Gravity Fields Past Paper Questions
Jan 2002—Jan 2010 (old spec)

2 Communications satellites are usually placed in a *geo-synchronous orbit*.

(a) State **two** features of a geo-synchronous orbit. **Q2 Jun 2003**

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(2 marks)

(b) Given that the mass of the Earth is 6.00×10^{24} kg and its mean radius is 6.40×10^{6} m,

(i) show that the radius of a geo-synchronous orbit must be 4.23×10^{7} m,

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(ii) calculate the increase in potential energy of a satellite of mass 750 kg when it is raised from the Earth's surface into a geo-synchronous orbit.

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(6 marks)

4 (a) The Moon's orbit around the Earth may be assumed to be circular. Explain why no work is done by the gravitational force that acts on the Moon to keep it in orbit around the Earth.

You may be awarded marks for the quality of written communication provided in your answer.

Q4 Jun 2004

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(3 marks)

(b) Give an example of a situation where a body

(i) travels at constant speed but experiences a continuous acceleration,

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(ii) experiences a maximum acceleration when its speed is zero.

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(2 marks)

3 (a) Explain what is meant by the *gravitational potential* at a point in a gravitational field.

Q3 Jan 2005

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(2 marks)

(b) Use the following data to calculate the gravitational potential at the surface of the Moon.

mass of Earth = 81 × mass of Moon
radius of Earth = 3.7 × radius of Moon
gravitational potential at surface of the Earth = –63 M Jkg^{-1}

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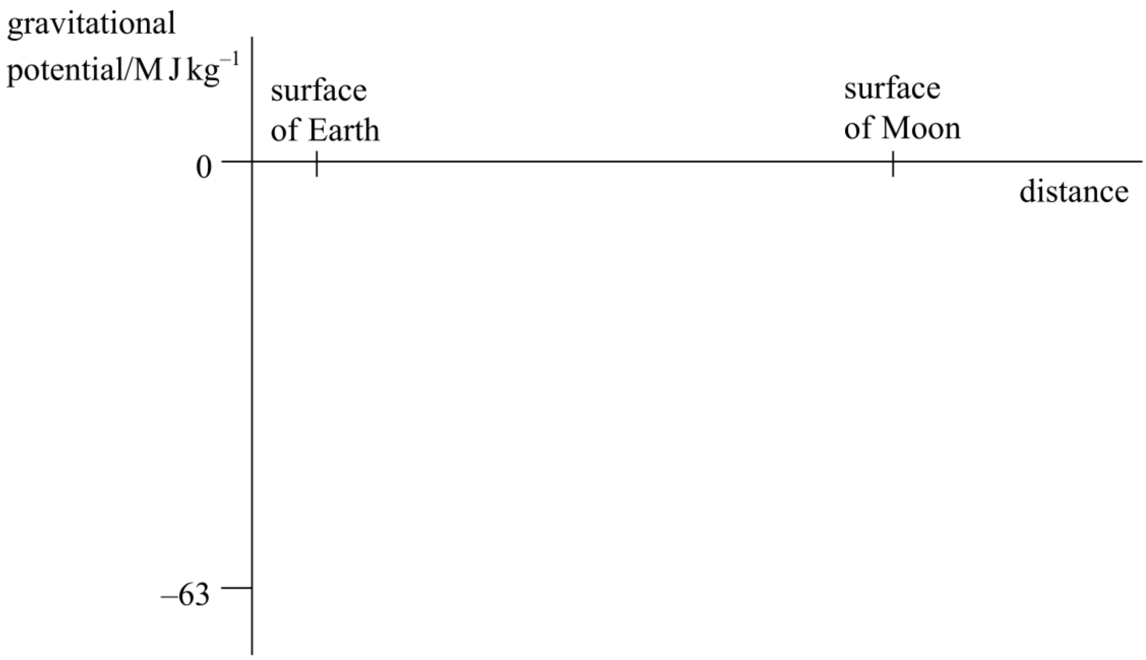
(3 marks)

(c) Sketch a graph on the axes below to indicate how the gravitational potential varies with distance along a line outwards from the surface of the Earth to the surface of the Moon.



(3 marks)

4 (a) State, in words, Newton's law of gravitation.

Q4 Jun 2005

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(3 marks)

(b) By considering the centripetal force which acts on a planet in a circular orbit, show that $T^2 \propto R^3$, where T is the time taken for one orbit around the Sun and R is the radius of the orbit.

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(3 marks)

(c) The Earth's orbit is of mean radius 1.50×10^{11} m and the Earth's year is 365 days long.

(i) The mean radius of the orbit of Mercury is 5.79×10^{10} m. Calculate the length of Mercury's year.

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(ii) Neptune orbits the Sun once every 165 Earth years.

Calculate the ratio $\dfrac{\text{distance from Sun to Neptune}}{\text{distance from Sun to Earth}}$.

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(4 marks)

4 (a) Artificial satellites are used to monitor weather conditions on Earth, for surveillance and for communications. Such satellites may be placed in a *geo-synchronous* orbit or in a low polar orbit.

Q4 Jan 2006

Describe the properties of the geo-synchronous orbit and the advantages it offers when a satellite is used for communications.

You may be awarded marks for the quality of written communication in your answer.

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(3 marks)

(b) A satellite of mass m travels at angular speed ω in a circular orbit at a height h above the surface of a planet of mass M and radius R.

(i) Using these symbols, give an equation that relates the gravitational force on the satellite to the centripetal force.

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(ii) Use your equation from part (b)(i) to show that the orbital period, T, of the satellite is given by

$$T^2 = \frac{4\pi^2(R+h)^3}{GM}.$$

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(iii) Explain why the period of a satellite in orbit around the Earth cannot be less than 85 minutes. Your answer should include a calculation to justify this value.

mass of the Earth $= 6.00 \times 10^{24}$ kg
radius of the Earth $= 6.40 \times 10^{6}$ m

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(6 marks)

(c) Describe and explain what happens to the speed of a satellite when it moves to an orbit that is closer to the Earth.

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(2 marks)

4 (a) State what is meant by *gravitational field strength* at a point in a gravitational field and state whether it is a scalar or vector quantity.

Q4 Jan 2007

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(2 marks)

(b) A satellite of mass 2.5×10^3 kg is to be moved from the surface of the Earth to an orbit of radius 1.6×10^7 m around the Earth.

(i) Calculate the gravitational force acting on the satellite when in orbit.

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(ii) Given that the gravitational potential at the surface of the Earth (due to the Earth) is $-63\,\text{MJ}\,\text{kg}^{-1}$, calculate the increase in the gravitational potential energy of the satellite when it is placed in the orbit.

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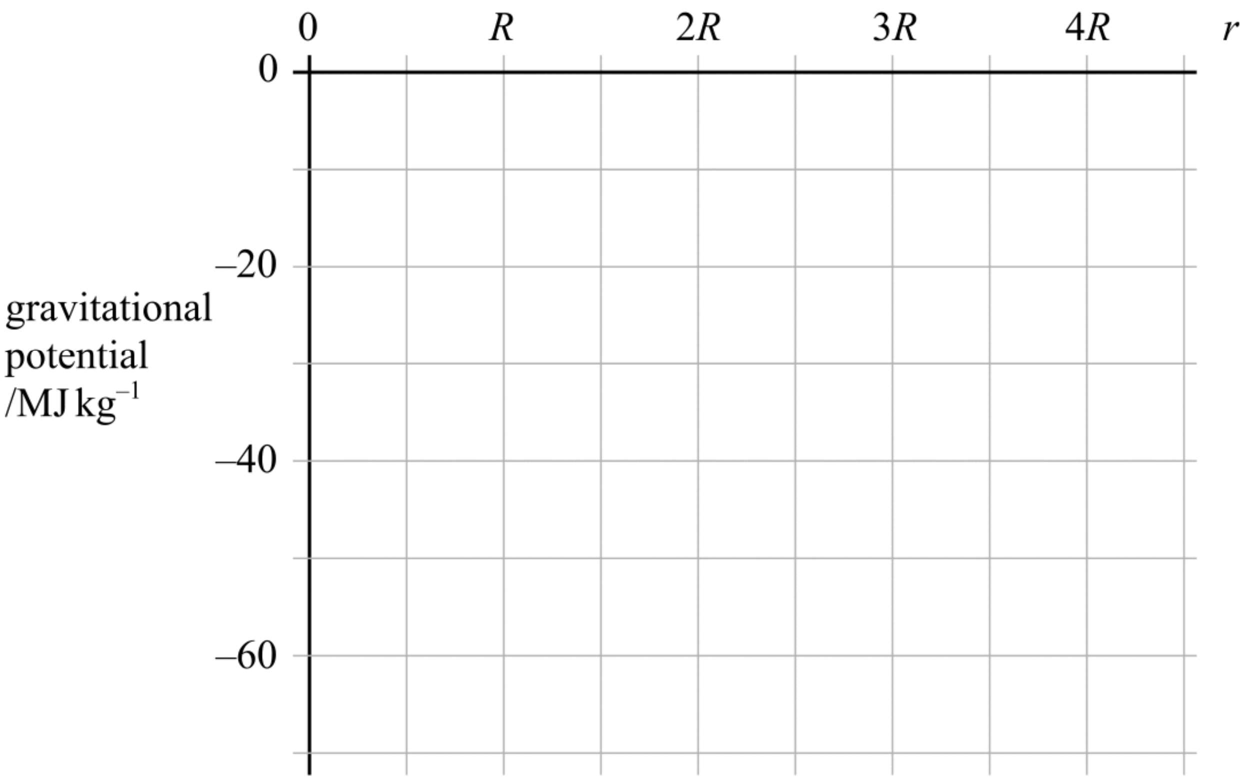
(5 marks)

(c) Draw a graph on the axes below to show how the gravitational potential due to the Earth varies with distance, r, measured from the centre of the Earth, for points outside the Earth. On the horizontal axis, R is the radius of the Earth.



(3 marks)

5 (a) By considering the force equation for a satellite of mass m in an orbit of radius r around a planet of mass M, show that the orbital time period T of the satellite does not depend upon m.

Q5 Jan 2008

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(3 marks)

(b) One of the moons of Jupiter, Ganymede, is the largest satellite in the solar system. Its orbital period is equal to 7.15 Earth days and the radius of its orbit is 1.07×10^6 km.

Calculate

(i) the angular speed of Ganymede in its orbit,

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(ii) the centripetal acceleration of Ganymede in its orbit,

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(iii) the mass of Jupiter.

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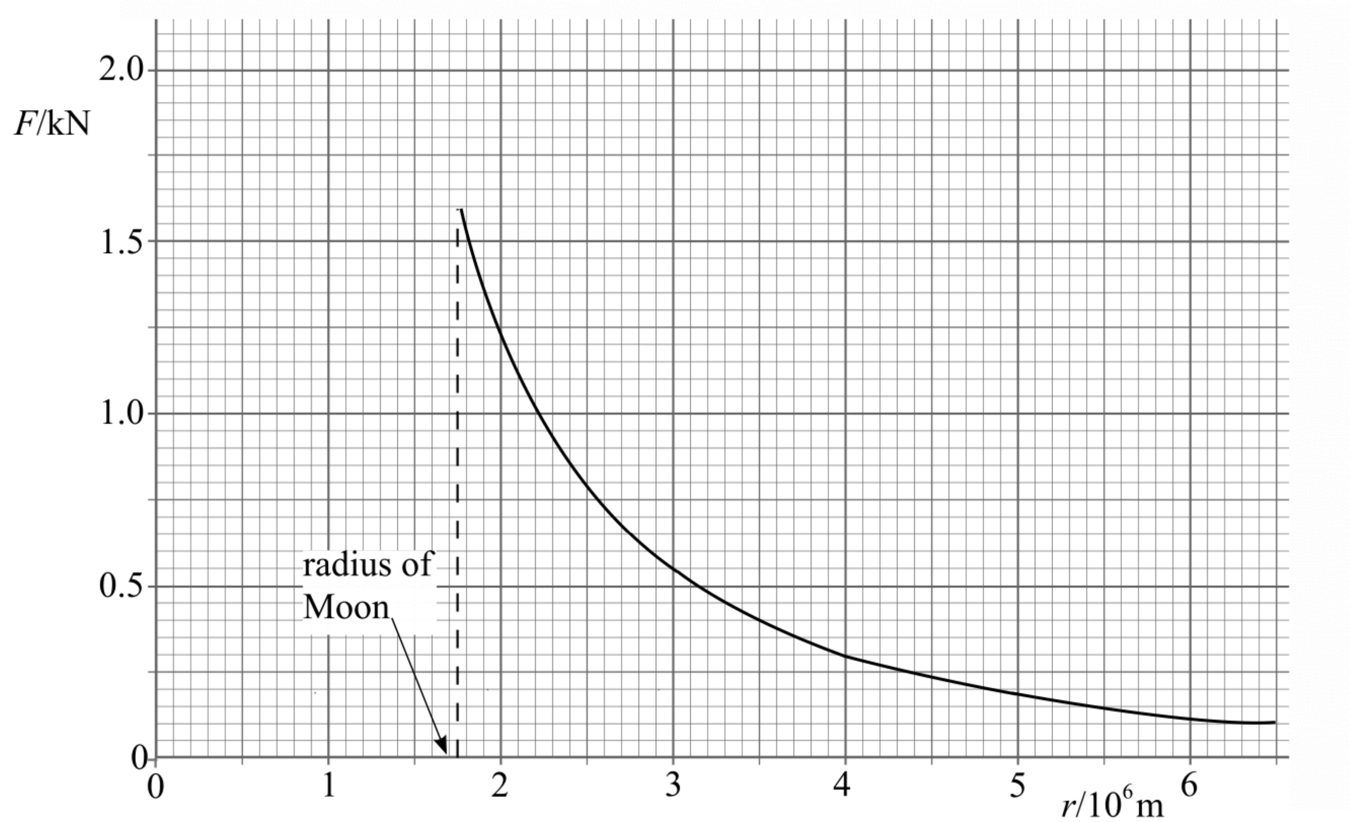
(5 marks)

3 (a) The graph shows how the gravitational force F between a 1000 kg mass and the Moon varies with the distance r from the centre of the Moon for points outside its surface.

Q3 Jun 2008



3 (a) (i) Explain why the graph has this shape for points outside the surface.

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3 (a) (ii) Use data from the graph to determine the mass of the Moon.

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(4 marks)

3 (b) (i) From the graph, estimate the potential energy lost by the 1000 kg mass as it falls to the surface of the Moon from a very large distance above it. Explain how you arrive at your estimate.

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3 (b) (ii) By considering the 1000 kg mass as a projectile, calculate the speed at which it should it be thrown vertically upwards from the surface of the Moon if it is to escape from the Moon's gravitational field.

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(5 marks)

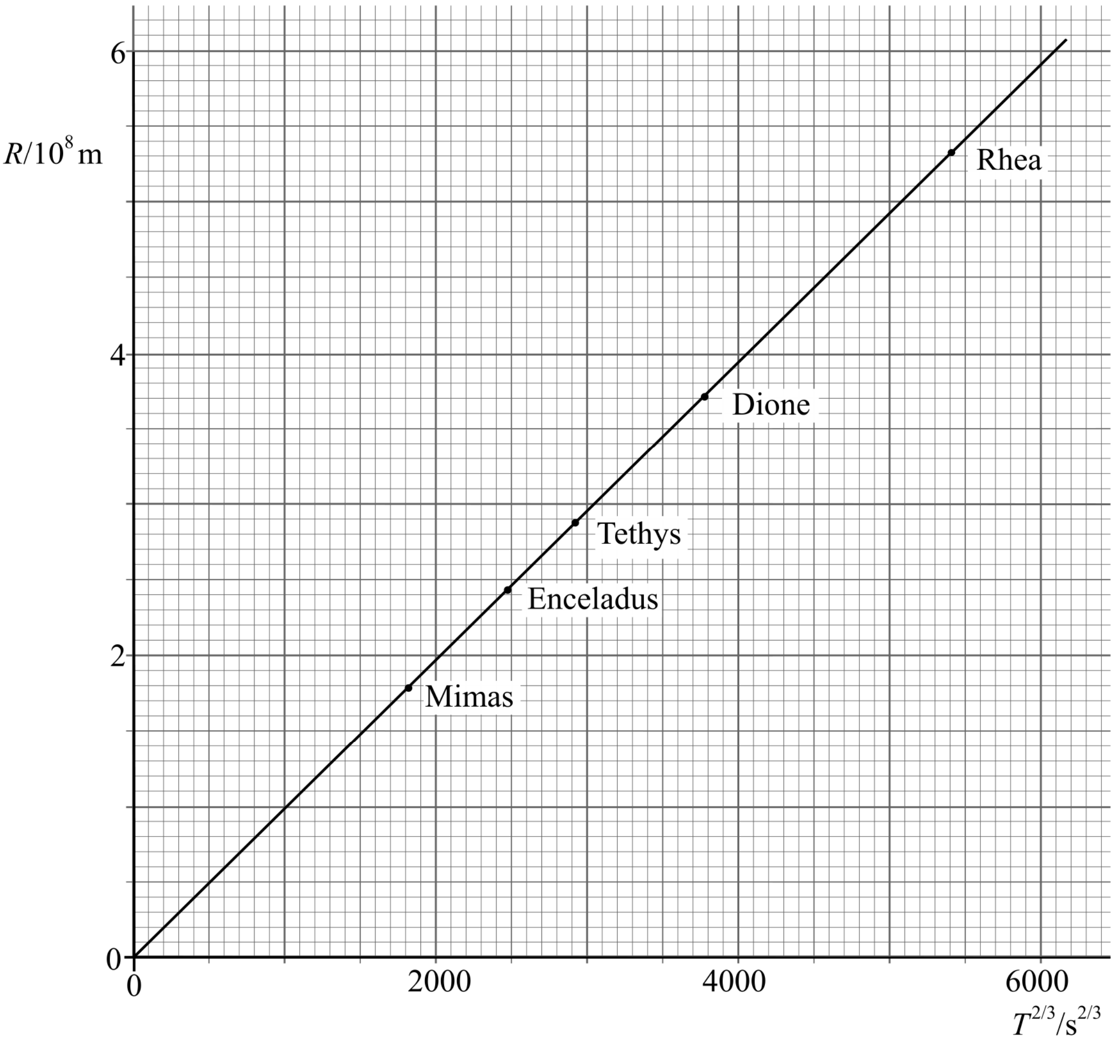
3 (a) For a satellite in orbit around a planet, theory shows that the relationship between the mean orbital radius, R, and the orbital period, T, is

Q3 Jun 2009

$$R^3 = \frac{GMT^2}{4\pi^2}, \text{ where } M \text{ is the mass of the planet.}$$

The graph in **Figure 3**, which is constructed from measurements based on observations, shows how R varies with $T^{2/3}$ for five of the inner satellites of the planet Saturn, named Mimas, Enceladus, Tethys, Dione and Rhea.

Figure 3



3 (a) (i) Determine the gradient of the graph in **Figure 3** in $m\,s^{-2/3}$.

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3 (a) (ii) Explain how the relationship between R and T in the equation given in part (a) is supported by this graph.

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3 (a) (iii) Use your value for the gradient, together with any other necessary data, to calculate the mass of Saturn.

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(6 marks)

3 (b) It is possible to plot a graph of R against $T^{2/3}$ for the orbits of the planets around the Sun.

State and explain **one** similarity, and **one** difference, between the properties of this graph and the graph shown in **Figure 3**.

Similarity:...

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Difference:...

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(2 marks)