Gravitation: Exercise Questions

Q.1 How does the force of gravitation between two objects change when the distance between them is reduced to half

Sol. According to the law of gravitation, the force between the two objects have the mass m_1 and m_2 and distance between them is R

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

Where, G is the gravitational constant.
According to question, if the distance (R) is reduced to half.

Then $F = \frac{Gm_1m_2}{(R/2)^2}$

Or F'= 4F

Thus, From the above result, as the distance between the objects is reduced to half the force of gravitation becomes four times of the original force.

Q.2 Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster than a light object?

Sol. As we know that weight of an object on surface of earth = mg
where 'm' is mass and 'g' is acceleration due to gravity.

Gravitational force acting on the object F = $F = \frac{GMm}{R^2}$

Where, M is mass of earth, R is radius of earth or distance between the objects and G is gravitational constant

Weight of object 'mg' = Gravitational force F

mg = $\frac{GMm}{R^2}$

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

From above expression, we can say that 'g' acceleration due to gravity is independent of mass of an object. So, all the objects fall from the height with constant acceleration (g). Hence, heavier objects don't fall faster than light object.

Q.3 What is magnitude of gravitational force between the earth and a 1 kg object on its surface? Take mass of earth to be 6×10^{24} kg and radius of the earth is 6.4×10^6 m. $G = 6.67 \times 10^{-11}$ $Nm^2\ kg^{-2}$.

Sol. Given: Gravitational Constant G = 6.67 × 10–11 N m2 kg^{-2}
Mass of the object m_1 = 1kg
Mass of the Earth m_2= 6 × 1024 kg
Radius of the earth R = 6.4 ×106 m

Then gravitational force $F = \frac{Gm_1m_2}{R^2}$

$$F = \frac{6.67x10^{-11}x1x6x10^{24}}{(6.4x10^6)^2}$$

$$F = \frac{6.67x6}{(6.4)^2}x10^{-11+24-12}$$

⇒ $F=0.977\times10^1=9.77N$
or F = 9.8 N Approximately

Q.4. The earth and the moon are attracted to each other by gravitational force. Does the earth attract the moon with a force that is greater or smaller or the same as the force with which the moon attracts the earth? Why?

Sol. As the Newton's universal law of gravitation states that the attraction force between the two objects is proportional to the product of their masses and inversely proportional to the square of the distance between them.

I.e. $F = \frac{Gm_1m_2}{R^2}$

Where M_1 = Mass of earth, M_2 = Mass of moon, R = Distance between earth and moon. G= Gravitational constant.

This law applies to all objects anywhere in the universe. This is also true in case of attraction force between Earth and moon. The magnitude of gravitation force (F) of attraction exerted by Earth on the moon is the same as that exerted by moon (F) on earth. These forces are equal and opposite because according to Newton's Third Law of Motion, every action there is an equal and opposite reaction.

Q.5 If the moon attracts the earth, why does the earth not move towards the moon?

Sol. As per the universal law of gravitation and Newton's third law, the force of attraction between two objects is the same and in the opposite directions. So, the earth attracts the moon with a force, the moon also attracts the earth with same force, but in opposite directions. Since earth has larger mass compared to the moon, it accelerates at lesser a rate than the acceleration rate of the moon towards the Earth. For this reason, the earth does not move towards the moon.

Q.6 What happens to the force between two objects, if

(i) The mass of one object is doubled?
(ii) The distance between the objects is doubled and tripled?
(iii) The masses of both objects are doubled?

Sol. According to the law of gravitation, the gravitation force:

i.e $F = \frac{Gm_1m_2}{R^2}$

Here G is the gravitational constant.

(i) When the mass of one object (m1) is doubled, then

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

∴ As the mass of one object is doubled the gravitational force becomes 2 times.

(ii) When the distance between the bodies is doubled and tripled,
When the distance is doubled.

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

The gravitation force is reduced to one fourth of the original force.

Now, when the distance is tripled:

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

The force is reduced to one ninth of the original force.

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

$$F' = \frac{G2m_1 2m_2}{R^2}$$

$$F' = \frac{4Gm_1m_2}{R^2} = 4F$$

∴ when the masses of both the objects are doubled, then the gravitation force becomes four times the original force.

Q.7 What is importance of universal laws of gravitation?

Sol. The Importance of Universal law of gravitation:

(i) It explains that how does the different objects present in the universe, affect others.
(ii) It explains that how gravity is responsible for the weight of a body and keeps us on the ground.
(iii) It explains that, how does the moon moves around the earth occur.
(iv) It explains, how does the planets moves around the sun
(v) The tidal waves originate, due to the gravitational pull of moon and the sun.

Q.8 What is the acceleration of free fall?

Sol. The acceleration of free fall is the acceleration experienced by an object which is drop from the certain height and it falls under the influence of gravitation force of earth. It is denoted by g and its value on the surface of earth is 9.8 m s^{-2}. This value is constant anywhere on earth.

Q.9 What do we call the gravitational force between an earth and an object?

Sol. The gravitational force between an earth and an object is weight and it is equal to product of mass (m) and acceleration due to gravity (g).

Weight =mass (m) x gravitation acceleration (g)

Q.10 Amit buys a few gram (force) of gold at the poles as per instruction of one of his friends. He hands over the same when he meets him at equator. Will the friend agree with the weight of gold bought? If not, why?

Sol. The force of gravity decreases with from poles to the equator. As we know that the weight is equal to the product of mass and acceleration due to gravity.

i.e. W = mg,
where 'm' is mass of the object 'g' is the acceleration due to gravity.

The value of g is higher at polar region than the equator. Due to change in gravitation acceleration (g), the weight of an object will also be more at polar region than at equator. Thus, his friend will not agree with weight of the gold bought at the poles.

Q.11 Why will a sheet of paper fall slower than one that is crumpled into a ball?

Sol. Surface area of crumpled paper is much smaller than the surface area of a plain or flat sheet. Therefore, both experience same force of gravity but the plain or flat sheet of paper will have to face more air resistance than the crumpled ball. Therefore sheet of paper will fall slower than the sheet crumpled into a ball.

Q.12 Gravitational force on the surface of the moon is only 1/6 as strong as gravitational force on the earth. What is the weight in newton of a 10 kg object on the moon and on the earth?

Sol given: gravitation force on the surface of moon = *(1/6)* gravitational force on the earth

$F_m = (1/6) F_E$

Mass of object=10kg

The mass of an object is always same in the universe.

Thus, the mass of the object on the moon and earth will be the same, i.e. m = 10 kg.

Acceleration due to gravity on earth (ge) = 9.81 ms^{-2}

So, weight of object on earth $F_E = mg_e = 10 \times 9.81 = 98.1$ N

Now weight of object on moon $F_m = (1/6) F_E = 1/6 \times (98.1) = 16.35$ N

Q.13 A ball is thrown vertically upwards with a velocity of 49 ms^{-1}. Calculate

(i) the maximum height to which it rises.

(ii) the total time it takes to return to the surface of the earth.

Sol. (i) Given: Initial velocity of the ball u = 49 ms^{-1}

Final velocity of the ball v = 0 ms^{-1}

Downward gravity (g) = 9.8 ms^{-2}

Upward gravity (g) = – 9.8 ms^{-2}

Max. Height attained by the ball s = ?

From the third equation of motion:

$v^2 - u^2 = 2gs$

=> $(0)^2 - (49)^2 = 2 \times (-9.8) \times s$

=> $s = -49 \times 49 - 2 \times 9.8$

$s = 122.5$ m

Max. Height attained by the ball is 122.5 m.

(ii) From the first Equation:

$v = u + gt$

=> $0 = 49 - 9.8 \times t$

=> $t = 49\ 9.8 = 5$ s

Time for upward journey of the ball will be the same as time for downward journey i.e.

So, total time taken by the ball to return to the surface of earth = $2 \times t = 2 \times 5 = 10$ s

Q.14 A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground.

Sol. Given: Initial velocity u = 0, g = – 9.8 ms^{-2}, height, s = –19.6 m

from the third equation of motion:

$u^2 - u^2 = 2\ gs$

so, $u^2 - 0^2 = 2 \times (-9.8) \times (-19.6)$

or $v^2 = (19.6)^2$

$\Rightarrow v = -19.6\ ms^{-1}$

Here, negative sign shows that the velocity is in the downward direction.

Q.15 A stone is thrown vertically upward with an initial velocity of 40 m/s. Taking g = 10 m/s², find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone?

Sol. Given: Initial velocity u = 40 ms^{-1} and g = – 10 ms^{-2}

at the maximum height reached S, final velocity, v = 0

So, from the third equation of motion: $v^2 - u^2 = 2gs$

$0^2 - 40^2 = 2 \times 10 \times s$

$\Rightarrow S = (40\times40)/20 = 80$m

Also, the total distance covered = $2 \times S = 2 \times 80 = 160$ m

since, the stone comes back to the initial position.

Therefore, Net = S – (S)

= 80 – 80 = 0

Thus, Distance = 160m and displacement = 0m.

Q.16 Calculate the force of gravitation between the earth and the sun, given that the mass of the earth = 6×10^{24} kg and of the sun = 2×10^{30} kg. The average distance between the two is 1.5×10^{11} m.

Sol. Given: Mass of earth $M_e = 6 \times 10^{24}$ kg,
Mass of Sun $M_s = 2 \times 10^{30}$
Distance between them $r = 1.5 \times 10^{11}$m

Then Gravitation force $F = \frac{GM_e M_s}{r^2}$

$$F = \frac{6.67x10^{-11}x6x10^{24}x2x10^{30}}{(1.5x10^{11})^2}$$

$$F = \frac{6.67x12x10^{21}}{1.5x1.5}$$

Therefore, $F = 3.56 \times 10^{22}$ N

Q.17 A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet?

Sol. Let the point at which, two stones meet be at a height x from the ground at the time t.
Given: Height of the tower = 100 m
Then distance covered by the stone allowed to fall from the top of the tower,

From the second equation of motion: $S = ut + \frac{1}{2}at^2$

$(100-x) = ut + ½ gt^2$
$(100-x) = 0 \times t + ½ gt^2$
$(100-x) = ½gt^2$ ... (1)
The distance covered by the stone thrown from the ground with velocity 25 m/s,
$x = ut - ½gt^2$
$X = 25t - ½gt^2$ ... (2)
Combining eq. (1) and (2), we get
100 = 25t
⇒ t = 4s
for calculating x, from the equation (2)
$x = 25 \times 4 - 12 \times 9.8 \times 4^2$
= 100 – 78.4
= 21.6 m

Q.18 A ball thrown up vertically returns to the thrower after 6s. Find:
(a) the velocity with which it was thrown up.
(b) the maximum height it reaches, and
(c) its position after 4s.

Sol. (a) The velocity with which ball was thrown up :
gravitation acceleration, $g = -9.8\ ms^{-2}$ (since velocity and acceleration in opposite direction)
Since, the total time taken to return the ball is 6 s.
the time for upward journey, t = 6/2 s = 3 s
Final velocity, $v = 0\ ms^{-1}$
Initial velocity, u = ?
From the first equation of motion:
u = u + gt
⇒ 0 = u + (9.8) × 3
⇒ 0 = 4 – 29.4
⇒ $u = 29.4\ ms^{-1}$
Thus, The velocity with which ball was thrown up = $29.4\ ms^{-1}$

(b) Max. Height the ball reaches s =?

From second equation of motion:

$s = ut + ½gt^2$

$s = 29.4 \times 3 + ½ (-9.8) \times 3^2$

$\Rightarrow$ s = 44.1m

(c) The position of the bell after 4 seconds

Time, t = 4 s

From the second equation of motion,

s = ut + ½ gt2

$s = 29.4 \times 4 + 12 \times (-9.8) (4)^2$

$\Rightarrow$ s = 117.6 m – 78.4 m

$\Rightarrow$ s = 39.2 m

Q.19 In what direction does the buoyant force on an object immersed in a liquid act?

Sol. The direction of Buoyant force on an object immersed in a liquid acts in vertically upward towards direction.

Q.20 Why a block of plastic does released under water come up to the surface of water?

Sol. In this situation, the density of plastic block is less than water, therefore, the upward force acting on the plastic block due to buoyancy, is much more than the downward force due to the weight of the block. Due to this force, the block will be forced up and plastic block come up to the surface of water.

Q.21 The volume of 50 g of substance is 20 cm^3. If the density of water is 1 g cm^{-3}, will the substance float or sink?

Sol. Given: The Mass of substance M= 50 g

the volume of substance V = 20 cm^3

density of water = 1 g cm^{-3}

Density of substance = Mass of substance / volume of substance

= 50 / 20 = 2.5 g cm^{-3}

since, the density of substance (2.5 g cm^{-3}) is more than water (1 g cm^{-3}), so it will sink.

Q.22 The volume of a 500 g sealed packed is 350 cm^3. Will the packet float or sink in water if the density of water is 1 g cm^{-3}? What will be the mass of water displaced by this packet?

Sol. Given:

Mass of sealed packed M = 500g

Volume of sealed packed V= 350 cm^3

Density of water = 1 g cm^{-3}

Density of sealed packet = M / V = 500 / 350

= 1.43 g cm^{-3}

Since, the density of packet which is 1.43 g cm^{-3} is more than that of water (1 g cm^{-3}), it will sink in water.
The volume of water displaced = the volume of packet V i.e., 350 cm^3.
Therefore, the Mass of the water displaced = Density × Volume

= 1 g cm^{-3} × 350 cm^3 = 350 g