BRIEF COURSE INTRODUCTION
Full course information, schedule, exam policy etc is at:
http://www.pa.msu.edu/courses/2005fall/PHY231/
Some things to note immediately:
- Weekly LON-CAPA homeworks are due Tuesdays at 11pm.
The first homework is due Tuesday September 6.
Your MSU account should give you access to LON-CAPA
- REGISTER YOUR CLICKER using LON-CAPA
- Get to know the exam formula sheet

OUTLINE - Mechanics, Thermal physics and Waves
Mechanics
Introduction to physics, units, scales and accuracy (1 lecture - Chapter 1)
Motion in one dimension (2 lectures - Chapter 2)
Motion in two dimensions (3 lectures - Chapter 3)
Newton's laws of motion (3 lectures - Chapter 4)
- *First Midterm*
Work, energy and power (3 lectures - Chapter 5)
Momentum, collisions (2 lectures - Chapter 6.1-3)
Rotational motion and gravity (3 lectures - Chapter 7)
Forces and rotational motion (2 lectures - Chapter 8.1-5
Energy and momentum in rotational motion (1 lecture - Chapter 8.1-8.7)
- *Second Midterm*
Thermal Physics
Solids and fluids (3 lectures - Chapter 9)
Thermal physics (2 lectures - Chapter 10)
Energy in thermal processes (3 lectures - Chapter 11,12.1)
Laws of thermodynamics (1 lecture - Chapter 12.2-3)
- *Third Midterm*
Laws of thermodynamics (1 lecture - Chapter 12.4-5)
Waves
Vibrations and waves (3 lectures - Chapter 13)
Sound and sound waves (3 lectures - Chapter 14)
- *Final*

Lecture 1 - Units, Accuracy and Estimates

UNITS, DIMENSIONAL ANALYSIS

Units

The base SI (système internationale) units used in mechanics are: meter (m), kilogram (kg), second (s). This set of units is also called the mks system. Two other systems in common use are the cgs (centimeter, gram, second) and the US system (foot, pound, second).

Besides the mks units used in mechanics, there are four other SI base units, which we will use later in the course, and for completeness it is worth noting them now: ampere (A), Kelvin (K), mole (mol), candela (cd).

Dimensional analysis

When using equations all terms which are added or subtracted in the equation must have the same units. Testing whether this is true is called *dimensional analysis* and is essential to any correct equation. To illustrate dimensional analysis consider the following quantities which describe motion in one dimension:

time, t - $[t] = T$
position x or displacement Δx - units $[x] = [\Delta x] = L$
speed or velocity v - units $[v] = L/T$
acceleration a - units $[a] = L/T^2$

Now consider a dimensional analysis of the following equations, if

$$\Delta t = v_0 + 2a\Delta x; \text{ then } T = \frac{L}{T} + \frac{L}{T^2}L \quad (INCORRECT\ EQUATION) \tag{1}$$

and if,

$$v^2 = v_0^2 + 2a\Delta x; \text{ then } (\frac{L}{T})^2 = (\frac{L}{T})^2 + \frac{L}{T^2}L \tag{2}$$

Equation (1) is dimensionally incorrect so it cannot be a valid law of physics. Equation (2) is dimensionally correct so it may be a valid law of physics. In many simple problems the simplest combination of the variables which is dimensionally correct is actually the correct answer. It is a very good problem solving strategy to try this if you have no better ideas! If you write down or use equations that are dimensionally incorrect on the other hand, examiners tend to be rather hard on you.

Changing units

Given the fact that $1meter = 3.281feet$ and $1mile = 5280feet$, convert $50miles/hour$ to $meters/second$

$$50miles/hour = 50\frac{5280ft}{3600s}\frac{1m}{3.281ft} = 22m/s \tag{3}$$

ACCURACY

It is really important to know how accurate numbers are. Yet in everyday life the accuracy of statistical results are often incorrect or in many cases not quoted at all. We will not get into the details of putting the correct error bars on measurements, though you will do this in the PHY251 laboratory. However we also need to know how to calculate the accuracy when we combine results in equations. For example if we have an equation like $v = v_0 + at$, and we have known accuracy in v_0, a and t, what is the accuracy of v? You need to know two different ways of treating the accuracy of a number:

The number of significant figures

Some examples:
0.0012 has two significant figures
1.2×10^{-3} has two significant figures
15000 has five significant figures
1.5×10^{4} has two significant figures
1.5000×10^{4} has five significant figures

Rule for multiplication and division

When dividing or multiplying two quantities A, B, the result has its number of significant figures equal to the *smallest number of significant figures* of the two quantities A, B.

In our example $v = v_0 + at$, the product at yields a value with its number of significant figures equal to the smallest number of significant figures of the two quantities a and t.

The number of decimal places

Some examples:
0.0012 has four decimal places
1.2×10^{-3} has four decimal places
15000 has no decimal places

1.5×10^4 has no decimal places
1.5000×10^4 has no decimal places

Rule for addition and subtraction

When adding or subtracting two quantities A, B, the result has its number of decimal places equal to the *smallest number of decimal places* of the two quantities A, B.

In our example $v = v_0 + at$, the product at yields a value with a number of decimal places. The result v has its number of decimal places equal to the smallest of the number of decimal places of the quantity v_0 and the quantity at.

Numerical example Consider $v_0 = 1.25 m/s$, $a = 9.8 m/s^2$, $t = 0.1 s$. The product $at = 1 m/s$ (one significant figure). The sum $v = v_0 + at = 2 m/s$ (no decimal places)

SCIENTIFIC NOTATION AND ABBREVIATIONS

In science and technology there is an enormous range of values for many of the quantities of interest. For example the power used by a bacteria to swim is about $0.00000000000000001 watts$, while the power produced by a nuclear power plant is about $1,000,000,000 watts$. It is clumsy to write all of these zeros so instead we introduce different notation. Though the terms million and billion are used most frequently in the news, they are not typical in science. One reason is that the billion has a different meaning in the US compare to in Europe. Instead we use scientific notation and abbreviations, which are universaly accepted.

Scientific notation

Examples (keeping the full number of significant figures)

$0.012 = 1.2 \times 10^{-2}$
$0.000,000,000,000,000,01 watts = 10^{-17} W$
$1,000.000 = 1.000000 \times 10^3$

Abbreviations

tera (T) $= 10^{12}$, giga (G) $= 10^9$, mega (M) $= 10^6$, kilo (k) $= 10^3$,
milli(m) $= 10^{-3}$, micro (μ) $= 10^{-6}$, nano (n) $= 10^{-9}$ pico(p) $= 10^{-12}$,
femto (f) $= 10^{-15}$

Examples

$0.012W = 1.2 \times 10^{-2}W = 12mW$

$0.000,000,000,000,000,01watts = 1 \times 10^{-17}W = 0.01fW$

$1,000.000 = 1.000000 \times 10^3 = 1.000000kW$

$1,000,000,000watts = 1GW$ (ignoring the implied 10 significant figures)

ORDER OF MAGNITUDE ESTIMATES

Find the order of magnitude of the gravitational force of attraction between two students at opposite ends of the lecture hall.

$$F = \frac{GMm}{r^2}; \quad G = 6.67 \times 10^{-11}\frac{Nm^2}{kg^2} \tag{4}$$

this leads to the estimate

$$F \approx \frac{6.67 \times 10^{-11}\frac{Nm^2}{kg^2}100kg100kg}{(30m)^2} \approx 10^{-10}N \tag{5}$$

Is this a big force? For comparison, the force of gravity on each of the two students is $mg \approx 9.8m/s^2 \times 100kg \approx 1000N$. Note that though this is small, gravitational detectors are sensitive enough to notice it. Gravitational detection is used for mining exploration, particularly in the search for heavy metals such as gold. It is important to be able to estimate so that you can quickly determine whether a hypothesis is likely to be true. For example is it likely that the electric field from power lines affects human health? An analogous question would be: Does living near a large gold repository (eg. fort Knox) affect human health?