Force and Acceleration

Why objects change their speed?

Objects can move with a constant speed or variable speeds. But in our daily experiences, we rarely deal with objects moving at uniform speeds. The speeds of the objects keep on increasing or decreasing. But why does the speed of an object changes. Why do objects accelerate or decelerate?

What is force and what is its relation to motion?

Whenever we do our daily chores, we apply force. For example, we open or close the door we apply force in particular direction. When a player hits a ball with bat, he is applying a force on the ball.

When a force is applied on an object, it can do three things:

1. It can change the speed of the object making it move faster or slower.
2. The direction of motion of the object can be changed by it.
3. The shape of an object can also be changed by it.

For example, if we push a ball hard, it can move faster, but we give only a slight push to the ball then it will move slower.

If the push to the ball is given from different angles then it will move in different directions.

If we take a plastic ball in our hand and squeeze it with our palms, then its shape is changed from a rounded one to oblong.

What are balanced and unbalanced forces?

Balanced forces do not change the speed of the object. They mostly change the shape of an object on which they are applied.

For example, when a equal forces are applied with our palms on a ball, the shape of the ball changes from round to oblong.

Unbalanced forces acting on an object on the other hand change the speed or direction of motion of the object.
One interesting example of unbalanced forces is the tug-of-war game. When the two teams pull with equal effort, the rope and the two teams remain stationary. The forces exerted by the two teams in this case are balanced. But when one of the team pulls harder, then it is able to pull the weaker team towards it. In this case the forces are not balanced. It, therefore, results in the motion of the weaker team along with the rope they are holding.

**Frictional Forces** - When we ride a bicycle, we have to pedal it so that it moves further. If we stop pedaling, the bicycle slowly comes to rest and stops. This shows that continuous application of the force is required to keep the bicycle moving. From this, we come to conclusion that continuous application of force is required to maintain the motion of an object. But this is not true.

To skate on snow, one of the shoe has very smooth surface. The other shoe has uneven surface, so as not to slip and find grip in the snow.

When we stop pedaling the bicycle, what happens? This depends. If the road is rough, the bicycle will stop sooner. If the road is smooth, it keeps going longer. What would happen if the road is very smooth? Even a very smooth surface can have some roughness in it. It has small cracks and bumps which cannot be seen by the naked eye. If we look at an enlarged photograph of such a surface, it will look more like a mountainous terrain. When an object like a
bicycle travels on such a surface, it has to overcome these imperfections which slow down the object. Forces which slow down moving objects in this way are called forces of friction. If frictional forces could somehow be eliminated, an object would continue moving with the same speed. But these forces cannot be eliminated entirely. They can only be reduced. For example, in the carom board game we sprinkle powder to reduce the frictional force between the coins and the wooden board. This helps the coins to move faster than on an unpowdered board. Thus we can say that the objects continue to move with the same velocity unless acted upon by an unbalanced force.

**Newton’s Laws of Motion**

When no forces act on an object, then its state of motion does not change. That is,

1. The object will continue to be at rest, if it was earlier at rest.
2. The object will continue to move with same velocity as earlier.
3. Once a force is applied on the object, its velocity will change. That is, it will accelerate.

These are universally true statements about the motion of the objects. Scientists, therefore call these statements a law. This law is called Galileo’s Law of Inertia. Also, this law is called Newton’s First Law.

**Newton’s First Law** states that – An object at rest or in uniform motion will remain at rest or in uniform motion unless an unbalanced force acts on it.

**Inertia and Mass**

Objects continue to be in their state of motion when no forces act on them. This property of the objects to resist any change in their motion is called inertia. The meaning of word inertia is “unchanging”. It comes from the Latin word- inert.

For example, when we are traveling in a bus, and bus is going at fast speed. The driver suddenly applies the brake and we are unable to control ourselves and our body plunges forward. It is because the bus and our body are moving at constant velocity. That is why in cars etc. we use seat belts. So that if there is sudden break we do not fall forward and hurt ourselves. The objects tend to maintain their state of motion.
Massive objects have more inertia than lighter ones. Mass is thus a measure of inertia. Body with more mass, has higher inertia.

**Newton’s Second Law**

Force applied on an object changes the velocity of the object, that is it accelerates the object. The resistance to the change in velocity of the object depends on the mass of the object. That is, the velocity of lighter objects can be changed easily as compared to heavier objects.

How can we measure the magnitude of the force on an object? The Newton’s Second Law helps us to measure the force on an object. The Newton’s Second Law states that the force on an object is proportional to the product of mass of the object and its acceleration. According to this law, the force acting on an object is given by

\[ \text{Force} \propto M \times a \]

Here \( M \) is the mass of the object and \( a \) is the acceleration. The proportionality symbol “\( \propto \)” tells that

\[ \text{Force} = k \cdot M \cdot a \]

Where \( k \) is a constant. The unit of mass is gram or kilogram. The units of acceleration are \( \text{cm/s}^2 \) or \( \text{m/s}^2 \).

One unit of Force\( = k \cdot (1 \text{ kg})(1 \text{ m/s}^2) \)

The value of constant \( k \) is therefore 1.

The force on an object is equal to the product of the mass of the object and its acceleration. The unit of force is Newton. A force of one Newton will produce an acceleration of \( 1\text{m/s}^2 \) in an object of mass one kilogram.

\[ \text{Force} = \text{mass} \times \text{acceleration} \]

**Momentum**

The momentum of an object is the product of its mass and velocity. And is denoted by \( p \)
\[ P = mv \]

**Newton’s Third Law of Motion**

In an interaction between two bodies the force exerted by the first body on the second is equal and opposite to that exerted by the second body on the first. Or Action and reaction are equal and opposite.

For example, when two marbles collide, after the collision they move in opposite directions.