Announcements – 22 Sep 2009

1. If you have **questions on exam 1**:
   a. Look over your own exam.
   b. Look over the exam solutions, see if you can figure out what you got problems wrong.
   c. Only then should you come talk to me (or Tutorial Lab TAs) about things you still don't understand.
2. **Newton's 2nd Law Problems: $\Sigma F = ma$**
   a. Inclined planes
   b. Pulleys
   c. Ropes
   d. Friction
   e. Etc

→ Remember **N2 is a blueprint** for obtaining a useful equation; it's not really the equation itself.

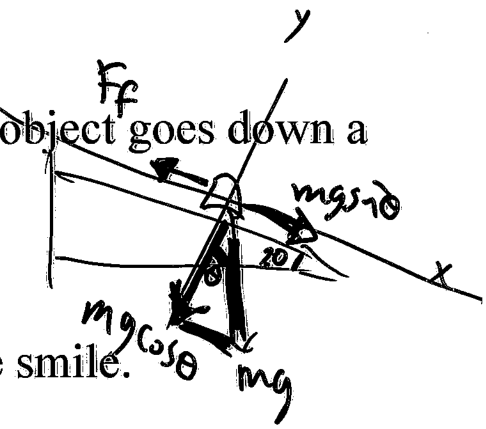
The "ΣF" on the left hand side means you have to consider all of the forces from your FBD and include them on the left hand side.

Do <u>not</u> put any forces on the right hand side!

Which part of today's assignment was particularly hard or confusing?

I really am still totally confused from last Thursday's lecture. We went through everything so quickly...are we going to ever review that stuff again?

I don't understand how gravity relates to friction as an object goes down a ramp. Can you please briefly explain it in class?



Everything!

Nothing

These were back-to-back; made me smile.

Can you help us find easier ways to remember all the formulas we are learning?

$$\sum \vec{F} = m\vec{a}$$

General comments:

Do you know of any study groups that have been created for this class?

Incoming JOKE: An experimental physicist performs an experiment involving two cats, and an inclined tin roof. The two cats are very nearly identical; same sex, age, weight, breed, eye and hair color. The physicist places both cats on the roof at the same height and lets them both go at the same time. One of the cats slides off the roof first so obviously there is some difference between the two cats. What is the difference?
One cat has a greater mew.

μ = "mu"

Accelerating Reference Frames (from last time)

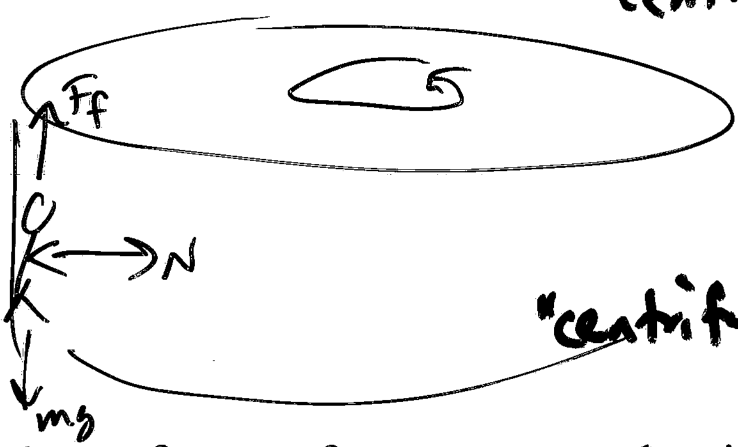
Demo: Rotating chair, Ball on string

To be able to ascribe accelerations to *real* forces, you must be observing the motion from a **non-accelerating (constant velocity) point of view**

Physics lingo: "point of view" = "reference frame"

Amusement Park Ride: Floor drops out. What are the forces on you?

"centripetal" = real force causes velocity to change direction



"centrifugal" = false force which results from inertia

In **accelerating** reference frames, we tend to invent fictitious forces.

Another example: Coriolis force

Question: A car rounds a curve while maintaining a constant speed. Is there a net force on the car as it rounds the curve?

a. No, because its speed is constant.

b. No, because the normal force is balanced by gravity.

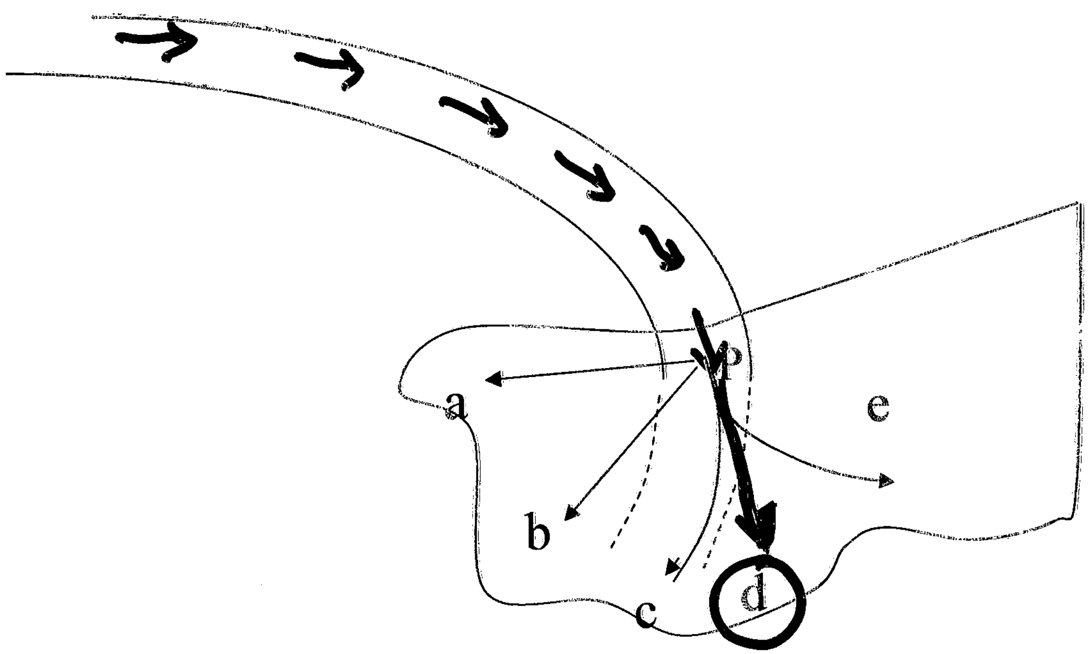
c. Yes, because it's changing direction.

d. Yes, because it's slowing down.

the $\vec{v}$ vector is changing

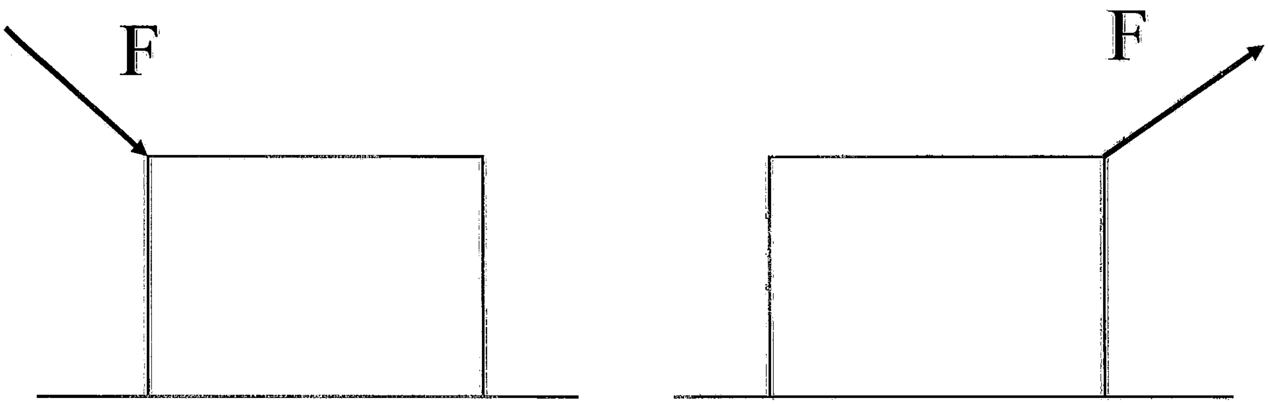
∴ there's an acceleration

Clicker quiz: A car hits a large icy spot on the road at point P. What is the path of the car if there is <u>no friction</u> on the ice?



Friction: *kinetic* and **static**

Question: Same box, same magnitude of **F**: which box is easier to get moving?



a. left is easier
b. right is easier
c. same

Friction opposes sliding motion!

(Typically that means it opposes motion, period, but there are rare exceptions…we'll see one later this lecture)

From warmup: Ralph noticed that in the equation for the force of static friction, there's a "less than or equal to" sign, but in the equation for kinetic friction, there is a plain equals sign. He wants to know why they are different. What should I tell him?

$F_{f\,static} \le \mu N$

Answer from the class:

565------------------------

Static: Not moving: $F_{pushing} = F_{friction}$

It takes that much amount of force to get the object to move. Any force below that will not cause it to move. With kinetic friction the object is already in motion so the friction is at a set place.

$F_{friction} = \mu_k N$

Static Friction:

Grows with sideways force, to a point....

At slipping pt:

Friction force proportional to Normal force

$$\boxed{\mathbf{F_f = \mu N}}$$

mu = "coefficient of friction"

Demo: Friction blocks

Kinetic "aka Moving" Friction

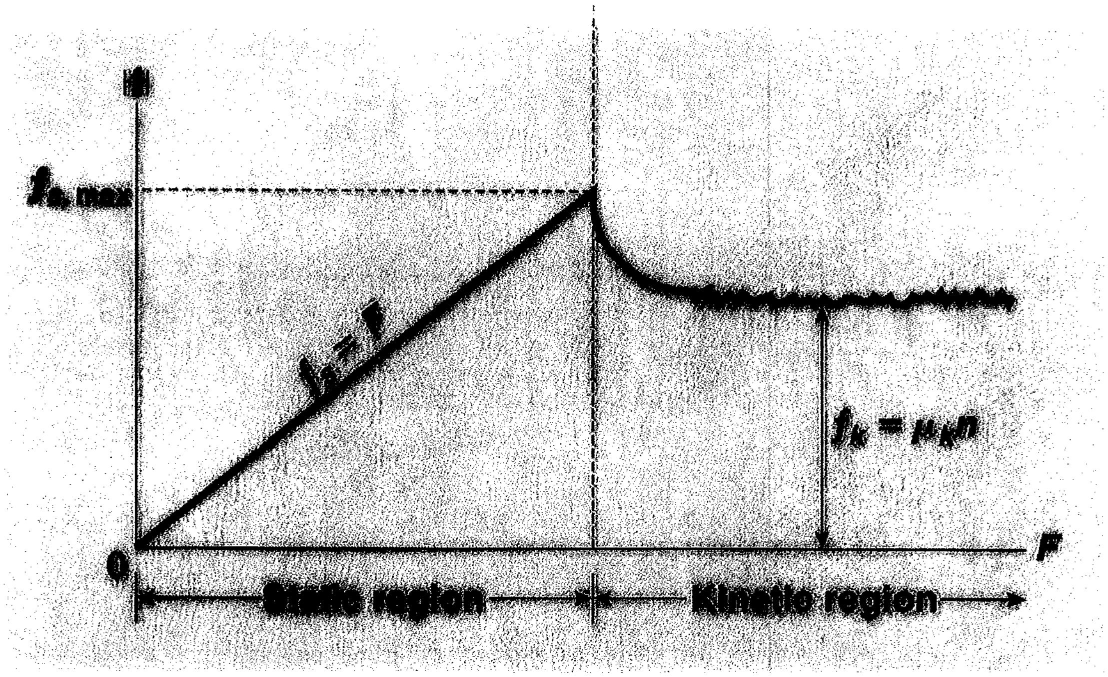
$T - F_f = 0$

$\Sigma F = 0$

$T = F_f$

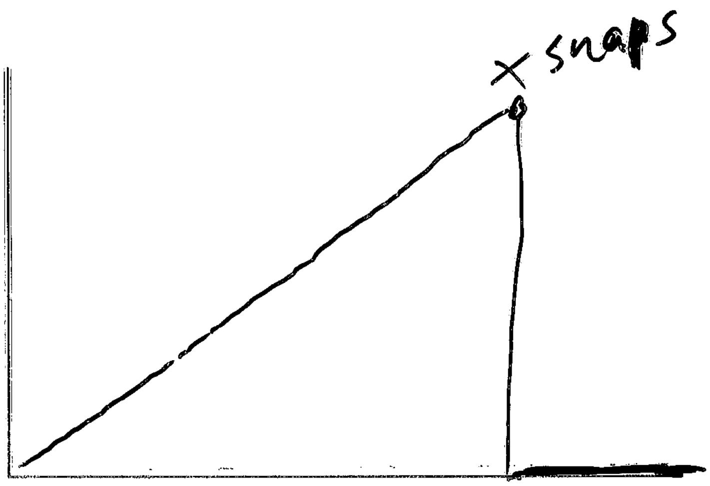
Demo: static vs. kinetic friction

Book figure:



Compare with the forces when you break a rope tied to a wall. What is the tension in the rope?

Tension T



Force of pull

Friction, Summary:

Static: $\mathbf{F_f\ (max) = \mu_S\ N}$

Kinetic: $\mathbf{F_f = \mu_K\ N}$

<u>Warning</u>: N is sometimes equal to mg, but not always!

TABLE 4.2

Coefficients of Friction[a]

	μ_s	μ_k
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Copper on steel	0.53	0.36
Rubber on concrete	1.0	0.8
Wood on wood	0.25–0.5	0.2
Glass on glass	0.94	0.4
Waxed wood on wet snow	0.14	0.1
Waxed wood on dry snow	—	0.04
Metal on metal (lubricated)	0.15	0.06
Ice on ice	0.1	0.03
Teflon on Teflon	0.04	0.04
Synovial joints in humans	0.01	0.003

[a]All values are approximate.

Worked Problem

Mary pulls a box of books with mass 25 kg to the right with a rope.

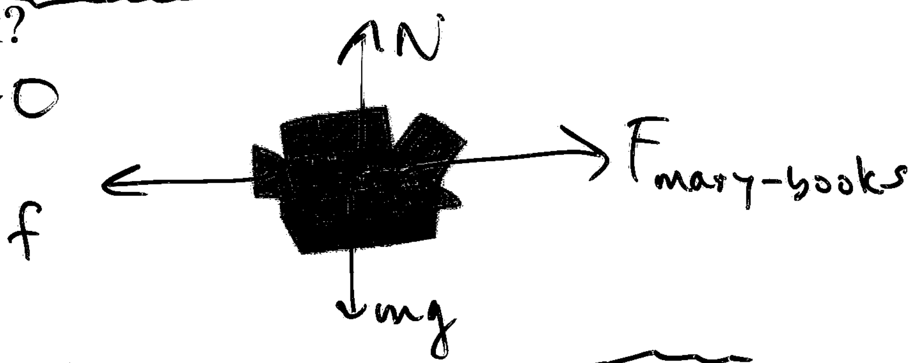
$\mu_s = 0.5 \qquad \mu_k = 0.3 \qquad$ (Use $g = 10\ \mathrm{m/s^2}$)

a. First she pulls horizontally on the box with a force of 40 N. The box doesn't move. What is the frictional force of the floor on the box?

$\Sigma F_x = 0 \qquad \Sigma F_y = 0$

$F_{m\text{-}b} - f = 0$

$f = F_{m\text{-}b} = 40\text{N}$



b. What minimum force will she have to exert to get it moving? max friction $= \mu_s N$

$\Sigma F_y = 0$

$N - mg = 0$

$N = mg = \underline{250\text{N}}$

$F_{m\text{-}b} - f = 0$

$F_{m\text{-}b} - \mu_s N = 0$

$F_{m\text{-}b} = (.5)(250) = 125\text{N}$

Clicker quiz: If she pulls with force 175 N, what will the acceleration be after it starts moving?

a. 1 m/s^2 c. 4 m/s^2

b. 2 m/s^2 d. 6 m/s^2 e. > 6 m/s^2

$\Sigma F = ma$

$F_{m\text{-}b} - \mu_k N = ma$

$175 - (.3)(250) = 25a$

$175 - 75 = 25a$

$100 = 25$

$a = 4\ \mathrm{m/s}$

Answers: 40N, 125 N

Dr Colton's Guide:
How to solve <u>all</u> Newton's 2nd Law Problems

1. Draw free-body diagrams for each object.
   1b. Divide forces into components if necessary.
   1c. Group objects together if it seems convenient.

2. Use the Newton's 2nd Law "blueprint equation" to get a "real equation" for each object.
   2b. Do this for each direction if necessary.

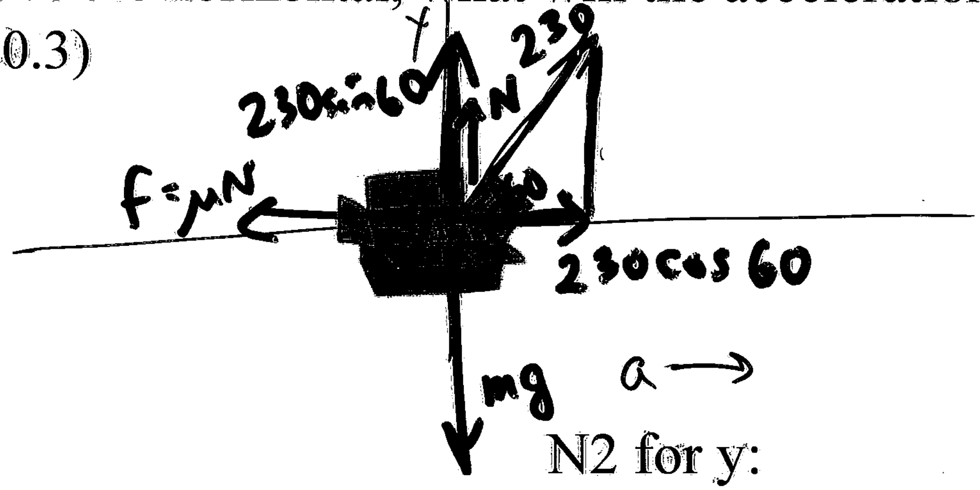
3. Plug what you know into the equations, and look at what results.
   3b. Don't forget to plug in the acceleration, if it's known.

4. Solve the equations for what you're looking for.
   4b. Sometimes this involves solving simultaneous eqns.

Worked Problem use $g = 10\,m/s^2$

If Mary pulls the 25 kg box with force 230 N at an angle of 60° above the horizontal, what will the acceleration be? ($\mu_k = 0.3$)

FBD:



N2 for x:

$$\Sigma F_x = m a_x$$

$$230\cos 60 - \mu_k N = m a_x$$

N2 for y:

$$\Sigma F_y = m a_y$$

$$230\sin 60 + N - mg = 0$$

Plug what you know into equations:

$$230\cos 60 - (.3)N = (25)a_x$$

$$a_x = \frac{230\cos 60 - .3(50.8)}{25}$$

$$230\sin 60 + N - (25)(10) = 0$$

$$N = 250 - 230\sin 60$$

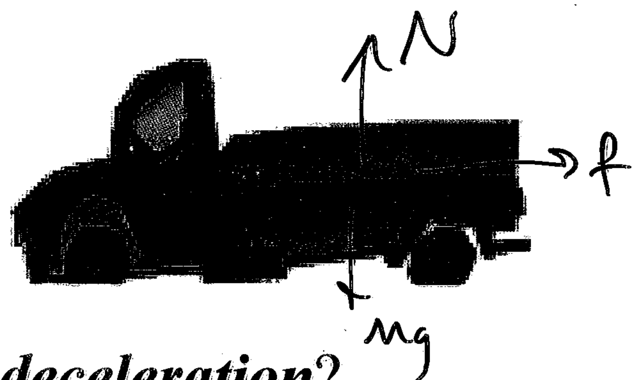
$$N = 50.8\,N$$

Solve the equations for what you're looking for:

$$a_x = 3.99\,m/s^2$$

Answers: N = 50.8 N, a = 3.99 m/s^2

The tires on a 5000 kg truck have $\mu_s = 0.8$, $\mu_k = 0.6$ (tire to road friction)



What is the maximum stopping ***deceleration***?

when max friction

max static: $\mu_s N$

$\sum F_x = ma$ $\quad$ $\sum F_y = 0$

$f = ma$ $\quad$ $N - mg$

$\mu_s N = ma$ $\quad$ $N = mg$

$\mu_s \cancel{m} g = \cancel{m} a$

$a = .8g \approx 8\ m/s^2$

What is the maximum stopping ***deceleration* if the wheels are locked**?

sliding : $f = \mu_k N$

same eqns

$a = .6g \approx 6\ m/s^2$

→ What do anti-lock brakes do?

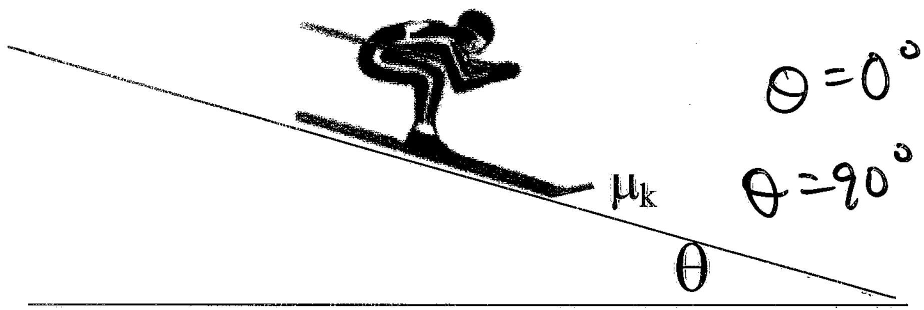
Answers: $0.8g \approx 8\ m/s^2$, $0.6g \approx 6\ m/s^2$

Friction on slopes

Clicker quiz: For the same skis and snow, as the slope angle **increases**, the ski/snow **frictional force**

a. increases
b. decreases
c. stays the same

$\mu_k N$



$\theta = 0^\circ$: big N

$\theta = 90^\circ$: $N \simeq 0$

Hint: Man with mass *m*: what is his frictional force on a slope? Use N2.

Warmup questions review

You start to push against a refrigerator. It initially does not budge, but then after you push hard enough it starts sliding along the floor. Which is correct?

a. The friction force was smallest just after the refrigerator started to move.
b. The friction force was largest just after the refrigerator started to move.
c. The friction force was largest just before the refrigerator started to move.
d. The friction force was constant the whole time.

49% correct

like monkey

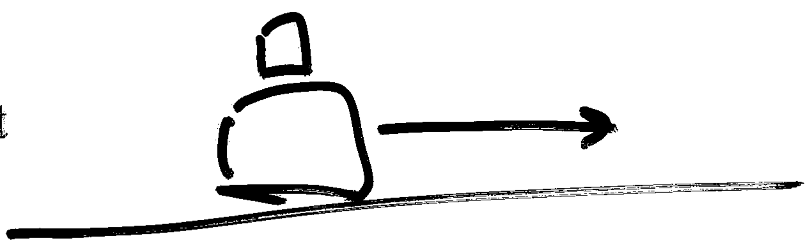
A block is sliding down a ramp with constant speed. There is friction between the block and the ramp. The friction force is:

a. smaller than the component of gravity down the ramp
b. larger than the component of gravity down the ramp
c. equal to the component of gravity down the ramp

42% correct

A small block is "riding" on top of a large block, which is being pulled to the right with a rope. Both blocks accelerate at the same rate to the right. The force of friction acting on the small block is:

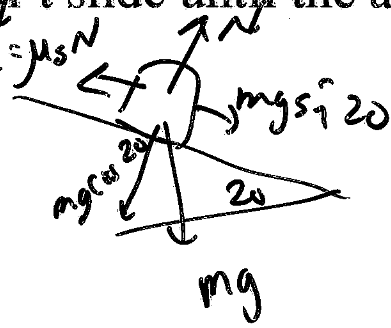
a. to the left
b. to the right
c. nonexistent



Demo: adjustable ramp

maximum

Demo Problem: a block on a ramp doesn't slide until the angle is 20 ° from horizontal. What is μ_s? $F_f = \mu_s N$



$\Sigma F_x = ma_x = 0$

$mg\sin 20 - \mu_s N = 0$

$\cancel{mg}\sin 20 = \mu_s \cancel{mg}\cos 20$

$\mu_s = \tan 20°$

$\Sigma F_y = ma_y = 0$

$N - mg\cos 20° = 0$

$N = mg\cos 20°$

Demo Problem: Once the block starts to slide at that angle, it takes _________ s to slide down the _________ m of the ramp. What is μ_k?

find accel. (kinematics)

$\Sigma F_x = ma_x$

$mg\sin 20 - \mu_k N = ma$

solve for μ_k