NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

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

PHYSICS 9749/02

Paper 2 Structured Questions **10 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.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

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	/ 5
2	/ 7
3	/ 8
4	/ 8
5	/ 11
6	/ 11
7	/ 10
8	/ 20
Total	/ 80

This document consists of **19** 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	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 **(a)** A beaker in air contains a liquid. The base area of the beaker is A, as shown in Fig. 1.1. The liquid has density ρ and fills the beaker to a height h.

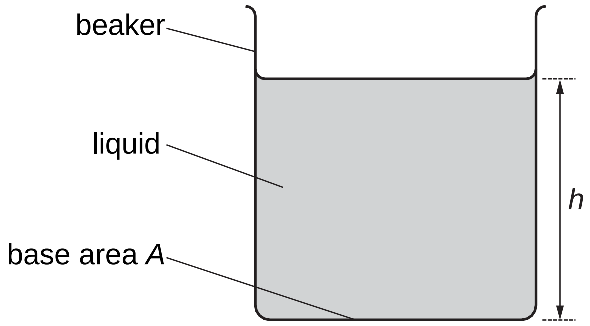

Fig. 1.1

(i) Show that the pressure P due to the liquid at the base of the beaker is given by

$$P = \rho g h$$

where g is the acceleration of free fall.

$P = \dfrac{F}{A}$ and $\rho = \dfrac{m}{Ah}$ both relations used

$P = \dfrac{m \times g}{A}$

$= \dfrac{\rho A h \times g}{A}$

$= \rho g h$ appropriate algebra leading to ans [B1]

[1]

(ii) Explain why the equation in **(i)** does not give the total pressure at the base of the beaker.

Total pressure at the base includes atmospheric / air pressure above the liquid [B1]

[1]

(iii) Fig. 1.2 shows the variation of the total pressure inside the liquid with depth x below the surface.

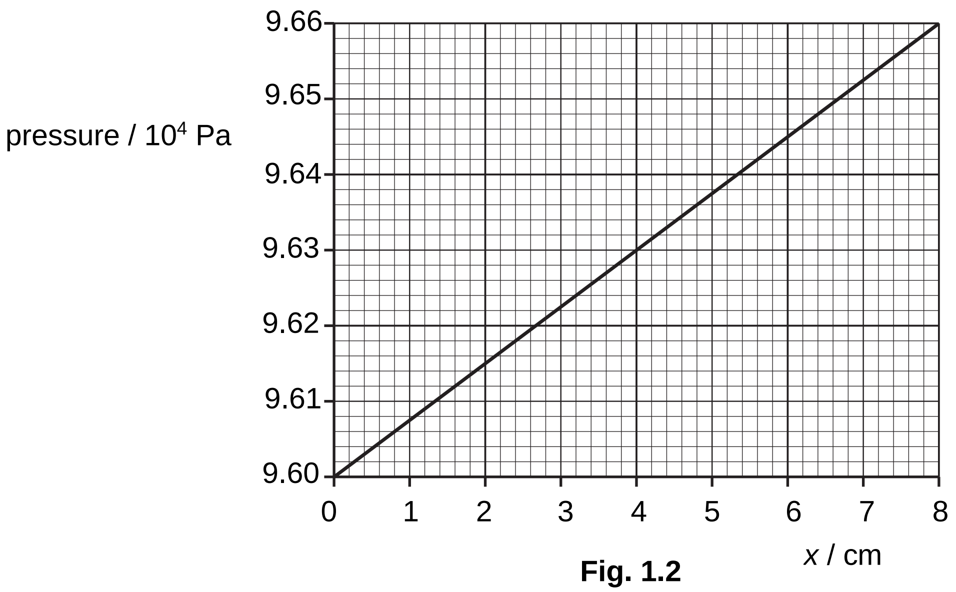

Fig. 1.2

Use Fig. 1.2 to determine the density of the liquid.

$$p_{\text{total}} = \rho g h + p_{\text{atm}}$$

$$9.66 \times 10^4 = \rho(9.81)(0.080) + 9.60 \times 10^4$$

$$\rho = 765 \text{ kg m}^{-3} \quad \text{[A1] (accept 760 to 770 kg m}^{-3}\text{)}$$

$$\Delta p = \rho g \Delta h$$

$$(9.66 - 9.60) \times 10^4 = \rho(9.81)(8.0 \times 10^{-2})$$

$$\rho = 765 \text{ kg m}^{-3} \quad \text{[A1] (accept 760 to 770 kg m}^{-3}\text{)}$$

density = ...760 to 770............ kg m^{-3} [1]

(b) A spherical buoy of density 220 kg m^{-3} floats in equilibrium on the surface of sea water of density 1050 kg m^{-3}, as shown in Fig. 1.3.

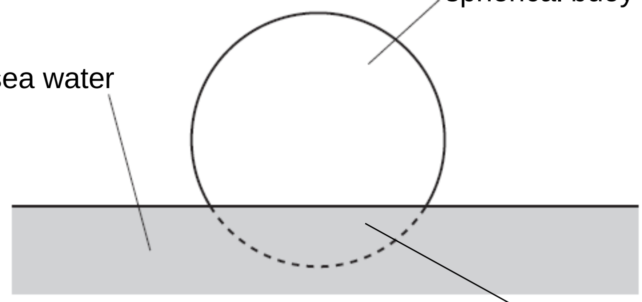

Fig. 1.3 (not to scale)

Determine the percentage of the volume of the buoy that is submerged in water.

At equilibrium during floating, upthrust = weight

Let submerged volume be V_{sub} and volume of sphere be V.

$$(\rho_W)(V_{\text{sub}})g = (\rho_S)(V)g$$

$$1050V_{\text{sub}} = 220V \quad \text{[C1]}$$

$$\frac{V_{\text{sub}}}{V} = 0.21$$

$$\therefore \text{percentage submerged} = 21\% \quad \text{[A1]}$$

percentage = ...21............ % [2]

[Total: 5]

2 **(a)** A body travelling at a constant speed in a circular path experience centripetal acceleration. Using Newton's laws of motion explain why there is acceleration although the speed is constant.

The velocity of the body changes along a circular path. By N1L this require an external resultant force to act on the body [B1]. Since the centripetal acceleration is pointing to the centre of circle and perpendicular to the instantaneous velocity, by N2L, it has no component along the path, hence speed is constant.[B1] [2]

(b) A car of mass 1500 kg travels in a horizontal circular path of radius 50.0 m on a banked road with speed of 15.0 m s^{-1} without any frictional force acting on the tyres along the slope.

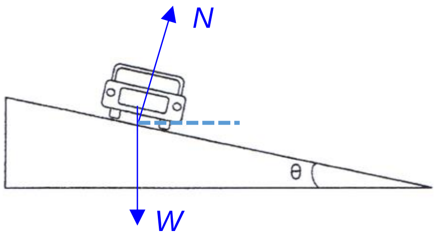

Fig. 2.1

(i) Calculate the angle θ at which the road is banked.

$N\cos\theta = mg$

$N\sin\theta = \frac{mv^2}{r}$ [M1 both eqn]

$\tan\theta = \frac{v^2}{rg} = \frac{15^2}{50.0 \times 9.81}$ [M1]

θ = 24.6° [A1]

θ = ...° [3]

(ii) Explain how friction force enables the car to travel in the same horizontal circular path at a lower speed.

The horizontal component of static friction acts away from the direction of centripetal force [B1], resulting in a smaller magnitude of centripetal force [B1]. A smaller centripetal force permits the car to move on the banked surface in uniform circular motion with a slower speed. [2]

[Total: 7]

3 **(a)** **(i)** The kinetic theory for an ideal gas of volume V at pressure p leads to the equation

$$pV = \frac{1}{3}Nm\langle c^2 \rangle,$$

where the other symbols refer to their usual meanings.

Use the equation of state for an ideal gas to show that the average translational kinetic energy E_K of a molecule of ideal gas is given by

$$E_K = \frac{3}{2}kT.$$

$$pV = NkT$$

$$\frac{1}{3}Nm\langle c^2 \rangle = NkT$$

$$\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$$ [B1] for $pV = NkT$ leading to $\frac{1}{2}m\langle c^2 \rangle$ seen

[1]

(ii) One helium atom has a mass of 6.68×10^{-27} kg.
Helium may be considered as an ideal gas.

Show that the total kinetic energy of the helium atoms in 1.00 mol of helium gas at 25 °C is 3720 J.

$$E_{K,\ total} = \frac{3}{2}NkT$$

$$= \frac{3}{2}(6.02 \times 10^{23})(1.38 \times 10^{-23})(25 + 273.15)$$ [C1]

$$= 3715$$

$$= 3720 \text{ J (shown)}$$ [A0]

[1]

(iii) State the value of the internal energy of 1.00 mol of helium gas at 25 °C. Explain your answer.

Internal energy is the sum of the random distribution of the microscopic kinetic energy (KE) and microscopic potential energy (PE) of the gas molecules [B1]

For an ideal gas, there are no intermolecular forces between molecules so PE = 0, so internal energy = KE = 3720 J [B1] [2]

(iv) The helium gas is gradually cooled from 25 °C to –150 °C at which the internal energy is 1540 J.

On Fig. 3.1, plot points and draw a line to show the variation with temperature θ of the internal energy U of the helium gas.

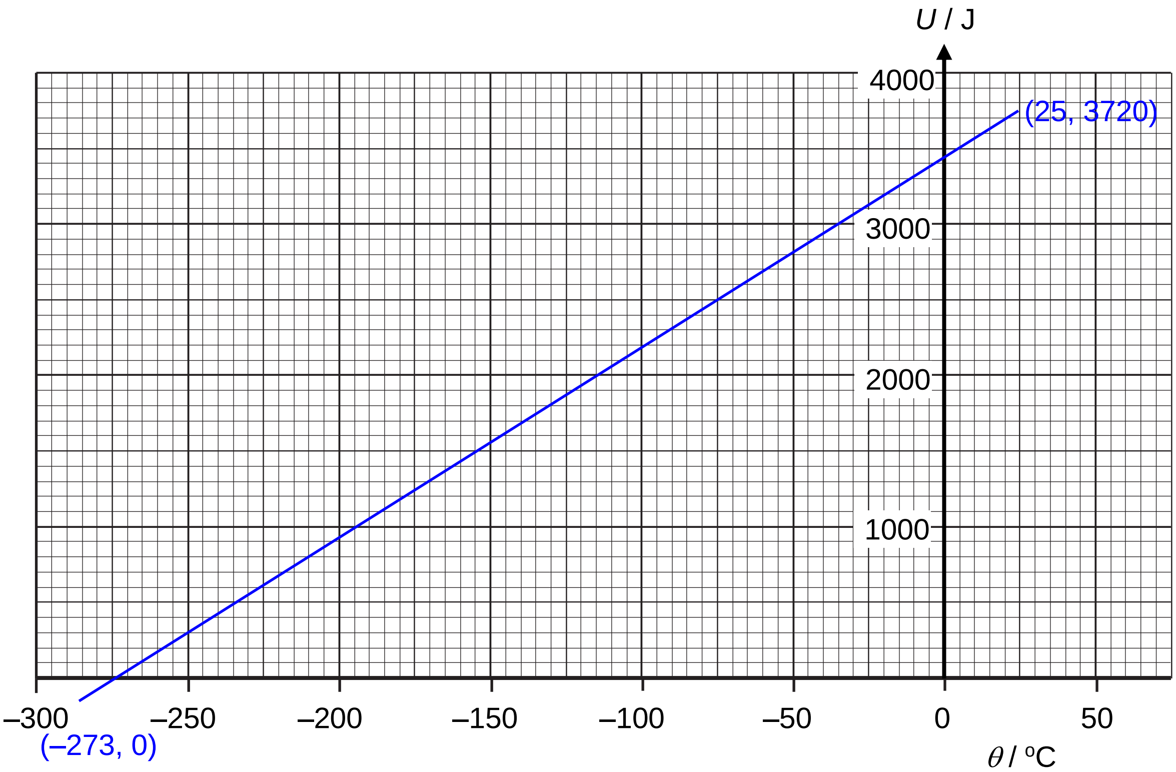

Fig. 3.1

[1]

(v) Explain how your graph leads to the idea of an absolute zero of temperature.

The graph shows a linear relationship between internal energy and temperature so extrapolate the graph to 0 internal energy to reach a temperature of –273.15 °C [B1]

[1]

(b) Gases like hydrogen and helium are found mainly in stars. These gases are at a very high pressure.

Use the assumptions of the kinetic theory of gases to suggest why, in practice, the gas found in stars is unlikely to behave as an ideal gas.

At very high pressure, gas molecules are very close to each other [B1]

EITHER intermolecular forces are not negligible OR volume of molecules are not negligible compared with the gas volume [B1]

[2]

[Total: 8]

4 A tube closed at one end, has a constant area of cross section A. Some lead shots are placed in the tube so that the tube floats vertically in a liquid of density ρ. The total mass of the tube and its contents is M.

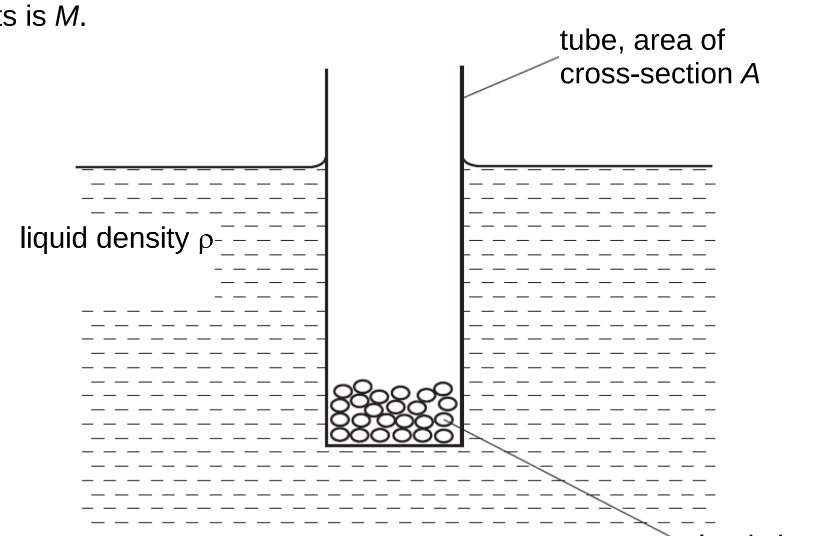

Fig. 4.1

(a) When the tube is given a small vertical displacement and then released, show that the acceleration a of the tube is related to its vertical displacement y by the expression

$$a = -\frac{A\rho g}{M}y.$$

When in equilibrium and submerge to a depth d, Weight = Upthrust

$Mg = \rho A d g$ [M1]

When displaced another depth y, (assign downward positive following downward displacement)

$Mg - U = Ma$

$Mg - \rho A g\left(d + y\right) = Ma$

$\rho A g d - \rho A g\left(d + y\right) = Ma$ [B1]

$a = -\frac{A\rho g}{M}y$ [A0]

[2]

(b) Fig. 4.2 shows the variation with time t of the vertical displacement y of the tube in another liquid.

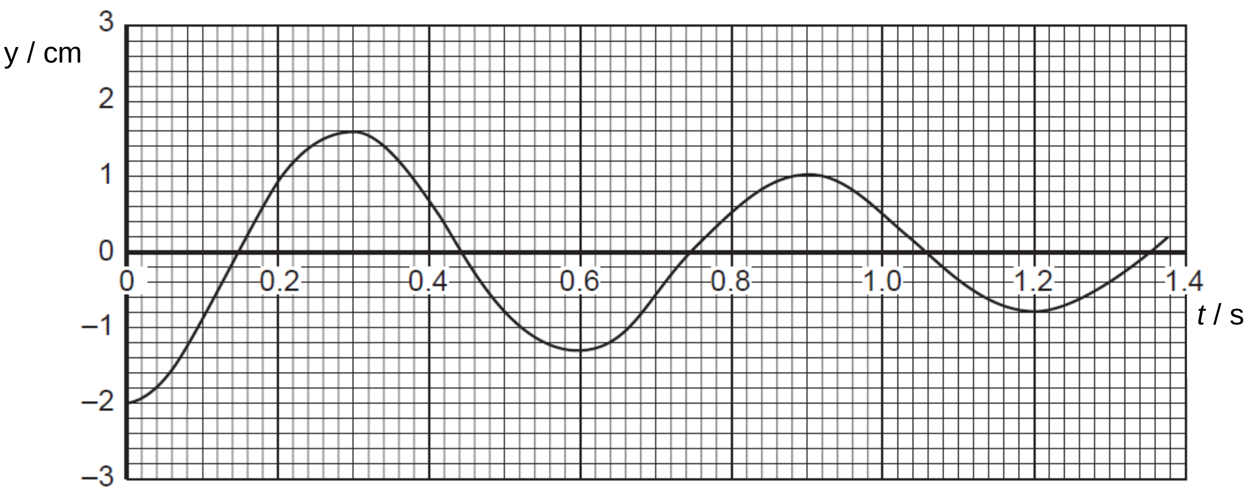

Fig. 4.2

(i) Determine the frequency f_0 of the oscillating tube.

The tube goes through two oscillations in a time of 1.20 s. [B1]

frequency, f_o = 2/1.20 = 1.67 Hz [A1]

f_0 = ... Hz [2]

(ii) The tube has an external diameter of 2.4 cm and is floating in a liquid of density 950 kg m^{-3}. Calculate the mass of the tube and its contents.

Compare $a = -\frac{A\rho g}{M}y$ with $a = -\omega^2 y$

$$\omega^2 = \frac{A\rho g}{M}$$

$$(2\pi f)^2 = \frac{A\rho g}{M}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{A\rho g}{M}} \text{ [C1]}$$

$$1.67 = \frac{1}{2\pi}\sqrt{\frac{\pi D^2 \rho g}{4 \times M}} = \frac{1}{2\pi}\sqrt{\frac{\pi \times (0.025)^2 \times 950 \times 9.81}{4 \times M}} \text{ [M1]}$$

$$M = 0.038 \text{ kg [A1]}$$

mass = ... kg [3]

(iii) More lead shots are added to the tube. State and explain the changes to the graph in Fig. 4.2.

The frequency is reduced with addition of lead shots.

Therefore the graph now shows greater period. [B1: both underlined points]

....[1]

[Total: 8]

5 Two dippers S_1 and S_2, oscillating in phase with equal amplitude at a frequency of 8.0 Hz, generate waves of wavelength 6.0 cm in a ripple tank as shown in Fig. 5.1.

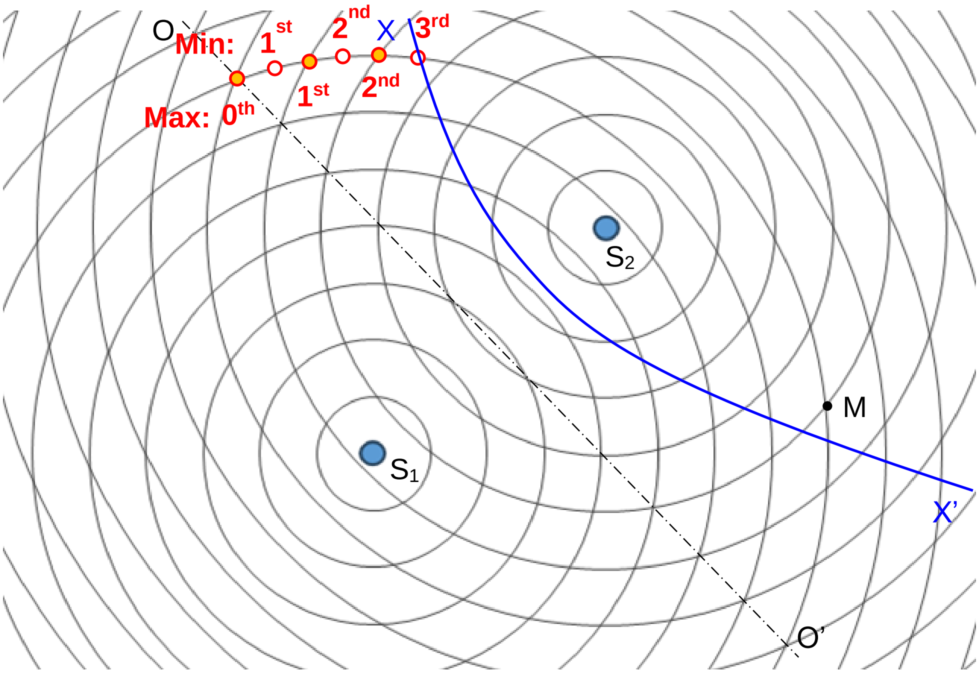

Fig. 5.1

The superposition of the waves generated produce an interference pattern of maxima and minima.

(a) State the *Principle of Superposition*.

When two or more waves meet at a point, [B1] the displacement at that point is equal to the vector sum of the displacements of the individual waves. [B1]

[2]

(b) For the waves from S_1 and S_2 meeting at point M, state

(i) their path difference,

$(8 - 5) \times 6.0 = 18.0$ cm [B1]

[1]

(ii) their phase difference.

Zero or 6π radians [B1]

[1]

(c) The waves radiate uniformly from the dippers in all directions on the surface of the water. Given that the amplitude of the wave at M when only S_1 is oscillating is 4.2 mm, deduce the amplitude of the wave at M

(i) when only S_2 is oscillating,

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}} = \frac{P}{\pi s d} \propto \frac{1}{d}$$

where d is distance from dipper and s is depth of surface of water,

and Intensity $\propto$ amplitude^2

→ amplitude $\propto \sqrt{\frac{1}{d}}$ [M1]

amplitude due to $S_2 = \sqrt{\frac{8}{5}} \times 4.2 = 5.3$ mm [A1]

amplitude = ... mm [2]

(ii) when both S_1 and S_2 are oscillating.

At M, the two waves are in phase → amplitude = 5.3 + 4.2 = 9.5 mm

amplitude = ... mm [1]

(d) OO' is the perpendicular bisector of S_1S_2.

(i) Draw a line on Fig 5.1 to represent the third minima from OO' and label it XX'. [1]

(ii) Explain why the amplitude of the wave along XX' is not zero.

(Due to the different distances from their respective sources,) the two waves have different amplitudes. [B1] Thus minimum amplitude = $a_1 - a_2 \neq 0$. [1]

(e) The frequency of S_1 is kept at 8.0 Hz and the frequency of S_2 is decreased slightly to 7.8 Hz.

Describe what will be observed at M.

The amplitude of the wave at M will vary from maximum to minimum and back to maximum [B1] once every 5 seconds. [B1]

....

....[2]

[Total: 11]

6 (a) Define *acceleration*.

Acceleration is the rate of change of velocity [B1]

[1]

(b) State what is meant by a *field of force*.

A field of force due to a body's property (eg. charge, mass) is a region in space in which another body carrying that property experiences a force when it is placed in the field [B1] [1]

(c) Two parallel metal plates A and B are separated by a distance of 2.8 cm in a vacuum, as shown in Fig. 6.1.

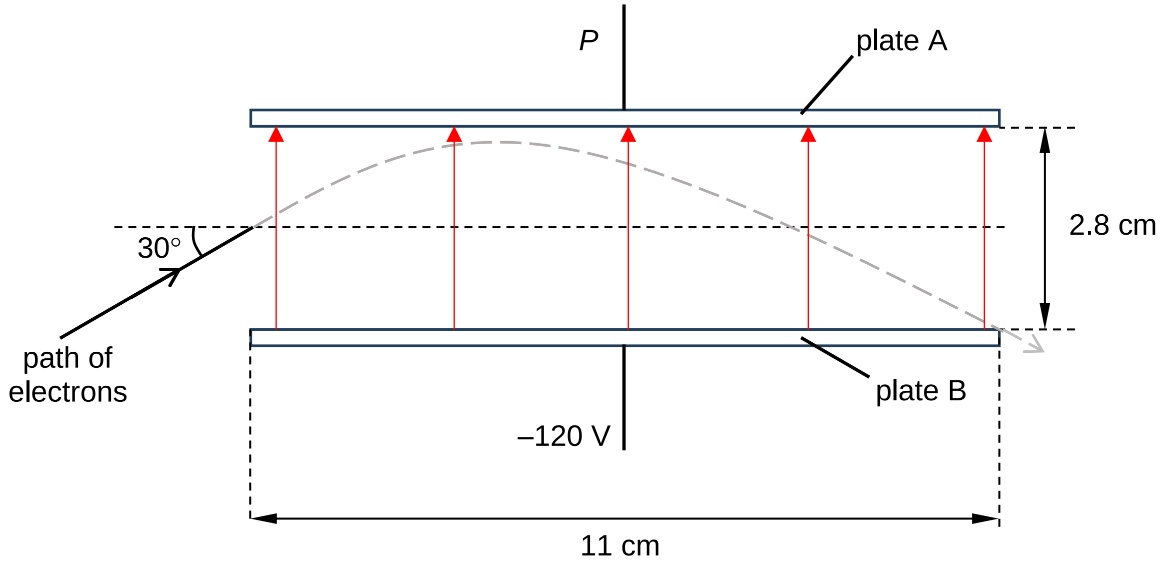

Fig. 6.1

The plates have length 11 cm. Plate A is at unknown potential *P* while plate B is at a potential of –120 V. The electric field may be assumed to be uniform between the plates and zero outside the plates.

An electron with kinetic energy 4.1×10^{-16} J enters the region midway between the plates. The initial direction of the electron is at an angle 30° above the horizontal. The electron charts out a parabolic path between the plates and exits just at the edge of plate B as shown in Fig. 6.1.

(i) Sketch on Fig. 6.1, lines to represent the electric field within the plates. [1]

(ii) For the electron between the metal plates,

1. show that the vertical component of velocity just as the electron enters the electric field is 1.5×10^7 m s^{-1},

$$KE = \frac{1}{2}m_e v^2 = 4.1\times10^{-16}$$

$$v = \sqrt{\frac{(2)(4.1\times10^{-16})}{9.11\times10^{-31}}} = 30.002\times10^6 \quad \text{B1}$$

$$v_y = v\sin 30°$$

$$= 1.50009\times10^7 \quad \text{B1}$$

$$= 1.5\times10^7 \text{ m s}^{-1} \quad \text{A0}$$

[2]

2. the time for the electron to travel a horizontal distance equal to the length of the plates,

$$s = u_x t$$

$$t = \frac{s}{u_x} = \frac{11\times10^{-2}}{30.0\times10^{6}\cos30°}$$

$$= 4.23\times10^{-9}\ \text{s} \qquad \text{A1}$$

time = ... s [1]

3. calculate the acceleration of the electron.

Upwards taken as positive direction

$$s = u_y t + \frac{1}{2}at^2$$

$$-1.4\times10^{-2} = (1.5\times10^{7})(4.23\times10^{-9}) + \frac{1}{2}a(4.23\times10^{-9})^2$$

$$a = -8.66\times10^{15}\ \text{m s}^{-2}$$

acceleration = ... m s^{-2} [2]

(iii) Hence or otherwise, determine the potential *P* of plate A for the electrons to chart out the path shown in Fig. 6.1.

$$F = qE = q\frac{\Delta V}{d} = ma$$

$$\Delta V = \frac{mad}{q} = \frac{(9.11\times10^{-31})(8.66\times10^{15})(2.8\times10^{-2})}{1.6\times10^{-19}} \qquad \text{M1}$$

$$= 1.38\times10^{3}\ \text{V} \qquad \text{C1}$$

Plate A is at a lower potential:

$$\Delta V = 1380 = -120 - P$$

$$P = -1500\ \text{V} \qquad \text{A1}$$

P = ... V [3]

[Total: 11]

7 A square coil of side 5.0 cm and 50 turns is placed horizontally midway between the poles of a magnet as shown in Fig. 7.1.

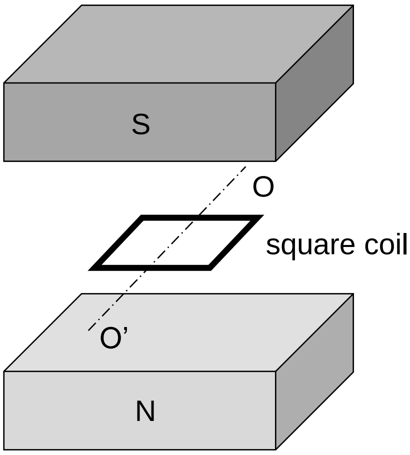

Fig. 7.1

The magnetic flux density due to the magnet in the area of the coil may be regarded as uniform and acts in a vertical direction with a magnitude of 0.12 T.

(a) Calculate the magnetic flux through the area of the coil.

magnetic flux = $BA = 0.12 \times 0.50^2 = 3.0 \times 10^{-4}$ Wb [A1]

magnetic flux = ... Wb [1]

(b) The coil can be displaced by any angle θ about its axis OO' as shown in Fig. 7.2.

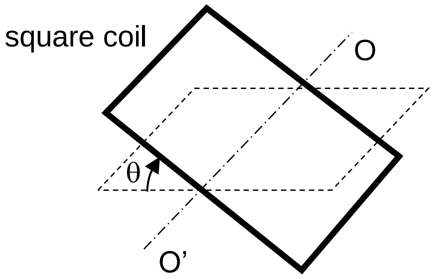

Fig. 7.2

Calculate the magnetic flux linkage in the coil when $\theta = 30°$.

magnetic flux linkage = $NBA\cos 30° = 50 \times 3.0 \times 10^{-4} \cos 30°$ [M1]

= 0.013 Wb [A1]

magnetic flux linkage = ... Wb-turns [2]

(c) The coil is rotated about OO' with a constant angular frequency. With reference to Faraday's law of electromagnetic induction,

(i) explain why a current is present in the coil,

As the coil rotates, the angle between the magnetic field and the plane of the coil changes, leading to a change in the magnetic flux linkage in the coil. [B1] By Faraday's law, an e.m.f. is induced in the coil which will produce a current in the closed loop. [B1]

....[2]

(ii) state and explain the value(s) of θ within one rotation of the coil at which the current in the coil is the greatest.

When $\theta = 90^{\circ}$ and 270°, [A1] the rate of the change in the flux linkage is the greatest [M1], thus by Faraday's Law, the e.m.f. induced at that instant is also the greatest, resulting in the greatest current.

....[2]

(d) Fig. 7.3 shows the current induced in the coil when it is rotating with a period of 50 ms.

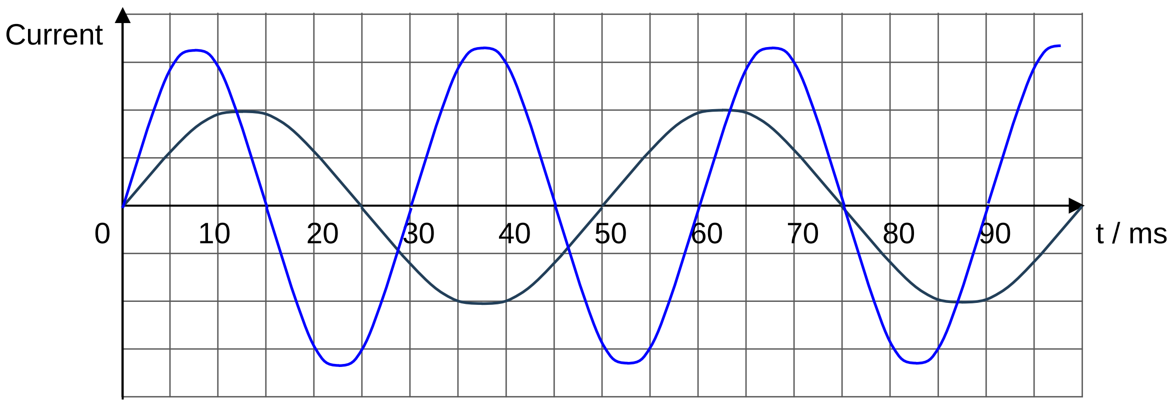

Fig. 7.3

(i) Without further calculations, draw another graph on Fig. 7.3 to show the current in the coil when the period of rotation is decreased to 30 ms. [1]

(ii) Determine the ratio of

$$\frac{\text{mean power required to rotate the coil with a period of 30 ms}}{\text{mean power required to rotate the coil with a period of 50 ms}}.$$

$P = \dfrac{E^2}{R}$ and $E = -\dfrac{d\Phi}{dt} \propto \omega \propto \dfrac{1}{T}$ → $P \propto \dfrac{1}{T^2}$ [M1]

ratio = $\left(\dfrac{50}{30}\right)^2 = 2.8$ [A1]

ratio = ... [2]

[Total: 10]

8 Recent developments show that there has been a significant surge in the number of commercial satellites being sent into low Earth orbits (LEO). LEOs are orbits situated relatively close to the Earth's surface, with altitudes of less than 2000 km, representing the height of the satellite above the Earth's surface. Some LEO satellites can orbit as close as 160 km above the Earth's surface, which, despite being considerably high, is still far above the altitudes typically reached by most commercial airplanes, which seldom exceed 14 km.

Fig. 8.1 shows the radii and periods of orbit of various LEO satellites.

satellite	**radius of orbit ,*r* / km**	**period of Orbit, *T* / min**
GOCE	6630	89.6
Tiangong Space Station	6770	92.3
GRACE	6870	94.5

Fig. 8.1

Due to the fast speed of LEOs, it is not easy for ground stations to track a specific LEO satellite. The ground station can only track the LEO satellite when it has line of sight as shown in Fig. 8.2.

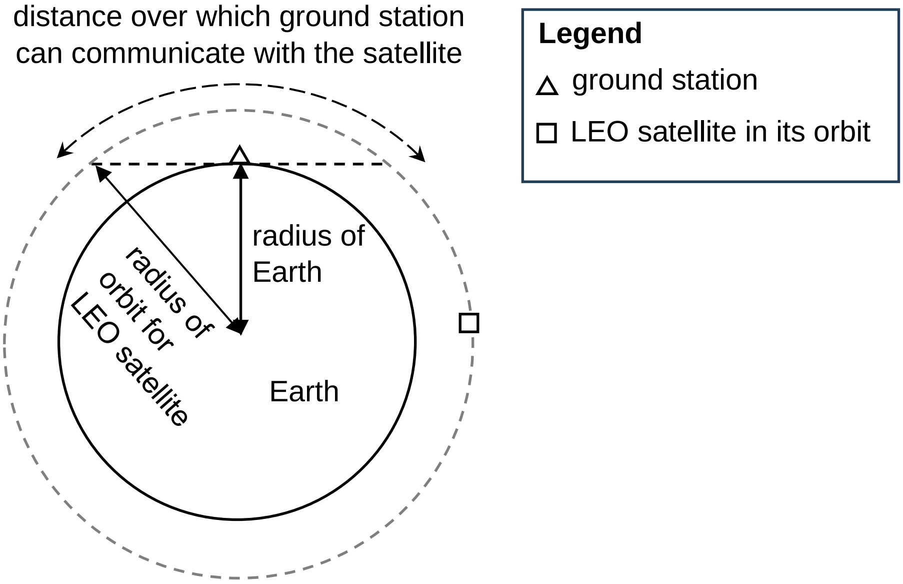

Fig. 8.2

There are challenges to operating LEO satellites. One of these challenges is atmospheric drag due to gases in the thermosphere, which leads to orbital decay, a loss of altitude over time. If the LEO satellite is not boosted back to its original altitude, the rate of orbital decay increases over time. This is partly due to the increase in the density of air with decreasing altitude.

Another challenge is space debris which can be very dangerous to LEO satellites. The Orbital Debris Program tracks over 25000 objects larger than 10 cm in LEO. It is estimated that there may also be up to 100 million smaller objects in LEO.

Satellites used for telecommunications are usually in geostationary orbits. Using suitable dishes to transmit the signals, communication over most of the Earth's surface is possible at all times by using only three satellites. Satellites used for meteorological observations and observations of the Earth's surface are usually in LEO. Polar orbits, in which the satellite passes over the North and South Poles of the Earth, are often used. One such satellite orbits at a height of about 12 000 km above the Earth's surface circling the Earth at an angular speed of 2.5×10^{-4} rad s^{-1}. The microwave signals from the satellite are transmitted using a dish and can only be received within a limited area, as shown in Fig. 8.3.

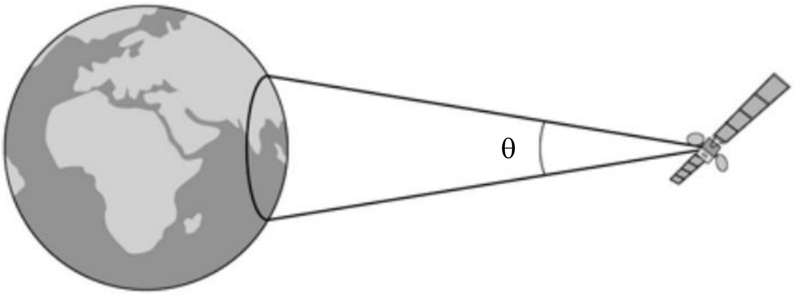

Fig. 8.3

The signal of wavelength λ is transmitted in a cone of angular width θ, in radian, given by $\theta = \dfrac{\lambda}{d}$ where d is the diameter of the dish. The satellite transmits a signal at a frequency of 1100 MHz using a 1.7 m diameter dish. As this satellite orbits the Earth, the area over which a signal can be received moves. There is a maximum time for which a signal can be picked up by a receiving station on Earth.

(a) Show that the distance travelled by the Tiangong Space Station during which it is able to communicate with a specific ground station is 4.7×10^6 m.
You may assume that the mass of the Earth to be 5.97×10^{24} kg.

$g = \dfrac{GM}{r_E^{\,2}}$, g = 9.81 m s^{-2} C1

r_E = 6370 km

Let α be the angle between the ground station and the point where the ground station has first/last contact with the space station

$\cos\alpha = \dfrac{\text{radius of Earth}}{\text{radius of orbit}} = \dfrac{6370}{6770}$

$\alpha = 0.345$ rad C1

Distance over which the ground station has contact = 2α x radius or orbit M1

$= 2 \times 0.345 \times 6770 \times 10^3$

$= 4.7 \times 10^6$ m A0 [3]

(b) Hence or otherwise, calculate the time of contact with the ground station (the time during which the ground station can communicate with the LEO satellite) for the Tiangong Space Station.

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{92.3 \times 60} = 1.135\times10^{-3} \text{ rad s}^{-1}$$

$$v = r\omega = 6770 \times 10^{3} \times 1.135\times10^{-3} = 7680 \text{ m s}^{-1}$$ M1

$$\text{Time of contact} = \frac{4.7 \times 10^{6}}{7680} = 612 \text{ s}$$ A1

time of contact = ... s [2]

(c) Suggest a reason other than the one given in the passage why loss of altitude causes the rate of orbital decay to increase over time.

As the LEO satellite decreases in altitude, its kinetic energy/speed increases M1

As drag increases with speed, the atmospheric drag increases leading to a greater rate of orbital decay A1

....[2]

(d) Explain why space debris as small as 10 cm can still be dangerous for LEO satellites.

The speed of objects in LEO is very high and have high momentum/energy A1

....[1]

(e) Suggest one advantage in the application of a satellite when a low polar orbit is used and one advantage when a geostationary orbit is used.

Low polar orbit

Good resolutions of photos taken B1

Geostationary orbit

Continuous observation of a specific region on Earth. B1

....

....[2]

(f) Determine the width of the area of reception on the Earth's surface when the satellite shown in Fig 8.3 is transmitting a 1100 MHz signal at a distance of 12 000 km from the Earth's surface.

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^{8}}{1100 \times 10^{6}} = 0.273\text{m}$$ C1

$$\theta = \frac{\lambda}{d} = \frac{0.273}{1.7} = 0.161 \text{ rad}$$ M1

$$\text{width} = D\theta = 1.2 \times 10^{7} \times 0.161 = 1.93 \times 10^{6}\text{m}$$ A1

width of area = ... m [3]

(g) For a satellite in a polar orbit 12000 km above the Earth's surface, determine the maximum amount of time that a stationary receiver at the South Pole can remain in contact with the satellite in each orbit.

Angle subtended by beam at Earth's surface $= \dfrac{\text{beam width}}{\text{Earth's radius}} = \dfrac{1.93 \times 10^3}{6370} = 0.30$ rad C1

Time taken $= \dfrac{0.30}{\omega} = \dfrac{0.30}{2.5 \times 10^{-4}}$ M1

$= 1.18 \times 10^3$ s A1

maximum amount of time = ... s [3]

(h) The satellite in **(g)** is moved into a higher orbit. Suggest, with a reason, how this affects

(i) the signal strength received by the receiver at the South Pole and,

Signal would be weaker A1 as

Energy spread over wider area M1

....[2]

(ii) contact time for the receiver at the South Pole.

Signal received for longer (each orbit) A1

Beam width increases with satellite height M1

....[2]

[Total: 20]

End of Paper