# Introduction

Physics 211
Syracuse University, Physics 211 Spring 2017
Walter Freeman

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# Physics 211
# Forces and Motion

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Merrill Asp, lead TA

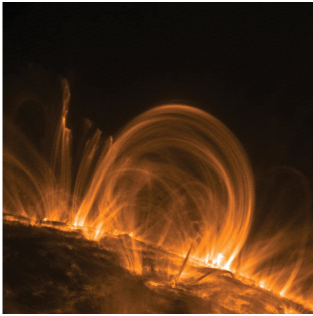
Course webpage:

http://walterfreeman.github.io/phy211/

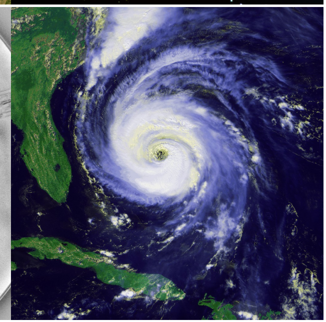
# Overview of today

- Introduction to physics and mechanics
- Course organization / syllabus
- How to succeed in this course
- Describing the physical world: the SI system
- Mathematics in the context of physics

Physics: what are the fundamental laws of nature?





These phenomena are all governed by the *same few principles*.

# Mechanics

The most fundamental question physics asks:

"Why do things move in the ways that they do?"

The answer is given by Isaac Newton's second law of motion:

"Objects accelerate when pushed by forces; they accelerate in the direction of the force, proportional to the size of the force divided by their mass."

That's it. We will spend much of our class talking about the meaning and consequences of this one statement.

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You'll also learn the skill of asking those two questions, and develop a physicist's perspective for solving problems.

This will serve you well in whatever field you pursue, since the ability to quickly look at a problem and understand the crucial elements is universally helpful.

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It turns out that people with physics training find good jobs all over industry, even in non-STEM fields, because of this skill!

# What is this (and how does it work)?

# How it works: the physicist's perspective

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- ... but a computer can do it!

Four broad sections:

1. Kinematics (understanding the right hand side of $\vec{F} = m\vec{a}$)
   - How do we describe motion?
   - How do an object's position, velocity, and acceleration relate?
   - What about rotational motion?
   - How do we deal with things in two or three dimensions?

# Course structure and syllabus review

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2. Forces and motion (both sides of $\vec{F} = m\vec{a}$)
   - What kinds of forces are there?
   - Torque: a rotational counterpart to force, with an equivalent to $\vec{F} = m\vec{a}$
   - Understanding different physical situations using $\vec{F} = m\vec{a}$
   - Collisions and momentum: taking the integral of $\vec{F} = m\vec{a}$

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3. Conservation laws: when you want to do less math
   - Energy: a way to simplify solving $\vec{F} = m\vec{a}$ when you don't care about time
   - Momentum: a way to simplify problems involving collisions and explosions
   - Rotational energy and angular momentum
4. Two more mechanics topics
   - How forces cause torques, and rotation in more detail
   - What properties do waves and vibrations have?
   - What happens to waves when they are trapped?
   - What are the physics of music and musical instruments?
   - How does this relate to chemistry, biology, and engineering?

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But this can go wrong in two ways:

- If someone's not careful they might fool yourself or other people (innocent error)
- If someone's not honest they can disguise phony conclusions as science and deliberately mislead other people (pseudoscience)

We'll study what science is, what it's not, and how you can protect yourself from ~~bullshit~~ flawed scientific reasoning.

# Syllabus review

- Two professors?

## Syllabus review

- Two professors?
- Our philosophy
- How grading works
- The components of the course
- Academic integrity
- Students with disabilities, solemn observance policy, excused absences

# Recitations

- Discussion sections led by your TA
- Homework is submitted and returned in recitation
- **Crucial** for your success in this class

In recitation, you can:

- Ask general questions to your TA and your peers
- You will be assigned groups, work together for a whole unit, and then have a "group exam"
- Ask questions about the homework, or work on it in your groups

Remember:

- Physics is not about how much you know – it's about **what you can do**
- This class isn't about amassing facts; it's about solving problems
- This takes practice, and the recitations (and the homework) are where you get it
- The TA's this year are an amazing group; make use of them!

# The course webpage

- All notes, etc., will be posted on the course website and on Blackboard
  - During Walter's weeks, the website will be updated first
  - During Matt's, the Blackboard site will be updated first
- I will also post course announcements there
- The syllabus is posted there, as is a FAQ
- You really should read the section on the course philosophy in the syllabus

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These things are skills, and they all require practice
... but they also require you to ask questions and ask for guidance!

# How to do well in this class: ask for guidance!

Some students might come to class, write down everything, go home and review, and then spend hours alone working on the homework. They're diligent, good, hardworking students, right?

## How to do well in this class: ask for guidance!

Some students might come to class, write down everything, go home and review, and then spend hours alone working on the homework. They're diligent, good, hardworking students, right?

... but this is not the best way to learn skills! Instead, we hope you will:

- Interrupt us in class and ask questions
- Ask us questions by email
  - I am often by a computer and you will often get a quick reply
  - You can take cellphone pictures of work and email them to me, too
- Come work with us and with your peers in our help sessions
- Do your homework in the Physics Clinic when you can

# Metaphors: sports and music

Learning physics is like learning to play a musical instrument.

The hard part isn't learning the notes – it's being able to play them, and tell a story with them.

How does studying the piano work?

- Your teacher shows you a few techniques, and gives you a piece to learn to play
- You take it home, practice it, and get stuck on difficult parts
- You ask your teacher for advice; she guides you
- You practice some more
- You repeat the previous steps until you've mastered the technique and the music
- Over time, you become fluent in music as a new language

Learning a sport works the same way.

Physics is like this. We don't expect you to master everything immediately; physics takes practice, and it's okay to get stuck and ask questions. In fact, it's what we expect!

# The Physics Clinic

The Clinic is in room 112; it's a large room with tables, boards, and (usually) a graduate teaching assistant. Often the professors and coaches are there, too.

You can go there whenever the building is open to work in groups on your homework, and ask each other and the GTA for help.

We also hold help hours there:

- Walter: 2-4 Tuesday, 9:30-11:30 Friday (but not this Friday), others TBA
- Matt: 2-4 Friday, others TBA?

This is an excellent resource for you to use; why do your homework alone when you can work with your peers and instructors?

# Office hours

You're also always free to drop by our offices:

- Walter: Physics 215 (the one with the birds on the door)
- Matt: Physics 325 (no birds, sorry)

We might not be there, and we might have other urgent stuff to do, but helping students learn is a very high priority, so if I'm around, likely I can drop whatever I'm doing and help you with physics.

# Dimensions

Things in nature aren't just described by numbers; they have an associated *dimension*, and we measure them using a *system of units*.

We have three different kinds of dimension:

- **Length**: usually measured in **meters**; also inches, miles, light-years...
- **Mass**: usually measured in **kilograms**; also grams, tonnes...
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For the Americans: the pound measures *force*, not mass. The word "weight" means "force due to gravity"; an object with a mass of one kilogram weighs 2.2 pounds on Earth.

"It is two hours from Syracuse to Adirondack State Park"

Does this statement make sense?

A: Yes

B: No

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"It is two hours from Syracuse to Adirondack State Park"

Does this statement make sense?

A: Yes

B: No

C: Only if I tell you something else, too

I've got to also tell you the car's velocity!

# Math, physics-style, I: working with dimensions

"The distance from Syracuse to the Adirondacks is two hours"

$$\text{Distance} = \text{Time}$$

**This statement makes no sense!**

"The distance from Syracuse to the Adirondacks is two hours"

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"The distance from 'Cuse to the Adirondacks is two hours at 100 km per hour"

$$\text{Distance} = \text{Time} \times \frac{\text{Distance}}{\text{Time}}$$

Here the dimensions match on both sides; this is a valid statement.

# Math, physics-style, II: working with units

Units of measure (km, hours) follow the rules of algebra.

$$s = (2\,\mathrm{hr}) \times \frac{100\,\mathrm{km}}{1\,\mathrm{hr}}$$
$$s = 200\,\mathrm{km}$$

Velocity is thus a length divided by a time: km/hr, m/s, etc. What about acceleration?

## Math, physics-style, II: working with units

"A falling object's speed increases by 10 meters per second every second."

$$10\,\frac{\frac{\text{meter}}{\text{second}}}{\text{second}}$$

This is really awkward to write...

$$10\,\frac{\frac{\text{meter}}{\text{second}}}{\text{second}} = 10\text{m}/\text{s}^2$$

Much better! Even though nobody's ever seen a "squared second", this still makes sense mathematically. We can build all kinds of compound units this way.

# Math, physics-style, III: compound units

Newton's second law says that force is equal to mass times acceleration. In symbols, $F = ma$. What units could you measure force in?

A: $\mathrm{kg\,m/s}$

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C: $\mathrm{m/s^2}$

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This gets awkward to keep writing, so we define:
$1\,\mathrm{kg\,m/s^2} = 1\,$newton, abbreviated N.

# The beginning: describing motion (1-D)

Recall that at first, we are only concerned with describing motion.

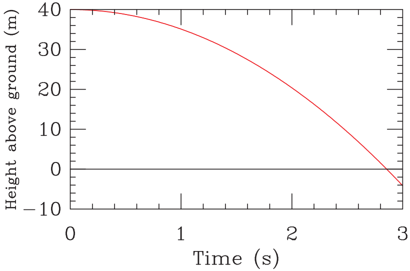
- Most fundamental question: "where is the object I'm talking about?"
- Quantify position using a "number line" marked in meters:
  - Choose one position to be the origin ("zero") – anywhere will do
  - Choose one direction to be positive
  - Measure everything relative to that
  - Can measure in any convenient units: centimeters, meters, kilometers...
- You're used to this already, perhaps:
  - Mile markers on highways
  - Yard lines in American football

# Equations of motion

Complete description of motion: “Where is my object at each point in time?”

This corresponds to a mathematical function. Two ways to represent these. Suppose I drop a ball off a building, putting the origin at the ground and calling “up” the positive direction:

Graphical representation




Algebraic representation

$$y(t) = (40\,\mathrm{m}) - Ct^2$$

(C is some number; we'll learn what it is Thursday)

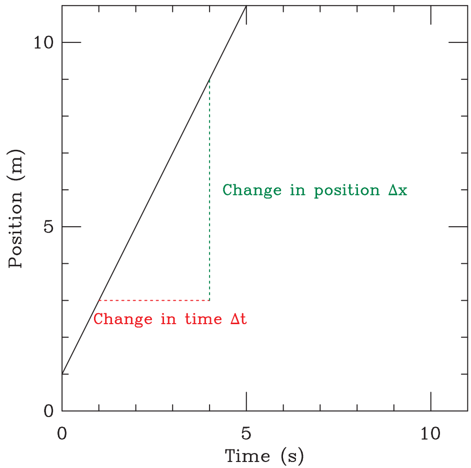
Both let us answer questions like “When does the object hit the ground?”

$\rightarrow$ ... the curve's x-intercept

$\rightarrow$ ... when $y(t) = 0$

# Velocity: how fast position changes

The slope of the position vs. time curve has a special significance. Here's one with a constant slope:



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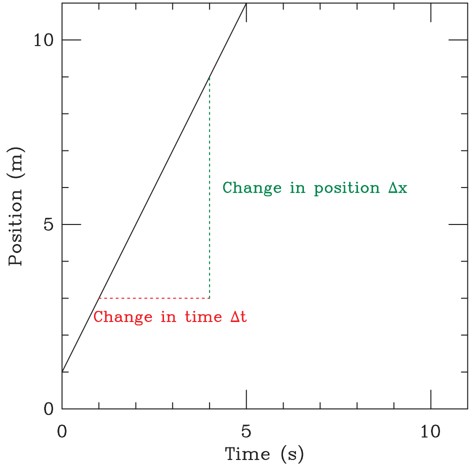


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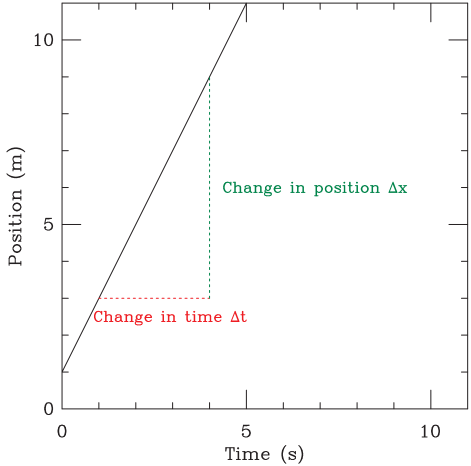


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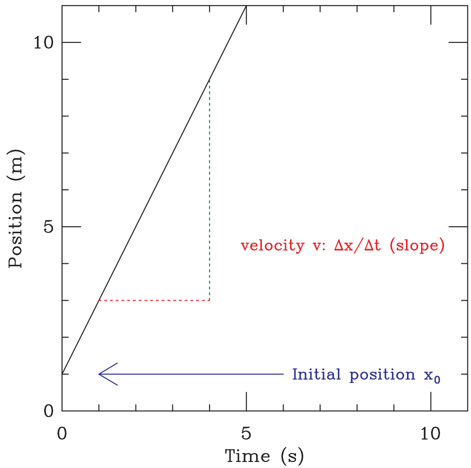
$\rightarrow$ The slope here – change in position over change in time – is the **velocity**! Note that it can be positive or negative, depending on which way the object moves.

# Constant-velocity motion: connecting graphs to algebra

If an object moves with constant velocity, its position vs. time graph is a line:




We know the equation of a straight line is is $x = mt + b$ (using $t$ and $x$ as our axes).

- $m$ is the slope, which we identified as the velocity
- $b$ is the vertical intercept, which we recognize as the value of $x$ when $t = 0$

We can thus change the variable names to be more descriptive:

$$x(t) = vt + x_0 \text{ (constant-velocity motion)}$$

# Going from "equations of motion" to answers

$x(t) = vt + x_0$ is called an *equation of motion*; in this case, it is valid for constant-velocity motion.

It gives you the same information as a position vs. time graph, but in algebraic form.

To solve real problems, we need to be able to translate physical questions into algebraic statements:

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- "When do two moving objects meet?"
  - Write down $x_1(t)$ and $x_2(t)$, then ask "At what time does $x_1 = x_2$?"

# A rough problem-solving guide for constant-velocity motion

A general framework for solving constant-velocity problems algebraically:

1. Decide on a coordinate system: where is $x = 0$, and which way is positive?
2. Write down the equation of motion $x(t) = x_0 + vt$ for each object
3. Ask "How can I translate the thing I'm looking for into an algebraic statement?"
4. Do the algebra!