Physics 211

Sections 1 & 70

Dr. Geoffrey Lovelace

Fall 2012

Lecture 17 (10/30/12)

Lecture 17 outline

- Announcements
- Linear momentum
  - Rocket demo redux
  - Momentum recap
  - Conservation of linear momentum
  - Collisions

Announcements

- Homework
  - Homework #8: due 11:59PM on Thurs Nov. 1
- Exams not yet graded
  - I'll grade them & post as soon as I can
  - Best guess: posted on Thursday
- Reading: For Thursday: continue chapter 6
- Office hours: 4PM-5PM today
- No SI session Thursday, November 1

Today →

Oct 23	**Exam 2**
Oct 25	Linear momentum, conservation of linear momentum
Oct 30	Conservation of linear momentum, collisions
Nov 1	Center of mass, rockets, *HW #8 due*
Nov 6	Circular motion, gravitation
Nov 8	Gravitation, Kepler's laws *HW #9 due*
Nov 13	Special feature: temperature, heat, entropy
Nov 15	**Exam 3**
Nov 20	*Fall Recess — No class*
Nov 22	*Fall Recess — No class*
Nov 27	Rigid body rotation, torque, rotational dynamics
Nov 29	Rotational dynamics, rotational energy, *HW #10 due*
Dec 4	Angular momentum, conservation of angular momentur
Dec 6	Harmonic motion, *HW #11 due*
Dec 11	Harmonic motion & waves
Dec 13	Gravitational waves, harmonic motion, black holes, *HW*
Dec 20	**Final exam 9:30AM–11:20AM**

Lecture 17 outline

- Announcements
- Linear momentum
  - Conservation of linear momentum
  - Collisions

Conservation of momentum

- Demonstrations
  - Rocket redux
    http://www.youtube.com/watch?v=ta6q6-52a3c
  - Newton’s cradle

Momentum recap

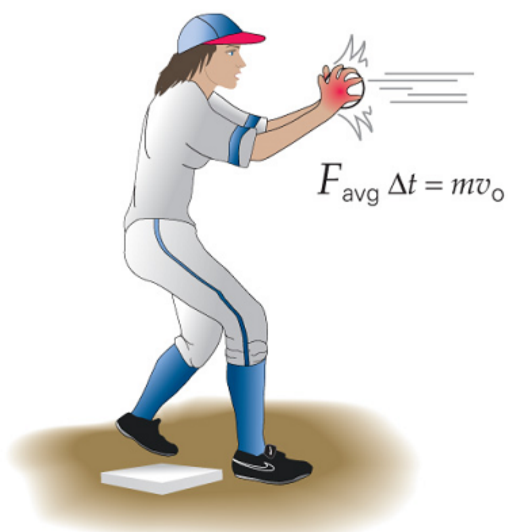
- Linear momentum
- Impulse
- Newton's second law

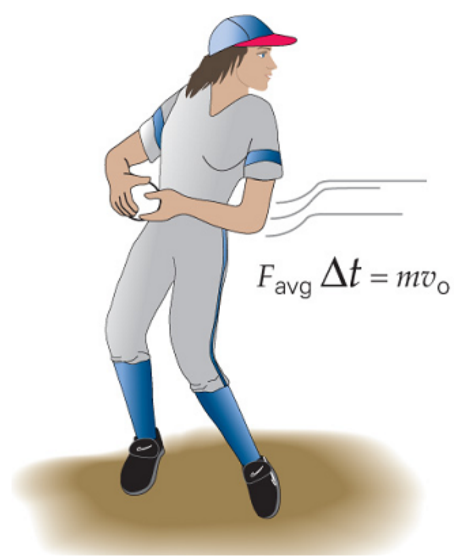
$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$$

$$\Delta\vec{\mathbf{p}} = \vec{\mathbf{p}}_2 - \vec{\mathbf{p}}_1$$

$$\vec{\mathbf{I}} = \vec{\mathbf{F}}_{\text{avg}}\Delta t = \Delta\vec{\mathbf{p}} = m\vec{\mathbf{v}} - m\vec{\mathbf{v}}_{\text{o}}$$

$$\vec{\mathbf{F}}_{\text{net}} = \frac{\Delta\vec{\mathbf{p}}}{\Delta t}$$





6.3 Conservation of Linear Momentum

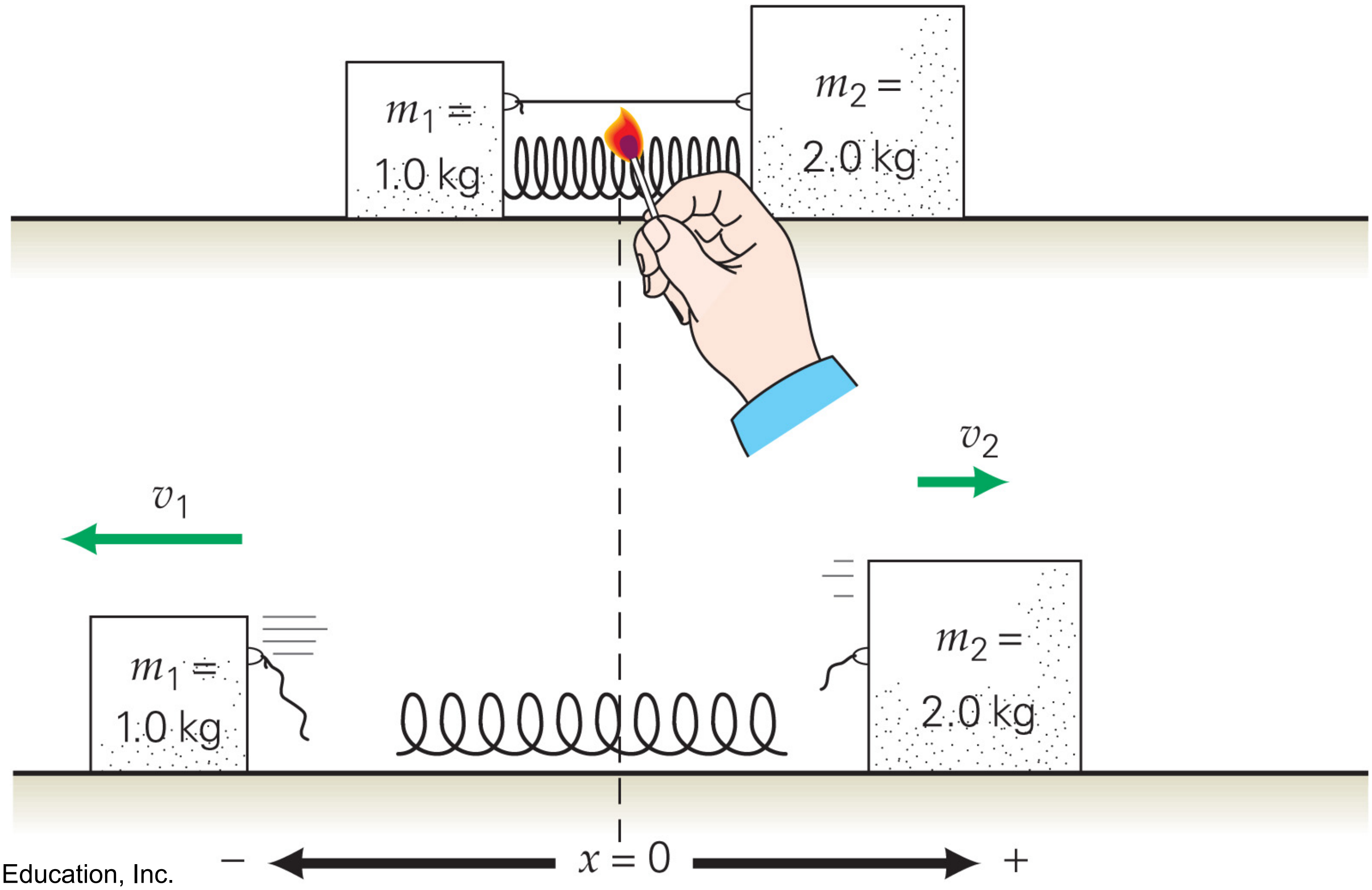
If there is no net force acting on a system, its total momentum cannot change.

This is the law of conservation of momentum.

If there are internal forces, the momenta of individual parts of the system can change, but the overall momentum stays the same.

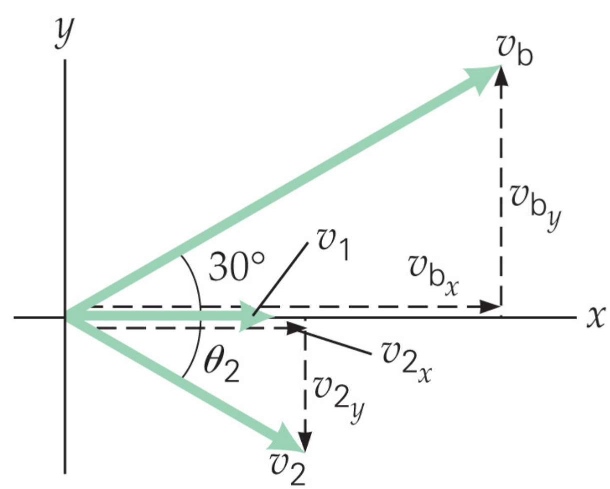
6.3 Conservation of Linear Momentum

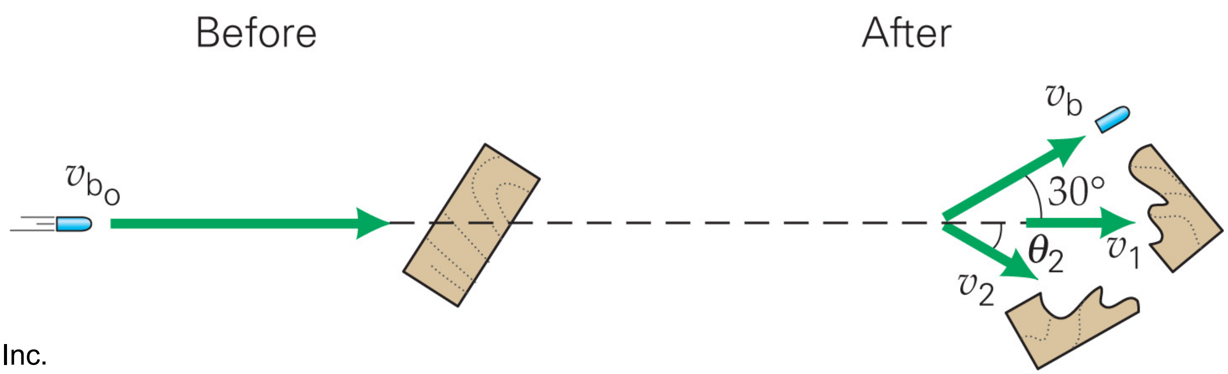
In this example, there is no external force, but the individual components of the system do change their momenta:



6.3 Conservation of Linear Momentum

Collisions happen quickly enough that any external forces can be ignored during the collision. Therefore, momentum is conserved during a collision.



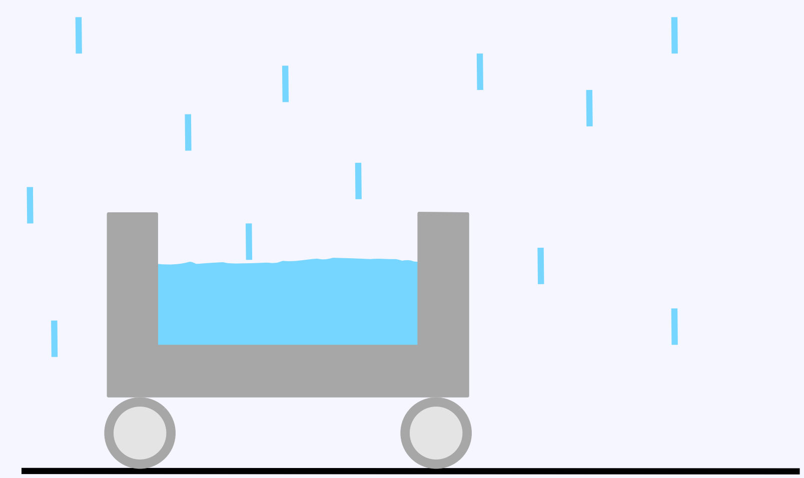


Clicker question #76

ConcepTest 6.1 Rolling in the Rain

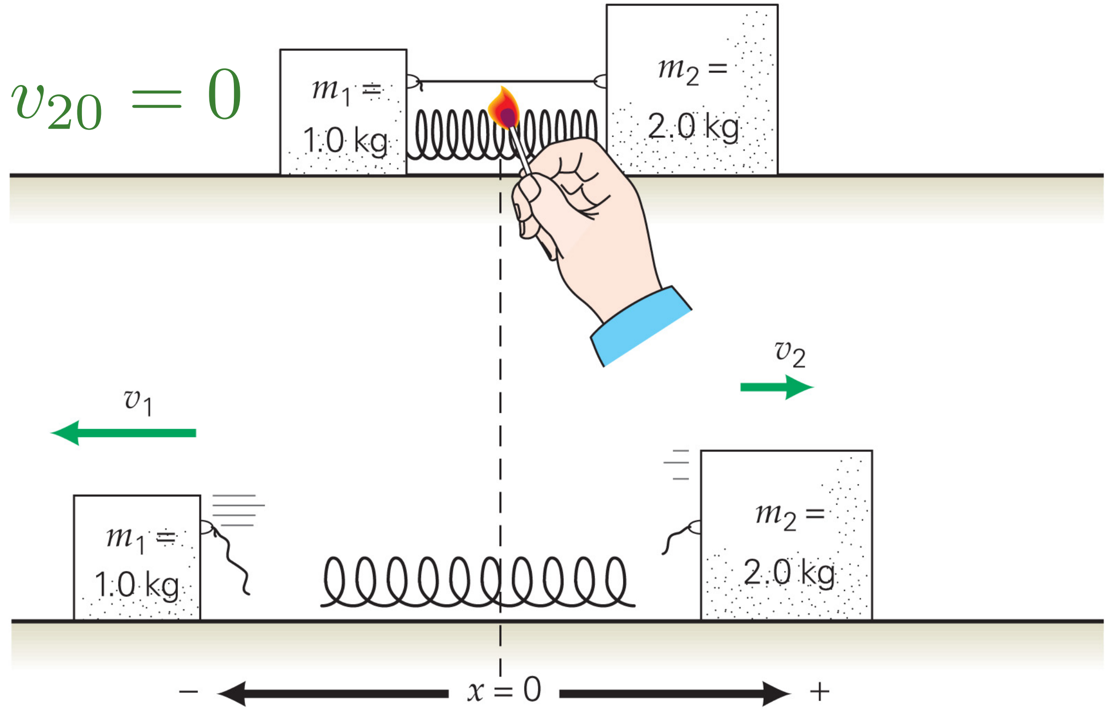
An open cart rolls along a frictionless track while it is raining. As it rolls, what happens to the speed of the cart as the rain collects in it? (Assume that the rain falls vertically into the box.)

A speeds up
B maintains constant speed
C slows down
D stops immediately



Ex. 6.6

$v_{10} = v_{20} = 0$



Burn the spring (negligible external force) and mass 1 moves left at 1.8 m/s. How does mass 2 move?

Given: m_1, m_2, v_{10}, v_{20}

Goal: v_2

Conservation of momentum

$$0 = m_1 v_1 + m_2 v_2$$

$$v_2 = -\frac{m_1}{m_2} v_1$$

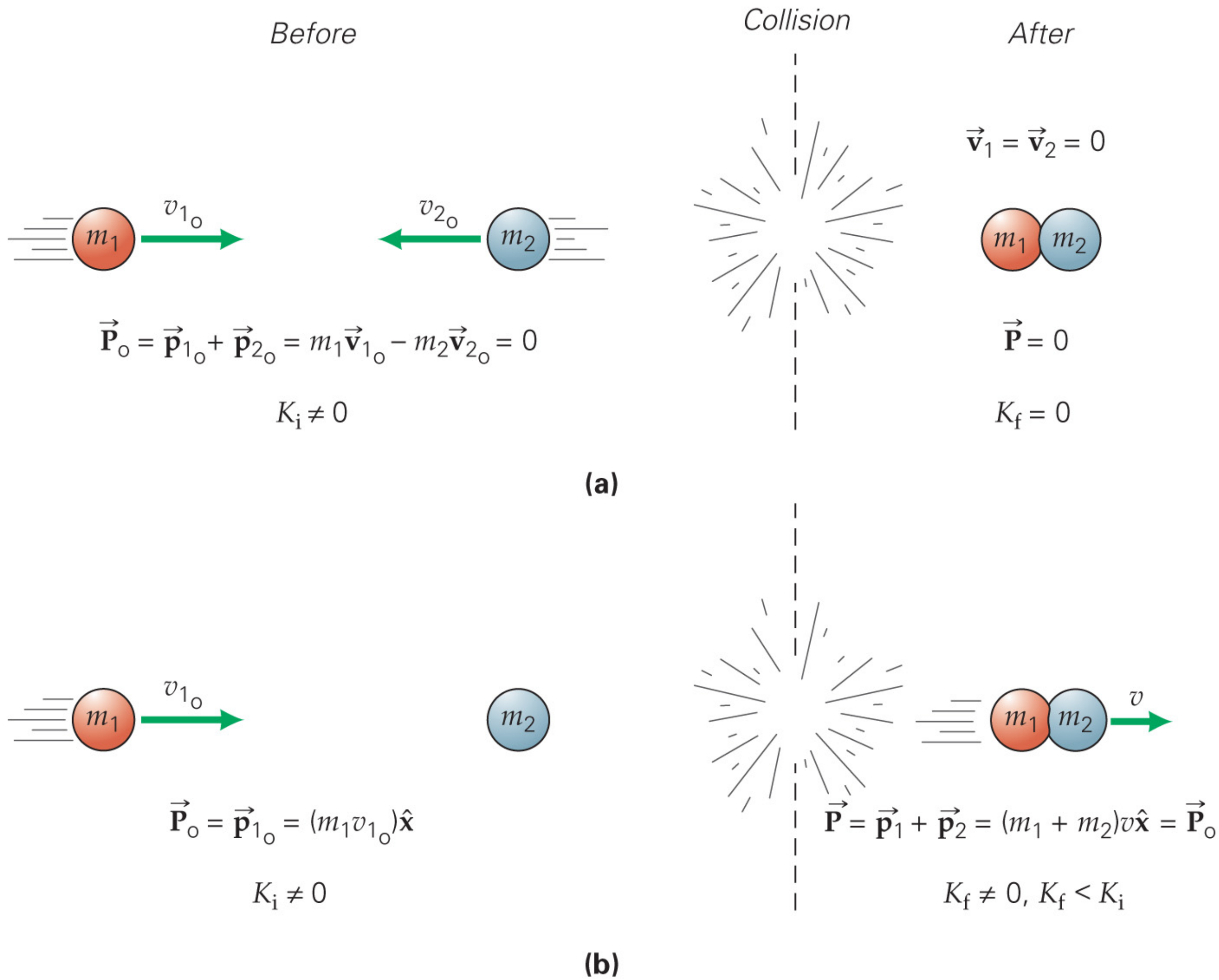
$$v_2 = -0.5 v_1 = -0.9 \text{ m/s}$$

1. Read carefully
2. (Draw a sketch)
3. Given? Goal?
4. Principles & equations?
5. Calculate
6. Plug in numbers
7. Is answer reasonable?

6.4 Elastic and Inelastic Collisions

In an elastic collision, the total kinetic energy is conserved.

Total kinetic energy is not conserved in an inelastic collision.



6.4 Elastic and Inelastic Collisions

For an elastic collision, both the kinetic energy and the momentum are conserved:

$$\overset{\textit{before}}{m_1\vec{\mathbf{v}}_{1_o} + m_2\vec{\mathbf{v}}_{2_o}} = \overset{\textit{after}}{m_1\vec{\mathbf{v}}_1 + m_2\vec{\mathbf{v}}_2}$$

$$\tfrac{1}{2}m_1v_{1_o}^2 + \tfrac{1}{2}m_2v_{2_o}^2 = \tfrac{1}{2}m_1v_1^2 + \tfrac{1}{2}m_2v_2^2$$

6.4 Elastic and Inelastic Collisions

In 1D: relative speeds = before, after collision

$$m_1 v_{1o} + m_2 v_{2o} = m_1 v_1 = m_2 v_2$$

$$m_1(v_1 - v_{1o}) = m_2(v_2 - v_{2o})$$

$$\frac{1}{2} m_1 v_{1o}^2 + \frac{1}{2} m_2 v_{2o}^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$

$$m_1(v_1^2 - v_{1o}^2) = m_2(v_2^2 - v_{2o}^2)$$

$$m_1(v_1 + v_{1o})(v_1 - v_{1o}) = m_2(v_2 + v_{2o})(v_2 - v_{2o})$$

$$v_1 + v_{1o} = v_2 + v_{2o}$$

$$v_{1o} - v_{2o} = v_2 - v_1$$

Clicker question #77

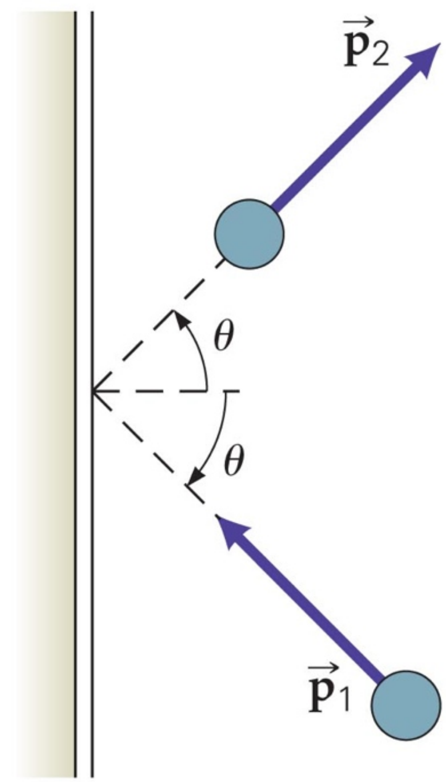
Question 6.10b Elastic Collisions II

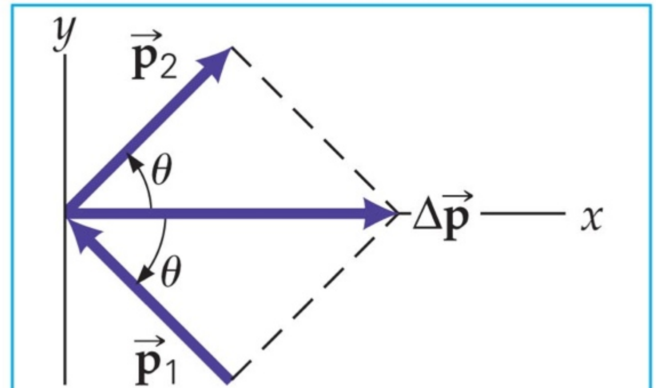
Carefully place a small rubber ball (mass *m*) on top of a much bigger basketball (mass *M*) and drop these from some height *h*. Just before hitting the ground, their velocity is *v*. What is the velocity of the smaller ball after the basketball hits the ground, reverses direction, and then collides with the small rubber ball?

- A zero
- B v
- C 2v
- D 3v
- 4v

Elastic collision

- Demonstrations
  - Ball drop http://www.youtube.com/watch?v=YlkTBbFikU8
  - Billiards http://www.youtube.com/watch?v=89bJMyGOknI





$$\Delta\vec{\mathbf{p}} = \vec{\mathbf{p}}_2 - \vec{\mathbf{p}}_1 = \Delta\vec{\mathbf{p}}_x + \Delta\vec{\mathbf{p}}_y$$

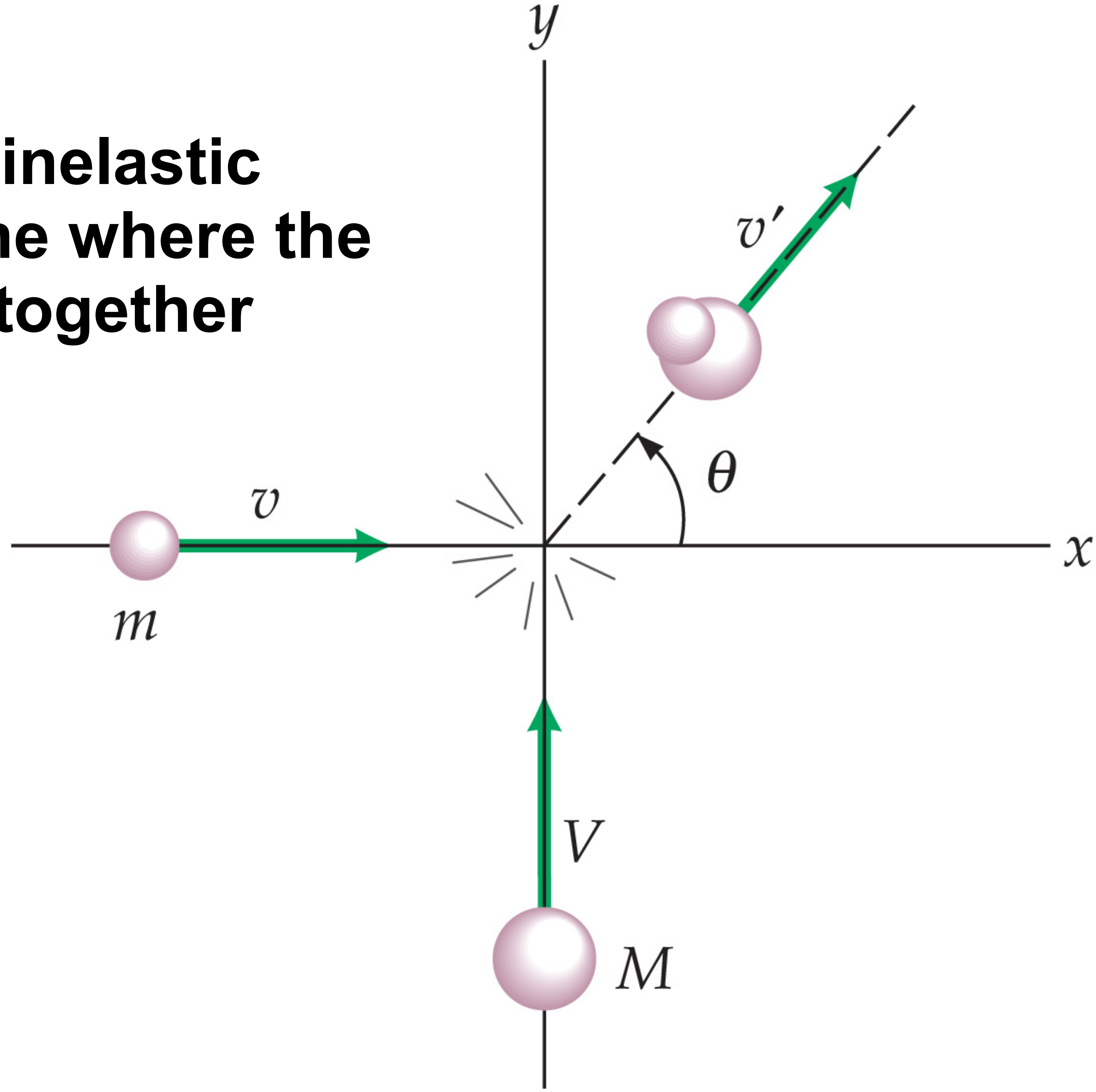
$$\Delta\vec{\mathbf{p}}_x = \vec{\mathbf{p}}_{2_x} - \vec{\mathbf{p}}_{1_x}$$
$$= (p_2 \cos\theta)\hat{\mathbf{x}} - (-p_1 \cos\theta)\hat{\mathbf{x}}$$
$$= (+2p \cos\theta)\hat{\mathbf{x}}$$

$$\Delta\vec{\mathbf{p}}_y = \vec{\mathbf{p}}_{2_y} - \vec{\mathbf{p}}_{1_y}$$
$$= (p_2 \sin\theta)\hat{\mathbf{y}} - (p_1 \sin\theta)\hat{\mathbf{y}} = 0$$

(b)

6.4 Elastic and Inelastic Collisions

A completely inelastic collision is one where the objects stick together afterwards.



6.4 Elastic and Inelastic Collisions

The fraction of the total kinetic energy that is left after a completely inelastic collision can be shown to be:

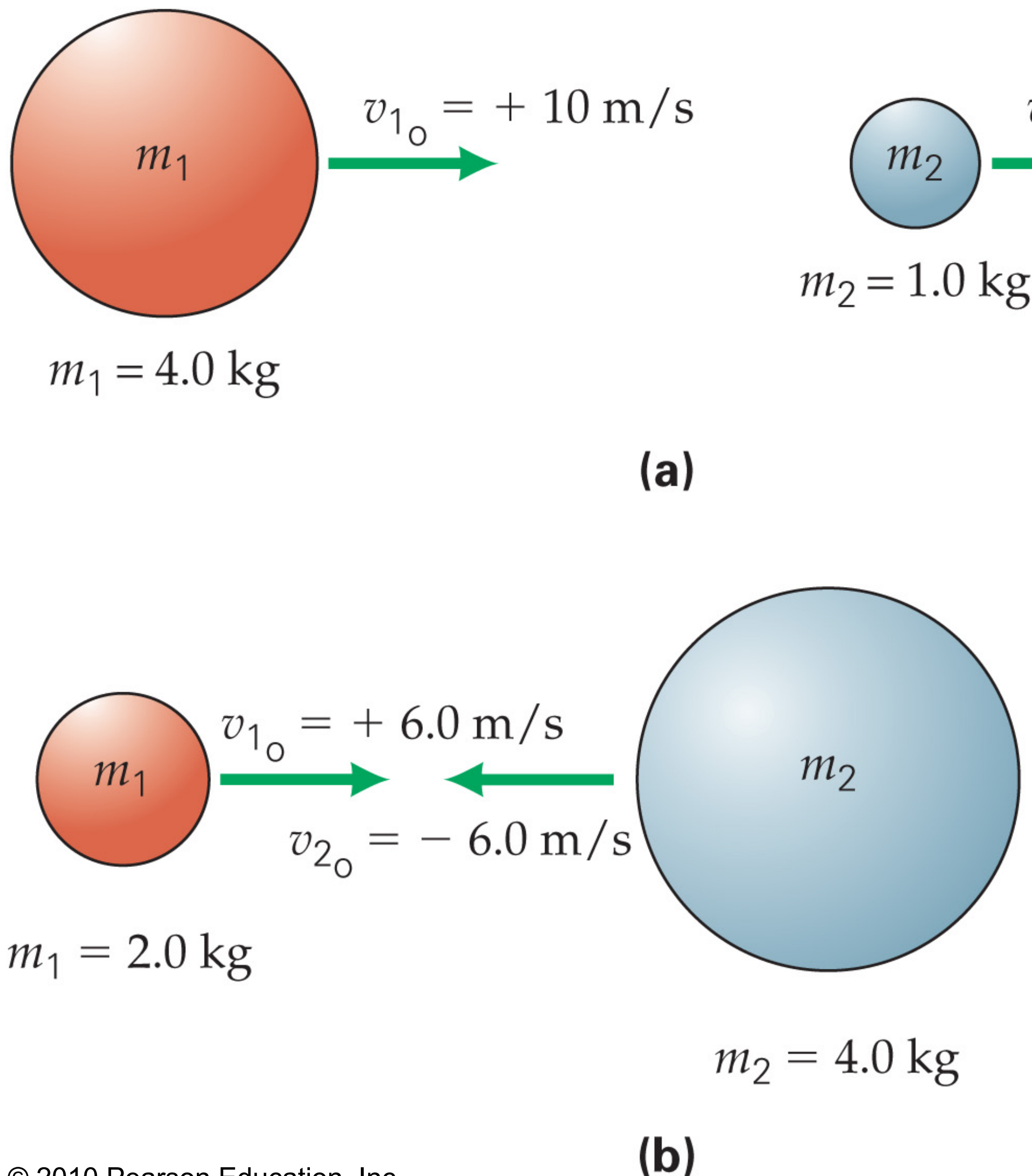
$$m_1 v_{10} = (m_1 + m_2)v \qquad \frac{m_1}{m_1 + m_2} v_{10} = v$$

$$\frac{1}{2}(m_1 + m_2)v^2 = \frac{1}{2}(m_1 + m_2)\left(\frac{m_1}{m_1 + m_2}\right)^2 v_{10}^2$$

$$K_f = \frac{m_1}{m_1 + m_2}\left(\frac{1}{2} m_1 v_{10}^2\right) = \frac{m_1}{m_1 + m_2} K_i$$

$$\frac{K_f}{K_i} = \frac{m_1}{m_1 + m_2}$$

6.4 Elastic and Inelastic Collisions



Collisions may take place with the two objects approaching each other, or with one overtaking the other.

Class participation: Ex. 6.9

- Complete the worksheet
- If you finish early, you can leave early!