Gravitation

Case Study Based Questions

Case Study 1

Universal law of gravitation states that every object in the universe attracts every other object with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. The direction of force is along the line joining the centres of the two bodies. The law is universal in the sense that it is applicable to all bodies, whether the bodies are big or small, whether they are celestial or terrestrial.

Read the given passage carefully and give the answer of the following questions:

Q1. The universal law of gravitation was postulated by:

a. Copernicus

b. Newton

c. Galileo

d. Archimedes

Q2. Which of the following is true for the universal law of gravitation?

(i) It acts on all the objects irrespective of their nature, shape and size

(ii) $F \propto M \times m$

(iii) It acts along the line joining the centres of the two objects.

(iv) $F \propto 1/d^2$

a. (i) and (iii)

b. (ii) and (iv)

c. (i), (ii) and (iv)

d. All of these

Q3. The mass of a body is increased 4 fold and mass of other body is increased 16 fold. How should the distance between them be changed to keep the same gravitational force between them?

a. 4 times

b. 1/4 times

c. 8 times

d. 1/8 times

Q4. Which of the following is not true for universal law of gravitation?

a. It is the gravitational force between the Sun and the Earth, which makes the Earth moves around the Sun.

b. The tides formed in sea are because of gravitational pull exerted by the Sun and the Moon on the surface of water.

c. It is the gravitational pull of the Earth which keeps us and other bodies firmly on the ground.

d. The gravitational force exerted by Sun on Earth is larger than that exerted by Earth on Sun.

Q5. The force of gravitation between two bodies of mass 1 kg each kept at a distance of 1 m is:

a. 6.67 N

b. 6.67 x 10^{-9} N

c. 6.67 x 10^{-7} N

d. 6.67 x 10^{-11} N

Solutions

1. (b) Newton

2. (d) All of these

We know that,

$$F \propto \frac{M \times m}{d^2};$$

$$i.e., F \propto M \times m \text{ and } F \propto \frac{1}{d^2}$$

It acts along the line joining the centres of those objects and it is said to be universal because it is applicable to all objects.

3. (c) 8 times

$$F = \frac{Gm_1 m_2}{d^2} = \frac{G(4m_1)(16m_2)}{d'^2}$$

$\therefore$ $d'^2 = 64d^2$ or $d' = 8d$

4. (d) The gravitational force exerted by Sun on Earth is larger than that exerted by Earth on Sun.

5. (d) 6.62 × 10−11 N

Force, $F = Gm_1 m_2/r^2$;

Given, $m_1 = m_2 = 1kg$, $r = 1m$

F = G = 6.67 × 10-11 N

Case Study 2

The uniform acceleration produced in a freely falling body due to the gravitational force of the Earth is known as acceleration due to gravity and it is denoted by the letter g. The value of acceleration due to gravity of the Earth, $g = 9.8\ ms^{-2}$. The value of acceleration due to gravity, g, is not constant at all the places on the surface of the Earth.

Read the given passage carefully and give the answer of the following questions:

Q1. Acceleration due to gravity of a body during free fall does not depend upon the:

a. mass of Earth

b. mass of falling body

c. universal gravitational constant

d. radius of Earth

Q2. When a body is thrown up, the force of gravity is:

a. in the upward direction

b. in the downward direction

c. zero

d. in the horizontal direction

Q3. A particle is taken to a height R above the Earth's surface, where, R is the radius of the Earth. The acceleration due to gravity there is:

a. $2.45\ m/s^2$

b. $4.9\ m/s^2$

c. $9.8\ m/s^2$

d. $19.6\ m/s^2$

Q4. A particle is dropped from a tower 180 m high. How long does it take to reach the ground? (Take g = 10 m/s².)

a. 6 s

b. 4.25 s

c. 18 s

d. 9 s

Q5. A ball is thrown up with a speed of 15 m/s. How high will it go before it begins to fall? (Take g = 9.8 m/s²)

a. 19.6 m

b. 14.3 m

c. 20 m

d. 11.4 m

Solutions

1. (b) mass of falling body

We know that,

g = G = M/R^2, where G = universal gravitation constant, M = mass of the Earth and R = radius of the Earth.

So, g does not depend on the mass of the falling body.

2. (b) in the downward direction

The acceleration due to gravity is always directed downwards towards the centre of the Earth for a freely falling body.

3. (a) 2.45 m/s^2

It is known that $g = \frac{GM}{R^2} = 9.8 \text{ m/s}^2$

When distance from centre of Earth = $2R$,

$$g' = \frac{GM}{(2R)^2} = \frac{1}{4}\left(\frac{GM}{R^2}\right)$$

$$= \frac{1}{4} \times 9.8 = 2.45 \text{ m/s}^2$$

4. (a) 6 s

Here, $u = 0, h = 180 \text{ m}, g = 10 \text{ m/s}^2, t = ?$

From, $h = ut + 0.5\, gt^2$

$$180 = 0 + 0.5\,(10)t^2$$

$$t^2 = 36$$

or, $t = 6 \text{ s}$

5. (d) 11.4 m

Here, $u = 15$ m/s, $v = 0$ (The ball stops),

$g = -9.8$ m/s^2, $h = ?$

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

$$(0)^2 = (15)^2 + 2 \times (-9.8) \times h$$

$$19.6\, h = 225$$

or $h = 11.4$ m

Case Study 3

Pallavi Mam was demonstrating an experiment in his class with the setup as shown in the figure below. She took an eraser, sharpener, steel spoon, plastic ruler, pencil, compass and rubber band and asked the students to place them on the surface of the water. Students observed that a few objects float on the surface of water while a few sink in water.

Read the given passage carefully and give the answer of the following questions:

Q1. An object floats in a liquid if the buoyant force is:

a. zero

b. greater than its weight

c. less than its weight

d. equal to its weight

Q2. An object sinks in a liquid if the buoyant force is:

a. zero

b. greater than its weight

c. less than its weight

d. equal to its weight

Q3. The buoyant force on an object immersed in a liquid acts:

a. in the vertically upward direction

b. in the vertically downward direction

c. at an angle of 90° to the direction in which weight of the object acts

d. at an angle of 45° to the direction in which weight of the object acts

Q4. The magnitude of buoyant force depends on the:

a. density of liquid

b. volume of liquid

c. weight of the object

d. viscosity of liquid

Q5. Magnitude of buoyant force is given by:

a. Newton's first law

b. Archimedes' principle

c. Newton's second law

d. None of these

Solutions

1. (b) greater than its weight

2. (c) less than its weight

3. (a) in the vertically upward direction

The buoyant force on an object immersed in a liquid always acts vertically upwards, that is, in a direction opposite to the weight of the object.

4. (a) density of liquid

5. (b) Archimedes' principle

Archimedes' principle states that 'when a body is immersed fully or partially in a fluid, it experiences an upward force (buoyant force) that is equal to the weight of the fluid displaced by it.'

Case Study 4

What do aching feet, a falling apple and the orbit of the Moon have in common? Each is caused by the gravitational force. An apple falls from a tree because of the same force acting a few metres above Earth's surface. And the Moon orbits Earth because gravity is able to supply the necessary centripetal force at a distance of hundreds of millions of metres. Sir Isaac Newton was the first scientist to precisely define the gravitational force, and to show that is could explain both falling bodies and astronomical motions.

The gravitational force is always attractive and it depends only on the masses involved and the distance between them (Newton's universal law of gravitation).

Read the given passage carefully and give the answer of the following questions:

Q1. What is gravitational force?

Q2. Briefly explain why Newton pondered over the existence of gravitation?

Q3. Define the universal gravitational constant.

Q4. State the value of G. Who obtained it for the first time?

Q5. 'Several phenomena of celestial bodies were believed to be unconnected but universal law of gravitation was successful to explain them. Mention any two phenomena.

Solutions

1. All objects (with mass) in the universe attract each other. This force of attraction between objects is called the gravitational force.

2. It is said an apple fell on Newton's head when he was sitting under a tree. He thought if Earth attracts an apple, can it also attract the Moon? Is the force same in both cases? This led to the study on gravitation.

3. The universal gravitational constant is numerically equal to the force of attraction between two unit masses when they are separated by a unit distance as measured from their centres.

4. The accepted value of G is 6.673×10^{-11} N-m^2 kg^{-2}.

The value of G was found out by Henry Cavendish by using a sensitive balance.

5. Two phenomena explained by universal law of gravitation are:

(i) the force that binds us to the Earth, and

(ii) the motion of the Moon around the Earth.

Case Study 5

The weight of a body is the force with which it is attracted towards the centre of the Earth. In other words, the force of Earth's gravity acting on a body is known as its weight. Weight is a vector quantity having magnitude as well as direction. The weight of a body is given by W = m × g (where m = mass of the body and g = acceleration due to gravity), and since the value of g changes from place to place, therefore, the weight of a body also changes from place to place.

Read the given passage carefully and give the answer of the following questions:

Q1. Define weight.

Q2. Is value of 'g' same at all places on the Earth? Give reason for your answer.

Q3. What is the mass of an object whose weight is 49 N on the Earth?

Q4. If a planet existed whose mass was twice that of Earth and whose radius 3 times greater, how much will a 1 kg mass weigh on the planet?

Q5. In spaceship moving in space, why does a person experience weightlessness?

Solutions

1. The weight of a body is the force with which it is attracted towards the centre of the Earth.

2. The value of acceleration due to gravity, g, is not constant at all the places on the surface of the Earth. This is due to the flattening of the Earth at the poles, all the places on its surface are not at the same distance from its centre and so the value of g varies with latitude.

3. Here,

W = 49 N, m = ?

As, $W = mg, m = \frac{W}{g} = \frac{49}{9.8} = 5 \text{ kg}$

4. Here, $M_p = 2\ M_e$ and $R_p = 3\ R_e$

m = 1kg, W_p = ?

As, $g_e = \frac{GM_e}{R_e^2}$ and $g_p = \frac{GM_p}{R_p^2}$

$$\therefore \quad \frac{g_p}{g_e} = \frac{M_p}{R_p^2} \times \frac{R_e^2}{M_e} = \frac{M_p}{M_e} \times \left(\frac{R_e}{R_p}\right)^2$$

$$\therefore \quad g_p = g_e \times \frac{M_p}{M_e} \times \left(\frac{R_e}{R_p}\right)^2$$

$$\text{or} \quad g_p = 9.8 \times 2 \times \left(\frac{1}{3}\right)^2 = 2.17 \text{ m/s}^2$$

$$W_p = mg_p = 1 \times 2.17 = 2.17 \text{ N}$$

5. A person experiences weightlessness as in spaceship moving in space, the acceleration due to gravity is zero.

∴ W = mg

In space, g = 0

∴ W = 0

Case Study 6

Pressure is defined as the physical force exerted on an object. The force applied is perpendicular to the surface of objects per unit area. The basic formula for calculating pressure is: Pressure = Force/Area.

The SI unit of measuring force is Newton (N), and the SI unit of measuring area is 'square metre' (m^2), therefore, the SI unit of measuring pressure is 'Newton per square metre' (N/m^2 or $N\text{-}m^{-2}$) which is also called Pascal (Pa).

Read the given passage carefully and give the answer of the following questions:

Q1. State and define the SI unit of pressure.

Q2. In which situation we exert more pressure on ground, when we stand on one foot or on the both feet? Justify your answer.

Q3. Which will exert more pressure: a 100 kg mass on the area of 10 m^2 or a 50 kg mass on 4 m^2?

Q4. When we stand on loose sand, our feet go deep into the sand. But when we lie down on the sand our body does not go that deep into the sand. But when we lie down on the sand our body does not go that deep in the sand. Why?

Q5. Why are railway tracks laid on large size concrete sleepers?

Solutions

1. SI unit of pressure is N/m^2 or Pascal (Pa).

When a force of 1 N acts normally on an area of 1 m^2 then pressure acting on the surface is called 1 Pascal.

2. The surface area of one foot is less than two feet. Therefore, we exert more pressure on the ground when we stand on one foot as pressure is inversely proportional to area of contact.

3. $$P_1 = \frac{\text{Force}}{\text{Area}} = \frac{m \times g}{(\text{Area})_1} = \frac{100 \times 10}{10} = 100 \text{ Pa}$$

$$P_2 = \frac{\text{Force}}{\text{Area}} = \frac{M \times g}{(\text{Area})_2} = \frac{50 \times 10}{4} = 125 \text{ Pa}$$

$\therefore$ 50 kg mass on 4 m^2 exerts more pressure.

4. When we stand, we apply more pressure than when we are lying due to less area of contact as

$$\text{Pressure} \propto \frac{1}{\text{Area}}.$$

5. Concrete sleepers are laid on railway tracks so that the weight of passing train is spread over a large area of ground. This reduces the pressure acting on the ground and the track may not sink into the ground.