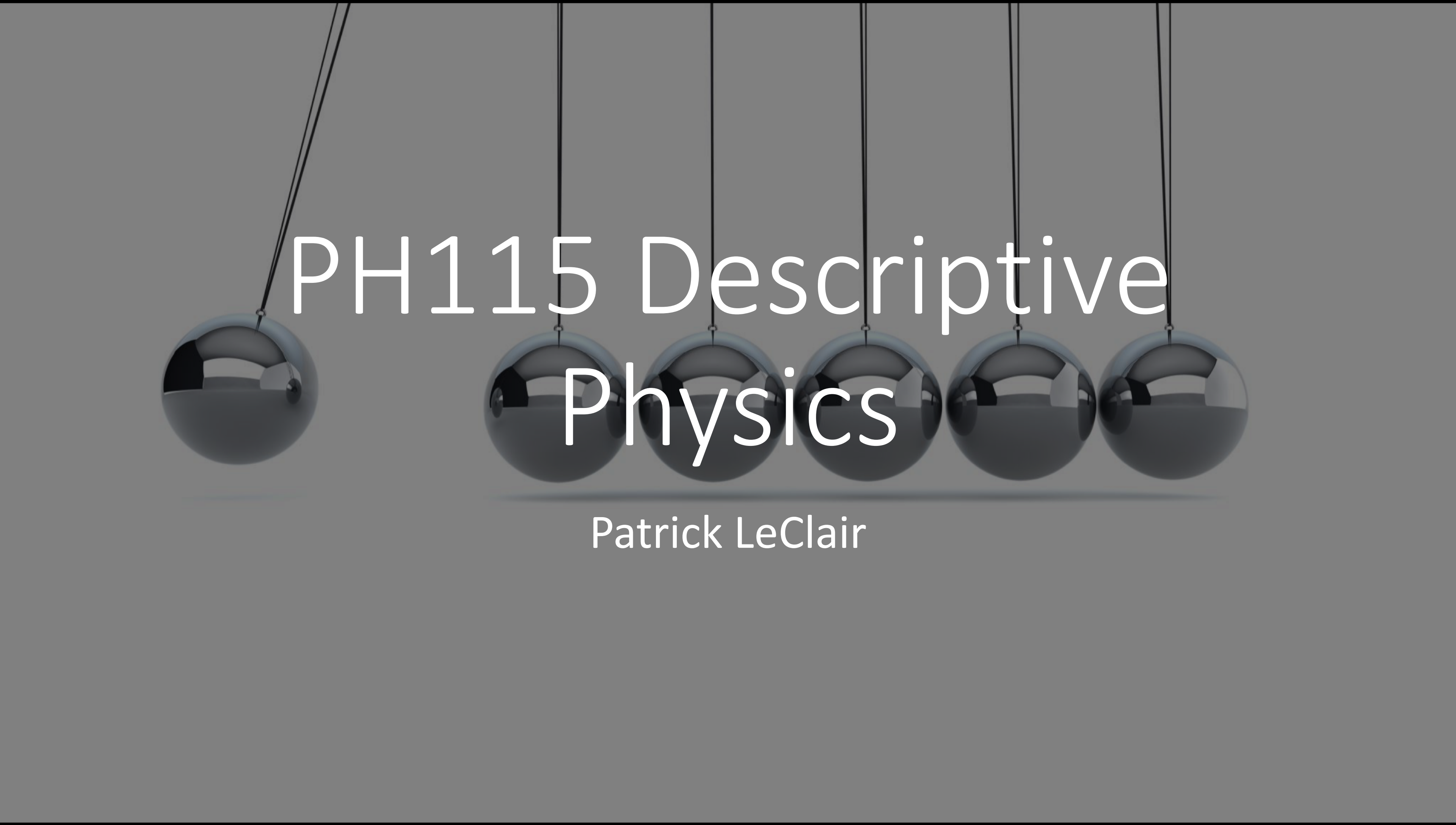


PH115 Descriptive Physics

Patrick LeClair

Contact

- pleclair@ua.edu
  - Put “PH115” in subject
- Office
  - 208 Gallalee (enter through 206)
- Office Hours
  - MWF 11-12 (after class)
  - By appointment – email for times

- ODS accommodations? Let me know as soon as you can.

Graduate Assistants

- May have an assistant to help with labs/exercises/etc.
- Will know this next week
- Additionally: grad students have pooled office hours (“help desk”)
  - Will have this schedule next week – help with homework, etc.

Why are you here

- You need a science but don’t like math.
  - This is fine.

- We don’t need you to be a physics major
- We do need you to appreciate how science relates to everyday life
- Why does that matter to us?
- Why should that matter to you?

- Isn’t this stuff hard?
  - You will be fine.

Lecture & discussion

- Principles
  - I’ll overview current material, mostly discussion and concepts
  - not going to just work out problems on board or define things
  - worry about logic, strategies ... *why* does it work this way?
  - read chapter ahead of time ... otherwise we can’t discuss
- Practice – not something you can watch!
  - have to do it!
  - work out problems, consequences on your own with guidance
- will devote time in class to group problem solving & discussion, particularly on Fridays

Experiments & activities

- More than baking a cake!
  - Hypothesis, experimental test, attempt to verify
  - If X is true, then Y should happen
  - The kind of thing kids do naturally
- Sometimes an experiment, sometimes an activity/skill, sometimes a simulation
- Usually during M/W classes
- Will introduce the lab and its main point
  - Often will have preliminary questions
- Assume you have read lab ahead of time
  - If not: do it before you start

Topics

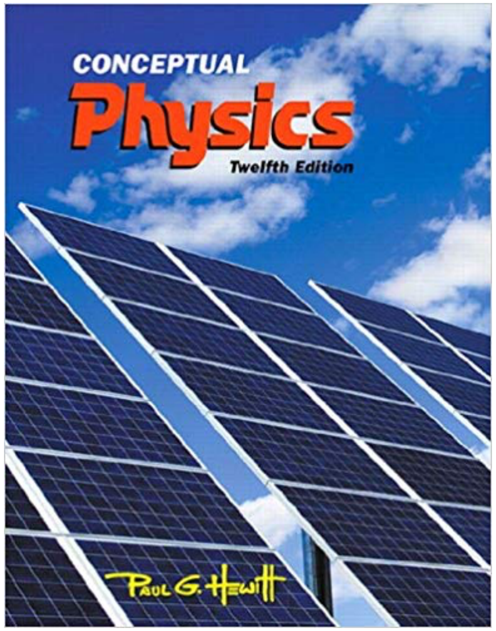
- What is science?
- Matter, atomic structure, phases
- Motion
- Energy
- Force
- Projectiles
- Heat
- Sound
- Electric fields and circuits
- Magnetic fields, magnetism, and applications
- Light & Color
- Mirrors & Lenses
- Waves
- Quantum phenomena

Schedule

- **Exams**
  - **13 Sept, 18 Oct, 15 Nov**
- Generally:
  - MW classes mix of lecture/discussion & activities
  - F classes to finish up chapter, work on problems, catch up
- Will adapt as we go, we are not really constrained in what we cover
- Do be on time. I'll usually start a few minutes past the hour.
- We will end on time.
- Detailed schedule on BlackBoard soon

Book

- Current is 12th edition.
- Any edition is fine.
- Many used, eBook ~$50



Grading

- 3 in-class exams, 10% each (30%)
- Homework (roughly weekly): 25%
- Labs/exercises: 15%
- Participation: 10%
- Final exam: 15%
- End of semester paper: 5%

Participation

- I don’t grade attendance. You have to do something.
- Labs/exercises are one part of this.
- The main part – online discussion/QA system

Homework

- Typically out on Friday, due next Friday
- Posted Blackboard, turn in there
- Encouraged to work together, but turn in your own individually

Quizzes

- Typically on Blackboard, due at start of class
- Based on reading for that day
- Counted with homework

Today & Friday

- “What is science” – broad overview
- Simple lab – linear relationships
  - i.e., “straight line” or “proportional” relationships
- Some math review

Next week

- Matter, Atomic Structure, Phases
- Typically:
  - Labs/exercises on Mon, Wed
  - Problems, discussion on Friday
  - Homework due Friday (BlackBoard)

Introductions

- Who are you
- What do you study
- Why are you here / what do you want to get out of this?

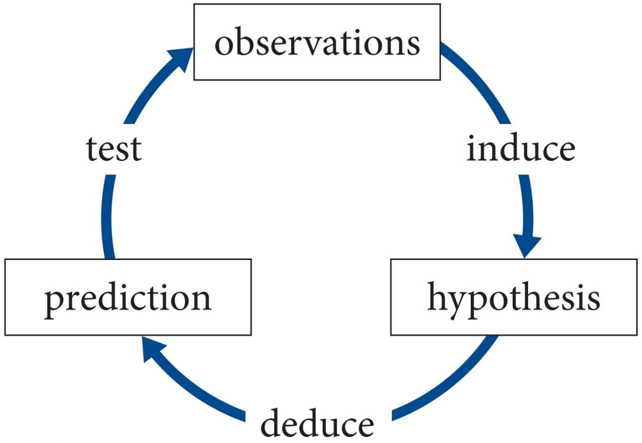
The scientific method

- Physics is about discovering the unifying patterns that underlie all physical phenomena
  - Ranging from the scale of subatomic particles to the DNA molecules and cells, and to the scale of stars and galaxies.

- The goal is to find the most fundamental laws that govern the universe and to formulate these laws in the most simple and precise way possible.
  - Some things are simpler than others

The scientific method

- **The Scientific Method** is an iterative process by which scientists endeavor to construct these laws of nature.



- If the prediction is inaccurate you modify the hypothesis
- If the predictions prove to be accurate test after test it is elevated to the status of a **law** or a **theory**.

Exercise: Hypothesis or not

Which of the following statements are hypotheses?

(a) Heavier objects fall to Earth faster than lighter ones.

(b) The planet Mars is inhabited by invisible beings that are able to elude any type of observation.

(c) Distant planets harbor forms of life.

(d) Handling toads causes warts.

The scientific method

Exercise: Hypothesis or not

Which of the following statements are hypotheses?

(a) Heavier objects fall to Earth faster than lighter ones.

~~(b) The planet Mars is inhabited by invisible beings that are able to elude any type of observation.~~

(c) Distant planets harbor forms of life.

(d) Handling toads causes warts.

Exercise: Hypothesis or not (cont.)

SOLUTION (*a*), (*c*), and (*d*).

A hypothesis must be experimentally verifiable.

a) I can verify this statement by dropping a heavy object and a lighter one at the same instant and observing which one hits the ground first.

b) This statement asserts that the beings on Mars cannot be observed, which precludes any experimental verification and means this statement is not a valid hypothesis.

Exercise: Hypothesis or not (cont.)

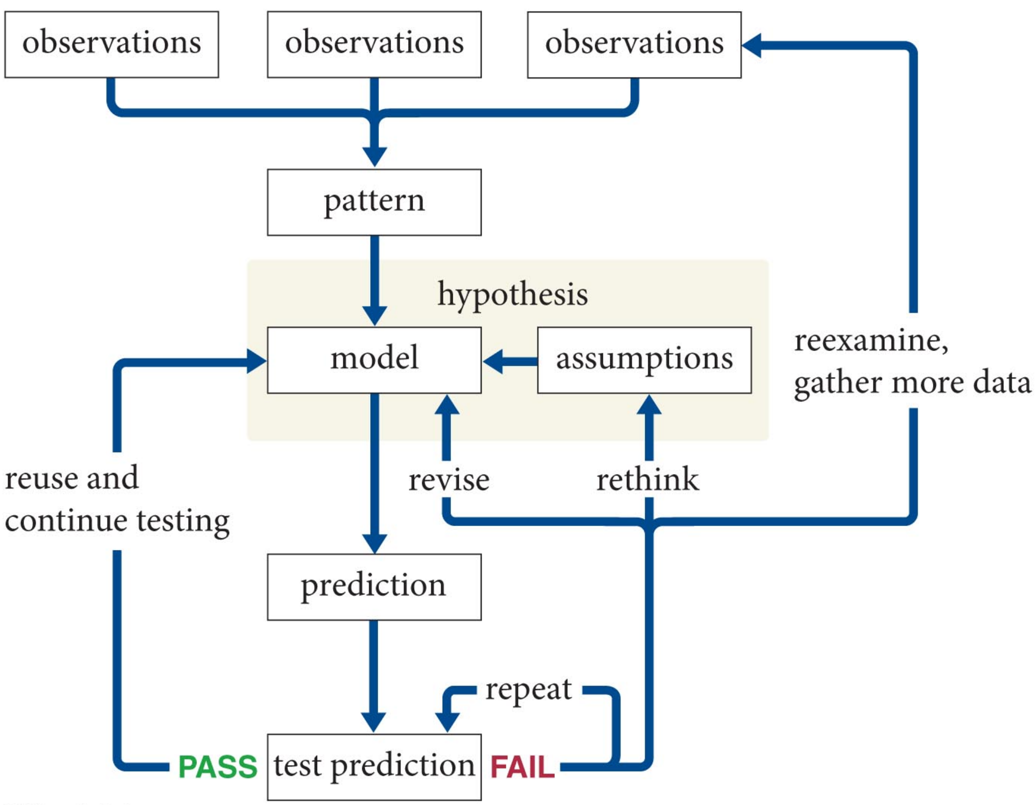
SOLUTION

c) Although we humans currently have no means of exploring or closely observing distant planets, the statement is in principle testable.

d) Even though we know this statement is false, it *is* verifiable and therefore is a hypothesis.

The scientific method

- forming a hypothesis almost always involves developing a **model**
- a **model** is a simplified conceptual representation of some phenomenon.



The scientific method

Exercise: Dead music player

A battery-operated music player fails to play when it is turned on.

- Develop a hypothesis explaining why it fails to play.
- Make a prediction that permits you to test your hypothesis.
- Describe two possible outcomes of the test and what you conclude from the outcomes.

The scientific method

Exercise: Dead music player (cont.)

SOLUTION (one example):

Hypothesis: The batteries are dead.

Prediction: If I replace the batteries with new ones, the player should work.

Possible outcomes:

(1) The player works once the new batteries are installed, which means the hypothesis is supported;

(2) The player doesn't work after the new batteries are installed, which means the hypothesis is not supported and must be either modified or discarded.

Checkpoint

Each outcome had a hidden assumption.

“supported” isn’t the same as “proven correct”

“unsupported” isn’t the same as “proven incorrect”

That the player works with new batteries doesn’t mean the old ones were dead *necessarily*.

- perhaps the old ones were in backwards?
- perhaps changing the batteries fixed a loose contact?

That the player doesn’t work with new batteries doesn’t mean the player is broken *necessarily*.

- batteries could be in backwards both times
- new batteries might be dead too

Matter and the universe

- The goal of physics: describe all that happens in the universe. (at least in principle)

- The use of **physical quantities** is pivotal in developing concepts that describe natural phenomena.

- The fundamental physical quantity by which we map the universe is **length**:
  - The SI unit of length to be a **meter** and is abbreviated m.
  - The current definition of the meter is precisely defined through the (constant) speed of light

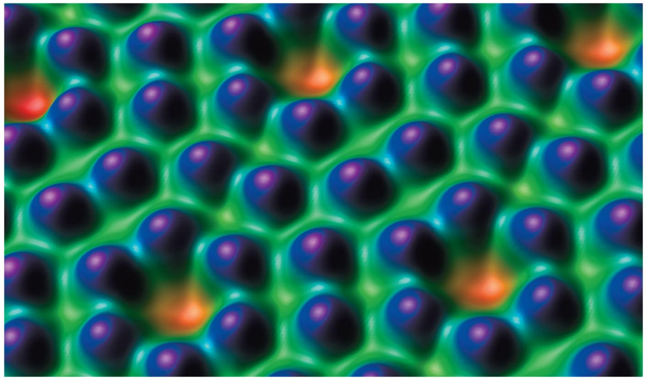
Matter and the universe

- Because of the vast range of size scales in the universe, we often round off any values to the nearest power of ten.
- Notation: $10^3 = 10 \times 10 \times 10$ = (add three zeros)
  - $2 \times 10^3 = 2 \times 10 \times 10 \times 10 = 2{,}000$
- The nearest power of ten is called an **order of magnitude**.

- Any number between 0.3–3, call it 1
- Any number >3 but <30, call it 10
  - Example: 3 min = 180 sec or 1.8×10^2 s. Since $1.8 < 3$, the order of magnitude value is 100 or 10^2 s.
  - Basically: “about 100” rather than “about 10 or 1000”
  - “Two orders of magnitude larger” means ~100 times or 10^2 times
  - Example: Earth’s circumference = 40,000,000 m
    = 4×10^7m. Order of magnitude value = 10^8 m.

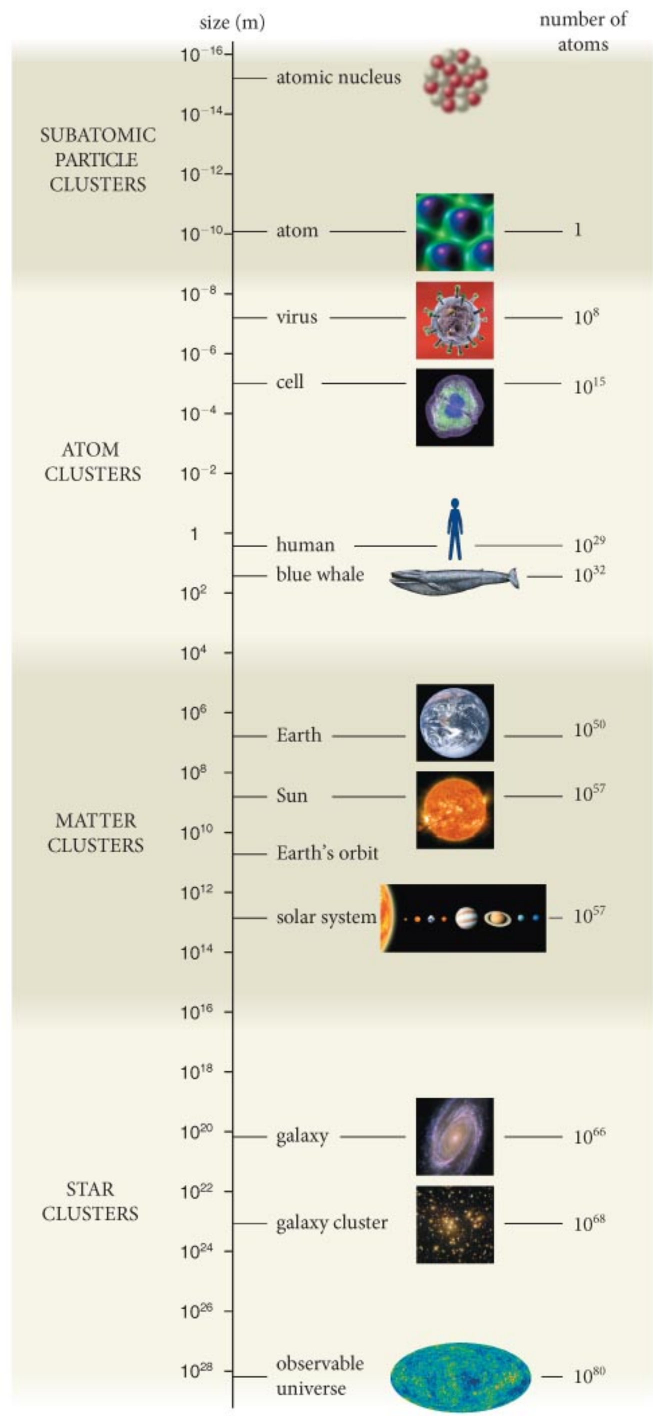
Matter and the universe

- All ordinary matter in the universe is made up of basic building blocks called atoms
  - Nearly all the matter in an atom is contained in a dense central nucleus, which consists of **protons** and **neutrons**.
  - A tenuous cloud of **electrons** surrounds this nucleus.
- Atoms have a diameter of about 10^{-10} m.
- The nucleus has a diameter of about 10^{-15} m.



Matter and the universe

- The figure shows the relative size of some representative objects in the universe.
- can you neglect things above/below a certain order away?
- One distinction between BIO, CH, PH



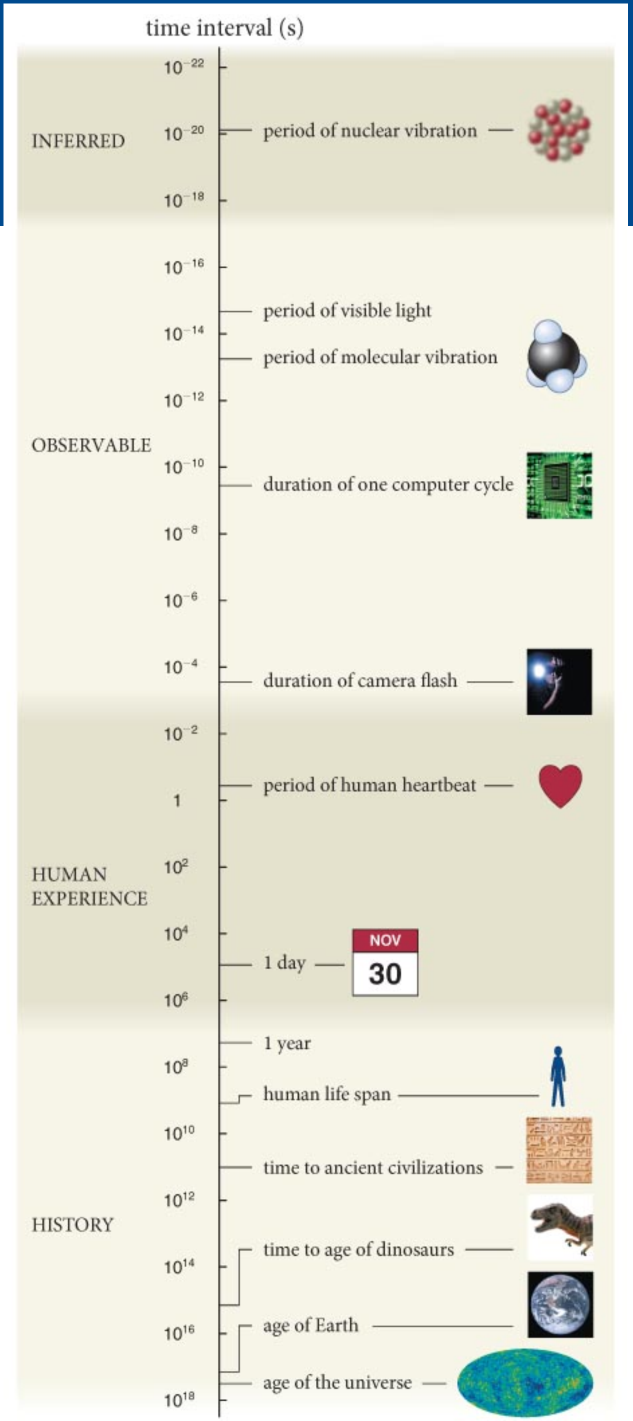
Time and change

- Whereas we can freely choose the direction in all three dimensions of space, time flows in a single direction.
- This “arrow of time” only points to the future, and allows us to establish a causal relationship between events, which leads to the **principle of causality**:

  Whenever an event A causes event B, all observers see event A happen first.

Time and change

- The standard unit of time is the **second** (abbreviated s).
- The second is *defined* as the duration of 9,192,631,770 periods of certain radiation emitted by cesium atoms.
- Essentially, based on the constant speed of light
- Neglect processes far slower/faster than what you're interested in?



Representations

- develop **representations** to visualize physical phenomena
- develop scientific models that explain them.
- recognize that representations can possess a range of information from abstract to concrete.
- classify representations into graphical and mathematical ones.

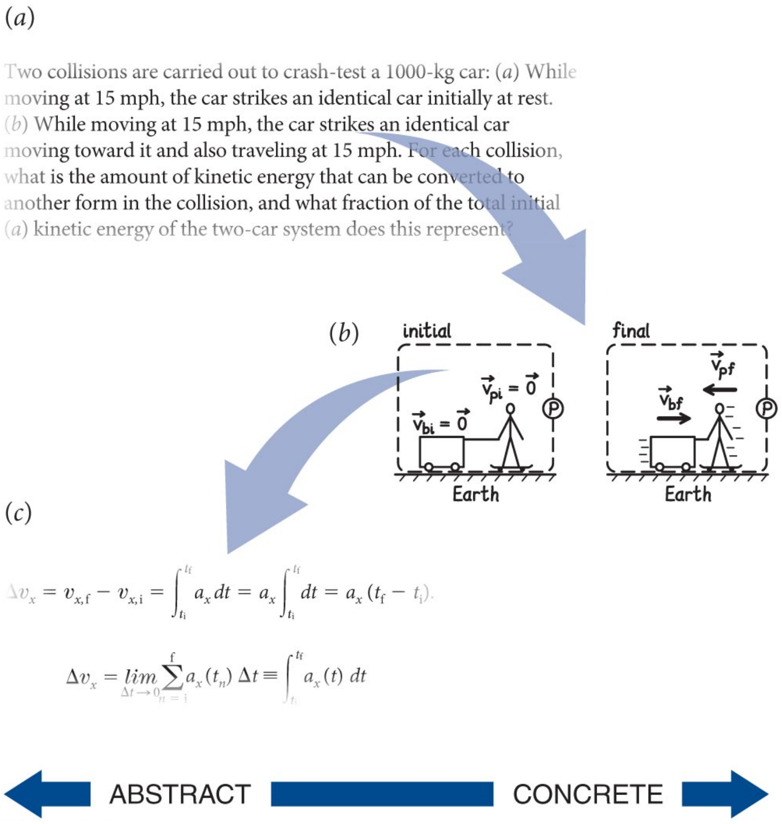
Representations

- An essential first step in solving a problem: make a **visual representation** of the available information

- Helps develop a qualitative understanding of the problem, and organize the information

Representations

- Visual representations are an integral part of getting a grip on physics problems and developing models
- Catalog what you know, what you want to find
- Sketch the situation noting these



Representations

Exercise: Stretching a spring

- One end of a spring is attached to a horizontal rod so that the spring hangs vertically.
- A ruler is hung vertically alongside the spring.
- The stretching properties of the spring are to be measured by attaching eight identical beads to the spring's free end.
- With no beads attached, the free end of the spring is at a ruler reading of 23.4 mm.
- With one bead attached, the end of the spring drops to 25.2 mm.

Representations

Exercise: Stretching a spring (cont.)

A total of six beads are added, giving the following readings:

bead number	ruler reading (mm)
0	23.4
1	25.2
2	26.5
3	29.1
4	30.8
5	34.3
6	38.2

Exercise: Stretching a spring (cont.)

Going forward?

(a) Make a pictorial representation of this setup.

(b) Tabulate the data *[mostly done]*

(c) Plot the data on a graph, showing the ruler readings on the vertical (y) axis and the numbers of beads on the horizontal (x) axis.

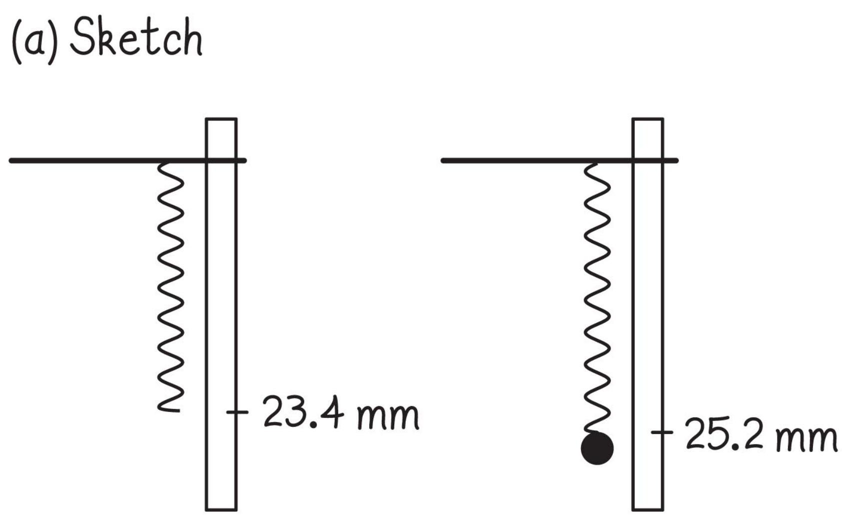
(d) Describe what can be inferred from the data.

Representations

Exercise: Stretching a spring (cont.)

SOLUTION (*a*) sketch

- Key items needed: spring, rod, ruler, and typical bead
- Indicate how the ruler readings are obtained.
- Don’t need to show all beads, one example is enough.
- Represented the general procedure of adding beads one (or two) at a time and how each addition changes the position of the spring end.



Representations

Exercise: Stretching a spring (cont.)

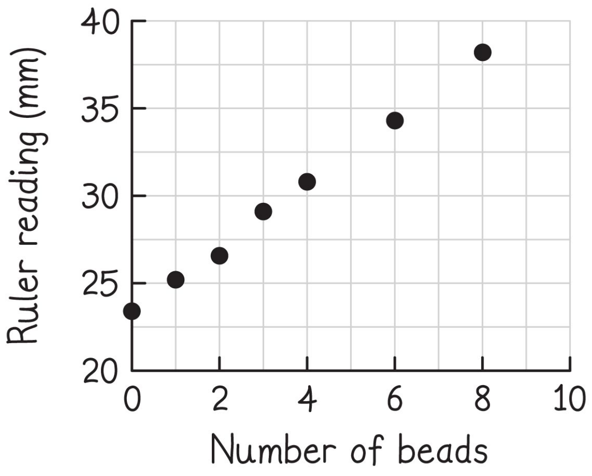
SOLUTION (*b*) complete table (*c*) make a plot (label axes! units! metric!)

(*d*) Ruler readings vs. the numbers of suspended beads is linear. Each additional bead stretches the spring by about the same amount.

(b) Table

Number of beads	Ruler reading (mm)
0	23.4
1	25.2
2	26.5
3	29.1
4	30.8
6	34.3
8	38.2

(c) Graph



Self-Quiz

Two children in a playground swing on two swings of unequal length. The child on the shorter swing is considerably heavier than the child on the longer swing. You observe that the longer swing swings more slowly.

Formulate a hypothesis that could explain your observation.

How could you test your hypothesis?

Self-Quiz

- No, really - formulate a hypothesis that could explain your observation. Come up with a way to test your hypothesis

Self-Quiz

Answer

Two *plausible* hypotheses to start with

(1) Longer swings swing more slowly than shorter swings.

Make swings the same length and have them swing again.

(2) Heavier children swing faster than lighter ones.

Ask them to trade places

(Turns out the first one is better. Many things are *possible*, what nature has chosen is not always the most sensible thing.)

Quantitative Tools

Physical quantities and units

- Name and understand the seven **base units** of the SI system of units.
- Use **power of 10 notation and metric prefixes** to represent large and small numbers and calculations involving them.
- Define the **density** of matter and its relationship to the mole and Avogadro's number.
- Perform **unit conversions** by use of a ratio of units.

Physical quantities and units

- The symbols of some of the physical quantities we use throughout this course.

Table 1.1 Physical quantities and their symbols

Physical quantity	Symbol
length	ℓ
time	t
mass	m
speed	v
volume	V
energy	E
temperature	T

Physical quantities and units

- The system of units in science is called *Système Internationale* or **SI units**.
- The SI system consists of seven base units from which all other units can be derived.

Table 1.2 The seven SI base units

Name of unit	Abbreviation	Physical quantity
meter	m	length
kilogram	kg	mass
second	s	time
ampere	A	electric current
kelvin	K	thermodynamic temperature
mole	mol	amount of substance
candela	cd	luminous intensity

Let’s be honest …

- You have no feel for the metric system.
  - We stand with Liberia and Myanmar!
- 1m ~ 1yd ~ 3ft
- 1m/s ~ 2mph
- 1kg ~ 2lbs on earth’s surface
  - kg is *mass*, lbs are *weight*
- second/ampere/etc are fine
- Kelvin/Celsius
  - 310K = 38C = hot day in AL (100F)
  - 295K = 22C = room temp (71F)
  - 285K = 12C = cold day in AL (53F)
  - 273K = 0C = water freezes (32F)

Physical quantities and units

- Often we deal with quantities much less or much greater than the standards of 1 m, 1 s, etc.
- Prefixes for powers of 10 to make things easier
- Multiples of 3 are the only ones used commonly

Table 1.3 SI prefixes

10^n	Prefix	Abbreviation	10^n	Prefix	Abbreviation
10^0	—	—			
10^3	kilo-	k	10^{-3}	milli-	m
10^6	mega-	M	10^{-6}	micro-	μ
10^9	giga-	G	10^{-9}	nano-	n
10^{12}	tera-	T	10^{-12}	pico-	p
10^{15}	peta-	P	10^{-15}	femto-	f
10^{18}	exa-	E	10^{-18}	atto-	a
10^{21}	zetta-	Z	10^{-21}	zepto-	z
10^{24}	yotta-	Y	10^{-24}	yocto-	y

Physical quantities and units

- It is important to be able to convert back and forth between SI units and other units.
- The simplest way to convert from one unit to another is to write the conversion factor as a ratio equal to one. For example we can write

$$\frac{1\text{ in.}}{25.4\text{ mm}} = 1 \;\text{ or }\; \frac{25.4\text{ mm}}{1\text{ in.}} = 1$$

- Because multiplying by 1 does not change a value, these ratios are easily used for unit conversions.
- As an example, if we want to convert 4.5 in into millimeters:

$$4.5\text{ in} = (4.5\,\cancel{\text{in}}.)\left(\frac{25.4\text{ mm}}{1\,\cancel{\text{in}}.}\right) = 4.5 \times 25.4\text{ mm} = 1.1 \times 10^2\text{ mm}$$

Exercise: Unit conversions

Convert each quantity to a quantity expressed either in meters or in meters raised to some power:

(a) 4.5 in.

(b) 3.2 acres

(c) 32 mi

(d) 3.0 pints

Exercise: Unit conversions (cont.)

SOLUTION See Appendix A for conversion factors. Or Google. Really.

$$(a) \qquad (4.5 \text{ in.})\left(\frac{2.54\times 10^{-2}\,\text{m}}{1 \text{ in.}}\right) = 1.1\times 10^{-1}\,\text{m}$$

$$(b) \quad (3.2 \text{ acres})\left(\frac{4.047\times 10^{3}\,\text{m}^2}{1 \text{ acre}}\right) = 1.3\times 10^{4}\,\text{m}^2$$

Exercise: Unit conversions (cont.)

SOLUTION

$$(c) \qquad (32\ \text{mi})\left(\frac{1.609\times10^{3}\,\text{m}}{1\ \text{mi.}}\right)=5.1\times10^{4}\,\text{m}$$

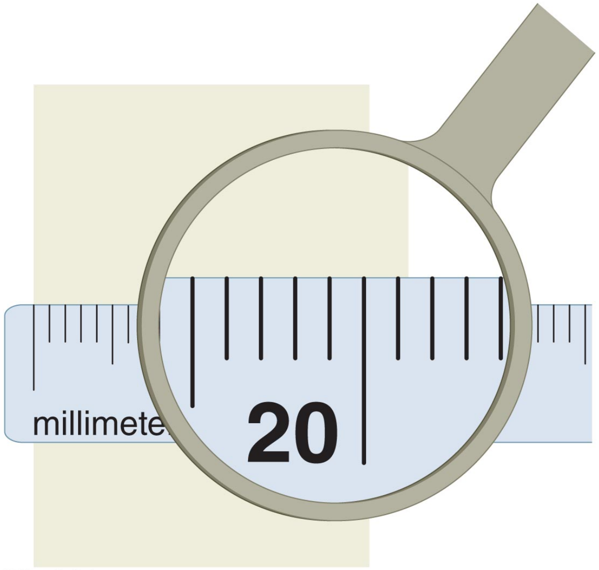
$$(d) \quad (3.0\ \text{pints})\left(\frac{4.732\times10^{-4}\,\text{m}^{3}}{1\ \text{pint}}\right)=1.4\times10^{-3}\,\text{m}^{3}$$

Significant digits

- Identify **significant digits** as the number of digits in a number that are known reliably.
- Enumerate the **number** of significant digits in a measurement.
- Apply the rules of significant digits in **calculations** involving measured quantities.

Significant digits

- Know how to precisely state what you know about a situation.
- Suppose you measure the width of a paper and it falls between 21 mm and 22 mm, but closer to 21 mm.
  - We might guess that it is 21.3 mm, but cannot be sure of the last digit.
  - By recording 21 mm, we are indicating the actual value lies between 20.5 and 21.5 mm.
  - The value 21 mm is said to have two **significant digits.**
- **Number of digits implies accuracy**



Significant digits

- By expressing a value with the proper number of significant digits, we can convey the precision to which that value is known.
- If a number does not contain zeros, all digits are significant:
  - 21 has two significant digits, 21.3 has 3 significant digits.
- Zeros that come between nonzero digits are significant:
  - 0.602 has 3 significant digits.
- Leading zeros are never significant:
  - 0.037 has two significant digits.

Significant digits

- Trailing zeros to the right of a decimal point are significant:
  - 25.10 has 4 significant digits.
- Trailing zeros that do not contain a decimal point are ambiguous.
  - 7900 can have two to four significant digits.

- More obvious with scientific notation:
  - 7.900×10^3 has four significant digits.
  - 7.9×10^1 has one significant digit.
- For simplicity, consider all trailing zeros to be significant.

Question

The number 0.03720 has ____ digits, ____ decimal places, and ____ significant digits?

1. 6, 5, 4
2. 5, 5, 3
3. 6, 5, 3
4. None of the above

Question

The number 0.03720 has _____ digits, _____ decimal places, and _____ significant digits?

1. 6, 5, 4 ✔
2. 5, 5, 3
3. 6, 5, 3
4. None of the above

Significant digits

- The rules for working with significant digits:
  - When **multiplying or dividing** quantities, result has same significant digits as **least accurate** input
  - When **adding or subtracting** quantities, the number of decimal places in the result is the same as the input that has the **fewest decimal** places.
- Don’t overthink it.
  - Least accurate thing wins in a calculation
- Don’t report every digit your calculator gives

Activity

Data collection, analysis, and visualization

Need:
- String
- Tape
- Weight
- Meter stick
- Stopwatch

- Timing the period of a pendulum
  - How to measure? Averaging.
  - How accurate? Spread.
- What does it depend on?
  - How does period vary with length? Weight on end?
- How to visualize?
  - Graph! Period on y axis, length on x axis
  - Does period go up or down as length increases?
- What does this tell us?
  - Straight line (proportional) relationship? More complicated?