PH 221 Week 9

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This material is borrowed/adapted from Chapter 11 of the *Student Workbook* for *Physics for Scientists and Engineers*.

R9-1: Comparing Pushed Particles

Particle A has less mass than particle B. Both are pushed forward across a frictionless surface by equal forces for 1 s. Both start from rest.

(a) Compare the amount of work done on each particle. That is, is the work done on A greater than, less than, or equal to the work done on B? Explain.

The amount of work done by a force depends on the sizes of the force and the displacement of the object under that force. The same force is applied to both particles, but since A has less mass, it will accelerate more and have greater displacement. Therefore, the work done on A is greater.

(b) Compare the impulses delivered to particles A and B. Explain.

Because the same net force is applied over the same elapsed time, the impulses are the same.

(c) Compare the final speeds of particles A and B. Explain.

Let the particles move along the x-axis so we may discuss the components of their momenta. The same impulse J_x is delivered to both particles, and since they both start from rest, we know $p_{ix} = 0$. This gives

$$J_x = \Delta p_x = p_{fx} - \cancel{p_{ix}} = p_{fx}.$$

As such, both particles have the same final momentum:

$$p_{fx} = m_A v_{fA} = m_B v_{fB}.$$

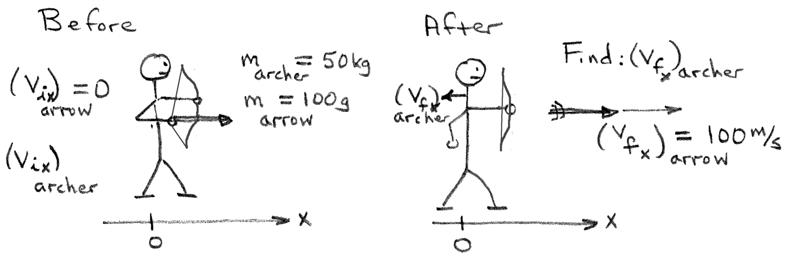
However, since $m_A < m_B$, we must conclude that $v_{fA} > v_{fB}$.

R9-2: Ice Archer and Cadillac Crash Setup

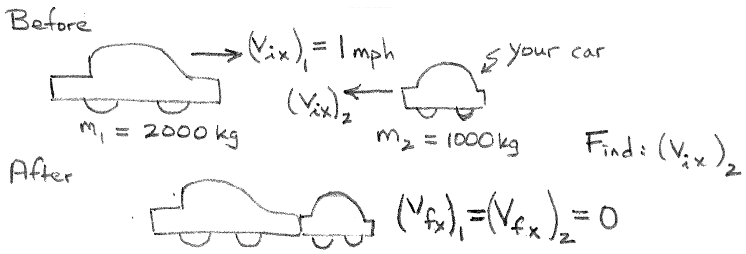
For each part of this activity, prepare a pictorial representation, but do not solve the problem (yet).

- Draw pictures of "before" and "after."
- Define symbols relevant to the problem.
- List known information, and identify the desired unknown.

(a) A 50 kg archer, standing on frictionless ice, shoots a 100 g arrow at a speed of 100 m/s. What is the recoil speed of the archer?



(b) The parking brake on a 2000 kg Cadillac has failed, and it is rolling slowly, at 1 mph, toward a group of small, innocent children. As you see the situation, you realize there is just time for you to drive your 1000 kg Volkswagen head-on into the Cadillac and thus save the children. With what speed should you impact the Cadillac to bring it to a halt?



R9-3: Ice Archer and Cadillac Crash Calculations

Using the setups from the previous activity, solve the following problems.

(a) A 50 kg archer, standing on frictionless ice, shoots a 100 g arrow at a speed of 100 m/s. What is the recoil speed of the archer?

The archer-arrow system conserves momentum, so the combined initial momentum of the pair (which is zero, since they both start from rest) is equal to the combined final momentum of the pair:

$$\begin{aligned}
m_{archer}\cancel{(v_{ix})}_{archer} + m_{arrow}\cancel{(v_{ix})}_{arrow} &= m_{archer}(v_{fx})_{archer} + m_{arrow}(v_{fx})_{arrow} \\
0 &= m_{archer}(v_{fx})_{archer} + m_{arrow}(v_{fx})_{arrow} \\
(v_{fx})_{archer} &= -\frac{m_{arrow}}{m_{archer}}(v_{fx})_{arrow} \\
&= -\frac{0.1\ \text{kg}}{50\ \text{kg}}(100\ \text{m/s}) \\
&= -0.2\ \text{m/s}.
\end{aligned}$$

The archer's recoil speed is 0.2 m/s.

(b) The parking brake on a 2000 kg Cadillac has failed, and it is rolling slowly, at 1 mph, toward a group of small, innocent children. As you see the situation, you realize there is just time for you to drive your 1000 kg Volkswagen head-on into the Cadillac and thus save the children. With what speed should you impact the Cadillac to bring it to a halt?

The Cadillac-Volkswagen system conserves momentum, so the combined initial momentum of the pair is equal to the combined final momentum of the pair (which is zero, since they crash to a dead stop):

$$\begin{aligned}
m_1(v_{ix})_1 + m_2(v_{ix})_2 &= m_1\cancel{(v_{fx})}_1 + m_2\cancel{(v_{fx})}_1 \\
m_1(v_{ix})_1 + m_2(v_{ix})_2 &= 0 \\
(v_{ix})_2 &= -\frac{m_1}{m_2}(v_{ix})_1 \\
&= -\frac{2000\ \text{kg}}{1000\ \text{kg}}(1\ \text{mph}) \\
&= -2\ \text{mph}.
\end{aligned}$$

You must hit the Cadillac at 2 mph to stop it.