AP Physics C

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Chapter 9: Momentum

Background/Summary:

- Chapter 9, Momentum, covers a wide variety of topics such as Linear Momentum, Impulse, Collisions, and Center of Mass. It explores how to calculate an object's momentum when acted upon by a force or another object and the Law of Conservation of Momentum.

Major Topics:

- **Linear Momentum**
  - Linear Momentum is the product of an object's mass and velocity and is often denoted with a **p**.
  - It is a vector quantity, which means it has both magnitude and direction, and it is conserved in isolated systems.
- **Impulse**
  - Impulse is the change of an object's momentum due to a force acted upon and is often denoted with a **J**.
  - It is a vector quantity as well.
- **Conservation of Linear Momentum**
  - Conservation of Linear Momentum is when two objects that collide within a closed system, the total momentum before and after the collision **is the same**.
- **Collisions**
  - Elastic Collision
    - Where there is a **negligible** loss of energy to heat within the collision. Kinetic Energy is **conserved** within this collision.
  - Inelastic Collision
    - Where there is **some** loss of energy to heat within the collision. Kinetic Energy is **not conserved** within this collision.
  - Perfectly Inelastic Collision
    - A special type of inelastic collision where the two objects collide and **stick together** after collision.
- **Center of Mass**
  - Center of Mass is located at the "weighted average position of the system's mass"[1]. It is where the object responds to forces as if they were all concentrated at that point.

[1] Taken from the Crashwhite Website.
https://www.crashwhite.com/apphysics/materials/presentations/sem1-ch9/index.html#three

Formulae:

Major Topic	*Equation*	*Situations Used*
Momentum	$\vec{p} = m\vec{v}$; Newton x Seconds	Used to figure out the momentum of an object.
Momentum	$\vec{F} = \frac{\Delta p}{\Delta t}; F = \frac{dp}{dt}$; Newton	Used to figure out the force of an object using momentum.
Impulse	$J = \int_{t1}^{t2} F(t)dt = \Delta p$; Newton x Sec	Used to figure out the impulse of an object with change in momentum or integral of force with respect to time.
Conservation of Momentum	$p_1 + p_2 = p_1^{\,I} + p_2^{\,I}$; $m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}_1^{\,I} + m_2\vec{v}_2^{\,I}$	Used to figure out the mass or velocity of objects at certain points when momentum is conserved during a collision
Elastic Collision	$p_1 + p_2 = p_1^{\,I} + p_2^{\,I}$; $K_1 + K_2 = K_1^{\,I} + K_2^{\,I}$	Used to figure out the momentum of each object during collision
Inelastic Collision	$p_1 + p_2 = p_1^{\,I} + p_2^{\,I}$; $m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}_1^{\,I} + m_2\vec{v}_2^{\,I}$	Used to figure out the momentum of each object during collision
Perfectly Inelastic Collision	$p_1 + p_2 = p^I$; $m_1\vec{v}_1 + m_2\vec{v}_2 = (m_1 + m_2)\,\vec{v}^{\,I}$	Used to figure out the momentum of each object during collision
Center of Mass	$x_{cm} = \frac{\Sigma m_i x_i}{\Sigma m_i}; y_{cm} = \frac{\Sigma m_i y_i}{\Sigma m_i}$; $z_{cm} = \frac{\Sigma m_i z_i}{\Sigma m_i}$;	Used to figure out the center of mass of an object in a 2d-3d plane.

Continuous Distribution	$M = \rho V; x_{cm} = \frac{1}{M}\int x dm$	Used to figure out the center of mass for a continuous distribution
Density Equations	$\rho = \frac{dm}{dV}; \lambda = \frac{dm}{dL}; \sigma = \frac{dm}{dA}$	Used within the continuous distribution equation
System in Motion	$v_{cm} = \frac{\sum m_i \vec{v}_i}{M}; Mv_{cm} = \sum \vec{p}_i$	Used to figure out the center of mass of the system in motion

Practice Problems

1. *A soccer ball of mass 7.55 kg is moving with a constant velocity of 10.0 m/s. What is the momentum of the bowling ball? Assuming an even distribution of mass, where would the ball's center of mass be?* *[Easy]*

1) Cal $p = mv$ $m = 7.55\ kg$ $v = 10.0\ m/s$

$p = (7.55)(10.0) = 75.5\ N \cdot s$

(b) Mass is distributed evenly, so the ball's center of mass should be in the center.

2. *The soccer ball in question 1 collides with another ball of mass 5.25 kg in an elastic collision. The ball keeps going at a velocity of 3.5 m/s. What is the velocity of the other ball?* *[Medium]*

2) $p_1 + \cancel{p_2}^{0} = p_1' + p_2'$

$m_1 = 7.55\ kg$ $m_2 = 5.25\ kg$

$v_1 = 10.0\ m/s$ $v_1' = 3.5\ m/s$

$v_2 = 0.0\ m/s$ $v_2' = ?$

$m_1v_1 = m_1v_1' + m_2v_2'$

$(7.55)(10.0) = (7.55)(3.5) + (5.25)v_2'$

$$v_2' = \frac{(7.55)(10.0) - (7.55)(3.5)}{5.25}$$

$$\boxed{v_2' = 9.35\ m/s}$$

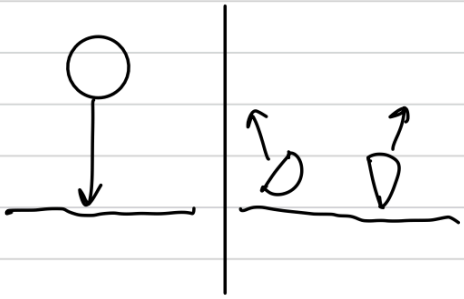
3. *A crystal of mass 8.44 kg is dropped from a height of 14.0 m. When the crystal hits the ground, it breaks into two pieces of ¼ the initial mass (R_1) and ¾ of the initial mass (R_2). Both of the pieces fly into the air.*

   (a) Calculate the net momentum for the rock just before it hits the ground. [Hard]

3) (a) $v_f = \sqrt{v_i^2 + 2a(\Delta x)}$

$v = \sqrt{0 + 2(9.81)(14)}$

$v = 16.57\ m/s$



$p = mv$ $p = (8.44)(16.57)$

$$\boxed{p = 139.85\ N \cdot s}$$