# Gravitation

CHAPTER 9

NCERT FOCUS — ANSWERS

## Topic 1

**1.** According to universal law of gravitation, every particle in the universe attracts every other particle with a force which is directly proportional to the product of their masses and inversely proportional to the square of distance between them. The direction of force is along the line joining the two particles.

**2.** The formula for the magnitude of gravitational force between the Earth and an object on its surface is

$$F = G\frac{M_e m}{R_e^2}$$

where $F$ is the gravitational force,
$G$ is the gravitational constant,
$M_e$ is the mass of the Earth,
$m$ is the mass of the object on the surface of the Earth,
$R_e$ is the radius of the Earth.

**3.** Force of gravitation,

$$F \propto \frac{1}{R^2}$$

If $R$ is reduced to $\frac{R}{2}$

$$F' \propto \frac{1}{\left(\frac{R}{2}\right)^2} \quad i.e., F' = 4F.$$

**4.** Gravitational force acts on all objects in proportion to their masses. But a heavy object does not fall faster than a light object. This is because of the reason that

$$\text{Acceleration} = \frac{\text{Force}}{\text{Mass}}$$

or Force = Acceleration × Mass

As force is directly proportional to mass, acceleration is constant for a body of any mass.

**5.** The gravitational force between the Earth and 1 kg object on its surface is given by

$$F = \frac{GM_e M_{body}}{R_e^2}$$

$$= \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 1}{(6.4 \times 10^6)^2}$$

This gives, $F = 9.8$ N

**6.** The Earth attracts the Moon with a force equal to the force with which the Moon attracts the Earth. This is because as per Newton's third law of motion, forces of action and reaction are always equal and opposite.

**7.** Both the Earth and the Moon attract each other with the same force. But according to Newton's second law of motion, acceleration produced in a body by any force is inversely proportional to the mass of the body. Since, mass of the Earth is much more than that of the Moon, the acceleration produced in the Earth is negligible. As a result, it appears as the Earth does not move towards the Moon.

**8.** From the relationship,

$$F = \frac{Gm_1m_2}{R^2}$$

(i) If the mass of one object (say body 1) is doubled, then

$$F' = \frac{G \times (2m_1)m_2}{R^2} = \frac{2 \times Gm_1m_2}{R^2} = 2F$$

Thus, the gravitational force between the two objects gets doubled.

(ii) If the distance between the two objects is doubled, then

$$F'' = \frac{Gm_1m_2}{(2R^2)} = \frac{1}{4} \times \frac{Gm_1m_2}{R^2} = \frac{1}{4}F = \frac{F}{4}$$

Thus, the gravitational force between the two objects becomes one-fourth.

If the distance between the two objects is tripled, then

$$F''' = \frac{Gm_1m_2}{(3R)^2} = \frac{1}{9} \times \frac{Gm_1m_2}{R^2} = \frac{1}{9} \times F = \frac{F}{9}$$

Thus, the gravitational force between the two objects becomes one-ninth.

(iii) If the masses of both the objects are doubled, then

$$F''' = \frac{G \times (2m_1) \times (2m_2)}{R^2} = \frac{4Gm_1m_2}{R^2} = 4F$$

Thus, the gravitational force between the two objects becomes 4 times.

**9.** Universal law of gravitation is important as it accounts,

(a) for the existence of the solar system, *i.e.*, motion of planets around the Sun.

(b) for holding the atmosphere near the surface of the Earth.

(c) for the flow of water in rivers.

(d) for rainfall and snowfall.

(e) for occurrence of tides.

# Topic 2

**1.** All objects falling towards Earth under the action of gravitational force of Earth alone are said to be in free fall.

**2.** The acceleration with which an object fall freely towards the Earth is known as acceleration due to gravity. It is denoted by $g$ and its value is 9.8 m $s^{-2}$.

**3.**

| | Mass | Weight |
|---|---|---|
| (i) | Mass of a body is the measure of its inertia. | Weight of the body is the force with which it is attracted towards the Earth ($W = m \times g$). |
| (ii) | Its S.I. unit is kg. | Its S.I. unit is N |
| (iii) | It remains constant everywhere. | Its value changes from place to place. |
| (iv) | It is measured by common balance. | It is measured by spring balance. |

**4.** The weight of an object depends on the value of acceleration due to gravity $g$. The value of $g$ on Earth is 6 times more than that of Moon because, the mass and radius of the Earth is More than the mass and radius of the Moon.

We have, $g = \frac{GM}{R^2}$ and $W = mg$

Weight of a body of mass $m$ on Earth is

$$W_e = mg_e = m\frac{GM_e}{R_e^2}$$

Weight of a body of mass $m$ on Moon is

$$W_m = mg_m = \frac{mGM_m}{R_m^2} \quad \text{or} \quad \frac{W_m}{W_e} = \frac{M_m}{R_m^2} \times \frac{R_e^2}{M_e}.$$

As mass of Moon $M_m$ is $\frac{1}{100}$ times the mass of Earth $M_e$ and radius of Moon $R_m$ is $\frac{1}{4}$ times the radius of Earth $R_e$.

$$\therefore \frac{W_m}{W_e} = \frac{M_m}{M_e}\left(\frac{R_e}{R_m}\right)^2 = \frac{1}{100} \times (4)^2 \simeq \frac{1}{6}$$

**5.** All objects moving towards Earth on account of gravitational force of Earth on them are said to be in free fall. This force produces a uniform acceleration in the object. This is acceleration of free fall and its value is 9.8 m $s^{-2}$.

**6.** The gravitational force between the Earth and an object is called the force of gravity or simply Earth's gravity.

**7.** We know that the value of $g$ is greater at the poles than at the equator. So the weight of gold at the equator will be less than the weight of gold at the poles. So it is obvious that the friend at equator will not agree with the weight of gold bought at poles.

**8.** Here, $m = 10$ kg

Mass is the same on Earth and Moon.

Now, weight of the object on Earth,

$$W_e = mg_e = 10 \times 9.8 = 98 \text{ N}$$

Weight of the object on moon

$$W_m = mg_m = \frac{10 \times 9.8}{6} = 16.3 \text{ N}$$

**9.** Initial velocity, $u = 49$ m/s

Acceleration, $a = g = -9.8$ m/$s^2$

Velocity at the highest point, $v = 0$ m/s

**(a)** If $h$ is the maximum height reached by the ball, then

$$2gh = v^2 - u^2$$

or $$h = \frac{v^2 - u^2}{2g} = \frac{(0 \text{ m/s})^2 - (49 \text{ m/s})^2}{2 \times (-9.8 \text{ m/s}^2)} = 122.5 \text{ m}$$

Thus, the ball will reach at a height of 122.5 m.

**(b)** We have, $v = u + gt$

Here, $0 = 49 - 9.8t$

$$\therefore \quad t = \frac{49}{9.8} = 5 \text{ s}$$

Total time = $2t = 2 \times 5$ s = 10 s

**10.** Initial velocity, $u = 0$ m $s^{-1}$

Final velocity, $v$ = ?

Height of the tower, $h = 19.6$ m

Acceleration due to gravity, $g = 9.8$ m $s^{-2}$

Using the equation, $v^2 - u^2 = 2gs = 2gh$

$v^2 - 0 = 2 \times 9.8$ m $s^{-2} \times 19.6$ m

$v^2 = 19.6$ m $s^{-2} \times 19.6$ m

or $v = 19.6$ m $s^{-1}$

**11.** Here, $u = 40$ m/s, $g = -10$ m/$s^2$, $h$ = ?, $v = 0$

From $v^2 - u^2 = 2gh$,

$$0 - (40)^2 = 2(-10)h$$

or $$h = \frac{40 \times 40}{20} = 80 \text{ m}$$

As final position of the stone coincides with its initial position,

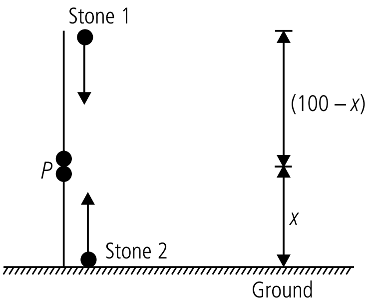
Net displacement = 0

Total distance covered by the stone

$= h + h = 80$ m + 80 m = 160 m

**12.** Here, $h = 100$ m.

Let the two stones meet after $t$ seconds at a point $P$ which is at a height $x$ above the ground as shown in figure.




For stone 1,

$u = 0, h = (100 - x)\ m,$

$a = g = 9.8\ m/s^2$

From $s = ut + \frac{1}{2}at^2$ or $h = ut + \frac{1}{2}gt^2$

$$(100 - x) = 0 + \frac{1}{2} \times 9.8t^2 = 4.9t^2 \quad ...(i)$$

For stone 2,

$u = 25$ m/s, $h = x, a = -g = -9.8\ m/s^2$

From $s = ut + \frac{1}{2}at^2$ or $h = ut + \frac{1}{2}gt^2$

$$x = 25t + \frac{1}{2}(-9.8)t^2 = 25t - 4.9t^2 \quad ...(ii)$$

Adding equations (i) and (ii)

$$100 - x + x = 25t \Rightarrow t = \frac{100}{25} = 4\ s$$

From equation (i),

$100 - x = 4.9 \times (4)^2 = 78.4$

$x = 100 - 78.4 = 21.6$ m

**13.** Here, time of ascent = time of descent,

$$t = \frac{6}{2} = 3\ s$$

**(a)** $v = 0, a = -g = -9.8\ m/s^2$

From $v = u + gt$,

$0 = u - 9.8 \times 3 \Rightarrow u = 29.4$ m/s

**(b)** From $v^2 - u^2 = 2gh$,

$0 - (29.4)^2 = 2(-9.8)h$

$$\Rightarrow h = \frac{29.4 \times 29.4}{2 \times 9.8} = 44.1\ m$$

**(c)** $t = 3$ s, ball is at maximum height.

From, $h = ut + \frac{1}{2}gt^2$,

$$h = 0 + \frac{1}{2} \times 9.8(1)^2 = 4.9 \text{ m below the top.}$$

# Topic 3

**1.** We know that pressure = force/area. When the strap of the school bag is thin, its area is small and as such the pressure exerted on the shoulders or the hands supporting the bag is large. In this case, the force acting on the shoulders or the hand which support the bag is equal to the weight of the bag. In case, the strap is broad, the area on which the force (weight of the bag) acts is large and the pressure is reduced as the weight of the bag is now distributed over a larger area.

**2.** Whenever an object is immersed in a liquid, either partially or fully, an upward force is exerted on the object by the liquid. This upward force is called upthrust or buoyant force or force of buoyancy and the property of the fluid due to which this upthrust is exerted on the object is called buoyancy.

**3.** When the object has density less than 1 g $cm^{-3}$ (density of water), then it floats on the surface of water, because, it always displaces more weight of water than its own weight. As buoyant force is more than its own weight, therefore, it floats.

When the object has density more than 1 g $cm^{-3}$, then it sinks in water, because it always displaces less weight of water than its own weight. As buoyant force is less than its own weight, therefore, it sinks.

**4.** A weighing machine is a sort of spring balance which measure the weight and not the mass of a body. When we stand on the weighing machine, our weight which is due to gravitational attraction of the earth acts vertically downwards. But the buoyancy due to air on our body acts vertically upwards. As a result of this, our apparent weight is true weight – buoyant force which is less than the true weight. Since the weighing machine measures the apparent weight, our true weight is more, *i.e.*, more than 42 kg.

**5.** We know that true weight = apparent weight + upthrust. The cotton bag is heavier than the iron bar. This is due to the reason, that the bag of cotton which has more volume (as it has less density) than the iron bar (which has more density), experiences more upthrust due to air.

**6.** A sheet of paper will fall slower than the one that is crumpled into a ball. This is because the air offers resistance due to friction to the motion of the falling objects. The resistance offered by air to the sheet of paper is more than the resistance offered by air to the paper ball because the sheet has larger area.

**7.** If an object is immersed in a liquid then the buoyant force due to liquid acts on the object in vertically upward direction.

**8.** The buoyant force acting on the block of plastic is more than its weight. As a result of this, it comes up when released under water. The cause of this larger buoyant force on the block of plastic is due to its density being lesser than that of water.

**9.** Density of water, $d_w = 1\text{ g cm}^{-3}$

Mass of substance, $m = 50$ g

Volume of substance, $V = 20\text{ cm}^3$

$\therefore$ Density of substance

$$d = \frac{m}{V} = \frac{50\text{ g}}{20\text{ cm}^3} = 2.5\text{ g cm}^{-3}$$

As the density of the substance is greater than that of water, the given substance will sink in water.

**10.** Here, mass of packet, $M = 500$ g

volume of the packet, $V = 350\text{ cm}^3$

Clearly, density of packet,

$$d = \frac{M}{V} = \frac{500}{350} = 1.428\text{ g cm}^{-3}$$

Since the density of packet is more than density of water, the packet will sink.

As the packet is fully submerged in water,

mass of water displaced by the packet = volume of the packet × density of water

$$= 350\text{ cm}^3 \times 1\text{ g cm}^{-3} = 350\text{ g}$$