ATOMIC ENERGY CENTRAL SCHOOL INDORE

CHAPTER : LAWS OF MOTION

CLASS : XI

SUBJECT : PHYSICS

Module : 1/3

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Aristotelian Law

Aristotelian law of motion: **An external force is required to keep a body in motion.**

Aristotle's view was proved wrong by Galileo. It was observed that external forces were necessary to counter the opposing forces of friction to keep the body moving in uniform motion. If there were no friction, no external force would be needed to maintain the state of motion of a body.

Law of Inertia

If the net external force is zero, a body at rest continues to remain at rest and a body in motion continues to move with a uniform velocity. This property of the body is called inertia.

Inertia means ‘**resistance to change**’

Newton’s First law of motion

- **Every body continues to be in its state of rest or of uniform motion in a straight line unless compelled by some external force to act otherwise.**
- The state of rest or uniform linear motion both imply zero acceleration.
- The first law of motion can, therefore, be simply expressed as:

If the net external force on a body is zero, its acceleration is zero. Acceleration can be non zero only if there is a net external force on the body.

Example:

- Problem :-Suppose we are standing in a stationary bus and the driver starts the bus suddenly. We get thrown backward with a jerk. Why ?
- Explanation: -Our feet are in touch with the floor. If there were no friction, we would remain where we were, while the floor of the bus would simply slip forward under our feet and the back of the bus would hit us. However, fortunately, there is some friction between the feet and the floor. If the start is not too sudden, i.e. if the acceleration is moderate, the frictional force would be enough to accelerate our feet along with the bus. But our body is not strictly a rigid body. It is deformable, i.e. it allows some relative displacement between different parts. What this means is that while our feet go with the bus, the rest of the body remains where it is due to inertia. Relative to the bus, therefore, we are thrown backward. As soon as that happens, however, the muscular forces on the rest of the body (by the feet) come into play to move the body along with the bus.

Linear Momentum

- Momentum of a body is defined to be the product of its mass *m and velocity v, and is* denoted by p:

  $$\mathbf{p} = \boldsymbol{m}\,\boldsymbol{v}$$

  Momentum is clearly a vector quantity.

Following common experiences indicate the importance of this quantity for considering the effect of force on motion.

- **Suppose a light-weight vehicle (say a small** car) and a heavy weight vehicle (say a loaded truck) are parked on a horizontal road. We all know that a much greater force is needed to push the truck than the car to bring them to the same speed in same time. Similarly, a greater opposing force is needed to stop a heavy body than a light body in the same time, if they are moving with the same speed.

- **If two stones, one light and the other heavy,** are dropped from the top of a building, a person on the ground will find it easier to catch the light stone than the heavy stone. The mass of a body is thus an important parameter that determines the effect of force on its motion.

- **Speed is another important parameter to** consider. A bullet fired by a gun can easily pierce human tissue before it stops, resulting in casualty. The same bullet fired with moderate speed will not cause much damage. Thus for a given mass, the greater the speed, the greater is the opposing force needed to stop the body in a certain time. Taken together, the product of mass and velocity, that is momentum, is evidently a relevant variable of motion. The greater the change in the momentum in a given time, the greater is the force that needs to be applied.

- Observations confirm that the product of mass and velocity (i.e. momentum) is basic to the effect of force on motion. Suppose a fixed force is applied for a certain interval of time on two bodies of different masses, initially at rest, the lighter body picks up a greater speed than the heavier body. However, at the end of the time interval, observations show that each body acquires the same momentum. **Thus the same force for the same time causes the same change in momentum for different bodies. This is a crucial clue to the** second law of motion.

Newton's second law of motion

- **The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts.**

Thus, if under the action of a force **F for time** interval Δt, *the velocity of a body of mass m* changes from **v to v + *Δv i.e. its initial momentum p = m v changes by Δp =mΔv .***

According to the Second Law,

$$F \propto \frac{\Delta p}{\Delta t}$$

$$F = k\frac{\Delta p}{\Delta t}$$

where *k is a constant of proportionality*.

- limit $\Delta t \to 0$, *the term* $\frac{\Delta p}{\Delta t}$ becomes the derivative or differential co-efficient of p with respect to *t, denoted by* $\frac{dp}{dt}$

$$F = k\frac{dp}{dt}$$

$$\frac{dp}{dt} = \frac{d(mv)}{dt} = m\,\frac{d(v)}{dt} = ma$$

$$F = k\,ma$$

m is the mass and a is the acceleration. Unit of force are so chosen that k=1.

$$F = ma$$

Impulse

- The product of force and time, which is the change in momentum of the body remains a measurable quantity. This product is called impulse:

Impulse = Force × time duration = Change in momentum.

$$I = F \times \Delta t = p_2 - p_1$$

Newton's Third law of motion

- To every action there is an equal and opposite reaction.
- important points about the third law, particularly in regard to the usage of the terms : action and reaction.

1. The terms action and reaction in the third law mean nothing else but 'force'. Using different terms for the same physical concept can sometimes be confusing. A simple and clear way of stating the third law is as follows :

   Forces always occur in pairs. Force on a body A by B is equal and opposite to the force on the body B by A.

2. The terms action and reaction in the third law may give a wrong impression that action comes before reaction i.e action is the cause and reaction the effect. **There is no cause effect relation implied in the third law. The force on *A by B and the force on B by A act* at the same instant. By the same reasoning,** any one of them may be called action and the other reaction.

3. Action and reaction forces act on different bodies, not on the same body. Consider a pair of bodies *A and B. According to the third law,*

$$\mathbf{F}_{AB} = -\mathbf{F}_{BA}$$

(force on *A by B) = – (force on B by A)*

- Thank you