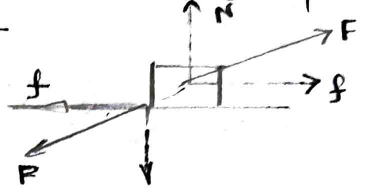
FRICTION

Friction: Whenever a body moves or tends to move over the surface of another body, a force comes in to play which acts parallel to the surface of contact and opposes the relative motion. This opposing force is called friction.

Origine of friction:

When two bodies are placed in contact, attractive forces acts between their particles at the surface of contact. As a result each body exerts a contact force on other. The component of the contact force F normal to the contact surface is called normal force or normal reaction N. The component parallel to the contact surface is called friction.



The force of friction is due to the atomic or molecular forces of attraction between the two surfaces at the points of actual contacts. Figure shows two surfaces in contact. Due to the irregularities to the surface the actual area of contact is much smallar than the apparent area of contact. The pressure at the points of contacts is very large. Molecular bonds are formed at these points. When one body is pulled over the other, the bond breaks, the mateerial is deformed and a new bonds are formed. The local deformation sends vibration waves into the bodies. The vibrations finally damped out and energy appears as heat. Hence a force is needed to start or maintain the motion.

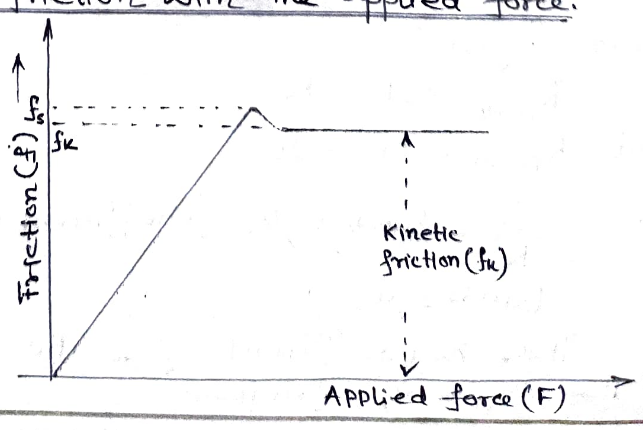
Static, Limiting and Kinetic friction

The force of friction which comes into play between two bodies before the relative motion starts is called static friction.

The maximum force of static friction which comes into play when a body just start moving over the surface of another body is called limiting friction (f_s)

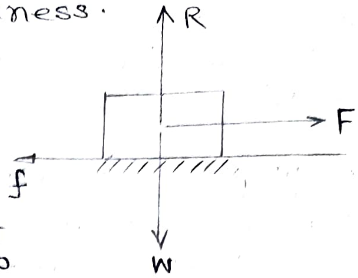
The force of friction which comes into play when a body is in a state of steady motion over the surface of another body is called kinetic or dynamic friction (f_k)

Variation of the force of friction with the applied force.



Laws of friction

- The Limiting friction depends on the nature of surfaces in contact and their state of smoothness.



- The limiting friction acts tangential to the two surfaces in contact and in a direction opposite to the direction of motion of the body.
- The value of limiting friction is independent of the area of the surface in contact so long as the normal reaction remains the same.
- The limiting friction is directly proportional to the normal reaction R between the two surfaces.

$$f_s \propto R \quad \text{or} \quad f_s = \mu_s R$$

$$\text{or} \quad \mu_s = \frac{f_s}{R} = \frac{\text{Limiting friction}}{\text{Normal reaction}}$$

The proportionality constant μ_s is called coefficient of static friction.
It is defined as limiting friction produced per unit normal reaction on the surface.

- The Kinetic friction does not depends on velocity, provided the velocity is neither too large nor too small.
- The value of kinetic friction f_k is directly proportional to the normal reaction R between the two surfaces.

$$f_k \propto R \quad \text{or} \quad f_k = \mu_k R$$

$$\text{or} \quad \mu_k = \frac{f_k}{R} = \frac{\text{Kinetic friction}}{\text{Normal reaction}}$$

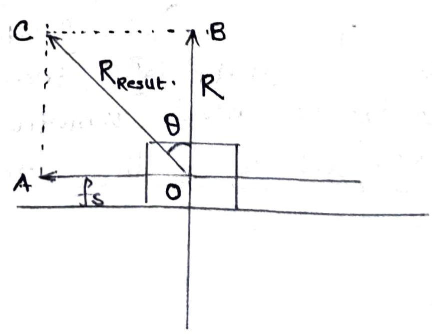
The proportionality constant μ_k is called coefficient of Kinetic friction.
It is defined as kinetic friction per unit normal reaction acts on the body.

As $f_k < f_s$ or $\mu_k R < \mu_s R$ $\therefore \mu_k < \mu_s$

Thus the coefficient of kinetic friction is lesser than Limiting friction.

Angle of friction :

The angle of friction may be defined as the angle which the resultant of the limiting friction and the normal reaction makes with the normal reaction.



From figure

$$R_{Result} \cos\theta = R$$

and $$R_{Result} \sin\theta = f_s$$

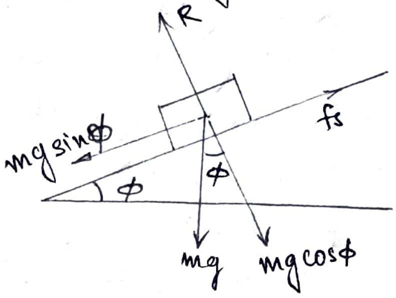
$$\therefore \frac{f_s}{R} = \tan\theta = \mu_s \text{ (coefficient of static friction)}$$

$$\therefore \tan\theta = \mu_s$$

Thus the coefficient of static friction is equal to the tangent of the angle of friction.

Angle of repose :

It is the minimum angle that an inclined plane makes with the horizontal when a body placed on it just begins to slide down due to force of gravity.



• Relation between angle of repose and coefficient of friction.

From fig. when the body placed on the inclined plane just begins to slide down.

$$mg\sin\phi = f_s$$

$$mg\cos\phi = R$$

$$\therefore \quad \tan\phi = \frac{f_s}{R} = \mu_s$$

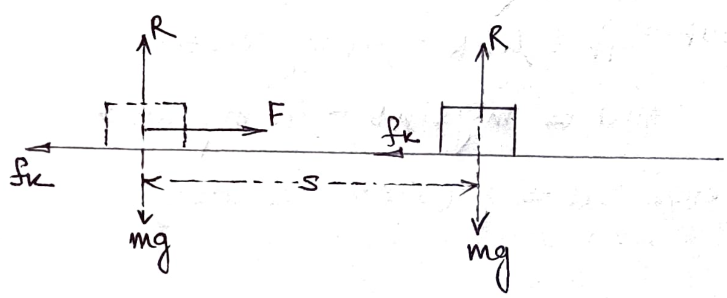
$\therefore$ Thus the coefficient of static friction is equal to the tangent of the angle of repose.

$\therefore$ Thus the angle of repose is equal to the angle of friction.

Work done against friction

• Work done in sliding a body over a horizontal surface

Suppose a force F is applied horizontally so that the body just begins to slide. Let f_k be the kinetic friction.



Workdone against friction in moving the body through distance s will be

$$W = f_k \times s$$

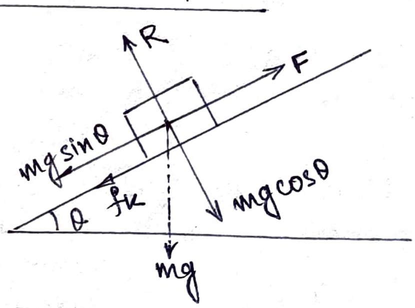
But $\quad f_k = \mu_k R = \mu_k mg$

$$W = \mu_k mg\,s.$$

• Work done in moving a body up an inclined plane

From figure : $\quad R = mg\cos\theta.$

$$F = mg\sin\theta + f_k$$



But $f_k = \mu_k R = \mu_k mg\cos\theta$

$$\therefore \quad F = mg\sin\theta + \mu_k mg\cos\theta$$

$$= mg(\sin\theta + \mu_k\cos\theta)$$

Workdone in pulling the body through distance s up the inclined plane with uniform velocity

$$W = F \times s = mg(\sin\theta + \mu_k\cos\theta)\,s$$

Workdone in moving a body down an inclined plane.

From figure

$R = mg\cos\theta$

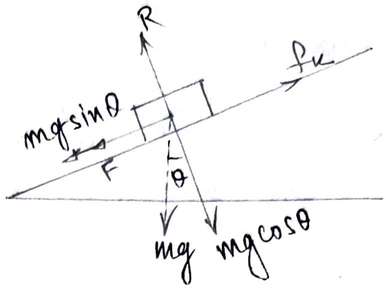
$F + mg\sin\theta = f_k$

$\therefore F = f_k - mg\sin\theta$

But $f_k = \mu_k R = \mu_k mg\cos\theta$

$F = \mu_k mg\cos\theta - mg\sin\theta$

$= mg(\mu_k\cos\theta - \sin\theta)$



$\therefore$ The workdone in sliding the body through distance s down the inclined plane with uniform motion.

$W = F \times S = mg(\mu_k\cos\theta - \sin\theta)\,s$

Acceleration of a body sliding down an inclined plane

From figure

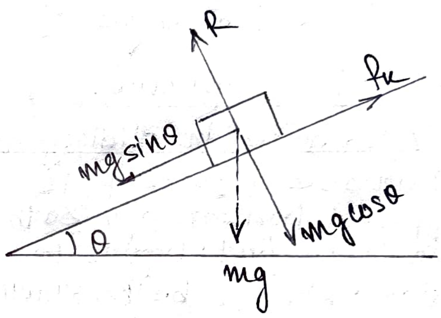
$R = mg\cos\theta$

$\therefore \quad F = (mg\sin\theta - f_k) =$ Net force.

But $f_k = \mu_k R = \mu_k mg\cos\theta$.

$ma = mg\sin\theta - \mu_k mg\cos\theta$

Hence $a = g(\sin\theta - \mu_k\cos\theta)$



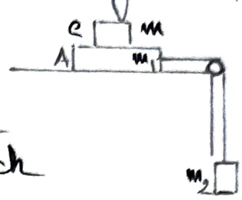
WORKSHEET (FRICTION)

DOSE: I

1. A block of mass 1 kg lies on a horizontal surface in a truck. The coefficient of static friction between the block and the surface is 0.6. If the acceleration of the truck is $5\ ms^{-2}$, calculate the frictional force acting on the block.

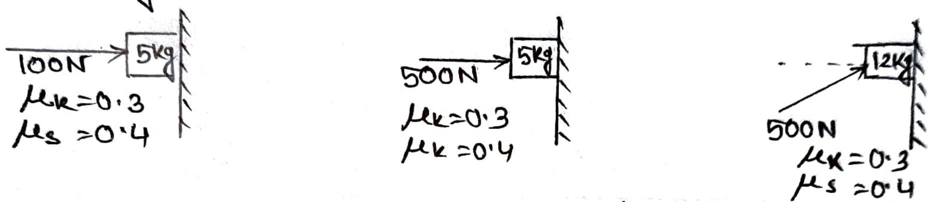
   Ans: 5 N

2. In figure, the masses of A and B are 10 kg and 5 kg respectively. Calculate the minimum mass of C which may stop A from slipping. Coefficient of static friction between A and table is 0.2.

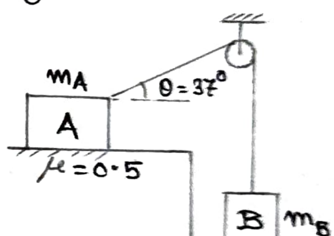


   Ans: 15 kg

3. Determine the magnitude of frictional force and acceleration of the block in each of the following case.

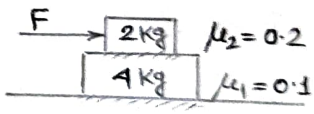


4. Two blocks A and B are connected by a light inextensible string passing over a fixed smooth pulley. The coefficient of friction between the block and the horizontal table is $\mu = 0.5$. If the block A is just to slip, find the ratio of the masses of the blocks. [$\cos 37° = 4/5$, $\sin 37° = 3/5$]

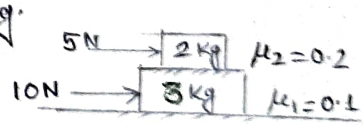


   Ans: 11:5

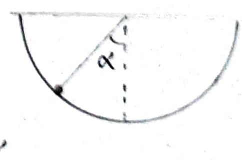
5. In the situation shown in figure
   (a) What minimum force F will make any part or whole system move?
   (b) Find the acceleration of two blocks and value of friction at the two surfaces if F = 6 N.



6. Find the acceleration of two blocks shown in fig. Find the friction force between all contact surfaces.



7. An insect crawls up a hemispherical surface very slowly. The coefficient of friction between the insect and the surface $1/3$. If the line joining the centre of the hemispherical surface of the insect makes an angle α with the vertical, find the maximum possible value of α.



8. Fig. shows two blocks in contact sliding down an inclined surface of inclination 30°. Calculate the acceleration of 2 kg block.