Notes for Module – I

A) THE SCIENTIFIC METHOD

1. Physics is a science. Science works according to the *scientific method*. The *scientific method* accepts only reason, logic, and experimental evidence to tell between what is scientifically correct and what is not. Scientists do not simply believe – they test, and keep testing until satisfied. Just because some "big scientist" says something is right, that thing does not become a fact of science. Unless a discovery is repeatedly established in different laboratories at different times by different people, or the same theoretical result is derived by clear use of established rules, we do not accept it as a scientific discovery. The real strength of science lies in the fact that it continually keeps challenging itself.

2. It is assumed that the laws of physics do not change from place to place. This is consistent with why experiments carried out in different countries by different scientists – of any religion or race – have always led to the same results. The condition is that the experiments have been done honestly and correctly. In science all big lies ultimately get caught. Small lies may not but they don't matter.

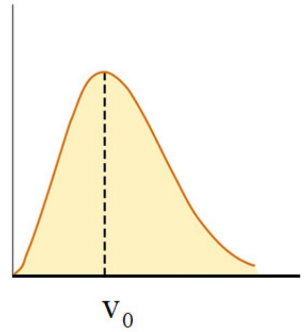
3. We also assume that the laws of physics today are the same as they were in the past. This has been checked and will be checked for the next thousand years and beyond. Evidence contained in the light that left distant stars billions of years ago strongly indicates that the laws operating at that time were no different than those today. The spectra of elements (H, He, O, C, etc.) then and now are impossible to tell apart, even though physicists have looked very carefully for differences.

B) ORDERS OF MAGNITUDE

1. A good scientist first thinks of the larger picture and then of the finer details. So, estimating *orders of magnitude* is extremely important. Students often make the mistake of trying to get the decimal points right instead of the first digit – which obviously matters the most! So if you are asked to calculate the height of some building using some data and you come up with 0.301219 metres or 4.01219×10^6 metres, then the answer is plain nonsense even though you may have miraculously got the last six digits right. Physics is commonsense first, so use your intelligence before submitting any answer.

2. Whenever you derive an equation that is a little complicated, see if you can find a special limit where it becomes simple and transparent. So, sometimes it is helpful to imagine that some quantity in it is very large or very small. Where possible, make a "mental graph" so that you can picture an equation. So, for example, a

formula for the distribution of molecular speeds in a gas could look like $f(\text{v}) = \text{v}e^{-(\text{v}-\text{v}_0)^2/a^2}$. Even without knowing the value of a you can immediately see that
a) $f(\text{v})$ goes to zero for large values of v, and $\text{v} = 0$.
b) The maximum value of $f(\text{v})$ occurs at v_0 and the function decreases on both side of this value.



C) DIMENSIONAL ANALYSIS

1. Every physical quantity can be expressed in terms of three fundamental dimensions: Mass (M), Length (L), Time (T). Some examples:

Speed	LT^{-1}
Acceleration	LT^{-2}
Force	MLT^{-2}
Energy	ML^2T^{-2}
Pressure	$ML^{-1}T^{-2}$

You can only add quantities that have the same dimensions. So force can be added to force, but force can never be added to energy, etc. A formula is definitely wrong if the dimensions on the left and right sides of the equal sign are not the same. This is a very useful check.

4. Remember that any function $f(x)$ takes as input a dimensionless *number* x and outputs a quantity f (which may or may not have a dimension). Take, for example, the function $f(\theta) = \sin\theta$. You know the expansion: $\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \cdots$ If θ had a dimension then you would be adding up quantities of different dimensions, and that is not allowed.

5. Do not confuse units and dimensions. We can use different units to measure the same physical quantity. So, for example, you can measure the mass in units of kilograms, pounds, or even in سیر and چھٹاک .In this course we shall always use the **MKS** or **M**etre-**K**ilogram-**S**econd system. When you want to convert from one system to another, be methodical as in the example below:

$$1\frac{mi}{hr} = 1\frac{mi}{hr} \times 5280\frac{ft}{mi} \times \frac{1}{3.28}\frac{m}{ft} \times \frac{1}{3600}\frac{hr}{s} = 0.447\frac{m}{s}$$

When you write it out in this manner, note that various quantities cancel out cleanly in the numerator and denominator. So you never make a mistake!

6. Always check your equations to see if they have the same dimensions on the left side as on the right. So, for example, from this principle we can see the equation

$v^2 = u^2 + 2at$ is clearly wrong, whereas $v^2 = u^2 + 13a^2t^2$ could possibly be a correct relation. (Here v and *u* are velocities, *a* is acceleration, and *t* is time.) Note here that I use the word *possibly* because the dimensions on both sides match up in this case.