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	**/ 8**
2	**/ 12**
3	**/ 8**
4	**/ 9**
5	**/ 6**
6	**/ 9**
7	**/ 8**
Section B	
8	**/ 20**
9	**/ 20**
Total	**/ 80**

This document consists of **24** 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	=	$-\dfrac{Gm}{r}$
temperature	T / K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\dfrac{3}{2}kT$
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	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

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

Impluse on object Y is the product of the force acting on object Y and the time of impact of the force.

....[1]

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

The principle of conservation of linear momentum states that the total momentum of the bodies remain constant [B1] if there is no resultant/net external forces acting on it. [B1]

....[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.

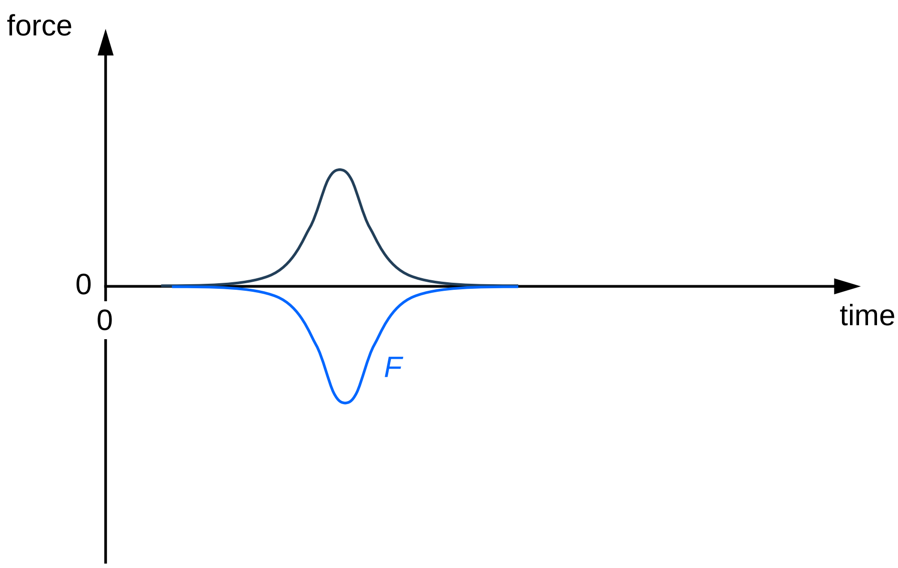

Fig. 1.2

(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.

No is it not possible. This is because the total initial momentum of both objects is non zero, hence by the principle of conservation of linear momentum, there will not be any instance where both objects can be at rest at the same time where total momentum is zero.
[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.

The area under the graph = impulse on Y

The change in momentum in Y is then 0.50 Ns.

$m_y v_y - m_y u_y = -0.50$ B1

$(0.25)v_Y - (0.25)(2.0) = 0.50$ M1

$v_Y = 4.0 \text{ m s}^{-1}$ A1

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.

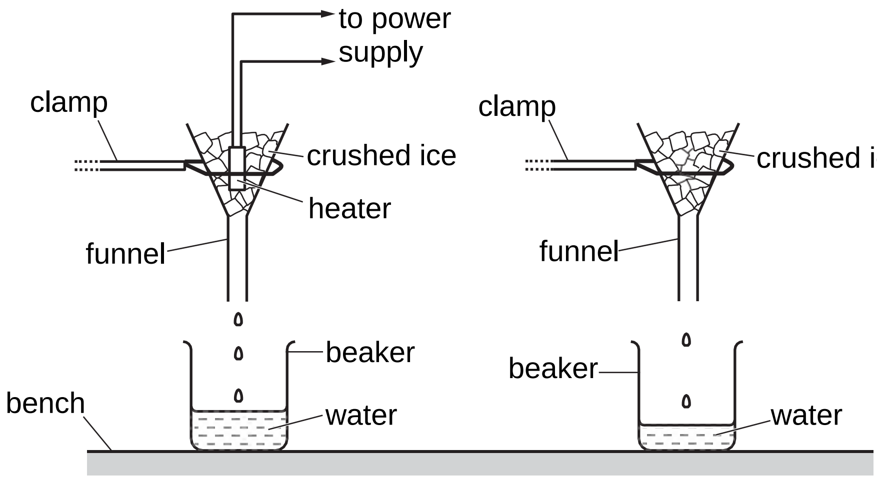

Fig. 2.1 **Fig. 2.2**

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*.

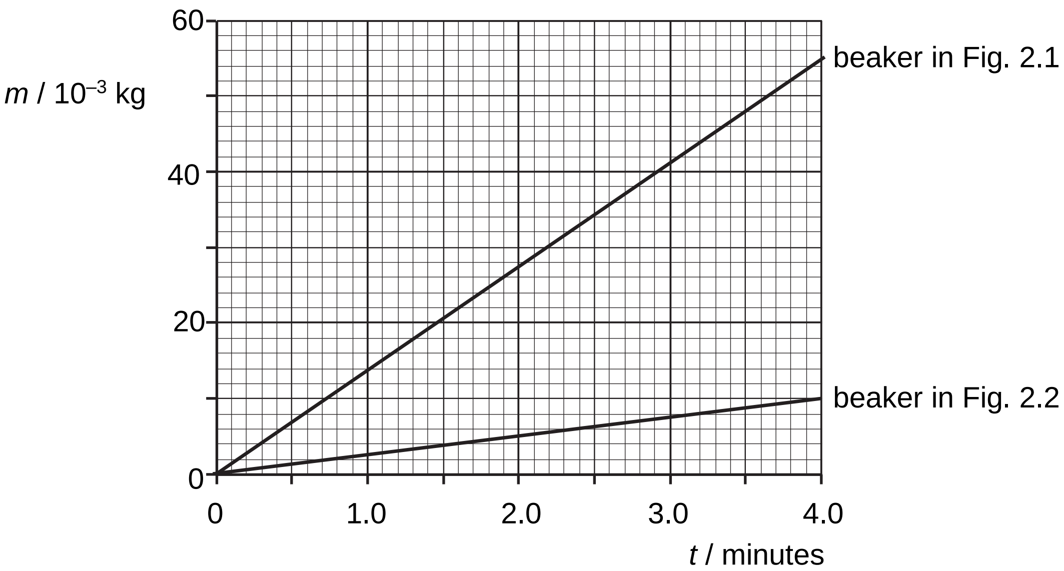

Fig. 2.3

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

<u>Rate</u> of mass of water collected OR <u>rate</u> of mass of ice melted in Fig. 2.1 is greater due to heat from heater <u>and</u> surroundings compared to Fig. 2.2 from surroundings only [B1] [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}.

$$\text{rate of ice melted} = \frac{m}{t} = \text{gradient}$$

$$\text{rate of ice melted by heater} = \left(\frac{m}{t}\right)_{\text{heater+surr}} - \left(\frac{m}{t}\right)_{\text{surr}}$$

$$= \frac{55 \times 10^{-3}}{4.0 \times 60} - \frac{10 \times 10^{-3}}{4.0 \times 60} \quad \text{[M1]}$$

$$= 1.875 \times 10^{-4} \text{ kg s}^{-1}$$

$$Pt = ml_f$$

$$IV = \left(\frac{m}{t}\right) l_f$$

$$l_f = \frac{(5.0)(12)}{1.875 \times 10^{-4}} \quad \text{[M1]}$$

$$= 3.2 \times 10^5 \text{ J kg}^{-1}$$

$$= 3 \times 10^5 \text{ J kg}^{-1} \quad \text{[A0]}$$

specific latent heat of fusion = ...3×10^5...... 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.

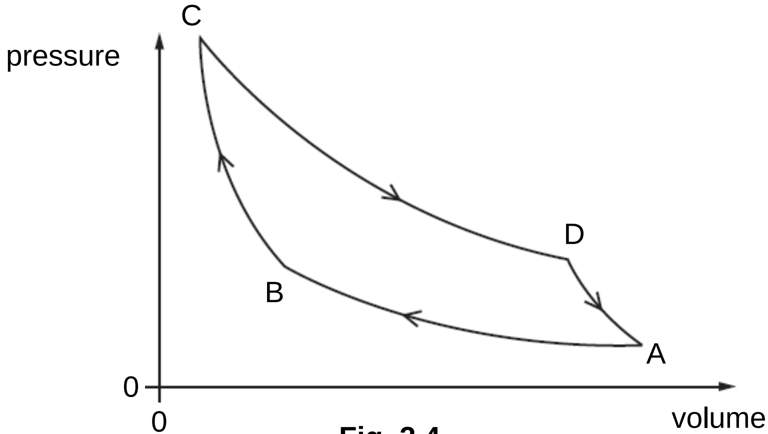

Fig. 2.4

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.

Speed / kinetic energy of gas molecules increase when hit by the moving piston,

so temperature of gas increases [B1] ....[1]

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

The gas returned to its original temperature so no change in internal energy [B1]

....................[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	–844	–844

[B1] for both

Fig. 2.5

[1]

(iii) Determine the efficiency of the heat engine.

Show your working clearly.

$$\eta = \frac{\text{net work done BY gas}}{\text{thermal energy supplied}} \times 100\%$$

$$= \frac{(936 + 844) - (702 + 844)}{936} \times 100\% \quad \text{[M1]}$$

$$= \frac{234}{936} \times 100\%$$

$$= 25\% \quad \text{[A1]}$$

efficiency = ...25.......... % [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.

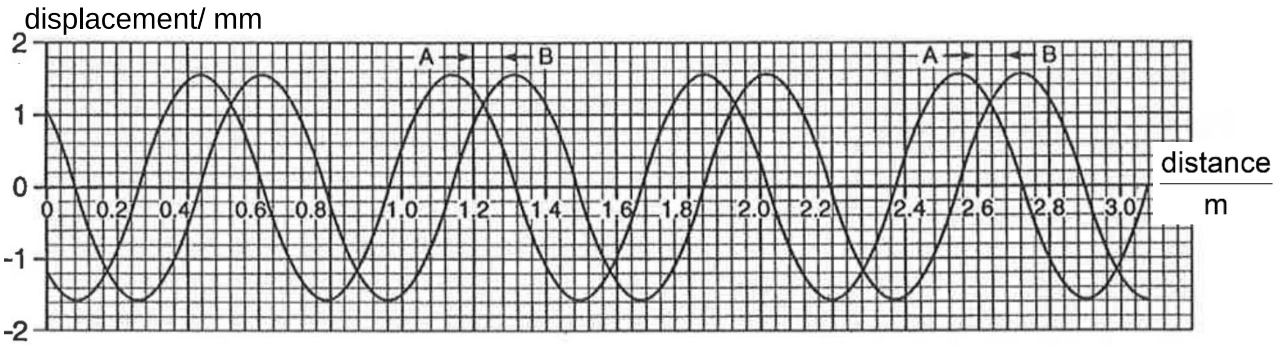

Fig. 3.1

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

From x = 0.08 to 1.84, there are 2.5 wavelengths.

Wavelength = (1.84 – 0.08) / 2.5 = 0.704 m

wavelength = ...m [2]

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

$v = f\lambda$

$v = 469 \times 0.704 = 330.2$ 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 ($x \pm \Delta x$).

$\Delta v / v = \Delta f / f + \Delta\lambda / \lambda = 5 + 8 = 13\%$ M1

$\Delta v = \pm 40$ m s^{-1}

$v = (330 \pm 40)$ m s^{-1} A1

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.

π radians B1 (must have the unit)

Since the vector sum of the displacements of the two waves is zero, the point is a node. B1

....

....[2]

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

Antinode is ¼ of wavelength away.

At antinode, distance = 1.40 – 0.70/4 = 1.22 m B1

Displacement = 1.1 + 1.1 = 2.2 mm B1

maximum displacement = ...[2]

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

From graph, distance between the two peaks = 0.16 m M1

Time for two peaks to meet, t = (0.16 / 2) / 330 = 0.24(2) ms A1

t = ...ms [2]

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

When the two waves meet in phase at their respective maximum displacements,

Maximum displacement of resultant wave = 1.6 + 1.6 = 3.2 mm

maximum displacement = ...mm [1]

[Total: 12]

4 **(a)** 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.

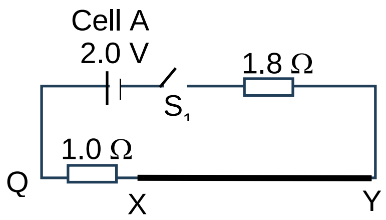

Fig. 4.1

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

An e.m.f. of 2.0 V is when 2.0 J of electrical energy converted from other forms of energy to drive 1 C of charge around a complete circuit. [B1]

....[1]

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

$$I = \frac{\varepsilon}{1.8 + 1.0 + R_{XY}} = \frac{2.0}{1.8 + 1.0 + 5.0} = 0.26\ (0.256)\ \text{A [A1]}$$

current = ... A [1]

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

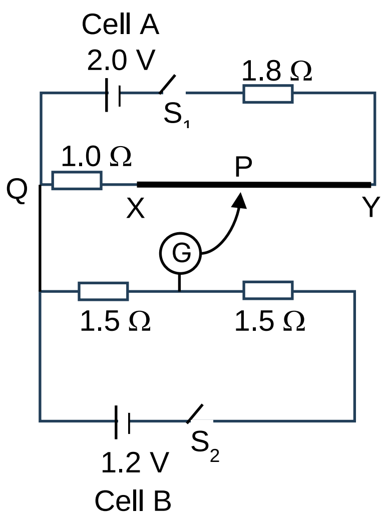

Fig. 4.2

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

For zero deflection, the p.d. across QP is 0.60 V. [B1]

$0.60 = 0.26\,(1.0 + R_{XP})$

$R_{XP} = 1.3(1.34)\ \Omega$ [B1]

$L_{XP} = \frac{1.3}{5.0} \times 1.000 = 0.26$ m (0.269)[A1]

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.

The pd across the 1 kΩ, $V_{1k\Omega} = \frac{1000}{1000 + 1.8 + 5} \times 2.0 = 1.99$ V OR

The pd across the 1 kΩ is almost 2V or much greater than 0.60 V. [B1]

Null deflection is not possible. [B1]

.... [2]

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

The two LDR have the same resistance even as the light intensity change.

The p.d. across QP is remains 0.60 V. [B1]

The *XP* is also unchanged. [B1]

.... [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.

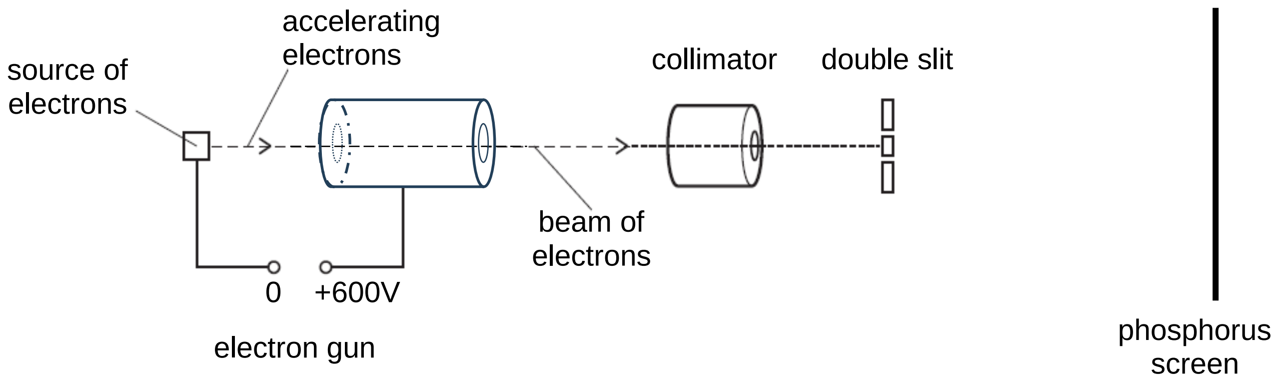

Fig. 5.1

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.

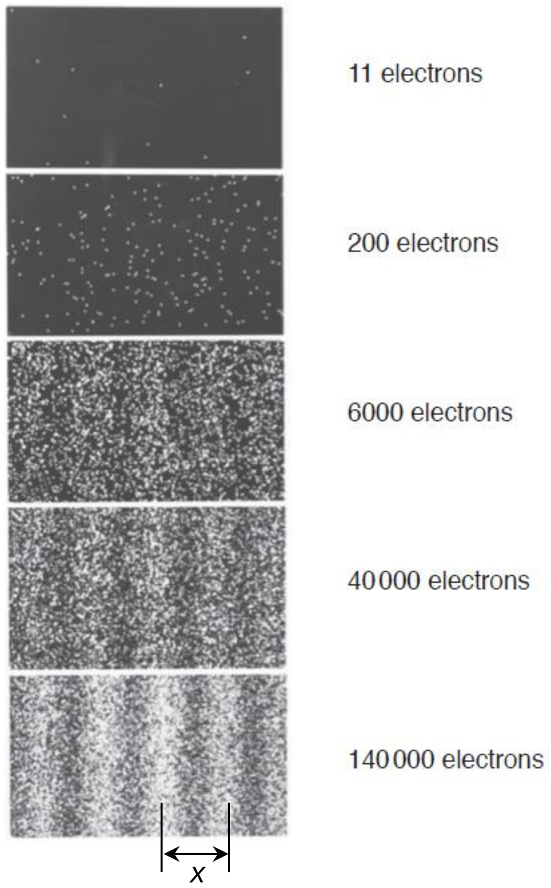

Fig. 5.2 (not to scale)

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

Particle property: Each electron registers as a single point/dot on the screen [B1]

Wave property: Regular maxima and minima (or bright and dark regions) indicates an interference pattern associated with waves [B1]

.... [2]

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

$$qV = \frac{1}{2}mv^2$$
$$v = \sqrt{\frac{2qV}{m}}$$
$$= \sqrt{\frac{2(1.60\times10^{-19})(600)}{9.11\times10^{-31}}}$$
$$= 1.452\times10^{7} \text{ m s}^{-1} \quad \text{[C1]}$$

$$\lambda = \frac{h}{mv}$$
$$= \frac{6.63\times10^{-34}}{(9.11\times10^{-31})(1.452\times10^{7})} \quad \text{[C1]}$$
$$= 5.01\times10^{-11} \text{ m} \quad \text{[A1]}$$

$$qV = \frac{p^2}{2m}$$
$$p = \sqrt{2mqV}$$
$$= \sqrt{2(9.11\times10^{-31})(1.60\times10^{-19})(600)}$$
$$= 1.322\times10^{-23} \text{ N s} \quad \text{[C1]}$$
$$\lambda = \frac{h}{p}$$
$$= \frac{6.63\times10^{-34}}{1.322\times10^{-23}} \quad \text{[C1]}$$
$$= 5.02\times10^{-11} \text{ m} \quad \text{[A1]}$$

wavelength = 5.01×10^{-11} 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.

$$x = \frac{\lambda D}{a}$$
$$= \frac{(5.01\times10^{-11})(1.2)}{280\times10^{-9}} \quad \text{[C1] ecf their de Broglie } \lambda$$
$$= 2.15\times10^{-4} \text{ m} \quad \text{[A1]}$$

x = 2.15×10^{-4} 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.

Since velocity affects the de Broglie wavelength ($\lambda = \frac{h}{mv}$) of the electron, a single de Broglie wavelength is needed to get a clear/observable interference pattern (so distance *x* can be similar) [B1]

[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 bounce off an electron causes the electron to change its momentum.

Photons have momentum [B1]

When photons bounce off/scattered by the electron, a collision occurs and momentum is transferred to the electron (by the principle of conservation of momentum), causing the electron's momentum to change [B1] [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.

(Since $p = \frac{h}{\lambda}$) Shorter wavelength of EM radiation leads to greater momentum transfer and change imparted to the electron [B1]

(By $\Delta x \Delta p \geq h$) so there is greater uncertainty in momentum Δp so uncertainty in position Δx is minimised (allowing for more precise measurement of position to be made) [B1] [2]

[Total: 12]

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

The ***decay constant ,λ***, is the probability of decay per unit time of a nucleus

[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**.**

If the decay constant is small, the activity will be small and thus there will be ample data to be collected. The data sets need to be large so that an accurate value of probability can be deduced for any random event.

[1]

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

To minimise the effects of randomness in decay, measurements will need to be taken in long time intervals and average value calculated for each set, B1
average may be different from true value as it is almost impossible to deduce when a nuclide will decay and what it will decay to. B1
which makes the measurements inaccurate

[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.

$$^{222}_{86}\text{Rn} \rightarrow \; ^{218}_{84}X + \, ^{4}_{2}He$$ [1]

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

Total ke = (final mass – initial mass) x c^2 M1

= 9.0×10^{-13}J. A1

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.

Alpha particles are highly ionising. Hence, if accidentally ingested or inhaled into the body, it can cause internal damage to cells, tissue etc. Therefore, although it has a short range, it can still be hazardous.

....[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 did the star explode that released the elements that formed our Earth.

Half lives of ^{235}U and ^{238}U are 0.704×10^9 years and 4.47×10^9 years respectively.

$$\frac{e^{-\lambda_5 t}}{e^{-\lambda_8 t}} = 0.00725,$$ M1

λ_5 – decay constant of ^{235}U , λ_8 – decay constant of ^{238}U

Hence t = 5.9×10^9 years A1

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	Electric Charge
Newton's Law of Gravitation	Coulomb's Law
Gravitational Field Strength is in the direction of decreasing Gravitational Potential	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.

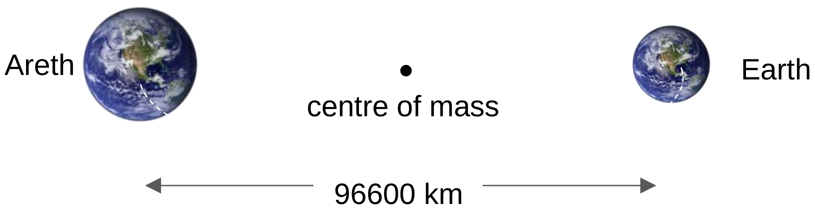

Fig. 7.2

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

Mass of Areth $M_A = 5.97\times10^{24} \times 1.20^3 = 1.03\times10^{25}$ kg [B1]

$$F = \frac{GM_E M_A}{d^2} = \frac{6.67\times10^{-11}\times5.97\times10^{24}\times1.03\times10^{25}}{(9.66\times10^{7})^2}$$ [B1]

$= 4.40\times10^{23}$ 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.

Each planet orbits due the gravitational force exerted by the other.

As a system, there are no external forces exerted on them. [B1]

Thus by Newton's 1st Law, the centre of mass must remain stationary. [B1]

So the centre of mass is the centre of both planets' orbit.

[2]

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

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

$M_E r_E \omega_E^2 = M_A r_A \omega_A^2$

Since $\omega_E = \omega_A$, $\frac{r_E}{r_A} = \frac{M_A}{M_E} = \frac{1.03 \times 10^{25}}{5.97 \times 10^{24}}$ [B1] = 1.73

[1]

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

$r_E = \frac{1.73}{2.73} \times 9.66 \times 10^7$ [B1] $= 6.12 \times 10^7$ m

$F = M_E r_E \omega^2 \rightarrow 4.40 \times 10^{23} = 5.97 \times 10^{24} \times 6.12 \times 10^7 \times \omega^2$ [M1]

$\omega = 3.47 \times 10^{-5}$ rad s^{-1}

$T = \frac{2\pi}{\omega} = \frac{2\pi}{3.47 \times 10^{-5}}$ [M1]

$= 1.81 \times 10^5$ s = 2.09 days [A1]

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.

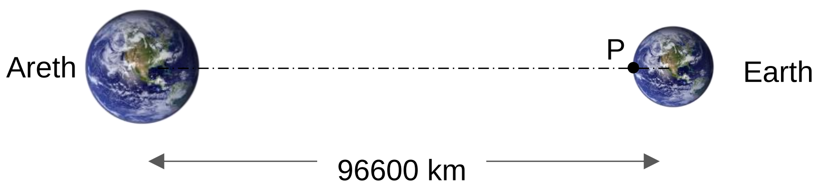

Fig. 7.3

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

field strength = ...9.81.......... N kg^{-1} [1]

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

Distance from Areth to P = $9.66\times10^{7} - 6.37\times10^{6} = 9.02\times10^{7}$ m

[B1]

$$g = \frac{GM}{r^2} = \frac{6.67\times10^{-11}\times1.03\times10^{25}}{(9.02\times10^{7})^2} \quad \text{[M1]}$$

$= 0.0845$ N kg^{-1} [A1]

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

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

Resultant field strength = 9.81 – 0.0845 = 9.73 N kg^{-1} [B1]

Gravitational force = 80.0 × 9.73 = 778 N [A1]

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.

The man is also orbiting about the double planet's centre of mass, thus it has an acceleration (and resultant force) towards it. [B1]

Thus the force the weighing scale exerts on the man (towards the centre of orbit) must be greater than the gravitational force (towards centre of Earth) [2]

[Total: 20]

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

Electric forces are (created by and) act on, both moving and stationary charges; while magnetic forces are (created by and) act on only moving charges. [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.

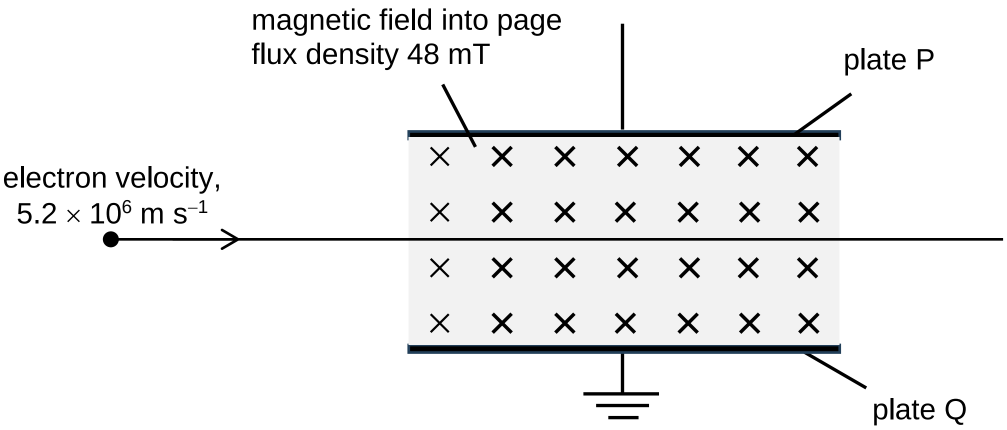

Fig. 8.1

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.

By Flemings left hand rule, the magnetic force on the electron acts downwards. [M1]
Hence the electric force on the electron should act upwards, and plate P will be positive with respect to plate Q. [A1]

[2]

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

$$F_M = Bqv$$
$$= (48\times10^{-3})(1.6\times10^{-19})(5.2\times10^{6}) \quad \text{M1}$$
$$= 4.0\times10^{-13}\ \text{N} \quad \text{A1}$$

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.

When the potential decreases, the electric field strength and hence the electric force on the electron decreases. ($F = qE$)[B1]
Upon entering the field, the downwards magnetic force is larger than the upward electric force and hence there is a net downward force. The electron is deflected downwards. [A1]
As the electron path curves downwards, the subsequent net force is the resultant of the upward electric force and the magnetic force tangential to the motion of the electron. The path curves further downwards. [B1]

[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.

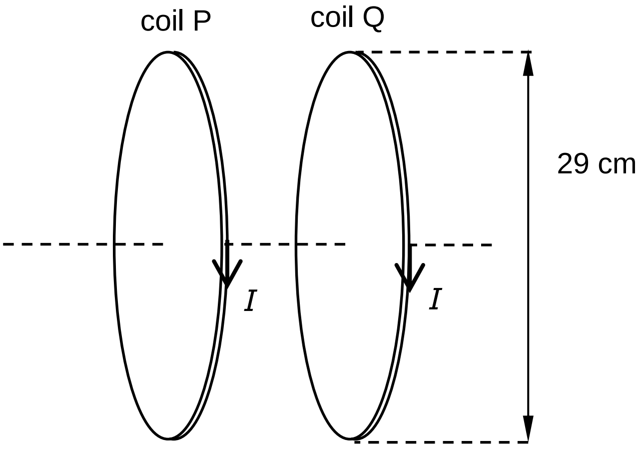

Fig. 8.2

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.

When there is a current in the coil, by right hand grip rule, there is field set up around each loop such that the magnetic flux passes from left to right. [B1]

The fields from each of the loops superpose to set up a close to uniform field between them.

[2]

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

$$B = 0.72\,\mu_0 \frac{NI}{r} = (0.72)(4\pi \times 10^{-7})\frac{(130)(1.3)}{(2.9 \times 10^{-2}/2)}$$

$$= 1.298 \times 10^{-3}$$

$$= 1.3 \text{ mA}$$

[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.

Magnetic force provides centripetal force [B1]

$$\sum F = ma_c$$

$$F_M = Bqv = \frac{mv^2}{r}$$

$$(1.3 \times 10^{-3})(1.6 \times 10^{-19})(5.2 \times 10^{6}) = \frac{(9.11 \times 10^{-31})(5.2 \times 10^{6})^2}{r} \quad \text{M1}$$

$$r = 2.2775 \times 10^{-2}$$

$$= 2.28 \text{ cm} \quad \text{A1}$$

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.

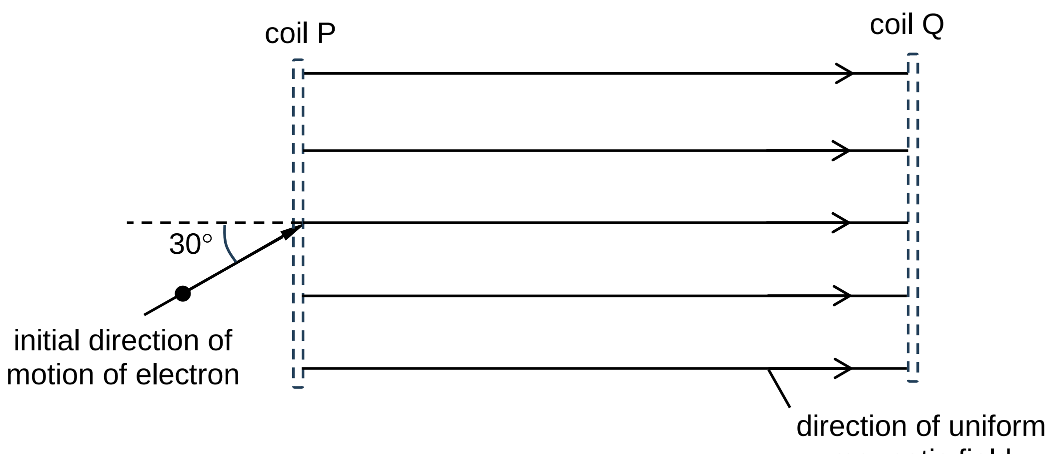

Fig. 8.3

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

The electron moves in a helical path. ....[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).**

The horizontal component of velocity is parallel to the direction of the B field, hence remains unchanged. [B1]

By Flemings left hand rule, a magnetic force acts on the electron perpendicular to the B field and its perpendicular component of velocity. This provides the centripetal force causes the electron to chart out a circular path in the plane perpendicular to the B field.

The motion of the electron is the vector sum of the horizontal and perpendicular components of velocity, hence a helical path. [A1]

[3]

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

When current I is increased, the magnetic flux density B increases.

$$Bqv = \frac{mv^2}{r}$$

$$r = \frac{mv}{Bq}$$

Since m, v and q are constants.[M1]

[2]

This causes the radius r of the helical path to decrease [A1]

[Total: 20]

End of Paper