Physics 2A Spring 2020
Discussion 8

TA: Jiashu Han
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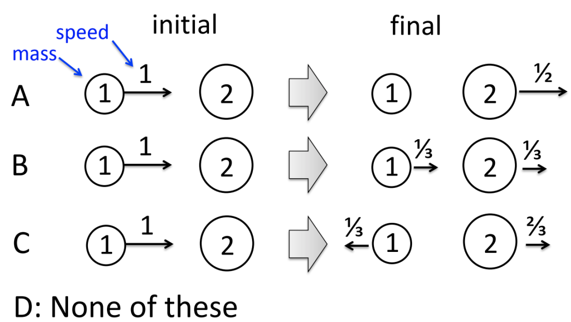
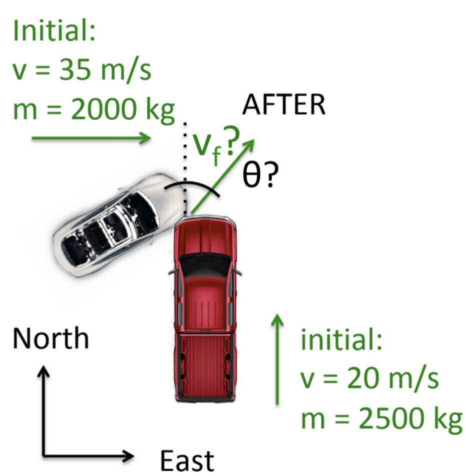
1. **Warm-ups**[1]

   (a) In which of the following collisions is kinetic energy conserved?

   Solution: C.

   (b) In the picture below, two cars collide inelastically. After the collision, the direction of motion relative to north will be

   A. Less than 45°
   B. Equal to 45°
   C. More than 45°

[1] From Prof. Burgasser's TPS worksheet

D. Not enough information

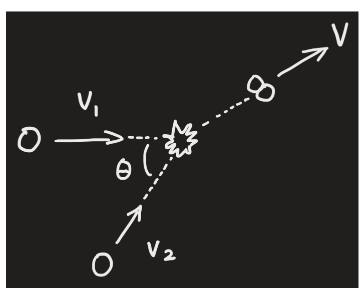
Solution: C. The final momentum is equal to the total initial momentum. Since initially the horizontal (eastward) component is larger, the horizontal component of the final momentum will also be larger.

2. **More momentum transfer**

A fire hose shoots a steady stream of water at a wall. The water flows from the hose at a rate of 8.0 kg/s. The water impacts the wall moving with a speed of 7.0 m/s at a 90° angle. After impact, the water sprays out along the wall and does not rebound. What is the time-averaged force exerted on the wall by the water?

Solution: We are given the rate $\frac{dm}{dt}$ and velocity v of the water flow. This is similar to the bullet problem in last week's worksheet. However, unlike the bullets, the water flow is continuous. Nevertheless, we can still consider a chunk of the water flow in some time interval Δt. The momentum carried by this chunk of water is then $\Delta p = \frac{dm}{dt}\Delta t \cdot v$. The rest of the calculation is the same as before. Since the water does not rebound, all of the momentum perpendicular to the wall carried by the water is transferred to the wall. The average force is therefore $\langle F \rangle = \frac{\Delta p}{\Delta t} = \frac{dm}{dt}v = 56$ N.

3. **2D collision**



Two balls with masses m_1 and m_2 are moving with speeds v_1 and v_2 respectively, and they collide inelastically as shown in the above figure. After the collision they stick together and travel with speed v. Find the final velocity if the two balls (both speed and direction) in terms of the quantities given.

Solution: Let us define x as the direction ball 1 is initially travelling in, and y to be upward (perpendicular to x). We first write down the initial momenta as vectors:

$$\vec{p}_1 = m_1 v_1 \hat{x} \tag{1}$$

$$\vec{p}_2 = m_2 v_2 (\cos\theta \hat{x} + \sin\theta \hat{y}) \tag{2}$$

Since the two balls stick together after the collision, the final momentum for the pair is just

$$\vec{p} = \vec{p}_1 + \vec{p}_2 = (m_1 v_1 + m_2 v_2 \cos\theta)\hat{x} + m_2 v_2 \sin\theta \hat{y} \tag{3}$$

and the velocity is $\vec{v} = \vec{p}/(m_1 + m_2)$. The final speed is

$$|\vec{v}| = \frac{1}{m_1 + m_2}\sqrt{(m_1 v_1 + m_2 v_2 \cos\theta)^2 + m_2^2 v_2^2 \sin^2\theta} \tag{4}$$

and the direction is

$$\phi = \arctan \frac{m_2 v_2 \sin\theta}{m_1 v_1 + m_2 v_2 \cos\theta} \tag{5}$$

measured counterclockwise from x.