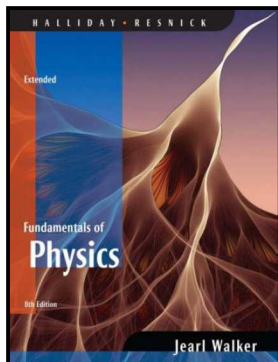


Workshop Physics

1017 - 311

University Physics I

Week 4 : Day 1



Force and Motion

In Chapters 2 and 4 we have studied “kinematics,” i.e., we described the motion of objects using parameters such as the position vector, velocity, and acceleration without any insights as to what caused the motion.

This is the task of Chapters 5 and 6, in which the part of mechanics known as “dynamics” will be developed. In this chapter we will introduce Newton’s three laws of motion which are at the heart of classical mechanics. We must note that Newton’s laws describe physical phenomena of a vast range. (From particles to planets...)

We must also note that Newton’s laws fail in the following two circumstances:

1. When the speed of objects approaches (1% or more) the speed of light in vacuum ($c = 3 \times 10^8$ m/s). In this case we must use Einstein’s special theory of relativity (1905).
2. When the objects under study become very small (e.g., electrons, atoms, etc.). In this case we must use quantum mechanics (1926).

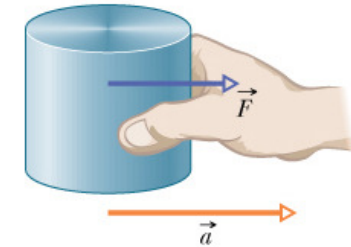
Newton's First Law

- Scientists before Newton thought that a force (the word “**influence**” was used) was required in order to keep an object moving at constant velocity.
 - An object was thought to be in its “natural state” when it was at rest. This mistake was made before **friction** was recognized to be a force.
 - For example, if we slide an object on a floor with an initial speed v_0 very soon the object will come to rest. If on the other hand we slide the same object on a very slippery surface such as ice, the object will travel a much larger distance before it stops.
- Newton checked his ideas on the motion of the moon and the planets. In space there is no friction, therefore he was able to determine the correct form of what is since known as “**Newton's first law**”:

If no net force acts on a body, the body's velocity cannot change; that is, the body cannot accelerate.

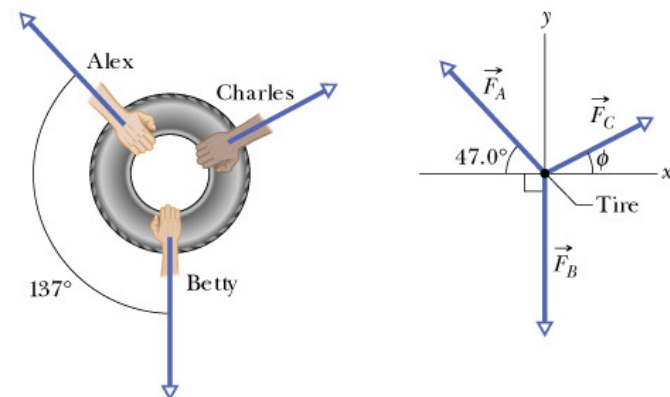
The Concept of “FORCE”

Force: The concept of force was tentatively defined as a push or pull exerted on an object. We can define a force exerted on an object quantitatively by measuring the acceleration it causes using the following procedure.

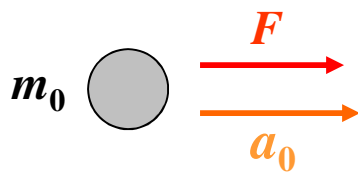


We place an object of mass $m = 1$ kg on a frictionless surface and measure the acceleration a that results from the application of a force F . The force is adjusted so that $a = 1$ m/s². We then say that $F = 1$ newton (symbol: N).

Note: If several forces act on a body (say \vec{F}_A , \vec{F}_B , and \vec{F}_C) the net force \vec{F}_{net} is defined as $\vec{F}_{\text{net}} = \vec{F}_A + \vec{F}_B + \vec{F}_C$, i.e., \vec{F}_{net} is the vector sum of \vec{F}_A , \vec{F}_B , and \vec{F}_C .



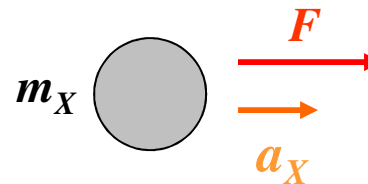
The Concept of “MASS”



Mass: Mass is an *intrinsic* characteristic of a body that automatically comes with the existence of the body. But what is it exactly? It turns out that the mass of a body is the characteristic that relates a force F applied on the body and the resulting *acceleration* a .

Consider that we have a body of mass $m_0 = 1$ kg on which we apply a force $F = 1$ N. According to the definition of the newton, F causes an acceleration $a_0 = 1$ m/s². We now apply F on a second body of unknown mass m_X , which results in an acceleration a_X . The ratio of the accelerations is inversely proportional to the ratio of the masses:

$$\frac{m_X}{m_0} = \frac{a_0}{a_X} \rightarrow m_X = m_0 \frac{a_0}{a_X}$$



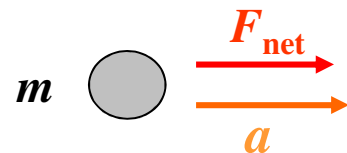
Thus by measuring a_X we are able to determine the mass m_X of any object.

Newton's Second Law

The results of the discussions on the relations between the net force F_{net} applied on an object of mass m and the resulting acceleration a can be summarized in the following statement known as “**Newton’s second law.**”

The net force on a body is equal to the product of the body’s mass and its acceleration.

In equation form Newton’s second law can be written as:



The diagram shows a grey circle representing mass m . To its right, two parallel arrows point to the right. The top arrow is red and labeled F_{net} . The bottom arrow is orange and labeled a .

$$\vec{F}_{\text{net}} = m\vec{a}$$

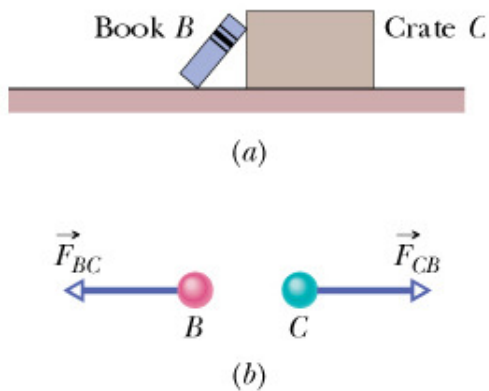
The above equation is a compact way of summarizing three separate equations, one for each coordinate axis:

$$F_{\text{net},x} = ma_x$$

$$F_{\text{net},y} = ma_y$$

$$F_{\text{net},z} = ma_z$$

Newton's Third Law



When two bodies interact by exerting forces on each other, the forces are equal in magnitude and opposite in direction.

For example, consider a book leaning against a bookcase. We label \vec{F}_{BC} , the force exerted on the book by the case. Using the same convention we label \vec{F}_{CB} , the force exerted on the case by the book. Newton's third law can be written as $\vec{F}_{BC} = -\vec{F}_{CB}$. The book together with the bookcase are known as a "third-law force pair."