Chapter 7: Gravitational Field

Solving Problems Involving Satellites and Planets

1 Always start with :

(a) Gravitational force provides the centripetal force

(b) $\dfrac{GMm}{r^2} = mr\omega^2$

2 Total energy $= -\dfrac{GMm}{2r}$

Kinetic energy $= +\dfrac{GMm}{2r}$

The above two expressions are true for satellites and planets which move in circular orbits. They are **not valid** for non-orbital motions, such as an asteroid crashing toward the Earth.

1 At a point on the surface of a uniform sphere of diameter d, the gravitational field due to the sphere is X. What would be the corresponding value on the surface of a uniform sphere of the same density but of diameter $2d$?

A $2X$ **B** $4X$ **C** $8X$ **D** $16X$

[1981/P2/Q8]

2 Two points P and Q are at distances X and 2X from the centre of a planet respectively. (X is greater than the radius of the planet.) The gravitational potential at P is –800 kJ kg^{-1}.

When a 1 kg mass is taken from P to Q, the work done on the mass by the gravitational force is

A +400 kJ **B** +200 kJ **C** –200 kJ **D** –400 kJ

[AJC/08/P1/Q12]

3 A satellite is moved from one circular orbit around the Earth to another circular orbit with a larger orbital radius. As a result of the change, which quantity of the satellite will increase?

(i) gravitational force (ii) gravitational potential energy

(iii) angular velocity (iv) linear speed

A (i) and (iv) **B** (ii) only **C** (ii) and (iv) **D** (iii) and (iv)

[TPJC/07/I/11]

4 A satellite skims the Moon's surface in a circular orbit. The acceleration due to gravity at the Moon's surface is $\dfrac{g}{6}$ and the Moon's radius is $\dfrac{R}{4}$, where g is the acceleration due to gravity on the surface of the Earth and R is the radius of the Earth.

If the satellite skimming the Earth's surface has a period T, the period of revolution of the Moon's satellite will be

A $\dfrac{2T}{3}$ **B** $\sqrt{\dfrac{2}{3}}T$ **C** $\left(\dfrac{2}{3}\right)^2 T$ **D** $\sqrt{\dfrac{3}{2}}T$

[NJC/08/P1/Q15]

Worked Example (Satellite Motion)

5 A satellite P of mass 2400 kg is placed in a geostationary orbit at a distance of 4.23×10^7 m from the centre of the Earth. Calculate

(a) the angular velocity of the satellite, [2]

(b) the speed of the satellite, [2]

(c) the acceleration of the satellite, [2]

(d) the force of attraction between the Earth and the satellite, [2]

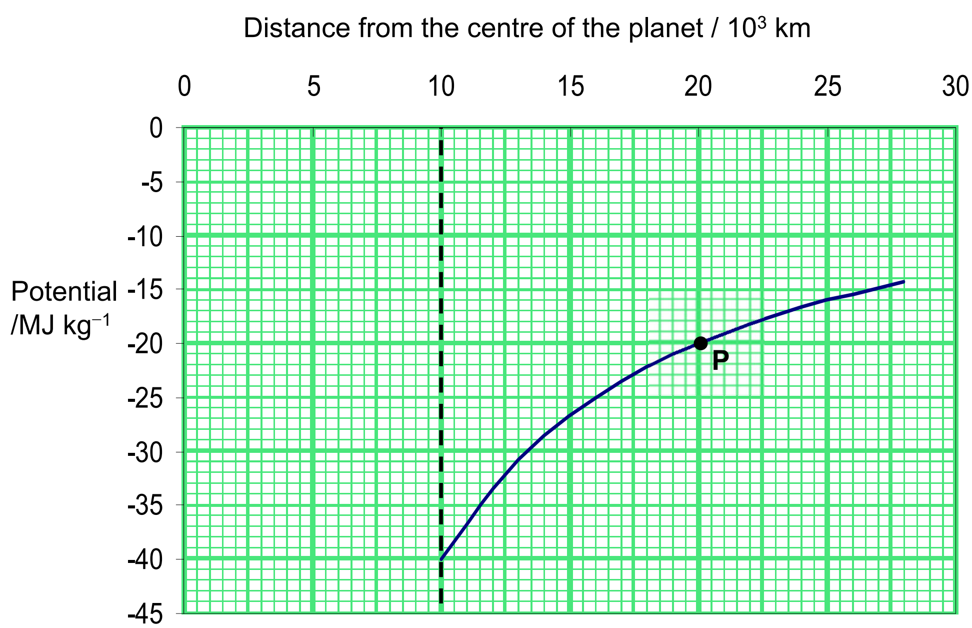
(e) the mass of the Earth. [2]

[1999/P3/Q2]

6 **(a)** **(i)** State in words the relationship between *gravitational potential* and *gravitational field strength*.

(ii) Explain why gravitational potential has a negative value.

(b) The variation of the gravitational potential near a certain planet of radius 10 000 km is shown by the graph in Fig. 2 below.



Use the information on the graph of Fig. 2 to determine

(i) the gravitational potential energy of a 2.0 kg mass at P, a distance of 20 000 km from the centre of the planet,

(ii) the gravitational field strength at P,

(iii) the difference in gravitational potential between the planet's surface and infinity.

(iv) The escape velocity for an object at the surface of the planet.

[2005 RI Prelim P2/Q2 (part)]

7 **(a)** The Earth spins on its axis with a period of one day.

(i) Show that the angular velocity of a point on the Earths' surface is 7.27×10^{-5} rad s^{-1}.

(ii) Calculate the centripetal acceleration of a point on the Earth's equator. The radius of the Earth's equator is 6.38×10^{6} m.

(b) The acceleration of free fall *g* at the equator is not equal to the acceleration of free fall at the poles. Explain

(i) why they are different,

(ii) why the difference is small.

[2007 P3/Q5 (part)]