GRAVITATION
Exercise-10.1 Page: 134

1. State the universal law of gravitation.

Solution:

The universal law of gravitation states that every object in the universe attracts every other object with a force called the gravitational force. The force acting between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.

2. Write the formula to find the magnitude of the gravitational force between the earth and an object on the surface of the earth.

Solution:

Consider F as the force of attraction between an object on the surface of earth and the earth

Also, consider 'm' as the mass of the object on the surface of earth and 'M' as the mass of earth

The distance between the earth's centre and object = Radius of the earth = R

Therefore, the formula for the magnitude of the gravitational force between the earth and an object on the surface is given as

$F = G\,Mm/R^2$

Exercise-10.2 Page: 136

1. What do you mean by free fall?

Solution:

Earth's gravity attracts each object to its center. When an object is dropped from a certain height, under the influence of gravitational force it begins to fall to the surface of Earth. Such an object movement is called free fall.

2. What do you mean by acceleration due to gravity?

Solution:

When an object falls freely from a certain height towards the earth's surface, its velocity keeps changing. This velocity change produces acceleration in the object known as acceleration due to gravity and denoted by 'g'.

The value of the acceleration due to gravity on Earth is,

$$g = \frac{9.8m}{s^2}$$

Exercise-10.3 Page: 138

1. What are the differences between the mass of an object and its weight?
Solution:

The differences between the mass of an object and its weight are tabulated below.

Mass	Weight
Mass is the quantity of matter contained in the body.	Weight is the force of gravity acting on the body.
It is the measure of inertia of the body.	It is the measure of gravity.
It only has magnitude.	It has magnitude as well as direction.
Mass is a constant quantity.	Weight is not a constant quantity. It is different at different places.
Its SI unit is kilogram (kg).	Its SI unit is the same as the SI unit of force, i.e., Newton (N).

2. Why is the weight of an object on the moon 1/6th its weight on the earth?
Solution:

The mass of the moon is 1/100 times and its radius 1/4 times that of earth. As a result, the gravitational attraction on the moon is about one-sixth when compared to earth. The moon's gravitation force is determined by the mass and the size of the moon. Hence, the weight of an object on the moon is 1/6th its weight on the earth. The moon is far less massive than the Earth and has a different radius(R) as well.

Exercise-10.4 Page: 141

1. Why is it difficult to hold a school bag having a strap made of a thin and strong string?
Solution:

It is tough to carry a school bag having a skinny strap because of the pressure that is being applied on the shoulders. The pressure is reciprocally

proportional to the expanse on which the force acts. So, the smaller the surface area, the larger is going to be the pressure on the surface. In the case of a skinny strap, the contact expanse is quite small. Hence, the pressure exerted on the shoulder is extremely huge.

2. What do you mean by buoyancy?

Solution:

The upward force possessed by a liquid on an object that's immersed in it is referred to as buoyancy.

3. Why does an object float or sink when placed on the surface of water?

Solution:

An object floats or sinks when placed on the surface of water because of two reasons.

(i) If its density is greater than that of water, an object sinks in water.

(ii) If its density is less than that of water, an object floats in water.

Exercise-10.5 Page: 142

1. You find your mass to be 42 kg on a weighing machine. Is your mass more or less than 42 kg?

Solution:

A weighing machine measures the body weight and is calibrated to indicate the mass. If we stand on a weighing machine, the weight acts downwards while the upthrust due to air acts upwards. So our apparent weight becomes less than the true weight. This apparent weight is measured by the weighing machine and therefore the mass indicated is less than the actual mass. So our actual mass will be more than 42 kg.

2. You have a bag of cotton and an iron bar, each indicating a mass of 100 kg when measured on a weighing machine. In reality, one is heavier than other. Can you say which one is heavier and why?

Solution:

The correct answer is the cotton bag is heavier than an iron bar. The bag of cotton is heavier than the bar of iron. The cotton bag experiences a larger air thrust than the iron bar. Therefore, the weighing machine indicates less weight than its actual weight for the cotton bag. The reason is

True weight = (apparent weight + up thrust)

The cotton bag's density is less than that of the iron bar, so the volume of the cotton bag is more compared to the iron bar. So the cotton bag experience more upthrust due to the presence of air.

Therefore, in the presence of air, the cotton bag's true weight is more compared to the true weight of the iron bar.

Exercises-10.6 Page: 143

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

Solution:

Consider the Universal law of gravitation,

According to that law, the force of attraction between two bodies is

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

Where,

m_1 and m_2 are the masses of the two bodies.

G is the gravitational constant.

r is the distance between the two bodies.

Given that the distance is reduced to half then,

r = 1/2 r

Therefore,

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

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

$$F = \frac{(4Gm_1m_2)}{(r)^2}$$

F = 4F

Therefore once the space between the objects is reduced to half, then the force of gravitation will increase by fourfold the first force.

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

Solution:

All objects fall from the top with a constant acceleration called acceleration due to gravity (g). This is constant on earth and therefore the value of 'g' doesn't depend on the mass of an object. Hence, heavier objects don't fall quicker than light-weight objects provided there's no air resistance.

3. What is the magnitude of the gravitational force between the earth and a 1 kg object on its surface? (Mass of the earth is 6 × 10²⁴ kg and radius of the earth is 6.4 × 10⁶m.)

Solution:

From Newton's law of gravitation, we know that the force of attraction between the bodies is given by

$$F = \frac{(Gm_1 m_2)}{r^2}$$

Here

m_1 = mass of Earth = 6.0×10^{24} kg

m_2 = mass of the body = 1kg

r = distance between the two bodies

Radius of Earth = 6.4×10^6 m

G = Universal gravitational constant = 6.67×10^{-11} Nm^2kg^{-2}

By substituting all the values in the equation

$$F = \frac{(Gm_1 m_2)}{r^2}$$

$$F = \frac{6.67 \times 10^{-11} \ (6.0 \times 10^{24} \times 1)}{(6.4 \times 10^6)^2}$$

F = 9.8 N

This shows that Earth exerts a force of 9.8 N on a body of mass 1 kg. The body

will exert an equal force of attraction of 9.8 N on the Earth.

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?

Solution:

The earth attracts the moon with a force same as the force with which the moon attracts the earth. However, these forces are in opposite directions. By universal law of gravitation, the force between moon and also the sun can be

$$F = \frac{(Gm_1 m_2)}{d^2}$$

Where,

d = distance between the earth and moon.

m_1 and m_2 = masses of earth and moon respectively.

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

Solution:

According to the universal law of gravitation and Newton's third law, we all know that the force of attraction between two objects is the same, however in the opposite directions. So the earth attracts the moon with a force same

as the moon attracts the earth but in opposite directions. Since earth is larger in mass compared to that of the moon, it accelerates at a rate lesser than the acceleration rate of the moon towards the Earth. Therefore, for this reason the earth does not move towards the moon.

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?
Solution:

(i)

According to universal law of gravitation, the force between 2 objects (m_1 and m_2) is proportional to their plenty and reciprocally proportional to the sq. of the distance(R) between them.

$$F = \frac{(G2m_1m_2)}{R^2}$$

If the mass is doubled for one object.
F = 2F, so the force is also doubled.

(ii)
If the distance between the objects is doubled and tripled
If it's doubled
Hence,
$F = (Gm_1m_2)/(2R)^2$
$F = 1/4 \, (Gm_1m_2)/R^2$
$F = F/4$
Force thus becomes one-fourth of its initial force.
Now, if it's tripled
Hence,
$F = (Gm_1m_2)/(3R)^2$
$F = 1/9 \, (Gm_1m_2)/R^2$
$F = F/9$
Force thus becomes one-ninth of its initial force.

(iii)
If masses of both the objects are doubled, then
$$F = \frac{(G2m_1 2m_2)}{R^2}$$

F = 4F, Force will therefore be four times greater than its actual value.

7. What is the importance of universal law of gravitation?

Solution:

The universal law of gravitation explains many phenomena that were believed to be unconnected:

(i) The motion of the moon round the earth

(ii) The responsibility of gravity on the weight of the body which keeps us on the ground

(iii) The tides because of the moon and therefore the Sun

(iv) The motion of planets round the Sun

8. What is the acceleration of free fall?

Solution:

Acceleration due to gravity is the acceleration gained by an object due to gravitational force. On Earth, all bodies experience a downward force of gravity which Earth's mass exerts on them. The Earth's gravity is measured by the acceleration of the freely falling objects. At Earth's surface, the acceleration of gravity is 9.8 ms^{-2} and it is denoted by 'g'. Thus, for every second an object is in free fall, its speed increases by about 9.8 metres per second.

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

Solution:

The gravitation force between the earth and an object is called weight. Weight is equal to the product of acceleration due to the gravity and mass of the object.

10. Amit buys few grams of gold at the poles as per the instruction of one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold bought? If not, why? [Hint: The value of g is greater at the poles than at the equator.]

Solution:

The weight of a body on the earth's surface;

W = mg (where m = mass of the body and g = acceleration due to gravity)

The value of g is larger at poles when compared to the equator. So gold can weigh less at the equator as compared to the poles.

Therefore, Amit's friend won't believe the load of the gold bought.

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

Solution:

A sheet of paper has a larger surface area when compared to a crumpled paper ball. A sheet of paper will face a lot of air resistance. Thus, a sheet of paper falls slower than the crumpled ball.

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's of a 10 kg object on the moon and on the earth?

Solution:

Given data:

Acceleration due to earth's gravity = g_e or g = 9.8 m/s^2

Object's mass, m = 10 kg

Acceleration due to moon gravity = g_m

Weight on the earth= W_e

Weight on the moon = W_m

Weight = mass x gravity

g_m = (1/6) g_e (given)

So W_m = m g_m = m x (1/6) g_e

W_m = 10 x (1/6) x 9.8 = 16.34 N

W_e = m x g_e = 10 x 9.8

W_e = 98N

13. A ball is thrown vertically upwards with a velocity of 49 m/s. Calculate

(i) The maximum height to which it rises,

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

Solution:

Given data:

Initial velocity u = 49 m/s

Final speed v at maximum height = 0

Acceleration due to earth gravity g = -9.8 m/s^2 (thus negative as ball is thrown up).

By third equation of motion,

2gH = v^2 – u^2

2 × (- 9.8) × H = 0 – (49)^2

– 19.6 H = – 2401

H = 122.5 m

Total time T = Time to ascend (T_a) + Time to descend (T_d)

v = u + gt

0 = 49 + (-9.8) x T_a

Ta = (49/9.8) = 5 s

Also, T_d = 5 s

Therefore T = T_a + T_d

T = 5 + 5

T = 10 s

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.

Solution:

Given data:

Initial velocity

u = 0

Tower height = total distance = 19.6m

g = 9.8 m/s²

Consider third equation of motion

v² = u² + 2gs

v² = 0 + 2 × 9.8 × 19.6

v² = 384.16

v = √(384.16)

v = 19.6m/s

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?

Solution:

Given data:

Initial velocity u = 40m/s

g = 10 m/s²

Max height final velocity = 0

Consider third equation of motion

v² = u² – 2gs [negative as the object goes up]

0 = (40)² – 2 x 10 x s

s = (40 x 40) / 20

Maximum height s = 80m

Total Distance = s + s = 80 + 80

Total Distance = 160m

Total displacement = 0 (The first point is the same as the last point)

16. Calculate the force of gravitation between the earth and the Sun, given that the mass of the earth = 6 × 10²⁴ kg and of the Sun = 2 × 10³⁰ kg. The average distance between the two is 1.5 × 10¹¹ m.

Solution:

Given data:

Mass of the sun $m_s = 2 \times 10^{30}$ kg
Mass of the earth $m_e = 6 \times 10^{24}$ kg
Gravitation constant G = 6.67 x 10^{-11} N m²/ kg²
Average distance r = 1.5×10^{11} m
Consider Universal law of Gravitation

$$F = \frac{(Gm_1 m_2)}{d^2}$$

$$F = \frac{(6.67 \times 10^{-11} \times 6 \times 10^{24} \times 2 \times 10^{30})}{(1.5 \times 10^{11})^2}$$

F = 3.56 x 10^{22} N

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.

Solution:

Given data:

(i) When the stone from the top of the tower is thrown,

Initial velocity u' = 0
Distance travelled = x
Time taken = t
Therefore,

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

x = 0 + (1/2) gt²
x = 5t² ---------(a)

(ii) When the stone is thrown upwards,
Initial velocity u = 25 m/s
Distance travelled = (100 – x)
Time taken = t

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

(100 – x) = 25t – (1/2) x 10 x t²
x = 100 -25t + 5t² ------- (b)

From equations (a) and (b)
5t² = 100 -25t + 5t²
t = (100/25) = 4sec.
After 4sec, two stones will meet
From (a)
x = 5t² = 5 x 4 x 4 = 80m.

Putting the value of x in (100-x)

= (100-80) = 20m.

This means that after 4sec, 2 stones meet a distance of 20 m from the ground.

18. A ball thrown up vertically returns to the thrower after 6 s. Find

(a) The velocity with which it was thrown up,

(b) The maximum height it reaches, and

(c) Its position after 4s.

Solution:

Given data:

$g = 10m/s^2$

Total time $T = 6sec$

$T_a = T_d = 3sec$

(a) Final velocity at maximum height $v = 0$

From first equation of motion:-

$v = u - gt_a$

$u = v + gt_a$

$= 0 + 10 \times 3$

$= 30m/s$

The velocity with which stone was thrown up is 30m/s.

(b) From second equation of motion

$s = ut_a - \frac{1}{2}g(t_a)^2$

$= 30 \times 3 - (1/2) \times 10 \times (3)^2$

$= 90\text{-}45 = 45m$

The maximum height stone reaches is 45m.

(c) In 3sec, it reaches the maximum height.

Distance travelled in another 1sec = s'

$s = ut_a - \frac{1}{2}g(t_a)^2$

$s = 0 + 10 \times 1 \times 1$

$s = 5m.$

The distance travelled in another 1sec = 5m.

Therefore in 4sec, the position of point p (45 – 5)

= 40m from the ground.

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

Solution:

The buoyant force on an object that is immersed in a liquid will be in a vertically upward direction.

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

Solution:

The density of plastic is lesser than that of water. Therefore, the force of buoyancy on plastic block will be greater than the weight of plastic block. Hence, the acceleration of plastic block is going to be in the upward direction. So, the plastic block comes up to the surface of water.

21. The volume of 50 g of a substance is 20 cm³. If the density of water is 1 g cm⁻³, will the substance float or sink?

Solution:

To find the Density of the substance the formula is

Density = (Mass/Volume)

Density = (50/20) = 2.5g/cm³

Density of water = 1g/cm³

Density of the substance is greater than density of water. So the substance will sink.

22. The volume of a 500 g sealed packet is 350 cm³. Will the packet float or sink in water if the density of water is 1 g cm⁻³? What will be the mass of the water displaced by this packet?

Solution:

Density of sealed packet = 500/350 = 1.42 g/cm³

Density of sealed packet is greater than density of water

Therefore the packet will sink.

Considering Archimedes Principle,

Displaced water volume = Force exerted on the sealed packet.

Volume of water displaced = 350cm³

Therefore displaced water mass = ρ x V

= 1 × 350

Mass of displaced water = 350g.

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