Welcome back to Physics 211

Today's agenda:

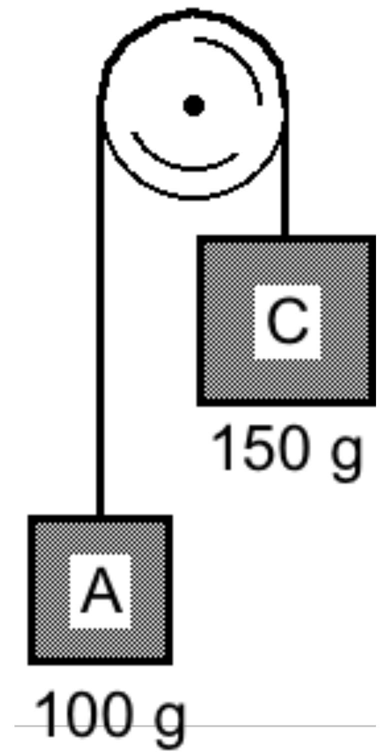
- *Forces in Circular Motion*

Current assignments

- Reading: Chapter 8 in textbook
  - Prelecture due Thursday
- HW#8 due this Friday at 5 pm.
- Midterm 2 on Tuesday, Oct 21:
  - Chapters 4.4-7
  - Newton's Laws, circular motion kinematics, relative motion

8-1.1 Blocks A and C are initially held in place as shown. After the blocks are released, block A will accelerate up and block C will accelerate down.

The magnitudes of their accelerations are the same. What is the magnitude of the acceleration?

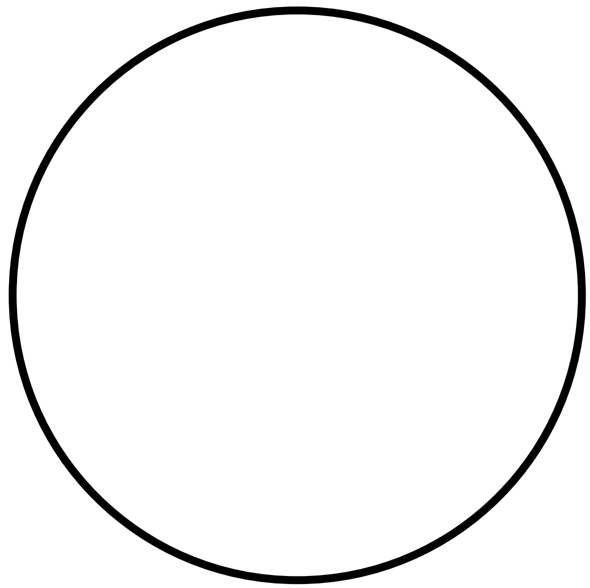


1. 3.9 m/s^2
2. 5.9 m/s^2,
3. 9.8 m/s^2
4. 2.0 m/s^2
5. None of the above

Pulley Demo

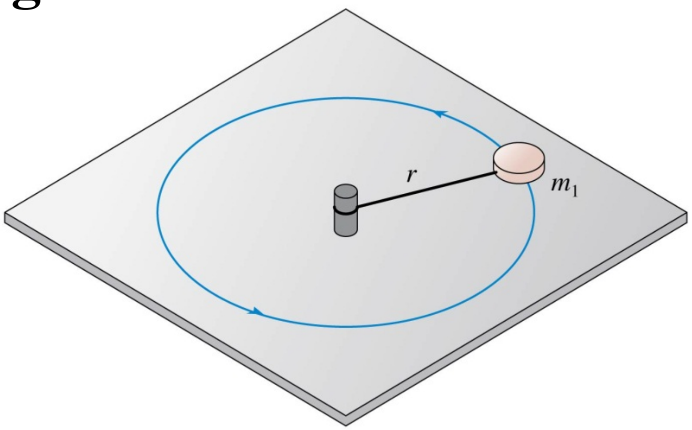
Forces in circular motion

- **Motion around circular track, constant speed (for now):**



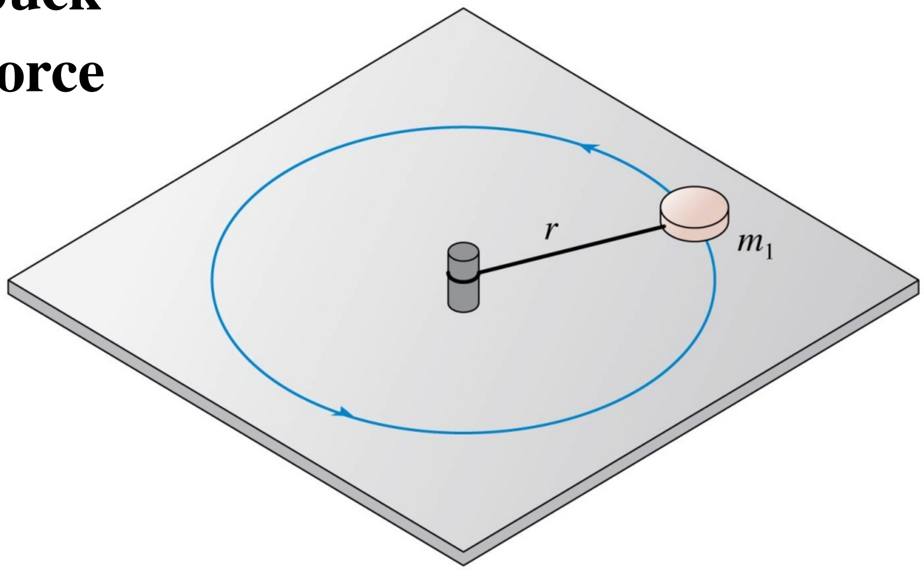
$$\mathbf{a_{rad} = v^2/r}$$

8-1.2 An ice hockey puck is tied by a string to a stake in the ice. The puck is then swung in a circle. What is true about the force or forces that the puck feels?



1. There is a new type of force: the centripetal force.
2. There is a new type of force: the centrifugal force.
3. One or more of our familiar forces pushes outward.
4. One or more of our familiar forces pulls inward.
5. I have no clue.

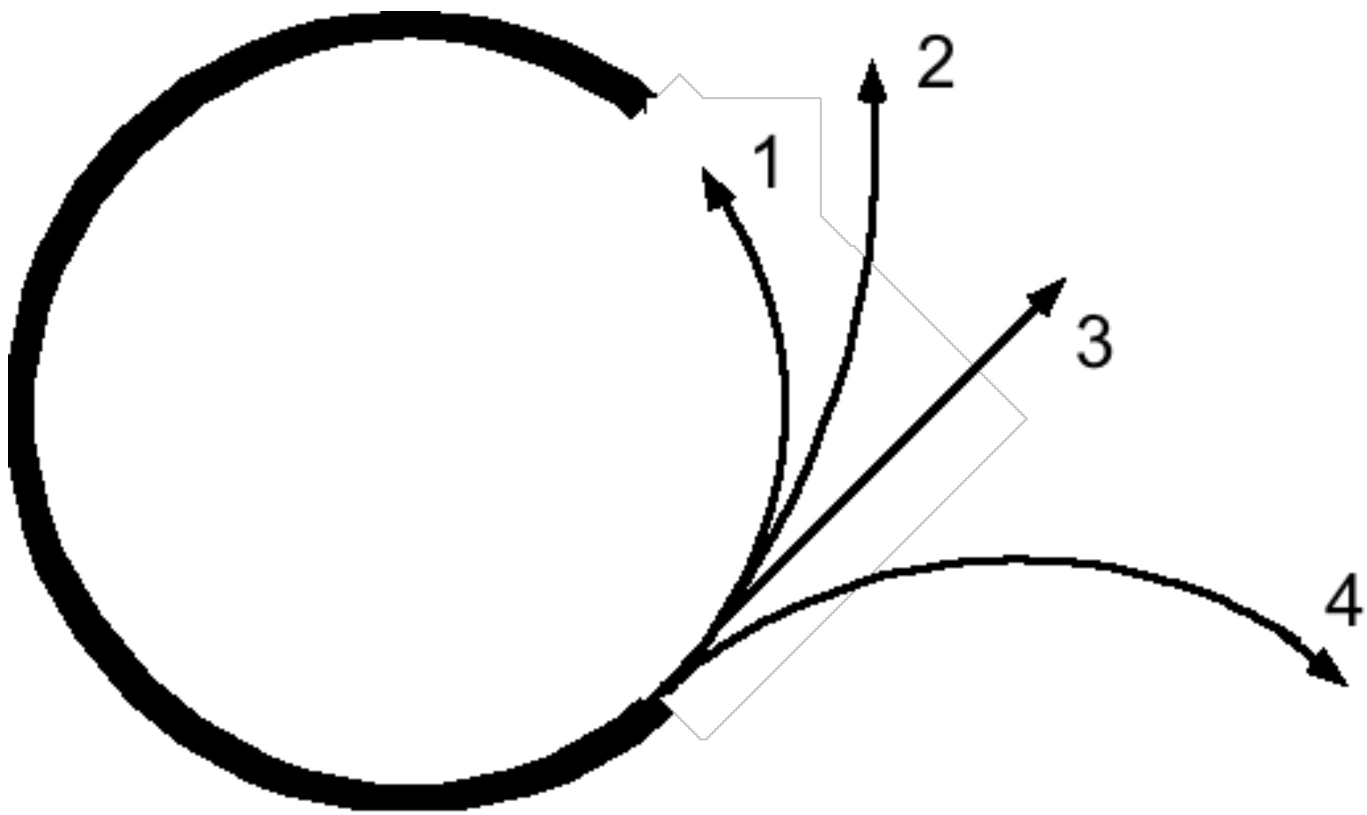
8-1. 3 An ice hockey puck is tied by a string to a stake in the ice. The puck is then swung in a circle. What force is producing the centripetal acceleration of the puck?



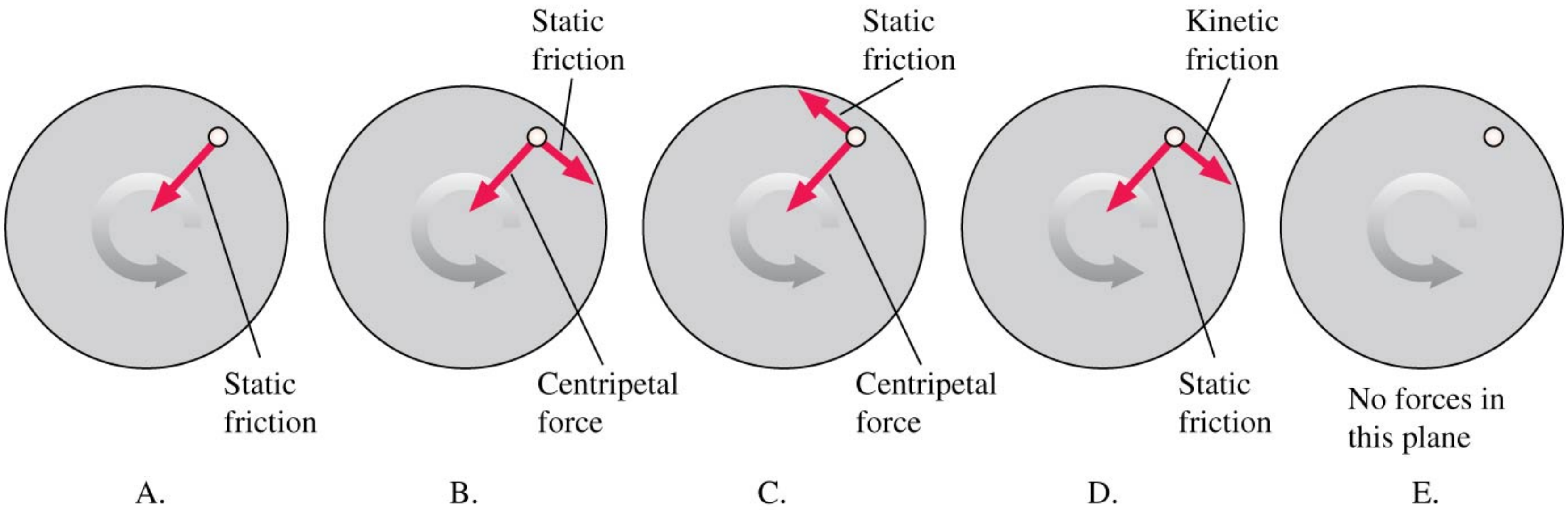
1. **Gravity**
2. **Air resistance**
3. **Friction**
4. **Normal force**
5. **Tension in the string**

A ball is rolling counter-clockwise at constant speed on a circular track. One quarter of the track is removed.

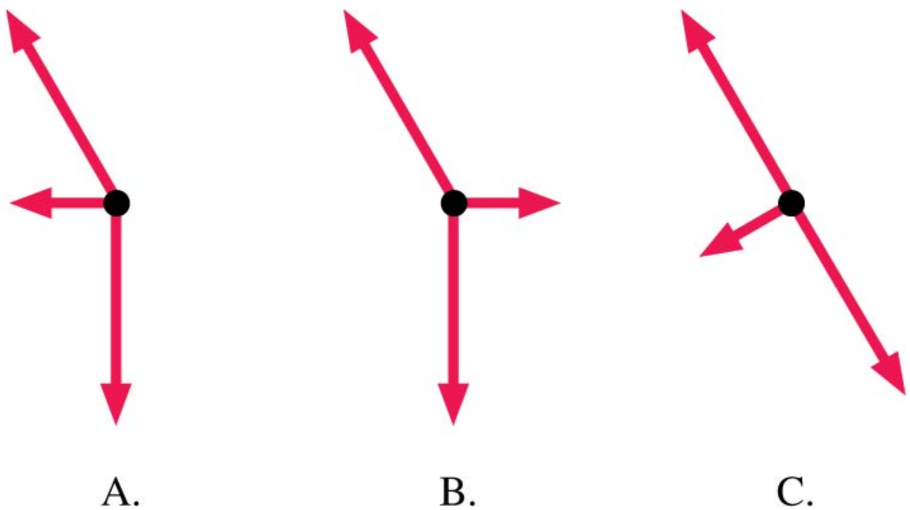
What path will the ball follow after reaching the end of the track?



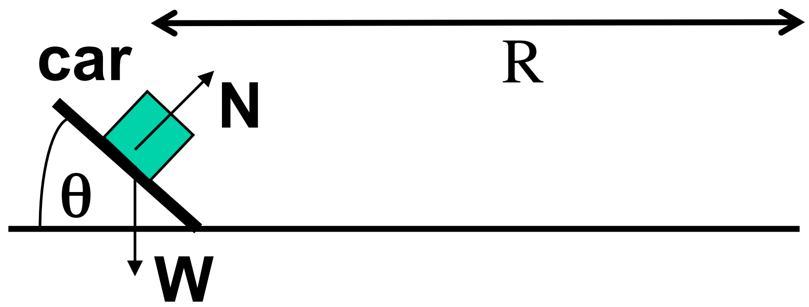
8-1.4 A coin sits on a turntable as the table steadily rotates ccw. What force or forces act in the plane of the turntable?



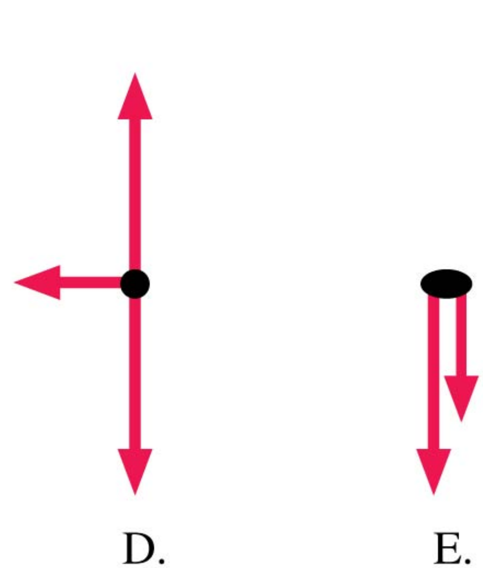
8-1.5 A car turns a corner on a banked road. Which of the diagrams could be the car's free-body diagram?



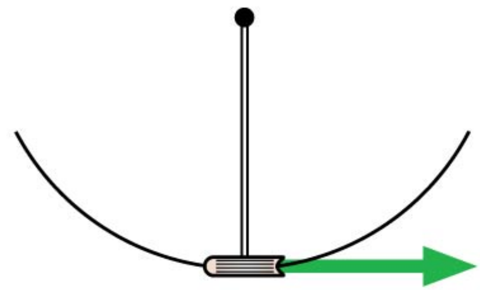
Sample problem: A 1000 kg car is going around a banked, **frictionless** circular track with radius 100 m and bank angle of 10 degrees. How fast should the car go so that it doesn't slide off the track?

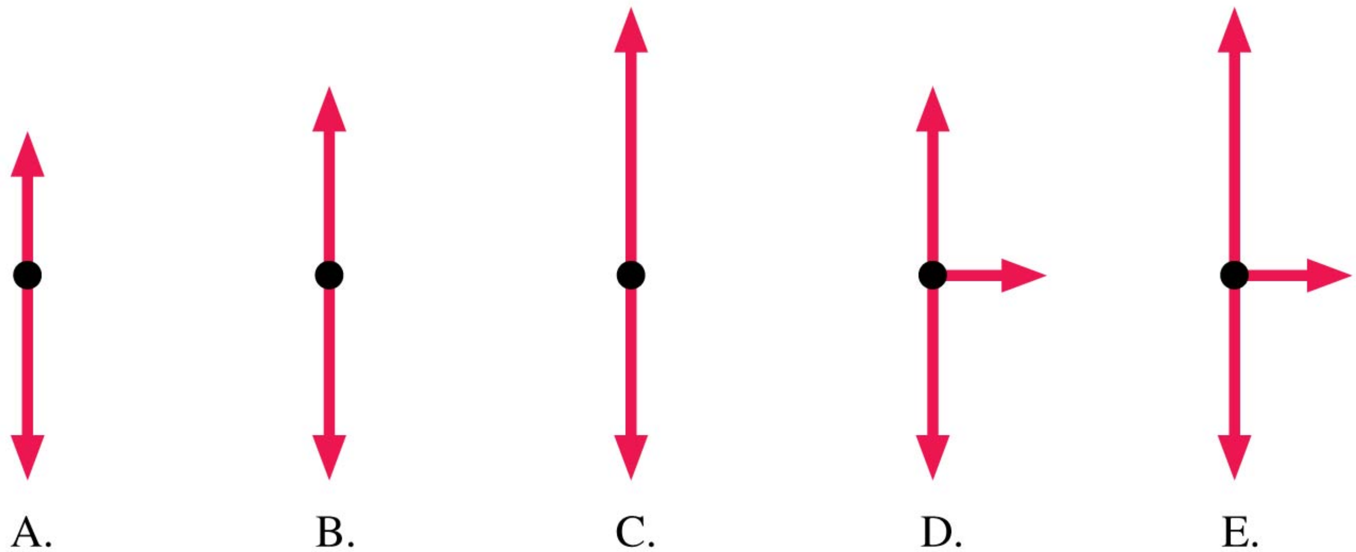


8-1.6 A roller coaster car does a loop-the-loop. Which of the free-body diagrams shows the forces on the car at the top of the loop? Rolling friction can be neglected.



8-1.7 A physics textbook swings back and forth as a pendulum. Which is the correct free-body diagram when the book is at the bottom and moving to the right?

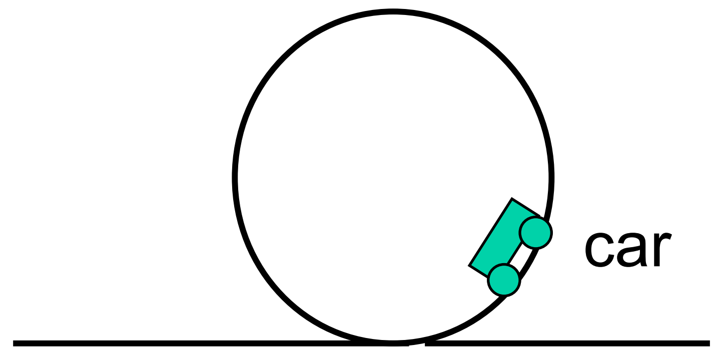


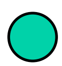


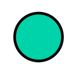
Demo: Motion on loop-the-loop

What is normal force on car at top and bottom of loop?

Neglect friction; assume moves with speed v_B at bottom and v_T at top



At bottom 

 At top

Demo – swinging water bucket

- Does the water fall out?

- What is the FBD for the water at the top of the swing?

Demo – swinging water bucket

- So why doesn't the water fall out?

- What if $mv^2/R < mg$ for the water?
- This is like a satellite in orbit around the earth

Forces in circular motion summary:

- Draw a free body diagram
- Sum the forces as usual
  - There IS NOT AN “EXTRA” centripetal force
  - find F_{NET}(radial) and F_{NET}(other)
  - Velocity is NOT a force
- THEN figure out what F_{NET} (radial) has to be: in uniform circular motion
  - $F_{NET}(\text{radial}) = ma$
  - $a = v^2/r$

Impulse

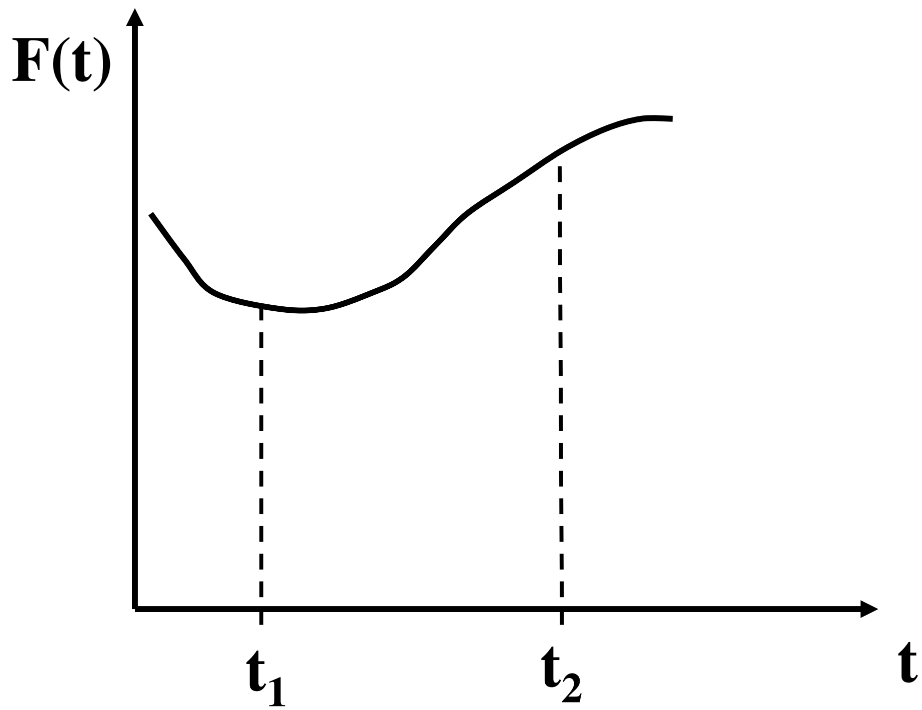
- Constant force F_{12} acting on object 1 due to object 2 for a time Δt yields an **impulse**

$$I_{12} = F_{12}\,\Delta t$$

- In general, for a time varying force need to use this for small Δt and add:

$$I = \sum F(t)\,\Delta t =$$

Impulse for time varying forces



*** area under curve equals impulse**

Impulse → change in momentum

- Consider first constant forces ...

- Constant acceleration equation:

$$v_f = v_i + at$$

↓

$$mv_f - mv_i = ma\Delta t =$$

- If we call p = mv ***momentum*** we see that

$$\Delta p =$$

8-1.5 A crash test vehicle is equipped with two sensors: (1) one on its front bumper that measures the force of impact as a function of time F(t), and (2) one measuring the velocity v(t). How are these two related in a crash with a wall?

1. They're not related.
2. The integral (area under the curve) of v(t) is proportional to the change in the force.
3. The derivative of the velocity equals the maximum force.
4. The change in the velocity is proportional to the maximum force
5. The change in the velocity is proportional to the integral (area under the curve) of the force.

Impulse demo

- Cart equipped with force probe collides with rubber tube
- Measure force *vs.* time and momentum *vs.* time
- Find that integral of force curve is precisely the change in p!

Definitions of *impulse* and *momentum*

Impulse imparted to object 1 by object 2:

$$I_{12} = F_{12}\Delta t$$

Momentum of an object:

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

Impulse-momentum theorem

$$\mathbf{I}_{\mathbf{net}} = \Delta \mathbf{p}$$

The net impulse imparted to an object is equal to its change in momentum.

8-1.6 Consider the **change in momentum** in these three cases:

A. A ball moving with speed *v* is brought to rest.

B. The same ball is projected from rest so that it moves with speed *v*.

C. The same ball moving with speed *v* is brought to rest and immediately projected backward with speed *v*.

In which case(s) does the ball undergo the largest magnitude of change in momentum?

1. Case A.
2. Case B.
3. Case C.
4. Cases A and B.

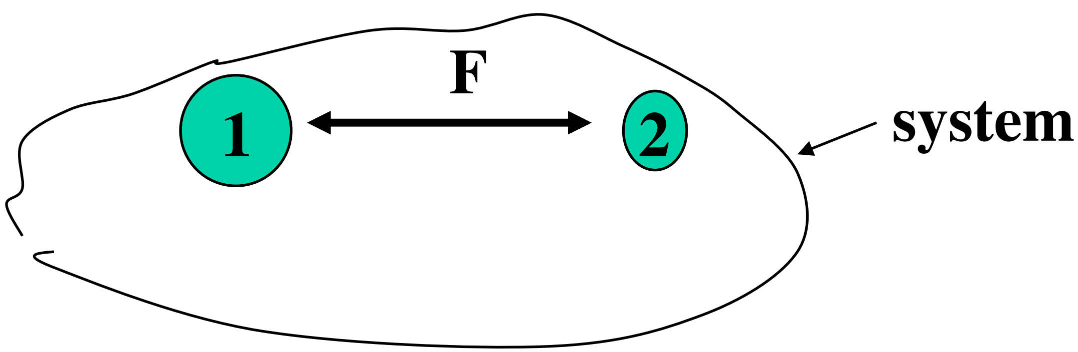
Newton’s 3rd law and changes in momentum

If all external forces (weight, normal, etc.) cancel:

Conservation of momentum

- Assuming no net forces act on bodies there is no net impulse on composite system

- Therefore, no change in ***total*** momentum $\Delta(p_1 + p_2) = 0$



Conservation of momentum

(for a system consisting of two objects 1 and 2)

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

If the net (external) force on a system is zero, the total momentum of the system is constant.

Whenever two or more objects in an isolated system interact, the total momentum of the system remains constant

Conservation of momentum with carts

- *One cart with mass m_1 begins at rest $v_{1i} = 0$, and the other cart (with the same mass) has a velocity $v_{2i} = v$. After the two carts hit each other, what is the sum of the velocities of the two carts $v_{2f} + v_{1f}$?*

Demo

- Experiment –> zero sensors

8-1.7 A cart moving to the right at speed *v* collides with an identical stationary cart on a low-friction track. The two carts stick together after the collision and move to the right.

What is their speed after colliding?

1. 0.25 *v*
2. 0.5 *v*
3. *v*
4. 2*v*

8-1.8 A student is sitting on a low-friction cart and is holding a medicine ball. The student then throws the ball at an angle of 60° (measured from the horizontal) with a speed of 10 m/s.

The mass of the student (with the car) is 80 kg. The mass of the ball is 4 kg.

What is the final speed of the student (with car)?

1. 0 m/s
2. 0.25 m/s
3. 0.5 m/s
4. 1 m/s

Reading assignment

- Work, Energy
- Chapter 10 in textbook