Litany For Momentum Problems **[©2004 RJ Bieniek]**

1. Since momentum methods are most often used to solve problems involving a collision, an explosion, or an impulsive event, draw separate sketches of the physical the physical situation *before* and *after* the "event". Draw the same coordinate system in each sketch that is convenient to solve the problem. Often this is the direction from which angles in the problem are already given.

2. Label the point masses in both sketches, and draw vectors to represent either (your choice) the velocities (with *v* labels) or the momenta (with *p* labels) for each particle involved. It is best to draw any unknown velocity or momentum with components that *appear* to be positive to avoid the temptation of putting in a spurious negative sign in your calculations. If a component turns out to be negative at the end, you just know that the physical vector is actually directed in the opposite direction.

3. *Lightly* draw in vector projections of all vectors that are not parallel to a coordinate axis. Make sure there are arrows at the end of these vectors to indicate their direction. This will give you a quick way of properly determining the sign of the component in a force equation.

4. Write down the an appropriate fundamental equation to start your mathematical solution, either in vector or component form, e.g., $\vec{\mathcal{P}}_f - \vec{\mathcal{P}}_i = \vec{\mathbf{J}}_{ext}$ or $\mathcal{P}_{fx} - \mathcal{P}_{ix} = (J_x)_{i\to f}$.

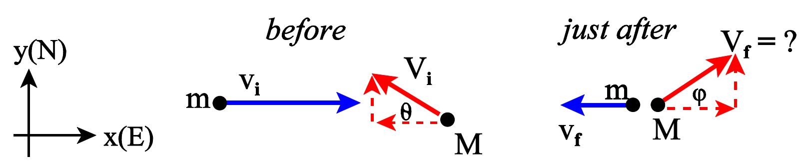
5. If no *outside* forces act during the process, the external impulse can be zeroed out to give conservation of linear momentum, e.g., $(\cancel{J}_x)_{i\to f}$ gives $\mathcal{P}_{fx} = \mathcal{P}_{ix}$. Remember: this is a *decision* that must verified.

6. Write out the total momentum of initial and final states in terms of a sum of momentum (not velocity) components of the individual particles. Refer to your sketches to make sure there is a term for each particle shown. You can now zero out any term that is known to be zero, e.g., a particle with zero speed.

7. Substitute in values for the components based on the given information, using magnitudes with appropriate preceding + or – signs. Then solve for the desired unknown component.

8. For example, consider the collision of a car of mass m and a truck of mass $M = 2m$. The car is initially traveling directly east with speed $v_i = 25$ m/s. It collides with the truck, which is moving $\theta = 36.9°$ north of west at a speed $V_i = 10$ m/s. As a result of the collision, the car rebounds directly west with a speed of $v_f = 3$ m/s.

What is the velocity of the truck right after the collision?



x-component **y - component**

$\mathcal{P}_{xf} - \mathcal{P}_{xi} = (\cancel{J}_x)_{i\to f} \Rightarrow \mathcal{P}_{fx} = \mathcal{P}_{ix}$

$p_{fx} + P_{fx} = p_{ix} + P_{ix}$

$m v_{fx} + M V_{fx} = m v_{ix} + M V_{ix}$

$(-mv_f) + 2m V_{fx} = (+mv_i) + 2m(-V_i\cos\theta)$

$\boxed{V_{fx} = ½(v_i + v_f) - V_i\cos\theta}$

$V_{fx} = ½(25+3) - 10\cdot 0.8 = 14 - 8 = +6$ m/s

$\mathcal{P}_{yf} - \mathcal{P}_{yi} = (\cancel{J}_y)_{i\to f} \Rightarrow \mathcal{P}_{fy} = \mathcal{P}_{iy}$

$p_{fy} + P_{fy} = p_{iy} + P_{iy}$

$m\cancel{v}_{fy} + M V_{fy} = m\cancel{v}_{iy} + M V_{iy}$

$\cancel{M} V_{fy} = \cancel{M}(+V_i\sin\theta)$

$\boxed{V_{fy} = +V_i\sin\theta}$

$V_{yf} = +10\cdot 0.6 = +6$ m/s

$$\boxed{\vec{\mathbf{v}} = [½(v_i + v_f) - V_i\cos\theta]\hat{\mathbf{i}} + V_i\sin\theta\,\hat{\mathbf{j}} = [+6\,\hat{\mathbf{i}} + 6\,\hat{\mathbf{j}}]\text{ m/s}}$$