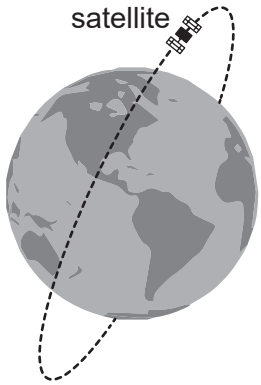
5. A satellite powered by solar cells directed towards the Sun is in a polar orbit about the Earth.



The satellite is orbiting the Earth at a distance of 6600 km from the centre of the Earth.

(a) Determine the orbital period for the satellite. [3]

Mass of Earth $= 6.0 \times 10^{24}$ kg

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(Question 5 continued)

(b) The satellite carries an experiment that measures the peak wavelength emitted by different objects. The Sun emits radiation that has a peak wavelength λ_S of 509 nm. The peak wavelength λ_E of the radiation emitted by the Earth is 10.1 μm.

(i) Determine the mean temperature of the Earth. [2]

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(ii) Suggest how the difference between λ_S and λ_E helps to account for the greenhouse effect. [3]

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(c) Not all scientists agree that global warming is caused by the activities of man. Outline how scientists try to ensure agreement on a scientific issue. [1]

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Higher Level only

5. (a) The moon Phobos moves around the planet Mars in a circular orbit.

(i) Outline the origin of the force that acts on Phobos. [1]

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(ii) Outline why this force does no work on Phobos. [1]

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(b) The orbital period T of a moon orbiting a planet of mass M is given by

$$\frac{R^3}{T^2} = kM$$

where R is the average distance between the centre of the planet and the centre of the moon.

(i) Show that $k = \frac{G}{4\pi^2}$ [3]

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(This question continues on the following page)

(Question 5 continued)

(ii) The following data for the Mars–Phobos system and the Earth–Moon system are available:

Mass of Earth = 5.97×10^{24} kg
The Earth–Moon distance is 41 times the Mars–Phobos distance.
The orbital period of the Moon is 86 times the orbital period of Phobos.

Calculate, in kg, the mass of Mars. [2]

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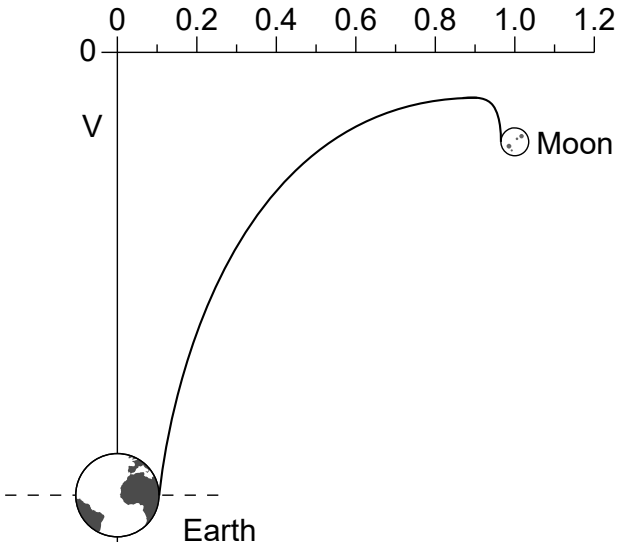
(c) The graph shows the variation of the gravitational potential between the Earth and Moon with distance from the centre of the Earth. The distance from the Earth is expressed as a fraction of the total distance between the centre of the Earth and the centre of the Moon.



Determine, using the graph, the mass of the Moon. [3]

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(Question 7 continued)

(c) An additional identical capacitor is connected in series with the first capacitor and the charging and discharging processes are repeated. Comment on the effect this change has on the height and time taken to raise the 45 g mass. [3]

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8. There is a proposal to place a satellite in orbit around planet Mars.

(a) (i) Outline what is meant by gravitational field strength at a point. [2]

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(ii) Newton's law of gravitation applies to point masses. Suggest why the law can be applied to a satellite orbiting Mars. [2]

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(Question 8 continued)

(b) The satellite is to have an orbital time T equal to the length of a day on Mars. It can be shown that

$$T^2 = kR^3$$

where R is the orbital radius of the satellite and k is a constant.

(i) Mars has a mass of 6.4×10^{23} kg. Show that, for Mars, k is about $9 \times 10^{-13}\ s^2\ m^{-3}$. [3]

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(ii) The time taken for Mars to revolve on its axis is 8.9×10^4 s. Calculate, in $m\ s^{-1}$, the orbital speed of the satellite. [2]

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(Question 8 continued)

(c) The ratio $\frac{\text{distance of Mars from the Sun}}{\text{distance of Earth from the Sun}} = 1.5$.

(i) Show that the intensity of solar radiation at the orbit of Mars is about 600 W m^{-2}. [2]

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(ii) Determine, in K, the mean surface temperature of Mars. Assume that Mars acts as a black body. [2]

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(iii) The atmosphere of Mars is composed mainly of carbon dioxide and has a pressure less than 1 % of that on Earth. Outline why the mean temperature of Earth is strongly affected by gases in its atmosphere but that of Mars is not. [3]

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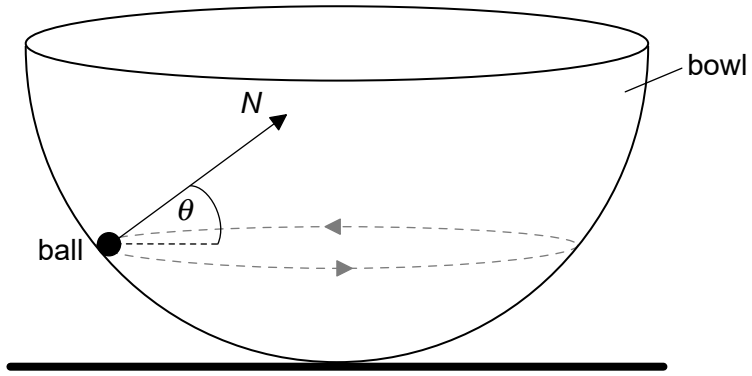
Answer **all** questions. Answers must be written within the answer boxes provided.

1. (a) A small ball of mass m is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl.



The normal reaction force N makes an angle θ to the horizontal.

(i) State the direction of the resultant force on the ball. [1]

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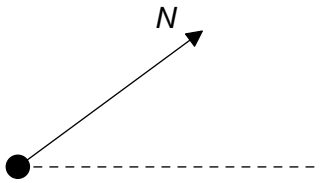
(ii) On the diagram, construct an arrow of the correct length to represent the weight of the ball. [2]



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(Question 1 continued)

(iii) Show that the magnitude of the net force F on the ball is given by the following equation. [3]

$$F = \frac{mg}{\tan\theta}$$

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(b) The radius of the bowl is 8.0 m and $\theta = 22^\circ$. Determine the speed of the ball. [4]

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(c) Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl. [2]

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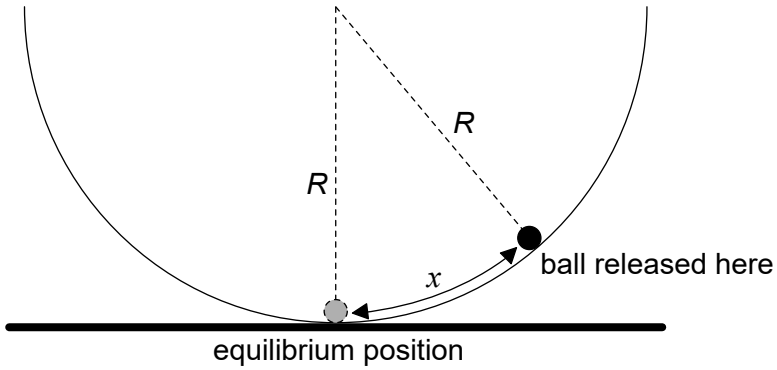
(This question continues on the following page)

(Question 1 continued)

(d) The ball is now displaced through a small distance x from the bottom of the bowl and is then released from rest.



The magnitude of the force on the ball towards the equilibrium position is given by

$$\frac{mgx}{R}$$

where R is the radius of the bowl.

(i) Outline why the ball will perform simple harmonic oscillations about the equilibrium position. [1]

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(ii) Show that the period of oscillation of the ball is about 6 s. [2]

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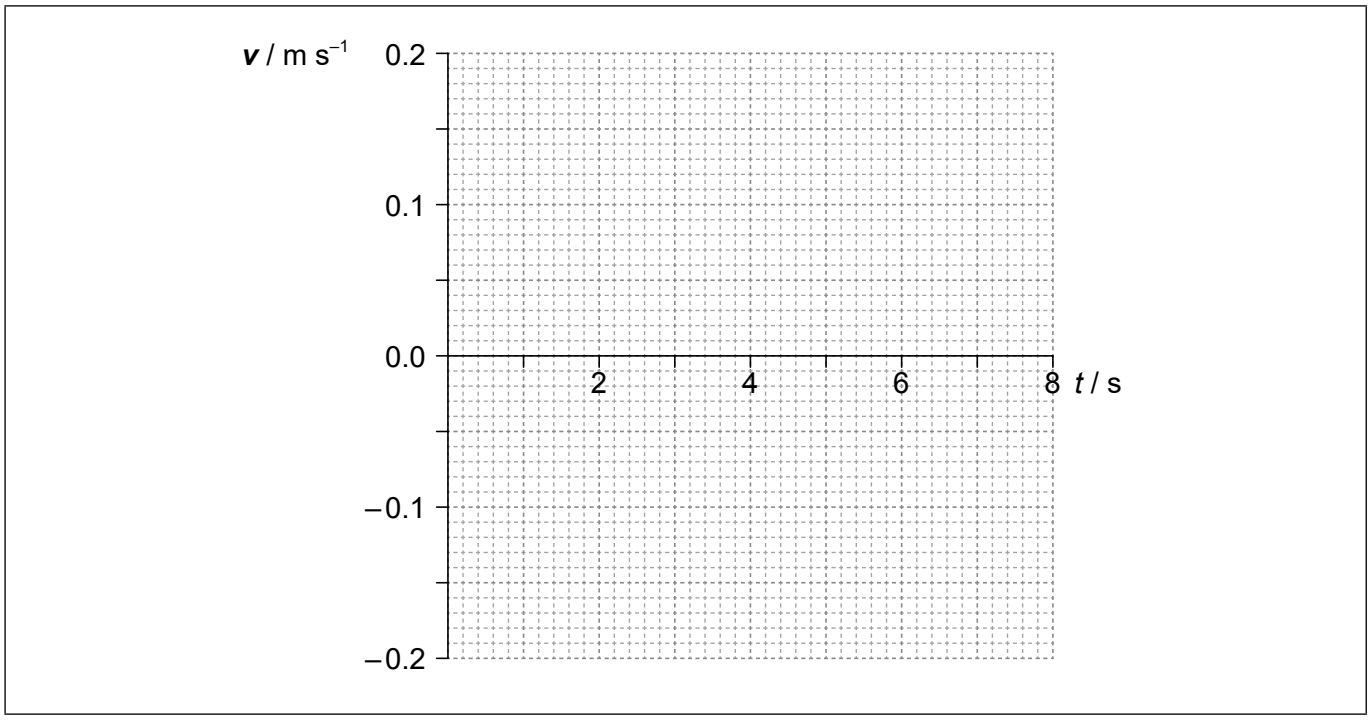
(This question continues on the following page)

(Question 1 continued)

(iii) The amplitude of oscillation is 0.12 m. On the axes, draw a graph to show the variation with time t of the velocity $\boldsymbol{v}$ of the ball during one period. [3]



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6. (a) A planet has radius R. At a distance h above the surface of the planet the gravitational field strength is g and the gravitational potential is V.

(i) State what is meant by gravitational field strength. [1]

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(ii) Show that $V = -g(R + h)$. [2]

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(iii) Draw a graph, on the axes, to show the variation of the gravitational potential V of the planet with height h above the surface of the planet. [2]

(This question continues on the following page)

(Question 6 continued)

(b) A planet has a radius of 3.1×10^6 m. At a point P a distance 2.4×10^7 m above the surface of the planet the gravitational field strength is 2.2 N kg^{-1}. Calculate the gravitational potential at point P, include an appropriate unit for your answer. [1]

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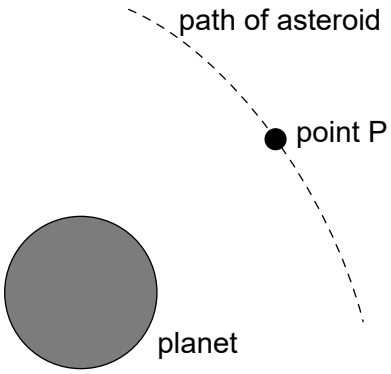
(c) The diagram shows the path of an asteroid as it moves past the planet.



When the asteroid was far away from the planet it had negligible speed. Estimate the speed of the asteroid at point P as defined in (b). [3]

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(Question 6 continued)

(d) The mass of the asteroid is 6.2×10^{12} kg. Calculate the gravitational force experienced by the **planet** when the asteroid is at point P. [2]

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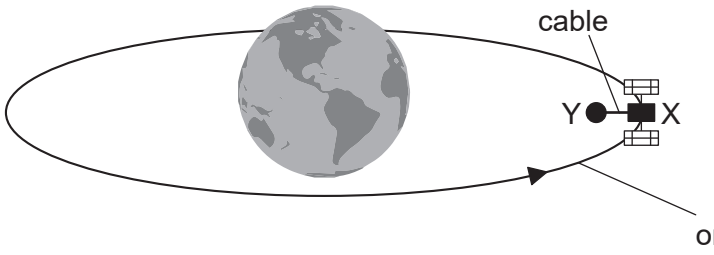
2. There is a proposal to power a space satellite X as it orbits the Earth. In this model, X is connected by an electronically-conducting cable to another smaller satellite Y.



not to scale

(a) Satellite X orbits 6600 km from the centre of the Earth.

$$\text{Mass of the Earth} = 6.0 \times 10^{24}\ \text{kg}$$

Show that the orbital speed of satellite X is about 8 km s^{-1}. [2]

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(b) Satellite Y orbits closer to the centre of Earth than satellite X. Outline why

(i) the orbital times for X and Y are different. [1]

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(ii) satellite Y requires a propulsion system. [2]

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