8.1 – Momentum

The apple doesn’t move!

1. Example

What is the momentum of a 12 g, 400 m/s bullet? (45 cal.)

Convert 12 grams to kg first: 0.012 kg

\[ p = mv \]

\[ = 0.012 \text{kg} \cdot 400 \frac{m}{s} = 4.8 \frac{kg \cdot m}{s} \]

2. Example

How fast would you have to be traveling to have the same momentum (4.8 kg m/s)?

(Conversion: There are 2.2 pounds per kilogram)

A 150 pound person is about 68 kg.

\[ p = mv \]

\[ \frac{v}{m} = \frac{4.8 \frac{kg}{s}}{68 \text{kg}} = 0.071 \frac{m}{s} \left( \frac{7.1 \text{cm}}{s} \right) \]

Not all that fast.

3. Example

Object A (p = 3.1 kg m/s) following object B (p = 2.5 kg m/s) collides with it and sticks. Both are 1.0 kg.

A. What is the resulting momentum?

\[ \vec{p} = \vec{p}_1 + \vec{p}_2 + \ldots = \sum \vec{p}_i \]

\[ p = \text{total momentum} \]

\[ p_i = \text{individual momenta} \]

\[ \vec{p} = 3.1 \text{kg m/s} + 2.5 \text{kg m/s} = 5.6 \text{kg m/s} \]

B. How fast will they be going after the collision?

\[ \vec{v} = \vec{p} \]

\[ \frac{v}{m} = \frac{5.6 \text{kg m/s}}{2.0 \text{kg}} = 2.8 \frac{m}{s} \]
4. Example

What is the overall momentum of these three objects? They are traveling parallel to the axes shown.

\[ p_x = 8.0 \text{ kg m/s} \]
\[ p_y = 4.0 \text{ kg m/s} \]
\[ p_z = 5.0 \text{ kg m/s} \]

Combining vectors:
\[ p_x = -3.0 \text{ kg m/s}, \quad p_y = p_z = 4.0 \text{ kg m/s} \]

Magnitude: Pythagorean Theorem
\[ P = \sqrt{x^2 + y^2} \]
\[ = \sqrt{(-3.0 \text{ kg m/s})^2 + (4.0 \text{ kg m/s})^2} \]
\[ = 5.0 \text{ kg m/s} \]

Change in Momentum

Momentum is a vector: changing direction changes momentum:
\[ \Delta \vec{p} = \vec{p}_2 - \vec{p}_1 \]

For a 180° rebound:
\[ \Delta \vec{p} = \vec{p}_2 - \vec{p}_1 = m(v_f - v_i) \]
Pay attention to direction, a negative sign matters.

4. Example

Find the vector sum of the momenta with respect to each axis, then combine those to find magnitude and direction of the resulting vector.

\[ P_x = p_1 + p_3 \]
\[ = 5.0 \text{ kg m/s} + \left(-8.0 \text{ kg m/s}\right) = -3.0 \text{ kg m/s} \]
\[ P_y = p_2 = 4.0 \text{ kg m/s} \]

Direction:
\[ \theta = \tan^{-1} \left( \frac{P_y}{P_x} \right) \]
\[ = \tan^{-1} \left( \frac{4.0 \text{ kg m/s}}{-3.0 \text{ kg m/s}} \right) \]
\[ = -53° = 127° \]

5. Example

Homework

8.1 Problems in your Booklet

Due: next class