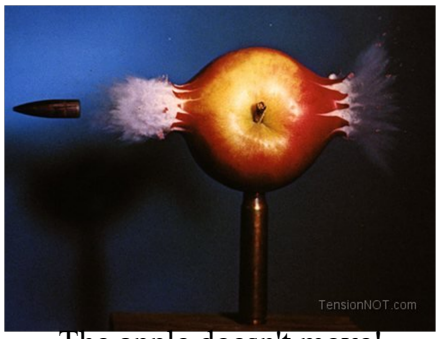
8.1 – Momentum



The apple doesn't move!

Linear Momentum

Compare bowling and tennis balls – which does more damage if both travel at same rate, and hit an object?

Momentum (vector quantity):

$\vec{p} = m\vec{v}$ AP Equation	p = momentum (kg·m/s) m = mass (kg) v = velocity (m/s)

Why is momentum 'P'?

Yahoo says: the word "impetus" (impulse) comes from the Latin "petere," to go towards or rush upon.

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

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

$$= 0.012\,kg \bullet 400.\frac{m}{s} = 4.8\,kg\frac{m}{s}$$

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.

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

$$v = \frac{p}{m} = \frac{4.8\,kg\frac{m}{s}}{68\,kg} = 0.071\frac{m}{s}\left(7.1\frac{cm}{s}\right)$$

Not all that fast.

Momenta

With multiple objects, overall momentum is the vector sum of individual momenta.

Mathematically:

$\vec{P} = \vec{p}_1 + \vec{p}_2 + \ \ldots\ = \sum \vec{p}_i$	P = total momenutm p_i = individual momenta

3. Example (A)→(B)→ = (A B)→

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?

$$\vec{P} = \vec{p}_1 + \vec{p}_2 = 3.1kg\frac{m}{s} + 2.5kg\frac{m}{s} = 5.6kg\frac{m}{s}$$

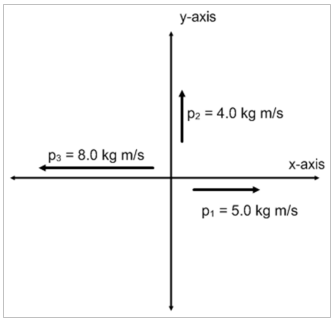
B. How fast will they be going after the collision?

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

$$v = \frac{p}{m} = \frac{5.6\,kg\frac{m}{s}}{2.0\,kg} = 2.8\frac{m}{s}$$

4. Example

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



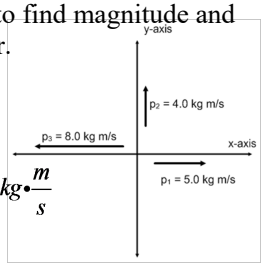
4. Example

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

$$P_x = p_1 + p_3$$

$$= 5.0\,kg\bullet\frac{m}{s} + \left(-8.0\,kg\bullet\frac{m}{s}\right) = -3.0\,kg\bullet\frac{m}{s}$$

$$P_y = p_2 = 4.0\,kg\bullet\frac{m}{s}$$



4. Example

Combining vectors:

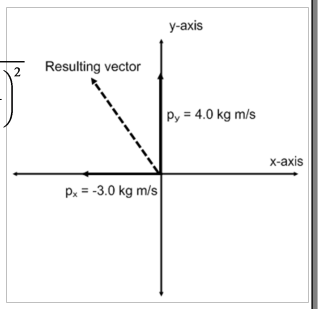
p_x = -3.0 kg m/s, $p_y = p_2$ = 4.0 kg m/s:

Magnitude: Pythagorean Theorem

$$P = \sqrt{x^2 + y^2}$$

$$= \sqrt{\left(-3.0\,kg\bullet\frac{m}{s}\right)^2 + \left(4.0\,kg\bullet\frac{m}{s}\right)^2}$$

$$= 5.0\,kg\bullet\frac{m}{s}$$



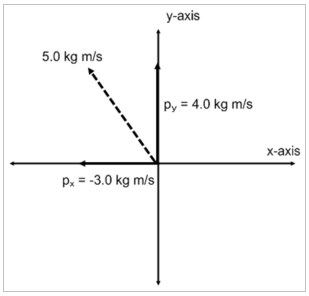
4. Example

Direction:

$$\theta = \tan^{-1}\left(\frac{y}{x}\right)$$

$$= \tan^{-1}\left(\frac{4.0\,kg\frac{m}{s}}{-3.0\,kg\frac{m}{s}}\right)$$

$$= -53^\circ = 127^\circ$$



Change in Momentum

Momentum is a vector: changing direction changes momentum:

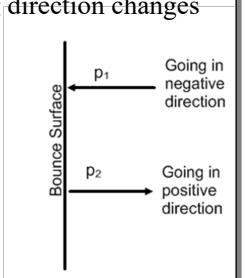
$$\boxed{\Delta\vec{p} = \vec{p}_2 - \vec{p}_1}$$

For a 180° rebound:

$$\Delta\vec{p} = \vec{p}_2 - \vec{p}_1$$

$$= mv_2 - mv_1 = m\left(v_2 - v_1\right)$$

Pay attention to direction, a negative sign matters.



5. Example

A 2.5 kg rock going 5.0 m/s hits a tree and bounces, going 3.8 m/s in the opposite direction.

What is the **magnitude** of its momentum change?

$$\Delta\vec{p} = \vec{p}_2 - \vec{p}_1 = m\left(v_2 - v_1\right)$$

$$= 2.5\,kg\left(3.8\frac{m}{s} - \left(-5.0\frac{m}{s}\right)\right) = 22\,kg\frac{m}{s}$$

Note: using +5.0 m/s, and -3.8 m/s gives the same magnitude.

Homework 8.1 Problems in your Booklet
Due: next class