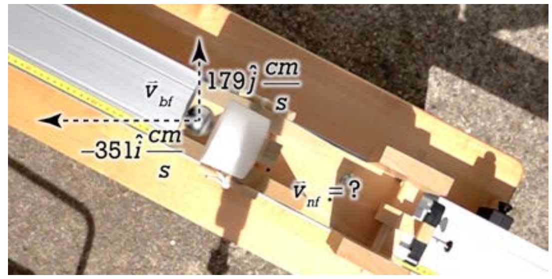
Flipping Physics Lecture Notes:

Conservation of Momentum using Unit Vectors
http://www.flippingphysics.com/momentum-conservation-unit-vectors.html




Example: A 66.0 g ball is launched from a stationary Nerd-A-Pult on wheels. The total mass of the Nerd-A-Pult on wheels is 1,791 g. If the ball moves with a velocity of $\left[-351\hat{i}+179\hat{j}\right]\frac{cm}{s}$ right after launching, what is the velocity of the Nerd-A-Pult right after the ball is launched?

Knowns: $m_b=66.0g;\ m_n=1{,}791g;\ \vec{v}_{bi}=\vec{v}_{ni}=0;\ \vec{v}_{bf}=\left[-351\hat{i}+179\hat{j}\right]\frac{cm}{s};\ \vec{v}_{nf}=?$

Because all forces are internal to the Nerd-A-Pult on wheels and ball system, the net force acting on the ball and Nerd-A-Pult system is zero and linear momentum is conserved, therefore, we can solve for the final velocity of the Nerd-A-Pult after launch.

$$\sum\vec{F}=\frac{d\vec{p}}{dt}=0\Rightarrow\sum\vec{p}_i=\sum\vec{p}_f\Rightarrow 0=\vec{p}_{bf}+\vec{p}_{nf}\Rightarrow\vec{p}_{nf}=-\vec{p}_{bf}\Rightarrow m_n\vec{v}_{nf}=-m_b\vec{v}_{bf}\Rightarrow\vec{v}_{nf}=-\frac{m_b\vec{v}_{nf}}{m_n}$$

$$\Rightarrow\vec{v}_{nf}=-\frac{(66)\left(-351\hat{i}+179\hat{j}\right)}{1791}=12.93467\hat{i}-6.59631\hat{j}\approx\left[12.9\hat{i}-6.60\hat{j}\right]\frac{cm}{s}$$

Now let's compare the predicted velocity of the ball final to the observed velocity of the ball final:

$$\vec{v}_{nf}\approx\left[12.9\hat{i}-6.60\hat{j}\right]\frac{cm}{s}(predicted)\ \&\ \vec{v}_{nf}=\left[13.0\hat{i}-6.60\hat{j}\right]\frac{cm}{s}(observed)$$

Notice that the ratio of y and x velocities of the ball and Nerd-A-Pult are the same:

$$\frac{179}{-351}=-0.50997\ \&\ \frac{-6.59631}{12.93467}=-0.50997$$

This is because the two objects move in opposite directions and the tangent of the angle is the same:

$$\tan\theta_b=\frac{O_b}{A_b}=\frac{179}{-351}=-0.50997\ \&\ \tan\theta_n=\frac{O_n}{A_n}=\frac{-6.59631}{12.93467}=-0.50997$$