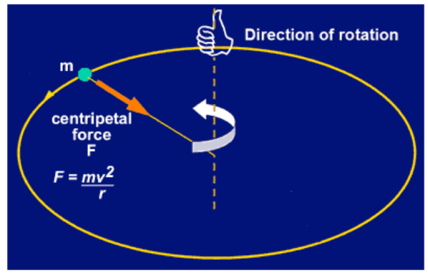
Welcome back to Physics 215

Today's agenda:

- *Forces in Circular Motion*
- *Impulse*



Extra credit

- Unobtrusively take a selfie at the talk and email it to me.

Undergraduate Physics Colloquium

"Impact into granular media:
A collisional process"

Prof. Cacey Bester, Swarthmore College

When: Thursday, Oct. 10, 3:45 pm
Where: 202/204 Physics Building
Refreshments: at 3:30 pm
All are welcome

Reading for Thursday

- Momentum and Collisions
  - Reading
  - OpenStax Vol 1: 9.1-9.4

Midterm 2: in 2.5 weeks (October 24)

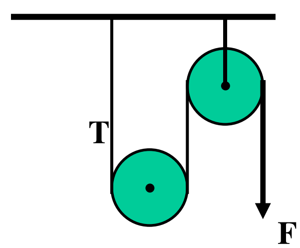
I will return your first exam by the end of this week.

Office hours are back to normal or by appointment

Tension

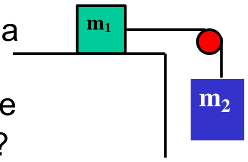
- For an <u>ideal</u> string or rope connecting two objects:
  - does not stretch → *inextensible*
  - has zero mass
  - If A and B interact through a massless string, we can omit the string and treat F_{AB} and F_{BA} as an action-reaction pair
- Often, two objects connected by a rope accelerate at the same rate

Pulleys



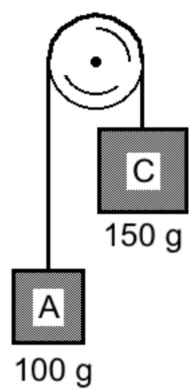
- For an <u>ideal</u> pulley:
  - The pulley has zero mass
  - There is no friction on the pulley
- Tension in a massless string remains constant as it passes over the ideal pulley
- Because Pulleys change direction, the direction of acceleration may change!

Sample problem: Two blocks are connected by a massless rope. Mass m_1 sits on top of a frictionless table top, while $m_2 > m_1$ hangs off the table as shown. What is the acceleration of m_2?



6-2.6 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.

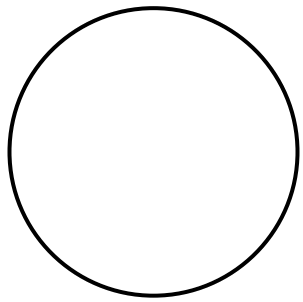
The magnitudes of their accelerations are the same. What is the magnitude of the acceleration?



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

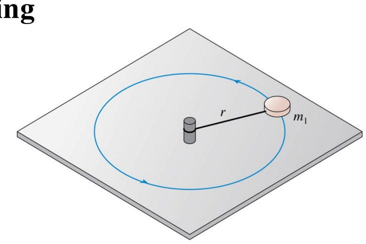
Forces in circular motion

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



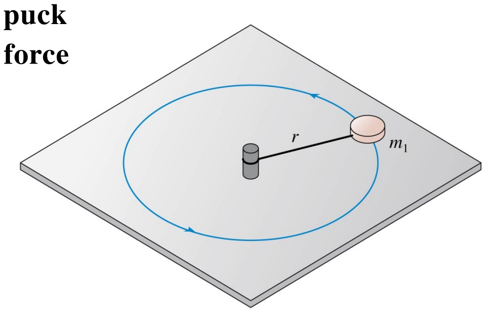
$$a_{rad} = v^2/r$$

6-2.7 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 or forces does the puck feel?



1. **A new force: the centripetal force.**
2. **A new force: the centrifugal force.**
3. **One or more of our familiar forces pushing outward.**
4. **One or more of our familiar forces pulling inward.**
5. **I have no clue.**

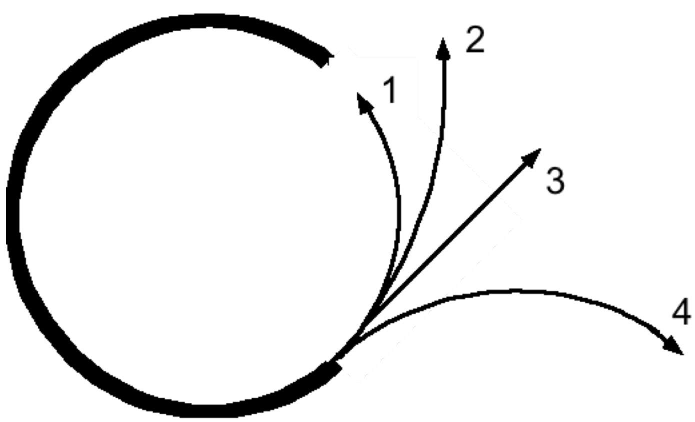
6-2. 8 An ice hockey puck is tied by a string to a stake in the ice. The puck is then swung in a circle. What force is producing the centripetal acceleration of the puck?



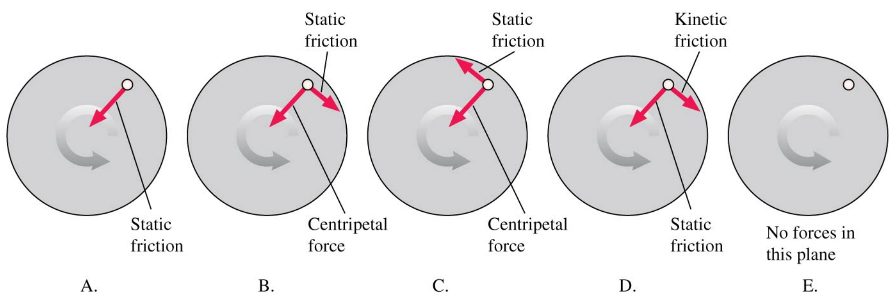
1. Gravity
2. Air resistance
3. Friction
4. Normal force
5. Tension in the string

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

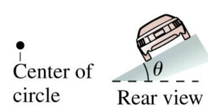
What path will the ball follow after reaching the end of the track?

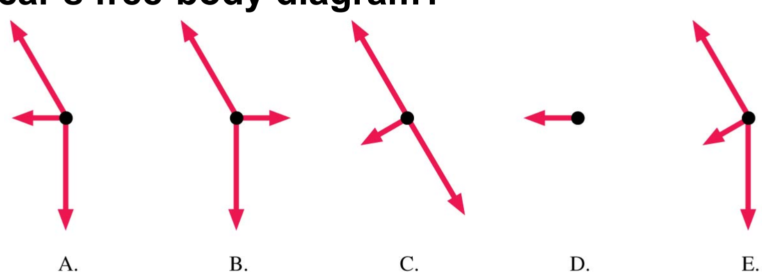


6-2.9 A coin sits on a turntable as the table steadily rotates ccw. What force or forces act in the plane of the turntable?

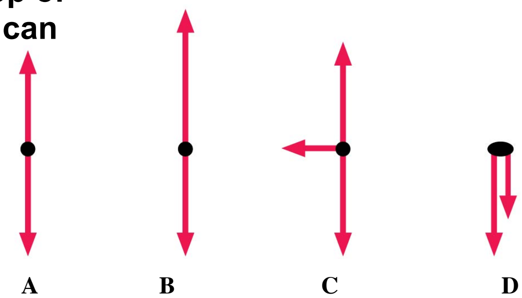


6-2.10 A car turns a corner on a banked road. Which of the diagrams <u>could</u> be the car's free-body diagram?



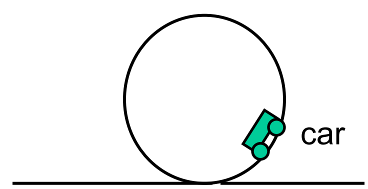


SG A roller coaster car does a loop-the-loop. Which of the free-body diagrams shows the forces on the car at the top of the loop? Rolling friction can be neglected.



Motion on loop-the-loop

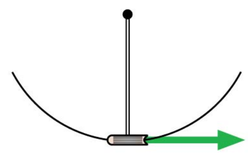
What is normal force on car at top and bottom of loop? *Neglect friction; assume moves with speed v_B at bottom and v_T at top*

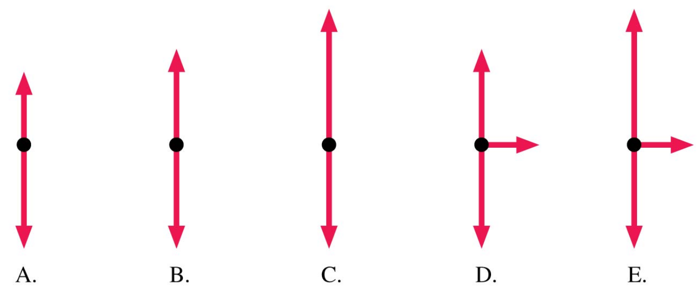


At bottom

At top

SG: 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 – swinging water bucket

- Does the water fall out?
- What is the FBD for the water?

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
  - The inward force is ______________

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}(radial) = ma
  - $a = v^2/r$

So far …

solved problems where forces don't change during the problem

what if they DO change?

Impulse

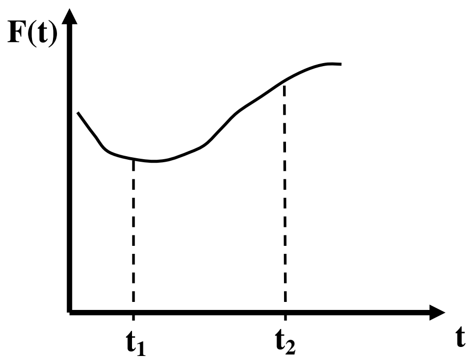
- Constant force F_{12} acting on object 1 due to object 2 for a time Δt yields an **impulse**

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

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

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

Impulse for time varying forces



*** area under curve equals impulse**

Impulse → change in momentum

- Consider first constant forces ...
- Constant acceleration equation:

$$v_f = v_i + at$$

$$\downarrow$$

$$mv_f - mv_i = mat =$$

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

$$\Delta p =$$

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

$$\mathbf{I_{net} = \Delta p}$$

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

SG 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?

A. Case A.
B. Case B.
C. Case C.
D. Cases A and B.

Demo: medicine ball and cart

- By Newton's 3rd law, the force on the ball is equal and opposite to the force on the student
- Acts for same time interval → equal and opposite changes in momentum

SG A student sitting on a cart is playing catch with an instructor standing on the ground. Assume everything is initially at rest, and the ball is thrown horizontally at the same velocity by both the student and instructor. Which action causes the student + cart system to move with the highest speed?

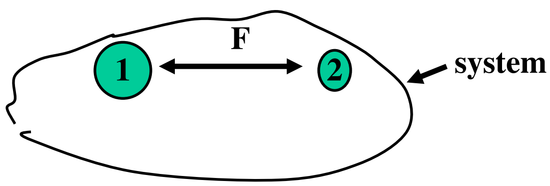
A. The student catching the ball from the instructor
B. The student throwing the ball to the instructor
C. Both actions result in the same speed for the student+cart system.

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 $v_{2f} + v_{1f}$?*