Gravitational Fields

Tutorial

SAQ 5.1 pg 53 Sang

Calculate the gravitational force of attraction between 2 objects each of mass 0.1 kg, separated by 1 cm. (ans. 6.67×10^{-9} N)

Guided Examples (1) pg 82 Francis

1) Calculate the mass of the moon given that its radius is 1.74×10^{6} m and the gravitational field strength at its surface, measured by the Apollo astronauts, is 1.70 N kg^{-1}. (Assume $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}) (ans. 7.72×10^{22} kg)

2) Calculate the gravitational field strength on the surface of a plane whose mean density is 0.5 x that of the Earth, and whose radius is 15 x the Earth's radius. Assume that g on the Earth's surface is 10 N kg^{-1}. (ans. 75 N kg^{-1})

Example pg 92 KF Chan

A satellite is put into orbit so that it appears stationary to an observer on the Earth. Find it's orbiting speed, and the radius of the orbit. (Assume $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2} and mass of Earth, $M = 6.0 \times 10^{24}$ kg) (ans. $r = 4.23 \times 10^{7}$ m, $v = 3.1 \times 10^{3}$ ms^{-1})

Example pg 96 KF Chan

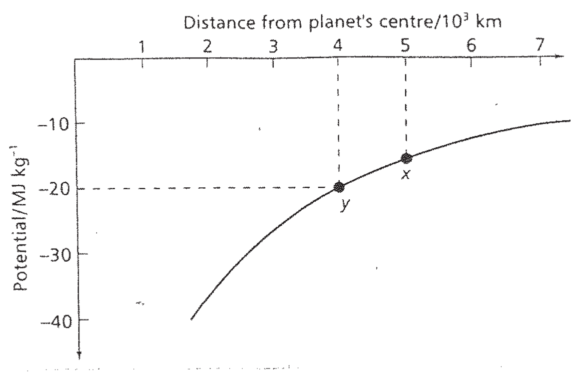
Find the gravitational potential at a height 3000 km from the Earth's surface. (Mass of Earth, $M = 6.0 \times 10^{24}$ kg; radius of Earth, $R = 6.3 \times 10^{6}$ m) (ans. $\phi = -4.3 \times 10^{7}$ J kg^{-1})

Q12.7 pg 236 Jim

The variation of gravitational potential near a certain planet is shown below. Use the graph to determine

(a) the gravitational potential at X, a distance of 5000 km from the centre of the planet,
(b) the change of P.E. of a 100 kg mass moved from point X to point Y, a distance of 4000 km from the centre of the planet,
(c) the gravitational field strength at X.

(ans. $\phi = -16$ MJ kg^{-1}, $\Delta U = -400$ MJ, $g = 3.2$ N kg^{-1})



Q 12.11 pg 236 Jim

Jupiter is the largest planet of the Solar System; its mass is 9.56×10^{-4} x the Sun's mass. The distance from the Sun to Jupiter is 7.78×10^{11} m on average. Calculate:-

(a) the distance from the sun to the point along the line between the Sun and Jupiter at which their combined gravitational field strength is zero
(b) the gravitational potential at this point

(Assume mass of Sun = 2×10^{30} kg)

(ans. $x = 7.55 \times 10^{11}$ m, $\phi = -182$ MJ kg^{-1})

2002

Answer **all** questions.

1 A communications satellite of mass m is to be placed in an orbit of radius R over the equator so that it rotates once per day around the Earth from west to east as shown in Fig. 1.1. The mass of the Earth is 5.98×10^{24} kg.

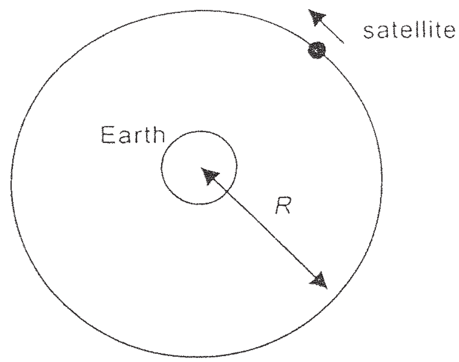


Fig. 1.1

(a) (i) Explain why such orbits are of importance.

....

....

....

(ii) Calculate the angular velocity ω of the satellite.

angular velocity = ...rad s^{-1}

(iii) Express the centripetal acceleration a of the satellite in terms of R and ω.

....

[5]

(b) (i) State the equation which summarises Newton's law of gravitation.

....

(ii) Apply this equation to the satellite in **(a)** in order to show that $R = 4.23 \times 10^7$ m.

[5]

(c) Calculate the gravitational potential in the Earth's field at a point in the satellite's orbit.

gravitational potential =.................... [1]

9702/4 , J/02, Gravitation / Circular motion

For Examiner's Use

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

1 (a) The Earth may be considered to be a uniform sphere of radius 6.38×10^6 m. Its mass is assumed to be concentrated at its centre.

Given that the gravitational field strength at the Earth's surface is $9.81\ \text{N kg}^{-1}$, show that the mass of the Earth is 5.99×10^{24} kg.

[2]

(b) A satellite is placed in geostationary orbit around the Earth.

(i) Calculate the angular speed of the satellite in its orbit.

angular speed = ... rad s^{-1} [3]

(ii) Using the data in **(a)**, determine the radius of the orbit.

radius = ... m [3]

Nov 2000 P3

2 (a) (i) Define *angular velocity* for an object travelling in a circle.

(ii) Calculate the angular velocity of the Earth in its orbit around the Sun. Assume that the orbit is circular and give your answer in terms of the SI unit for angular velocity. [4]

(b) In order to observe the Sun continuously, a satellite of mass 425 kg is at point X, a distance of 1.60×10^9 m from the centre of the Earth, as shown in Fig. 2.1.

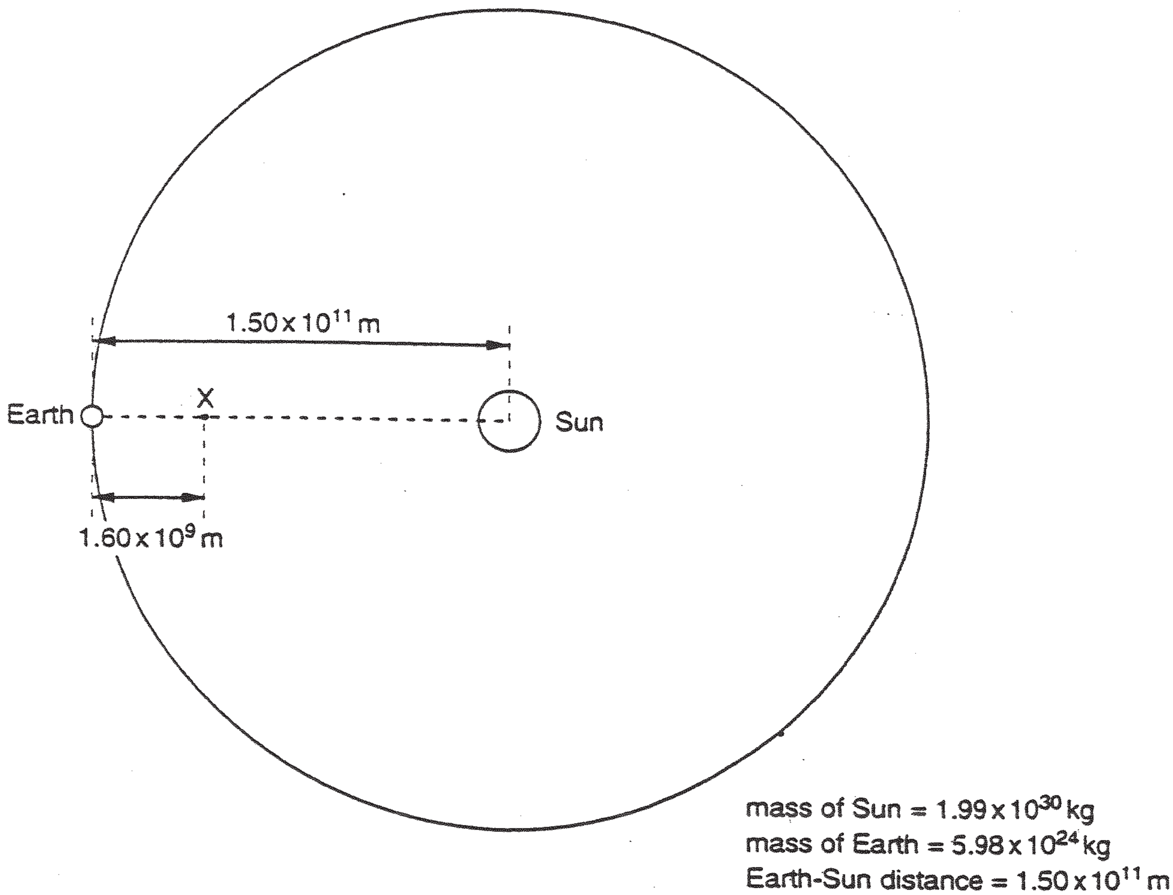


Fig. 2.1

(i) Calculate, using the data given,

1. the pull of the Earth on the satellite,
2. the pull of the Sun on the satellite. [3]

(ii) Using Fig. 2.1 as a guide, draw a sketch to show the relative positions of the Earth, the Sun and the satellite. On your sketch, draw arrows to represent the two forces acting on the satellite. Label the arrows with the magnitude of the forces. [2]

(iii) Calculate

1. the magnitude and direction of the resultant force on the satellite,
2. the acceleration of the satellite. [3]

(iv) The satellite is in a circular orbit around *the Sun*. Calculate the angular velocity of the satellite. [3]

(v) Using your answer to (a) (ii) describe the motion of the satellite relative to the Earth. Suggest why this orbit around the Sun is preferable to a satellite orbit around the Earth. [3]

(vi) Suggest two disadvantages of having a satellite in this orbit. [2]

Q2 J96 P3

[9]

(c) The Earth may be considered to be a uniform sphere of radius 6370 km, spinning on its axis with a period of 24.0 hours. The gravitational field at the Earth's surface is identical with that of a point mass of 5.98×10^{24} kg at the Earth's centre. For a 1.00 kg mass situated at the Equator,

(i) calculate, using Newton's law of Gravitation, the gravitational force on the mass,

(ii) determine the force required to maintain the circular path of the mass,

(iii) deduce the reading on an accurate newton-meter (spring balance) supporting the mass. [6]

(d) Using your answers to (c), state what would be the acceleration of the mass at the Earth's surface due to

(i) the gravitational force alone,

(ii) the force as measured on the newton-meter.

[2]

(e) A student, situated at the Equator, releases a ball from rest in a vacuum and measures its acceleration towards the Earth's surface. He then states that this acceleration is 'the acceleration due to gravity'. Comment on his statement. [2]