AP Physics C: Mechanics
Unit 5 – Momentum and Collisions
Assessment

Name: _____ Period: _____

Summary

- The **linear momentum** of a particle of mass m moving at a velocity **v** is defined to be:

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

- The **impulse**, **J**, of a force **F** on a particle is equal to the change in the momentum of the particle and is given by:

$$\boldsymbol{J} = \Delta p = \int_{t_1}^{t_2} \boldsymbol{F} dt$$

- **Impulsive forces** are forces that are very strong compared with other forces on the system and usually act for a very short time, as in the case of collisions.
- The **Law of Conservation of Momentum** for two interacting particle states that if the two particles form an isolated system, their total momentum is conserved regardless of the nature of the force between them. Therefore, the total momentum of the system at all times equals its initial total momentum, or

$$\mathbf{p}_{1i} + \mathbf{p}_{2i} = \mathbf{p}_{1f} + \mathbf{p}_{2f}$$

- When two particles collide, the total momentum of the system before the collision always equals the total momentum of the system after the collision, regardless of the nature of the collisions. In an **elastic collision**, kinetic energy, T, (or mechanical energy) is also conserved. In an **inelastic collision**, the two particles bounce off each other and kinetic energy is not conserved. A **perfectly inelastic collision** results in the two bodies sticking together after the collision (kinetic energy is also not conserved).
- The **vector position** of the center of mass of a system of particles is defined by:

$$\boldsymbol{r}_c = \frac{\sum m_i \boldsymbol{r}_i}{M}$$

Where M is the total mass of the system and $\mathbf{r}_i$ is the vector position of the *i*th particle.

- The **vector position of the center of mass of a rigid body** can be obtained from the integral expression:

$$\boldsymbol{r}_c = \frac{1}{M}\int \boldsymbol{r} dm$$

- The **velocity for the center of mass** for a system of particles is given by:

$$\boldsymbol{v}_c = \frac{\sum m_i \boldsymbol{v}_i}{M}$$

- The **total momentum of a system of particles** equals the total mass multiplied by the velocity of th center of mass:

$$\mathbf{P} = M\mathbf{v}_c$$

- **Newton's Second Law applied to a system of particles** is given by:

$$\sum \boldsymbol{F}_{ext} = M\boldsymbol{a}_c = \frac{d\boldsymbol{P}}{dt}$$

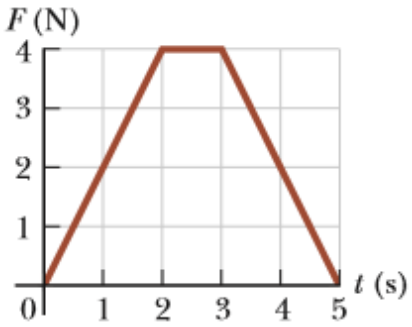
Where $\mathbf{a}_c$ is the acceleration of the center of mass and the sum is over all external forces. Therefore, the center of mass loves like an imaginary particles of mass M under the influence of the resultant force on the system. The total momentum of the system is conserved.

Concepts

1) Does a large force always produce a large impulse on a system? Why or why not?
2) If two objects collide and one is initially at rest, is it possible for both to be at rest after the collision? Is it possible for one to be at rest after the collision? Explain.
3) Is it possible to have a collision in which all kinetic energy is lost? If so, cite an example.
4) In a perfectly elastic collision between two particles, does the kinetic energy of each particle change as the result of the collision?
5) A sharpshooter fires a rifle while standing with the butt of the gun against his shoulder. If the forward momentum of the bullet is the same as the backward momentum of the gun, why isn't it as dangerous to be hit by the gun as by the bullet?
6) A piece of gum is thrown against a brick wall and sticks to the wall. What happens to the momentum of the gum? Is momentum conserved? Explain.

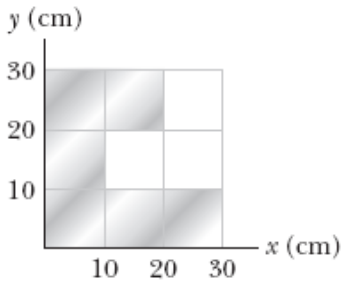
Problems

7) The force F_x acting on a 2 kg particle varies in time as shown. Find the
    a. impulse of the force.
    b. final velocity of the particle if it is initially at rest.
    c. final velocity of the particle if it is initially moving along the x-axis with a velocity of -2**i** m/s.
    d. average force exerted on the particle for the time interval $t_i = 0$ s to $t_f = 5$ s.



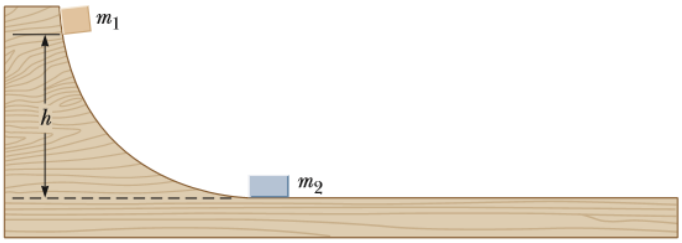
8) A steel ball (3 kg) strikes a massive wall with a speed of 10 m/s at an angle of 60° with respect to the surface. It bounces off with the same speed and angle. If the ball is in contact with the wall for 0.20 s, what is the average force exerted on the ball by the wall?
9) Two ice skaters, a 60 kg boy and a 40 kg girl are at rest facing each other. When their routine begins, the boy pushes the girl, sending her eastward with a speed of 4 m/s. Describe the subsequent motion of the boy.
10) A 1200 kg car is travelling eastward at a speed of 25 m/s. it crashes into the rear end of a 9000 kg truck moving in the same direction at 20 m/s. The velocity of the car right after the collision is 18 m/s to the east.
    a. What is the velocity of the truck right after the collision?
    b. How much mechanical energy is lost in this collision?
    c. How do you account for the loss in energy?
11) A 10 kg mass, initially at rest, explodes into three pieces. A 4.5 kg mass goes north at 20 m/s, and a 2 kg piece moves eastward at 60 m/s.
    a. Determine the magnitude and direction of the velocity of the third piece.
    b. Find the energy of the explosion.

12) A uniform piece of sheet steel is shaped as shown. Compute the x- and y-coordinates of its center of mass.



13) A 12 g bullet is fired into a block of mass 100 g that is initially at rest on a horizontal surface. After impact, the block slides 7.5 m before coming to rest. If the coefficient of friction between the block and the surface is 0.65, what is the speed of the bullet immediately before impact?

14) Consider a frictionless track, as shown below. A block of mass m_1 = 5 kg is released from a height h. It makes a head-on elastic collision with a block of mass m_2 = 10 kg at rest at the bottom of the ramp. Calculate the maximum height to which m_1 will rise after the collision.



15) A shell is fired from a cannon at ground level to hit an enemy bunker situated a distance R from the cannon. At the highest point of the trajectory, the shell explodes into two equal parts. One part of the shell is found to hit the ground at R/2 At what distance from the cannon would the second fragment fall? You may assume air resistance is negligible.

16) A chain of length L and total mass M is being held vertically with the lower end just touching the top of a table. It is held at the top at rest and then released. Find the force of the table on the chain after the chain has fallen a distance x. You may assume that each link comes to rest immediately upon reaching the table.