CHAPTER

7 Friction

Friction

Friction force is of two types: (*a*) Kinetic, (*b*) Static.

Kinetic Friction

$$f_k = \mu_k \times N$$

The proportionality constant μ_k is called the coefficient of kinetic friction and its value depends on the nature of the two surfaces in contact.

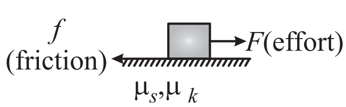
Static Friction

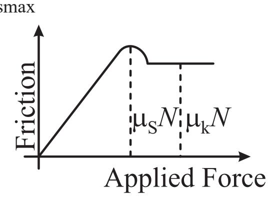
It exists between the two surfaces when there is tendency of relative motion but no relative motion along the two contact surfaces.

This means static friction is a variable and self adjusting force. However it has a maximum value called limiting friction.

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

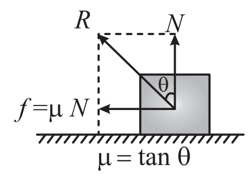
$$0 < f_S < f_{smax}$$





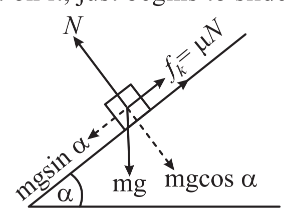
Angle of Friction

It is the angle which the resultant of the force of limiting friction and the normal reaction (*N*) makes with the direction of *N*.



Angle of Repose or Angle of Sliding

It is the angle of inclination of a plane with the horizontal, such that a body placed on it, just begins to slide down.



If angle of repose is α and coefficient of limiting friction is μ_s, then

$$\mu_s = \tan \alpha$$

CHAPTER

6 Newton's Laws of Motion

First Law of Motion

A body continues to be in its state of rest or of uniform motion along a straight line unless an external force is applied on it. This law is also called law of inertia.

Example: If a moving vehicle suddenly stops, then the passengers inside the vehicle bend forwards.

Second Law of Motion

$$F_x = \frac{dP_x}{dt} = ma_x\,; \quad F_y = \frac{dP_y}{dt} = ma_y\,; \quad F_z = \frac{dP_z}{dt} = ma_z$$

Third Law of Motion

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

$\vec{F}_{AB}$ = Force on A due to B

$\vec{F}_{BA}$ = Force on B due to A

Force

Force is a push or pull which changes or tries to change the state of rest, the state of uniform motion, size or shape of body.

Its SI unit is newton (N) and its dimensional formula is [MLT^{-2}].

Forces can be categorised into two types:

(i) **Contact Forces:** Frictional force, tensional force, spring force, normal force etc are the contact forces.

(ii) **Distant Forces:** (Field Forces) Electrostatic force, gravitational force, magnetic force etc. are distant forces.

Weight (w)

It is a field force. It is the force with which a body is pulled towards the centre of the earth due to gravity. It has the magnitude mg, where m is the mass of the body and g is the acceleration due to gravity.

$$w = mg$$

Weighing Machine

A weighing machine does not measure the weight but measures the force exerted by object on its upper surface.

Normal Reaction

It is a contact force. It is the force between two surfaces in contact, which is always perpendicular to the surfaces in contact.

Tension

Tension force always pulls a body. Tension is a reactive force. It is not an active force. Tension across a massless pulley or frictionless pulley remains constant. Rope becomes slack when tension force becomes zero.

Spring Force

$$F = -kx$$

x is displacement of the free end from its natural length or deformation of the spring where k = spring constant.

Spring Property

$k \times \ell$ = constant where ℓ = Natural length of spring

If spring is cut into two in the ratio $m : n$ then spring constant is given by

$$k\ell = k_1 \ell_1 = k_2 \ell_2, \text{ where } \ell_1 = \frac{m\ell}{m+n};\ \ell_2 = \frac{n\ell}{m+n}$$

For series combination of springs

$$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} + \cdots$$

For parallel combination of spring

$$k_{eq} = k_1 + k_2 + k_3 \ldots$$

Spring Balance

It does not measure the weight. It measures the force exerted by the object at the hook.

Wedge Constraint

Components of velocity along perpendicular direction to the contact plane of the two objects is always equal if there is no deformations at contact place and they remain in contact.

Newton's Law for a System

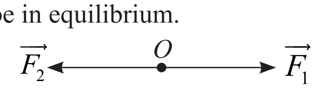
$$\vec{F}_{ext} = m_1\vec{a}_1 + m_2\vec{a}_2 + m_3\vec{a}_3 + \cdots$$

F_{ext} = Net external force on the system.

m_1, m_2, m_3 are the masses of the objects of the system and a_1, a_2, a_3 are the acceleration of the objects respectively.

Equilibrium of a Particle

When the vector sum of the forces acting on a body is zero, then the body is said to be in equilibrium.



If two forces $\vec{F_1}$ and $\vec{F_2}$ act on a particles, then they will be in equilibrium if $\vec{F_1} + \vec{F_2} = 0$.