PHYSICS

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01. First Law of Motion

If the (vector) sum of all the farces acting on a particle is zero then and only then the particle remains unaccelerated (i.e., remains at rest or moves with constant velocity).

If the sum of all the forces on a given particle is $\vec{F}$ and its acceleration is $\vec{a}$, the above statement may also be written as

“ $\vec{a}=0$ if and *only* if $\vec{F}=0$“.

Thus, if the sum of the forces acting on a particle is known to be zero, we can be sure that the particle is unaccelerated, or if we know that a particle is unaccelerated, we can be sure that the sum of the forces acting on the particle is zero.

02. Inertial Frames other than Earth

Suppose S is an inertial frame and *S*’ a frame moving uniformly with respect to *S*. Consider a particle P having acceleration $\vec{a}_{p,s}$ with respect to S and $\vec{a}_{p,s'}$ with respect to *S*’.

We know that,

$$\vec{a}_{p,s} = \vec{a}_{p,s} + \vec{a}_{s',s}.$$

As *S*’ moves uniformly with respect to *S*,

$$\vec{a}_{s',s} = 0.$$

Thus, $\vec{a}_{p,s} = \vec{a}_{p,s'}$ ...(i)

Now S is an inertial frame. So from definition, $\vec{a}_{p,s} = 0$, if *F*=0 and hence, from (i), $\vec{a}_{p,s'} = 0$ if and only if $\vec{F}=0$.

Thus, *S*’ is also an inertial frame. We arrive at an important result : *All frames moving uniformly with respect to an inertial frame are themselves inertial.*

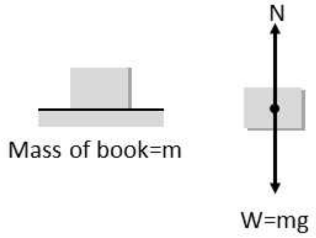
03. Free Body Diagram

No system, natural or man made, consists of a single body alone or is complete in itself. A single body or a part of the system can, however be isolated from the rest by appropriately accounting for its effect on the remaining system.

A free body diagram (FBD) consists of a diagrammatic representation of a single body or a sub-system of bodies isolated from its surroundings showing all the forces acting on it.

Consider, for example, a book lying on a horizontal surface.

A free body diagram of the book alone would consist of its weight (*W=mg*), acting through the centre of gravity and the reaction (*N*) exerted on the book by the surface.



04. Equilibrium

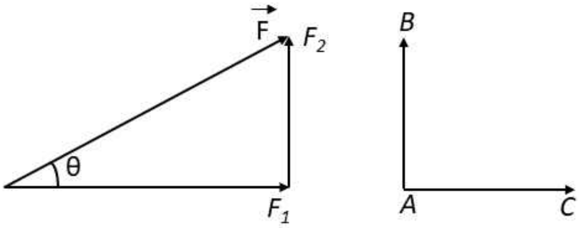
Forces which have zero linear resultant and zero turning effect will not cause any change in the motion of the object to which they are applied. Such forces (and the object) are said to be in equilibrium. For understanding the equilibrium of an object under two or more concurrent or coplanar forces let us first discuss the resolution of force and moment of a force about some point.

(a) Resolution of a Force

When a force is replaced by an equivalent set of components, it is said to be resolved. One of the most useful ways in which to resolve a force is to choose only two components (although a force may be resolved in three or more components also) which are at right angles also. The magnitude of these components can be very easily found using trigonometry.

In Fig. $F_1 = F \cos\theta$ = component of $\vec{F}$ along AC

$F_2 = F \sin\theta$ = component of $\vec{F}$ perpendicular to AC or along AB



Finding such components is referred to as resolving a force in a pair of perpendicular directions. Note that the component of a force in a direction perpendicular to itself is zero. For example, if a force of 10 N is applied on an object in horizontal direction then its component along vertical is zero. Similarly, the component of a force in a direction parallel to the force is equal to the magnitude of the force. For example component of the above force in the direction of force is equal to the magnitude of the force. For example component of the above force in the direction of force (horizontal) will be 10 N.

05. Moment of a Force

The general name given to any turning effect is **torque**. The magnitude of torque, also known as the moment of a force F is calculated by multiplying together the magnitude of the force and its perpendicular distance $r_\perp$ from the axis of rotation. This is denoted by C or τ (tau).

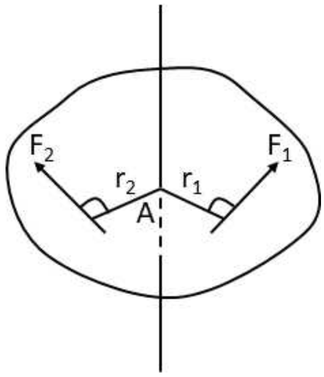
i.e., $C = Fr_\perp$ or $\tau = Fr_\perp$

Direction of Torque

The angular direction of a torque is the sense of the rotation it would cause.

Consider a lamina that is free to rotate in its own plane about an axis perpendicular to the lamina and passing through a point A on the lamina. In the diagram the moment about the axis of rotation of the force F_1 is F_1r_1 anticlock-wise and the moment of the force F_2 is F_2r_2 clockwise. A convenient way to differentiate between clockwise and anticlock-wise torques is to allocate a positive sign to one sense (usually, but not invariably, this is anticlockwise) and negative sign to the other.

With this convention, the moments of F_1 and F_2 are $+F_1r_1$ and $-F_2r_2$ (when using a sign convention in any problem it si advisable to specify the chosen positive sense).



06. Second Law of Motion

The acceleration of a particle as measured from an inertial frame is given by the (vector) sum of all the forces acting on the particle divided by its mass.

In symbols : $\vec{a}=\vec{F}/m$ or, $\vec{F}=m\vec{a}$.

07. Working with Newton's First and Second Laws

Normally any problem relating to Newton's laws is solved in following four steps

(i) First of all we decide the system on which the laws of motion are to be applied. The system amy be a single particle, a block or a combination of two or more blocks, two blocks connected by a string, etc. The only restriction is that all parts of the system should have the same acceleration.

(ii) Once the system is decided, we make the list of all the forces acting on the system. Any force applied by the system on other bodies is not included in the list of the forces.

(iii) Then we make a free body diagram of the system and indicate the magnitude and directions of all the forces listed in step 2 in this diagram.

(iv) In the last step we choose any two mutually perpendicular axes say x and y in the plane of the forces in case of coplanar fores. Choose the x-axis along the direction in which the system is known to have or is likely to have the acceleration. A direction perpendicular to it may be chosen as the y-axis. If the system is in equilibrium, any mutually perpendicular directions may be chosen. Write the components of all the forces along the x-axis and equate their sum to the product of the mass of the system and its acceleration, i.e.,

$$\Sigma F_x = ma \qquad \text{(i)}$$

This gives us one equation. Now, we write the components of the forces along the y-axis and equate the sum to zero. This gives us another equation, i.e.,

$$\Sigma F_y = 0$$

08. Pseudo Force

Before studying pseudo force let us first discuss frame of reference. A system of coordinate axes which defines the position of a particle or an event in two or three dimensional space is called a frame of reference. The simplest frame of reference is, of course, the familiar cartesian system of coordinates, in which the position of the particle is specified by its three coordinates *x, y* and *z*. Frame of references are of two types.

(a) Inertial frame of reference

A non-accelerating frame of reference is called an inertial frame of reference. A frame of reference moving with a constant velocity is an inertial frame of reference.

(b) Non-inertial frame of reference

An accelerating frame of reference is called a non-inertial frame of reference.

09. Friction

As we have discussed in Article friction is the parallel component of contact force between two bodies in contact. These forces are basically electromagnetic in nature. Friction can operate between a given pair of solids between a solid and a fluid or between a pair of fluids. Frictional force exerted by fluids is called viscous force. When two bodies slip over each other the force of friction is called kinetic friction, but when they do not slip but have a tendency to do so the force of friction is called static friction.

Regarding friction it si worth noting that

(a) If a body is at rest and no pulling force is acting on it, force of friction on it is zero.

(b) If a force is applied to pull the body and it does not move, the friction acts which is equal in magnitude and opposite in direction to the applied force, i.e., friction is self adjusting force. Further, as the body is at rest the friction is called static friction.

(c) force exceeds a certain (maximum) value, the body starts moving. This maximum force of static friction upto which body does not move is called limiting friction. Thus, static friction is a self adjusting force with an upper limit called limiting friction.

(d) This limiting force of friction (f_L) is found experimentally to depend on normal reaction (*N*). Hence, $f_L \propto N$

or $f_L = \mu_s N$

Here, μ_s is a dimensionless constant and called coefficient of static friction, which depends on nature of surfaces in contact.

(e) f the applied force is further increased, the friction opposing the motion is called kinetic or sliding friction. Experimentally, it is well established that kinetic friction is lesser than limiting friction and is given by

$$f_k = \mu_k N$$

where μ_k is coefficient of kinetic friction and less than μ_s.