The Nature of Science

Chapter 1

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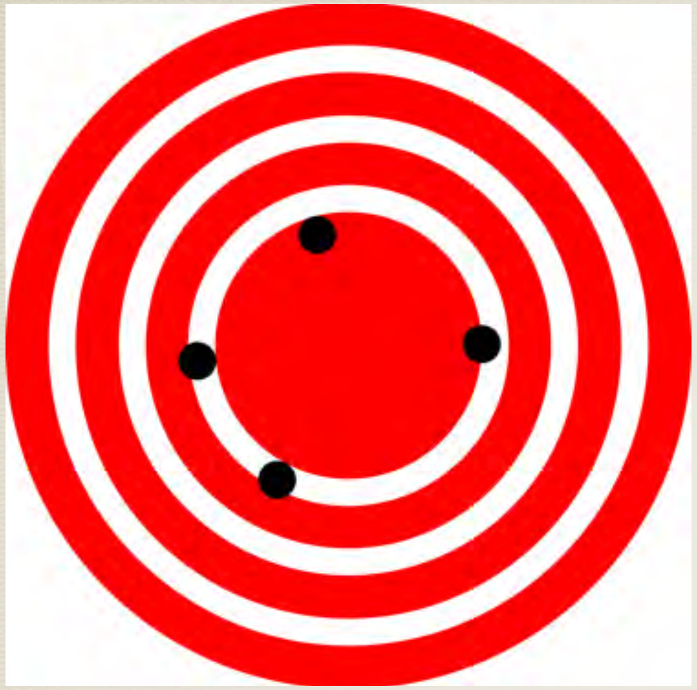
What is Science?

* Physics is not just a science but the ideal of what a science should be.
* A science is a field where the scientific method is used to determine truth. The scientific methods is:
  * Observation
  * Experiment and Measurement
  * Formulation of a Theory or Model
  * Testing and Refinement
* In physics your theory needs to also be writable as a mathematical expression.

Accuracy and Precision



Accuracy is how close a measurement is to the expected value. Precision is how close different measurements are to one another. Uncertainty is a quantitative measure of how far measurements are from the expected value.

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Uncertainty

* Measurement is essential to all sciences for without accurate measurement you can never prove or disprove a theory. That is one of the reason you have a laboratory section associated with this lecture.

* No measurement can be perfect. A measurement always differs from the actual value of some quantity. We can see this because if some measurement is done over and over again you won't always get the same answer. This is called measurement error.

* More generally, the fact that the measurement has a certain limit to its accuracy means there is always some uncertainty to the value measured.

* Thus understanding the uncertainty of a measurement is crucial to testing a scientific theory.

Significant Figures

* One way to be mindful of the limited accuracy of measurement is to pay attention to significant figures.

* Significant figures refers to how many digits to keep in a calculation and the guiding principle is that your answer shouldn't become more accurate because you perform some math operation.

$$4 \div 3 = 1.3333333$$

Is what you get on your calculator, but notice that the 4 and 3 you only had one digit accuracy and now after the division you know the answer to a ten millionth. That seems wrong.

$110 + 0.0037 = 110.0037$ same in this case

Basically significant figures just comes down to not increasing the accuracy of your results when you do math. Round off the answer so that it has the same accuracy as when you started.

$4 \div 3 = 1.3$ $110 + 0.0037 = 110$

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Units

* As mentioned earlier, when talking about the real world a number must either refer to a number of things, or it must have a unit associated with it.

* If you do not have a unit with your number and it needs one then your answer is wrong.

* Since we will be using units all the time, we will abbreviate them so we don't have to write as much. Thus meters will just be m and seconds just s.

* Make sure you know what the abbreviation stands for. Don't just write a letter if you don't know what it means.

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The Metric System

* We will always use the metric system for our units.
* This is because the metric system is a really good system that makes sense. The American system is terrible, so terrible that the English who we got it from use the metric system and not the English system.
* The basis of the metric system is that there is one fundamental unit for any kind of measurement and then you just make it bigger or smaller by adding something in front.
* For example meters gives you centimeters, kilometers, nanometers, pico-meters, giga-meters, etc.

The Fundamental Units

* Most units can be derived from other units. There are only a few fundamental units that have to be defined by some physical means.

* Time - is measured in seconds. The second used to be defined as 1/86,400 of a solar day. But since the length of the day is getting longer, this is not truly a constant. In 1967 the definition was changed to be 9,192,631,770 vibrations of a Cesium atom which can be made to vibrate in a very steady way.

* Length - is measured in meters. The meter was first defined as 1/10,000,000 the distance from the equator to the North Pole. In 1889 this was changed to the distance between two lines on a platinum-iridium bar kept near Paris. In 1960 this was changed to 1,650,763.73 wavelengths of orange light emitted by Krypton atoms. In 1983, this was changed to the distance light travels in 1/299,792,458 of a second. So actually length is not a fundamental unit anymore.

* Mass - is measured in kilograms. The kilogram is defined by a platinum-iridium cylinder kept near Paris which has exact copies kept in the U.S. and other countries.

* Charge - Next semester you will learn about the fundamental unit of electric charge, the Ampere

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Table 1.2 Metric Prefixes for Powers of 10 and their Symbols

Prefix	Symbol	Value[1]	Example (some are approximate)			
exa	E	10^{18}	exameter	Em	10^{18} m	distance light travels in a century
peta	P	10^{15}	petasecond	Ps	10^{15} s	30 million years
tera	T	10^{12}	terawatt	TW	10^{12} W	powerful laser output
giga	G	10^{9}	gigahertz	GHz	10^{9} Hz	a microwave frequency
mega	M	10^{6}	megacurie	MCi	10^{6} Ci	high radioactivity
kilo	k	10^{3}	kilometer	km	10^{3} m	about 6/10 mile
hecto	h	10^{2}	hectoliter	hL	10^{2} L	26 gallons
deka	da	10^{1}	dekagram	dag	10^{1} g	teaspoon of butter
—	—	10^{0} (=1)				
deci	d	10^{-1}	deciliter	dL	10^{-1} L	less than half a soda
centi	c	10^{-2}	centimeter	cm	10^{-2} m	fingertip thickness
milli	m	10^{-3}	millimeter	mm	10^{-3} m	flea at its shoulders
micro	µ	10^{-6}	micrometer	µm	10^{-6} m	detail in microscope
nano	n	10^{-9}	nanogram	ng	10^{-9} g	small speck of dust
pico	p	10^{-12}	picofarad	pF	10^{-12} F	small capacitor in radio
femto	f	10^{-15}	femtometer	fm	10^{-15} m	size of a proton
atto	a	10^{-18}	attosecond	as	10^{-18} s	time light crosses an atom

Notice that the metric system is just scientific notation with words.

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SI or MKS units

* The standard unit of measurement is physics is called the MKS, or meter, kilogram, second system.
    * Length - the basic unit of length is the meter.
    * Mass - the basic unit of mass is the kilogram.
    * Time - the basic unit of time is the second.
* From these basic units all other more complicated units are derived. There are other systems of basic units, like CGS. When you change the basic units you get different names for derived units.
* For example in MKS the unit of energy is the Joule, but in CGS the unit of energy is the erg.

Unit Conversion

* To convert units just multiply by a conversion factor which should have a value of one. That is the numerator and denominator of the conversion factor should be equal to each other.

* Units should cancel out to give the units you want. Remember each power of a unit must be converted.

$$80\text{m} \quad \frac{1\text{km}}{1000\text{m}} = 0.080\ \text{km}$$

$$30\text{cm}^2 \quad \frac{(1\text{m})(1\text{m})}{(100\text{cm})(100\text{cm})} = 0.0030\ \text{m}^2$$

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Example 1.1: A Short Drive Home

* Suppose that you drive the 10.0 km from your university to home in 20.0 min. Calculate your average speed (a) in kilometers per hour (km/h) and (b) in meters per second (m/s). (Note: Average speed is distance traveled divided by time of travel.)

* First we calculate the average speed using the given units. Then we can get the average speed into the desired units by picking the correct conversion factor and multiplying by it. The correct conversion factor is the one that cancels the unwanted unit and leaves the desired unit in its place.

* (1) Calculate average speed. Average speed is distance traveled divided by time of travel. (Take this definition as a given for now—average speed and other motion concepts will be covered in a later module.) In equation form,

$$average\ speed = \frac{distance}{time}$$

* (2) Substitute the given values for distance and time.

$$average\ speed = \frac{10.0\,km}{20.0\,min} = 0.500\frac{km}{min}$$

* (3) Convert km/min to km/h: multiply by the conversion factor that will cancel minutes and leave hours. That conversion factor is 60 min/hr . Thus,

$$average\ speed = 0.500\frac{km}{min} \times \frac{60min}{hr} = 30km/h$$

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Estimation

* It is very useful in physics (and in the rest of you life) to be able to estimate calculations.

* Often the estimate is enough to figure out there is no need to be more precise.

* In class, the importance of estimation is that you want to estimate what answer you get for a problem so that if you get a very different answer when you work it out in detail, you can see that you made a mistake.

When you work out a problem the answer you get is wrong!

* Estimate $987{,}654 \times 48.65 \quad \backsimeq 50{,}000{,}000$

$$1{,}000{,}000 \times 50 = 50{,}000{,}000$$

now this actually equals 48,049,367.1

* Estimate $(14{,}870-942)/6.85 \quad \backsimeq 2{,}000$

$$14{,}000/7 = 2{,}000$$

correct answer is 2,033.284672

Estimation

* What is the volume of a bath tub?
* How many people can a subway train carry?
* What is the total mass of people on the Earth?

Dimensional Analysis

* Because physics is a science the units correspond to real things. There may be many different units but there is one physical thing that they are measuring.

* For example, seconds, hours, years, microseconds and Giga-years all measure time.

* We can use this to see if the units in a formula make any sense. This is called dimensional analysis even though unit analysis would make more sense.

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Dimensional Analysis

Pay = Pay Rate × Time

What could be units of time? How about units of Pay?
Then what must be the units of Pay Rate?

Mass = Length × Time

If I gave you the above equation could it be correct?
How about these?

$\text{Mass} = A \times \text{Length} \times \text{Time}$ $\qquad$ $\text{Mass} = A \times \text{Mass}_1 + B \times \text{Mass}_2$

You can only add or subtract terms that have the same units

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Homework

* Chapter 1 - 27,31,40,60,64,81