Physics 1501

Fall 2008

Mechanics, Thermodynamics, Waves, Fluids

Lecture 1: the SI unit system; significant figures; estimations

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- **Course components:**
  - Lectures
  - Homework
  - Tests: three midterms and a **cumulative** final.
  - Labs

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How to do well in the course ?

- FINAL GRADE WILL BE MADE OF:
  - 3 Midterms 30%
  - Final Exam 30%
  - Homework 20%
  - Labs 20%
- **Remember:**

If you miss more then one LAB => incomplete

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Announcements

- Most of the info about the class will be posted on:
  - **http://www.phys.uconn.edu/phys1501/**
    - Lecture notes
    - Sample exams and solutions
    - Syllabus
    - Academic Calendar
- **Labs** start in the third week of classes (week starting Monday, Sep 8)
- **Lab website**: http://www.phys.uconn.edu/labs/

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Handouts & Homework

- Handouts – download prior to the class
- Homework – www.webassign.net

username: initial part of your huskymail address, before '@' sign. E.g. email Isaac.Newton@uconn.edu -> username isaac.newton (case insensitive)
institution: uconn
password: 7-digit peoplesoft ID, or existing password if any

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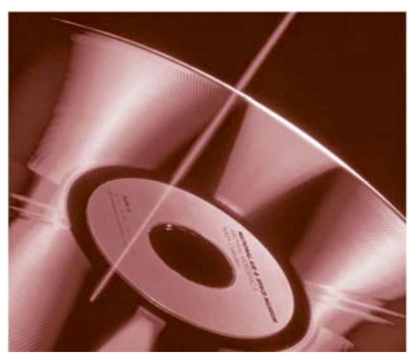
In this lecture:

- The SI unit system
- How to express and manipulate numbers in physics calculations
  - Scientific notation
  - Accuracy and significant figures
  - Making quick estimates



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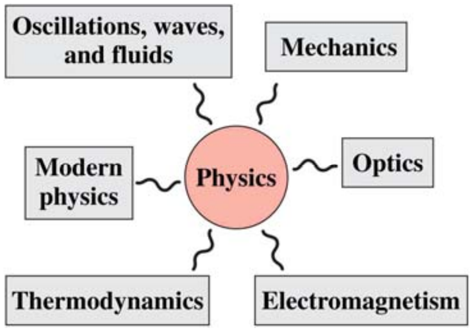
Realms of physics

- Physics provides a unified description of basic principles that govern physical reality.
- It's convenient to divide physics into a number of different but related realms.
  - Here we consider six distinct realms:



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The SI unit system

- Provides precise definitions of seven fundamental physical quantities
  - **Length**: the meter
  - **Time**: the second
  - **Mass**: the kilogram
  - **Electric current**: the ampere
  - **Temperature**: the kelvin
  - Amount of a substance: the mole
  - Luminous intensity: the candela
- Supplementary units describe angles
  - **Plane angle**: the radian
  - Solid angle: the steradian

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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.

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Scientific notation

- The vast range of quantities that occur in physics are best expressed with ordinary-sized numbers multiplied by powers of 10:
  - $31416.5 = 3.14165\times10^{4}$
  - $0.002718 = 2.718\times10^{-3}$
- SI prefixes describe powers of 10:
  - Every three powers of 10 gets a different prefix.
  - Examples:
    - 3.0×10^{9} W = 3.0 GW (3 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}

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Converting units

- Units matter! Measures of physical quantities must always have the correct units.
- Conversion tables (Appendix C of the textbook) give relations between physical quantities in different unit systems:
  - Convert units by multiplying or dividing so that the units you don't want cancel, leaving only the units you do want.
  - Example: Since 1 ft = 0.3048 m, a 5280-foot race (1 mile) is equal to

$$\left(5280 \text{ ft}\right)\frac{0.3048 \text{ m}}{1 \text{ ft}} = 1609 \text{ m}$$

  - Example: 1 kilowatt-hour (kWh, a unit of energy) is equivalent to 3.6 megajoules (MJ, another energy unit). Therefore a monthly electric consumption of 343 kWh amounts to

$$\left(343 \text{ kWh}\right)\frac{3.6 \text{ MJ}}{1 \text{ kWh}} = 1.23\times10^{3} \text{ MJ} = 1.23 \text{ GJ}$$

Significant figures

- The answer to the last example in the preceding slide is 1.23 GJ—not 1234.8 MJ or 1.2348 GJ as your calculator would show.
  - That's because the given quantity, 343 kWh, has only three **significant figures.**
  - That means we know that the actual value is closer to 343 kWh than to 342 kWh or 344 kWh.
  - If we had been given 343.2 kWh, we would know that the value is closer to 343.2 kWh than to 343.1 kWh or 343.3 kWh.
    - In that case, the number given has four significant figures.
  - Significant figures tell how accurately we know the values of physical quantities.
    - Calculations can't increase that accuracy, so it's important to report the results of calculations with the correct number of significant figures.

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, normally used when units are multiplied (the kWh is an exception).
- 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 = 0.008 m
    - Note the loss of accuracy, with the answer having only one significant figure.

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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}

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Estimation

- It's often sufficient to estimate the answer to a physical calculation, giving the result to within an order of magnitude or perhaps one significant figure.
- Estimation can provide substantial insight into a problem or physical situation.
- 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.

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A strategy for problem solving

- The IDEA strategy consists of four broad steps.
- IDEA is not a "cookbook" but rather a general framework to organizing your path to the solution of a problem.
- The four IDEA steps are
    - INTERPRET
    - DEVELOP
    - EVALUATE
    - ASSESS

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INTERPRET

INTERPRET You can't begin a problem unless you're sure what it's about. So the first step is to *interpret* the problem to be sure you know what it's asking. Then *identify* the applicable concepts and principles—Newton's laws of motion, the conservation of energy principle, the first law of thermodynamics, Gauss's law for electricity, and so forth. Also *identify* the players in the situation—the object whose motion you're asked to describe, the forces acting on an object, the thermodynamic system whose heat flow you're going to determine, the charges that produce an electric field, the components in an electric circuit whose power consumption you're after, the light rays that will help you locate an image, and so on.

DEVELOP

DEVELOP The second step is to *develop* a plan for solving the problem. As part of this step, it's always helpful and often essential to *draw* a diagram showing the essential aspects of the situation. Your drawing should indicate objects, forces, and other physical entities. Labeling masses, positions, forces, velocities, heat flows, electric or magnetic fields, and other quantities will be a big help. Next, *determine* the relevant mathematical formulas—namely, those that contain the quantities you're given in the problem as well as the unknown(s) you're solving for. Don't just grab equations—rather, think about how each reflects the underlying concepts and principles that you've identified as applying to this problem. The plan you develop might include calculating intermediate quantities, finding values in a table or in one of this text's several appendices, or even solving a preliminary problem whose answer you need to get your final result.

EVALUATE

EVALUATE Physics problems have numerical or symbolic answers, and you need to *evaluate* your answer. In this step you *execute* your plan, going in sequence through the steps you've outlined. Here's where your math skills come in. Use algebra, trig, or calculus, as needed, to solve your equations. It's a good idea to keep all numerical quantities, whether known or not, in symbolic form as you work through the solution of your problem. At the end you can plug in numbers and work the arithmetic to *evaluate* the numerical answer, if the problem calls for one.

ASSESS

ASSESS Don't be satisfied with your answer until you *ask* whether it makes sense! Are the units correct? Do the numbers sound reasonable? Does the algebraic form of your answer work in obvious special cases, like perhaps "turning off" gravity or making an object's mass zero or infinite? Checking special cases not only helps you decide whether your answer makes sense but can also give you insights into the underlying physics. In worked examples, we'll often use this step to enhance your knowledge of physics by relating the example to other applications of physics.

Summary

- Together, the different realms of physics provide a unified description of basic principles that govern physical reality.
- The SI unit system provides precise definitions of fundamental physical quantities.
  - Those with operational definitions can be reproduced anywhere.
- Handling the numbers that represent physical quantities involves
  - Using scientific notation and SI prefixes
  - Understanding significant figures
  - Estimation

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