UNIT 5
GRAVITATION

PROBLEMS

5.1 Find the gravitational force of attraction between two spheres each of mass 1000 kg. The distance between the centers of the spheres is 0.5m.

Given Data

Mass of each sphere = $m_1 = m_2 = 1000$ kg

Distance between their centers = d = 0.5 m

Required

Gravitational force between the spheres = F = ?

Solution

From the law of gravitation, we have

$$F = \frac{G\,m_1 m_2}{d^2}$$

By putting the values, we have

$$F = \frac{6.67\times10^{-11}\times1000\times1000}{(0.5)^2}$$

$$F = \frac{6.67\times10^{-5}}{0.25}$$

$$F = 26.68 \times 10^{-5}$$

$$F = 2.67 \times 10^{-4}\ \text{N}$$

Result

Gravitational force between the spheres = F = 2.67 x 10^{-4} N

5.2 The gravitational force between two identical lead spheres kept at 1 m apart is 0.006673 N. Find their masses.

Given Data

Gravitational force = F = 0.006673 N

Distance between centers = r = 1 m

Gravitational constant = 6.67 x 10^{-11} Nm^2kg^{-2}

Required

Mass of each lead spheres = $m_1 = m_2 = ?$

Solution

From law of gravitation, we have

$$F = G\,\frac{m_1\times m_2}{r^2}$$

OR $m_1 \times m_2 = \frac{F\times r^2}{G}$

By putting the values, we have

$$m_1 \times m_2 = \frac{0.006673 \times (1)^2}{6.67 \times 10^{-11}}$$

$$m_1 \times m_2 = 0.001000 \times 10^{11}$$

$$m_1 \times m_2 = 1.00 \times 10^8$$

As $m_1 = m_2$

So $m_1^2 = 1.00 \times 10^8$

$$m_1 = 1.00 \times 10^4 \text{ kg}$$

So $m_2 = 1.00 \times 10^4$ kg

Result

Mass of each lead spheres = $m_1 = m_2 = 1 \times 10^4$ kg

5.3 Find the acceleration due to gravity on the surface of the Mars. The mass of Mars is 6.42×10^{23} kg and its radius is 3370 km.

Given Data

Mass of the mars = M = 6.42×10^{23} kg

Radius of mars = R = 3370 km = 3370×10^3 m = 3.37×10^6 m

Required

Gravitational acceleration = g = ?

Solution

As we know that

$$g = \frac{GM}{R^2}$$

by putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}{(3.77 \times 10^6)^2}$$

$$g = \frac{42.8214 \times 10^{12}}{11.3569 \times 10^{12}}$$

$$g = 3.77 \text{ ms}^{-2}$$

Result

Gravitational acceleration = g = 3.77 ms^{-2}

5.4 The acceleration due to gravity on the surface of moon is 1.62 ms^{-2}. The radius of Moon is 1740 km. Find the mass of moon.

Given Data

Gravitational acceleration on Moon = g_m = 1.62 ms^{-2}

Radius of moon = R_m = 1740 km = 1740×10^3 m = 1.74×10^6 m

Gravitational constant = G = 6.67×10^{-11} N m^2 kg^{-2}

Required

Mass of the moon = M = ?

Solution

As we know that

$$M = \frac{gR^2}{G}$$

by putting the values, we have

$$M = \frac{1.62 \times (1.74 \times 10^6)^2}{6.67 \times 10^{-11}}$$

$$M = \frac{1.62 \times 3.0276 \times 10^{12}}{6.67 \times 10^{-11}}$$

$$M = \frac{4.90 \times 10^{12}}{6.67 \times 10^{-11}}$$

$$M = 0.735 \times 10^{23}$$

$M = 7.35 \times 10^{22}$ kg

Result

Mass of the moon = M = 7.35 x 10^{22} kg

5.5 Calculate the value of *g* at a height of 3600 km above the surface of the Earth.

Given Data

Height above the surface of Earth = h = 3600 km = 3600 x 10^3 = 3.6 x 10^6 m

Gravitational constant = G = 6.67 x 10^{-11} N m^2 kg^{-2}

Mass of Earth = M = 6 x 10^{24} kg

Required

Gravitational acceleration = g = ?

Solution

As we know that

$$g = \frac{GM}{(R+h)^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6 + 3.6 \times 10^6)^2}$$

$$g = \frac{40.02 \times 10^{13}}{(10 \times 10^6)^2}$$

$$g = \frac{40.02 \times 10^{13}}{1 \times 10^{14}}$$

$$g = 40.02 \times 10^{-1}$$

$$g = 4.002 \text{ ms}^{-2}$$

$$g = 4.0 \text{ ms}^{-2}$$

Result

Gravitational acceleration = g = 4 ms^{-2}

5.6 Find the value of *g* due to the Earth at geostationary satellite. The radius of the geostationary orbit is 48700 km.

Given Data

Radius of geostationary satellite = R =48700 km=48700 x 10^3 m=4.87 x 10^7 m

Mass of earth = M = 6 x 10^{24} kg

Gravitational constant = R = 6.67 x 10^{-11} N m^2 kg^{-2}

Required

Gravitational acceleration = g_h = ?

Solution

As we know that

$$g = \frac{GM}{(R+h)^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(4.87 \times 10^7)^2}$$

$$g = \frac{40.02 \times 10^{13}}{23.72 \times 10^{14}}$$

$$g = 1.68 \times 10^{-1}$$

$$g = 0.168 \text{ ms}^{-2}$$

$$g = 0.17 \text{ ms}^{-2}$$

Result

Gravitational acceleration = g_h = 0.17 ms^{-2}

5.7 The value of *g* is 4.0 ms^{-2} at a distance of 10000 km from the centre of the Earth. Find the mass of the Earth.

Given Data

Gravitational acceleration = $g_h = 4.0\ ms^{-2}$

Distance from centre of Earth = R+ h = 10000 km = 10000 km = 1×10^7 m

Gravitational constant = G = $6.67 \times 10^{-11}\ N\ m^2\ kg^{-2}$

Required

Mass of earth = M = ?

Solution

As we know that

$$g_h = \frac{GM_e}{(R+h)^2}$$

By putting the values, we have

$$M_e = \frac{g_h (R+h)^2}{G}$$

$$M_e = \frac{4 \times (1.0 \times 10^7)^2}{6.67 \times 10^{-11}}$$

$$M_e = \frac{4 \times 10^{14}}{6.67 \times 10^{-11}}$$

$$M = 0.599 \times 10^{25}$$

$$M_e = 5.99 \times 10^{24}$$

$$M_e = 6 \times 10^{24}\ kg$$

Result

Mass of Earth = $M_e = 6 \times 10^{24}$ kg

5.8 At what altitude the value of *g* would become one fourth than on the surface of the Earth?

Given Data

Gravitational acceleration = g = 10 m^{-2}

Gravitational acceleration at height = $g_h = \frac{g}{4} = \frac{10}{4} = 0.25\ ms^{-2}$

Gravitational constant = G = $6.67 \times 10^{-11}\ Nm^2kg^{-2}$

Mass of earth = M = 6×10^{24} kg

Required

Height of the satellite = h = ?

Solution

As we know that

$$g_h = \frac{GM_e}{(R+h)^2}$$

$$\frac{g}{4} = \frac{GM_e}{(R+h)^2}$$

Again we know that

$$M_e = \frac{gR^2}{G}$$

or $GM_e = gR^2$

Putting he value of GM_e in eq-------(1)

$$\frac{g}{4} = \frac{gR^2}{(R+h)^2}$$

or $\frac{1}{4} = \frac{R^2}{(R+h)^2}$

or $(R+h)^2 = 4R^2$

Taking square root on both sides

$$\sqrt{(R+h)^2} = \sqrt{4R^2}$$

$R + h = 2R$

$h = 2R - R$

$h = R$

Result

Required altitude is equal to one earth's radius.

5.9 A polar satellite in launched at 850 km above Earth. Find its orbital speed. (LHR 2014)

Given data:

Hight of satellite = h = 850 km

$= 850 \times 1000$

$= 8.5 \times 10^5 m$

Mass of earth = Me = 6×10^{24} kg

Gravitational constant = G = 6.673×10^{-11} $Nm^2\ kg^{-2}$

Required:

Orbital speed of satellite = V_o = ?

Solution:

We know that

$$V_o\sqrt{g_h(R+h)}$$

Putting the value of g_h

$$V_o = \sqrt{\frac{GM_e}{(R+h)^2}(R+h)}$$

$$V_o = \sqrt{\frac{GM_e}{R+h}}$$

$$= \sqrt{\frac{(6.673\times10^{-11})(6\times10^{24})}{6.4\times10^6 + 8.5\times10^5}}$$

$$= \sqrt{\frac{4.0038\times10^{14}}{7250000}}$$

$$V_o = \sqrt{55224827.59}$$

$$V_o = 7431\,ms^{-1}$$

Result:

Orbital speed of satellite = V_o = 7431 ms^{-1}

5.10 A communication satellite is launched at 42000 km above Earth. Find its orbital speed.

Given Data

Height of satellite = h = 42000 km = 42000 x 10^3 m = 4.2 x 10^7 m

Mass of earth = M = 6 x 10^{24} kg

Gravitational constant = G = 6.673 x 10^{-11} Nm^2kg^{-2}

Required

Orbital speed of satellite = V_o = ?

Solution

As we know that

$$v_o = \sqrt{g_h (R+h)}$$

Putting the value of g_h

$$V_o = \sqrt{\frac{GM_e}{(R+h)^2}(R+h)}$$

$$V_o = \sqrt{\frac{GM_e}{(R+h)}}$$

By putting the values, we have

$$v_o = \sqrt{\frac{(6.673 \times 10^{-11})(6 \times 10^{24})}{6.4 \times 10^6 + 4.2 \times 10^7}}$$

$$v_o = \sqrt{\frac{4.0038 \times 10^{14}}{48400000}}$$

$$v_o = \sqrt{8272314.05}$$

$$v_o = 2876 \text{ ms}^{-1}$$

Result

Orbital speed of satellite = v_o = 2876 ms^{-1}