University Physics 226N/231N
Old Dominion University

Introductions, Units, Measurements, Survey

Dr. Todd Satogata (ODU/Jefferson Lab)

satogata@jlab.org

http://www.toddsatogata.net/2012-ODU

Monday, August 27 2012

Happy Birthday to Alexa Vega, Alex Lifeson (Rush), Darren McFadden, and Norman Foster Ramsey Jr (1989 Nobel Prize in Physics – Ramsey Method for NMR, MRI, atomic clocks)

Happy Moldovan Independence Day!

Madden Physics

KOTAKU

TOP STORIES

MADDEN

The Real Time for Physics is Now, Says *Madden*

BY OWEN GOOD

JUN 4, 2012 5:00 PM

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It's true. A real-time physics engine will debut in *Madden NFL 13*. The wait is over, the disappointment is over and along with it, the era of animation-based gameplay in one of the most visual of sports video games.

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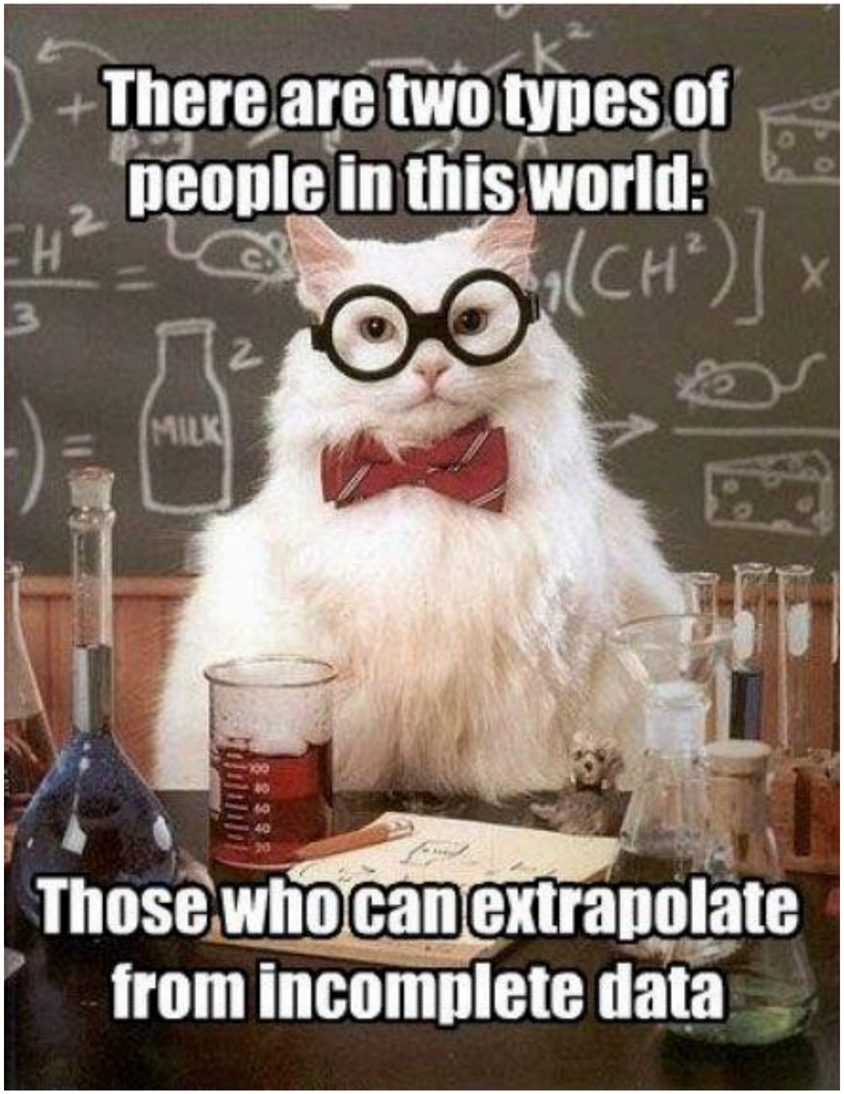
Like Tom McKibben and 212,311 others like this.

What is SCALE-UP?

- **Observation:** you're not seated in a lecture-style hall
  - Lectures are boring (yawn)
  - Lectures let you (the folks who are learning) become passive
  - Lectures isolate you from your peers
- In this class, we'll do it a bit differently
  - **Me:** less lecturer - more moderator, coach, mentor
  - **You:** regular, active, group participants in class activities
- So what do we do?
  - **(Some) Lectures:** Setting up the day's topics, and summaries
  - **Observations:** Related to the current class topic
  - **Ponderables:** Conceptual or calculating group exercises
  - **Tangibles:** Try it out and see group exercises
  - (And, most importantly, Preparation **outside** of class)

Preparation Outside of Class

- Me: Post reading, (some) of the class slides, and Mastering Physics homework
  - By evening after previous class
- You
  - Look through the reading before class
    - You can't engage a topic you haven't at least briefly thought about
  - Do the homework
    - ~half review, half new
    - Keep notebook (see syllabus)
  - ~Maybe 6-12 hours/week



Homework: Brain Exercise

- Do the homework. You won't do well if you don't. 'Nuff said.
- By this Wednesday, at least do the Introduction to Mastering Physics section.
  - It doesn't count towards your grade, but everything following it does, and you'll be a lot less frustrated if you get this out of the way.
- I'll have homework up for 1D motion on Wednesday afternoon.

Class Website and Syllabus

http://www.toddsatogata.net/2012-ODU

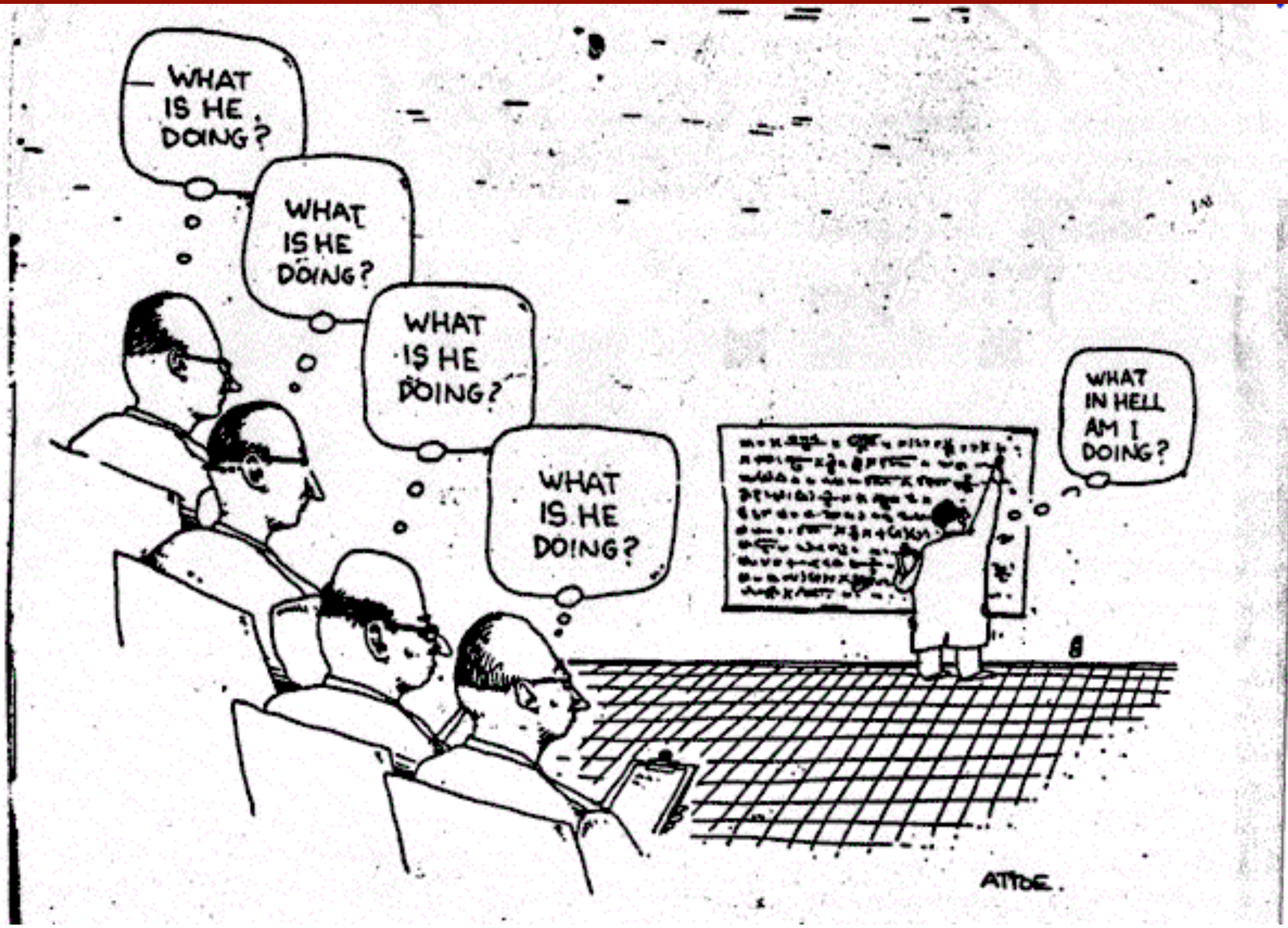
ODU University Physics
PHYS 226N/231N

CRNs 10138/24368 and lab 11777/24369
Dr. Satogata / satogata@jlab.org or tsatogat@odu.edu
TAs: Dave Fisher (dfish014.odu.edu) and Karki Shankar (skark002@odu.edu>
Fall Semester, Aug 27-Dec 08 2012

- Class Information
  - Class Syllabus and Information [last updated 12 Aug 2012] ← **Syllabus**
  - Detailed Class Schedule [last updated 22 Aug 2012]
  - **Textbook:** Essential University Physics (2nd Ed), Richard Wolfson (recommended but not required)
  - **Homework:** Online through Mastering Physics (required!) ← **Mastering Physics**
    Some instructions for using MasteringPhysics are located here.
  - **Class:** MW 9:00-10:50, F 9:00-9:50 in OOCNPS 142-144 (SCALE-UP Classroom)

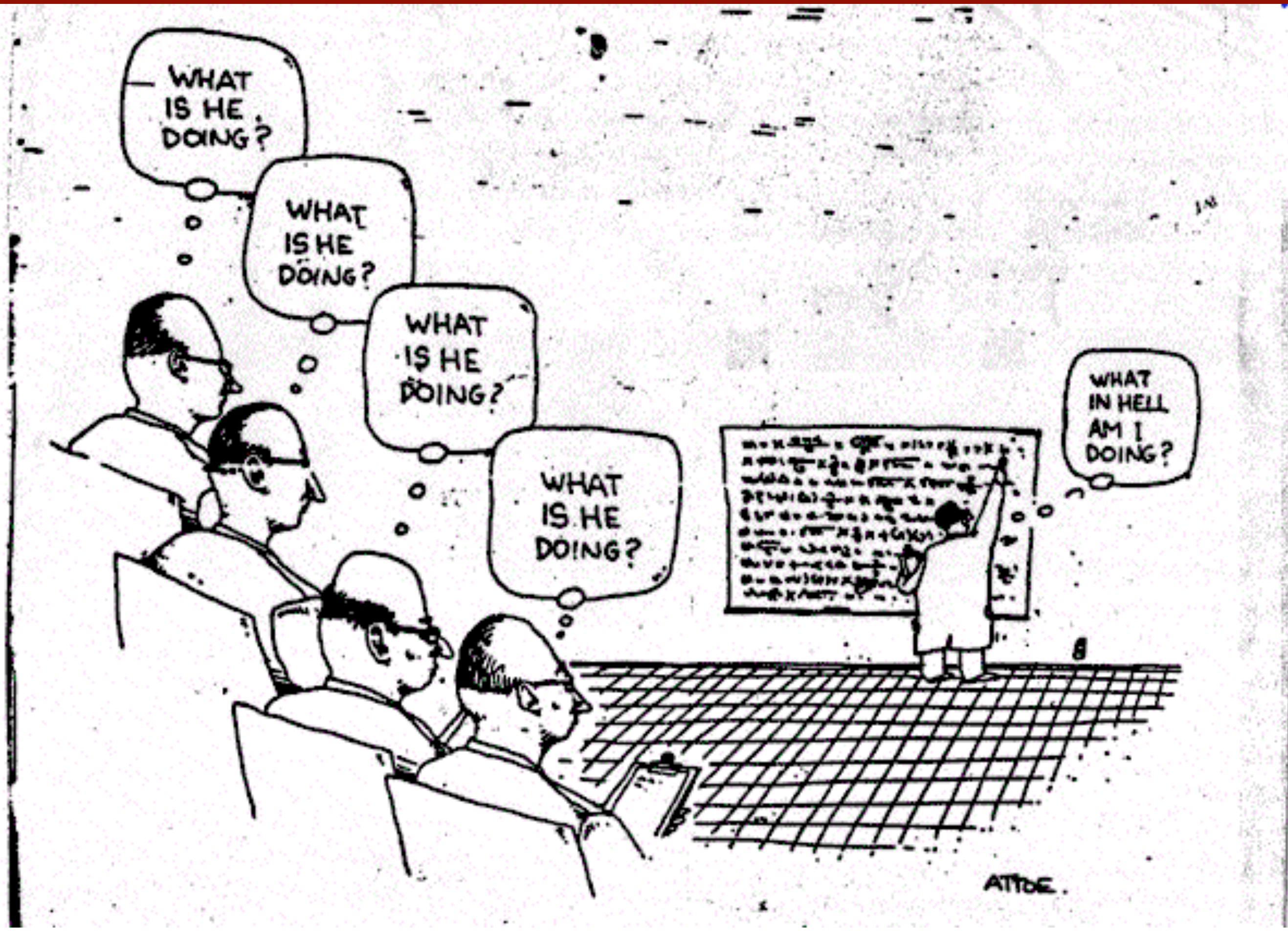
- Class Materials
  - M Aug 27: Slides [-- Mb pdf]. Reading is the class syllabus. ← **Class Materials**
  - W Aug 29: (Coming soon)
  - F Aug 31: (Coming soon)
  - M Sep 3: (Coming soon)
  - W Sep 5: (Coming soon)
  - F Sep 7: (Coming soon)

Tangible (5 minutes)



- Who are you? Why are you here? (5 minutes)
  - Introduce yourself to those around you and say hi!
  - Determine if you share a birthday with anyone else in class.
    - Use boards and markers in creative ways if you like.

Tangible



- Who are you? Why are you here? (boy, that was quick)
  - Introduce yourself to those around you and say hi!
  - Determine if you share a birthday with anyone else in class.
    - There is a 99.99997% chance that we have at least one pair.

Physics!

- Physics is a quantitative, predictive science of…
  - physical material and its motion through space and time
  - related abstract concepts such as energy and force
  - based on a fundamental belief in “rules” of objective reality

- Qualitative and predictive: numerical generality
  - Use mathematical models (we’ll use a little bit of calculus)
  - Test these models vs observation and experiment
    - “What happens if…?” becomes “Why does that happen?”

- Everything in physics is related to observations
  - These provide “data points” to test against vs models/intuition
  - In case of disagreement, either experiment or theory is wrong!
    - But reality is always right and does not care about your theory
  - Quantitative observations have **precision, accuracy, and units**

SI and Metric Units

- The modern, scientific and engineering form of the metric system
  - You should get in the habit of writing units for **all** physical quantities!

- Length: meter [m]
- Time: second [s]
- Mass: kilogram [kg]

We'll deal with these for most of the first semester

- *Electric current: ampere [A]*
- *Temperature: kelvin [K]*
- *Amount of a substance: mole [mol]*
- *Luminous intensity: candela [cd]*
- *Plane angle: radian [rad]*
- *Solid angle: steradian [sr]*

1 cm is about 2.54 inches
1 m is about 3.281 feet
1 km is about 0.6214 miles

$(100\text{ m})^2$ is about 2.471 acres

$(10\text{ cm})^3$ = 1 liter, about 0.264 gal

1 kg is about 2.205 lbs
1 g is about 0.0353 oz

1 year is about $\pi \times 10^7$ s
1 Hz is 1 s^{-1}

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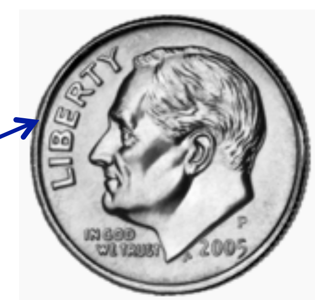
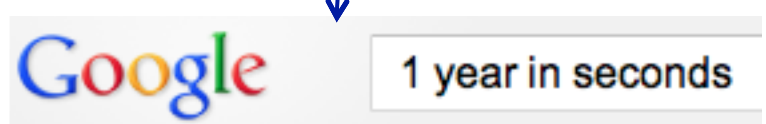




Converting Units

- Units matter! Measures of physical quantities must always have the correct units so we can compare them properly!

- Conversion tables or Google can be used to convert:
  - Example: What is the length of the Olympic 200 meter dash in feet?

$$(200\ \mathrm{m})\left(\frac{3.281\ \mathrm{feet}}{1\ \mathrm{m}}\right) = 656.2\ \mathrm{feet}$$

Multiplying by "1"

  - Example: What is 60 mph in feet/s? in m/s?

$$(60\ \mathrm{miles/hr})\left(\frac{5288\ \mathrm{feet}}{1\ \mathrm{mile}}\right)\left(\frac{1\ \mathrm{hr}}{3600\ \mathrm{s}}\right) = \left(\frac{5288}{60}\right)\ \mathrm{ft/s} = 88\ \mathrm{ft/s}$$

$$(60\ \mathrm{miles/hr})\left(\frac{5288\ \mathrm{feet}}{1\ \mathrm{mile}}\right)\left(\frac{1\ \mathrm{hr}}{3600\ \mathrm{s}}\right)\left(\frac{1\ \mathrm{m}}{3.281\ \mathrm{feet}}\right) = 27\ \mathrm{m/s}$$

  - Units are an excellent double-check to your physics calculations.

Significant Figures

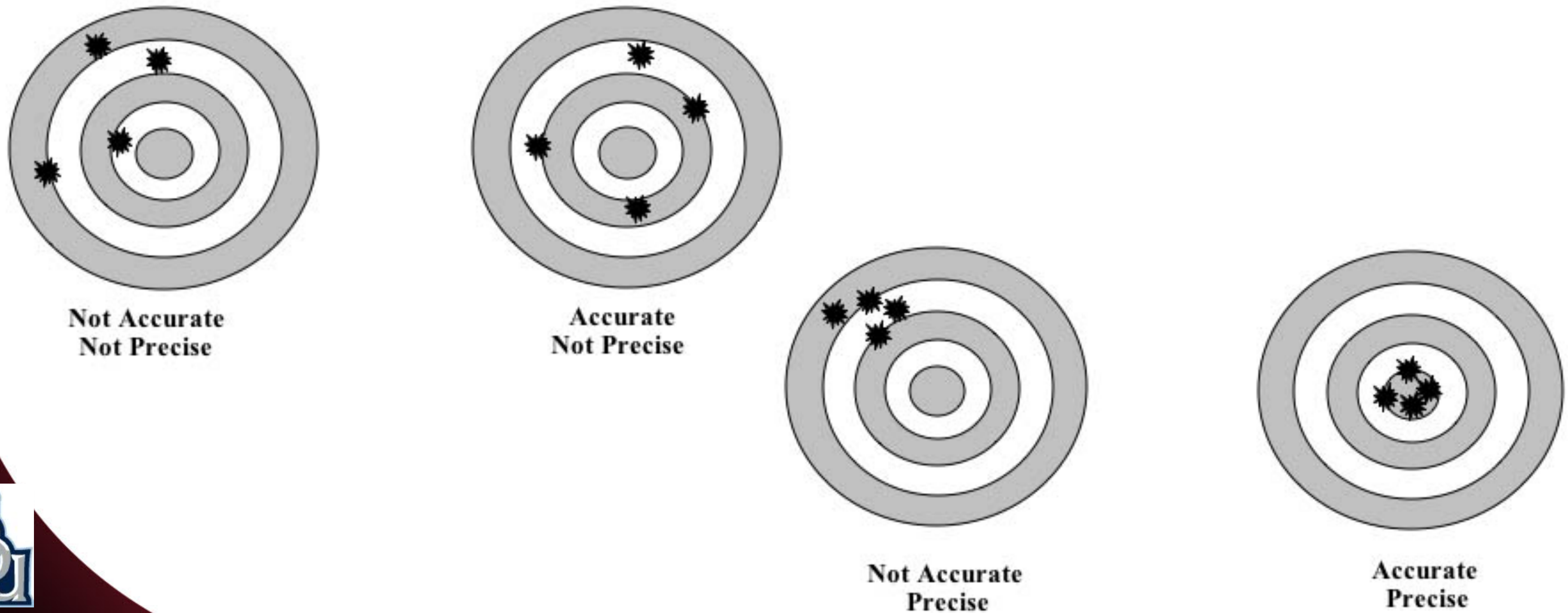
- The answer to the last example is 27 m/s, **not** 26.86 m/s or 26.8617 m/s or 2.68617×10^1 (units!) as a calculator might show.
  - That's because the given quantity, 60 mph, has only two **significant figures.**
  - That means we know that the actual value is closer to 60 mph than to 61 mph or 59 mph. (This matters when, say, you're speeding!)
  - If we had been given 60.00 mph, we would know that the value is closer to 60.00 mph than to 60.01 mph or 59.99 mph.
    - In that case, the number given has four significant figures.
  - Significant figures tell how precisely we know the values of physical quantities based on our observations (measurements).
    - Calculations can't increase that precision, so it's important to report the results of calculations with the correct number of significant figures.

Ponderable (10 minutes)

- Note that I was very careful with my language there!
  - Significant figures tell how **precisely** we know the values of physical quantities based on our observations (measurements).
    - Calculations can't increase that **precision**, so it's important to report the results of calculations based on measurements with the correct number of significant figures.
  - I intentionally did **not** use the words "accurately" and "accuracy"
- Ponderables (10 minutes)
  - Is there a difference between precision and accuracy?
  - Can a repeated measurement be precise without being accurate?
  - Can a repeated measurement be accurate without being precise?

Measurements: Precision and Accuracy

- All measurements (and experiments) have both precision and accuracy. These are independent descriptions of uncertainty (technically random and systematic uncertainty).
  - **Precision:** what is the smallest difference we can measure?
  - **Accuracy:** how close is the average of many measurements to the actual value?



Rules for Significant Figures

- In multiplication and division, the answer should have the same number of significant figures as the **least** accurate of the quantities entering the calculation.
  - Example: (3.1416 N)(2.1 m) = 6.6 N·m
    - Note the centered dot, often used when units are multiplied (though there are historical exceptions like kWh).

- In addition and subtraction, the answer should have the same number of digits to the right of the decimal point as the term in the sum or difference that has the smallest number of digits to the right of the decimal point.
  - Example: 3.2492 m – 3.241 m = 0.008 m
    - Note the loss of precision, with the answer having only one significant figure.
    - This includes explicit trailing zeros: 1.1×10^3 is **not** the same as 1.10×10^3!

Scientific Notation

- The vast range of quantities that occur in physics are best expressed with ordinary-sized numbers multiplied by powers of 10:
  - $31416.5 = 3.14165 \times 10^4$
  - $0.002718 = 2.718 \times 10^{-3}$

- SI prefixes describe powers of 10:
  - Every three powers of 10 gets a different prefix
  - Examples with units:
    - 1.21×10^9 W = 1.21 GW (1.21 gigawatts!)
    - 1.6×10^{-8} m = 16 nm (16 nanometers)
    - 10^{12} kg = 1 Pg (1 petagram)

Table 1.1 SI Prefixes

Prefix	Symbol	Power
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
—	—	10^{0}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

Rules for Scientific Notation

- You should be comfortable with rules of exponents when handling numbers with scientific notation
  - It's all just convenient bookkeeping for powers of 10

$$x \times 10^a + y \times 10^a = (x+y) \times 10^a$$

$$(x \times 10^a) \times (y \times 10^b) = (x \times y) \times 10^{(a+b)}$$

  - Example: How many miles are in a light-year?
  - Answer: Light travels about 3×10^8 m/s, and a light-year is the distance light travels in one year. So

$$1 \text{ light year} \approx (3 \times 10^8 \text{ m/s})(\pi \times 10^7 \text{ s}) \left(\frac{3.3 \text{ feet}}{\text{m}} \right) \approx \pi \times 10^{16} \text{ feet}$$

Google

1 light year = 3.1038479 × 10^{16} feet

More about calculator.

Quick Question

- Choose the sequence that correctly ranks the numbers according to the number of significant figures. (Rank from fewest to most.)

A. 0.041×10^{9}, 3.14×10^{7}, 2.998×10^{-9}, 0.0008.

B. 3.14×10^{7}, 0.041×10^{9}, 0.0008, 2.998×10^{-9}.

C. 2.998×10^{-9}, 0.041×10^{9}, 0.0008, 3.14×10^{7}.

D. 0.0008, 0.041×10^{9}, 3.14×10^{7}, 2.998×10^{-9}.

E. 0.0008, 0.041×10^{9}, 2.998×10^{-9}, 3.14×10^{7}.

Quick Question

- Choose the sequence that correctly ranks the numbers according to the number of significant figures. (Rank from fewest to most.)

A. 0.041×10^{9}, 3.14×10^{7}, 2.998×10^{-9}, 0.0008.	2,3,4,1 significant figures
B. 3.14×10^{7}, 0.041×10^{9}, 0.0008, 2.998×10^{-9}.	3,2,1,4 significant figures
C. 2.998×10^{-9}, 0.041×10^{9}, 0.0008, 3.14×10^{7}.	4,2,1,3 significant figures
D. 0.0008, 0.041×10^{9}, 3.14×10^{7}, 2.998×10^{-9}.	1,2,3,4 significant figures
E. 0.0008, 0.041×10^{9}, 2.998×10^{-9}, 3.14×10^{7}.	1,2,4,3 significant figures

Estimation

- You should often estimate an answer to a given problem
  - It can provide substantial insight into a problem or physical situation
  - It's a good "reality check" or "gut check" to compare to calculation
  - It's good mental exercise in rough calculation of various quantities
- Example: What's the United States' yearly gasoline consumption?
  - There are about 300 million people in the U.S., so perhaps about 100 million cars (10^8 cars).
  - A typical car goes about 10,000 miles per year (10^4 miles).
  - A typical car gets about 20 miles per gallon.
  - So in a year, a typical car uses (10^4 miles)/(20 miles/gallon) = 500 gal.
  - So the United States' yearly gasoline consumption is about (500 gal/car)(10^8 cars) = 5×10^{10} gallons.
    - That's about 20×10^{10} L or 200 GL.
    - That's also only about a factor of two too low from the actual number!

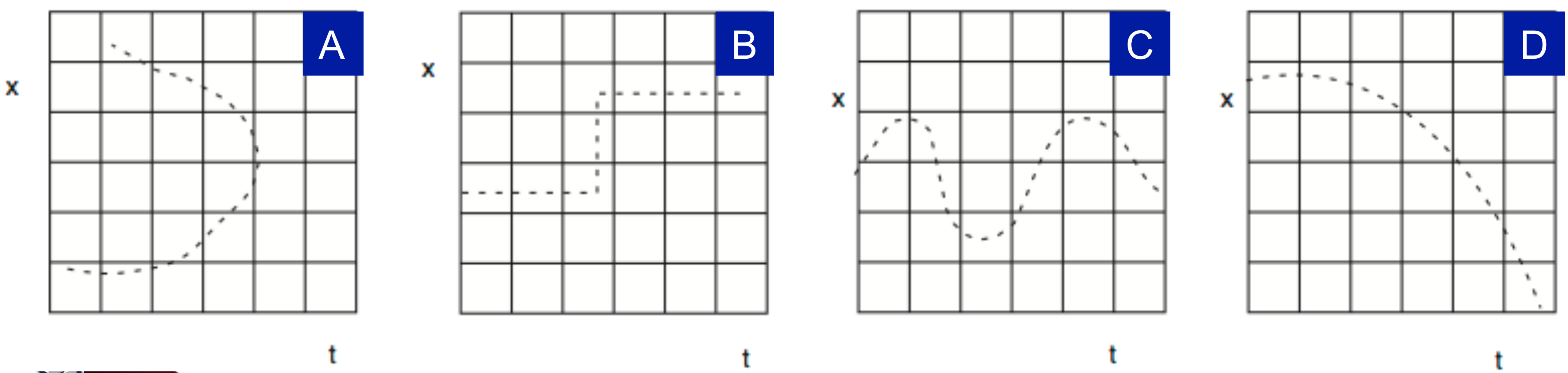
(Honors Estimation)

- These are extra problems if the honors students are feeling up to the challenge. I'll include at least one in every class.

- About how far away is the Earth's horizon…
  - For a 6' tall person standing at ground level?
  - For someone looking out the window of a plane flying at 30,000 feet?
  - Assume a spherical Earth, of course… ☺
  - (Hint: To within a few percent, each time zone of the Earth is about 1000 miles at the equator. We'll use this later in the semester.)

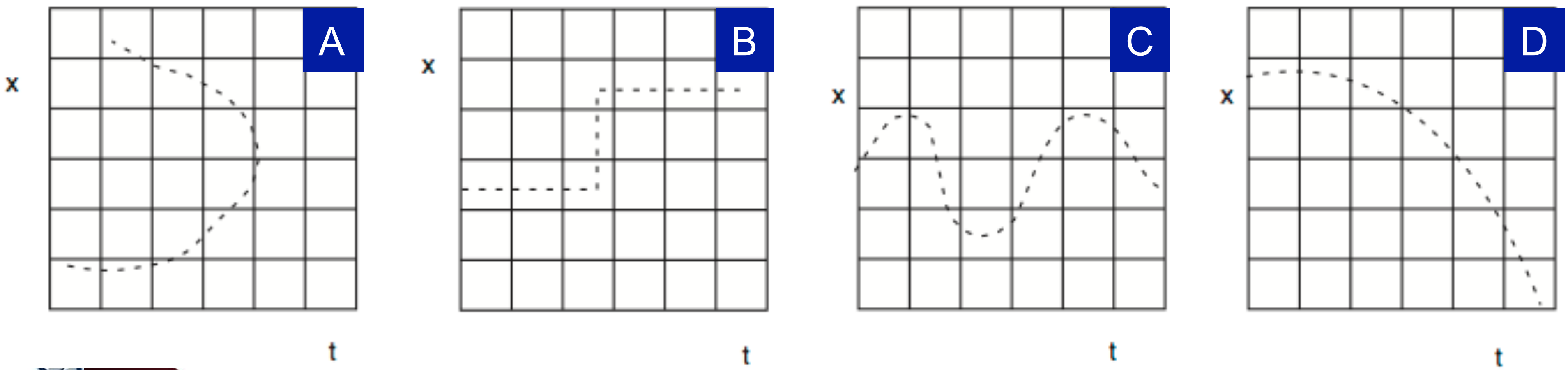
Ponderable: Graphs and Observation (10 minutes)

- Physics involves relating physical quantities together over ranges of their possible values
  - Graphs are an excellent way of visualizing relationships between numerical quantities
- Ponderables (10 minutes)
  - These plots depict an object's position x as a function of time t.
  - For each plot, describe the motion in words or explain why it is not a type of motion we see in normal everyday objects.



Ponderable: Graphs and Observation

- A: Normal objects are usually not in two places at once, and they usually have a well-defined position for all time.
- B: Normal objects usually don't suddenly jump from one location to another.
- C: Normal objects can oscillate in time, like a mass on a spring or a pendulum (we cover those later this semester)
- D: Normal objects can move parabolically (we cover that soon!)
  - I emphasize "normal" to avoid questions of quantum mechanics.
    - More on velocity (dx/dt) and acceleration (d^2x/dt^2) next class.



Ponderable (10 minutes)

- We will distribute boxes to the teams in class (one box per team)

- Ponderable (10 minutes)
  - Think of ways that you can measure how many objects are inside the box without opening the box.
    - The goal is to be right within a factor of 1 in 20.
  - Brainstorm your ideas on the white board and into your notebooks.
    - Don't worry much about cost; your job is to measure!
    - Do you think your best method is precise enough?
    - Do you think your best method is accurate enough?
    - Are there methods that are precise enough without being accurate enough?

Estimation (5 minutes)

- Estimation (5 minutes)
  - Estimate how many objects are in your team's box without opening it.
  - You can take a survey amongst yourselves, take measurements (shake it, balance it, look it up on the internet).
  - Write your answers down on your board. How uncertain are you?

Estimation

- Estimation (5 minutes)
  - Estimate how many objects are in your team's box without opening it.
  - You can take a survey amongst yourselves, take measurements (shake it, balance it, look it up on the internet).
  - Write your answers down on your board. How uncertain are you?

- Now you can open your box and share the contents with your new friends in your group (and at other tables if they're nice).
  - I've got extra baggies up front.
  - How close was your estimate?
  - I'll have a bigger jar at the end of the semester…

Tangible (up to 30 minutes)

- It's time for a little survey… (30 minutes)
- This survey is NOT part of your grade but it is important.
- Please use a #2 pencil and do not write on the survey paper.
- Please answer to the best of your ability. To repeat, this survey is NOT part of your grade, but it does help me get a feeling for how fast or slow to go for the semester.
  - It's in your best interest to think about your answers so that I can get an *accurate* idea of how best work with you so you can get the most out of class without feeling overburdened or overwhelmed or bored.

- You're free to go when you're done with the survey.
- I look forward to an interesting (and perhaps even fun) semester together!

=========== Extra Slides ===========

Operational Definitions

- Of the three most basic units— length, time, and mass — two are defined operationally, so their definitions can be implemented in any laboratory.
- The meanings of both these definitions will become clearer as you advance in your study of physics:
  - The **meter** is the length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second.
  - The **second** is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium-133 atom.
- The standard of mass is less satisfactory:
  - The **kilogram** is defined by the international prototype kilogram kept at the International Bureau of Weights and Measures at Sèvres, France.