GRAVITATION

Question (1): Define force of gravitation.

Answer: The force of attraction which exists between any two objects in the universe is known as force of gravitation.

Question (2): State Newton's law of gravitation.

Answer: According to this law, "Every particle in this 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 the distance between them".

Question (3): Why is G called a universal constant?

Answer: G is known as universal constant, because its value remains the same throughout the universe.

Question (4): List out the physical quantities on which the gravitational force between objects depends.

Answer: The gravitational force between two objects depends on
a) the mass and
b) the distance between them

Question (5): What do you mean by a freely falling object?

Answer: An object which moves towards the earth due to force of gravity is described as a freely falling object.

Question (6): What is acceleration due to gravity?

Answer: The acceleration produced in a body due to force of gravity is known as acceleration due to gravity.

Question (7): Two bodies of mass 10 kg and 12 kg are falling freely. What is the acceleration produced in the bodies due to force of gravity?

Answer: The acceleration due to gravity produced in both the bodies is the same as it is independent of the mass of the body.
Acceleration produced in both the bodies 10 kg and 12 kg is 9.8 m/s^2.

Question (8): What will happen to the force of gravitation between two objects A and B if the distance between them is reduced to half?

Answer: Let d be the distance between the two objects A and B of mass m_1 and m_2 respectively,

$$\text{Force between A and B, } F = \frac{Gm_1m_2}{d^2} \quad \ldots(1)$$

The force between A and B when distance between them is reduced to half

$$F_1 = \frac{Gm_1m_2}{\left(\frac{d}{2}\right)^2}$$

$$F_1 = \frac{Gm_1m_2 \times 4}{d^2}$$

$$= 4\left(\frac{Gm_1m_2}{d^2}\right)$$

But we know that $\left(\frac{Gm_1m_2}{d^2}\right) = F$ from equation (1)

$F_1 = 4F$

i.e., the force increases.

The force of gravitation between any two objects increases by a factor 4 if the distance between the objects is reduced to half.

Question (9): What would you observe if there are two massive bodies A and B of equal masses which experience only force of gravitation?

Answer: The objects A and B would be moving around each other.

Question (10): List out the factors on which the acceleration due to gravity of a planet depends on.

Answer:
- Mass of the planet
- Radius of the planet

Question (11): Consider two objects A and B of masses m_1 and m_2 respectively separated by a distance d. If the mass of the object A is doubled, then calculate the force of gravitation between them.

Answer: According to Newton's law of gravitation $F = \frac{Gm_1m_2}{d^2}$

The force of attraction between A and B when the mass of A is doubled

$$F_1 = \frac{G\,2m_1m_2}{d^2}$$

$$F_1 = 2\left(\frac{G\,m_1m_2}{d^2}\right)$$

$F_1 = 2F$

The force of gravitation is doubled when the mass of one objects is doubled.

Question (12): State Newton's law of gravitation and using this law, show that if the earth exerts equal force on the two bodies on its surface, then their masses are equal.

Answer: Newton's law of gravitation states that every particle in this universe attracts every other particle with a force which is directly proportional to the product of their masses and the inversely proportional to the square of the distance between them, the direction of the force being along the line joining the masses.

Let A and B be the two objects of mass m_A and m_B respectively. Then according to Newton's law of gravitation, the forces exerted by the earth on mass A is given by

$$F_A = \frac{GM_em_A}{R_e^2} \qquad ...(1)$$

Where M_e is the mass of the earth, R_e is the radius of the earth.

Force exerted by earth on mass B is

$$F_B = \frac{GM_em_B}{R_e^2} \qquad ...(2)$$

Given $F_A = F_B$

Equating equation (1) and equation (2)

$$\frac{GM_e m_A}{R_e^2} = \frac{GM_e m_B}{R_e^2}$$

$$\frac{GM_e m_A}{R_e^2} = \frac{GM_e m_B}{R_e^2}$$

$$m_A = m_B$$

i.e., the masses are equal.

Question (13): Derive an expression for acceleration due to gravity.

Answer: Consider an object of mass m lying on or near the surface of the Earth. Let M_e be the mass of the Earth and R_e be its radius i.e., R_e is the distance between the object and the centre of the Earth.
According to Newton's law of gravitation, the force of attraction (F) between the Earth and the object is

$$F = \frac{GM_e m}{R_e^2} \quad ...(1)$$

A Body of Mass m Lying on the Surface of the Earth
According to Newton's second law of motion this force produces an acceleration (g) in the object.
F = ma (a = g)
F = mg

$$g = \frac{F}{m} \quad ...(2)$$

Substituting the value of F in equation (2) we get,

$$g = \frac{GM_e m}{R_e^2 \times m}$$

$$g = \frac{GM_e}{R_e^2} \quad ...(3)$$

Equation (3) is the expression for acceleration due to gravity.

Question (14): Show that acceleration due to gravity is independent of the mass of the object.
Answer: Consider an object of mass m lying on or near the surface of the Earth. Let M_e be the mass of the Earth and R_e be its radius i.e., R_e is the distance between the object and the centre of the Earth.
According to Newton's law of gravitation, the force of attraction (F) between the Earth and the object is

$$F = \frac{GM_e m}{R_e^2} \quad ...(1)$$

A Body of Mass m Lying on the Surface of the Earth

According to Newton's second law of motion this force produces an acceleration (g) in the object.

F = ma (a = g)

F = mg

$$g = \frac{F}{m} \quad ...(2)$$

Substituting the value of F in equation (2) we get,

$$g = \frac{GM_e m}{R_e^2 \times m}$$

$$g = \frac{GM_e}{R_e^2} \quad ...(3)$$

The expression for acceleration due to gravity does not contain the physical quantity - mass of the object. Hence, we can conclude that the acceleration due to gravity is independent of the mass of the object.

Question (15): The value of acceleration due to gravity on earth varies from place to place. Justify this statement.

Answer:
The expression for acceleration due to gravity is $g_e = \frac{GM_e}{R_e^2}$

That means acceleration due to gravity is inversely proportional to the distance between the centre of the earth and the object. The radius of the earth decreases as we move from the equator to the poles as the earth is not a perfect sphere and hence the acceleration due to gravity will also vary.
If the object is at a height above the ground - for example, on top of a mountain, the value of acceleration due to gravity decreases. Acceleration due to gravity at the centre of the earth is zero. Thus, the above statement is justified.

Question (16): It is said that acceleration due to gravity on the surface of the earth is same for all objects irrespective of their mass, but why does a piece of paper take more time to reach the ground than a coin when dropped simultaneously from the same height?
Answer: The piece of paper takes a longer time to reach the surface of the earth because it has a larger surface as compared to the coin. Hence, it has to overcome more resistance due to air.

Question (17): Define acceleration due to gravity and list out the equations of motion for a freely falling object.
Answer: Acceleration due to gravity is the acceleration produced in an object due to force of gravity.
Equation of motion are:

$$v = u + gt$$

$$h = ut + \frac{1}{2}gt^2$$
$$v^2 - u^2 = 2gh$$

Question (18): Suppose the earth began to shrink without any change in its mass, will there be any change in the value of acceleration due to gravity.

Answer: Yes, the acceleration due to gravity will definitely change because the radius will change and acceleration due to gravity is inversely proportional to the radius of the earth, $g_e = \frac{GM_e}{R_e^2}$ .When earth shrinks its radius decreases thus increasing the value of acceleration due to gravity.

Question (19): Show that universal gravitational constant is nothing but force of gravitation between two unit masses separated by unit distance.

Answer: The mathematical representation of Newton's law of gravitation is

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

Given, $m_1 = m_2 = 1Kg$

d = 1 kg

$$\therefore \quad F = \frac{G \times 1 \times 1}{1^2}$$

or F = G i.e., gravitational constant is equal to the force of gravitation.

Question (20): A boy drops a stone from a cliff, which reaches the ground in 16 seconds. Calculate the height of the cliff.

Answer: Initial velocity (u)=0

Time (t) = 16 s

Acceleration due to gravity g= 9.8 m/s^2.

To find: Height of the cliff

h = ?

We make use of the II equation of motion

$$h = ut + \frac{1}{2}gt^2$$
$$= 0 + \frac{1}{2} \times 9.8 \times 256$$
$$= \frac{1}{2} \times 9.8 \times 256$$

Height of the cliff = 1254.4 m.

Question (21): A stone when dropped from a bridge takes 40 seconds to hit the surface of water. Calculate,

a) the height of the bridge

b) the velocity of the stone.

Answer: Initial velocity (u)=0

Time (t) = 4 s

Acceleration due to gravity (g) = 9.8 m/s^2

Height of the bridge h = ?

Using the II equation of motion, we calculate the height of the bridge

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

$$h = 0 \times 4 + \frac{1}{2} \times 9.8 \times 4^2$$

$$h = 0 + \frac{1}{2} \times 9.8 \times 4^2$$

$$h = 4.9 \times 16$$

h = 78.4 m

To calculate the velocity we use the I equation of motion

$$v = u + gt$$

$$v = 0 + 9.8 \times 4$$

Velocity of the stone = 39.2 m/s

Question (22): A stone projected vertically upward, takes 5 seconds to reach the highest point. Calculate the maximum height attained by the stone.

Answer: Time taken (t) = 5 s

Final velocity (v) = 0

(when an object attains the maximum height its final velocity is zero)

Acceleration due to gravity g= -9.8 m/s^2 (∵ the stone is moving against gravity)

First we have to calculate the initial velocity (u) of the stone.

Using I equation of motion, we get

$$v = u + gt$$

$$0 = u - 9.8 \times 5$$

$$0 = u - 49.0$$

u = 49 m/s

The maximum height is calculated using the II equation of motion.

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

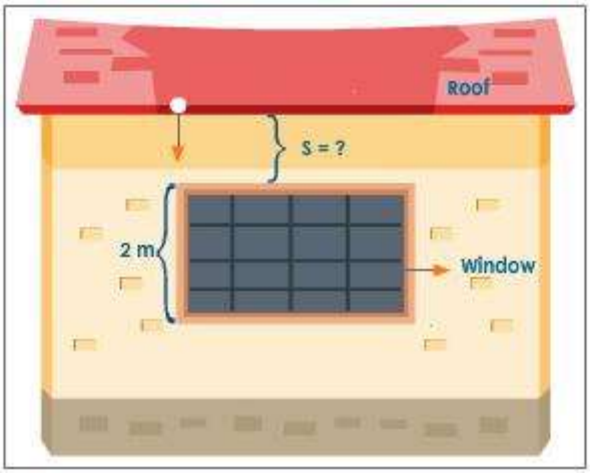
$$h = 49 \times 5 + \frac{1}{2} \times -9.8 \times (5)^2$$

h = 245 + (-4.9)25

$$= 245 - 122.5$$

= 122.5 m

Question (23): A stone dropped from the edge of a roof, passes a window 2 metres high in 0.1 seconds. How far is the roof above the top of the window?



Answer:

Height of the window (h) = 2m

Acceleration due to gravity g = 9.8 m/s^2

Time taken (t) = 0.1 s

The velocity of the stone when it reaches the top of the window is to be calculated.

Applying the II equation of motion,

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

$$2 = u \times 0.1 + \frac{1}{2} \times 9.8 \times (0.1)^2$$

$$2 = 0.1u + 4.9 \times 0.01$$

$$2 = 0.1u + 0.049$$

$$0.1u = 2 - 0.049$$

$$0.1u = 1.951$$

$$u = \frac{1.951}{0.1}$$

$$= 19.51\, m/s$$

Thus, the velocity 19.51 m/s will be the final velocity of the stone when it is covering the distance between the roof and the window.

Initially the stone is at rest i.e., u = 0

$$v = 19.51\, m/s$$

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

Applying the III equation of motion we get

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

$$(19.51)^2 - 0 = 2 \times 9.8 \times h$$

$$(19.51)^2 = 19.6h$$

$$h = \frac{(19.51)^2}{19.6}$$

Distance between the roof and the window =19.42 m.

Question (24): A ball thrown vertically upwards rises to a height of 25 m. If the acceleration due to gravity g = -9.8 m/s^2

Calculate

a) the initial velocity of the ball

b) the time taken to attain the maximum height.

Answer: As the ball is moving against gravity, acceleration due to gravity is negative.

Initial velocity (u)=?

Final velocity is zero whenever the object attains the maximum height

i.e, v = 0

Maximum height (h) = 25 m

Time (t) = ?

Acceleration due to gravity g = 9.8 m/s^2

Using the III equation of motion we can calculate the initial velocity of the ball.

$$v^2 - u^2 = 2gh$$
$$0 - u^2 = 2 \times -9.8 \times 25$$
$$-u^2 = -9.8 \times 50$$
$$-u^2 = -98 \times 5$$
$$u^2 = 98 \times 5$$
$$u^2 = 490$$
$$u = \sqrt{490}$$

Initial velocity = 22.14 m/s

To calculate the time taken, we make use of the I equation of motion

$$v = u + gt$$
$$0 = 22.14 - 9.8 \times t$$
$$9.8t = 22.14$$
$$t = \frac{22.14}{9.8} = \frac{22.14 \times 100}{9.8 \times 100}$$
$$= \frac{2214}{980}$$

Time taken to gain maximum height = 2.259 s.

Question (25): A boy on a cliff 49 m high drops a stone. One second later, he throws a second stone after the first. They both hit the ground at the same time. With what speed did he throw the second stone?

Answer: Case I

For the first stone

Initial velocity (u) = 0

Height of cliff (h) = 49 m

Acceleration due to gravity (g)= 9.8 m/s^2

Time (t) = ?

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

$$49 = 0 + \frac{1}{2} \times 9.8t^2$$

$$49 = 4.9\,t^2$$

$$t^2 = \frac{49}{4.9} = \frac{490}{49} = 10$$
$$t = \sqrt{10}$$

= 3.16 s

Case II

For the second stone

The second was thrown one second later, therefore the time taken by the second stone to travel 49 m is 3.16 - 1 = 2.16 s.

Velocity of the second stone (u) = ?

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

$49 = u \times 2.16 + \frac{1}{2} \times 9.8 \times (2.16)^2$

$49 = 2.16u + 4.9(2.16)^2$

$49 = 2.16u + 22.86$

$2.16u = 49 - 22.86$

$2.16u = 26.14$

$u = \frac{26.14}{2.16}$

Velocity of the second stone =12.10 m/s

i.e, the second stone is thrown with an initial velocity of 12.10 m/s.

Question (26): How long will a ball dropped from a height of 20 m take to reach the surface of the earth?

Answer: Given $(g) = 10\ m/s^2$

Height = distance (S)= 20 m

$(g) = 10\ m/s^2$

Let the time required to reach the surface of the earth be equal to t.

The initial velocity u is zero as the body is dropped from a height of 20 m.

We make use of II equation of motion

$S = ut + \frac{1}{2}gt^2$

$20 = 0 \times t + \frac{1}{2} \times 10 \times t^2$

$20 = 0 + 5t^2$

$5t^2 = 20$

$t^2 = \frac{20}{5} = 4$

$t = \sqrt{4} = 2s$

Time taken by the ball to reach the ground = 2 s.

Question (27): Give any two difference between mass and weight. Show that the weight of an object of mass 'm' on moon is 1/6 the weight of the object on earth.

Answer:

Mass	Weight
It is the amount of matter contained in an object	It is the force with which an object is pulled towards the Earth
The mass of a body is constant throughout the universe	Weight varies from place to place as **g** varies

Weight of an object of mass m on earth = $W_e = mg_e$

But $g_e = \frac{GM_e}{R_e^2}$ where G is the gravitational constant.

M_e is the mass of the earth and R_e is the radius of the earth.

$\therefore \quad W_e = \frac{mGM_e}{R_e^2} \quad ....(1)$

Weight of the same object on moon = $W_m = mg_m$

But $g_m = \frac{GM_m}{R_m^2}$

Where M_m is the mass on the moon R_m is the radius of the moon.

$$\therefore \quad W_m = \frac{mGM_m}{R_m^2} \quad ....(2)$$

Divide equation (1) by equation (2)

$$\frac{W_e}{W_m} = \frac{mGM_e}{R_e^2} \times \frac{R_m^2}{mGM_m}$$

$$\frac{W_e}{W_m} = \frac{M_e R_m^2}{R_e^2 M_m}$$

$$\frac{W_e}{W_m} = \left(\frac{M_e}{M_m}\right)\left(\frac{R_m}{R_e}\right)^2 \quad ....(3)$$

But we know that

$R_e = 4 R_m$

$$\frac{R_m}{R_e} = \frac{1}{4}$$

$$M_e = 100 M_m$$

$$\frac{M_e}{M_m} = 100$$

Substituting the values of $\frac{M_e}{M_m}$ and $\frac{R_m}{R_e}$ in equation

We get,

$$\frac{W_e}{W_m} = 100 \times \left(\frac{1}{4}\right)^2$$

$$\frac{W_e}{W_m} = \frac{100}{16}$$

$$\frac{W_e}{W_m} = \frac{25}{4} \text{ or}$$

$$\frac{W_e}{W_m} = 6.25 \text{ or } W_e \cong 6W_m$$

$$W_m = \frac{1}{6} W_e$$

Question (28): What is the force exerted by the earth on a freely falling object of 10 kg? What is the reaction force exerted by the object on the earth? Does this reaction force produce an acceleration in earth? If so calculate the acceleration.

Answer: Given mass of the earth $= 6 \times 10^{24}$ kg

Force exerted by the earth on the object = mg (according to Newton's II law of motion)

Mass of the object = 10 kg

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

F = mg

$F = 10 \times 9.8$

F = 98 N

According to Newton's III law of motion the object will also exert an equal force on the earth but in opposite direction

∴ Force exerted by the object on the earth = 98 N

The reaction force produces acceleration on earth.

F = Ma Where M is the mass of the earth

$$a = \frac{F}{M} = \frac{98}{6 \times 10^{24}} \text{ (mass of earth kg)}$$

a = 16.33×10^{-24} m/s^2

Acceleration produced in earth $a = 16.33 \times 10^{-24}$ m/s^2

Question (29): List out the equation of motion for a body moving against gravity.

Answer: The equation of motion are:

$$v = u - gt$$

$$h = ut - \frac{1}{2}gt^2$$

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

Question (30): Two spheres of masses 10 kg and 20 kg are 0.3 m apart. Calculate the force attraction between them.

According to Newton's law of gravitation $F = \frac{Gm_1m_2}{d^2}$

Answer:

m_1 = 10 kg

m_2 = 20 kg

d = 0.3 m

Gravitational constant $G = 6.6734 \times 10^{-11}$ N m^2/kg^2

$$F = \frac{6.6734 \times 10^{-11} \times 10 \times 20}{(0.3)^2} = \frac{6.6734 \times 2 \times 10^{-9}}{0.09}$$

$$= \frac{6.6734 \times 2 \times 10^{-9} \times 100}{0.09 \times 100} = \frac{6.6734 \times 2 \times 10^{-7}}{9}$$

$$F = \frac{13.3468 \times 10^{-7}}{9}$$

Force of attraction = 1.4829×10^{-7} N

Question (31): A spaceship is 10^{12} Km from a certain star. The force of attraction between the spaceship and star is 50 N. Calculate the distance between them, if the force between them is increased to 5×10^7 N.

Answer: Let mass of the star and the spaceship be M and m respectively.

Case I

Distance between the star and space ship =10^{12} Km

Force of attraction between the star and spaceship = 50 N

According to Newtons law of gravitation $F = \frac{Gm_1m_2}{d^2}$

$$F = \frac{GMm}{(10^{12})^2}$$

$$50 = \frac{GMm}{(10^{12})^2}$$

$50 = \frac{GMm}{10^{24}}$ ...(1)

Case II

Let d be the distance between the spaceship and the star when the force is increased to 5 x 10^7 N.

$F = \frac{GMm}{d^2}$

$5 \times 10^7 = \frac{GMm}{d^2}$ ... (2)

Dividing equation (1) by equation (2)

$\frac{50}{5 \times 10^7} = \frac{GMm}{10^{24}} \times \frac{d^2}{GMm}$

$\frac{5}{5 \times 10^6} = \frac{d^2}{10^{24}}$

$10^{-6} = \frac{d^2}{10^{24}}$

$d^2 = 10^{24} \times 10^{-6}$

$d^2 = 10^{18}$

$d = 10^9$ km

∴ The distance between the space ship and the star is 10^9 km.

Question (32): Hydrogen atom consists of an electron of mass 9 x 10^{-31} kg and a proton of mass 1.9 x 10^{-27} kg separated by an average distance of 6x10^{-11}m. What is the gravitational force between them?

Answer: Mass of electron $M_e = 9 \times 10^{-31}$ kg

Mass of proton $M_p = 1.9 \times 10^{-27}$ kg

Distance between the electron and proton $d = 6 \times 10^{-11}$ kg

$G = 6.6734 \times 10^{-11}$ N m^2/kg^2

Force of gravitation $= \frac{GM_eM_p}{d^2}$

$= \frac{6.6734 \times 10^{-11} \times 9 \times 10^{-31} \times 1.9 \times 10^{-27}}{(6 \times 10^{-11})^2}$

$= \frac{6.6734 \times 9 \times 1.9 \times 10^{-11} \times 10^{-31} \times 10^{-27}}{36 \times 10^{-22}}$

$= \frac{6.6734 \times 9 \times 1.9 \times 10^{-69} \times 10^{22}}{36}$

$= \frac{6.6734 \times 1.9 \times 10^{-47}}{4}$

Force of gravity between a proton and electron in a hydrogen atom
= 3.16 x 10^{-47} N.

Question (33): A man has a mass of 70 kg on earth.
a) What is his weight?
b) Calculate his mass and weight on the moon.
Answer: Mass of man on earth = 70 kg
a) Weight of man on earth $W_e = mg_e$
Acceleration due to gravity (g_e)= 9.8 m/s^2
W_e = 70 x 9.8
= 686 N
b) Mass of the man on moon = 70 kg (because mass remains constant throughout the universe)

Weight of the man on moon $W_m = mg_m$

$$g_m = \frac{1}{6} g_e$$

$$g_m = \frac{1}{6} \times 9.8$$

$$W_m = 70 \times \frac{1}{6} \times 9.8$$

$$= \frac{7 \times 98}{6}$$

$$= \frac{686}{6}$$

$$= 114.33 \text{ N}$$

Question (34): What is the gain in speed of a freely falling object? List out the equations of motion for an object moving against gravity.
Answer: The gain in speed per second for a freely falling object is 9.8 m/s
The equations of motion are

$$v = u - gt$$

$$h = ut - \frac{1}{2} gt^2$$

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

Where, v - final velocity
u - initial velocity
h - height from the ground
(a = -g as the object is moving against gravity)

Question (35): If the distance between two bodies m_1 and m_2 is doubled then by what factor should the mass of one of the bodies be altered so that the gravitational force between them remains the same.
Answer: The gravitational force between the bodies of masses m_1 and m_2 is given by the equation

$$F = \frac{Gm_1m_2}{d^2} \quad \cdots(1)$$

The gravitational force F^1 between m_1 and m_2 when the distance is doubled is given by the equation

$$F^1 = \frac{Gm_1m_2}{(2d)^2}$$

$$F^1 = \frac{Gm_1m_2}{4d^2} \quad \cdots(2)$$

Given $F = F^1$. Since $F = F^1$ the product of the masses changes. Let this be represented by $(m_1m_2)^1$.

Then equation (2) becomes

$$F^1 = \frac{G(m_1m_2)^1}{4d^2}$$

But $F = F^1$

$$\frac{Gm_1m_2}{d^2} = \frac{G(m_1m_2)^1}{4d^2}$$

$$m_1m_2 = \frac{(m_1m_2)^1}{4}$$

$$4(m_1m_2) = (m_1m_2)^1$$

i.e., mass of one of the bodies should be increased by a factor of 4 or mass of both the bodies should be doubled.

Question (36): A rock is dropped from the top of a building of 70 m height.
a) How long does it take to reach the ground?
b) What is the speed of the rock as it strikes the ground?
Answer: Height of the building (h) = 70 m
Initial velocity (u) = 0
Acceleration due to gravity (g_e) = 9.8 m/s^2
Applying II equation of motion

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

$$70 = 0 \times t + \frac{1}{2} \times 9.8 \times t^2$$

$$70 = 0 + 4.9t^2$$

$$4.9t^2 = 70$$

$$t^2 = \frac{70}{4.9} = \frac{700}{49} = \frac{100}{7}$$

$t^2 = 14.28$
t = 3.78 s
Applying the I equation of motion
v = u + gt we can calculate the initial velocity
v = 9.8 x 3.78
v = 37.044
Velocity of the rock = 37.044 m/s.

Question (37): A bullet fired upwards reaches a height of 5000 m.
a) What was its initial speed?
b) How long will it take to reach the height of 2500 m?
Answer: Maximum height attained (h) = 5000 m
Acceleration due to gravity (g) = -9.8 m/s^2
($\because$ the bullet is moving against gravity)
Final velocity (v) = 0
a) Applying III equation of motion we can calculate the initial speed

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

$$0 - u^2 = -2 \times 9.8 \times 5000$$

$-u^2 = -2 \times 9.8 \times 5000$

$u^2 = 2 \times 98 \times 500$

$u^2 = 98 \times 1000$

$u^2 = 98000$

$u = \sqrt{98000}$

u = 313.05 m/s

b) We calculate the time taken by using the I equation of motion

$v = u - gt$

0 = 313.05 - 9.8 t

9.8 t = 313.05

$t = \frac{313.05}{9.8}$

Time taken by the bullet to attain maximum height = 31.94 s

Question (38): What is the mass of a person whose weight on the surface of the earth is 775 N? Given (g_e) = 10 m/s^2 .

Answer: Weight of the person on earth = 775 N

$W_e = mg_e$

$775 = mg_e$

$775 = m \times 10$

$m = \frac{775}{10} = 77.5 \text{ kg}$

Mass of person = 77.5 kg.

Question (39): If you weigh 60 kg.wt on earth, how far must you go from the centre of the earth so that you weigh 30 kg.wt? Given radius of the earth=6400 km.

Answer: Weight on earth (W_e) = 60 kg.wt

= 60 x 9.8 N

Weight on space (W_{space}) = 30 kg.wt

= 30 x 9.8 N

$W_e = \frac{GM_e}{r_e^2}$ and $W_{space} = \frac{GM_e}{d^2}$

Where d is the distance from the earth to that point in space.

G and M_e are constants.

$W_e \alpha \frac{1}{R_e^2}$ ...(1)

$W_{space} \alpha \frac{1}{d^2}$ ...(2)

Dividing equation (1) by equation (2), we get

$$\frac{W_e}{W_{space}} = \frac{\frac{1}{R_e^2}}{\frac{1}{d^2}}$$

$\frac{W_e}{W_{space}} = d^2 / R_e^2$ ...(3)

Givem R_e = 6400 km, W_e = 60 x 9.8 N, W_{space} = 30 x 9.8 N

Substituting these values in equation (3)

$$\frac{60 \times 9.8}{30 \times 9.8} = \frac{d^2}{(6400)^2}$$

$$\frac{60}{30} = \frac{d^2}{(6400)^2}$$

$$2 = \frac{d^2}{(6400)^2}$$

$$d^2 = 2 \times (6400)^2$$

$$d^2 = 2 \times (6400)^2$$

$$d = \sqrt{2 \times (6400)^2}$$

$$d = \sqrt{2} \times 6400$$

$$d = 1.414 \times 6400$$

d = 9049.6 km

You must be at a distance of 9049.6 km from the centre of the earth.

Question (40): Planet X has a mass thrice that of the earth and radius four times that of the earth. Calculate
a) the weight of 80 kg mass on that planet
b) the weight of the same object on moon

Answer:

$$W_x = \frac{mGM_x}{R_x^2} \quad ...(1)$$

Where W_x is the weight of the object of mass m on planet X.
G is the gravitational constant, M_x and R_x are the mass and radius of the planet X respectively.
Weight of the same object on earth is given by the relation

$$W_e = \frac{mGM_e}{R_e^2} \quad ...(2)$$

M_e and R_e is the mass and radius of the earth respectively
Dividing equation (1) by equation (2)

$$\frac{W_x}{W_e} = \frac{mGM_x}{R_x{}^2} \times \frac{R_e{}^2}{mGm_e}$$

$$\frac{W_x}{W_e} = \frac{M_x R_e{}^2}{R_x{}^2 M_e}$$

$$\frac{W_x}{W_e} = \frac{M_x}{M_e}\left(\frac{Re}{R_x}\right)^2 \quad ...(3)$$

Given $M_x = 3\ M_e$

$$\frac{M_x}{M_e} = 3$$

$$R_x = 4R_e$$

$$\frac{R_e}{R_x} = \frac{1}{4}$$

Substuting the value of $\left(\frac{M_x}{M_e}\right)$ and $\left(\frac{R_e}{R_x}\right)$ in eq(3)

$$\frac{W_x}{W_e} = 3 \times \left(\frac{1}{4}\right)^2$$

$$\frac{W_x}{W_e} = 3 \times \frac{1}{16}$$

$$W_x = \frac{3}{16} \times W_e$$

$$= \frac{3}{16} mg_e$$

$$= \frac{3}{16} \times 80 \times 9.8$$

$$= 3 \times 5 \times 9.8$$

$$= 15 \times 9.8$$

Weight of the object on the planet X = 147 N

Weight of the object on earth $W_e = mg_e$

$$= 80 \times 9.8$$

$$= 8 \times 98$$

= 784 N

Question (41): A stone thrown vertically upward rises to a height of 30 m on the surface of the moon. Calculate

a) The initial velocity of the stone

b) The time taken to gain the maximum height.Given $g_m = 1.63\ m/s^2$.

Answer: Maximum height (h) = 30 m

Initial velocity (v) = 0 (at the maximum height, the velocity is Zero)

Acceleration due to gravity $g_m = -1.63\ m/s^2$

Using the III equation of motion, we can calculate the initial velocity

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

$$0 - u^2 = -2 \times 1.63 \times 30$$

$$-u^2 = -2 \times 16.3 \times 3$$

$$-u^2 = -2 \times 48.9$$

$$u^2 = 97.8$$

$$u = \sqrt{97.8}$$

Initial velocity = 9.89 m/s

(t) = ?

Applying v = u - gt

$$0 = 9.89 - 1.63 \times t$$

$$9.89 - 1.63t = 0$$

$$1.63t = 9.89$$

$$t = \frac{9.89}{1.63}$$

Time taken to gain maximum height = 6.067 s

Question (42): Give any three difference between mass and weight.

Answer:

Mass	Weight
It is the amount of matter contained in an object	It is the force with which an object is pulled towards the Earth
The mass of a body is constant throughout the universe	Weight varies from place to place as **g** varies
Mass can never be equal to zero	Weight can be equal to zero
Mass is a scalar quantity	Weight is a vector quantity
SI unit of mass is kg	SI unit of weight is newton

Question (43): Calculate the acceleration due to gravity on the surface of the planet X if its mass and radius are half that of the earth.

Answer: The acceleration due to gravity on earth is given by the equation

$$g_e = \frac{GM_e}{R_e^2} \qquad ...(1)$$

Where M_e is the mass of the earth and R_e is the radius of the earth.

Let R_x and M_x be the radius and mass of the planet X respectively.

$$g_x = \frac{GM_x}{R_x^2}$$

$$\text{Given } M_x = \frac{M_e}{2} \text{ and } R_x = \frac{R_e}{2}$$

$$g_x = \frac{G(\frac{M_e}{2})}{(\frac{R_e}{2})^2} = \frac{GM_e \times 4}{2 \times R_e^2} = \frac{4GM_e}{2R_e^2}$$

$$g_x = \frac{2GM_e}{R_e^2} \qquad ...(2)$$

Divide equation (1) by equation (2)

$$\frac{g_e}{g_x} = \frac{GM_e}{R_e^2} \times \frac{2R_e^2}{2GM_e}$$

$$\frac{g_e}{g_x} = \frac{1}{2}$$

$$g_x = 2g_e \qquad (\text{But } g_e = 9.8 m/s^2)$$

$$g_x = 2 \times 9.8$$

$$g_x = 19.6 m/s^2$$

The acceleration due to gravity on the surface of the planet X is 19.6 m/s^2.

Question (44): Calculate the gravitational acceleration produced in a spaceship which is at a distance equal to twice the radius of the earth.

Answer: The acceleration due to gravity on earth is given by

$$g_e = \frac{GM_e}{R_e^2} \qquad ...(1)$$

The acceleration due to gravity at a distance twice the radius of the earth is given by

$$g^1 = \frac{GM_e}{(2R_e)^2} \quad ...(2)$$

$$g^1 = \frac{GM_e}{4R_e^2}$$

Divide equation (1) by equation (2)

$$\frac{g_e}{g^1} = \frac{GM_e}{R_e^2} \times \frac{4R_e^2}{GM_e}$$

$$\frac{g_e}{g^1} = 4 \qquad (\text{but } g_e = 9.8\, m/s^2)$$

$$\frac{9.8}{g^1} = 4$$

$$\therefore \qquad g^1 = \frac{9.8}{4} = 2.45\, m/s^2$$

The gravitational acceleration produced in the spaceship is 2.45 m/s^2.

Question (45): Establish a relation between g and G where the symbols have their usual meaning.
Answer: Consider an object of mass m lying on or near the surface of the Earth. Let M_e be the mass of the Earth and R_e be its radius i.e., R_e is the distance between the object and the centre of the Earth.
According to Newton's law of gravitation, the force of attraction (F) between the Earth and the object is

$$F = \frac{GM_e m}{R_e^2} \quad ...(1)$$

A Body of Mass m Lying on the Surface of the Earth
According to Newton's second law of motion this force produces an acceleration (g) in the object.
F = ma (a = g)
F = mg

$$g = \frac{F}{m} \quad ...(2)$$

Substituting the value of F in equation (2) we get,

$$g = \frac{GM_e m}{R_e^2 \times m}$$

$$g = \frac{GM_e}{R_e^2} \quad ...(3)$$

Question (46): Give any three differences between Acceleration due to Gravity (g) and Gravitational Constant (G).

Answer:

Acceleration due to Gravity	Gravitational Constant
It is the acceleration produced in a body due to force of gravity	It is defined as the force of attraction between two unit masses separated by unit distance.
The value of 'g' varies from place to place	'G' is a universal constant i.e., its value remains the same throughout the universe.
It is a vector quantity	It is a scalar quantity

Question (47): Show that $g_m = \frac{1}{6} g_e$ where the symbols have their usual meaning.

Answer: The expression for acceleration due to gravity is

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

where G is the universal gravitation constant, M is the celestial body which produces acceleration in a body and R is the radius of the celestial body.

The equation for g shows that the value of acceleration due to gravity depends on the mass and radius of the celestial body and hence will be different for different celestial bodies.

Let us now derive a relation between the acceleration due to gravity on moon (g_m) and acceleration due to gravity on Earth (g_e).

$$g_e = \frac{GM_e}{R_e^2} \qquad ...(1)$$

Where M_e and R_e are the mass and radius of the Earth respectively.

$$g_m = \frac{GM_m}{R_m^2} \qquad ...(2)$$

Where M_m and R_m are the mass and radius of the moon respectively.

Divide equation (1) by equation (2)

$$\frac{g_e}{g_m} = \frac{GM_e}{R_e^2} \times \frac{R_m^2}{GM_m}$$

$$\frac{g_e}{g_m} = \left(\frac{M_e}{M_m}\right)\left(\frac{R_m}{R_e}\right)^2 \qquad ...(3)$$

We know that mass of the Earth is 100 times that of the moon and its radius is four times that of the moon. i.e.,

$M_e = 100\ M_m$

$$\left(\frac{M_e}{M_m}\right) = 100$$

$R_e = 4\ R_m$

$$\left(\frac{R_m}{R_e}\right) = \frac{1}{4}$$

Substituting the values of $\left(\frac{M_e}{M_m}\right)$ and $\left(\frac{R_m}{R_e}\right)$ in equation (3), we get

$$\frac{g_e}{g_m} = 100 \times \left(\frac{1}{4}\right)^2$$

$$\frac{g_e}{g_m} = \frac{100}{16} = \frac{25}{4} = 6.25 \qquad (6.25 \text{ is rounded off to } 6)$$

$$\frac{g_e}{g_m} = 6 \text{ or } g_m = \frac{1}{6} g_e$$

Which means that acceleration due to gravity on moon is $1/6^{th}$ that on the Earth.

Question (48): What is the mass of an object whose weight is 49 N?

Answer: $W = mg$

W = 49 N

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

$$m = \frac{W}{g} = \frac{49}{9.8} = \frac{490}{98} = 5 \text{ kg}$$

Mass = 5 kg

Question (49): What is the acceleration produced in a 10 kg and a 1 kg object when they are made to fall freely? Justify your answer.

Answer: The acceleration produced in both the bodies will be 9.8 m/s^2. This is because both the objects are acted upon by the forces of gravity and force of gravity acting on the 10 kg and 1 kg objects is the same. Acceleration due to gravity is independent of the mass of the object.

Question (50): A stone dropped from a building, takes 10 seconds to reach the ground. Calculate the velocity of the stone.

Answer: The initial velocity of the stone (u) = 0

Time taken (t) = 10 s

Acceleration produced in the stone (g) = 9.8 m/s^2.

v = ?

We make use of the first equation of motion

$v = u + gt$

v = 0 + 9.8 x 10

v = 98 m/s

Velocity of the stone = 98 m/s.

Question (51): At which place on the surface of the earth does an object experience the maximum acceleration due to gravity and why?

Answer: The object experiences the maximum acceleration due to gravity at the poles because the radius is minimum at the poles and we know that acceleration due to gravity is inversely proportional to the square of the radius.

Question (52): Define Pressure. Give the S.I. unit of pressure.

Answer: The force acting per unit area of the surface is known as friction. The S.I. unit of pressure is $N\ m^{-2}$.

Question (53): State Archimedes Principle.

Answer: According to Archimedes Principle, when a body is partially or wholly immersed in a fluid, it experiences an upthrust or buoyant force equal to the weight of the liquid displaced.

Question (54): List out the factors affecting buoyant force.

Answer: The buoyant force experienced by a body submerged in a liquid depends on the volume of the submerged body and the density of the liquid.

Question (55): Explain the meaning of the term buoyancy.
Answer: The tendency of a liquid to exert an upward force on an object placed in it there by making it float or rise is called buoyancy.

Question (56): Define density and state its SI unit.
Answer: The density of a substance is defined as the mass of the substance per unit volume. SI unit density is kg/m^3.

Question (57): Define the term relative density. What do you mean by the statement relative density of gold is 19.3?
Answer: The relative density of a substance is the ratio of the density of the substance to the density of water at 4^oC.
The statement relative density of gold is 19.3 means that gold is 19.3 times denser than an equal volume of water.

Question (58): Why does a mug full of water weigh less inside water?
Answer: The buoyant force exerted by the water is responsible for the apparent loss of weight.