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]

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(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.

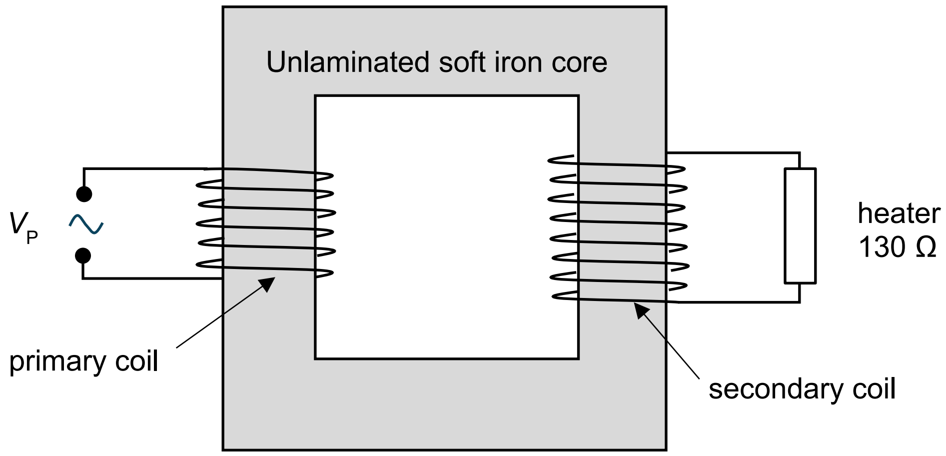

Fig. 5.1

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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)**.

....

....

....

.... [1]

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

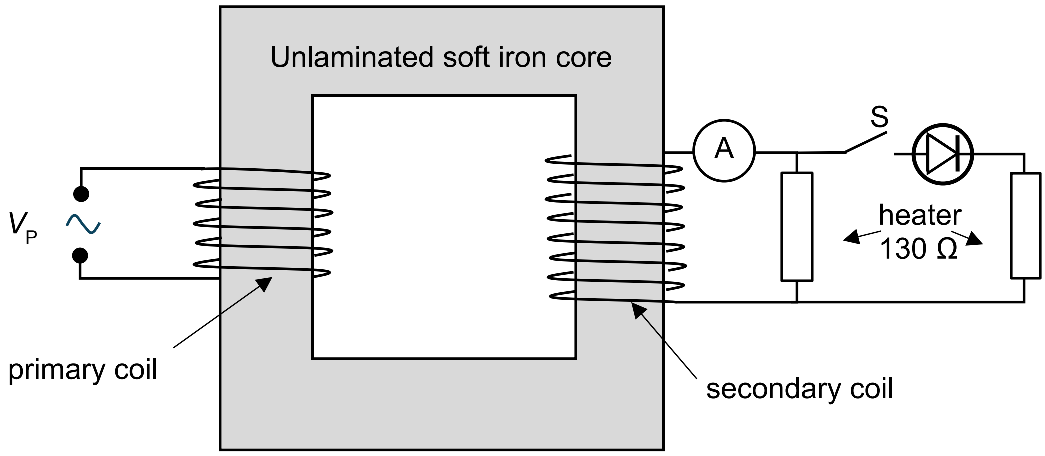

Fig. 5.2

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]

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.

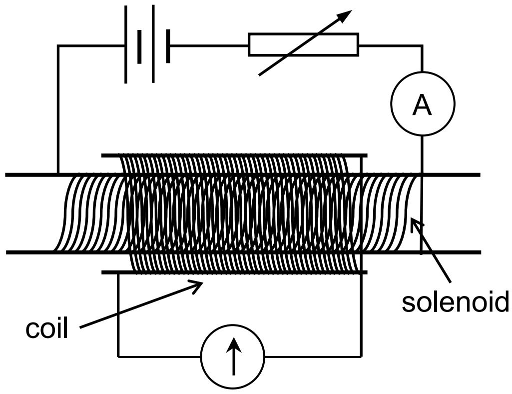

Fig. 6.1

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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.

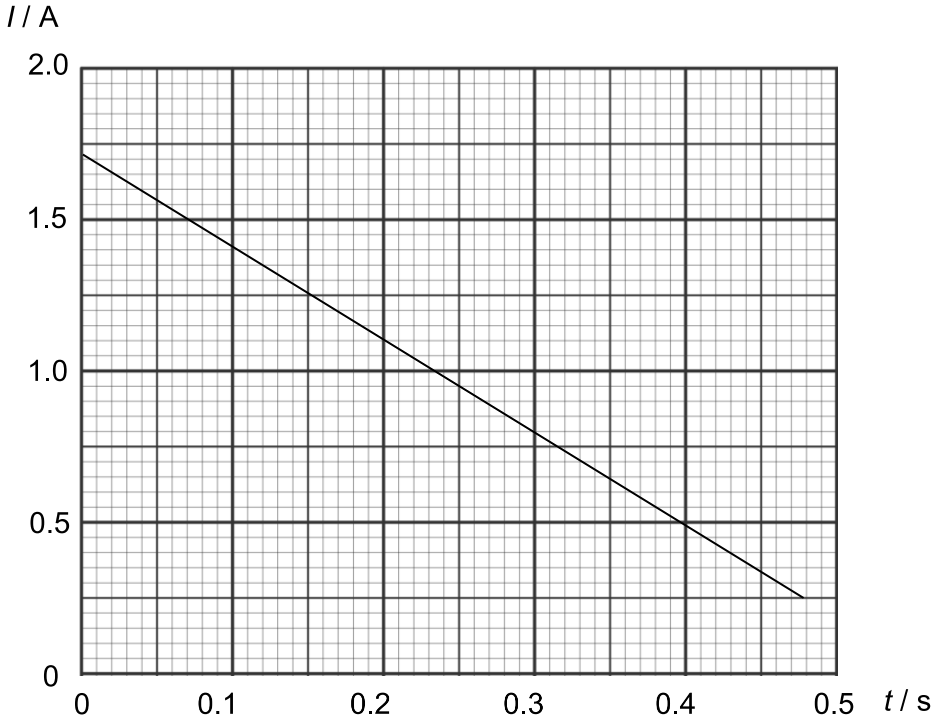

Fig. 6.2

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

(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.

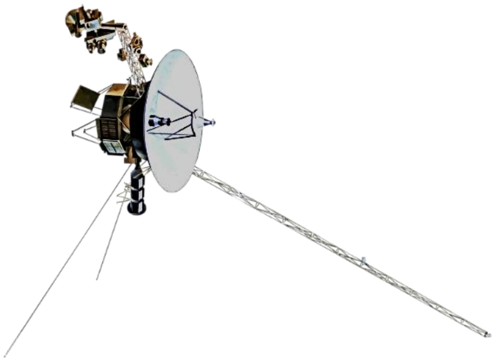

Fig. 7.1

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.)

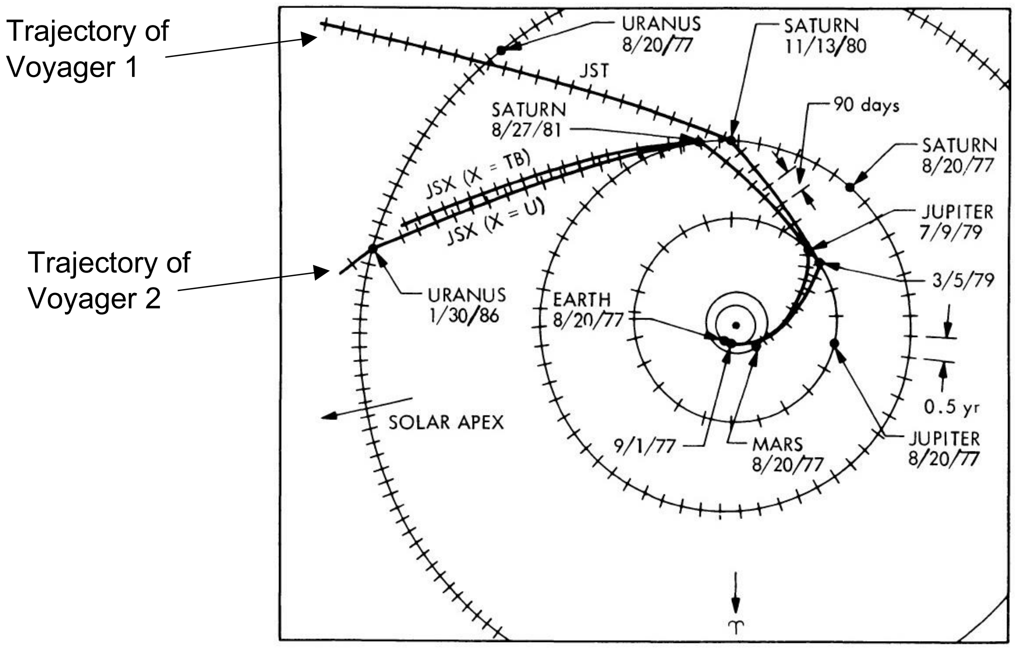

Fig. 7.2

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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.

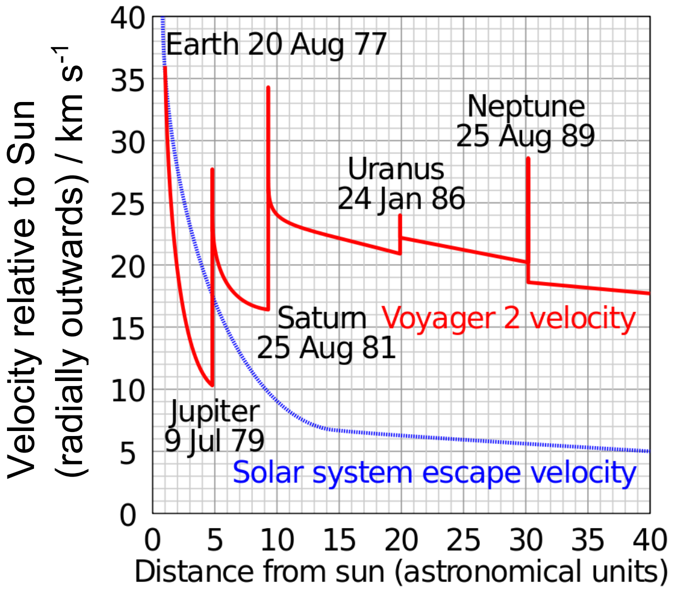

Fig. 7.3

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]

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(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.

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.

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

[Total: 20]

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