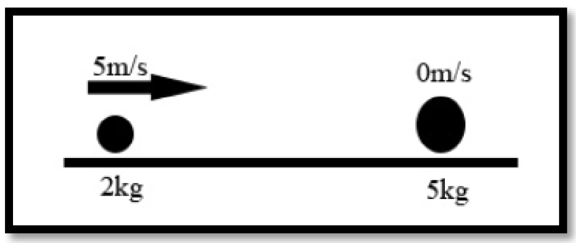
SYSTEM OF PARTICLES AND ROTATIONAL MOTION

LINEAR MOMENTUM OF A SYSTEM OF PARTICLES

Linear Momentum of a System of Particles

Linear momentum is a product of the mass (m) of an object and the velocity (v) of the object. If an object has higher momentum, then it harder to stop it. The formula for linear momentum is p = mv. The total amount of momentum never changes, and this property is called conservation of momentum. Let us study more about Linear momentum and conservation of momentum.



Linear Momentum of System of Particles

We know that the linear momentum of the particle is

$$p = mv$$

Newton's second law for a single particle is given by,

$$F = \frac{dP}{dt}$$

where F is the force of the particle. For ‘ n ‘ no. of particles total linear momentum is,

$$P = p_1 + p_2 + \cdots .. + p_n$$

each of momentum is written as $m_1 v_1 + m_2 v_2 + \ldots\ldots\ldots.. + m_n v_n$. We know that velocity of the center of mass is $V = \sum \frac{m_i v_i}{M}$

$$mv = \Sigma m_i v_i$$

So, comparing these equations we get,

$$P = M\,V$$

Therefore, we can say that the total linear momentum of a system of particles is equal to the product of the total mass of the system and the velocity of its center of mass. Differentiating the above equation we get,

$$\frac{dP}{dt} = M\frac{dV}{dt} = MA$$

dv/dt is acceleration of centre of mass, MA is the force external. So,

$$\frac{dP}{dt} = F_{ext}$$

This above equation is nothing but Newton's second law to a system of particles. If the total external force acting on the system is zero,

$$F_{ext} = 0 \text{ then, } \frac{dP}{dt} = 0$$

This means that $P =$ constant. So whenever the total force acting on the system of a particle is equal to zero then the total linear momentum of the system is constant or conserved. This is nothing but the law of conservation of total linear momentum of a system of particles.

Conservation of Total Linear Momentum of a System of Particles

Let us take the example of radioactive decay. What is radioactive decay? It is a process where an unstable nucleus splits up in relatively stable nuclei releasing a huge amount of energy.

Suppose there is a parent nucleus which is unstable and it wants to become stable, in order to attain stability it will emit α particle and another daughter nucleus.

This daughter nucleus is much more stable than the parent nucleus. This what radioactive decay is. Now suppose the parent nucleus is at rest and also the mass of the α is ' m ' and the daughter nucleus is M.

So the mass of the parent nucleus will be m + M. Here everything that is happening is not due to the external force but all that happens is due to the internal force. So here $F_{ext} = 0$, we can say that

$$\frac{dP}{dt} = 0 \Rightarrow P = \text{ constant}$$

Q. Two unequal masses are tied together with a compressed spring. When the cord is burnt with a matchstick releasing the spring; the two masses fly apart with equal :

a) Momentum

b) Acceleration

c) Speed

d) Kinetic energy

Sol. A. Initially, two unequal masses are tied together with a compressed spring. Then the cord is burnt with the matchstick and the spring released due to this the two masses fly apart and acquire velocities in inverse proportional to their masses and hence fly with equal momentum.