Lab: AP Review Sheets
Mechanics Chapter 9: Momentum

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Background / Summary

Momentum is defined as mass times velocity (p=mv). By putting acceleration in terms of velocity and time, we can find momentum in Newton's second law; $F_{net} = m\frac{v_f - v_i}{\Delta t} = \frac{mv_f - mv_i}{\Delta t}$.

The Center of Mass of an object or system is also relevant to these calculations. An object's center of mass is simply where mass is evenly distributed on each side of a point.

Relevant Formulas (courtesy of the AP Equations sheet)

$$\vec{p} = m\vec{v} \qquad \vec{J} = \int \vec{F}\,dt = \Delta\vec{p} \qquad \vec{F} = \frac{d\vec{p}}{dt} \qquad x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$$

Other Key Points

- The Law of Conservation of Momentum states that "Whenever two or more particles in an isolated system interact, their total linear momentum remains constant."[1]
  - Can solve these types of problems simply by setting initial momentum equal to final momentum amongst two (or more) objects like so: $m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$[2]
- There are three types of collisions, elastic, inelastic, and perfectly inelastic
  - Elastic Collisions lose negligible amounts of or no energy, thus both energy and momentum can be solved for in the same manner as above, in the case of energy by setting initial Kinetic Energy equal to final Kinetic energy.
  - Inelastic Collisions, the most common type, do lose energy, but momentum is still conserved.
  - Perfectly Inelastic Collisions occur when the two objects stick together at the end of the problem, having the same velocity. Momentum is still conserved, but because the velocity is the same these problems can be simplified further to: $m_1v_1 + m_2v_2 = v_f(m_1 + m_2)$

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[1] Taken word for word from crashwhite.com, there is no better worded definition

[2] ' here denotes a change in the relevant variable. Traditionally it is the velocity that changes, but the mass can also change in certain instances (such as explosions).

Review Problems

1. [Easy]
    a. A bowling ball of mass 6.35 kg is moving with a constant velocity of 8.0 m/s. What is the momentum of the bowling ball?
    b. Assuming an even distribution of mass, discounting the lack of mass for finger holes, where should the ball's center of mass be?
2. [Medium] The above bowling ball collides with two pins of 1.5 kg each in an elastic collision. The ball keeps going at a velocity of 2.0 m/s. Assuming the two pins move at the exact same velocity, what is that velocity?[3]
3. [Hard] A rock of mass 7.38 kg is dropped from a height of 12.0 m. When the rock hits the ground, it breaks into three pieces of ½ the initial mass (R_1), ⅓ the initial mass (R_2), and ⅙ the initial mass (R_3). All three pieces fly straight up into the air.
    a. Calculate the net momentum for the rock just before it hits the ground
    b. The time between the rock hitting the ground and the three pieces bouncing back into the air is 0.2s. How does this change the momentum?

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[3] The author of these problems doesn't bowl, please excuse any mistakes or misconceptions regarding the game.

#1 a) $p = mv$

$M = 6.35$ kg
$v = 8.0$ m/s

$$p = (6.35)(8.0) = \boxed{50.8 \text{ kg m/s}}$$

b) If mass is distributed evenly, the center of mass is the center of the ball

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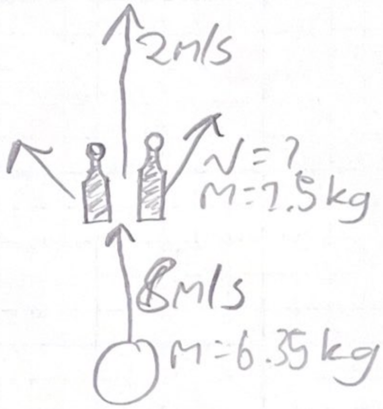
#2

$$p_b + \overset{v=0}{\cancel{p_{p1}}} + \overset{v=0}{\cancel{p_{p2}}} = p_b' + p_{p1}' + p_{p2}'$$



$$50.8 = (6.35)(2) + 1.5v + 1.5v$$

$$50.8 - 12.7 = v(3)$$

$$v = \frac{38.1}{3} = \boxed{12.7 \text{ m/s}}$$

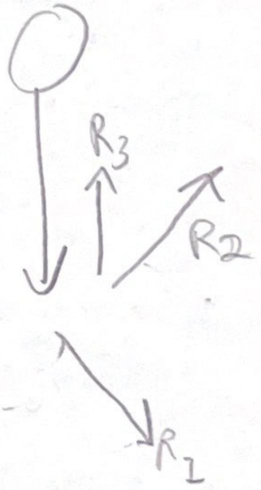
#3

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

$v = \sqrt{0 + 2(9.8)(12)}$

$= 15.3 \, m/s$

$p = 7.38 \cdot 15.3 = \boxed{113.0^{kg\,m/s}}$



b) $F = \frac{dp}{dt} = ma$

$\int dp = \int ma \, dt$

$\Delta p = mat$

$= (7.38)(9.8)(0.2) = 14.5^{kg\,m/s}$

$p_1, p_2, p_3 = 113 - 14.5 = 98.5^{kg\,m/s}$