Announcements

• Exam next Tuesday, Feb. 9 (Driscoll)
  – Will cover chapters 1 – 5 materials in lectures, homeworks, and quizzes, and Chapter 6 materials from lectures. All of this is posted on the web (Ch. 6 lecture materials will go up today)
  – i.e. you have already experienced the test, some small things will be changed.

• Homework for Chapter 5 has been assigned, and the answers are already posted. This assignment is not due to you TA, but will be covered on the exam.

• Expect 4 -7 multiple choice, and 2 –3 problems
Please come see me after class

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• Shawn Sellers
• Justin Johnson
Chapter 6: Friction

Frictional forces are everywhere in our daily life.

- **Two kinds of friction forces**
  - Static friction force: $f_s$
  - Kinetic friction force: $f_k$

Direction of frictional force: always opposes the direction of motion (or intended motion) relative to the surface.
Friction happens when there is a relative motion (or tendency of relative motion) between two contacting surfaces.
Static Friction Force

• An applied force $F$ attempts to slide a block along a surface
  
  – If the block does not move,
    
    $$f_s = F$$
    
    $f_s$ increases when $F$ increases until “breakaway”…. 
  
  – $f_s$ has a maximum value: $f_{s, \text{max}}$
    
    $$f_{s, \text{max}} = \mu_s N$$
    
    $\mu_s$ : coefficient of static friction 
    
    $N$ : normal force
Kinetic Friction Force

When the body begins to slide, the friction force rapidly decrease to $f_k$

$$f_k = \mu_k N$$

$\mu_k$ : coefficient of kinetic friction

$N$ : normal force

$-\mu_s$ and $\mu_k$ depend on the nature of the contacting surfaces, can be determined experimentally
A block lies on a horizontal floor.

a) What is the magnitude of the friction force \( f \) on it from the floor? \( f = 0 \text{ N}, \) but note \( f_{s,\text{max}} = \mu_s F_N \)

b) If a horizontal force of 5 N is now applied to it, but it does not move, what is \( f \) now? \( f_s = 5\text{ N} \)

c) If \( f_{s,\text{max}} = 10 \text{ N}, \) will the block move if the horizontal applied force is 8 N? no, because \( F < f_s \)

d) How about 12 N? yes, because \( F > f_s \)
Physics book + Wall

You push horizontally a physics book against a vertical wall. In which direction does the frictional force point if the book is held motionless against the wall?

1. Downward
2. Upward
3. Out from the Wall
4. Into the Wall
You push horizontally a physics book against a vertical wall. In which direction does the frictional force point if the book is held motionless against the wall?

If I were to release it, the book would **fall down**. Since there was no motion initially, the vertical forces had to be balanced.

The frictional force had to point **up**.
A crate is located at the center of a flatbed truck. The truck *accelerates* toward the *east*, and the crate moves with it, not sliding on the bed of the truck. What is the direction of the friction force exerted by the bed of the truck on the crate?

1) to the west  
2) to the east  
3) there is no friction because the crate is not sliding
A crate is located at the center of a flatbed truck. The truck *accelerates* toward the *east*, and the crate moves with it, not sliding on the bed of the truck. What is the direction of the friction force exerted by the bed of the truck on the crate?

1) to the West
2) to the East
3) there is no friction because the crate is not sliding

What caused the crate to accelerate to the East? **FRICTION**

*F is in the direction that opposes the motion that would otherwise occur w/o friction*
Food for thought

What causes an auto with anti-lock brakes to stop in a shorter distance than a car with regular brakes? The anti-lock brakes work by pulsing the brakes to keep the tires from skidding (Use static friction, avoid “breakaway”).
Sled + Rope

You are playing with your friend in the snow. She is sitting on a sled and asking you to slide her across a flat, horizontal field. You have a choice of pushing him on the shoulder with a force at 30° below the horizontal, or pulling him with a rope with a force 30° above the horizontal as shown in figure.

Which way is easier for you?

1) pull him with the rope (R)
2) push him on the shoulder (S)
3) Both are equally hard
4) It was MY turn on the sled, that dirty, rotten ...
Sled + Rope

By pushing down, the Normal force is increased, thereby increasing the frictional force.

Which way is easier for you?

1) pull her with the rope (R) thereby decreasing the normal force (& thereby decreasing the frictional force).
A loaded penguin sled weighing 80 N rests on a plane inclined at 20° to the horizontal. Between the sled and the plane, $\mu_s = 0.25$, $\mu_k = 0.15$.

(a) What is the minimum magnitude of the force $F$, parallel to the plane, that will prevent the sled from slipping down the plane?

Set up free-body force diagram.

Notice that $f$ is pointing with $F$ because without $F$ the penguin will slide *down* the plane.
Problem 6-20

A loaded penguin sled weighing 80 N rests on a plane inclined at 20° to the horizontal. Between the sled and the plane, \( \mu_s = 0.25 \), \( \mu_k = 0.15 \).

(a) What is the minimum magnitude of the force \( F \), parallel to the plane, that will prevent the sled from slipping down the plane?

Set up free-body force diagram.

\[
\begin{align*}
\text{Apply Newton’s Second Law} & \\
\text{y: } & N - mg \cos \theta = 0 \\
\text{x: } & F - mg \sin \theta + f_s = 0 \\
\end{align*}
\]
A loaded penguin sled weighing 80 N rests on a plane inclined at 20° to the horizontal. Between the sled and the plane, $\mu_s = 0.25$, $\mu_k = 0.15$.

(a) What is the minimum magnitude of the force $F$, parallel to the plane, that will prevent the sled from slipping down the plane?

Set up free-body force diagram.

$$F = mg \sin \theta - \mu_s mg \cos \theta$$

$$= (80) \sin(20) - 0.25(80)\cos(20)$$

$$= 27.36N - 18.79N = 8.57N$$
Problem 6-20

A loaded penguin sled weighing 80 N rests on a plane inclined at 20° to the horizontal. Between the sled and the plane, \( m_s = 0.25 \), \( m_k = 0.15 \).

(b) What is the minimum magnitude \( F \) that will start the sled moving up the plane?

Now \( f \) points *down* the plane, opposing motion due to \( F \) *up* the plane.

Set up free-body force diagram.

Apply Newton’s Second Law

\[
F = mg \sin \theta + \mu_s mg \cos \theta \\
= (80) \sin(20) + 0.25(80)\cos(20) \\
= 27.36N + 18.79N = 46.15N
\]
Problem 6-20, continued

c) What value of $F$ is required to move the sled up the plane at constant velocity?

Now $f$ points *down* the plane because $F$ causes motion *up* the plane

Constant velocity $\Rightarrow$ zero acceleration $\Rightarrow$ forces are balanced

$$F = mg \sin \theta + \mu_k mg \cos \theta$$

$$= 27.36 \text{N} + 11.28 \text{N} = 38.64 \text{N}$$

will cause the sled to move up the inclined plane at constant velocity