Summary of Lecture 4 – FORCE AND NEWTON'S LAWS

1. Ancient view: objects tend to stop if they are in motion; force is required to keep something moving. This was a natural thing to believe in because we see objects stop moving after some time; frictionless motion is possible to see only in rather special circumstances.

2. Modern view: objects tend to remain in their initial state; force is required to *change* motion. Resistance to changes in motion is called *inertia*. More inertia means it is harder to make a body accelerate or decelerate.

3. Newton's First Law: An object will remain at rest or move with constant velocity unless acted upon by a net external force. (A non-accelerating reference frame is called an <u>inertial</u> frame; Newton's First Law holds only in inertial frames.)
4. More force leads to more acceleration: $\Rightarrow \quad a \propto F$

5. The greater the mass of a body, the harder it is to change its state of motion. More mass means more inertia. In other words, more mass leads to less acceleration:

$$\Rightarrow \quad a \propto \frac{1}{m}$$

   Combine both the above observations to conclude that:

$$a \propto \frac{F}{m}$$

6. Newton's Second Law: $a = \dfrac{F}{m}$ (or, if you prefer, write as $F = ma$).

7. $F = ma$ is one relation between three independent quantities (m, a, F). For it to be useful, we must have separate ways of measuring mass, acceleration, and force. Acceleration is measured from observing the rate of change of velocity; mass is a measure of the amount of matter in a body (e.g. two identical cars have twice the mass of a single one). Forces (due to gravity, a stretched spring, repulsion of two like charges, etc) will be discussed later.

8. Force has dimensions of $[\text{mass}] \times [\text{acceleration}] = M\,L\,T^{-2}$. In the MKS system the unit of force is the Newton. It has the symbol N where:
   1 Newton = 1 kilogram.metre/second^2.

9. Forces can be internal or external. For example the mutual attraction of atoms within a block of wood are called internal forces. Something pushing the wood

is an external force. In the application of $F = ma$, remember that F stands for the total external force upon the body.

10. Forces are vectors, and so they must be added vectorially:

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$$

This means that the components in the $\hat{x}$ direction must be added separately, those in the $\hat{y}$ direction separately, etc.

11. Gravity acts directly on the mass of a body - this is a very important experimental observation due to Newton and does not follow from $F = ma$. So a body of mass m_1 experiences a force $F_1 = m_1 g$ while a body of mass m_2 experiences a force $F_2 = m_2 g$, where g is the acceleration with which any body (big or small) falls under the influence of gravity. (Galileo had established this important fact when he dropped different masses from the famous leaning tower of Pisa!)

12. The weight of a body W is the force which gravity exerts upon it, $W = mg$. Mass and weight are two completely different quantities. So, for example, if you used a spring balance to weigh a kilo of grapes on earth, the same grapes would weigh only 1/7 kilo on the moon.

13. Newton's Third Law: for every action there is an equal and opposite reaction. More precisely, $F_{AB} = -F_{BA}$, where F_{AB} is the force exerted by body *B* upon *A* whereas F_{BA} is the force exerted by body *A* upon *B.* Ask yourself what would happen if this was not true. In that case, a system of two bodies, even if it is completely isolated from the surroundings, would have a net force acting upon it because the net force acting upon both bodies would be $F_{AB} + F_{BA} \neq 0$.

14. If action and reaction are always equal, then why does a body accelerate at all? Students are often confused by this. The answer: in considering the acceleration of a body you must consider only the (net) force acting upon that body. So, for example, the earth pulls a stone towards it and causes it to accelerate because there is a net force acting upon the stone. On the other hand, by the Third Law, the stone also pulls the earth towards it and this causes the earth to accelerate towards the stone. However, because the mass of the earth is so large, we are only able to see the acceleration of the stone and not that of the earth.