Introduction

Syracuse University, Physics 211 Spring 2021
Walter Freeman

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Physics 211
Forces and Motion

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Course webpage:

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

Overview of today

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

What is physics?

So what is this class?

Physics: what are the fundamental laws of nature?

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

... and tend to manifest *similar patterns* that can be understood in *similar ways*.

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, but inversely proportional to their mass.”

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

Why study physics?

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"The **far-reaching expertise** that physics students develop while receiving their degrees–through exposure to a broad set of skills and techniques–makes them **exceptional problem solvers.** Moreover, their ability to **approach problems from general principles** often means that physicists can **apply their knowledge in novel contexts**, leading to innovative advances in technological development. Their intimate **understanding of the laws of the universe**, along with the ability to harness the **powerful machinery of mathematics to model and predict**, puts physics students in a unique position to tackle some of the world's biggest challenges."

–Crystal Bailey, APS Careers 2020

"As a physicist, you have scientific, technical, and problem-solving skills that are valuable in a wide range of employment sectors. You have learned to **approach problems from first principles** and can serve as a **generalist when collaborating on interdisciplinary teams**. You understand how to set up and run experiments, analyze data, and create mathematical or computational models. **Most importantly, you have the confidence to advance beyond the edge of what is known... This habit of continued learning is a hallmark of a physicist, and greatly valued in all employment sectors.**"

–Kate Kirby, APS Careers 2020

What is this (and how does it work)?

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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?

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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 $\vec{F} = m\vec{a}$
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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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Components of this course

- **Lecture:** Held on Zoom and Twitch Tuesday/Thursday. Please contribute your comments as we go!
- **Recitation:** Held on Blackboard Collaborate or in person Wednesday/Friday. The most important part of the course!
- **My office hours:** Held on the same Zoom link as class, Tuesday 1:30-4:30 and Friday 9:30-12.
- **TAs' office hours:** Location/time TBD.

Tools everyone will want to use:

- **Zoom:** – for lecture and office hours
- **Blackboard:** – you will turn in assignments on Blackboard. Announcements also posted here.
- **Course website:** – `walterfreeman.github.io/phy211/`: you can find materials and announcements here, and links to everything
- **Blackboard Collaborate:** – for online recitations

Optional tools that may make your life easier:

- **Twitch:** – a less-clunky way to participate in lecture (accounts are free)
- **Discord:** – a popular chat program; the course has a Discord server (invite on the webpage)

Syllabus review

https://walterfreeman.github.io/phy211/syllabus.html

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

Since Blackboard is so clunky, I maintain a separate website:

`https://walterfreeman.github.io/phy211/`

I will post announcements, homework assignments, and recitation materials there.

I will also post announcements to Blackboard and send them out by email.

I will *sometimes* post slides. Other times everything will be on the chalkboard, so we won't have slides.

The best reference for class is your own notes.

The second-best reference is the video recording of class – you can get it on Twitch or YouTube.

Dimensions: what kinds of things do we measure?

“It is two hours from Syracuse to Adirondack State Park”

Math and the real world

Algebra with units: velocity

“A falling rock’s speed increases by 10 meters per second every second.”

What units might we measure *force* in?

The beginning: describing motion (1-D)

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

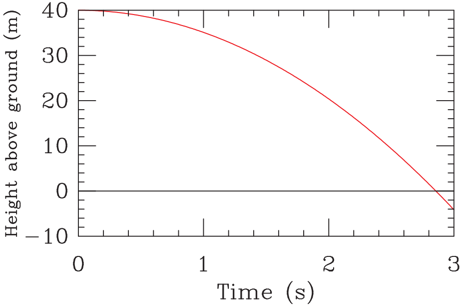
- Most fundamental question: “where is the object I’m talking about?”
- Quantify position using a “number line” marked in meters:
  - Choose one position to be the origin (“zero”) – anywhere will do
  - Choose one direction to be positive
  - Measure everything relative to that
  - Can measure in any 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

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

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

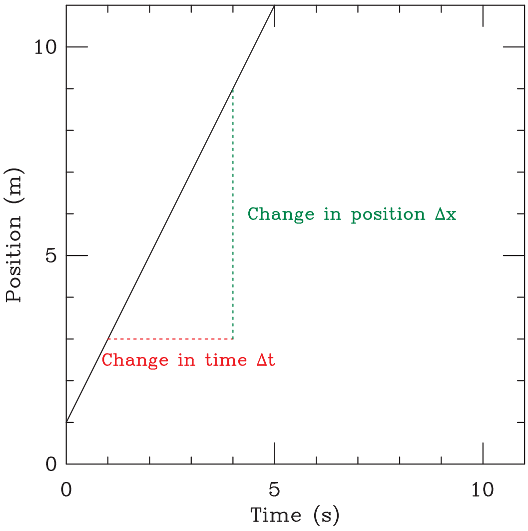
Both let us answer questions like "When does the object hit the ground?"

→ ... the curve's x-intercept

→ ... 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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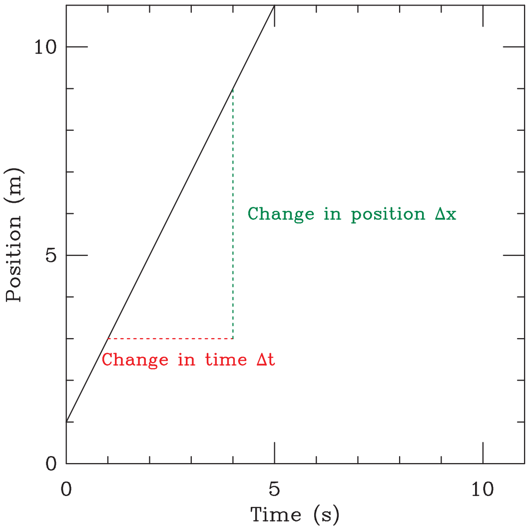

Slope is $\frac{\text{rise}}{\text{run}} = \frac{\Delta x}{\Delta t} = \frac{2\,\text{m}}{1\,\text{s}} = 2$ meters per second (positive; it could well be negative!)

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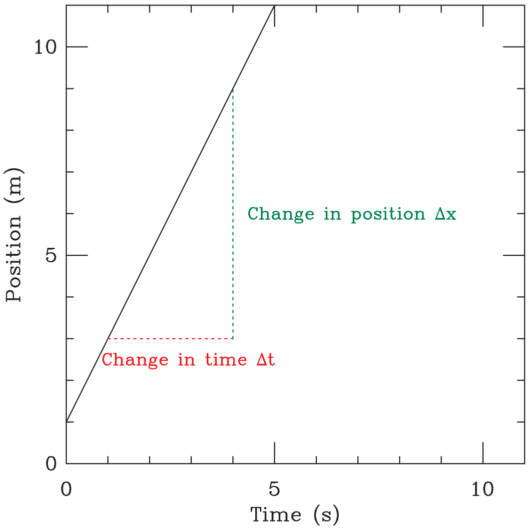

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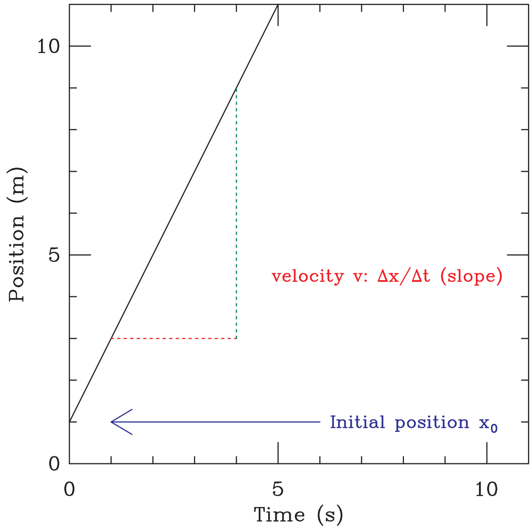
$\rightarrow$ The slope here – change in position over change in time – is the **velocity**! Note that it can be positive or negative, depending on which way the object moves.

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:

- "If a car starts at milepost 30 and drives at 50 mph, where is it an hour later?"

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  - If the ground is at $y = 0$, then we ask: "What is the value of t when $y = 0$?"
- "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!