Gravitation

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

Solution:

The gravitational force of attraction between two objects is inversely proportional to the square of the distance between them. Mathematically, F ∝ 1/r2 where 'F' is the force and 'r' is the distance between them. If the distance between them is reduced to half, let 'F1' be the force. Hence, F1 ∝ 1/(r/2)2 => F1 ∝ 4/r2 = 4F. Thus, the force between them increases four times its initial value.

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

Solution:

The force on an object is equal to the product of its mass acceleration. The gravitational force on any object is equal to the weight of the object. The weight of an object is proportional to its mass, but it does not affect the acceleration of the object. The fastness or slowness of an object depends on its acceleration. As the gravitational force does not affect its acceleration, even though the gravitational force on objects is proportional to its masses, a heavy object does not fall faster than a lighter object.

What is the magnitude of the gravitational force between the earth and a 1 kg object on its surface? (Mass of the earth is 6×10^{24}kg and radius of the earth is 6.4×10^{6} m.)

Solution:

Given,

Mass of the object m = 1 Kg

Mass of the earth M = 6×10^{24} Kg

Radius of earth = 6.4×10^{6} m

=> Distance, r, between object and centre of earth = 6.4×10^{6} m

The gravitation force of attraction between two objects is given by F = $Gm^{1}m2/r^{2}$

G is Universal gravitational constant whose value is 6.67×10^{-11} Nm^{2}/Kg^{2} and m^{1}, m^{2} are the object separated by a distance of 'r'.

$F = (6.67\times10^{-11} \times 6 \times10^{24}\times 1)/(6.4\times10^{6})^{2}$

= 9.77 N

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 magnitude of the force of attraction of the earth on the moon is the same as that of the force of attraction of the moon on the earth. This follows from Newton's third law of motion that every action has an equal and opposite reaction. If the force of attraction of the earth on the moon is the action, then the force of attraction of the moon on the earth is the reaction.

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

Solution:

The earth does not move towards the moon even though the latter attracts the former, as the earth, too, exerts an equal force of attraction on the moon. This keeps the two celestial bodies intact.

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) If the mass of one of the objects is doubled, then the force between them is doubled.

(ii) If the distance between the objects is doubled, then the force between them is reduced to one-fourth its present value; and if the distance id tripled, then the force between them is reduced to one-ninths its present value.

(iii) If the masses of both the objects are doubled, then the force between them increases to four times its present value.

What is the importance of universal law of gravitation?

Solution:

The universal law of gravitation helps in understanding the existence of twin stars in the universe. It also helps understand the nature of different celestial bodies, including the earth.

What is the acceleration of free fall?

Solution:

Acceleration of free fall is the acceleration due to gravity and is equal to 9.8 m/s2

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

Solution:

The gravitational force between the earth and an object is called the weight of the object.

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 an object is the gravitational force of the earth on the body and depends on the acceleration due to gravity at a place. The acceleration due to gravity changes from place to place on the earth and depends on various factors. It is inversely proportional to the square of the radius of the earth. As the earth is not a perfect sphere and its equatorial radius of the earth. As the earth is not a perfect sphere and its equatorial radius is greater than its polar radius, the value of acceleration due to gravity is greater at the poles than at the equator. Thus, Amit's friend does not agree with him regarding the weight of the gold he purchased at the poles.

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

Solution:

The Dwight of a sheet of paper remains the same whether it is crumpled into a ball or not. The surface area of the paper is minimised when it is crumpled into a ball compared to when it was not. This reduces the air resistance, which is the buoyant force, on paper. Thus, the resistance due to air on the paper is more when it was not crumpled. This reduces the net force on the paper when it was not crumpled and it falls slower than when it was crumpled.

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:

Weight W = mg where m = mass of the object and

g = acceleration due to gravity

Acceleration due to gravity on the surface of earth (ge) is 9.8m/s2

Mass of the object = 10Kg (given)

Weight of the object (We) on the surface of the earth

$= mg_e$

= 10 x 9.8

= 98 N

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

Mass of the object on the surface of noon $= mg_m$

$= m \times \frac{1}{6}$ ge

$= 10 \times \frac{1}{6} \times 9.8$

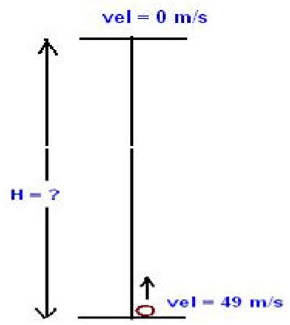
= 16.33 N

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:



i) Given,

Initial velocity of the ball, u = 49 m/s

Final velocity of the ball, v = 0 m/s

Acceleration due to gravity = - 9.8 m/s2

Let H be the maximum height attained by the ball.

We know that

v2 - u2 = 2as

Where v = final velocity

u = initial velocity

a = acceleration

s = displacement

02 - 492 = 2(-9.8) H

=> H = - 492/ (-9.8 × 2)

= - 2401/- 19.6 = 122.5 m

Therefore, Maximum height attained by ball = 122.5m

ii) We know that

s = ut + ½ at2

Where u = initial velocity

s = displacement

a = acceleration

t = time taken

$0 = ut + \frac{1}{2} at2$

$\Rightarrow -ut = \frac{1}{2} at2$

$-u = \frac{1}{2} at$

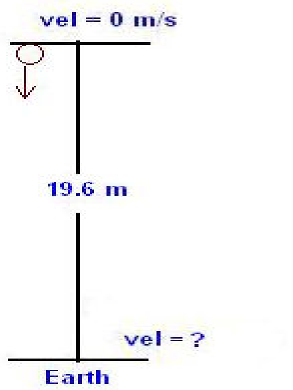
$- 49 = \frac{1}{2} (- 9.8) t$

$\Rightarrow t = (-2 \times 49)/ -9.8 = 10s$

Therefore Total time taken to return to surface of the ground = 10s

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:



Initial velocity of the stone u = 0 m/s

Displacement(s) = 19.6m

Let the final velocity of the stone be v m/s

The acceleration (a) = Acceleration due to gravity (g)

$= 9.8\ m/s^2$

We know that

v2 - u2 = 2as where v = final velocity

u = initial velocity

a = acceleration

s = displacement

v2 - 02 = 2(9.8) (17.6)

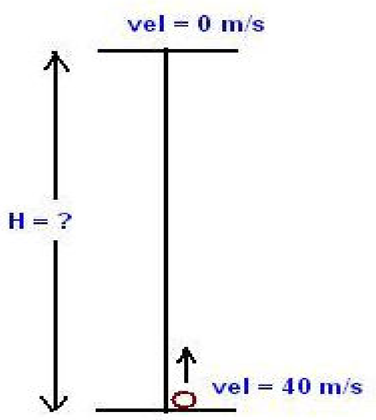
$v2 = 19.6 \times 19.6 = (19.6)^2$

=> v = 19.6 m/s

Therefore the final velocity of the stone = 19.6 m/s.

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,

Initial velocity of the stone, u = 40 m/s

Final velocity of the stone, v = 0 m/s

Acceleration (a) of the stone = - 10 m/s2

Let the maximum height attained by the stone be H.

The relationship between initial velocity (u), final (v), acceleration (a), and displacement (s) if given by:

v2 - u2 = 2as

02 - 402 = 2(-10) H

- 1600 = -20H

H = -1600/-20 = 80m

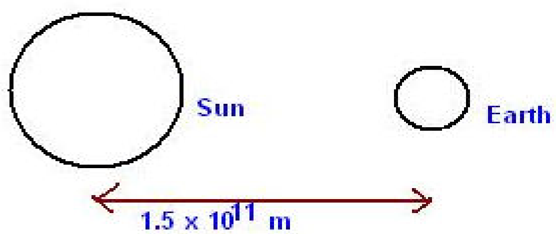
Net displacement = 0

Total distance travelled by the stone = 80 + 80

= 160 m

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.

Solution:



Given that,

Mass of earth Me = 6×10^{24} Kg

Mass of sun Ms = 2×10^{30} Kg

The average distance between sun and earth r = $1.5\times^{11}$m

The gravitational force of attraction between two objects is given by F = Gm_1m_2/r^2 where G is the Universal gravitational constant whose value is

6.67×10^{-11} Nm^2/Kg^2, m1, m2 are mass of objects and r is the distance between them.

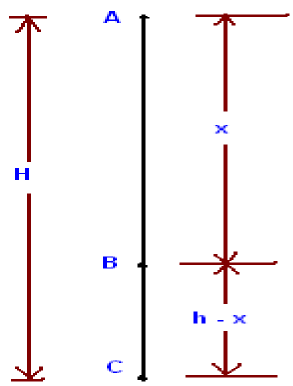
Here $m_1 = m_e$, $m_2 = m_s$

$F = (6.67\times10^{-11}\times6\times10^{24}\times2\times10^{30}) / (1.5\times1011)^2$

$F = 3.56\times10^{22}$ N.

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 that,

Height of the tower, H = 100m

Let AC represents tower whose top is A.

Let 'C' be the point on the ground from where another stone is projected and let both the stones meet at B.

The distance AC = H

AB = x (say) and

BC = AC - AB = (H - x)

Let 'x' be the time taken by two stones to travel from A and C to B respectively.

For the stone that dropped:

Initial velocity, $u = 0$ m/s

Displacement = x m

Time of travel ='t' seconds

Acceleration (a) due to gravity = 10 m/s^2

We know that

$s = ut + ½ at^2$

Where u = initial velocity,

s = displacement

a = acceleration and

t = time

s = (0)t + ½ (g)t2

x = ½ gt2 …..(1)

Stone that is thrown vertically upwards:

Initial velocity, u = 25 m/s

Displacement = H - x

Time taken ='t' seconds

Acceleration (a) = -10m/sec2

We know that

s = ut + ½ at2

H - x = 25t - ½ gt2

H - ½ gt2 = 25t - ½ gt2

H = 25t

100 = 25t

t = 100/25 = 4s

From eq (1),

$x = ½ gt2$

$= ½ x 10 \times 4 \times 4$

$x = 80$ m

The two stones collide after 4 seconds at a height of 20 m from the ground.

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 4 s.

Solution:

Time taken by ball to reach initial position = 6s

Let the initial velocity be u m/s

Maximum height attained be H mitres

a) Displacement (s) = 0

Time of flight = 6s and Acceleration due to gravity (a) = -9.8 m/s^2

Using the relation,

$s = ut + ½ at^2$ Where s = displacement

t = time

a = acceleration

u = initial velocity

$0 = (4)6 + ½ (9.8) (6)^2$

$\Rightarrow - 6u = ½ (-9.8)(6)^2$

$u = 29.4$ m/s

b) Final velocity (at maximum height), $v = 0$ m/s

Using the relation,

$v^2 - u^2 = 2as$

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

$\Rightarrow H = -(29.4)^2/(2(-9.8)) = 44.1m$

c) We know that $s = ut + \frac{1}{2} at^2$

$s = 29.4 \times 4 + \frac{1}{2} (-9.8) (4)^2$

$= 39.2$ m

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

Solution:

The buoyant force on an object immersed in a liquid act in the vertically upward direction.

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

Solution:

The density of plastic is less than that of water. Thus, the up thrust on the plastic block is greater than the weight of the block, which acts vertically downward. Thus, the net force on the plastic block immersed in water is in the upward direction, and hence, when the block is released, it comes to the surface of water, till the up thrust is equal to the weight of the block (the situation where the net force on the block is zero).

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?

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

Solution:

Given,

Mass of the substance, m = 50 g

Its volume, v = 20 cm3

Density is mass per unit volume.

Density of the substance ρ = m/v = 50/20 = 2.5g/cm3

Density of water = 1 gm/cm3

=> Density of substance > density of water

=> The substance SINKS.

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:

Given,

Mass of the seated packet, m = 500g

Its volume v = 350 cm3

Density is the mass per unit volume.

Density of seated packet, ρ = m/v = 500/350 = 1.428 g/cm3

Density of water is 1g/cm3 (given)

Density of seated packet > density of water

∴ Seated packet SINKS in water.

Volume of water displaced = Vol of seated packet

= 350 cm3

Density = Mass/Volume

=> Mass = density × Volume

= 1 g/cm3 × 350 cm3

= 350 g