

# Introduction

Physics 211  
Syracuse University, Physics 211 Spring 2017  
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February 15, 2017

- Homework 3 due tomorrow
- Homework 4 posted; due next Friday
- Extra office hours today, 4-7PM, in Room 208 (intended for homework help)
- Recording of solutions to HW3: tomorrow, room 208, from 4-6PM

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  - Yes, I know this is before the end of recitations
  - If you come and haven't gone to recitation yet, please turn in your homework when you arrive, and I'll get it to your TA

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... like all of the possible encryption keys for a code at once...

# Some feedback from you all

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The overarching concept:

- Newton's second law  $\sum \vec{F} = m\vec{a}$  tells us the relation between the forces on an object and how it moves
- If we know the forces on an object, we can use those to compute its acceleration
  - Once we find its acceleration, we can learn about its movement, using kinematics
- If we know its acceleration, we can go the other way, and learn about the forces that act on it

# Breaking these bits down

Everything we're dealing with here is a **vector**:

- Decompose all forces into  $x$ - and  $y$ -components
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Knowing about the forces on objects:

- Newton's *third* law tells us that forces come in pairs:  $\vec{F}_{ab} = -\vec{F}_{ba}$
- Normal forces are however big they need to be to stop objects from moving through each other
- Tension is the same at all points in a rope
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Keeping the forces straight:

- Draw a force diagram: a dot representing each object, with arrows going outward for each force
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Applying this to Newton's second law:

- You can look at your diagrams and read off the  $x$ - and  $y$ -components of the forces that are present
- This will let you write down things like

$$\text{list of forces in } x = ma_x$$

$$\text{list of forces in } y = ma_y$$

- Do this separately for each object
- This will give you a bunch of equations
- Solve the system of equations by substitution for whatever you want

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  - Write down any constraints you have: are the accelerations of two objects related?
  - Are two forces the same magnitude by Newton's third law?



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“Ask physics the question, don't tell it the answer”

## Sample question (11:00)

A stone hangs from the roof of a car by a string; the car accelerates forward at  $3 \text{ m/s}^2$ .

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- What angle does the string make with the vertical?
- What is the tension in the string?

## Sample question (9:30)

Two weights, of mass  $M$  and  $m$ , hang from a light, frictionless pulley. How do they move when they are released?



A cart slides down a frictionless track elevated at angle  $\theta$ ; what is its acceleration?

# A new force: Friction

- Friction: stops two surfaces from sliding past each other
- Can either make things move or make things stop; opposes *relative* motion
- Two types:
  - Static friction: keeps two things that aren't sliding stuck together
  - Kinetic friction: opposes the relative motion of two things sliding

## Friction is really complicated!

- Depends on details of surfaces, molecular forces, etc.
- No way to create a completely accurate general principle

## There are a few general principles, though:

- Friction is higher if the normal force is higher
- Kinetic friction doesn't depend that much on the speed of travel

## Simple model: often pretty close

- Friction depends on a property of the surfaces called the coefficient of friction  $\mu$
- Force of kinetic friction =  $\mu_k F_N$
- Max force of static friction =  $\mu_s F_N$

# Friction, a summary

- Kinetic friction points in whichever direction opposes the relative motion
- $F_{f,k} = \mu_k F_N$
- Static friction points in whichever direction it needs to in order to keep the objects from sliding
- You will need to think carefully about this: the direction can change, depending on other things
- Static friction is however big it needs to be to keep the objects from sliding, up to a maximum value:
- $F_{f,s,\max} = \mu_s F_N$

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We call this force “traction”. It can point in either direction, depending on how the car is trying to turn its wheels, with the engine, brakes, or so on.

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In normal use, though, the piece of the wheel touching the ground does not move.

This means that the traction force is really **static friction**.

So

$$F_{\text{trac}} < \mu_s F_N,$$

just like for static friction. It points either forwards or backwards, depending on what the engine/brakes/bicyclist/etc. are doing.

**TABLE 6.1** Coefficients of friction

Materials	Static $\mu_s$	Kinetic $\mu_k$	Rolling $\mu_r$
Rubber on concrete	1.00	0.80	0.02
Steel on steel (dry)	0.80	0.60	0.002
Steel on steel (lubricated)	0.10	0.05	
Wood on wood	0.50	0.20	
Wood on snow	0.12	0.06	
Ice on ice	0.10	0.03	

## Sample questions

A block slides down a track elevated at angle  $\theta$  with  $\mu_k$  known; what is its acceleration?



## Sample questions

A block with mass  $m$  on a track is connected by a rope to a hanging weight of mass  $M$ . The coefficients of friction are  $\mu_s$  and  $\mu_k$ . What is the acceleration of both objects?

An object slides down a ramp with coefficient of kinetic friction  $\mu_k$ .  
How fast does it accelerate?

## Sample questions

Multiple pulleys (classroom demo): what hanging mass is required to balance the mass hanging from the pulleys?