

Physics 1408/1420 – General Physics 1

Week of February 26th, 2022

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Hello Fellow Physicists,

I am Jorge Martinez, the Master Tutor for Physics this semester. To help you on your journey to learn about this wonderful branch of science and the understanding it gives us of the world around us, I will be preparing this resource every week to give you an additional tool to better prepare for your week. I will also be conducting Group Tutoring sessions every week, the information for which will be given below. If you are unable to attend group tutoring, the tutoring center also offers one-on-one tutoring session, so be sure to visit the tutoring center or visit <https://baylor.edu/tutoring>.

PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Monday from 6:30-7:30 pm in the Sid Richardson building basement, Room 75. See you there!

Over the last week, your professors will have covered energy and conservation of mechanical energy.

This week, you will explore momentum.

Keywords: Momentum, Conservation of Momentum, Impulse

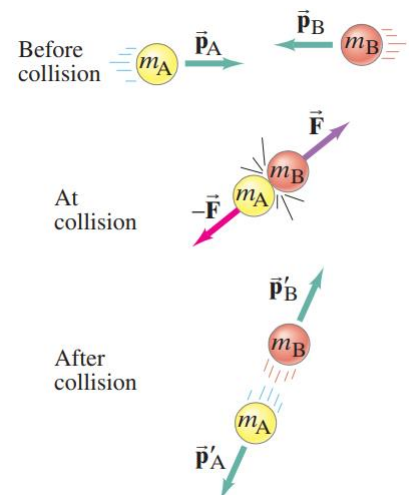
Important Notes

Important Conventions

Topic of the Week : 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

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



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

Highlight 1: Impulse

Just as forces can do work on an object, **forces can also change the momentum of the 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.

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

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:

$$\text{Mass} = 0.06 \text{ kg}$$

$$v = 55 \text{ m/s}$$

$$\Delta t = 0.004 \text{ s}$$

$$F \Delta t = \Delta p$$

$$F = \Delta p / \Delta t$$

$$F = mv_2 - mv_1 / \Delta t$$

$$F = (0.06)(55) - 0 / 0.004$$

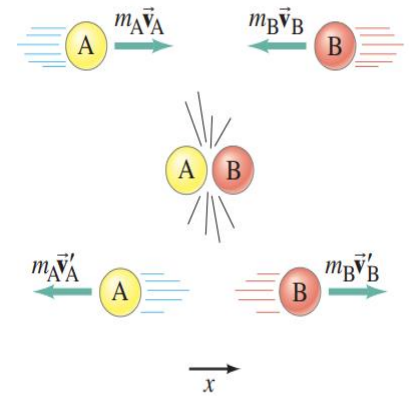
$$F = 825 \text{ N}$$

Highlight 2: Conservation of Momentum

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

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

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

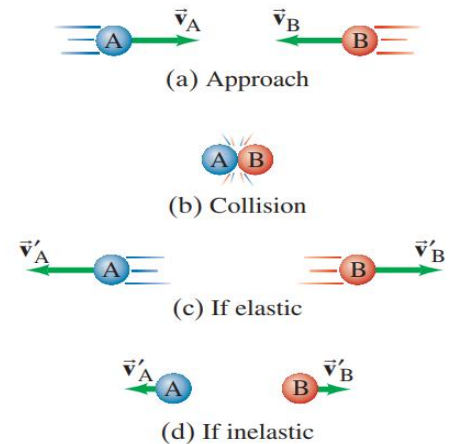


Highlight 3: Collisions

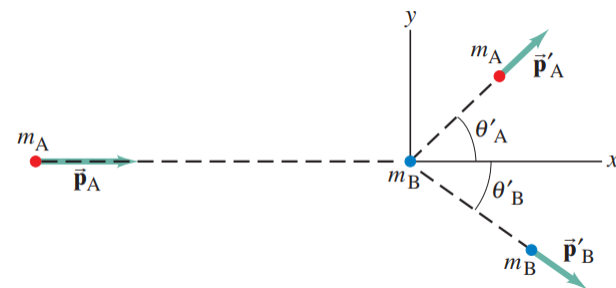
There are two different types of collisions: elastic and inelastic. In both of these collisions, **momentum is always conserved but energy is not always conserved.**

Elastic Collisions are 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 are 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.

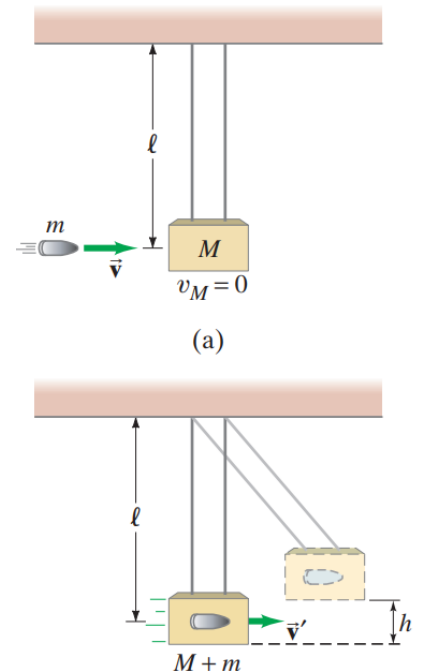
$$E_{\text{before}} = E_{\text{after}}$$

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

$$v' = [2gh]^{1/2}$$

so, substituting v' from the momentum equation

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



CHECK YOUR LEARNING

1. A child in a boat throws a 2 kg package out horizontally with a speed of 5 m/s. What is the velocity of the boat right after the package is thrown? The mass of the child is 30 kg and the boat is 50 kg.
 2. What impulse is applied to a 0.2 kg baseball for it to be thrown at 3 m/s? What was the acceleration of the ball if the force was applied for 1 s?
 3. A 10g rifle bullet traveling at v embeds itself in 1 kg pendulum hanging on a 1 m long string. The pendulum is displaced by 0.4 m in the vertical direction. What is the horizontal displacement of the pendulum and what is the velocity of the bullet after leaves the rifle?
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THINGS YOU MAY STRUGGLE WITH

1. Make sure that you understand the difference between elastic and inelastic collisions. Remember, when energy is conserved in the collision, that is an elastic collision. When energy is not conserved in a collision, that is an inelastic collision.
2. Read the problem carefully, looking for words that indicate the type of collision involved. Problem questions will generally mention whether the collision was elastic or not. Whenever things collide or pass through something, like a bullet through a block, there is a change in shape or physical properties of the material, indicating that they are inelastic collisions since energy is lost in the form of heat or to change the shape.
3. You will need to combine the laws of conservation of momentum and energy. For collisions, whenever they are inelastic, momentum and energy are conserved. On the other hand, for elastic collisions, only momentum is conserved. Notice that momentum is conserved in both cases! This means that it is always a good idea to start analyzing the problem by calculating the momentum in the system!!
4. Be careful with collision problems in two dimensions. Remember, whenever you encounter vectors that are diagonal with respect to each other, always, always, always analyze the system in x and y axis separately to find the final vectors in each dimension. Once you have done this, combine the x and y components to find the final vector. In other words, if the vectors are at an angle, always break up the problem into its components to analyze the motion.

I hope you have a wonderful week! Please feel free to reach out to me if you have any questions and check out all the resources the Tutoring Center has to offer at: <https://baylor.edu/tutoring>

Answer: 1. 0.125 m/s, 2. 0.6 N.s, 3 m/s², 3. 0.8 m, 283 m/s

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