Physics 101: Lecture 07
Frictional forces and circular motion

What concepts did you find most difficult, or what would you like to be sure we discuss in lecture?

- i get confused as to which way the friction force points to
- for the lecture handout pdf, would you be able to make it so that there are 2 slides per page rather than 6?
- tetherball problems
- uniform circular motion
- Everything honestly
- Go over when to use kinetic or static friction
- can you just explain everything
- What's your favorite color?

EXAM 1

- Exam 1 will be held Wed 2/21 – Fri 2/23
- You MUST sign up for a time slot here:

https://my.physics.illinois.edu/undergrad/onlineexams/signup-student.asp

- Exam is computer-administered in Loomis 257
- Exam covers Lectures 1-8 (kinematics and dynamics—Newton's Laws; friction; circular motion)
- No lab the week of exam (good sign-up slot!)
- Discussion **IS** held the week of the exam
- Contact Dr. Schulte w/ Qs about sign up: eschulte@illinois.edu
- Exam is all multiple choice (3 & 5 choice Qs)
- How to study for exam?

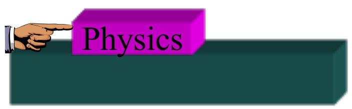
Today

- Friction (two types)
- Example problems with friction
- Circular motion

2-Dimensional Equilibrium example

An example with Friction

Calculate force of hand to keep a book sliding at *constant speed (i.e. $a = 0$)*, if the mass of the book is 1 Kg, the coefficient of static friction is μ_s=0.84, and the coefficient of kinetic friction is μ_k=0.75



Let's talk about friction first
There are two types of friction:
1) kinetic friction and 2) static friction

1. **Kinetic friction**: Object must be sliding on a rough surface to experience kinetic friction—kinetic implies motion, so it is friction when something moves:

$$F_k = \mu_k N$$

μ_k is the **coefficient of kinetic friction**

usually a number between 0 and 1.

μ_k depends on the two surfaces that rub against each other.

2. Static friction: Object must be stationary on a rough surface if it is going to MAYBE experience static friction. Static = not moving.

- Ex. 1: Book rests on table. Is there a frictional force?
- Ex. 2: Push book horizontally with a force of 3 N; doesn't move. Is there a frictional force?
- Ex. 3. Push book harder, 6 N, and it does not move.
- Static friction force: $F_s \leq \mu_s N$ (this one is hard). Static friction can prevent motion, **up to a maximum force**! Once object starts to move, then it is *kinetic* friction.
- Bottom line: Static frictional force can have any value between 0 and a maximum of $\mu_s N$.
- Note: $\mu_k < \mu_s$ for same object on same surface

2 Dimensional Equilibrium!

Calculate force of hand to keep a book sliding at *constant speed (i.e. $a = 0$)*, if the mass of the book is 1 Kg, μ_s=.84 and μ_k=.75

We do exactly as before (apply Newton's 2[nd]) in both x and y directions (and treat x & y independently)!

Plan step 1 – Identify object,

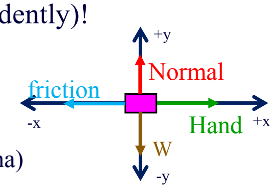
Plan step 2 – Pick coordinate system

Plan step 3 – Identify Forces (draw FBD)

Plan step 4 – Apply Newton's 2[nd] ($F_{Net} = ma$)

Plan Step 5 – Solve for force of the hand

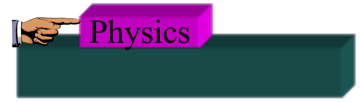
Treat x and y independently!



$F_{Net,\,y} = N - W = ma_y = 0$

$F_{Net,\,x} = H - f_k = ma_x = 0$

This is what we want!



Calculate force of hand to keep the book sliding at a ***constant speed (i.e. a = 0)***, if the mass of the book is 1 Kg, μ_s = .84 and μ_k=.75.

Plan Step 5 - Solve for force of the hand

$F_{Net,\,y} = N - W = 0$ ⇒ $N = W = mg$

$F_{Net,\,x} = H - f_k = 0$ ⇒ $H = f_k$

- Magnitude of kinetic frictional force is proportional to the normal force and always opposes motion!

$f_k = \mu_k N$ — μ_k coefficient of Kinetic (sliding) friction

$H = f_k = \mu_k N = \mu_k W = \mu_k mg$

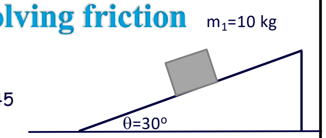
$= (0.75)x(1\ kg)x(9.8\ m/s^2)$

$H = 7.35\ N$

Note: In this case N=weight since surface was horizontal

Another example involving friction

The block is **stationary** and there is friction between the block and the incline.
The coefficients of friction are μ_s=0.7 & μ_k=0.45
What is the normal force on the block?



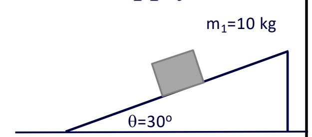
Big idea: Newton's 2nd

Justification: N#2 allows you to find forces and acceleration

Plan:

1. Identify body, choose coordinate system, draw a FBD
2. Apply Newton's Second Law in y direction
3. Solve for N

To find what static friction **needs to be**, apply N#2 in x-direction.



Plan:

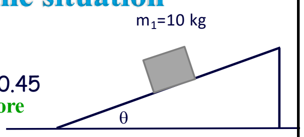
1. Use FBD and coordinate system from previous
2. Apply Newton's Second Law in x direction
3. Solve for static friction force knowing *a*=0

If static friction were maximum value, block would have a positive net force pointing up the incline and would accelerate in that direction—that would be very creepy, even magical!

Continuing with the same situation

The block is stationary and there is friction between the block and the incline.
The coefficients of friction are μ_s=0.7 & μ_k=0.45

What maximum angle can we tilt the incline before the block starts to slide down the ramp?



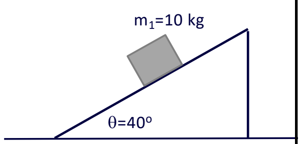
Plan:

1. Coordinate system and FBD as before
2. Apply Newton's Second Law in x direction and set static friction to maximum value with a=0
3. Solve for max.angle

Continuing with the same situation

The block is released from rest.
The coefficients of friction are μ_s=0.7 & μ_k=0.45

Now assume the angle is $\theta=40^o$.
What is the acceleration of the block down the incline?



Plan:

1. Block is body, usual coordinate system, same FBD as before
2. Apply Newton's Second Law in x direction and use $f_k=\mu_k N$
3. Solve for acceleration

Force at Angle Example

A person is pushing a 15 kg block across a floor with μ_k= 0.4 at a constant speed. If she is pushing down at an angle of θ=25°, what is the magnitude of her force on the block?

Plan step1: Body is the block, draw a FBD

Step 2: Apply N#2 in x-direction

$P_x - f_k = P\cos(\theta) - f_k = 0$ (note: a=0)

$P\cos(\theta) - \mu_k N = 0$

$N = P\cos(\theta) / \mu_k$

Step 3: Apply N#2 in y-dir

$N - W - P_y = N - W - P\sin(\theta) = 0$

$N - mg - P\sin(\theta) = 0$

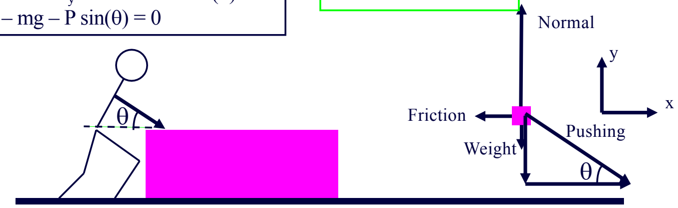
Step 4: Use algebra to combine Equations and solve for P

$(P\cos(\theta) / \mu_k) - mg - P\sin(\theta) = 0$

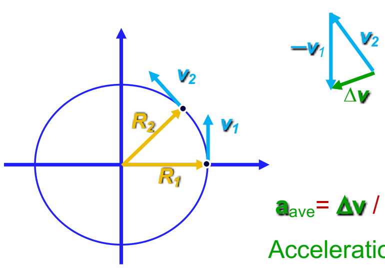
$P(\cos(\theta) / \mu_k - \sin(\theta)) = mg$

$P = mg / (\cos(\theta)/\mu_k - \sin(\theta))$

$P = 80$ N



Recall Acceleration in Uniform Circular Motion



$a_{ave} = \Delta v / \Delta t$

Acceleration inward

$$a = \frac{v^2}{R}$$

Centripetal Acceleration

Directed radially inward!

Acceleration is due to change in direction, not speed. Since the object turns "toward" center, there must be a force toward center: "Centripetal Force"

Common Incorrect Forces (due to Spooky Rules)
Items below are NOT forces

- Acceleration: $F_{Net} = ma$
  - Centripetal Acceleration
- Force of Motion (Inertia not a force)
  - Forward Force,
  - Force of velocity
  - Momentum of car moving forward
- Centrifugal Force (No such thing!)
  - Centripetal (really friction)
  - Inward force (really friction)
- Internal Forces (don't count, cancel)
  - Car
  - Engine
  - Thrust (force moving car forward)