H

TEMASEK JUNIOR COLLEGE
2025 JC2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CENTRE NUMBER	S					INDEX NUMBER				

PHYSICS **9749/02**

Paper 2 **29 August 2025**

Structured Questions **2 hour**

Candidates answer on the Question Paper.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
s.f	
Total	

READ THESE INSTRUCTIONS FIRST

Write your name and civics group 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 or 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

The number of marks is given in brackets [ ] at the end of each question or part question.

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} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} Js
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	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
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	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
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	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{ln2}{t_{1/2}}$

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

1 Fig. 1.1 shows a force diagram that represents a boat that is being lifted by two ropes so that the boat remains horizontal and travels vertically upwards at a constant speed after leaving the water.

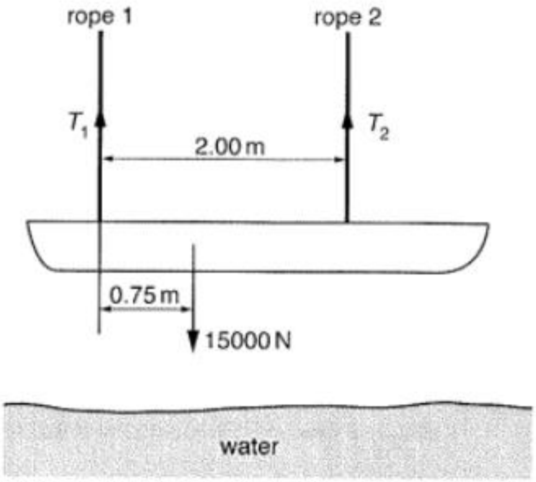

Fig. 1.1

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The weight of the boat is 15000 N and the tensions in the ropes 1 and 2 are T_1 and T_2 respectively.

(a) The position of the centre of gravity of the boat is not at its midpoint. Suggest what this implies about the distribution of mass in the boat.

....

....

.... [1]

(b) Explain two conditions required for the boat to be in a state of equilibrium while it is moving upwards.

....

....

....

.... [2]

(c) Determine the tension in the two ropes

T_1 = ... N

T_2 = ... N [3]

(d) The two ropes are connected to a motor.
Calculate the minimum power generated by the motor to lift the boat off the water onto a 30.0 m cliff within a time of 12s.

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P = ... W [2]
[Total: 8]

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2 An open cube is placed in a liquid of density ρ, with a length l submerged as shown in Fig. 2.1. The cross-sectional area of the cube A is constant.

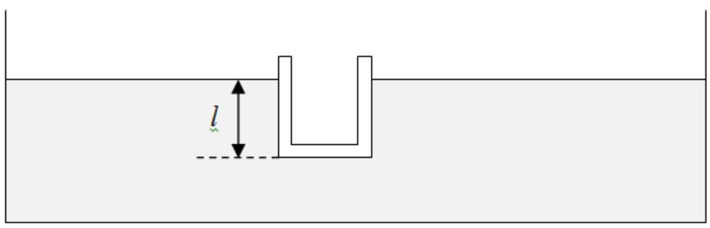

Fig. 2.1

When the cube is displaced downwards by a small distance from the equilibrium position and released, it resulted in simple harmonic motion of the cube. The frequency f of the cube is given by $f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$.

In an experiment, surface water waves of speed 0.90 m s^{-1} and wavelength 0.45 m are generated using a dipper shown in Fig. 2.2. The generated waves are incident on the cube, causing resonance in its up-and-down motion.

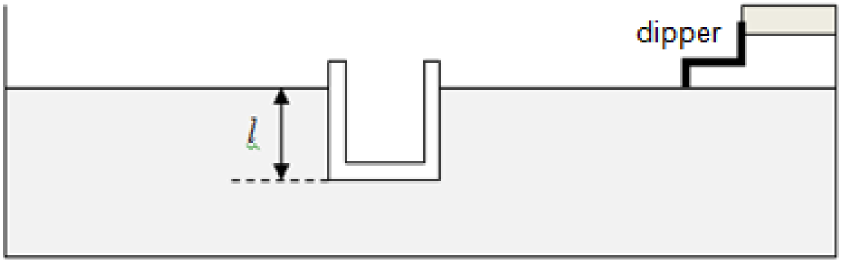

Fig. 2.2

(a) Explain why the cube undergoes *resonance.*

....

....

.... [2]

(b) Calculate the length l.

l = ... m [2]

(c) Describe and explain what happens to the amplitude of the vertical oscillations of the cube after the following changes are made independently:

(i) the distance between the wave crests increases,

....

....

.... [2]

(ii) some water is poured into the cube, without sinking it.

....

....

.... [2]

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(d) Explain why the value of l that you found in **(b)** is larger than the actual measurement of l in the experiment

....

....

....

....

.... [2]

[Total: 10]

3 A sound wave that is *propagating towards the left* is represented by the two graphs below.
Fig. 3.1 shows the variation with position along the wave of the displacement of the air particles from their equilibrium position at time t = 0.
Fig. 3.2 shows the variation with time t of the displacement of an air particle from its equilibrium position.

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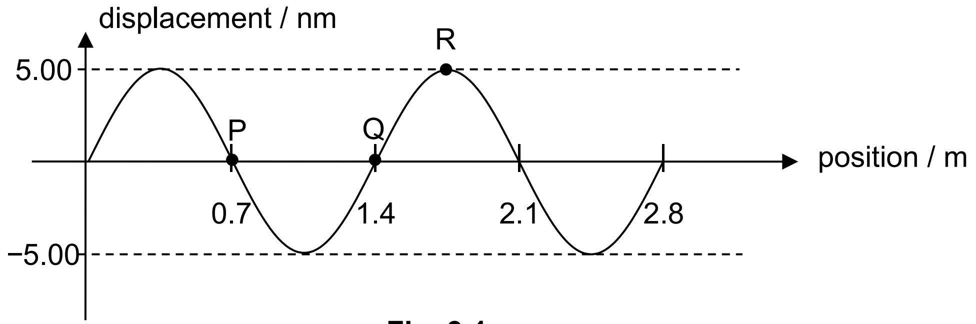

Fig. 3.1

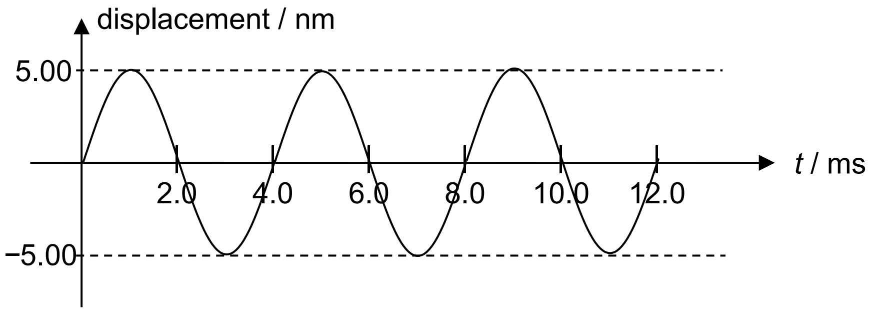

Fig. 3.2

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(a) Calculate the speed of the sound wave.

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

(b) Fig. 3.1 shows three particles P, Q and R along the sound wave.
Taking rightwards to be positive, identify the particle that is

(i) instantaneously at rest at $t = 0$,

particle = ... [1]

(ii) at the centre of a rarefaction at $t = 0$.

particle = ... [1]

(iii) Explain why displacement-time graph for particle Q is represented by Fig. 3.2.

.... [1]

(c) **(i)** Sketch in Fig. 3.1 the graph of the wave 1.0 ms later. Label the graph Y. [2]

(ii) Particle S is 0.70 m to the right of particle R. [2]

Sketch in Fig. 3.2, the graph that corresponds to particle S. Label the graph Z.

[Total: 9]

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4 **(a)** Two coherent light wavetrains having the same plane of polarization meet at a point. State two conditions that must be fulfilled before **totally destructive interference** can occur.

1. ....

....

2. ....

.... [2]

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(b) Fig. 4.1 shows an experiment to demonstrate interference effects with microwaves. A transmitter, producing microwaves of wavelength λ is placed in front of two slits separated by a distance a. A receiver is used to detect the strength of the resultant wave at different points along the line YZ which is at a distance D in front of the slits.

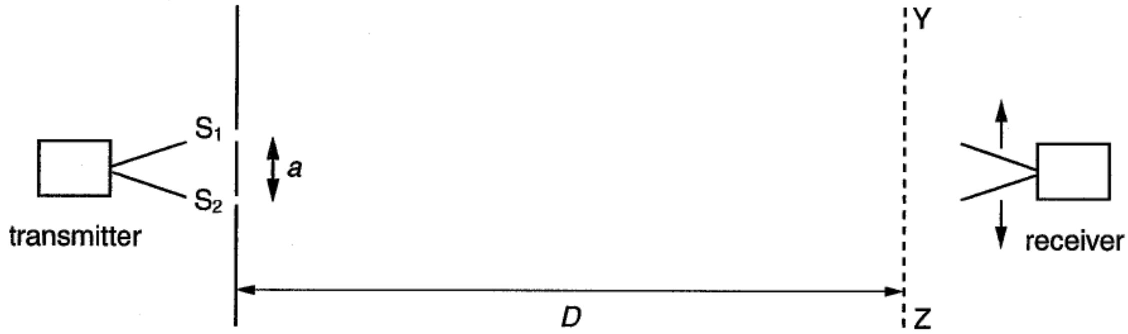

Fig. 4.1

(i) Explain, in terms of the path difference between the wavetrains emerging from the slits S_1 and S_2, why a series of interference maxima are produced along the line YZ.

....

....

....

.... [2]

(ii) State how the distance *x* between neighbouring maxima on the line YZ would change if the distance *a* was doubled while the distance *D* was halved.

....

.... [1]

(iii) In another experiment using the apparatus in Fig. 4.1, a student notices that the distances between the maxima are not equal. Suggest a reason for this difference.

....

.... [1]

(iv) Describe how you could test whether the microwaves leaving the transmitter were plane polarised.

....

....

....

.... [2]

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(c) The microwave transmitter is now placed in front of a plane reflector as shown in Fig. 4.2 and stationary waves are set up in the space between them.

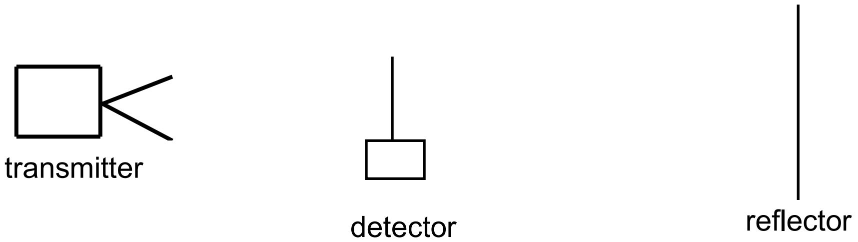

Fig. 4.2

A detector is moved between the transmitter and the reflector at a constant speed of 10 mm s^{-1}. The frequency of detection of minima is 1.5 Hz.

Determine the frequency of the microwave oscillator.

frequency = ... Hz [3]

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(d) In a separate experiment, white light is incident on a diffraction grating, as shown in Fig. 4.3.

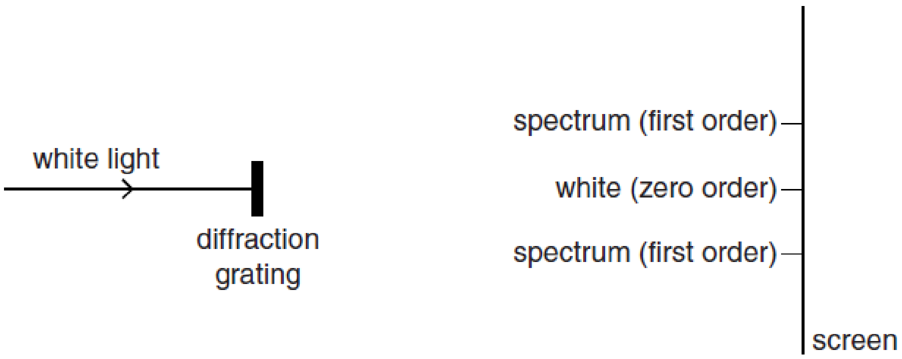

Fig. 4.3

The diffraction pattern formed on the screen consists of a white light band in the zeroth order and coloured spectra in other orders.

Describe how the principle of superposition is used to explain

(i) the presence of white light in the zeroth order.

....

....

....

.... [2]

(ii) the difference in the angular positions of red and blue light in the first-order spectra.

....

....

....

.... [2]

[Total: 15]

5 **(a)** The variation of an alternating voltage V_P in volts with time t in seconds is given by

$$V_P = 170 \sin (314t)$$

Determine

(i) the r.m.s. potential difference $V_{r.m.s.}$

$V_{r.m.s}$ = ... V [1]

(i) the period, T of the voltage supply.

T = ... s [1]

(b) The alternating voltage V_P is connected to the primary coil of a transformer as shown in Fig. 5.1.

An electric heater with resistance 130 Ω is connected to the secondary coil of the transformer.

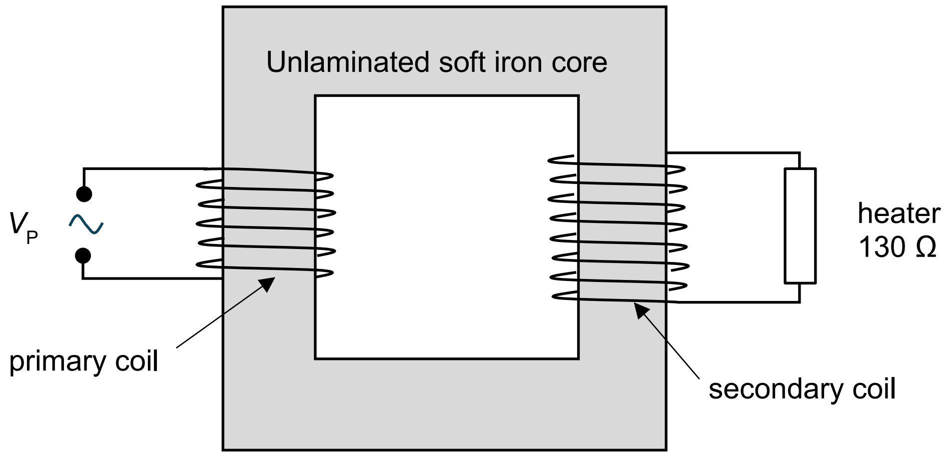

Fig. 5.1

The primary coil consists of 2000 turns and the secondary coil consists of 3500 turns.

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(i) Determine peak potential difference, V_S of the secondary coil.

V_s = ... V [2]

(ii) Determine the peak current, I_P in the primary coil.

I_P = ... A [2]

(iii) It was subsequently verified that the actual peak current, I_P in the primary coil is 8.00 A. Using this data, determine the efficiency of the transformer.

efficiency = ... % [1]

(iv) Suggest what could have led to the efficiency calculated in **(b) (iii)**.

....

....

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.... [1]

(c) A diode and another identical heater are connected to the secondary coil as shown in Fig. 5.2.

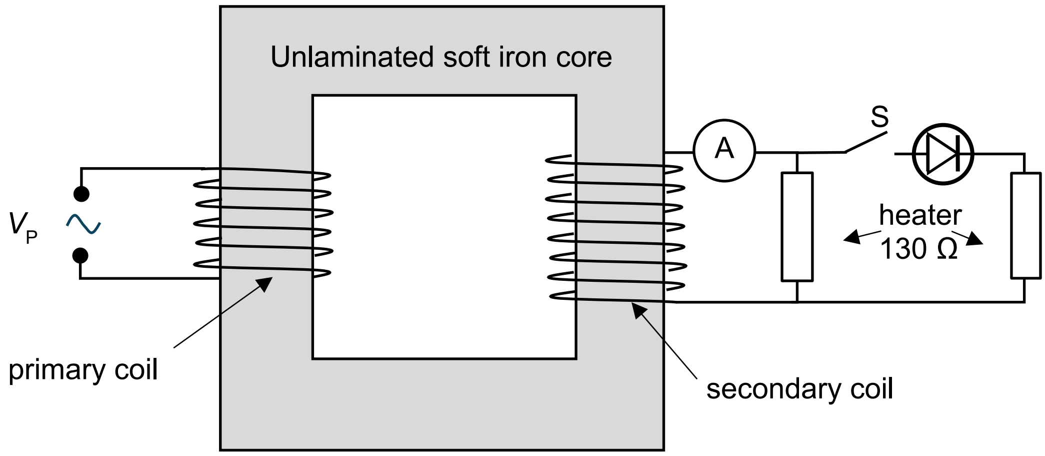

Fig. 5.2

Sketch on the axes of Fig. 5.3, the variation with time of the current *I* in the secondary coil when switch S is closed. Label the axes with appropriate values, Include on your graph a time equal to two periods of the alternating potential difference.

[2]

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Fig. 5.3

[Total :10]

6 A solenoid of length 15 cm, cross-sectional area 2.5×10^{-4} m^2, and 3000 turns is placed in the middle of a coil of 1500 turns as shown in Fig. 6.1. The solenoid is connected to a battery, a rheostat and an ammeter. The coil is connected to a galvanometer.

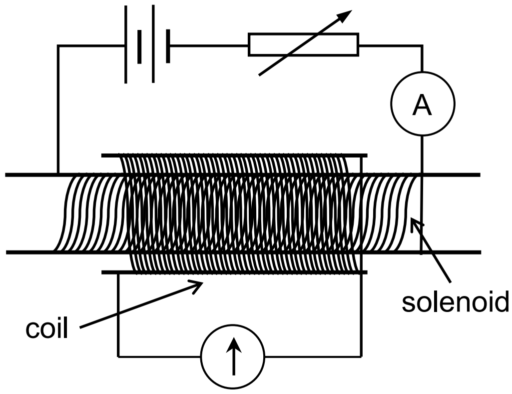

Fig. 6.1

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Fig. 6.2 shows the variation with time t of the current I through the solenoid as the resistance of the rheostat is varied.

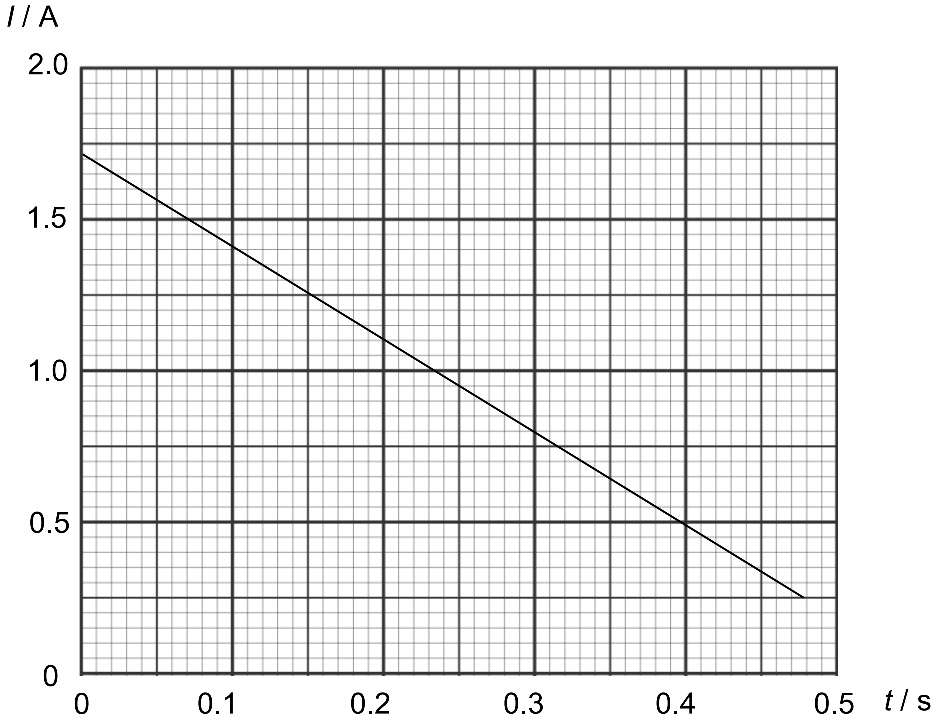

Fig. 6.2

(i) Show that the magnetic flux density produced in the solenoid at t = 0.070 s is 3.77×10^{-2} T .

[2]

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(ii) Calculate the e.m.f. induced in the coil.

emf = ... V [3]

(iii) State and explain the direction of the current through the galvanometer.

....

....

....

....

....

....

.... [3]

[Total :8]

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7 In 1977, two robotic interstellar probes, Voyager 1 and Voyager 2, were launched. The spacecrafts as shown in fig. 7.1, now still travelling at around 17 km s^{-1}, are the most distant human-made objects from Earth and the first two to leave the Solar System. Having operated for 48 years as of 2025, they still receive routine commands and transmit data back to Earth.

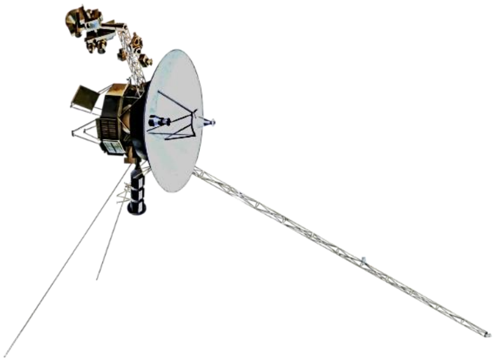

Fig. 7.1

Their trajectories were calculated to bring them very close to the planets Jupiter, Saturn, Uranus and Neptune, which were in a rare alignment at that time. Besides being able to collect data of these planets, their close fly-bys also allowed them to use the gravitational attraction of the planets to increase their momentum and bend their trajectories from one planet to the next as shown in fig. 7.2. Without such *gravity assists*, the chemical energy available from the propellant fuel carried by the spacecraft would not allow them to even reach Saturn before the Sun's gravity pulled them back. Saturn is roughly 9.6 AU from the Sun. (1 AU, or astronomical unit, is roughly the distance from the Sun to the Earth.)

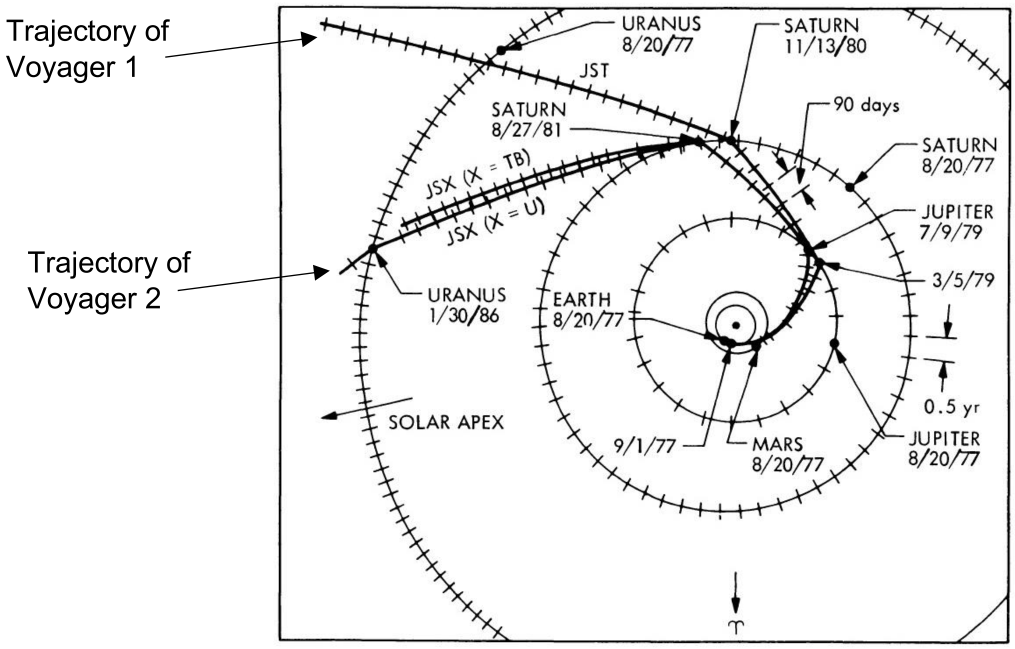

Fig. 7.2

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Data

	Mass / kg	Average distance from the Sun / AU
Sun	2.0×10^{30}	0.0
Earth	6.0×10^{24}	1.0
Jupiter	1.9×10^{27}	5.2
Saturn	5.7×10^{26}	9.6

The Voyager spacecraft each has a mass of 773 kg. On board are scientific cameras and sensors, a power source, a radio communication system, and small rocket thrusters that expel propellant.

The variation with distance (from the Sun) of the speed of Voyager 2 is shown in Fig. 7.3.

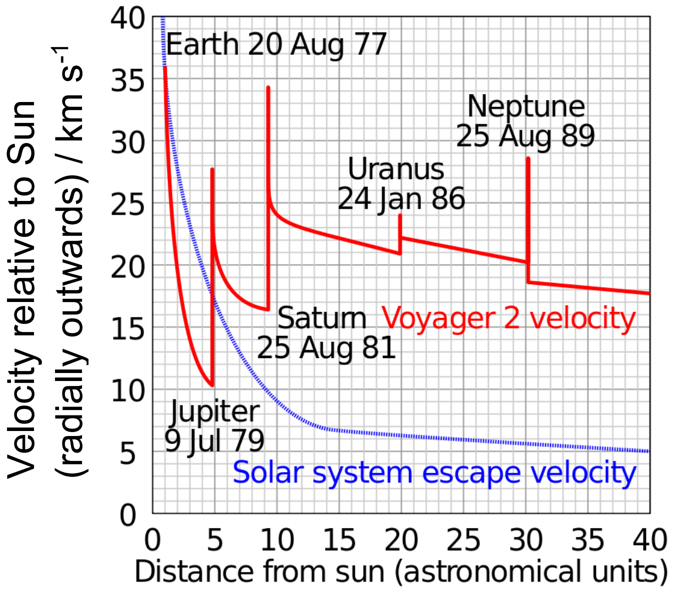

Fig. 7.3

The spacecraft reached Jupiter in 1979. Both spacecraft used the gravity of Jupiter to bend their trajectories toward Saturn. The two spacecraft next visited Saturn, reaching the planet in 1980 and 1981.

Electrical power is supplied by three radioisotope thermoelectric generators (RTGs), which use the heat produced from the nuclear fission of its radioactive plutonium-238 fuel to generate electricity using thermocouples. They provided approximately 470 W when the spacecraft was launched. Plutonium-238 decays with a half-life of 87.74 years.

The two spacecraft transmit radio signals to Earth. As they move farther away from the Earth, their radio signals reaching us become weaker, making communication increasingly difficult. In the 1980's, to address this problem, the total receiving area of the antennae on Earth was increased. It is estimated that, by 2030, the intensity of the radio signals from Voyager 1 arriving at Earth will be too low to be detected.

In 1990, as it was about to leave the Solar system, Voyager 1 took a photograph of Earth from a distance of 40.47 AU. Due to the great distance, Earth appeared as only a tiny dot in the photograph.

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(a) The Earth takes 365 days to orbit the Sun. The orbital path can be assumed to be circular in shape with a radius of 1 AU (astronomical unit).

Show that the distance represented by 1 AU is 1.50×10^{11} m.

1 AU = ... m [3]

(b) **(i)** Suggest why it is reasonable to assume that the gravitational influence of all the planets is small compared with that of the Sun when determining the motion of the spacecraft in the solar system.

....

....

.... [1]

(ii) Determine the minimum speed that an object near Jupiter must have for it to be able to overcome the Sun's gravitational field and escape to infinity. Explain your working.

Minimum speed = ... $m\ s^{-1}$ [3]

(iii) Explain how Fig. 7.3 shows that the Voyager 2 was not travelling fast enough from Jupiter on 9 July 1979 to escape from the solar system.

....

....

.... [1]

(iv) Using Fig. 7.3, calculate the gain in momentum by Voyager 2 as it interacted with Jupiter's gravitational field during its flyby.

Gain in momentum = ... kg m s^{-1} [2]

(v) Using the principle of conservation of momentum or otherwise, explain how Voyager 2 gains momentum as it flew by Jupiter.

....

....

.... [1]

(c) (i) Calculate the percentage decrease in the activity of the plutonium-238 radioactive fuel in the RTG over a duration of one year.

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Percentage decrease = ... % [3]

(ii) By 2036, the activity of the plutonium-238 will be 62.3 % of its initial activity when the spacecraft was launched.
Estimate the power available to the spacecraft in 2036.

Power available = ... W [2]

(iii) Explain why the receiving area of the antennae on Earth was increased in the 1980s.

....

....

....

.... [2]

(d) The angular diameter of a planet is the angle subtended by its diametrically opposite edges at the position of the observer.

The radius of the Earth is 6.4×10^6 m.

Calculate the angular diameter of the Earth from the point of view of Voyager 1 when it took the photograph of Earth in 1990. Express your answer in radians.

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Angular diameter of Earth = ... rad [2]

[Total: 20]