UNIT-4

WORK & FRICTION

WORK

- Work is said to be done by a force acting on the body, provided the body is displaced actually in any direction except in a direction perpendicular to the direction of force.
- When a constant force '$\vec{F}$' acting on a body produces a displacement '$\vec{s}$' in the body , then the work (W) done by the force is the **dot product** of force ($\vec{F}$) & displacement ($\vec{S}$)

$$W = \vec{F}.\vec{s}$$

$$\boxed{W = Fs\ \cos\theta}$$ 'θ' is the angle between $\vec{F}$ & $\vec{s}$.

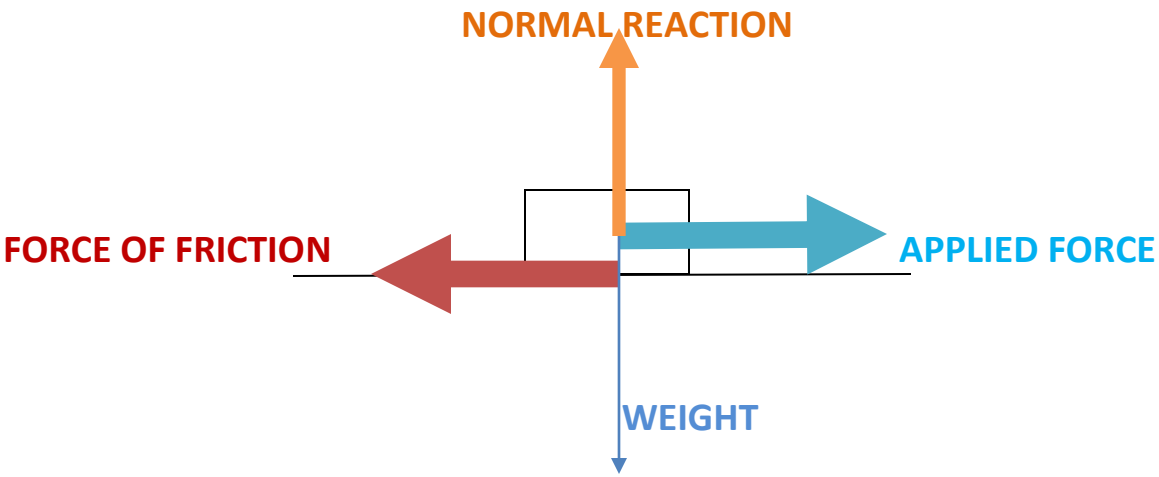
- Work is a scalar quantity.
- It can be positive/negative/zero.
- S.I. unit is N.m = joule (J)
- C.G.S. unit is dyne.cm = erg
- Dimension of work is $[M^1L^2T^{-2}]$

FRICTION

- Force of friction is the force that develops at the surfaces of contact of two bodies & opposes their relative motion.
- This force acts tangentially to the interface of two bodies.

NORMAL REACTION

- Let us consider a block of weight 'mg' lying on a horizontal surface.
- When the body presses against a surface, the surface deforms even if it appears to be rigid.
- The deformed surface pushes the body with a normal force 'R' i.e. perpendicular to the surface.
- This is called normal reaction. It balances 'mg'.



TYPES OF FRICTION

STATIC FRICTION, LIMITING FRICTION & KINETIC FRICTION

- Suppose a small force 'P' is applied on a block. The force of friction 'F' opposes the motion.
- So long as the block does not move

$$F = P$$

This means as we increase 'P' friction 'F' also increases, remaining equal to 'P' always.

STATIC FRICTION

- It is the opposing force that comes into play between two bodies in contact, when one body tends to move over the surface of another but the actual motion has yet not started.

LIMITING FRICTION

- It is the maximum opposing force that comes into play between two bodies in contact, when one body is just at the verge of moving over the surface of another.

DYNAMIC/KINETIC FRICTION

- It is the opposing force that comes into play between two bodies in contact, when one body is actually moving over the surface of another body.
- It is of 2 types.

1. SLIDING FRICTION

- It is the opposing force that comes into play between two surfaces in contact when one body is actually sliding over the surface of another body.

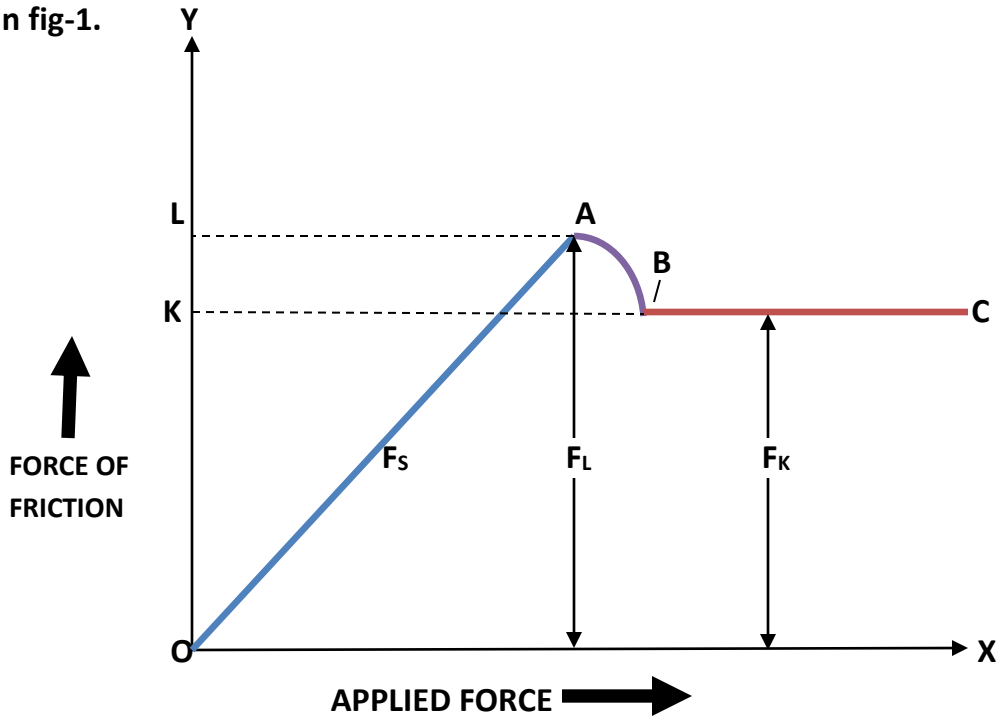
2. ROLLING FRICTION

- It is the opposing force that comes into play between two surfaces in contact when one body is actually rolling over the surface of another body.

- **FLUID FRICTION**

Fluid friction is the opposing force which comes into play when a body moves through a fluid.

If we plot a graph between applied force & the force of friction, we get a curve of the type shown in fig-1.



- The part OA of the curve represents static friction, F_s which goes on increasing with applied force.
- At A, the static friction is maximum. This represents the limiting friction (F_L = OL).
- Beyond A, the force of friction is seen decrease slightly.
- The portion BC of the curve, represents the kinetic friction (F_k = OK)
- Kinetic friction is always slightly less than the limiting friction.
- This is because, once the motion started actually, inertia of rest has been overcome. Also, when motion has actually started, irregularities of one surface have little time to get locked again into the irregularities of the other surface.

LAWS OF LIMITING FRICTION

1. The direction of force of friction is always opposite to the direction of motion.

2. The force of limiting friction depends upon the nature & state of polish of the surfaces in contact & act tangentially to the interface between the two surfaces.

3. The magnitude of limiting friction 'F' is directly proportional to the magnitude of normal reaction 'R' between the two surfaces in contact i.e. $F \ \alpha \ R$

4. The magnitude of limiting friction between two surfaces is independent of the area & shape of the surfaces in contact so long as the normal reaction remains the same.

COEFFICIENT OF FRICTION-

- According to the the law of limiting friction

$$F \alpha R$$

$$F = \mu R$$

Where μ is the constant of proportionality & is called the coefficient of limiting friction between two surfaces in contact.

$$\boldsymbol{\mu = \frac{F}{R}}$$

- Coefficient of friction of a pair of surfaces in contact is defined as the ratio between the force of limiting friction 'F' to the normal reaction 'R'
- The value of μ depends on the nature of surfaces in contact & material of surfaces in contact.
- It has no unit & no dimension.
- When a body is actually moving over the surface of another body, we replace 'F' by 'F_k' & μ by μ_k.

$$\boldsymbol{\mu_k = \frac{F_k}{R}}$$

μ_k is the coefficient of kinetic friction.

- Since $F_k < F$, therefore μ_k is always less than μ.

METHODS OF REDUCING FRICTION

1. BY RUBBING & POLISHING

- Polishing makes the surface smoother. Therefore friction reduces.

2.BY LUBRICANTS

- Lubricants like oil, grease etc fill up the irregularities of the surfaces, making them smoother. Hence friction decreases.

3. BY PROPER SELECTION OF MATERIALS

- Tyres are made up rubbers. This because friction between concrete & rubber is much less than the friction between iron & concrete.

4. BY STREAMLINING

- Friction due to air is considerably reduced by streamelining the shape of the object.

5. BY CONVERTING SLIDING INTO ROLLING FRICTION

- Rolling friction is much smaller than sliding friction.
- Sliding friction can be converted into rolling friction by means of ball bearing system.