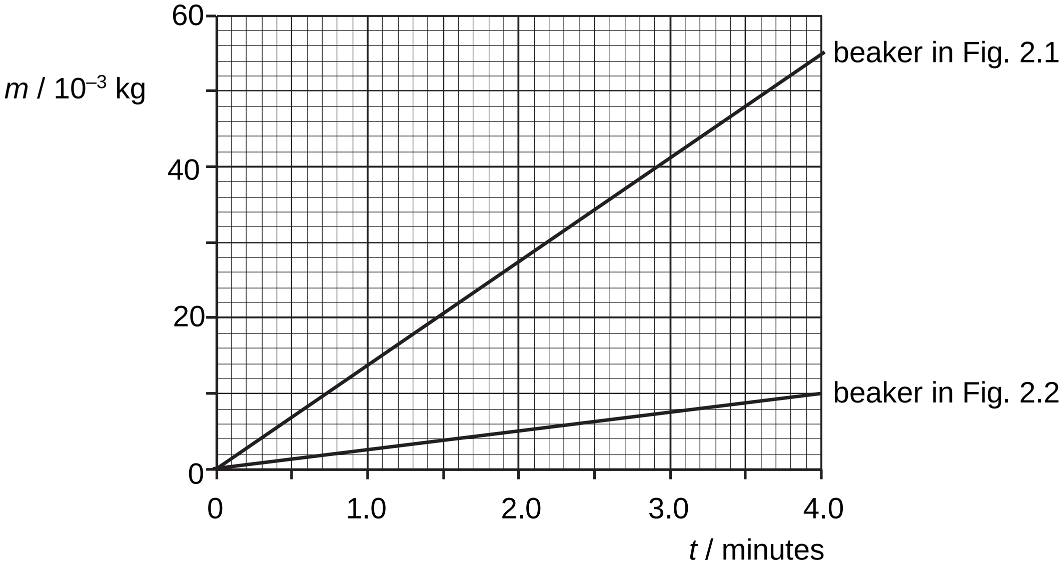

Fig. 2.3

(i) Explain why the gradients of the two graphs are different.

....

.... [1]

(ii) Use Fig. 2.3 to show that the specific latent heat of fusion of ice is about 3×10^5 J kg^{-1}.

specific latent heat of fusion = ... J kg^{-1} [2]

(b) A heat engine, such as a car engine, is a device that converts thermal energy into mechanical work.

When the heat engine operates, a fixed amount of gas expands and contracts repeatedly in a cylinder with a piston.

The cycle of expansion and contraction for a fixed quantity of an ideal gas is illustrated graphically in Fig. 2.4.

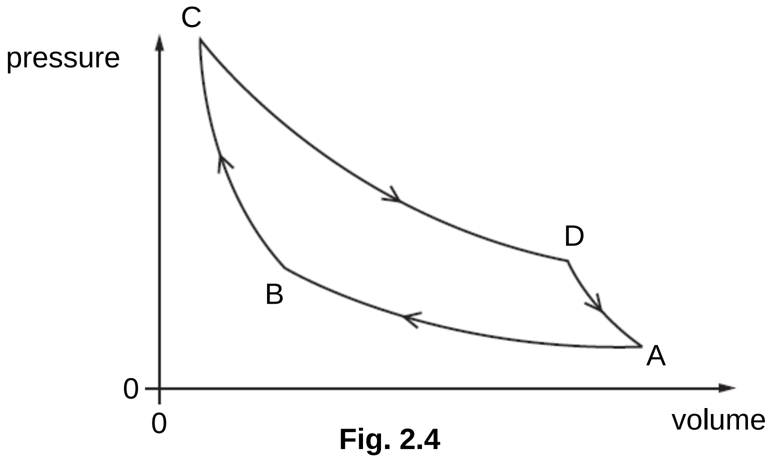

Fig. 2.4

There are four stages in the cycle.

Stage	Description
A to B	a slow compression of the gas at constant temperature
B to C	a sudden compression of the gas causing an increase in temperature
C to D	a slow expansion of the gas at constant temperature
D to A	a sudden expansion back to its original pressure, volume, and temperature

(i) Explain each of the following facts about the cycle:

1 During stage B to C, the piston causes a sudden compression of the gas, causing an increase in temperature, with reference to the kinetic theory of gases.

....

....[1]

2 At the end of all four stages, the change in internal energy of the gas is zero.

....

....[1]

(ii) Complete the table in Fig. 2.5 for the cycle.

stage	thermal energy supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A to B	–702	702	0
B to C	0	844	844
C to D	936	–936	0
D to A	0		

Fig. 2.5

[1]

(iii) Determine the efficiency of the heat engine.

Show your working clearly.

efficiency = ... % [2]

[Total: 8]

3 Fig 3.1 shows a displacement-distance graph for two sound waves, A and B, of the same frequency and amplitude at a particular instant. Wave A is travelling to the right and wave B is travelling to the left.

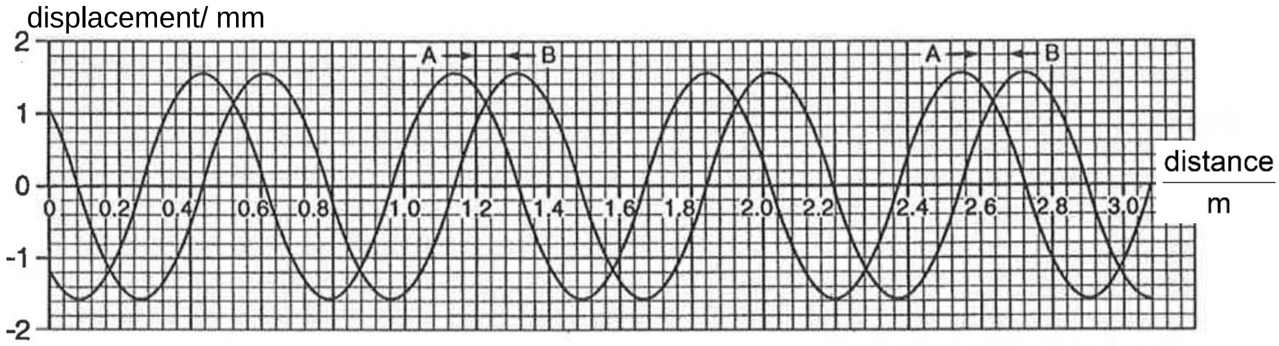

Fig. 3.1

(a) (i) Using Fig. 3.1, determine the wavelength of the two waves.

wavelength = ... m [2]

(ii) The frequency of the sound is determined to be 469 Hz. Calculate the speed of sound to 4 significant figures.

speed = ... m s^{-1} [1]

(iii) The frequency and the wavelength of the sound were determined to a precision of ± 5% and ± 8% respectively. Write down the calculated value for the speed of sound in the form ($x \pm \Delta x$).

speed = (.................. ± ....) m s^{-1} [2]

(b) (i) State the phase difference between the two waves at the point where distance = 1.40 m in the instant shown in Fig. 3.1. Explain your answer.

....

....

.... [2]

(ii) Hence, calculate the maximum displacement of the resultant wave in the instant shown in Fig. 3.1. Explain your working clearly.

maximum displacement = ...mm [2]

(iii) The maximum displacement of the resultant wave increases to a maximum value some time *t* later. Calculate the value of *t*.

t = ... ms [2]

(iv) Deduce the maximum value of the maximum displacement in **(iii)**.

maximum displacement = ...mm [1]

[Total: 12]

4 **(a)** In a laboratory, a circuit is set up as shown in Fig. 4.1. Cell A has an electromotive force (e.m.f.) of 2.0 V and negligible internal resistance. XY is a uniform wire of length 100.0 cm and resistance 5.0 Ω.

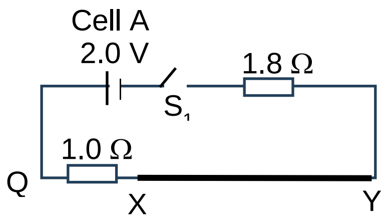

Fig. 4.1

(i) Explain what is meant by *electromotive force* (e.m.f.) of 2.0 V.

....

....

....[1]

(ii) Calculate the current in the 1.0 Ω resistor and wire XY when switch S_1 is closed.

current = ... A [1]

(b) A second circuit which contains Cell B of e.m.f. 1.2 V and negligible resistance is connected to the circuit in **(a)** at Q and P.

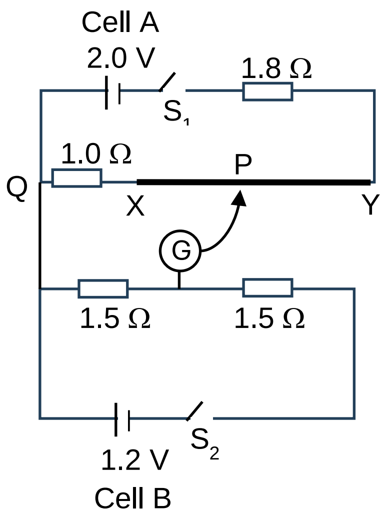

Fig. 4.2

(i) Calculate the balance length XP required to produce a zero deflection on the galvanometer when both switches S_1 and S_2 are closed.

length = ... m [3]

(ii) Describe and explain how the balance length XP will be different if the 1 Ω resistor is replaced with a 1 kΩ resistor.

....

....

....

....[2]

(iii) If both 1.5 Ω resistors are replaced with identical LDRs, describe and explain how the balance length XP will be different as the light intensity in the laboratory decreases.

....

....

....

....[2]

[Total: 9]

5 (a) In 1965, Richard Feynman hypothesised that electrons could be used in the double slit experiment to demonstrate wave particle duality. This experiment has since been conducted and verified by physicists.

A simplified set-up of the experiment is shown in Fig. 5.1.

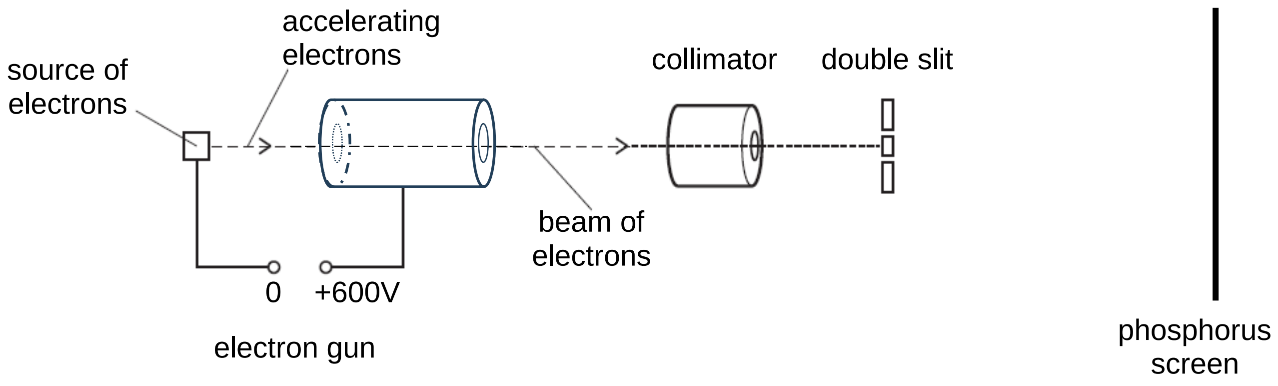

Fig. 5.1

An electron gun accelerates electrons in vacuum through a potential difference of 600 V. The collimator narrows the beam of electrons which then passes through the double slit.

The double slit only allows electrons to pass through one at a time, with each electron detected as a single bright spot on the phosphorus screen. The bright spots cumulate with time, showing a pattern formed on the screen as shown in Fig. 5.2.

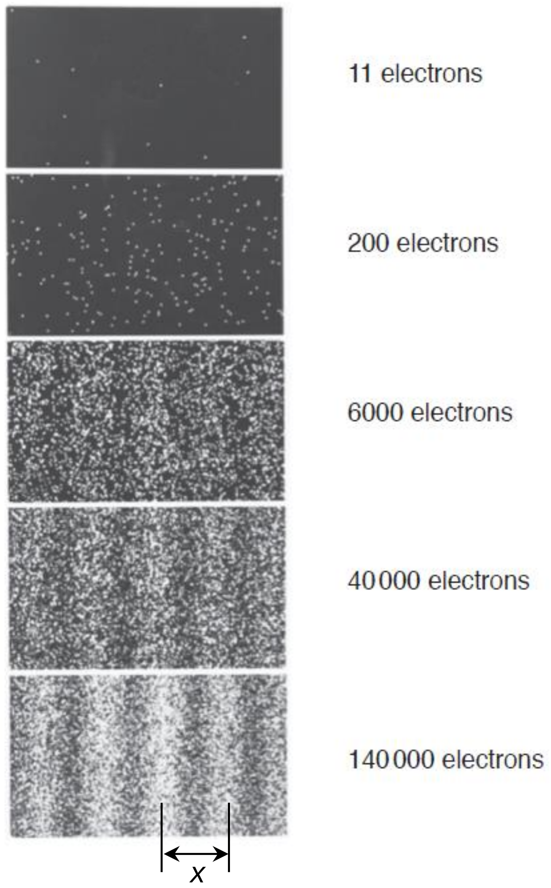

Fig. 5.2 (not to scale)

(i) Explain how the images in Fig. 5.2 show that electrons exhibit both particle-like and wave-like properties.

....

....

....

....[2]

(ii) Calculate the de Broglie wavelength of the electrons reaching the double slit.

wavelength = ... m [3]

(iii) The double slit consists of two 50 nm wide slits with a separation of 280 nm. The distance from the double slit to the screen is 1.2 m.

Calculate the expected value of the centre-to-centre distance *x* shown in the last image of Fig. 5.2.

x = ... m [2]

(iv) In order for clear patterns to be formed, suggest why it is important for the electrons reaching the double slit to have velocities very close to a single value.

....

....

....[1]

(b) In 1927, Werner Heisenberg proposed that we can only be clear about what is meant by the position of an object if we can specify experiments by which its position can be measured.

Heisenberg realised that a microscope using visible light would be useless for making a precise measurement of the position of something as small as an electron. He thought of using a 'gamma ray microscope', where gamma rays bounce off the electron and into a measuring device which can be used to determine the location of the electron.

(i) Explain why scattering light or gamma rays bouncing off an electron causes the electron to change its momentum.

....

....

....

....[2]

(ii) By reference to how the momentum change of an electron depends on the wavelength of the electromagnetic radiation used to observe it, explain why using gamma rays could allow a more precise measurement of position to be made.

....

....

....

....[2]

[Total: 12]

6 **(a)** **(i)** Define *decay constant*.

....

....[1]

(ii) Suggest why the determination of decay constant by measuring the mass and activity of a sample can be used only for nuclides that have relatively *small* decay constant**.**

....

....[1]

(iii) Explain why the random nature of radioactive decay makes it difficult to measure the decay constant to a high degree of accuracy.

....

....

....

....[2]

(b) A stationary radon nucleus may undergo alpha decay to form the daughter nuclide X.

The masses of the nuclei and of the alpha particle are given in the Fig. 6.1.

nucleus or particle	mass / u
radon	222.0176
X	218.0090
alpha particle	4.0026

Fig. 6.1

(i) Complete the nuclear decay equation, including all the decay products.

$$^{222}_{86}\text{Rn} \rightarrow$$ [1]

(ii) Calculate the total kinetic energy of the products.

total kinetic energy = ... J [2]

(iii) Alpha particles can be stopped by tissue paper.

Suggest if this implies that alpha-emitters present no health hazards in a school laboratory.

....

....

....[1]

(c) A theory of nuclear astrophysics proposes that all the elements heavier than iron ore are formed in supernova explosions ending the lives of massive stars. Assume equal amounts of ^{235}U and ^{238}U were created at the same time and the present $\frac{^{235}U}{^{238}U}$ ratio is 0.00725.

Calculate how long ago the explosion of the star that released the elements that formed our Earth occurred.
Half-lives of ^{235}U and ^{238}U are 0.704×10^9 years and 4.47×10^9 years respectively.

time = ... years [2]

[Total: 10]

Section B

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

7 **(a)** There are quantitative and qualitive aspects of gravitational field that are analogous to those of electric field. Complete the table in Fig. 7.1 below to show these analogous aspects.

Analogy	
Gravitational Field	Electric Field
Mass	
Newton's Law of Gravitation	
	Electric Field Strength is in the direction of decreasing Electric Potential

Fig 7.1 [3]

(b) In an imagined universe, Earth has a larger sibling Areth with which it forms a double planet system, and the two orbit about each other. Earth has a mass of 5.97×10^{24} kg and a radius of 6370 km. Areth has the same mean density as Earth but is 20% bigger in radius. They are separated by a distance of 96600 km.

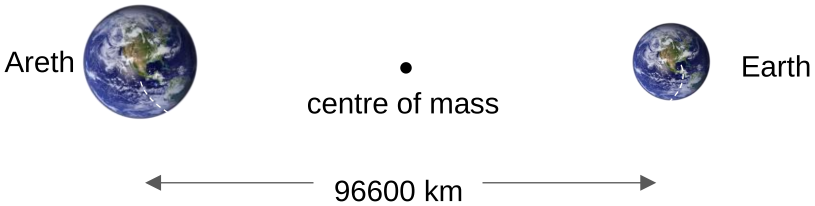

Fig. 7.2

(i) Show that the magnitude of the force that Earth and Areth exert on each other is 4.40×10^{23} N.

[2]

(ii) Using Newton's Laws of Motion, explain why the two planets orbit about the centre of mass of the double planet system.

....

....

....

....[2]

(iii) By considering the centripetal forces on the two planets, show that

$$\frac{\text{radius of Earth's orbit}}{\text{radius of Areth's orbit}} = 1.73$$

[1]

(iv) Determine the orbital period, in days, of the double planet system.

period = ... days [4]

(c) P is a point on the surface of Earth that lies on the line joining the centres of Earth and Areth, as shown in Fig. 7.3.

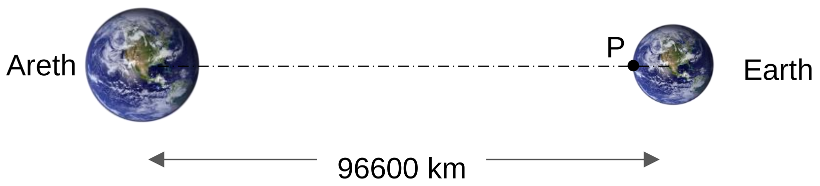

Fig. 7.3

(i) State the value of the gravitational field strength at P due to Earth only.

field strength = ... N kg^{-1} [1]

(ii) Using the values given in **(b)**, calculate the gravitational field strength at P due to Areth only.

field strength = ... N kg^{-1} [3]

(iii) Hence determine the gravitational force on a man of mass 80.0 kg standing at point P.

force = ... N [2]

(iv) When the man in **(iii)** steps on a weighing scale, the reading produced is greater than the value determined in **(iii)**.

Suggest a reason for this.

....

....

....

....[2]

[Total: 20]

8 **(a)** Apart from being different types of forces, state a difference between electric force and magnetic force.

....

....[1]

(b) Two oppositely charged parallel metal plates P and Q are placed in a vacuum. The electric field is uniform in the region between the plates.

A uniform magnetic field also exists in the region between the plates. The direction of the magnetic field is into the page as illustrated in Fig. 8.1.

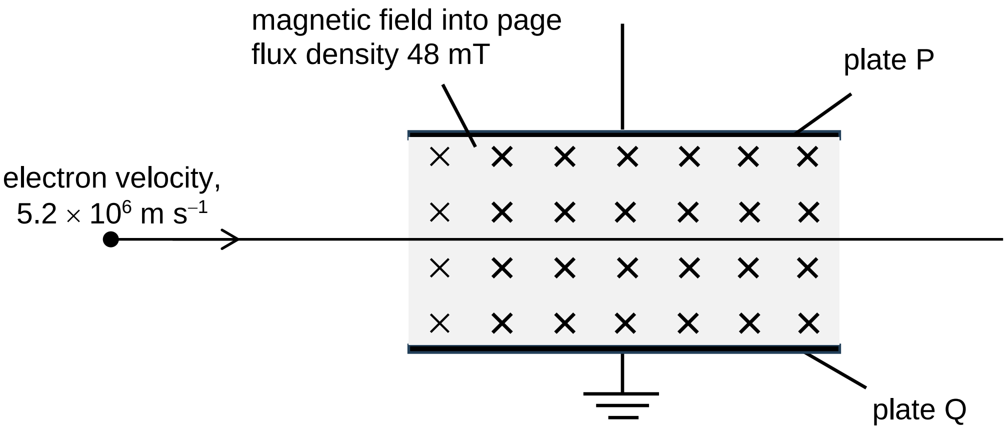

Fig. 8.1

An electron enters the region between the plates at right angles to both the electric field and the magnetic field. The electron travels through the field.

The magnetic flux density is 48 mT. The velocity of the electron is 5.2×10^{6} m s^{-1}.

The magnetic force and electric force acts on the electron in opposite directions.

(i) State and explain the polarity, positive or negative, of plate P.

....

....

....[2]

(ii) Calculate the magnitude of the magnetic force F_M acting on the electron.

F_M = ... N [2]

(iii) The electron passes through the field undeflected when the magnitudes of the magnetic and electric forces are the same.

With reference to the forces acting on the electron as it passes through the plates, state and explain how the path will change if the potential across the metal plates is decreased slightly.

....

....

....

....

....[3]

(c) Two flat coils, P and Q each of diameter 29 cm are fixed so that their planes are parallel and are separated by a constant distance equal to the radius of each coil, with the direction of the current as shown in Fig. 8.2.

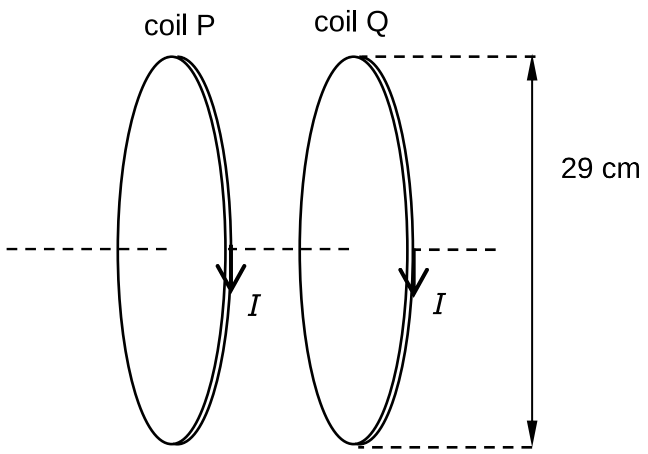

Fig. 8.2

The current I in both coils is 1.3 A.

The magnetic flux density B in the region between the two coils is uniform and given by the expression

$$B = 0.72\,\mu_0\,\frac{NI}{r}$$

where N is the number of turns on each of the flat coil of radius r. The permeability of free space is μ_0.

(i) Explain how a uniform field is set up between the coils.

....

....

....

....[2]

(ii) Each coil has 160 turns. Show that the magnetic flux density B is approximately 1.3 mT.

[1]

(iii) The space between the coil in **(c)** is a vacuum.

An electron of velocity 5.2×10^6 m s^{-1} travels at right angles into the uniform field produced by the two coils.

Calculate the radius of its orbit in the magnetic field.

radius = ... m [3]

(d) The magnetic field in **(c)** is rotated. The initial direction of the electron is now at an angle of 30° to the direction of the uniform magnetic field, as shown in Fig. 8.3.

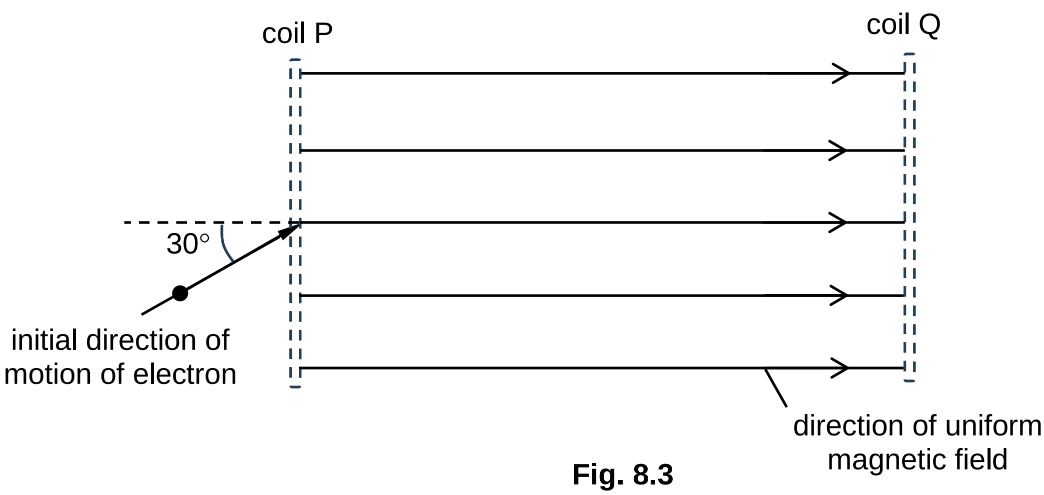

Fig. 8.3

(i) State the path of the election in the magnetic field.

....[1]

(ii) By considering the components of the velocity parallel to the magnetic field and at right angles to the magnetic field, explain the motion of the electron as stated in your answer in **(d)(i).**

....

....

....

....

....

....[3]

(iii) State and explain how the path of the electron will change if the current I in the coils were increased.

....

....

....

....[2]

[Total: 20]

End of Paper