Physics 211

Sections 1 & 70

Dr. Geoffrey Lovelace

Fall 2012

Lecture 16 (10/25/12)

Lecture 16 outline

- Announcements
- Linear momentum
  - Linear momentum
  - Force & impulse
  - Conservation of linear momentum
  - Collisions

Announcements

- Homework
  - Homework #8: due today 11:59PM on Nov. 1
  - Bonus: No homework due today
- Exams not yet graded
  - I’ll grade them & post as soon as I can
  - Best guess: 1 week from today
- Reading: For Thursday: continue chapter 6
- Office hours: 10AM-11AM, 4PM-5PM today

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 16 outline

- Announcements
- Linear momentum
  - Linear momentum
  - Force & impulse
  - Conservation of linear momentum
  - Collisions

6.1 Linear Momentum

Definition of linear momentum:

The linear momentum of an object is the product of its mass and velocity.

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

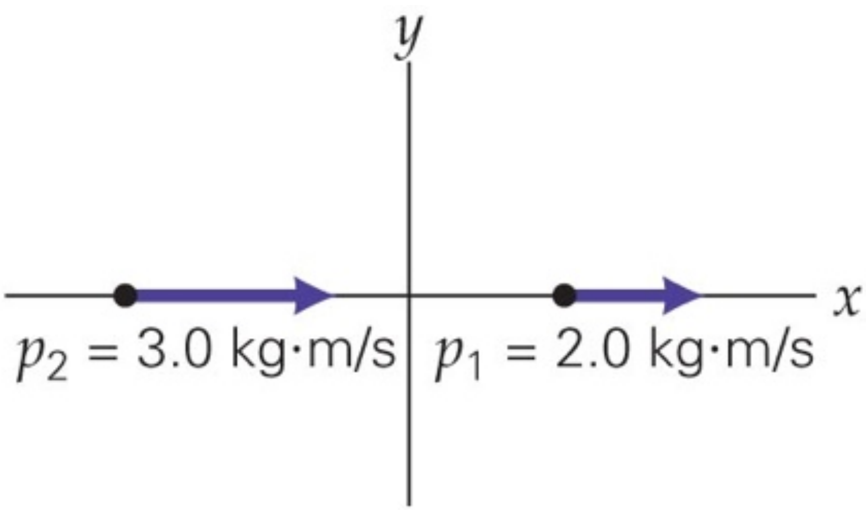
Note that momentum is a vector—it has both a magnitude and a direction.

SI unit of momentum: kg • m/s. This unit has no special name.

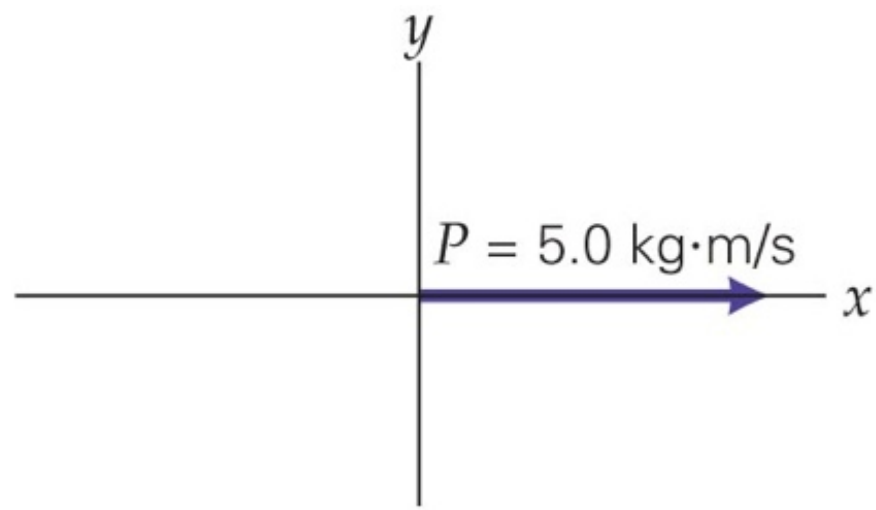
6.1 Linear Momentum

For a system of objects, the total momentum is the vector sum of each.

$$\vec{\mathbf{P}} = \vec{\mathbf{p}}_1 + \vec{\mathbf{p}}_2 + \vec{\mathbf{p}}_3 + \cdots = \sum \vec{\mathbf{p}}_i$$



Individual momenta

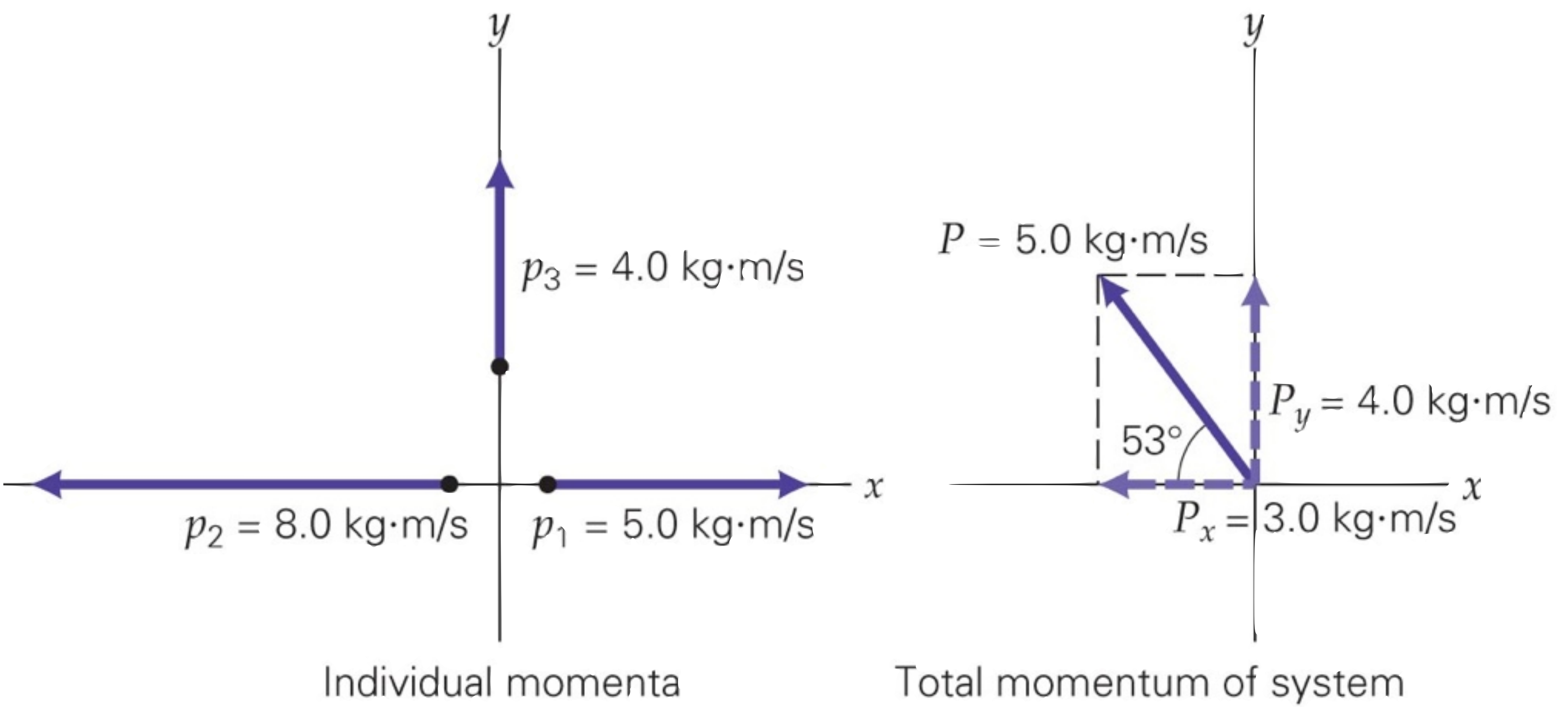


Total momentum of system

6.1 Linear Momentum

For a system of objects, the total momentum is the vector sum of each.

$$\vec{\mathbf{P}} = \vec{\mathbf{p}}_1 + \vec{\mathbf{p}}_2 + \vec{\mathbf{p}}_3 + \cdots = \sum \vec{\mathbf{p}}_i$$



Clicker question #68

Question 6.2a Momentum and KE I

A system of particles is known to have a total kinetic energy of zero. What can you say about the total momentum of the system?

A momentum of the system is positive

B momentum of the system is negative

C momentum of the system is zero

D you cannot say anything about the momentum of the system

Clicker question #69

Question 6.2b Momentum and KE II

A system of particles is known to have a total momentum of zero. Does it necessarily follow that the total kinetic energy of the system is also zero?

A) yes

B) no

Clicker question #70

Question 6.2c Momentum and KE III

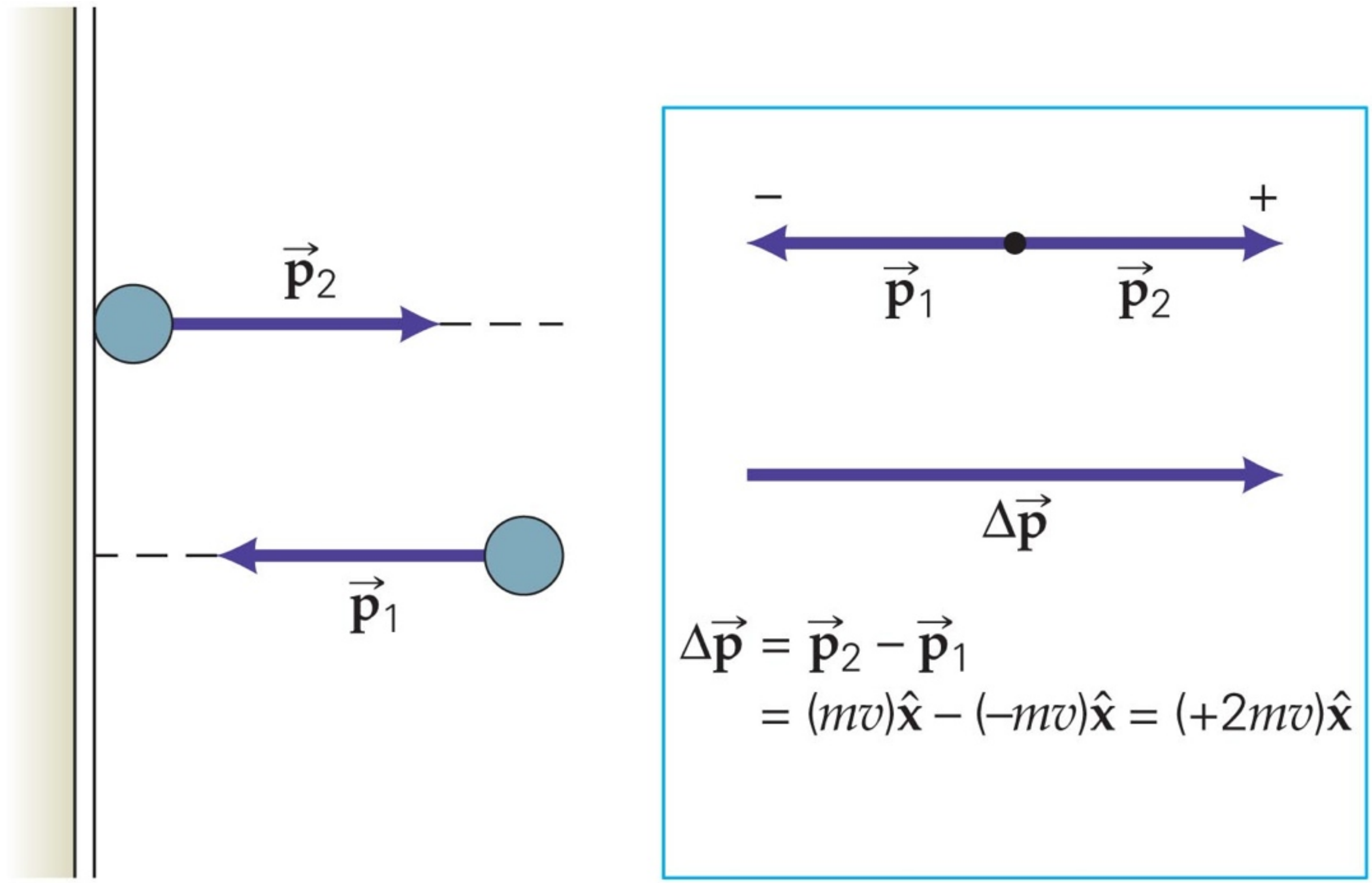
Two objects are known to have the same momentum. Do these two objects necessarily have the same kinetic energy?

A yes

B no

6.1 Linear Momentum

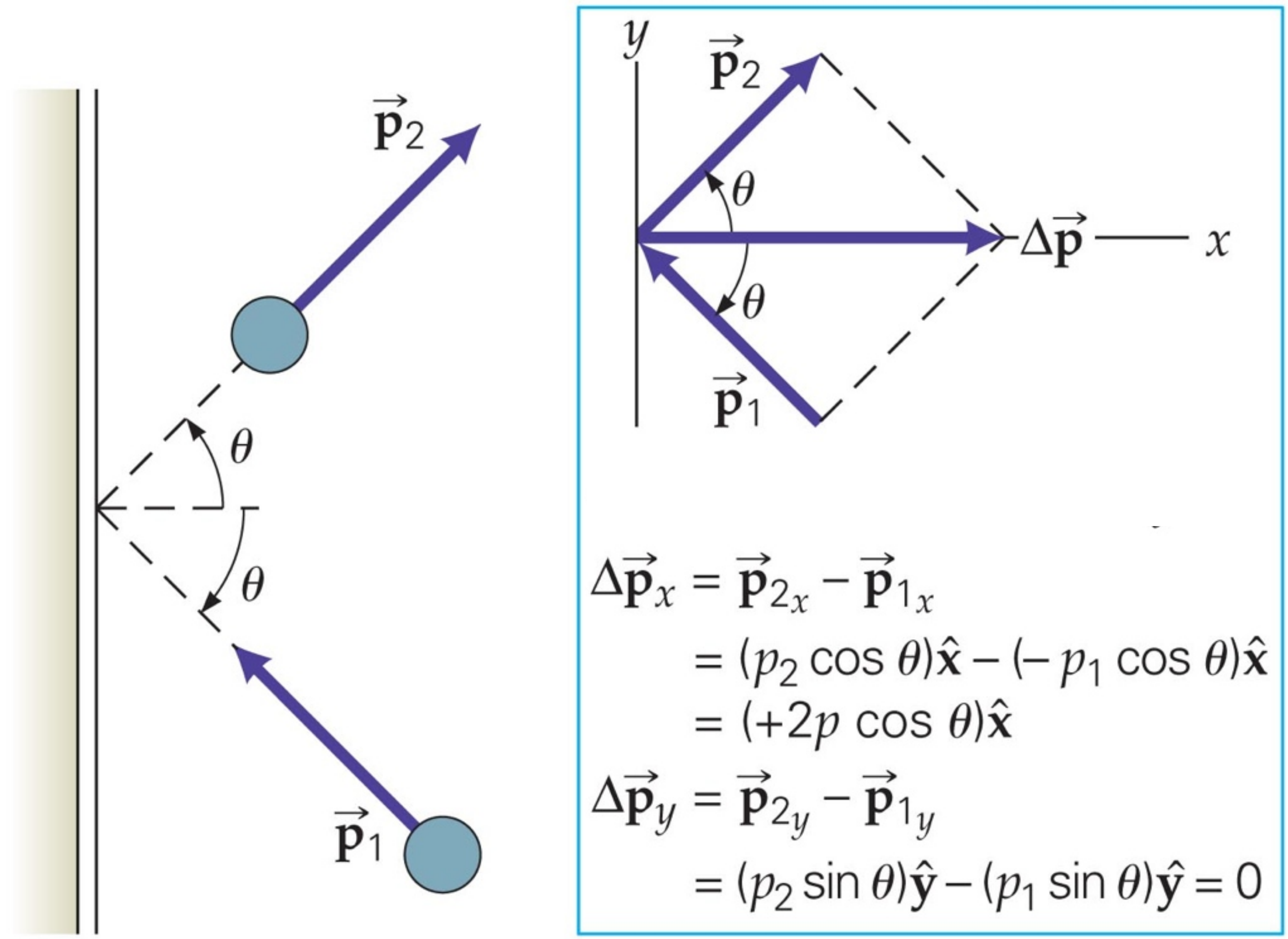
The change in momentum is the difference between the momentum vectors.



(a)

6.1 Linear Momentum

The change in momentum is the difference between the momentum vectors.



(b)

6.1 Linear Momentum

If an object's momentum changes, a force must have acted on it, because it accelerated.

$$\vec{\mathbf{F}}_{\text{net}} = m\vec{\mathbf{a}} = \frac{m(\vec{\mathbf{v}} - \vec{\mathbf{v}}_o)}{\Delta t} = \frac{m\vec{\mathbf{v}} - m\vec{\mathbf{v}}_o}{\Delta t} = \frac{\vec{\mathbf{p}} - \vec{\mathbf{p}}_o}{\Delta t} = \frac{\Delta\vec{\mathbf{p}}}{\Delta t}$$

$$\vec{\mathbf{F}}_{\text{net}} = \frac{\Delta\vec{\mathbf{p}}}{\Delta t}$$ *Newton's second law of motion in terms of momentum*

The net force is equal to the rate of change of the momentum.

Clicker question #71

Question 6.3a Momentum and Force

A net force of 200 N acts on a 100-kg boulder, and a force of the same magnitude acts on a 130-g pebble. How does the rate of change of the boulder's momentum compare to the rate of change of the pebble's momentum?

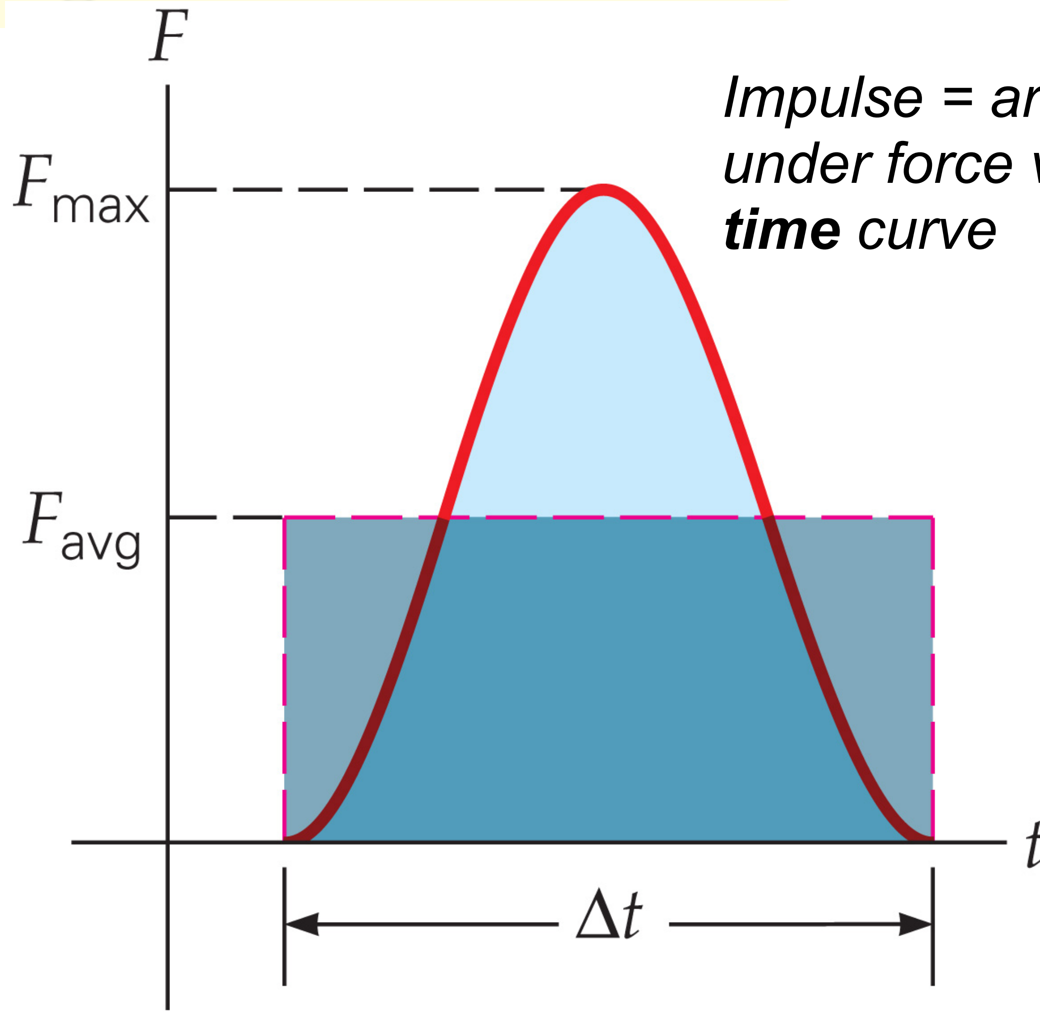
A. greater than
B. less than
C. equal to

6.2 Impulse

Impulse is the change in momentum:

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

Typically, the force varies during the collision.



Impulse = area under force vs. ***time*** *curve*

6.2 Impulse

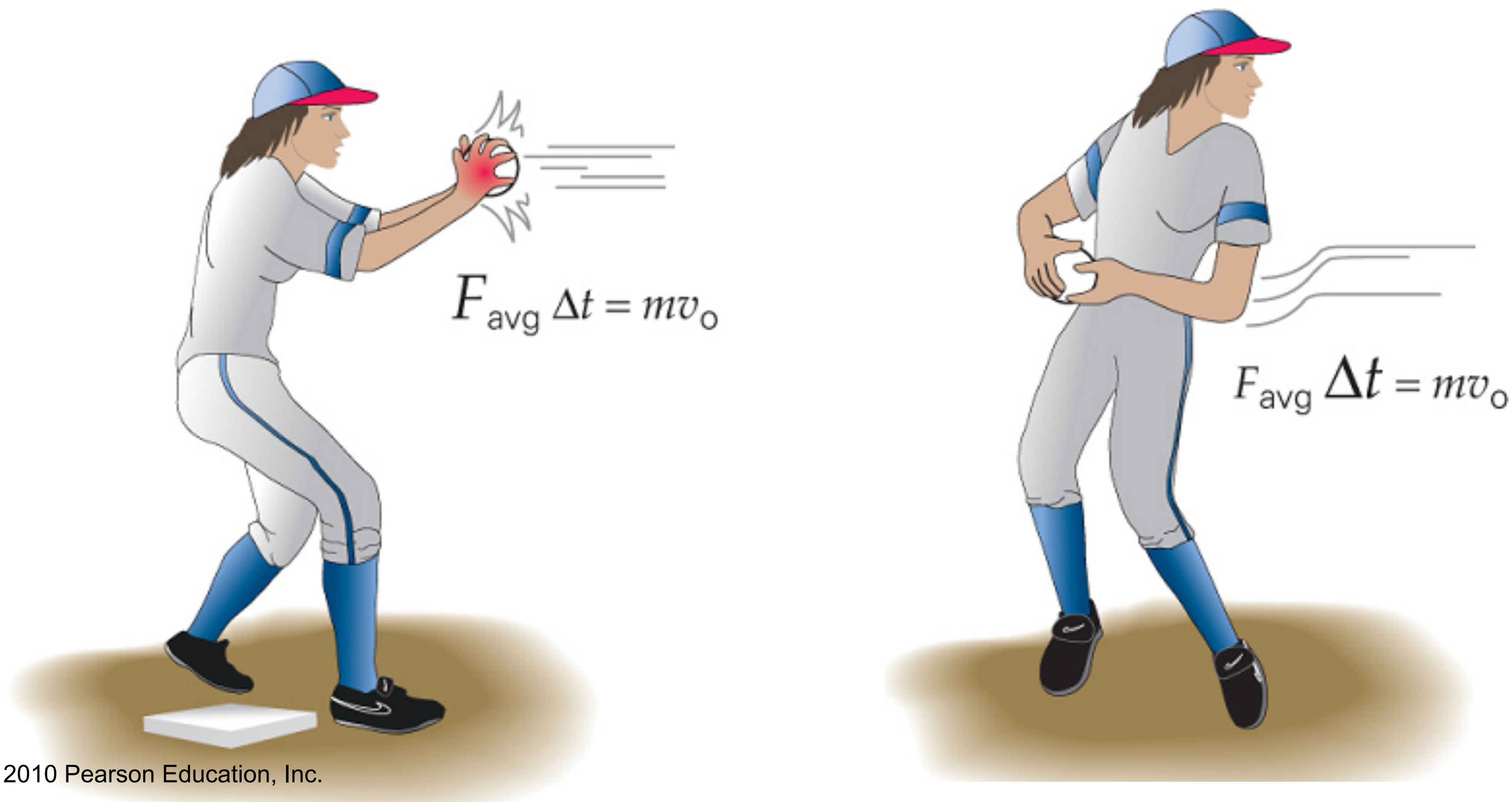
Actual contact times may be very short.

TABLE 6.1 Some Typical Contact Times (Δt)

	Δt (milliseconds)
Golf ball (hit by a driver)	1.0
Baseball (hit off tee)	1.3
Tennis (forehand)	5.0
Football (kick)	8.0
Soccer (header)	23.0

6.2 Impulse

When a moving object stops, its impulse depends only on its change in momentum. This can be accomplished by a large force acting for a short time, or a smaller force acting for a longer time.



6.2 Impulse

We understand this instinctively—we bend our knees when landing a jump; a "soft" catch (moving hands) is less painful than a "hard" one (fixed hands).

This is how airbags work—they slow down collisions considerably—and why cars are built with crumple zones.

Video: crash test

http://www.youtube.com/watch?v=d7iYZPp2zYY&feature=related

Clicker question #72

Question 6.5a Two Boxes I

Two boxes, one heavier than the other, are initially at rest on a horizontal frictionless surface. The same constant force *F* acts on each one for exactly *1 second*. Which box has more momentum after the force acts ?

A) the heavier one

B) the lighter one

C) both the same

Clicker question #73

Question 6.5b **Two Boxes II**

In the previous question, which box has the larger velocity after the force acts?

A the heavier one

B the lighter one

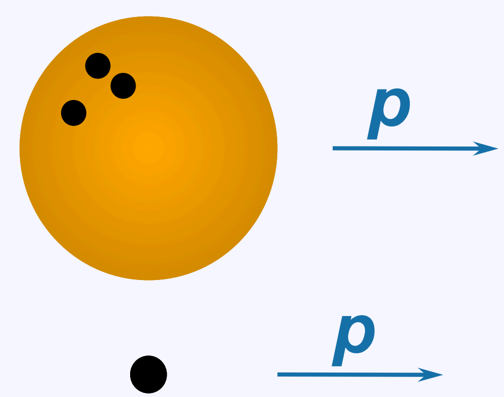
C both the same

Clicker question #74

Question 6.9a Going Bowling I

A bowling ball and a Ping-Pong ball are rolling toward you with the same momentum. If you exert the same force to stop each one, which takes a longer time to bring to rest?

- A the bowling ball
- B same time for both
- C the Ping-Pong ball
- D impossible to say



Clicker question #75

Question 6.7 Impulse

A small beanbag and a bouncy rubber ball are dropped from the same height above the floor. They both have the same mass. Which one will impart the greater impulse to the floor when it hits?

A the beanbag

B the rubber ball

C both the same

Conservation of momentum

- Demonstrations
  - Rocket redux
    http://www.youtube.com/watch?v=ta6q6-52a3c
  - Gun recoil
    http://www.youtube.com/watch?v=_O-Wedt3N4U
  - Colliding black holes & gravitational waves
    http://spiegel.cs.rit.edu/~hpb/CCRG/
    kick_sphere_radiation_and_zoom_bh_movement.mp4

Class participation

- 0. Name
- 1. Do you like today’s slides better, worse, or about the same as previous lecture slides?
- 2. On the exam, what concept or problem do you feel the happiest about?
- 3. On the exam, what concept or problem do you feel the least happy about?