Lab: AP Review Sheets AP Physics
Chapter 9: Momentum Peter Panossian

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Background/Summary:

Momentum measures an object's motion after an impact and is a vector quantity (has both magnitude and direction). In a closed system, total momentum is conserved, remaining constant over the course of a collision.

Major Topics:

Linear Momentum: Describes the object's motion and includes magnitude and direction.

- Linear Momentum(p) = Mass(m) x Velocity (v)

Impulse: Product of force and the total time. Measures the change in momentum in Newton-seconds (N·s).

- Impulse (J) = ∫Force(F)dt = Change in momentum(Δp)

Conservation of Linear Momentum: The total momentum of a closed system remains constant if no external forces act on the object

- $\Sigma p_{initial} = \Sigma p_{final}$

Elastic Collision: A collision between two or more objects where momentum and kinetic energy are conserved. The objects bounce off each other without losing kinetic energy (K) to other forms, such as heat or sound.

- $\Sigma p_{initial} = \Sigma p_{final}$ or $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$
- $\Sigma K_{initial} = \Sigma K_{final}$ or $(½)m_1v_{1i}^2 + (½)m_2v_{2i}^2 = (½)m_1v_{1f}^2 + (½)m_2v_{2f}^2$

Inelastic Collision: A collision between two or more objects in which momentum is conserved, but kinetic energy is not conserved. The kinetic energy is transformed into heat, sound, or deformation of the objects involved.

- $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$

Perfectly Inelastic Collision: A specific type of inelastic collision where the colliding objects stick together after the collision, moving as a single mass. In this type of collision, momentum is conserved, but kinetic energy is not.

- $m_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v_f$

Center of Mass: The point the system's mass is considered to be concentrated to calculate its motion

- $r_{cm} = \Sigma m_i r_i$ or $r_{cm} = x_{cm}\hat{\imath} + y_{cm}\hat{\jmath} + z_{cm}\hat{k}$

Continuous Distribution of Mass: A situation where mass spreads continuously over a region. An object's mass is not made up of discrete particles but is distributed smoothly over space.

- $r_{cm} = (1/M)\int(r)dm$

Density: Measure of mass per unit volume of a substance

Volume: $\rho = \dfrac{dm}{dV} \rightarrow dm = \rho\, dV$

Length: $\lambda = \dfrac{dm}{dL} \rightarrow dm = \lambda\, dL$

Area: $\sigma = \dfrac{dm}{dA} \rightarrow dm = \sigma\, dA$

λ = linear mass density
σ = area mass density

(Easy) A soccer player kicks a ball with a force of 50 N for 0.2 seconds. If the ball's mass is 0.4 kg, calculate the impulse experienced by the ball.

Solution:

List of known values:

F = 50N, t = 0.2 seconds, m = 0.4 kg

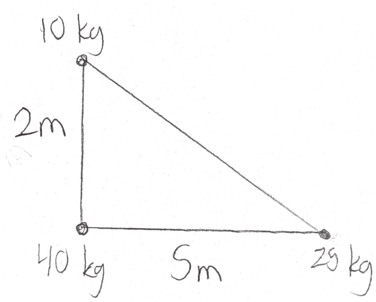
You can use the impulse formula by plugging in the values given in the question. Since the force is constant, the mass is not relevant in this situation:

J = F x t

J = 50N x 0.2s

J = <u>10 N·s</u>

(Medium) Find the center of mass of the system below.



Solution:

Must analyze the center of mass in both the x and y directions and equations posted above:

X-direction:

$x_{cm} = (1/M)\mathbf{\Sigma} m_i x_i$

$x_{cm} = (1/10 + 40 + 25)\ (25(0) + (40)(5) + 10(5))$

$x_{cm} = (1/75)\ (250)$

$x_{cm} = 3.33$ m

Y-direction:

$y_{cm} = (1/M)\mathbf{\Sigma} m_i y_i$

$y_{cm} = (1/10 + 40 + 25)\ (25(0) + (40)(0) + 10(2))$

$y_{cm} = (1/75)\ (20)$

$y_{cm} = 0.27$ m

Then, put the final answer in terms of r_{cm} and $\hat{i}\hat{j}\hat{k}$:

$r_{cm} = \underline{(3.33\hat{i} + 0.27\hat{j})\text{m}}$

(Hard) A 0.240-kg billiard ball that is moving at 3.00 m/s strikes the pool table bumper and bounces straight back at 2.40 m/s (80% of its original speed). The collision lasts 0.0150s. (A) Calculate the average force exerted on the ball by the bumper. (B) How much kinetic energy in joules is lost during the collision? (C) What percent of the original energy is left?

Solution:

Part A: First, solve for the momentum of the ball using $\Delta p = F\Delta t$:

$\Delta p = F\Delta t$

$p_f - p_i = F\Delta t$

$(p_f - p_i)/\Delta t = F$

$m(v_f - v_i)/\Delta t = F$

$0.240(-2.40 - 3.00)/0.0150 = F$

F = <u>-86.4 N</u>

This answer makes sense because the force applied to the ball had to be pointing to the left in order to change its momentum/velocity.

Part B: Reorganizing the conservation of kinetic energy in order to solve for the kinetic energy lost during the collision:

$K_{lost} = K_{initial} - K_{final}$

$K_{lost} = (½)mv_i^2 - (½)mv_f^2$

$K_{lost} = (½)(0.240)(3.00)^2 - (½)(0.240)(2.40)^2$

K_{lost} = <u>0.389 J of kinetic energy lost</u>

Part C: Creating a fraction of the kinetic energy lost over the initial kinetic energy:

$1 - (K_{lost}/K_{initial})$ = energy left

$1 - (0.389/1.08) = 0.64$

Multiply 0.64 by 100 to convert the decimal into a percent:

0.64 x 100 = <u>64.0% of original energy left</u>