LAWS OF MOTION

NEWTON'S LAWS

Newton's First Law

When there is no net force on an object

–An object at rest remains at rest, and

–An object in motion continues to move with a velocity

that is constant in magnitude and direction.

Newton's Second Law

Newton's second law states the relation between the ***net force*** and the ***inertial mass.***

$$\Sigma \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

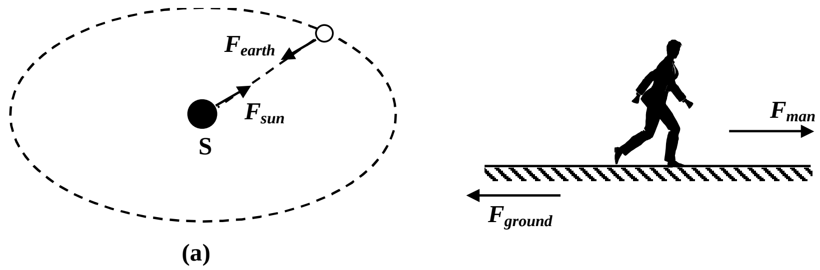
Note that the direction of *acceleration* is in the direction of the net force.

In terms of components

$$\Sigma F_x = ma_x \qquad \Sigma F_y = ma_y \qquad \Sigma F_z = ma_z$$

Newton's Third Law

If the object exerts a force ***F*** on a second, then the second object exerts an equal but oppositely force –***F*** on the first.



Forces exists in pairs.
(a) the force exerted by earth on the sun is equal and opposite to the force exerted by the sun on the earth. $\boldsymbol{F}_{earth} = -\boldsymbol{F}_{sun}$.
(b) The force exerted by the man on the ground is equal and opposite to the force acting on the man by the ground. $\boldsymbol{F}_{man} = \boldsymbol{F}_{ground}$.

FRICTION

Whenever the surface of a body slides over that of another, each body exerts a force of friction on the other, parallel to the surfaces. The ***force of friction*** on each body is in a direction *opposite to its motion relative to the other body*.

It is a *self-adjusting force,* it can adjust its magnitude to any value between zero and the limiting (maximum) value i.e.

$$0 \leq f \leq f_{max}$$

Friction force is of two types

1. Static frictions 'f_S'

2. Kinetic friction ‘f_k’

Static Friction

The static friction between two contact surfaces is given by $f_s \leq \square_s N$, where N is the normal force between the contact surfaces and $\square_s$ is a constant is called the **coefficient of** Static **friction’.**

Kinetic Friction ($\square_k$)

It acts on the two contact surfaces only when there is relative slipiry or relative motion between two contact surfaces.

$$f_k = \square_k N$$

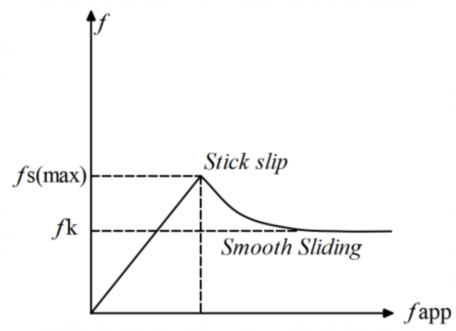
where N is the normal force between the contact surfaces and $\square_k$ is a constant called **‘coefficient of kinetic friction’**

LAWS OF FRICTION

The limiting (or maximum) force of friction is proportional to the normal force that keeps the two surfaces in contact with each other, and is independent of the area of contact between the two surfaces. Mathematically,

$$f_{max} = \mu N$$

PROPERTIES OF FRICTION



1. If the body is at rest, then the static friction force f_s is parallel to the surface and the external force F, are equal in magnitude and F is direct opposite to F. So, if external force F increases then f_s increases.
2. The *maximum* value of static friction is given by

   $$f_{s(max)} = \mu_s N$$

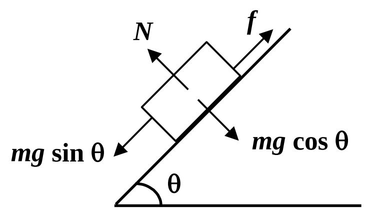
   Where, μ_s = static
   The coefficient of friction and N is the magnitude of the normal response. If the external force is greater than F, $f_{s(\max)}$ the body slides on the surface.
3. If the body starts moving along the surface, the magnitude of the constant force decreases to a constant value f_k

   $$f_k = \mu_k N$$

   Where, μ_k is the *coefficient of kinetic friction.*

ANGLE OF REPOSE

Suppose a body is placed on an inclined surface whose angle of inclination θ varies between 0 to π/2. The *coefficient of friction* between the body and the surface is μ_s. then at a particular value of θ = ϕ the block *just starts to move*. This value of θ =ϕ is called the ***angle of repose.***



A block of mass m is placed on an incline whose inclination may be varied between 0 to π/2. When θ = ϕ the friction force is maximum and block just starts sliding

Mathematically, if the block is just about to move, then $mg \sin\theta = f$

When $\theta = \phi$, $mg \sin\phi = f_{max}$

or $mg \sin\phi = \mu_s N = \mu_s mg \cos$□

or $\tan\phi = \mu_s$

Thus $\phi = \tan^{-1}\mu_s$

The angle of friction is that minimum angle of inclination of the inclined plane at which a body placed at rest on the inclined plane is about to slide down.

CENTRIPETAL FORCE

A particle moving in a circular path with speed v has a centripetal (or radial) acceleration

$$a_r = \frac{v^2}{r} = \omega^2 r$$

If there is angular acceleration, the speed of the particle changes and thus we can find the tangential acceleration

$$a_t = \frac{dv}{dt} = \left(\frac{d\omega}{dt}\right) r = \alpha r$$

The net acceleration is:

$$\vec{a} = \vec{a}_r + \vec{a}_t$$

The magnitude of acceleration is given by

$$a = \sqrt{a_r^2 + a_t^2}$$