**LINEAR MOMENTUM AND COLLISIONS**

THE **LINEAR MOMENTUM (p)** of a body is the product of its mass (m) and velocity (v):

Linear momentum = (mass of body) (velocity of body)

Momentum is a vector quantity whose direction is that of the velocity. The units of momentum are kg.m/s in the SI.

Momentum can be expressed in component form:

*px = m vx py = m vy pz = m vz*

Newton’s Second Law and Momentum

Newton’s Second Law can be used to relate the momentum of a particle to the resultant force acting on it.

The time rate of change of the linear momentum of a particle is equal to the net force acting on the particle.

The momentum of a system changes if a net force from the environment acts on the system.

**IMPULSE-MOMENTUM THEOREM**

The change in the momentum of a particle is equal to the impulse (I) of the new force acting on the particle.

Impulse = change in momentum

From

Thus, an impulse is also defined as the product of a force (F) and the time interval (Δt) over which the force acts:

Impulse is a vector quantity whose direction is that of the force. Its units are N.s in the SI.

**CONSERVATION OF LINEAR MOMENTUM:** If the net external force acting on a system of objects is zero, the vector sum of the momenta of the objects will remain constant.

**IN COLLISIONS AND EXPLOSIONS**, the vector sum of the momenta just before the event equals the vector sum of the momenta just after the event. The vector sum of the momenta of the objects involved does not change during the collision or explosion.

Thus, when two bodies of masses m1, and m2 collide,

Total momentum before impact = Total momentum after impact

where u1 and u2 are the velocities before impact, and v1 and v2 are the velocities after.

Oblique Collision

* The sum of the momentum before collision along the x- axis is equal to the sum of the momentum after collision along the x – axis

and similarly for the y- and z-axes.

**A PERFECTLY ELASTIC COLLISION** is one in which the sum of the translational kinetic energies of the objects is not changed during the collision. In the case of two bodies,

**COEFFICIENT OF RESTITUTION:** For any collision between two bodies in which the bodies move only along a single straight line (e.g., the x-axis), a coefficient of restitution e is defined. It is a pure number given by

where u1x and u2x are values before impact, and v1x and v2x are values after impact. Notice that is the relative speed of approach and || is the relative speed of recession.

For a perfectly elastic collision, e = 1. For inelastic collisions, e < 1. If the bodies stick together after collision, e = 0.

Sample Problems

1. A 2-kg brick is moving at a speed of 6m/s. How large a force *F* is needed to stop the brick in a time of 7x10-4 s?
2. A 0.25-kg ball moving in the +x-direction at 13m/s is hit by a bat. Its final velocity is 19m/s in the –x-direction. The bat acts on the ball for 0.01 s. Find the average force exerted on the ball by the bat.
3. An 8-g bullet is fired horizontally into a 9-kg cube of wood, which is at rest, and sticks in it. The cube is free to move and has a speed of 40cm/s after impact. Find the initial velocity of the bullet.
4. A 16-g mass is moving in the +x-direction at 30cm/s while a 4 g mass is moving in the –x-direction at 50cm/s. They collide head on and stick together. Find their velocity after the collision.
5. A 1-kg ball is moving at 12m/s collides head-on with a 2-kg ball moving in the opposite direction at 24 m/s. Determine the motion of each after impact if (a) *e* = 2/3, (b) the balls stick together, and (c) the collision is perfectly elastic.