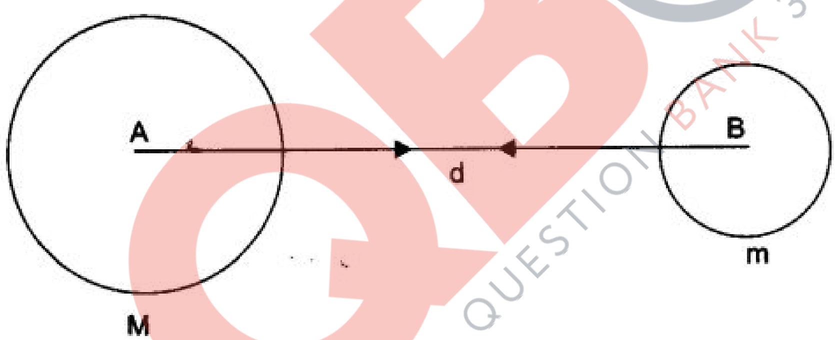
9th Standard Science

Gravitation

The universal law of gravitation: Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them.
The force is along the line joining the centres of two objects.



Gravitational force between two uniform objects is directed along the line joining their centres.

Let two objects A and B of masses M and m lie at a distance of d from each other as shown in the figure.

Let F be the force of attraction between the law of gravitation

$$F \propto \frac{Mm}{d^2}$$

$$F = G\frac{Mm}{d^2} \qquad \because \; G = \text{universal gravitational constant}$$

$$G = \frac{Fd^2}{Mm}$$

G is called a universal constant because its value does not depend on the nature of intervening medium or temperature or any other physical variable.

S.I. unit of G = Nm^2/kg^2

Value of G = 6.673 x 10-11 Nm^2/kg^2 (Found by Henry Cavendish)

Importance of universal law of gravitation

Universal law of gravitation successfully explained several phenomena like :

- the force that binds us to the earth.
- the motion of moon around the earth.
- the motion of planets around the sun.
- the tides due to the moon and the sun.

Freefall

When an object falls down towards the earth under the gravitational force alone, we say the object is in free fall.

The velocity of a freely falling body changes and is said to be accelerated.

This acceleration is called acceleration due to gravity, denoted by 'g'. Unit is m/s^2.

As $F = ma \quad (\because a = g) \quad ...(i)$

$F = mg \quad ...(ii)$

and $F = G\frac{Mm}{d^2}$ ($\because$ Universal law of gravitation) $...(iii)$

From (ii) and (iii)

$$\therefore \quad mg = G\frac{Mm}{d^2}$$

$$\therefore \quad g = \frac{GM}{d^2}$$

M = Mass of the earth

d = Distance between the object and the earth

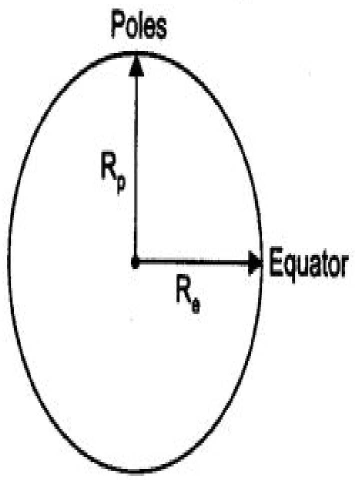
G = Gravitational constant

If the object is placed on the earth then $d = R$

(R = radius of the earth)

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

Earth is not a sphere it is flattened at poles.



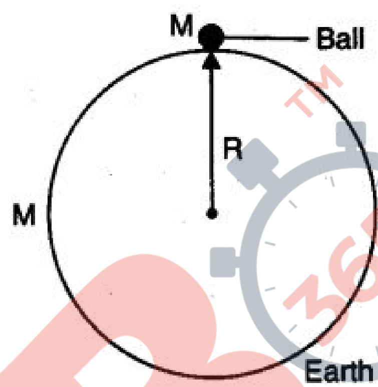
Hence R_p – Radius at pole and R_e – Radius at equator

$$R_e > R_p$$

$$g \propto \frac{1}{R}$$

∴ The value of 'g' is more at poles = (9.9 m/s^2)
and less at equator = (9.8 m/s^2)

Calculation of value of g



$$g = G\frac{M}{R^2}$$

$$G = 6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2$$

$$M = 6 \times 10^{24}\ \text{kg}\ \text{(Mass of the earth)}$$

$$R = 6.4 \times 10^6\ \text{m}$$

On substituting the given values

$$g = \frac{6.7 \times 10^{-11}\text{Nm}^2\ \text{kg}^{-2} \times 6 \times 10^{24}\text{kg}}{(6.4 \times 10^6\text{m})^2}$$

$$g = 9.8\ \text{m/s}^2.$$

The motion of objects under the influence of gravity 'g' does not depend on the mass of the body. All objects small, big, heavy, light, hollow or solid fall at the same rate.

The three equation of motion viz.

(i) $v = u + at$ (ii) $s = ut + \frac{1}{2}at^2$ (iii) $v^2 - u^2 = 2as$ are true for motion of objects under gravity. For free fall, value of acceleration $a = g = 9.8\ ms^{-2}$.

If an object is just let fall from a height then in that as u = 0 and a = g = 9.8 m/s^{-2}.

If an object is projected vertically upward with an initial velocity u, then a = – g = – 9.8 ms^{-2} and the object will go to a maximum height h where its final velocity becomes zero (i.e., v = 0).

Mass: Mass of an object is the measure of its inertia. It is the matter present in it. It remains the same everywhere in the universe.

Weight: The force of attraction of the earth on the object is known as the weight of the object. It's S.I. unit is Newton.W = m x g

$$W_m = \frac{GM_m \times m}{R_m^2}$$

W_m = weight of an object on moon

M_m = mass of the moon = 7.36×10^{22}

R_m = radius of the moon = 1.74×10^6

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

$$\therefore \quad W_m = G\frac{7.36 \times 10^{22} kg \times m}{(1.74 \times 10^6 m)^2}$$

$$W_m = 2.431 \times 10^{10}\ G \times m$$

and $W_e = 1.474 \times 10^{11}\ G \times m$

$$\therefore \quad \frac{W_m}{W_e} = \frac{\text{Weight of object on moon}}{\text{Weight of object on earth}} = \frac{2.431 \times 10^{10} Gm}{1.474 \times 10^{11} Gm} = \frac{1}{6}.$$

$\therefore$ Weight of an object on moon = $\frac{1}{6}$th the weight of an object on the earth.