Physics 1408/1420

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Hello Fellow Physicists

I am Aman Patel, the Master Tutor for Physics this semester. I have created this resource document to help you review some of the topics you have been introduced to this semester to better prepare for your Final in physics.

Keywords: Momentum, Impulse, Conservation of Momentum, Collisions

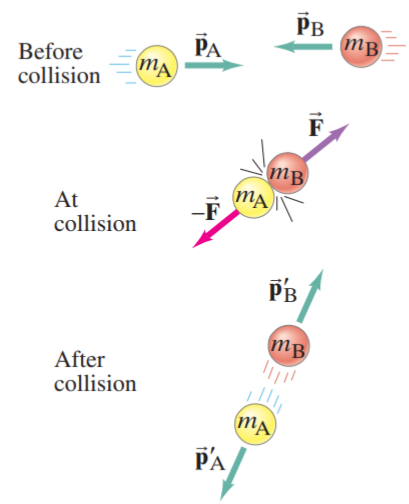
Important Notes

Important Conventions

Momentum

The momentum of an object is another variable that defines the motion of object. The momentum of an object is defined by the product of the object's mass and velocity. The momentum of an object is a vector quantity. It is extremely important to remember that the direction of momentum matters a lot when looking at momentum problem. Momentum can be calculated using

$$\mathbf{p = m \cdot v}$$



Impulse

Much like how forces that do work on an object, forces can change the momentum of an object. you can observe this when cars collide. You can see the crumple of the cars when they collide. That is the effect of the force both cars experience when their momentum goes to zero in a very short time span. This force they experience over the period of time is called impulse. Impulse is the product of the force and time. It is also equal to the change in momentum of the object. Impulse can be calculated using the following formula.

$$\textbf{Impulse} = \mathbf{F}.\ \Delta t = \Delta p$$

Example

For top players, a tennis ball may leave the racket on the serve with a speed of 55 m/s. if the ball has a mass of 0.06kg and is in contact with the racket for about 4 ms, estimate the average force on the ball

Solution:

Mass = 0.06 kg

v = 55 m/s

▲t = 0.004 s

F ▲t = ▲p

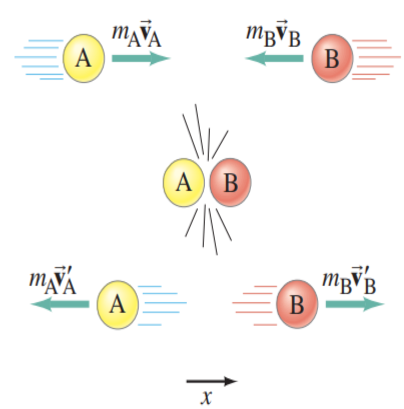
F = ▲p / ▲t

F = $mv_2 – mv_1$/ ▲t

F = (0.06)(55) – 0 / 0.004

F = 825 N

Conservation of Momentum



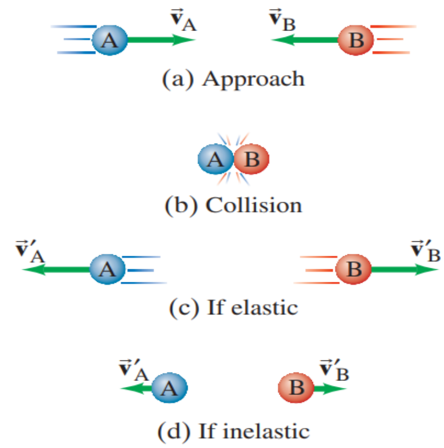
Much like energy, momentum is also conserved in a system. The momentum before will equal the momentum after in the system. So, in an isolated system,

$$p_{before} = p_{after}$$

$$m_A v_{A1} + m_B v_{B1} = m_A v_{A2} + m_B v_{B2}$$

Collisions

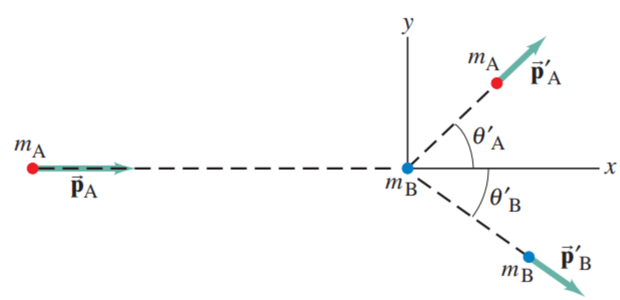
There are two different types of collisions: elastic and inelastic. In both of these collisions, momentum is always conserved but energy is not always conserved.



Elastic Collisions: collisions in which the kinetic energy of the colliding objects is conserved. The objects bounce off one another and we assume there is no friction or heat given off. Hence, the total kinetic energy is conserved.

Inelastic Collisions: collisions in which the kinetic energy of the colliding objects is not conserved. The objects stick together, which gives off heat, hence kinetic energy would not be conserved.

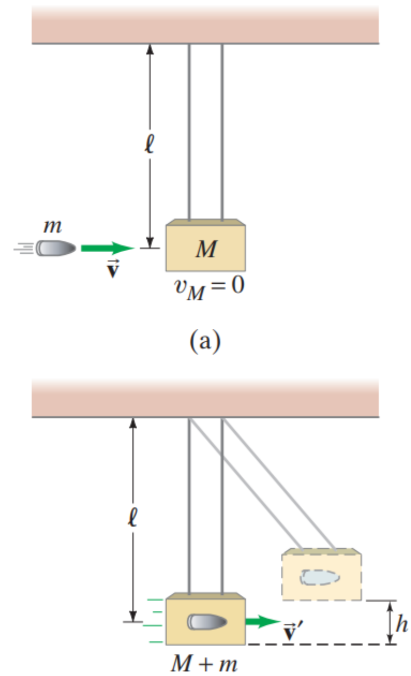
Collisions can also occur in two dimensions. In this scenario, you must approach the problem from each axis separately and then combine the x and y components to find the resultant momentum vector.



Example

The ballistic pendulum is a device used to measure the speed of a projectile, such as a bullet. The projectile, of mass m, is fired into a large block of mass M, which is suspended like a pendulum. After the collision, the pendulum and projectile together swing up to a maximum height h. Determine the relationship between the initial horizontal speed of the projectile, v, and maximum height h.

Solution



When the projectile collides with the large block of mass, it resides in the large block. This is an inelastic collision. Hence, energy will not be conserved in this collision, but momentum will be conserved.

$p_{\text{before}} = p_{\text{after}}$

$mv = (m + M)\, v'$

$v = [(m + M) / m]\, v'$

When the projectile and the block have collided at the bottom, the kinetic energy of the system will convert to gravitational potential energy.

$E_{\text{before}} = E_{\text{after}}$

$(1/2)(m+M)v'^2 = (m+M)gh$

$v' = [\, 2\, g\, h\,]^{1/2}$

so, substituting v' from the momentum equation

$v = [(m + M) / m]\, [2gh]^{1/2}$

All images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli