

# Physics

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(Chapter 7) (Gravitation) (Exercises)  
(Class 11)

## Question 7.16:

Assuming the earth to be a sphere of uniform mass density, how much would a body weigh half way down to the centre of the earth if it weighed 250 N on the surface?

### Answer 7.16:

Weight of a body of mass  $m$  at the Earth's surface,  $W = mg = 250 \text{ N}$

Body of mass  $m$  is located at depth,  $d = \frac{1}{2} R_e$

Where,  $R_e$  = Radius of the Earth

Acceleration due to gravity at depth  $g$  ( $d$ ) is given by the relation:  $g' = \left(1 - \frac{d}{R_e}\right)g = \left(1 - \frac{R_e}{2 \times R_e}\right)g = \frac{1}{2}g$

Weight of the body at depth  $d$ ,

$$W' = mg' = m \times \frac{1}{2}g = \frac{1}{2}mg = \frac{1}{2}W = \frac{1}{2} \times 250 = 125 \text{ N}$$

## Question 7.17:

A rocket is fired vertically with a speed of  $5 \text{ km s}^{-1}$  from the earth's surface. How far from the earth does the rocket go before returning to the earth? Mass of the earth =  $6.0 \times 10^{24} \text{ kg}$ ; mean radius of the earth =  $6.4 \times 10^6 \text{ m}$ ;  $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$ .

### Answer 7.17:

Velocity of the rocket,  $v = 5 \text{ km/s} = 5 \times 10^3 \text{ m/s}$

Mass of the Earth,  $M_e = 6.0 \times 10^{24} \text{ kg}$  and radius of the Earth,  $R_e = 6.4 \times 10^6 \text{ m}$

Height reached by rocket mass,  $m = h$

At the surface of the Earth,

$$\text{Total energy of the rocket} = \text{Kinetic energy} + \text{Potential energy} = \frac{1}{2}mv^2 + \left(\frac{-GM_e m}{R_e}\right)$$

$$\text{At highest point } h, v = 0 \text{ and, Potential energy} = -\frac{GM_e m}{R_e + h}$$

$$\text{Total energy of the rocket} = 0 + \left(\frac{-GM_e m}{R_e + h}\right) = \frac{-GM_e m}{R_e + h}$$

From the law of conservation of energy, we have,

Total energy of the rocket at the Earth's surface = Total energy at height  $h$

$$\frac{1}{2}mv^2 + \left(\frac{-GM_e m}{R_e}\right) = \frac{-GM_e m}{R_e + h} \Rightarrow \frac{1}{2}v^2 = GM_e \left(\frac{1}{R_e} - \frac{1}{R_e + h}\right)$$
$$= GM_e \left(\frac{R_e + h - R_e}{R_e(R_e + h)}\right) \Rightarrow \frac{1}{2}v^2 = \frac{GM_e h}{R_e(R_e + h)} \times \frac{R_e}{R_e} \Rightarrow \frac{1}{2}v^2 = \frac{gR_e h}{R_e + h}$$

Where  $g = \frac{GM_e}{R_e^2} = 9.8 \text{ m/s}^2$  (Acceleration due to gravity on the Earth's surface)

$$\therefore v^2(R_e + h) = 2gR_e h \Rightarrow v^2 R_e = h(2gR_e - v^2)$$

$$h = \frac{R_e v^2}{2gR_e - v^2} = \frac{6.4 \times 10^6 \times (5 \times 10^3)^2}{2 \times 9.8 \times 6.4 \times 10^6 - (5 \times 10^3)^2} = \frac{6.4 \times 25 \times 10^{12}}{100.44 \times 10^6} = 1.6 \times 10^6 \text{ m}$$

Height achieved by the rocket with respect to the centre of the Earth

$$= R_e + h = 6.4 \times 10^6 + 1.6 \times 10^6 = 8.0 \times 10^6 \text{ m}$$

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**G Orfield**



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