CONCEPT OF THE FORCE

The concept of force has existed for a time. Physically, it is understood very vaguely. For example, if somebody hits you, then the hitting body exerts a force on you. Intuitively, we all know that all the bodies in the universe exert some force on one another. Till Newton came up with his laws, the concept of force was not understood in physical terms. Newton brought out three important points. Let us consider the points raised out by Newton. Assume that a body is moving with velocity v as shown in figure 1.

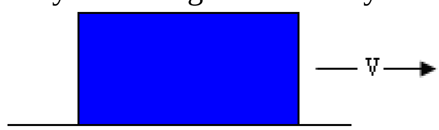


Figure 1: Body moving with velocty V

What will happen to the body?

Aristotle would say that the body would naturally come to rest. It was assumed that it was natural for bodies like this to rest ultimately. This was called the natural state.

Let us take another example. Assume that an apple is falling down to earth. What is its nature state?

We all know that apple's velocity increases as it falls down. Again Aristotle would say that it was natural for a body fall faster as it was nearing earth's surface.

Newton proved that this kind of thinking was wrong. He said that the natural state of a body is to continue its motion. It changes its velocity only when an external force acts on the body.

In both the cases, it is not natural for the bodies to stop. The body in the first example stops only because there is a force, which is acting in to body. Similarly the apple falls faster only because the earth is exerting a force.

This is called Newton's first law. Any body in the absence of a force will continue to move with same velocity (in the same direction as before).

Consider the example in figure 2.

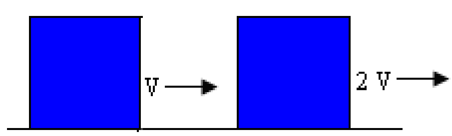


Figure2 : Velocity of a body increases

Notice that the velocity of the body has increased. Therefore there must be a force acting on the body in the forward direction. The value of velocity has increased because of the force acting on the body. Force will be along the direction of change in velocity. Here the direction of change in velocity is forward. Therefore, the force will be acting in the forward direction.

Consider the case in figure3.

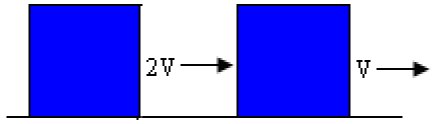


Figure3 : Velocity of a body decreases

Newton combined all these factors factors and gave us "Newton's second law", which is $\vec{F} = m\vec{a}$. Note that this rule is valid only for particles are bodies, which do not have dimensions. They look like points.

If the mass of the body varies, then we have to consider the product of mass and velocity. We have to calculate the change in both. This kind of situation happens in rockets. If we consider the force acting on a rocket, the mass of the rocket changes since the fuel is continually ejected out the velocity also changes. There fore for a rocket, the correct equation will be:

$$F = \frac{Change\ in\ (mv)}{time}$$

Remember this equation is valid only for particles. How do we write down this equation of bodies, that is, masses that have dimensions? Consider the situation as in figure 4.

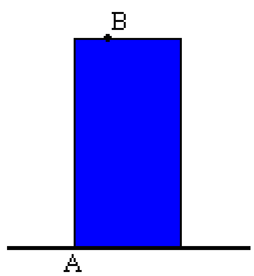


Figure 4: A body topples

Assume that a body topples down. Point A of the body remains at the same point. Therefore it has zero velocity at all times. Obviously the change in velocity of point A is zero. Consider point B, B has some velocity when it hits the ground.

Now which point do we consider?

According to Newton, we should not consider point A or point B. instead we should look at the center of mass of the body. The force equation for such bodies thus becomes;

$$\vec{F} = m\left(\frac{d\vec{v}_{cm}}{dt}\right). \quad or \quad \vec{F} = m\vec{a}_{cm}.$$

- Force is the action of one upon another. The may either produce deformation (change in the size of shape of bodies) or acceleration (change in magnitude or direction of velocity). It is a vector with units kgms^{-2} or newton (N).
- There are, basically, five forces, which are commonly encountered in mechanics.

There are many more types of force, some of the force that are considered in this unit of e-education are:

1. Normal force
2. Tension
3. Friction force
4. Gravitational force

Normal force

Normal force acts wherever two bodies are contact with each other. The number of normal forces that will acts on a body on the number of surface or points of contact. The rule can be stated below.

Number of normal forces acting on a body is equal to the number of points/surfaces of contact.

Normal Force (N)

It is the component of contact force normal to the surface. It measures how strongly the surface in contact are pressed the surface in contact are pressed together.

Normal force will be perpendicular to the surface of contact.

or

If perpendicular to the surface of contact cannot be draw, the normal force will act perpendicular to the surface of the body.

or

If neither can be done, normal force has to be draw as two components-one in the X-direction and one in the Y-direction. Remember there is no relation between the forces acting along the X- and Y- direction. They are independent of each other.

Let us apply this to figure 5.

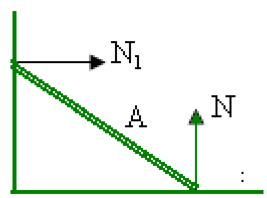


Figure 5 : Normal force acting on the bod

Number of normal forces on body A will be 2. the direction of the force will be perpendicular to surface.

Normal force N and N, acts perpendicular to the surface.

On the other hand consider the diagram in figure 6.

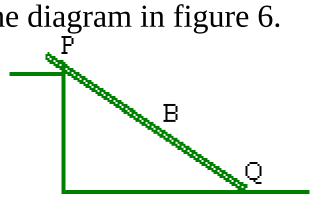


Figure 6 : Body resisting at point Q

Here body B is resting on two points. Therefore two normal forces, will acts on the body- one at point P and another at Q point . The normal force at point Q will act perpendicular to the surface. This is as shown in figure 7.

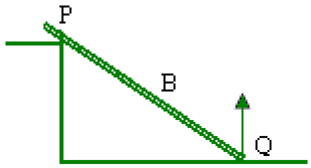


Figure 7 : Normal force acting at point Q

The force is perpendicular to the surface and acting outward point Q.

But what about the force at point P?

You cannot draw a perpendicular to the surfaced at point P. According to the rule, if you cannot draw perpendicular to the surface, a perpendicular to the body should be draw at that point. The perpendicular is shown in figure 8.

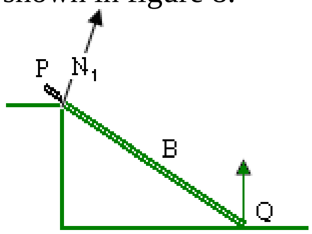


Figure 8 : Normal force acting at point P

Notice that the force N_1 is acting outward.

Figure 9 shows another case where a perpendicular to the surface cannot be drawn.

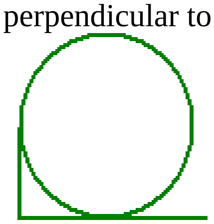


Figure 9 : Disc lying on two surface

The disc is touching the surfaced at two points. Therefore will be two normal force will be perpendicular to the body. The perpendicular at the point of contact of the disc will be pointing towards the center of the circle.

The force diagram is shown in figure10.

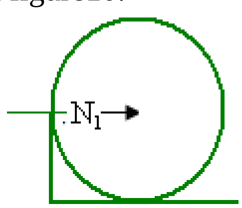


Figure 10: Normal forc disc

We see that the disc is in contact with one surface. Therefore one normal force and one frictional force will act on the disc Figure 11.

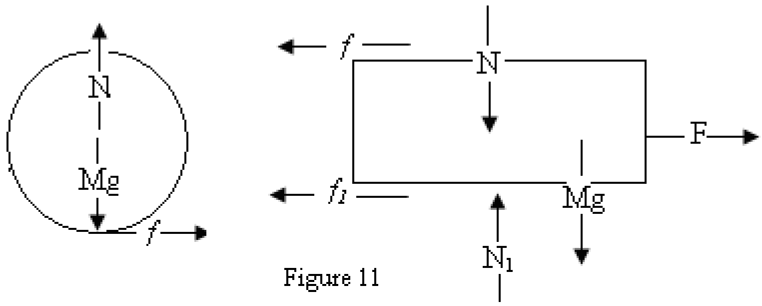


Figure 11

Tension

This is a force where ropes are involved. How do we visualize tension? All of us must have played the rope game, where two parties pull the rope on either sides and try to win the game. The diagram in figure 12 shown two men pulling a rope.

The force exerted by the end of a taut string, rope or chain is called the tension. The direction of tension is so as to pull the body while that of **normal reaction** is to push the body.

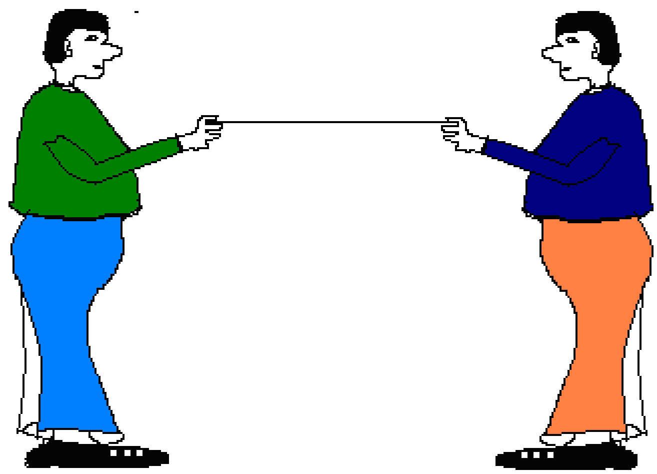


Figure 12: Two men pulling rope

- Tension force always pulls a body.
- Tension can never push a body or rope.
- Tension across massless pulley or frictionless pulley remains constant.
- Ropes become slack when tension force become zero.

Weight

Weight of an object is the force with which earth attracts it. It is also called the force of gravity or the gravitational force.

Contact Force

When two bodies come in contact they exert forces on each other that are called contact forces. Figure 13.

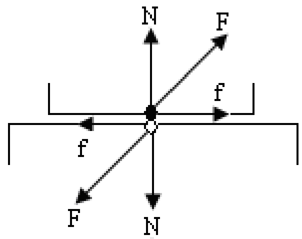


Fig 13: Contact force F exists between the two surface in contact. N and f are the normal and parallel components of F.

Frictional Force (f)

It is the component of contact force parallel to the surface. It opposes the relative motion (or attempted motion) of the two surface in contact.

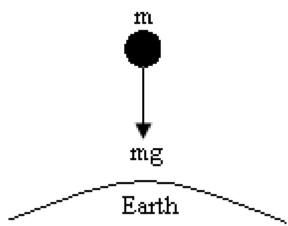
Spring Force

Every spring by the attempt to change its length; the more you alter its length the harder it resists. The force exerted by a spring is given by F = -kx, where x Is the change in length and k is the stiffness constant or spring constant (units Nm-1).

3. FREE BODY DIAGRAM

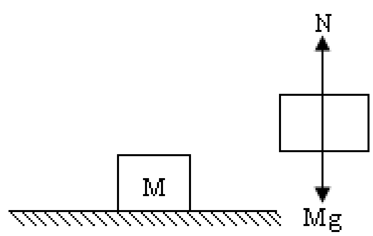
In this diagram the object of internet is isolated form its surrounding and the interactions between the object and the surroundings are represented in terms of forces.

[A]



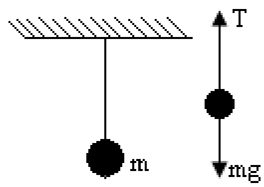
F.B.D of a particle in gravitational field. The earth pulls the particle of mass in by a force *mg*.

[B]



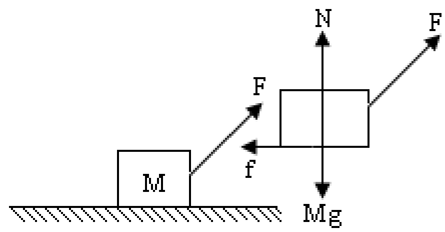
F.B.D of a block placed on a horizontal surface. Two vertical forces act on the block: the force pulls the block downward by mg, and the surface pushes the block upward by N.

[C]



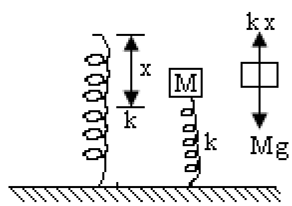
F.B.D of a ball suspended by a string. Two vertical force act on the ball; the earth pulls the ball downward by mg and the string pulls the ball upwards by T.

[D]



F.B.D of a block paced on a rough surface being pulled by an external force. There are four forces acting on the block: the gravitational pull mg; the normal reaction N; the external force F; and the tangential friction force f.

[E]



F.B.D of a supported by a spring of stiffness k. Two vertical forces act on the block: the gravitational pulling, and the spring force kx.

NEWTON'S LAWS

1. FIRST LAW

Every particle continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by of an applied force.

2. SECOND LAW

The net acting on a particle produces acceleration. The magnitude of the acceleration produced depends on the quantity of matter being acted upon. The quantity of matter is referred to as the Inertial mass. The direction of acceleration is the direction of the net force.

3. THIRD LAW

Whenever two bodies interact they exert forces on each other which are equal in magnitude and opposite in direction. So whenever body A exerts a force F on body B, B exerts a force –F on A.

4. SIGNIFICANCE OF NEWTON'S LAWS

(i) The first tells us about the nature state of motion of a body, which is motion along a straight line with constant speed.

(ii) The second law tells us that if a body does not follow its natural state of motion than it is under the influence of other bodies, that is, a net unbalanced force must be acting on it.

(iii)The third law tells us about the nature of that force.

REFERENCE FRAMES

Concepts

1. wherever the observer is situated in space that is called the frame of reference. The reference frame is associated with a co-ordinate system and a clock to measure the position and time of the events happening in space.
2. **INERTIAL REFERENCE FRAME**

   A reference in which Newton's first law is valid is called an inertial reference frame. An inertial frame is earth at rest or moving with uniform velocity. Any frame moving at constant velocity relative to a known inertial frame is also called an inertial frame. In an inertial frame, an object subject to no net force will stay at test or move at constant velocity. If the acceleration of a particle is zero in one inertial frame, it is zero in all inertial frames

   Ideally, no inertial frame exists in the universe. For practical purpose, a frame of reference may be considered as inertial of its acceleration is negligible with respect to the accelerations of the object to be observed. For example, to measure the acceleration of a falling apple, earth can be considered as an inertial frame. On the contrary, to observe the motion of planets, earth cannot be considered as an inertial frame but for this purpose the sum may be assumed as an inertial frame.

3. **NON-INERTIAL FRAME**

   It accelerated frame of reference is called a non-inertial frame. Objects in non-inertial frames do not obey Newton's first law.
4. **PSEUDO FORCE**

   It is imaginary force which is recognized only by a non-inertial observer to explain the physical situation according to Newton's laws.

   The magnitude of this force F_p is equal to the product of the mass m of the object and acceleration a of the frame of reference. The direction of the force is opposite to the direction of the acceleration.

   $$Fp = -ma$$

This force is imaginary in the sense that it has no physical origin, that is, it is not caused by one of the basic interactions in nature. It does not exist in the action-reaction pair.

A ball is dropped inside a car which is initially at rest but has an acceleration a to the right. A stationary observer on the ground observes that the ball is falling vertically downwards with an acceleration g (downwards).

Horizontally the ball does not move, only the car moves to the right. Figure 14.

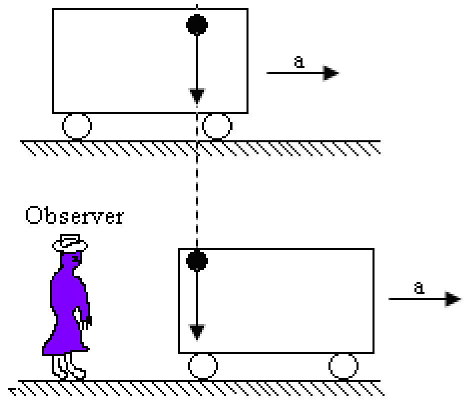


Figure 14
A ball falling under gravity inside an accelerated car is observed by a stationary observer.

A person in the accelerated car observes that the ball moves down and towards the left of the car.
According to this observer, the backward acceleration of there ball is caused by the pseudo force.

13. The concept of relative velocity we are just simplifying to problem of motion of two particles (say A & B) into the problem of motion of one particles, assuming other to be at rest, e.g. V_{AB} velocity of A assuming b to be at rest.
Similarly $\overrightarrow{V_{BA}}$ is the velocity of B assuming A to be at rest. Figure 15.

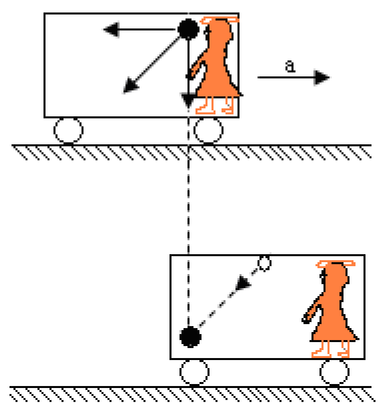
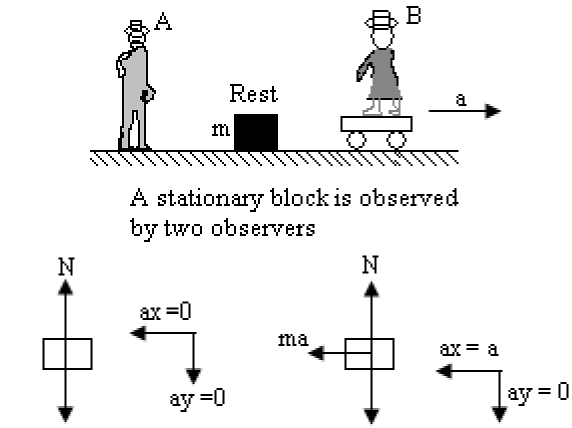


Figure 15
A ball falling under gravity an accelerated car is observed by a poerson inside the car.

Example:- A block mass m rests on a smooth horizontal surface. It is being observed by two observers A and B: observer A is stationary on the ground, observer B rides on a car moving towards right with an acceleration a. Draw free body by A and B.



F.B.D of the block w.r.t. the observe A

F.B.D. of ther block w.r.t. obwerver B

Example:- A man of mass M stand on a weighing machine in an elevator accelerating upwards with an acceleration a0.

Draw the free body diagrams pf the man as observed by the observer A (stationary on the ground) and observer B (stationary on the elevator). Also, calculate the reading of the weighing machine.