Impulse

A car and a semi are traveling down the road at the same velocity. They come to a stop in the same amount of time. What can we say about the two systems?

There is a larger amount of force required to stop the semi versus the car. This force applied during the time change is called the impulse.

$$\text{Impulse} = F\Delta t$$

Momentum

The amount of force needed to stop an object would depend on the size of the object and the speed in which it is traveling.

Momentum is a quantity that describes the velocity of the object and the object's mass. Momentum (p) is described by the following equation:

$$p = mv \quad (p \text{ unit} = kg*m/s)$$

Newton's first law applies to momentum just like it applies to velocity.

Impulse - Momentum Theorem

Applying Newton's 2nd law to momentum, we can change F = ma into

$$F = \frac{m\Delta v}{\Delta t}$$

Which then can be rearranged into

$$F\Delta t = m\Delta v$$

$$\text{or } F\Delta t = \Delta p$$

This shows that in order to change momentum, an impulse must be applied.

Example

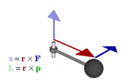
A 0.75 kg football is flying horizontally through the air at a speed of -10 m/s. It is intercepted by an opposing player who is running at +4 m/s.

a) What is the momentum of the football while in the air?
b) What impulse is required to change the football's direction?
c) If the ball changes from -10 m/s to +4 m/s in 0.5 s, what force is applied by the player?

Angular Momentum

Angular momentum is the momentum of an object moving in a circle. For an object moving in a circle with a constant speed, the angular momentum calculated as:

$$L = mvr$$



This relationship is true as long as there is no torque on the object (Force that changes the speed of circular motion).

Conserving Angular Momentum

When the torque doesn't change, the angular momentum is conserved in a system.

Therefore, if the radius changes, the speed of the object changes accordingly.

Applications: orbiting planets, figure skaters

Changing Angular Momentum

- Angular momentum will remain constant unless a torque is applied. When torque (which changes rotational motion) is applied over a period of time, the speed or radius of the motion will alter.

$$\tau(\Delta t) = \Delta L$$

$$Fr(\Delta t) = m\Delta vr$$

$$Fr\sin\theta(\Delta t) = m\Delta vr$$

(when F applied at angle)

Momentum & Collisions

Because of Newton's 3rd Law of Motion, forces in a collision are equal and opposite.

If this is true, then the impulses (FΔt) are also equal, which means the momentum changes are also equal. ($F\Delta t = \Delta p$)

In other words, in a collision, the momentum gained by object 1 will be equal to the momentum lost by object 2.

$$\Delta p_1 = \Delta p_2$$

Momentum in a collision is conserved. This means that the total amount of momentum in the system is constant, or the sum of the initial momentums have to equal the sum of the final momentums.

Types of Collisions

In a closed system, where no external forces are applied, then three* types of collisions can occur.

1) Elastic - collision results in objects bouncing off of one another.
2) Inelastic - collision results in objects sticking together.
3) Explosion - objects are motionless, and an internal force pushes them apart.

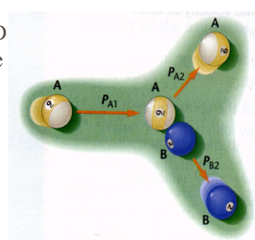
Example

In a serious accident, two cars hit head-on. Car 1 has a mass of 1500 kg and was traveling at a speed of 32 m/s. Car 2 has a mass of 2000 kg and was traveling at a speed of - 21 m/s.

a) What is the momentum of each car before the collision?
b) What is the total momentum of the system before the crash?
c) What must the total momentum be after the crash?
d) If the cars stuck together in the collision, at what speed would the wreckage travel after colliding?

Conservation of Momentum in 2D

Momentum is conserved in 2D collisions as it is in 1D collisions. The difference is that the total of the initial momentum vector(s) is equal to the total of the final momentum vector(s).



Example

A 2.0 kg ball (A) is moving at a speed of 5.0 m/s. It collides with a stationary 1.5 kg ball (B). After the collision, ball A moves off in a direction 30^O to the left of its original direction. Ball B moves off in a direction 60^O to the right of ball A's original direction.

a) Determine the initial momentum of the system.
b) What would be the final momentum of the whole system (magnitude and direction)
c) What is the final momentum of each ball?
d) What is the final speed of each ball?