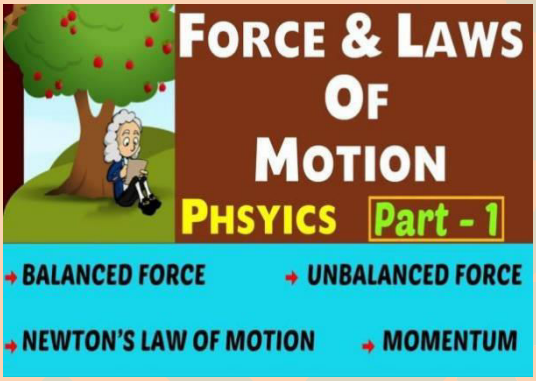
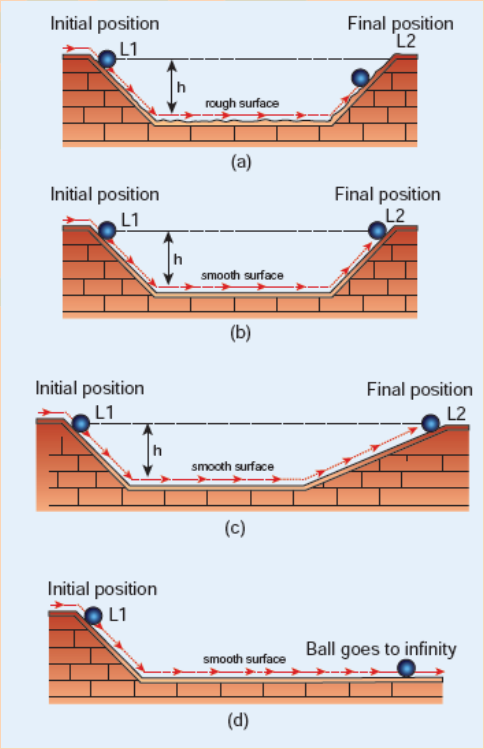
UNIT 3 – LAWS OF MOTION

GREETINGS Students, This class we are going to discuss about introduction to laws, Newton's laws.



INTRODUCTION

- Motion in simple is tendency to move. An object is said to be in motion when it changes its position with time
- A body is said to be at Rest if it is not moving.
- An external force is always involved in motion. This force helps body to perform required actions and these actions are according to rules or laws i.e. Laws of Motion.
- In the 15th century, Galileo challenged Aristotle's idea by doing a series of experiments. He said force is not required to maintain motion.
- Galileo demonstrated his own idea using the following simple experiment. When a ball rolls from the top of an inclined plane to its bottom, after reaching the ground it moves some distance and continues to move on to another inclined plane of same angle of inclination.

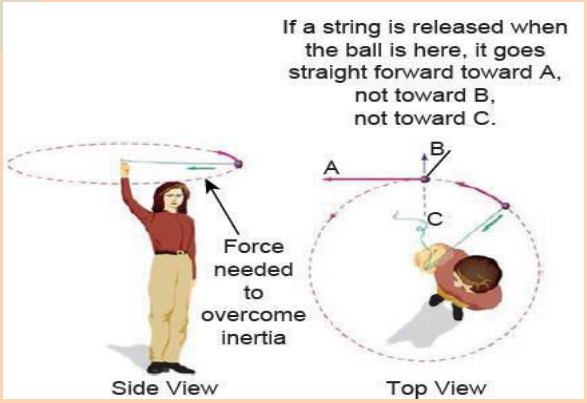


- Figure (a). By increasing the smoothness of both the inclined planes, the ball reach almost the same height(h) from where it was released (L1) in the second plane (L2).
- Figure (b)). The motion of the ball is then observed by varying the angle of inclination of the second plane keeping the same smoothness. If the angle of inclination is reduced, the ball travels longer distance in the second plane to reach the same height.
- (Figure (c)). When the angle of inclination is made zero, the ball moves forever in the horizontal direction.
- (Figure (d)). If the Aristotelian idea were true, the ball would not have moved in the second plane even if its smoothness is made maximum since no force acted on it in the horizontal direction.

Newton's First Law

Every object continues to be in the state of rest or of uniform motion (constant velocity) unless there is external force acting on it.

1. **Inertia of rest:** When a stationary bus starts to move, the passengers experience a sudden backward push. Due to inertia, the body (of a passenger) will try to continue in the state of rest, while the bus moves forward. This appears as a backward push as shown in Figure 3.2. *The inability of an object to change its state of rest is called inertia of rest*.
2. **Inertia of motion:** When the bus is in motion, and if the brake is applied suddenly, passengers move forward and hit against the front seat. In this case, the bus comes to a stop, while the body (of a passenger) continues to move forward due to the property of inertia as shown in Figure 3.3. *The inability of an object to change its state of uniform speed (constant speed) on its own is called inertia of motion*.
3. **Inertia of direction:** When a stone attached to a string is in whirling the stone will not continue to move in circular motion but moves tangential to the circle as illustrated . This is because the body cannot change its direction of motion without any force acting on it. *The inability of an object to change its direction of motion on its own is called inertia of direction*.



Inertial Frames

If an object is free from all forces, then it moves with constant velocity or remains at rest when seen from inertial frames. Thus, there exists some special set of frames in which, if an object experiences no force, it moves with constant velocity or remains at rest.

The person and vehicle are inertial frames

Car 2 is a non-inertial frame

- Suppose an object remains at rest on a smooth table kept inside the train, and if the train suddenly accelerates (which we may not sense), the object appears to accelerate backwards even without any force acting on it.
- It is a clear violation of Newton's first law as the object gets accelerated without being acted upon by a force. It implies that the train is not an inertial frame when it is accelerated.

Newton's Second Law

This law states that *The force acting on an object is equal to the rate of change of its momentum.*

$$\vec{F} = \frac{d\vec{p}}{dt} \qquad (3.1)$$

In simple words, whenever the momentum of the body changes, there must be a force acting on it. The momentum of the object is defined as $\vec{p} = m\vec{v}$. In most cases, the mass of the object remains constant during the motion. In such cases, the above equation gets modified into a simpler form

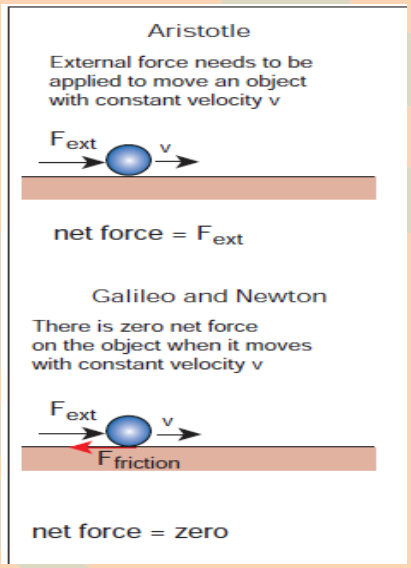
$$\vec{F} = \frac{d(m\vec{v})}{dt} = m\frac{d\vec{v}}{dt} = m\vec{a}.$$

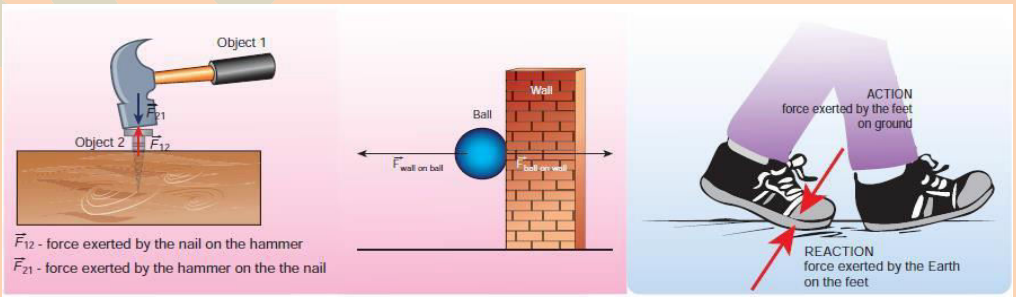
$$\vec{F} = m\vec{a}. \qquad (3.2)$$

- The force and acceleration are always in the same direction. Newton's second law was a paradigm shift from Aristotle's idea of motion.
- According to Newton, the force need not cause the motion but only a change in motion. It is to be noted that *Newton's second law is valid only in inertial frames*. In non-inertial frames Newton's second law cannot be used in this form. It requires some modification.
- In the SI system of units, the unit of force is measured in Newton's and it is denoted by symbol 'N'.
- *One Newton is defined as the force which acts on 1 kg of mass to give an acceleration 1 m s-2 in the direction of the force*.

Aristotle vs. Newton's approach on sliding object

- Newton's second law gives the correct explanation for the experiment on the inclined plane that was discussed in section 3.1. In normal cases, where friction is not negligible, once the object reaches the bottom of the inclined plane.
- It is this frictional force that reduces the velocity of the object to zero and brings it to rest.





Newton's Third Law

- whenever an object 1 exerts a force on the object 2(F_{21}), then object 2 must also exert equal and opposite force on the object 1 (F_{12}). These forces must lie along the line joining the two objects.

- Newton's third law assures that the forces occur as equal and opposite pairs. An isolated force or a single force cannot exist in nature.
- *Newton's third law states that for every action there is an equal and opposite reaction*.
- Here, action and reaction pair of forces do not act on the same body but on two different bodies. Any one of the forces can be called as an action force and the other the reaction force. Newton's third law is valid in both inertial and non-inertial frames.
- These action-reaction forces are not cause and effect forces.
- It means that when the object 1 exerts force on the object 2, the object 2 exerts equal and opposite force on the body 1 at the same instant.

URL : https://www.youtube.com/watch?v=g3VTT13Ch2s