Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	
CENTRE NUMBER	S 3 0 0 4	INDEX NUMBER	

PHYSICS **9749/03**

Paper 3 Longer Structured Questions

3 September 2025
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class 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 an 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 Examiners' use only	
Section A	
1	/ 6
2	/ 10
3	/ 13
4	/ 11
5	/ 10
6	/ 10
Total	/ 60
Section B	
7 / 8	/ 20
Grand Total	/ 80

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\,\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
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	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{x_o^2 - x^2}$
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	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{½}}$

[Turn over

For Examiner's Use

Section A

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

1 **(a)** Express the unit of resistivity in SI base units.

SI base units = …………………… [2]

(b) Estimate the current flowing into a smartphone while it is being charged by a standard phone charger.

current = …………………… A [1]

For Examiner's Use

(c) Fig. 1.1 shows a circuit set up to measure the resistance *R* of a resistor.

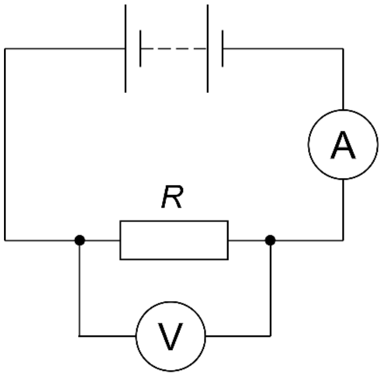

Fig. 1.1

The following readings are obtained:

voltmeter: $V = (5.02 \pm 0.01)$ V

ammeter: $I = (0.038 \pm 0.001)$ A

Determine the value of *R* together with its actual uncertainty.

R = …………………… ± …………………… Ω [3]

[Total: 6]

[Turn over

For Examiner's Use

2 **(a)** State Coulomb's law.

....

....

.... [2]

(b) State the relationship between electric field strength and electric potential.

....

.... [1]

(c) Fig. 2.1 shows two charged isolated conducting spheres.

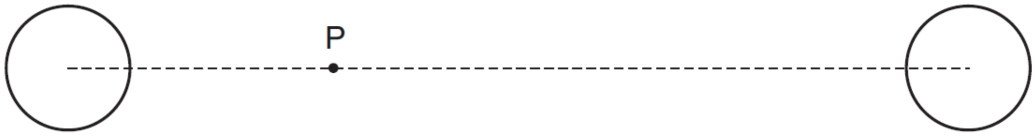

Fig. 2.1

P is a point on the line joining the centres of the spheres.

Explain why it is not possible for the total electric potential and the resultant electric field to simultaneously be zero at point P.

....

....

....

.... [2]

For Examiner's Use

(d) A conducting sphere is held midway between two vertical, parallel metal plates in a vacuum, as shown in Fig. 2.2.

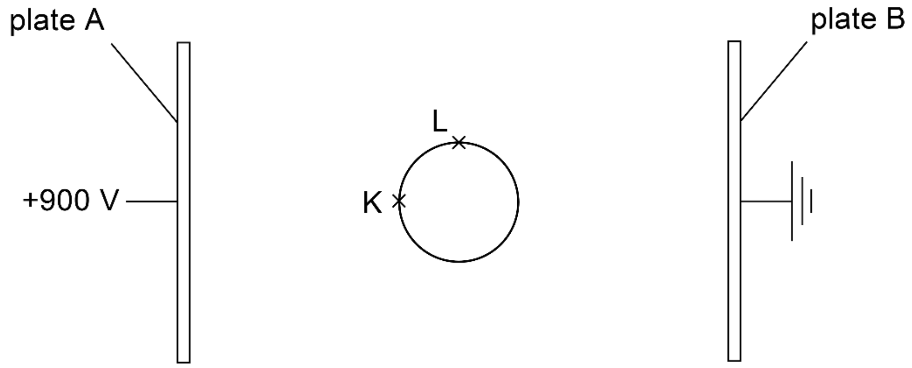

Fig. 2.2

Plate A is at a potential of +900 V and plate B is earthed.

Points K and L are two points on the surface of the sphere.

(i) On Fig. 2.2, draw field lines to represent the electric field between the sphere and the two metal plates. [2]

(ii) Explain why the electric potentials at points K and L are equal.

……………………………………………………………………………………...

……………………………………………………………………………………...

……………………………………………………………………………………...

…………………………………………………………………………………… [2]

(iii) Determine the electric potential at point K.

electric potential = ……………………… V [1]

[Total:10]

For Examiner's Use

3 **(a)** State what is meant by the *internal energy* of a system.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………. [1]

(b) A square box of volume V contains N molecules of an ideal gas. Each molecule has mass m.

Using the kinetic theory of ideal gases, it can be shown that, if all the molecules are moving with speed v at right angles to one face of the box, the pressure p exerted on the face of the box follows the expression

$$pV = Nmv^2 \qquad \text{(equation 1)}$$

This expression leads to the formula

$$p = \frac{1}{3}\rho\langle c^2\rangle \qquad \text{(equation 2)}$$

for the pressure p of an ideal gas, where ρ is the density of the gas and $\langle c^2\rangle$ is the mean-square speed of the molecules.

Explain how each of the following terms in equation 2 is derived from equation 1:

$\frac{1}{3}$: ………………………………………………………………………………………

…………………………………………………………………………………………………..

$\langle c^2\rangle$: ……………………………………………………………………………………

…………………………………………………………………………………………………..
[2]

For Examiner's Use

(c) Hence, use equation 2 to show that the internal energy U of an ideal gas is given by

$$U \propto T$$

where T is the thermodynamic temperature of the gas.

[3]

(d) An ideal gas of volume 0.26 m^3 is at a pressure of 2.0×10^5 Pa and temperature of 20 °C.

(i) Calculate the number of molecules of the gas.

no. of molecules = ... [2]

(ii) Hence, calculate the internal energy of the gas.

internal energy = ... J [1]

For Examiner's Use

(e) The volume *V* of the gas in **(d)** is now varied, keeping its pressure constant.

On Fig. 3.1, sketch the variation with *V* of the internal energy *U* of the gas.

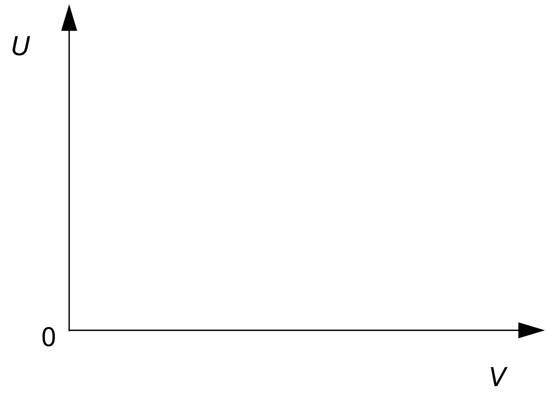

Fig. 3.1

[1]

(f) The heat capacity of a fixed mass of gas depends on the conditions under which heat is supplied. If the gas is heated at constant pressure, the heat capacity is C_p; while that heated at a constant volume is C_v.

Suggest, with a reason, if C_p or C_v is higher.

....

....

....

....

.... [3]

[Total: 13]

For Examiner's Use

4 A light spring hangs vertically from a fixed point. An object of mass m is attached to the free end of an unstretched spring as shown in Fig. 4.1.

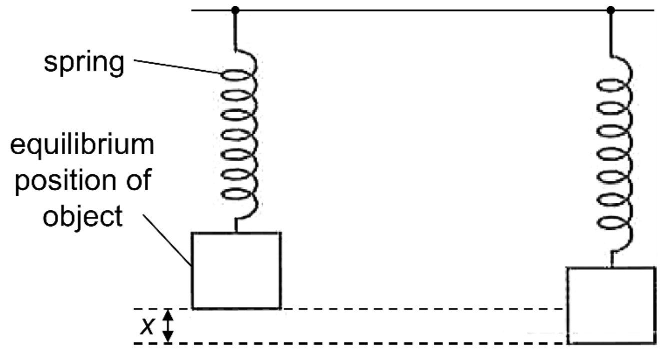

Fig. 4.1

The extension of the spring at equilibrium is x_o and its spring constant is k.

(a) State an expression relating the forces acting on the object when it is in the equilibrium position.

.... [1]

(b) The object is displaced vertically downwards and then released.

Using the expression in **(a)**, show that the object's acceleration a is related to its displacement x from the equilibrium position by the equation:

$$a = -\frac{k}{m}x$$

Explain your working.

[2]

For Examiner's Use

(c) Fig. 4.2 shows the variation of the kinetic energy of the object with time.

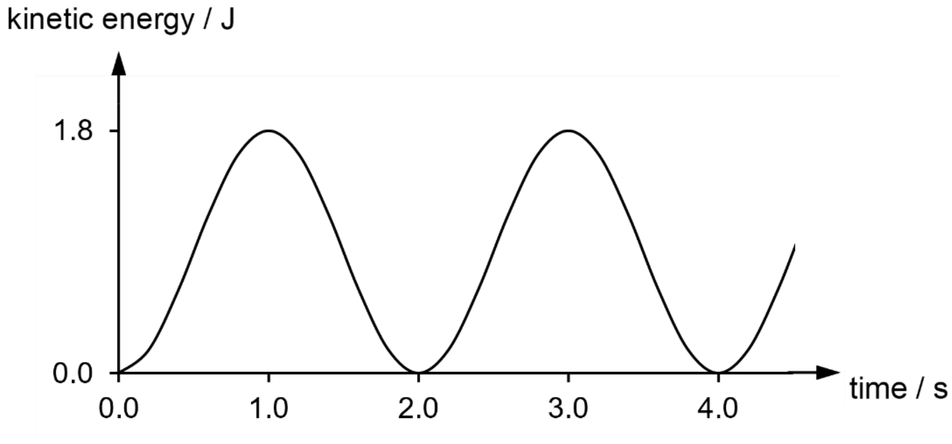

Fig. 4.2

(i) Determine the frequency of the oscillation.

frequency =…………………… Hz [2]

(ii) Determine the mass of the object given that the spring constant is 28 N m^{-1}.

mass = …………………… kg [2]

(iii) Calculate the maximum velocity of the object.

velocity = …………………… m s^{-1} [1]

For Examiner's Use

(iv) Calculate the amplitude of the oscillation.

amplitude = ………………….. m [1]

(d) On Fig. 4.3, sketch the variation with time t of the displacement x of the object.

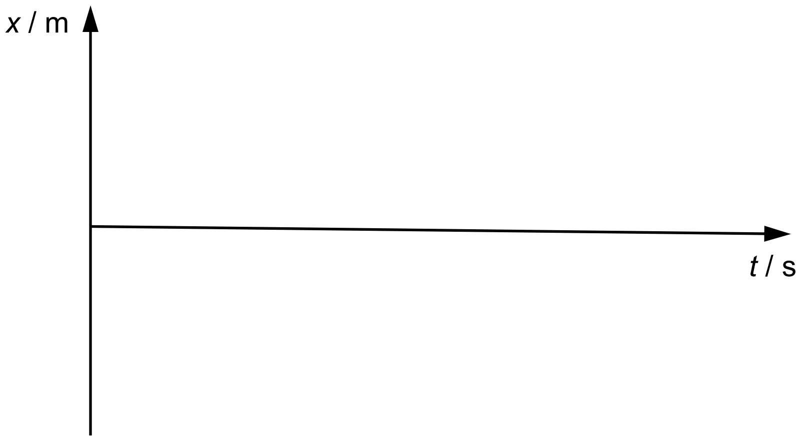

Fig. 4.3

[2]

[Total: 11]

[Turn over

For Examiner's Use

5 (a) State Faraday's law of electromagnetic induction.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………… [1]

(b) A small coil C is placed inside a solenoid as shown in Fig. 5.1.

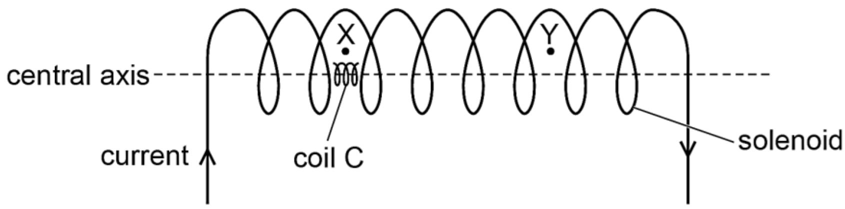

Fig. 5.1 (not to scale)

The centre of coil C is on the central axis of the solenoid.

There is a constant current in the solenoid and coil C is moved through the solenoid from position X to position Y.

Explain why the magnetic flux linkage in coil C is constant.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………… [1]

(c) Coil C is now held stationary at X and an alternating current (a.c.) power supply is now connected to the solenoid. The alternating current I varies with time t according to

$$I = 4.8\sin(10\pi t)$$

where I is in A and t is in s.

(i) Show that the period of the alternating current is 200 ms.

[1]

For Examiner's Use

(ii) Coil C has 71 turns and cross-sectional area 0.64 cm^2. The solenoid has 4000 turns per unit metre.

Show that the maximum magnetic flux linkage in coil C is 1.1×10^{-4} Wb.

[3]

(iii) Hence, determine the maximum electromotive force (e.m.f.) induced in coil C.

e.m.f. = ……………………… V [2]

(iv) On Fig. 5.2, sketch the variation of the induced e.m.f. *E* in coil C with time between *t* = 0 and *t* = 400 ms.

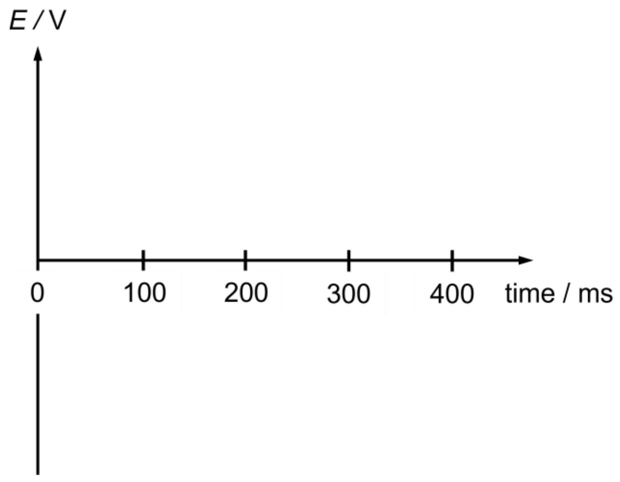

Fig. 5.2

[2]

[Total: 10]

[Turn over

For Examiner's Use

6 **(a)** State and explain two observations of the photoelectric effect that provide evidence for the particulate nature of electromagnetic radiation.

1. ……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

2. ……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [4]

(b) Electromagnetic radiation of a varying frequency *f* and constant intensity I is used to illuminate a metal surface. The variation with *f* of the maximum kinetic energy E_{MAX} of the emitted electrons is shown in Fig. 6.1.

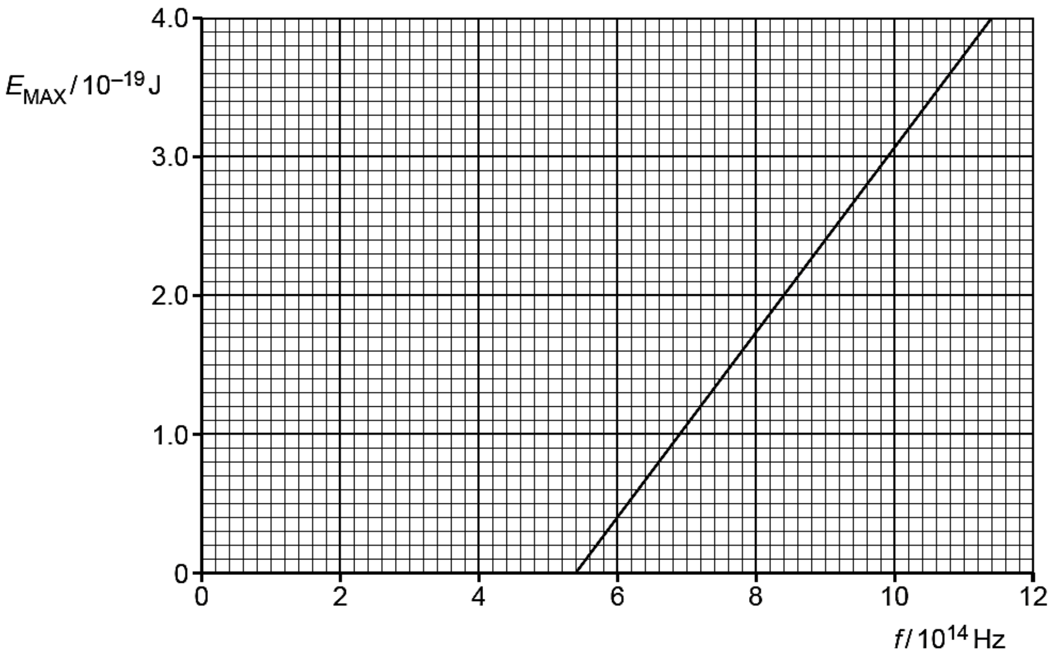

Fig. 6.1

For Examiner's Use

Using Fig. 6.1, determine

(i) the Planck constant, and

Planck constant = ... J s [2]

(ii) the work function of the metal surface in eV.

work function = ... eV [2]

(c) A different metal with a lower work function is used, with the same intensity I of radiation.

On Fig. 6.1, sketch the variation with f of the maximum kinetic energy E_{MAX} of the emitted electrons. [2]

[Total: 10]

For Examiner's Use

Section B

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

7 A submarine uses cables to recover a submerged wooden chest as shown in Fig. 7.1.

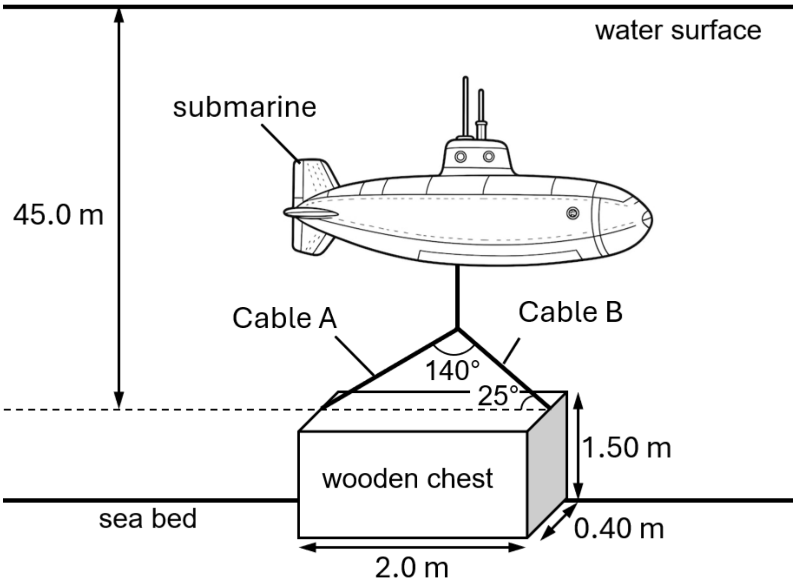

Fig. 7.1 (not to scale)

The submarine has a mass of 3600 kg. The density of seawater is 1030 kg m^{-3} and the average density of the chest is 1800 kg m^{-3}.

(a) Show that the hydrostatic pressure p of a fluid at a depth h and density ρ is given by the expression

$$p = \rho g h.$$

[2]

For Examiner's Use

(b) The box is held in equilibrium slightly above the sea bed.

(i) Explain why the seawater exerts an upthrust on the chest.

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [2]

(ii) Calculate the upthrust of the wooden chest when it is raised above the sea bed.

upthrust = …………………… N [2]

(iii) Calculate the weight of the wooden chest.

weight = ……………………… N [1]

(iv) Determine the tension in cable A and cable B.

tension in cable A = ……………………… N

tension in cable B = ……………………… N

[4]

[Turn over

For Examiner's Use

(c) The submarine is propelled forward at a constant velocity of 4.5 m s^{-1} by a 0.50 MW motor connected to a propeller. The drag force F_d acting on the submarine and the chest is given by

$$F_d = kv^2,$$

where $k = 3.5 \times 10^3$ N s^2 m^{-2}.

(i) Calculate the thrust provided by the propeller.

thrust = ... N [2]

(ii) Calculate the efficiency of the motor when the submarine is cruising at a speed of 4.5 m s^{-1}.

efficiency = ... % [2]

(d) The total mass of the submarine is suddenly decreased by 200 kg by pumping water out of the submarine horizontally in a negligible time. The volume of the submarine remains unchanged.

(i) Calculate the initial upward acceleration of the submarine.

acceleration = ... m s^{-2} [3]

For Examiner's Use

(ii) Explain why the acceleration of the submarine eventually decreases to zero as the submarine ascends.

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [2]

[Total: 20]

For Examiner's Use

8 **(a)** State what is meant by a *geostationary orbit*.

…………………………………………………………………………………………………

…………………………………………………………………………………………… [1]

(b) The planet Saturn has the most extensive and complex ring system of any planet in the Solar System. The rings have varying width and thickness. They are made up of mainly ice particles, with a trace of rocky material which are in orbit around Saturn. One of the rings, the D-ring, has an outer radius of 7.45×10^7 m and a particle on the outer circumference of the ring has a speed of 2.26×10^4 m s^{-1}.

(i) Calculate the angular velocity of the particle about Saturn.

angular velocity = ………………….. rad s^{-1} [1]

(ii) A stationary orbit about Saturn is defined in the same way as a geostationary orbit about Earth, except that it applies to Saturn instead.

The rotational period of Saturn is 10 hours and 14 minutes. Use your answer in **(i)** to deduce whether the particle is in a stationary orbit about Saturn.

……………………………………………………………………………………..

…………………………………………………………………………..……. [2]

For Examiner's Use

(iii) Show that the radius r of the orbit of a particle moving with angular velocity ω around Saturn is given by the expression

$$r^3\omega^2 = GM,$$

where M is the mass of Saturn. Assume that Saturn is a point mass.

[2]

(iv) Hence, show that the mass of Saturn is 5.7×10^{26} kg.

[2]

[Turn over

For Examiner's Use

(c) **(i)** Define *gravitational potential* at a point.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………..…….. [2]

(ii) On Fig 8.1, draw equipotential lines to illustrate the gravitational field around Saturn.

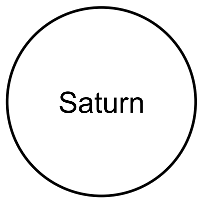

Fig. 8.1

[2]

(iii) Determine the minimum additional velocity required for the particle in **(b)** to escape from Saturn's gravitational field.

minimum additional velocity = ………………….. m s^{-1} [3]

For Examiner's Use

(d) Saturn's largest moon, Titan, is the second largest moon in the solar system. Titan has a radius of 2580 km and is 1.22×10^6 km from Saturn. The mass of Titan is 1.4×10^{23} kg. Ignore the effect of other nearby masses.

(i) Determine the distance from the centre of Titan where the resultant gravitational field strength between Titan and Saturn is zero.

distance = …………………… m [3]

(ii) On Fig. 8.2, sketch the variation with distance from the centre of Titan of the gravitational field strength along the line joining the centres of Titan and Saturn. The graph should range from Titan's surface to Saturn's surface.

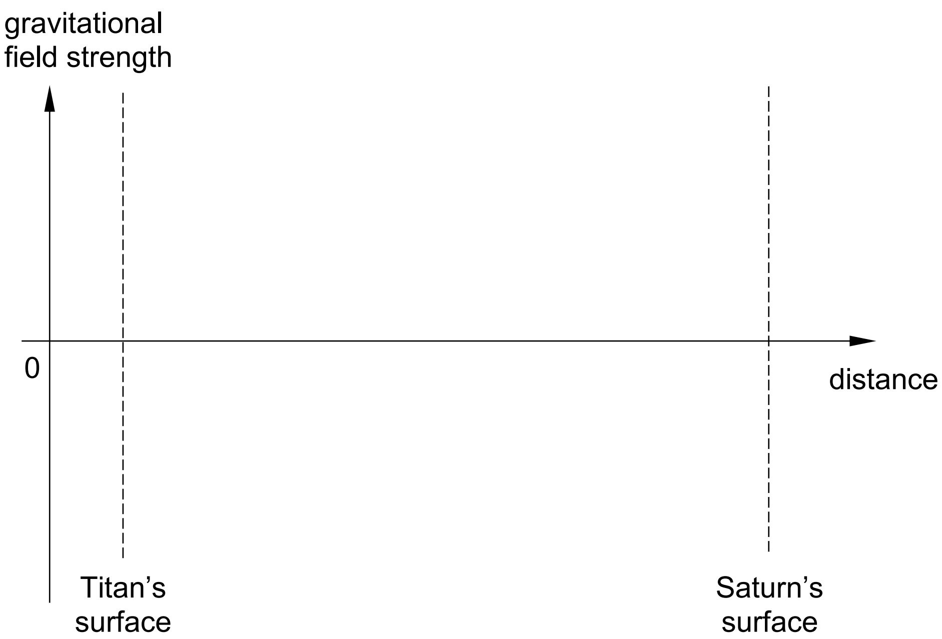

Fig. 8.2

[2]

[Total: 20]

End of Paper