H

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 =	$\rho g h$
gravitational potential	ϕ =	$-\dfrac{Gm}{r}$
temperature	T/K =	$T/°\text{C} + 273.15$
pressure of an ideal gas	p =	$\dfrac{1}{3}\dfrac{Nm}{V}<c^2>$
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 =	$R_1 + R_2 + \dots$
resistors in parallel	$1/R$ =	$1/R_1 + 1/R_2 + \dots$
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 =	$\dfrac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B =	$\mu_0 n I$
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.
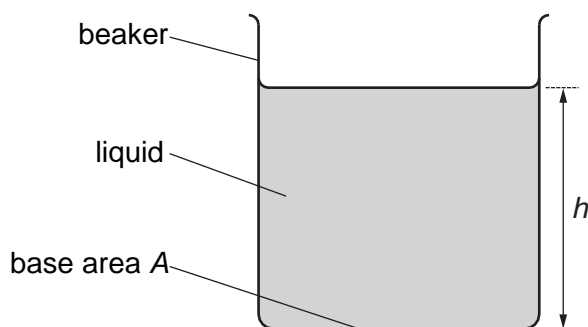
Fig. 1.1

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

$$P = \rho gh$$

where g is the acceleration of free fall.

[1]

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

....

....[1]

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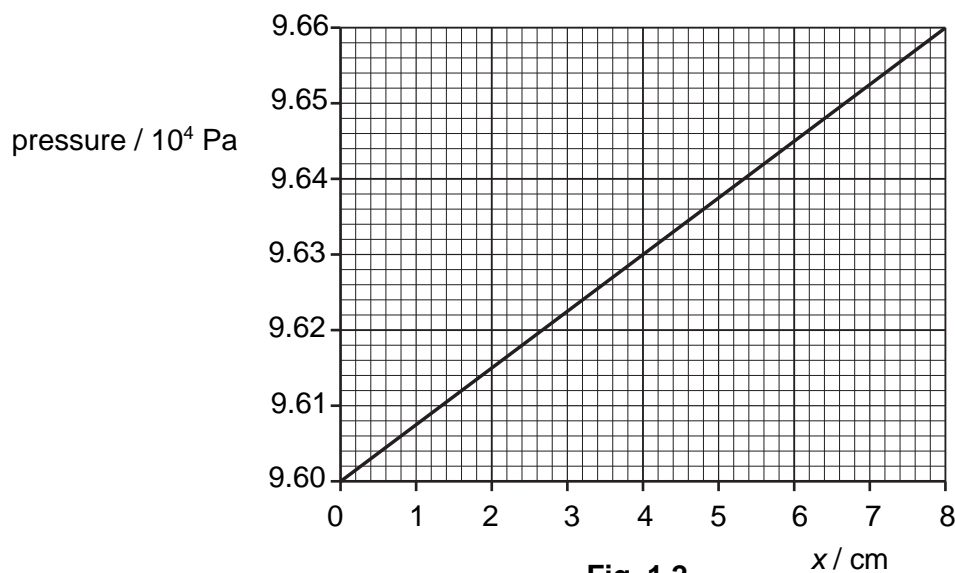
Fig. 1.2

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

density = ... 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.

percentage = ... % [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.

....

....

....

....[2]
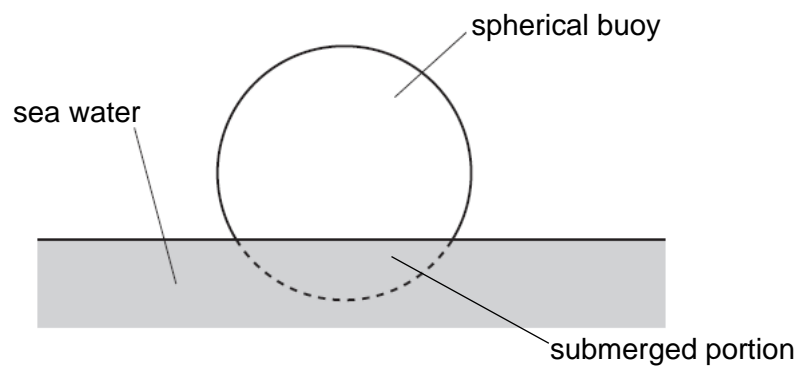
(b) A car of mass 1500 kg travels in a horizontal circular path of radius 50.0 m on a banked road with speed of 15.0 m s^{-1} without any frictional force acting on the tyres along the slope.
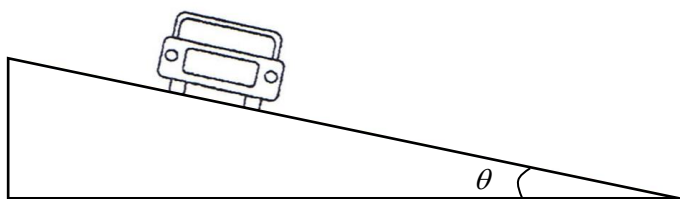
Fig. 2.1

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

θ = ...° [3]

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

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

[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.

[1]

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

....

....

....

....[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.
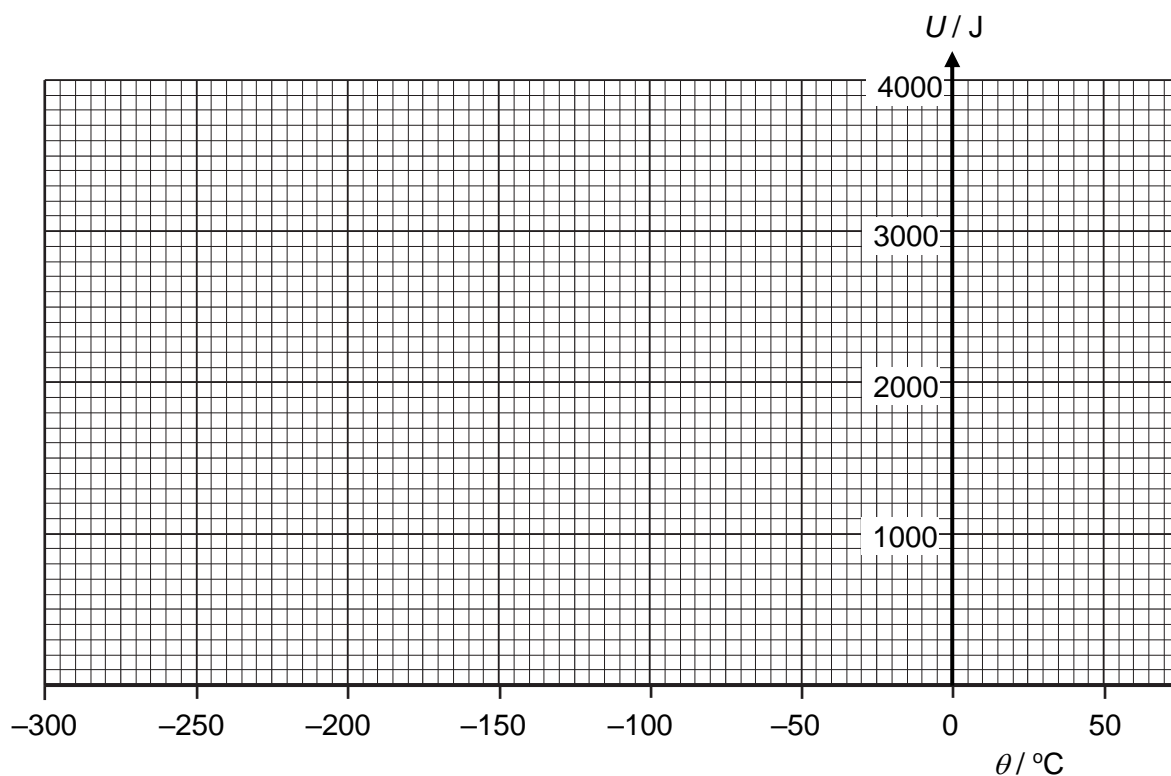

Fig. 3.1

[1]

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

....

....

....[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.

....

....

....

....[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*.
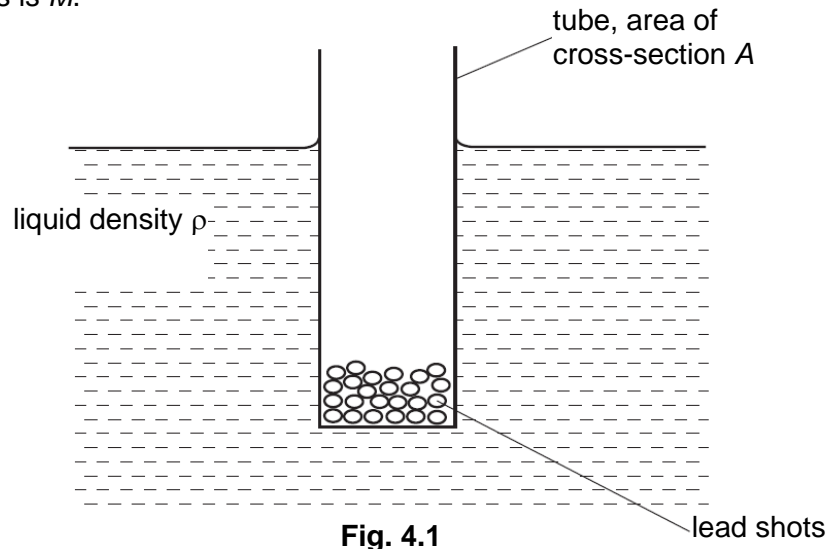

Fig. 4.1

(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

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

[2]

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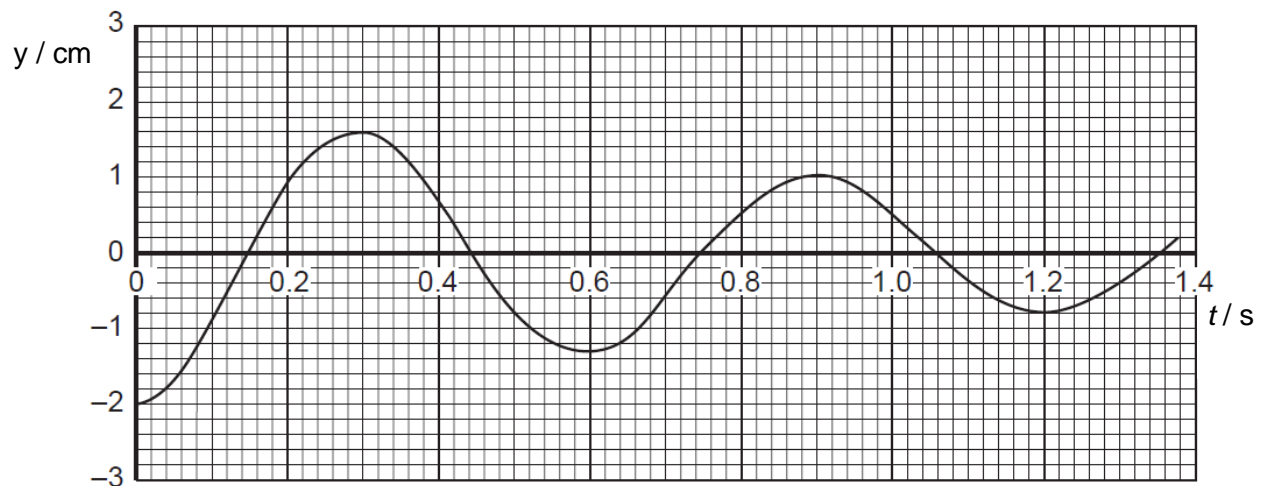

Fig. 4.2

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

$f_0 =$ .... 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.

mass = ... kg [3]

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

....

....

....[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.
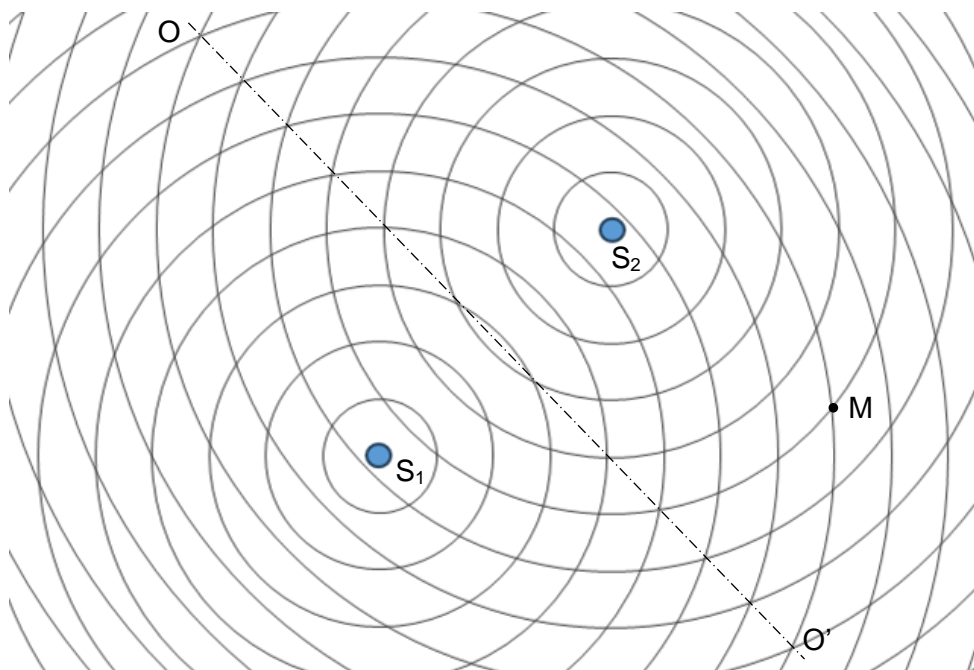

Fig. 5.1

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

(a) State the *Principle of Superposition*.

....

....

....

....[2]

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

    (i) their path difference,

    ....[1]

    (ii) their phase difference.

    ....[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,

amplitude = ... mm [2]

    (ii) when both S_1 and S_2 are oscillating.

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.

....

....[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.

....

....

....

....[2]

[Total: 11]

6 (a) Define *acceleration*.

....

....[1]

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

....

....[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.
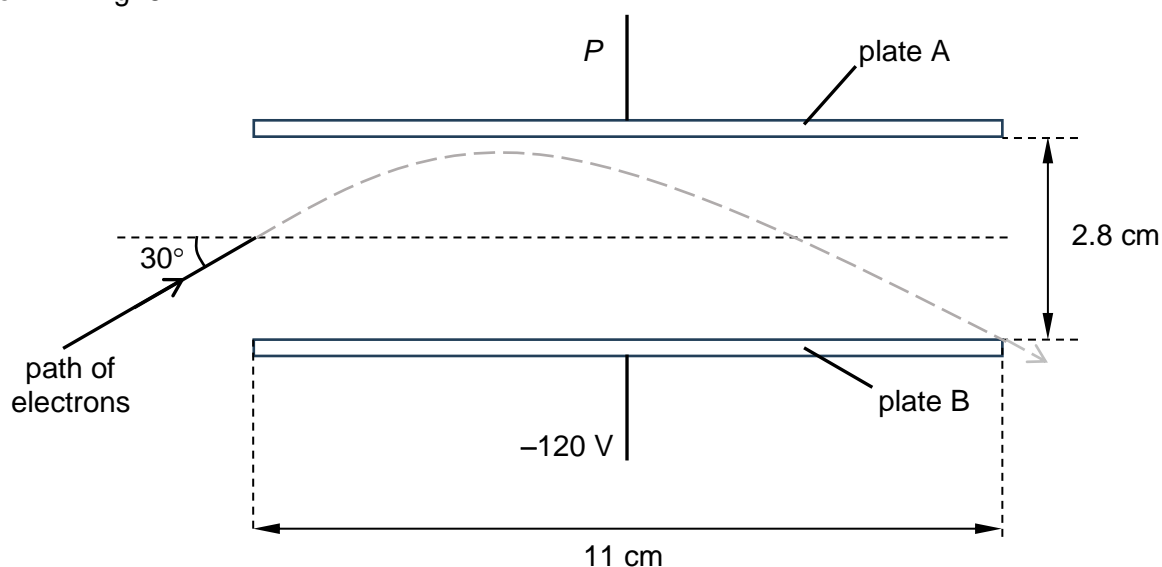

Fig. 6.1

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},

[2]

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

time = ... s [1]

3. calculate the acceleration of the electron.

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.

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.
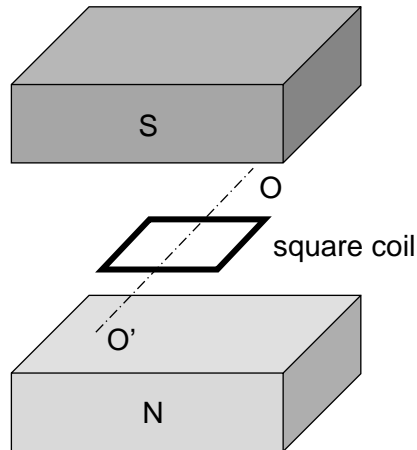

Fig. 7.1

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 = ... Wb [1]

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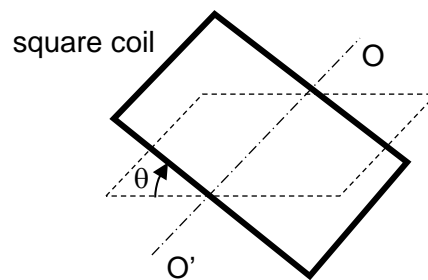
Fig. 7.2

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

magnetic flux linkage = ... 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,

....

....

....

....[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.

....

....

....

....[2]

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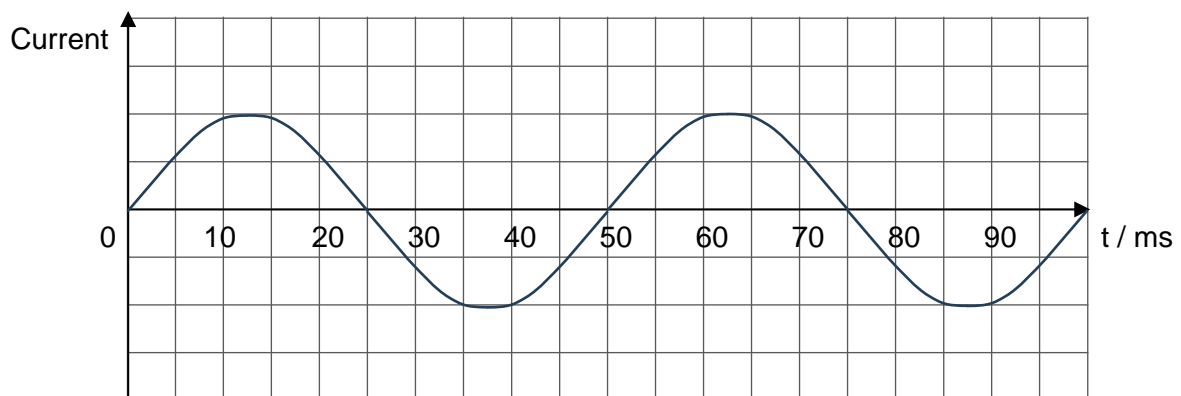

Fig. 7.3

(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

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

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.
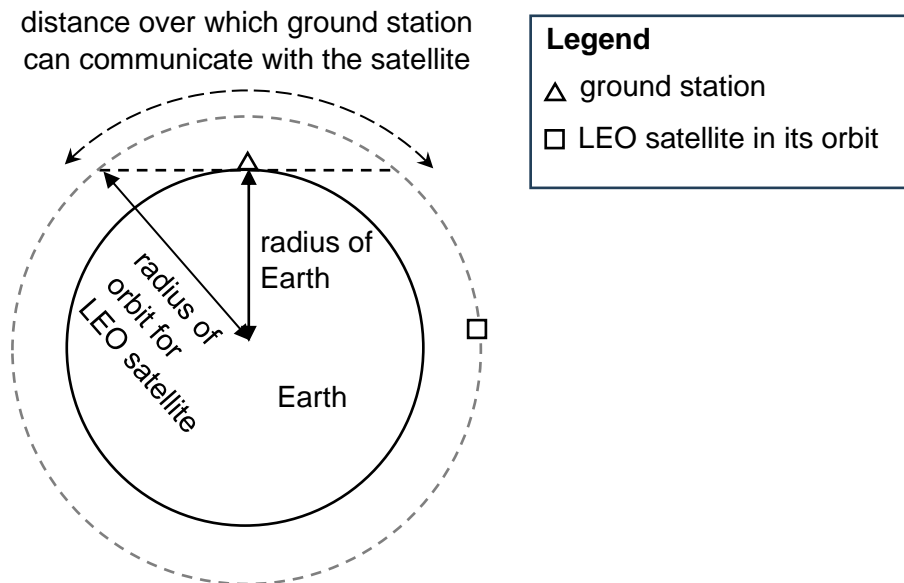

Fig. 8.2

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.
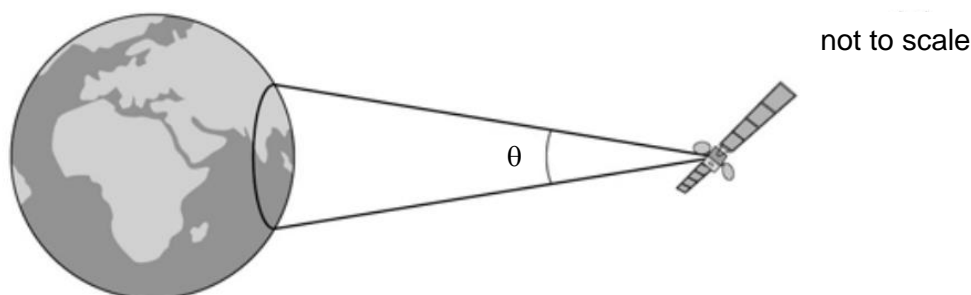
Fig. 8.3

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.

[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.

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.

....

....

....

....[2]

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

....

....[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.

....

....

....

....[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.

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.

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,

    ....

    ....

    ....[2]

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

    ....

    ....

    ....[2]

[Total: 20]

End of Paper