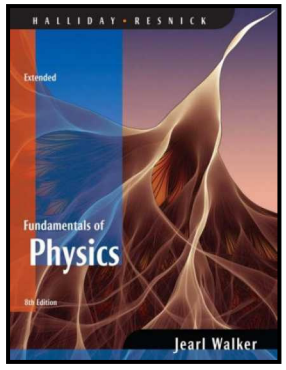
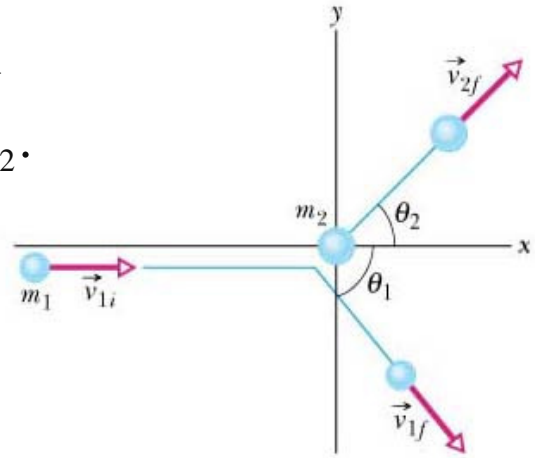
University Physics I



Week 10 : Day 1

Collisions in Two Dimensions

In this section we will remove the restriction that the colliding objects move along one axis. Instead we assume that the two bodies that participate in the collision move in the *xy*-plane. Their masses are m_1 and m_2.

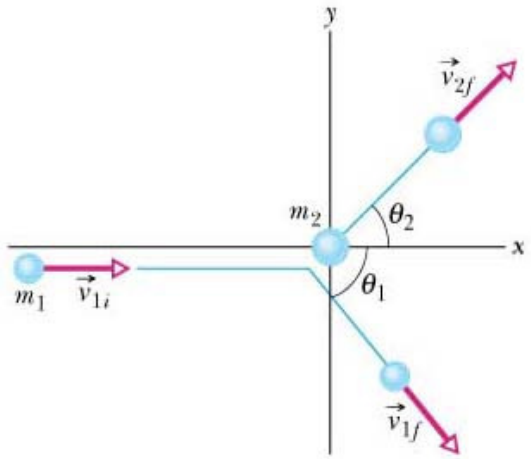


The linear momentum of the system is conserved: $\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$.

If the system is elastic the kinetic energy is also conserved: $K_{1i} + K_{2i} = K_{1f} + K_{2f}$.

We assume that m_2 is stationary and that after the collision particle 1 and particle 2 move at angles θ_1 and θ_2 with the initial direction of motion of m_1.

2D Collision Analysis



In this case the conservation of momentum and kinetic energy take the form:

$x-$axis: $m_1 v_{1i} = m_1 v_{1f} \cos\theta_1 + m_2 v_{2f} \cos\theta_2$ (eq. 1)

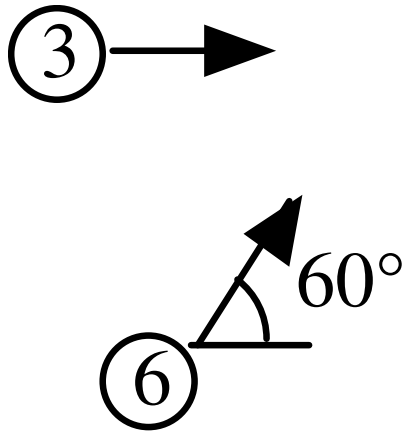
$y-$axis: $0 = -m_1 v_{1f} \sin\theta_1 + m_2 v_{2f} \sin\theta_2$ (eq. 2)

$\frac{1}{2} m_1 v_{1i}^2 = \frac{1}{2} m_1 v_{2f}^2 + \frac{1}{2} m_2 v_{2f}^2$ (eq. 3) We have three equations and seven variables:

Two masses: m_1, m_2; three speeds: v_{1i}, v_{1f}, v_{2f}; and two angles: θ_1, θ_2. If we know the values of four of these parameters we can calculate the remaining three.

Activity – Analysis of a 2-D Collision

- **Two pucks move on a horizontal air-hockey table. One puck has mass 3.0 kg and initially moves east at 4.0 m/s. The other puck has a mass of 6.0 kg and moves at 5.0 m/s at 60° north of east, as shown.**
  - (a) The two pucks collide and separate. After the collision the 3.0 kg puck moves north at 1.0 m/s. Find the velocity of the 6.0 kg puck after the collision.
  - (b) The two pucks collide and stick together. Find the velocity after the collision of the combined pucks.

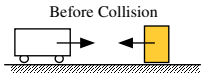


Momentum and Impulse Problems

- **For next time**
  - Practice setting up the collision equations…

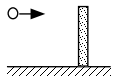
Problems Using Momentum and Impulse

1. A one dimensional collision occurs between a cart of mass 11.0 kg moving to the right at 3.0 m/s and a block of mass 5.0 kg moving to the left at 12.0 m/s. After the collision, the block moves to the right at 4.0 m/s.



   (a) What is the velocity of the cart after the collision?
   (b) If the collision lasts 0.020 s, find the average force on the cart.
   (c) Find the average force on the block.

2. A board is standing on the floor, and two different experiments are done. In one a piece of clay is thrown toward the top of the board, it collides and sticks to the board. In the other experiment, a superball is thrown that bounces off the top of the board. The masses of the board, the clay and the ball are the same, and the initial velocities are the same. In one experiment the board falls over, and in the other it wobbles but stays standing. Which object, clay or ball, made the board fall over? Explain.



3. Two pucks move on a horizontal air-hockey table. One puck has mass 3.0 kg and initially moves east at 4.0 m/s. The other puck has a mass of 6.0 kg and moves at 5.0 m/s at 60° north of east, as shown. The two pucks collide and stick together.
   (a) Find the velocity after the collision of the combined pucks.
   (b) If the collision lasts 35 ms, find the average force on the 3.0 kg puck.

4 The same two pucks as in problem 3 now collide and separate. After the collision the 3.0 kg puck moves north at 1.0 m/s.
   (a) Find the velocity of the 6.0 kg puck after the collision.
   (b) If the collision lasts 35 ms, find the average force on the 3.0 kg puck.

5. A ball with mass 2.5 kg is moving in outer space with a velocity of 6.0 m/s horizontally, and a box of mass 4.5 kg is moving with a velocity of 4.0 m/s at an angle of 120° from the horizontal. The two collide and stick together. Find the final velocity of the pair.

6. Consider a rail car of mass 500 kg coasting along a horizontal frictionless track at 3.0 m/s. I drop a 100 kg box from a height of 60 cm into the car.
   (a) Find the final velocity of the car+box.
   (b) If the collision between the box and the car lasts 12 ms, find the average normal force that acts on the box during the collision.