GRAVITATION

statemen : Newton said that the force of gravity is the force of attraction between all objects in the universe

Or

The force of attraction offered by the Earth on the object which lies on the surface of the earth.

The force of gravity is also called as force of attraction

Why not the Moon get attracted towards the earth?

Due to the force of gravity between the moon and the earth. Between the moon and earth and other force has been producing name is centripetal force. Due to this centripetal force only any object can move in a circular path. Centripetal force is a vector quantity and direction is about the centre.

what Apple is attracted by the ground but ground is not attracted by the Apple?

Newton's third law every action has equal and opposite reaction

From Newton's second law

F=mxa

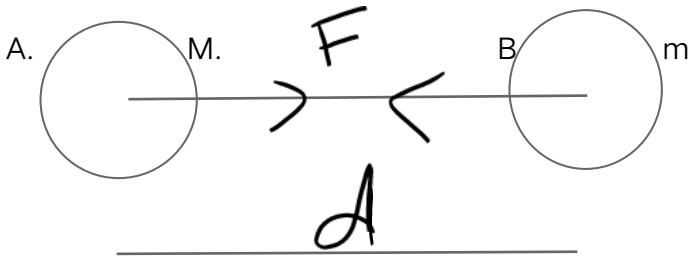
a=F/m

$a \propto \frac{1}{m}$

so Apple mass is less than Apple acceleration is more in the same way the earth mass is more than the acceleration of the Earth is less which is negligible so the movement of the earth towards the Apple is negligible

universal law of gravitation

Statement: everybody in the universe attract every other body with a force which is proportional to the product of their masses and inversely proportional to the square of distance between them



The force is along the line joining the centres of the two objects.

$F \propto Mm$

$F \propto 1/d^2$

$F \propto Mm/d^2$

$F = GMm/d^2$

G Is the constant of proportionality is called the universal gravitational constant . to know the value of gravitational constant G

$Fxd^2 = GMm$

$G = Fxd^2 /Mm$

SI unit of universal gravitational constant G = Nm^2kg^{-2}

$G = 6.673 \times 10^{-11} Nm^2kg^{-2}$

Importance of the universal law of gravitation :

The universal law of gravitation successfully explain several phenomena which were believed to be uncountable

1. force that binds us to the earth.
2. the motion of the Moon around the earth.
3. the motion of the planets around the sun.
4. the Tides due to the moon and the sun.

Free fall

1. is there any change in the velocity of falling object?

Ans: 1. Due to US attraction there will be a change in the magnitude of the velocity.

2. any change in the velocity involves acceleration so,

whenever an object Falls towards Earth and acceleration is involved.

3. the acceleration is due to the earth's gravitational force is called. acceleration due to gravity . It is denoted by 'g'.

The unit of g is as that of acceleration ms^{-2}.

Acceleration due to gravity g:

Statement: The magnitude of the gravitational force will be equal to the product of mass and acceleration due to gravity.

$$F=mg$$

but we know. $F= GMm/d^2$

from equations 1 and 2

$$mg=GMm/d^2$$

$$g=GM/d^2$$

The earth is not a perfect sphere so as a radius of the earth increases from pole to the equator the value of g becomes greater at the poles than at the equator.

Motion of objects under the influence of gravitational force of the earth:

1. Acceleration experienced by an object is independent of its mass.
2. motion of the object becomes valid with acceleration a replaced by g.

the equations are

1. $V=u+at.$ $V=u+gt$
2. $S= ut+1/2\ at^2$ $S= ut+1/2\ gt^2$
3. $V^2=u^2+2as$ $V^2=u^2+2gs$

in applying these equations we will take acceleration a to be positivewhen it is in the direction of velocity and negative when it is opposite to the motion

mass:

In the previous chapter that the mass of an object is the measure of its inertia we know that mass increases, inertia also increases mass of an object is constant and does not change from place to place.

Weight

We know that the Earth attracts every object with a certain force and this force depends upon the mass(m) of the object and acceleration due to gravity(g). The weight of an object is a force with which it is attracted towards the earth.

$$F=ma$$

$$F=mg$$

the force of attraction of the earth of an object is known as weight of the object.

It is denoted by W

$$W= mg$$

the SI unit of weight is Newton N

The weight is a force acting vertically downwards it has both magnitude and direction.

Exercise questions

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

Ans: given that

distance $r=r/2$

we know that

$F= GMm/r^2$

$F= GMm/(r/2)^2$

$F= GMm/(r^2/4)$

$F= 4(GMm/r^2)$

$F=4F$

If the distance between them is reduced by half then the force of gravitation will be increased by 4 times of the force

2. gravitational force acts on all object in proportion to their masses why then a heavy object does not fall faster than a lighter object?

Ans: because of the reason that acceleration is equal to force divided by mass. as the force is directly proportional to mass acceleration is constant for a body of any mass.

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

Ans : given that

$$M = 6 \times 10^{24} \text{ kg}$$

$$m = 1\text{kg}$$

$$r = 6.4 \times 10^{6} \text{ m}$$

We know that. $F = GMm/r^2$

$$F = 6.7 \times 10^{11} \text{ Nm}^2\text{kg}^{-2} \times 1\text{kg} \times 6 \times 10^{24} \text{ kg} / 6.4 \times 10^{6} \text{ m} \times 6.4 \times 10^{6} \text{ m}$$

$$F = 1.0 \times 10$$

$$F = 10\text{N}$$

4. The Earth and the Moon are attracted to each other by gravitational force. Does the Earth attracts the moon with a force that is Greater or smaller or the same as the force with which the moon attracts the earth ?why?

Ans: according to the universal law of gravitation two objects attract each other with equal forces But in opposite direction that for the earth attracts the moon with the same force as the moon attracts the earth

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

Ans: the moon attracts the earth with the same gravitational force as the earth attracts the moon the mass of the earth is very large the acceleration produced is negligible therefore the earth does not move towards the moon.

6. what happens to the force between the objects if

(I) the mass of one object is doubled

(II) the distance between the two objects is doubled and tripled

(III) the masses of the both objects are doubled

Ans: 1. given that

Mass of one object is doubled

$$M=2M$$

$$F= GMm/r^2$$

$$F= G(2M)m/r^2$$

$$F= 2(GMm/r^2)$$

$$F=2F$$

the force is doubled when one object mass is doubled

II. Given that distance is doubled

$$r=2r$$

$$F= GMm/(2r)^2$$

$$F= GMm/4r^2$$

$$F= 1/4(GMm/r^2$$

$$F=1/4\ F$$

when the distance is doubled then the force will be reduced to 1/4 times of force

Given that the distance is tripled

$$r=3r$$

$$F= GMm/(9r)^2$$

$$F= GMm/9r^2$$

$$F= 1/9(GMm/r^2$$

$$F=1/9\ F$$

when the distance is Tripled then the force will be reduced to 1/9 times of force

III. given that mass of both objects are

$$M=2M,m=2m$$

$$F= GMm/(r)^2$$

$$F= G(2M)(2m)/r^2$$

$$F= 4(GMm/r^2$$

$$F=4F$$

if mass of both objects are doubled then the fourth will be 4 times of the initial force

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

Ans: The universal law of gravitation successfully explain several phenomena which were believed to be uncountable

I. force that binds us to the earth.

2. the motion of the Moon around the earth.

3. the motion of the planets around the sun.

4. the Tides due to the moon and the sun.

8.what is the acceleration of free fall?

Ans: 1. Due to US attraction there will be a change in the magnitude of the velocity.

2. any change in the velocity involves acceleration so,

whenever an object Falls towards Earth and acceleration is involved.

3. the acceleration is due to the earth's gravitational force is called. acceleration due to gravity . It is denoted by 'g'.

9. what do we call gravitational force between the Earth and the object?

Ans: Gravitational force between the Earth and an object is known as Earth's gravity or weight of the object.

10. Amit 22 few grams of gold at the poles as per the instruction of one of his friends. Hi handover the same when he made at the equator will the friend agree with the weight of bold brought if not why?

Ans:Mass of the object remains same every where.

$g = G M1 M1 / d^2$

M1 and M2 are masses of the bodies. d = distance between Earth center and the person on the surface.

The distance d is less at the poles. So the gravity g' is more at the poles than at the equator. Now, the gold bought at the poles reads W grams weight. The mass of the gold purchased is W/g' grams.

The gravity at the equator is g. The weight = W/ g' * g = W * g / g' .

Since g < g', the weight will be < W. So the weight of the gold as shown by the machine at the equator will be less.

So the person will have paid more at the poles. Same mass of gold will cost less at the equator.

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 Newtons of a 10kg object on the moon and the earth?

Ans: Mass of the object, m=10 kg

Acceleration due to gravity at earth, g_e =9.8 ms^{-2}

∴ Weight of the object on earth, W=mg =10×9.8=98 N

Acceleration due to gravity at moon, g_m=1/6 ×9.8=1.63 ms^{-2}

∴ Weight of the object on moon, W=mg_m

=10×1.63=16.3 N

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

I. The maximum height to which it Rises.

II. the total time it takes to return to the surface of the earth.

Ans. Given That

Initial velocity of the ball (u) = 49m/s.

The velocity of the ball at maximum height (v) = 0.

g = 9.8m/s^2

Let us considered the time taken is t to reach the maximum height H.

Consider a formula,

$v^2 = u^2 + 2gH$

$2gH = v^2 - u^2$

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

$-19.6\,H = -2401$

$H = 122.5$ m

Now consider a formula,

$v = u + g \times t$

$0 = 49 + (-9.8) \times t$

$-49 = -9.8t$

$t = 5$ sec

(1) The maximum height to ball rises = 122.5 m

(2) The total time ball takes to return to the surface of the earth = 5 + 5 = 10 sec.

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?

Ans:Initial Velocity u=0

Fianl velocity v=?

Height, s=19.6m

By third equation of motion

$v^2 = u^2 + 2gs$

$v^2 = 0 + 2 \times 9.8 \times 19.6$

$v^2 = 384.16$

$\Rightarrow v = 19.6$m/s

15. A stone is thrown vertically upward with an initial velocity of 40 m/ s taking g= 10 m/s^2 find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone?

Ans: Initial Velocity u=40m/s

Fianl velocity v=0

Height, s=?

By third equation of motion

$v^2 = u^2 + 2gs$

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

$s = 160/20$

$\Rightarrow s = 80 m/s$

Toatl distance travelled by stone = upward distance + downwars distance $= 2 \times s = 160m$

Total Diaplacement =0, Since the initial and final point is same.

16. calculate the force of gravitation between the Earth and the Sun given the mass of the earth is 6x 10 ^ 24 kg and of the sun is he is 2 x 10 ^ 30 kg is the average distance between the two is 1.5 x 10 ^ 11 m

Ans:

Given : Mass of earth $m = 6 \times 10^{24}$ kg

Mass of Sun $M = 2 \times 10^{30}$ kg

Distance between sun and earth $r = 1.5 \times 10^{11}$ m

Force of gravitation between them $F = GMm/r^2$

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

$= 3.557 \times 10^{22}$ N

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

Ans:Let the stones meet at point A after time t.

For upper stone :

$u' = 0$

$x = 0 + 1/2\ gt^2$

$x = 1/2 \times 10 \times t^2$

$\Rightarrow x=5t^2$.....(1)

For lower stone :

u=25 m/s

$100-x=ut-1/2gt^2$

$100-x=(25)t-1/2\times10\times t^2$

$\Rightarrow 100-x=25t-5t^2$ .....(2)

Adding (1) and (2), we get

25t=100

$\Rightarrow$t=4 s

From (1),

$x=5\times4^2$

$\Rightarrow$x=80 m

Hence the stone meet at a height of 20 m above the ground after 4 seconds.

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

a) the velocity with which it was thrown up

b) the maximum height it reaches.

c) position after 4 s

Ans:

The ball returns to the ground after 6 seconds.

Thus the time taken by the ball to reach to the maximum height (h) is 3 seconds i.e t=3 s

Let the velocity with which it is thrown up be u

(a). For upward motion,

v=u+at

$\therefore$ $0=u+(-10)\times3$

$\Rightarrow$u=30 m/s

(b). The maximum height reached by the ball

$h=ut+ 1/2\ at^2$

$h=30\times3+ 1/2\quad(-10)\times3^2$

$h=45$ m

(c). After 3 second, it starts to fall down.

Let the distance by which it fall in 1 s be d

$d=0+ 1/2at^2$

where $t=1$ s

$d= 1/2\times10\times(1)^2$

$=5$ m

∴ Its height above the ground, $h=45-5=40$ m

Hence after 4 s, the ball is at a height of 40 m above the ground.