Welcome back to Physics 211

Today's agenda:
- *Friction*
- *Tension*
- *Forces in Circular Motion*

Thinking about elevators…

- Y-axis: up is positive
- If an elevator is moving upward, then
  - if it speeds up the acceleration is _______
  - If it slows down the acceleration is ______
- If an elevator is moving downward
  - Speeding up: a 0
  - Slowing down: a 0

SG 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

A. Must be slowing down
B. Must be speeding up
C. could be slowing down or speeding up
D. I'm not sure.

Conclusions

- Scale reads magnitude of normal force $|N_{SP}|$
- Reading on scale does *not* depend on velocity
- Depends on acceleration *only*
  - * $a > 0 \rightarrow$ normal force bigger
  - * $a < 0 \rightarrow$ normal force smaller

“Weight”: W_{EO}

- Free fall: only force acting is gravity
  - a = g
- From Newton’s 2nd law, a = F/m
  - But F = W_{EO} (gravitational force of earth on an object)
  - So g = a =
- In this class, when we say “weight” we usually mean “force due to gravity” = “force on a scale when at rest”: W_{EO} = mg

Forces of friction

- There are two types of situations in which frictional forces occur:
  - Two objects “stick to each other” while at rest relative to one another ***(static friction)****.*
  - Two objects “rub against each other” while moving relative to each other ***(kinetic friction)****.*
- We will use a macroscopic description of friction that was obtained by experiment.

Two types of friction

- Static friction: depends on surface and normal force for pulled block
- Kinetic friction: generally **less** than maximal static friction

The *maximum* magnitude of the **force of static 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

$$f_{B,T}^{\text{static}} \leq \mu^{\text{static}} N_{B,T}$$

The *actual* magnitude of the force of static friction is generally less than the maximum value.

6-2.1 A 2.4-kg block of wood is at rest on a concrete floor. (Using g = 10 m/s^2, its weight force is about 24 N.)

No other object is in contact with the block. If the coefficient of static friction is μ_s = 0.5, the frictional force on the block is:

1. 0 N
2. 8 N
3. 12 N
4. 24 N

6-2.2 A 2.4-kg block of wood is at rest on a concrete floor. (Using g = 10 m/s^2, its weight force is about 24 N.)

Somebody is pulling on a rope that is attached to the block, such that the rope is exerting a horizontal force of 8 N on the block. If the coefficient of static friction is μ_s = 0.5, the frictional force on the block is:

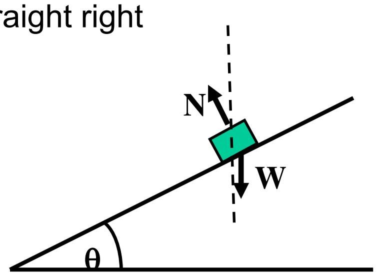
1. 0 N
2. 8 N
3. 12 N
4. 24 N

phone book demo

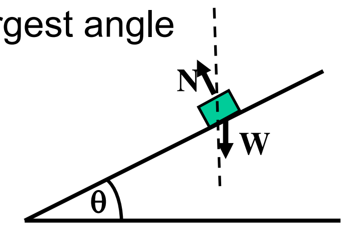
http://www.youtube.com/watch?v=hOt-D_ee-JE

6-2.3 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?



6-2.4 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

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

6-2.5 : 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**

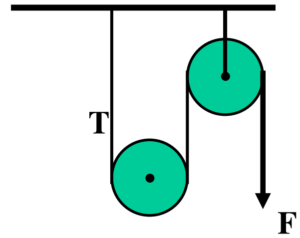
$$F_s \leq \mu_s N$$

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

Tension

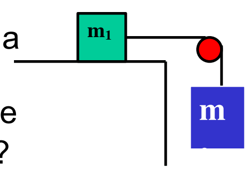
- For an ideal string or rope connecting two objects:
  - does not stretch → *inextensible*
  - has zero mass
  - If A and B interact through a massless string, we can omit the string and treat F_{AB} and F_{BA} as an action-reaction pair
- Often, two objects connected by a rope accelerate at the same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

Pulleys



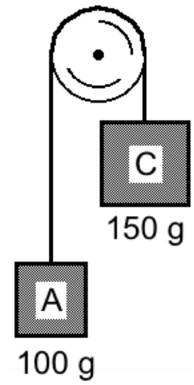
- For an ideal pulley:
  - The pulley has zero mass
  - There is no friction on the pulley
- Tension in a massless string remains constant as it passes over the ideal pulley
- Because Pulleys change direction, the direction of acceleration may change!

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?



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.

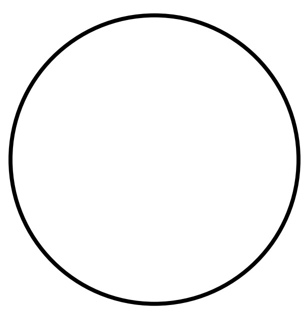
The magnitudes of their accelerations are the same. What is the magnitude of the acceleration?



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

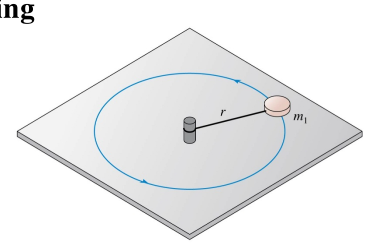
Forces in circular motion

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



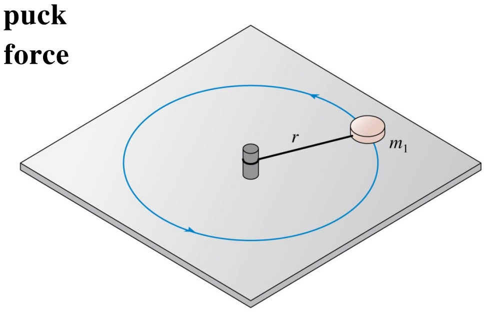
$$\mathbf{a_{rad} = v^2/r}$$

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.

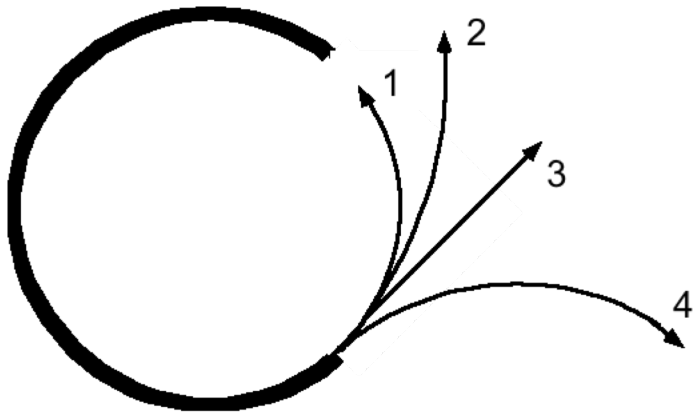
6-2. 8 An ice hockey puck is tied by a string to a stake in the ice. The puck is then swung in a circle. What force is producing the centripetal acceleration of the puck?



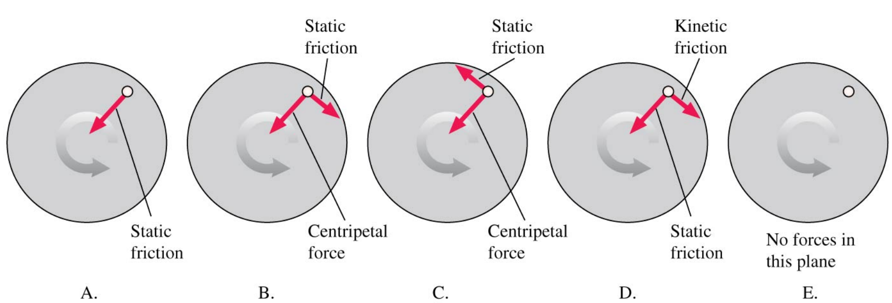
1. Gravity
2. Air resistance
3. Friction
4. Normal force
5. Tension in the string

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

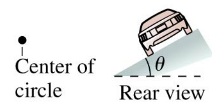
What path will the ball follow after reaching the end of the track?

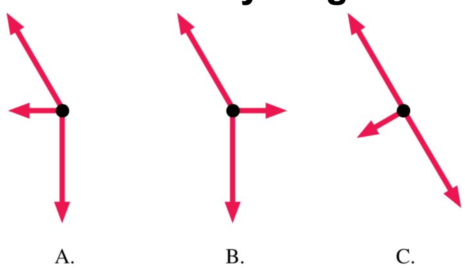


6-2.9 A coin sits on a turntable as the table steadily rotates ccw. What force or forces act in the plane of the turntable?

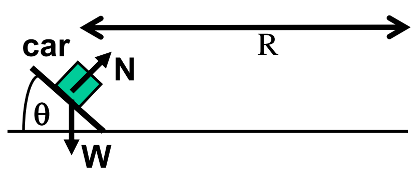


6-2.10 A car turns a corner on a banked road. Which of the diagrams <u>could</u> be the car's free-body diagram?





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



Reading for next week:

- Newton’s laws in 2D: 6.1, 6.3