Welcome back to Physics 211

Today's agenda:

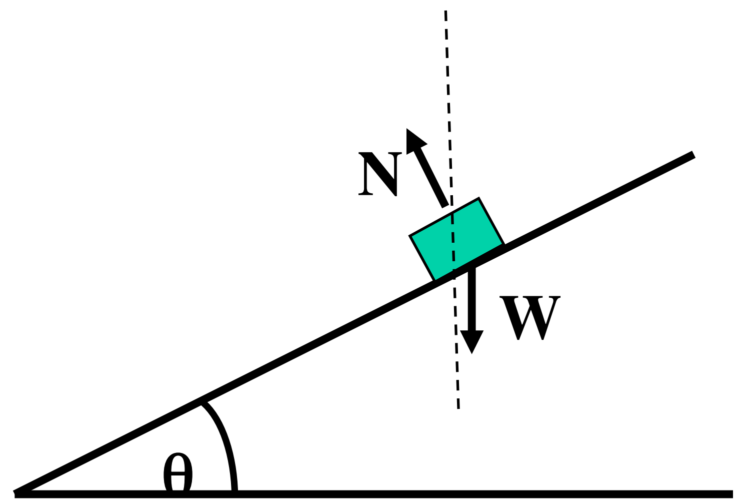
- *Friction*
- *Accelerating Frames*
- *Tension*
- *Forces in Circular Motion*

Current assignments

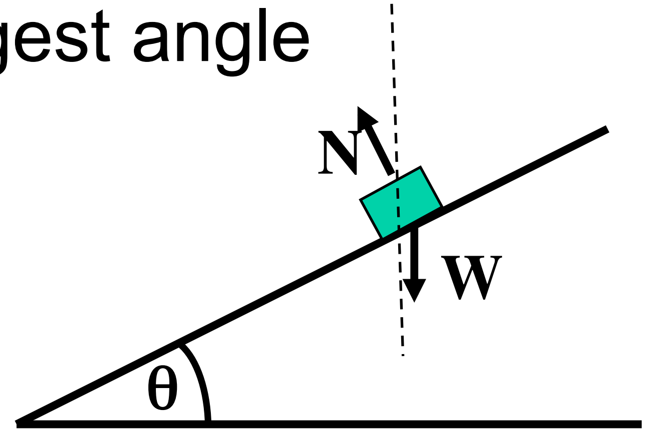
- Reading: Chapter 8 in textbook (motion in a plane)
  - Prelecture due next Tuesday
- HW#7 due this Friday at 5 pm.

7-2.1 A block is sitting at rest on an incline with friction. Which way does the friction force on the block point?

1. Down and to the left (along incline)
2. Up and to the right (along incline)
3. Straight left
4. Straight right



Sample problem: What is the largest angle before the block slips?



7-2.2 Having no choice, you have parked your old heavy car on an icy hill, but you are worried that it will start to slide down the hill.

Would a lighter car be less likely to slide when you park it on that icy hill?

1. No, the lighter car would start sliding at a less steep incline.
2. It doesn't matter. The lighter car would start sliding at an incline of the same angle.
3. Yes, you could park a lighter car on a steeper hill without sliding.

What if $\theta > \tan^{-1}\mu_s$?

The magnitude of the **force of *kinetic* friction** between two objects

- depends on the type of surfaces of the objects
- depends on the normal force that the objects exert on each other
- does ***not*** depend on the surface area where the two objects are touching
- does ***not*** depend on the speed with which one object is moving relative to the other

$$f_{B,T}^{\text{kinetic}} = \mu^{\text{kinetic}} N_{B,T}$$

7-2.3 : A block of mass 1 kg sits on an incline with angle 30 degrees. The static friction coefficient is 0.2 and the kinetic friction coefficient is 0.1. Does the block slide? If so, what is the magnitude of its acceleration?

1. It doesn't slide.
2. It slides with $|a| = 3.2\ m/s^2$
3. Slides with $|a| = 4.1\ m/s^2$
4. Slides with $|a| = 9.8\ m/s^2$
5. None of the above.

Summary of friction

- 2 laws of friction: *static* and *kinetic*
- Static friction tends to oppose motion and is governed by **inequality**

$$F_s \leq \mu_s N$$

- Kinetic friction is given by **equality** $F_K = \mu_K N$

Weight, mass, and acceleration

- What does a bathroom scale ``weigh''?

- Does it depend on your frame of reference?

- Consider elevators….

Sample problem: If a scale measures 200 lbs for a person who weighs 160 lbs at rest, how fast is the elevator accelerating?

7-2.3 A person is standing on a bathroom scale while riding an express elevator upwards (towards the top) in a tall office building. When the elevator is at rest, the scale reads about 160 lbs.

While the elevator is moving, the reading is frequently changing, with values ranging anywhere from about 120 lbs to about 200 lbs.

At a moment when the scale shows the *maximum* reading (*i.e.,* 200 lbs) the elevator

1. Must be slowing down
2. Must be speeding up
3. could be slowing down or speeding up
4. I'm not sure.

Demo: Force on a person in an elevator

Conclusions

- Scale reads magnitude of normal force $|N_{PS}|$

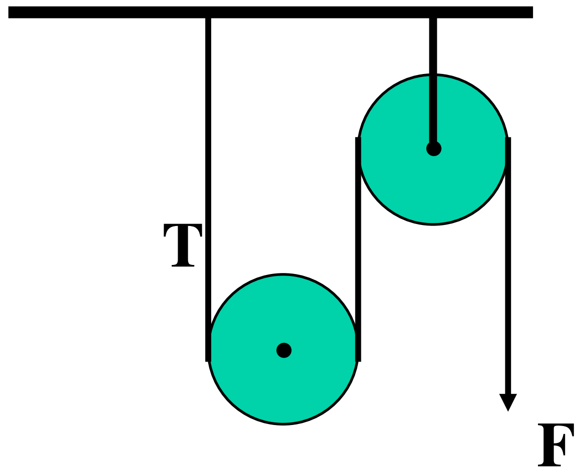
- Reading on scale does *not* depend on velocity (principle of relativity again!)

- Depends on acceleration *only*
  - * $a > 0 \rightarrow$ normal force bigger
  - * $a < 0 \rightarrow$ normal force smaller

Tension

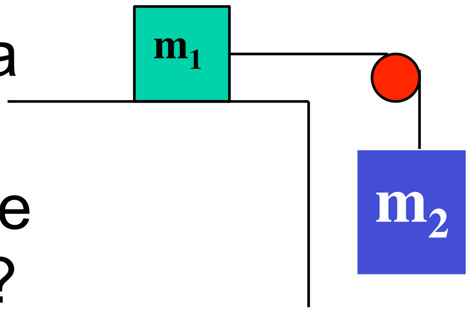
- For an <u>ideal</u> string or rope connecting two objects:
  - does not stretch → *inextensible*
  - has zero mass
  - If A and B interact through a massless string, we can omit the string and treat F_{AB} and F_{BA} as an action-reaction pair
- Often, two objects connected by a rope accelerate at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

Pulleys



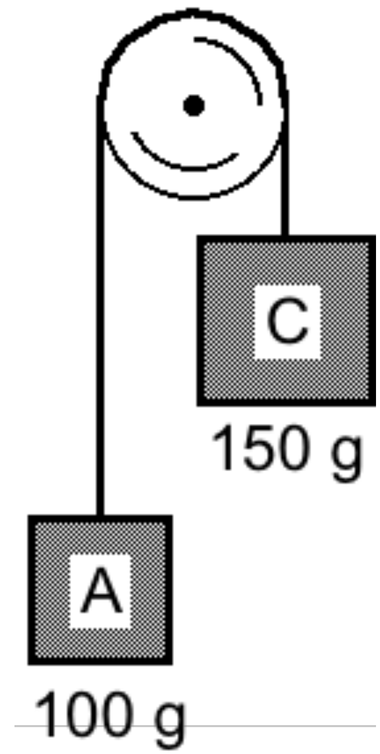
- For an ideal pulley:
  - The pulley has zero mass
  - There is no friction on the pulley
- Tension in a massless string remains constant as it passes over the ideal pulley
- Because Pulleys change direction, the direction of acceleration may change!

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?



7-2.5 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?

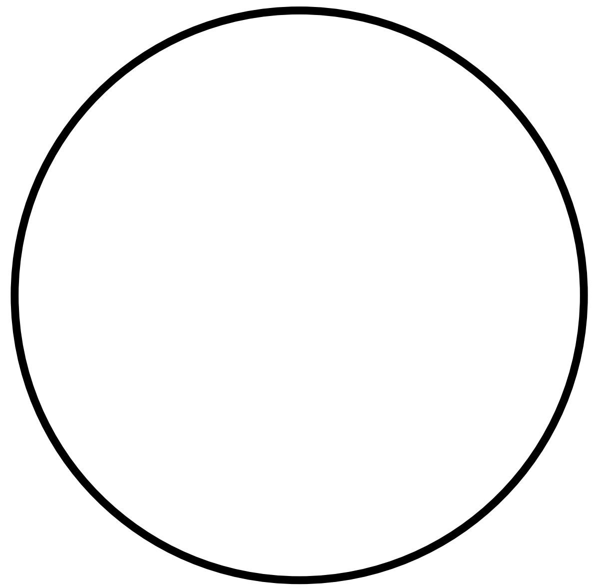


1. 3.9 m/s^2
2. 5.9 m/s^2,
3. 9.8 m/s^2
4. 2.0 m/s^2
5. None of the above

Pulley Demo

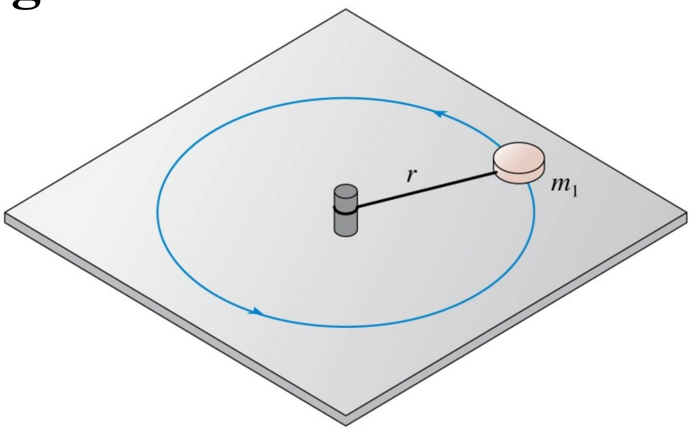
Forces in circular motion

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



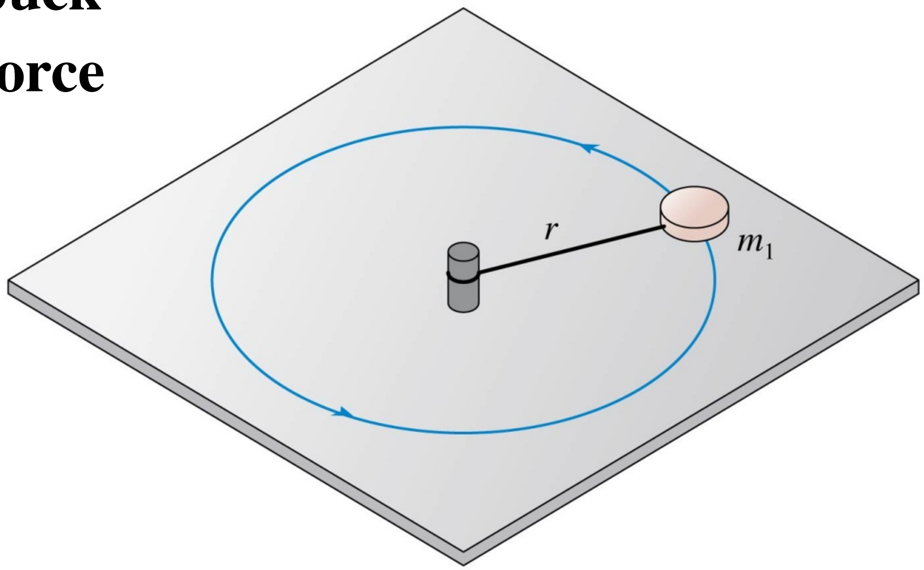
$$\mathbf{a_{rad} = v^2/r}$$

7-2.6 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.**

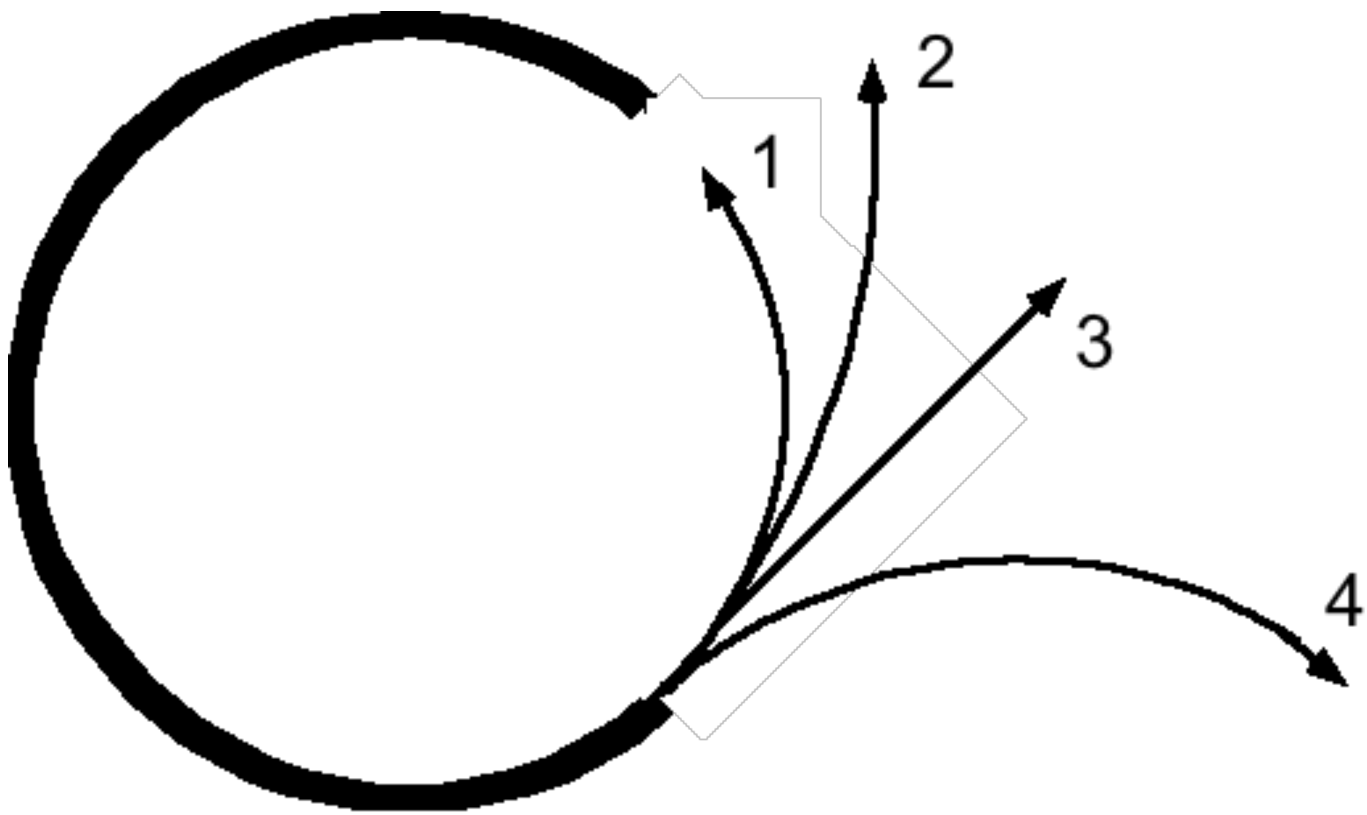
7-2. 7 An ice hockey puck is tied by a string to a stake in the ice. The puck is then swung in a circle. What force is producing the centripetal acceleration of the puck?



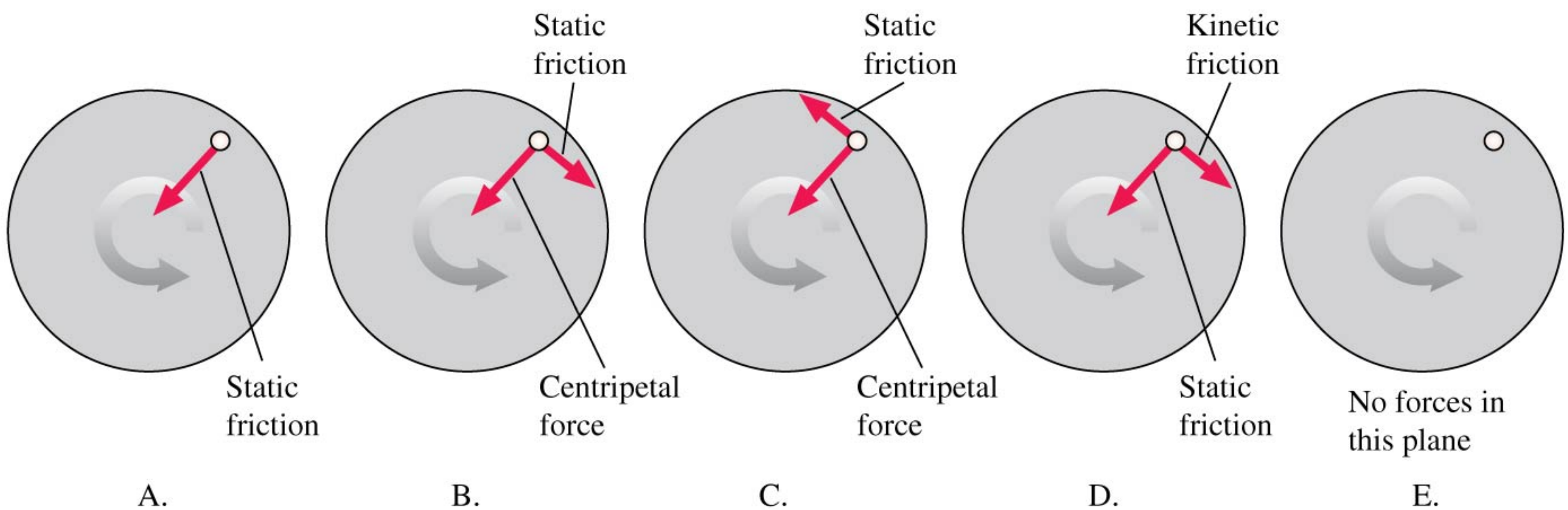
1. **Gravity**
2. **Air resistance**
3. **Friction**
4. **Normal force**
5. **Tension in the string**

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

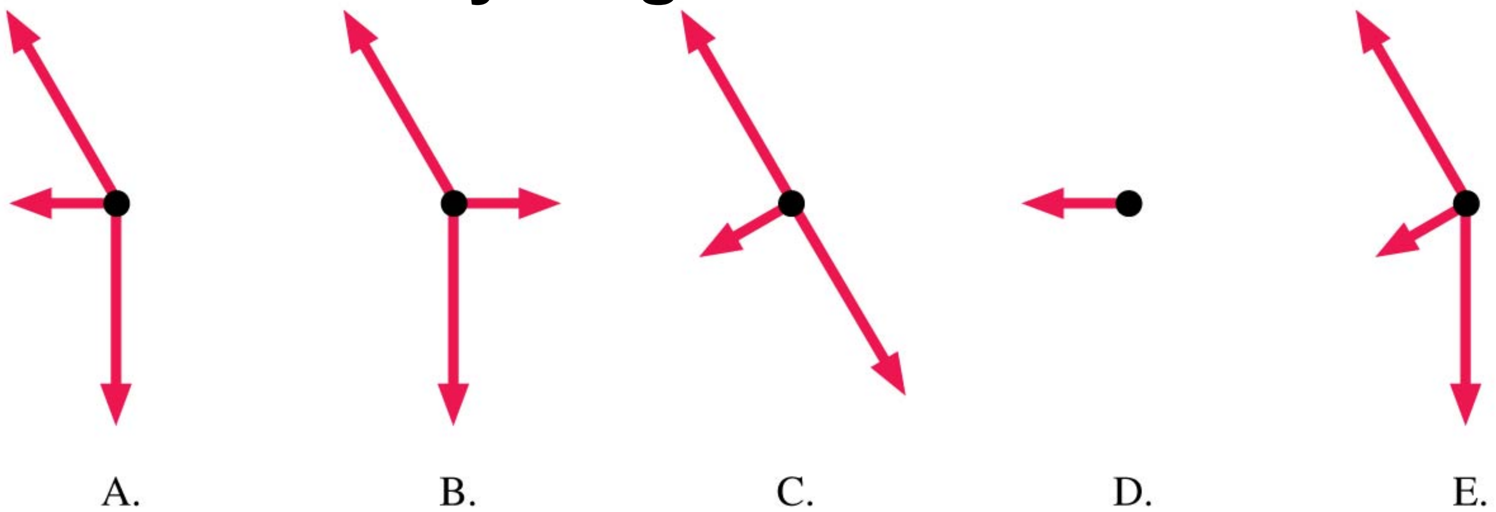
What path will the ball follow after reaching the end of the track?



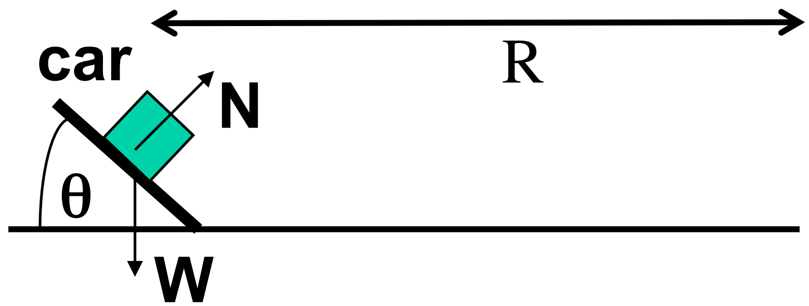
7-2.8 A coin sits on a turntable as the table steadily rotates ccw. What force or forces act in the plane of the turntable?



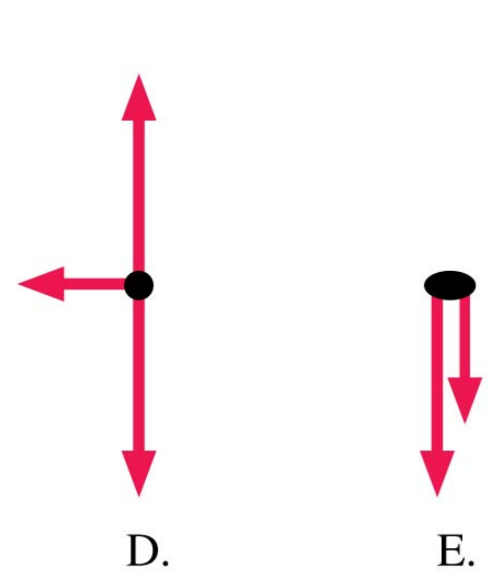
7-2.9 A car turns a corner on a banked road. Which of the diagrams could be the car's free-body diagram?



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?

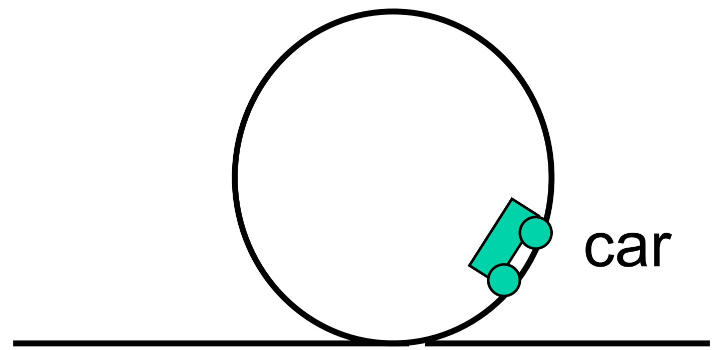


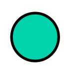
7-2.10 A roller coaster car does a loop-the-loop. Which of the free-body diagrams shows the forces on the car at the top of the loop? Rolling friction can be neglected.

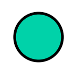


Motion on loop-the-loop

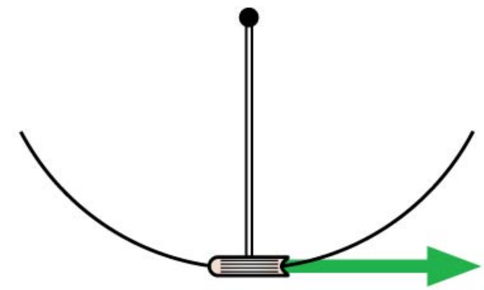
What is normal force on car at top and bottom of loop?
Neglect friction; assume moves with speed v_B at bottom and v_T at top

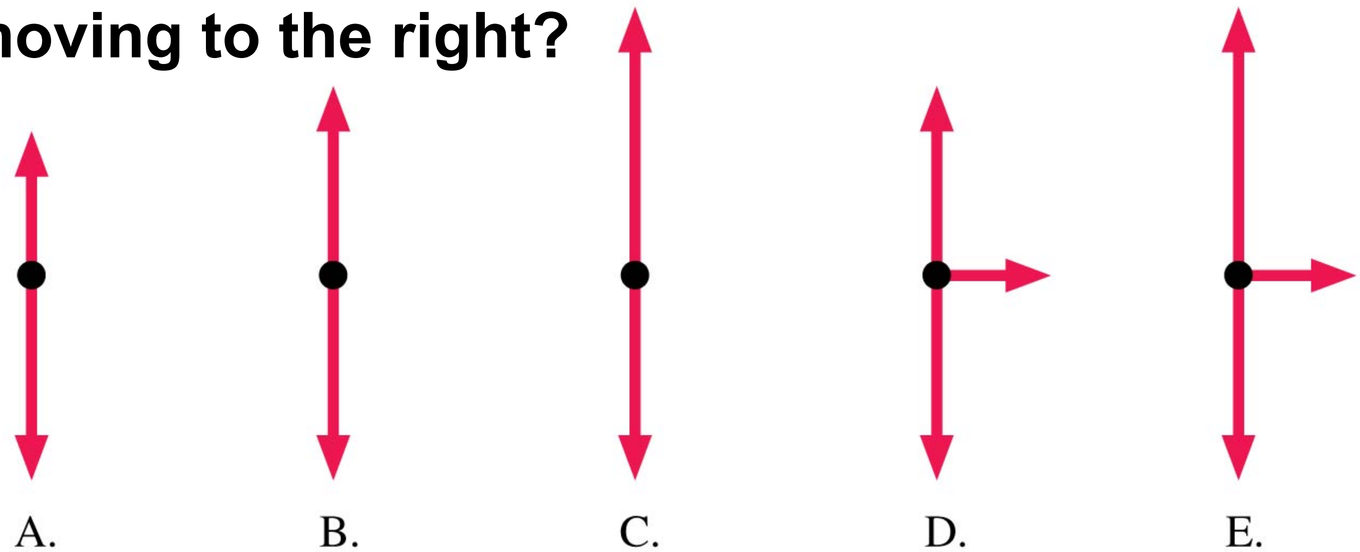


At bottom 

 At top

7-2.11 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

Demo – Amusement park "Rotor"

- What happens when the floor drops out? (Or I let go of the string?)

- What is the FBD?

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
  - $a = v^2/r$

Impulse

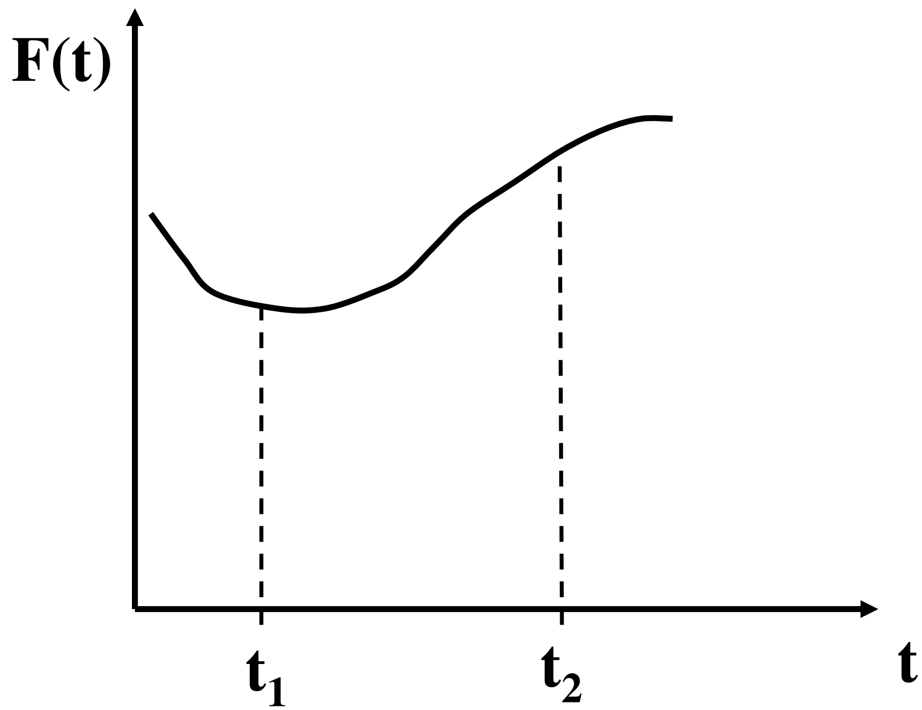
- Constant force F_{12} acting on object 1 due to object 2 for a time Δt yields an **impulse**

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

- 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:

$$v_f = v_i + at$$

$$\downarrow$$

$$mv_f - mv_i = mat =$$

- 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

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

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

7-2.9 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 change in momentum?

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