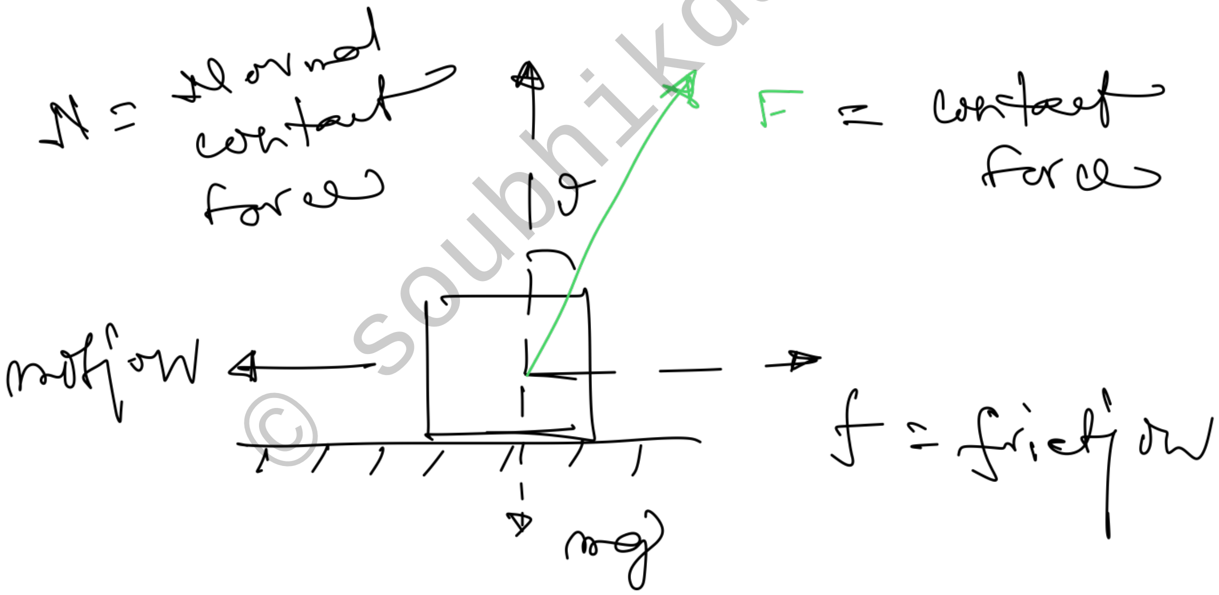
Friction

- When two bodies are kept in contact, electromagnetic forces act between the charged particles at the surface of the bodies. As a result, each body exerts a contact force on each other.

- The magnitude of contact forces acting on the two bodies are equal but their directions are opposite.



$F\cos\theta = N = mg$

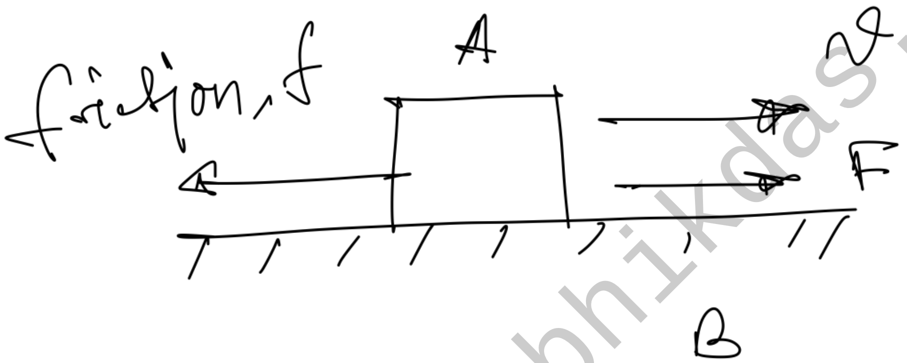
$F\sin\theta = f$

and, $F = \sqrt{N^2 + f^2}$

- Frictional force exerted by fluids is called viscous force.

- **Kinetic Friction**: Two bodies slip over each other.
- **Static Friction**: Two bodies do not slip over each other.

- The force of kinetic friction opposes the relative motion.



$f_k = \mu_k N$

N = Normal force

μ_k = coefficient of kinetic friction.

- For smooth surface μ_k is small, for rough surface μ_k is large.
- μ_k does not depend on the speed of the sliding bodies. Once the body slip over each other frictional force is $\mu_k N$, whatever be the speed.

— The frictional force is independent of the area of the surface in contact.

— Two bodies are in contact but are not sliding with respect to each other, the friction in such case is called static friction.

— The max^m static friction that a body can exert on the other body in contact with it, is called limiting friction.

This limiting friction is proportional to the normal contact force between the two bodies.

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

μ_s → coefficient of static friction.

(depends on material & roughness of the two contact surface)

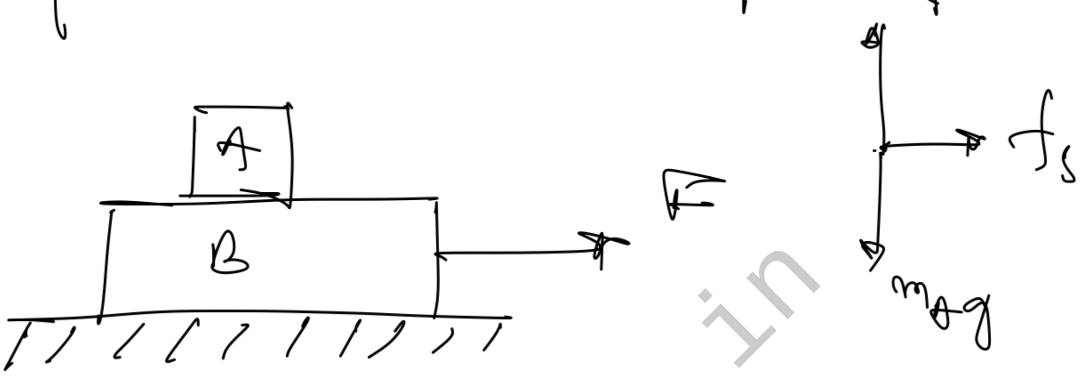
$$\boxed{\mu_s > \mu_k}$$

f_{max} does not depend on the area of the surfaces.

— To keep the body at relative rest

$$f_s \le f_{max} = \mu_s N$$

Direction of static friction



— The direction of static friction on a body is such that the total force acting on it keeps it at rest with respect to the body in contact.

— Friction opposes the relative motion between the bodies in contact.

— For a moment consider the surfaces to be frictionless. In absence of friction the bodies will start slipping against each other. One should then find the direction of friction are opposite to the velocity with respect to the body applying the friction.

Laws of Friction

- If the bodies slip over each other, the force of friction is given by

$$f_k = \mu_k N$$

- μ_k = coefficient of kinetic friction
- N = Normal contact force.

— The velocity of kinetic friction on a body is opposite to the velocity of this body with respect to the body applying the force of friction.

— If the body do not slip over each other, the force of friction is given by,

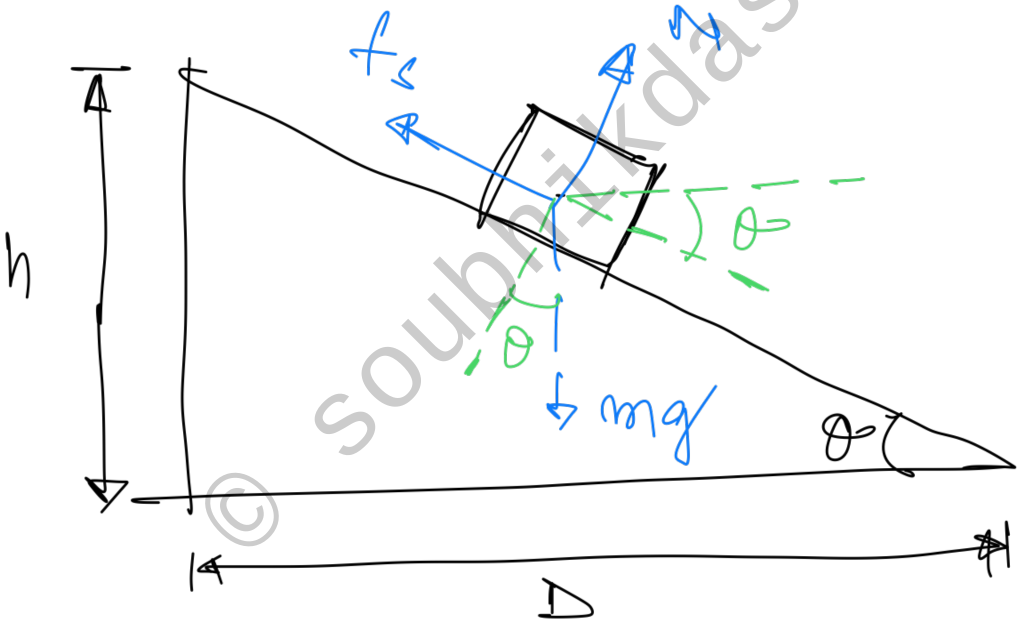
$$f_s \leq \mu_s N$$

- μ_s = coefficient of static friction

- The frictional force f_k or f_s does not depend on the area of contact as long as the normal force N is same.

III Measure friction coefficient (Inclined Table Method)

- Find μ_s & μ_k.



$$\tan\theta = \frac{h}{D}$$

- Taking components along the incline and applying Newton's first law,

$$f_s = mg\sin\theta.$$

- Taking component along the normal to the incline

$$N = mg\cos\theta$$

Now, $f_s = \mu_s N$

or, $\mu_s = \dfrac{f_s}{N} = \dfrac{mg\sin\theta}{mg\cos\theta} = \tan\theta$

$$= \frac{h}{D}$$

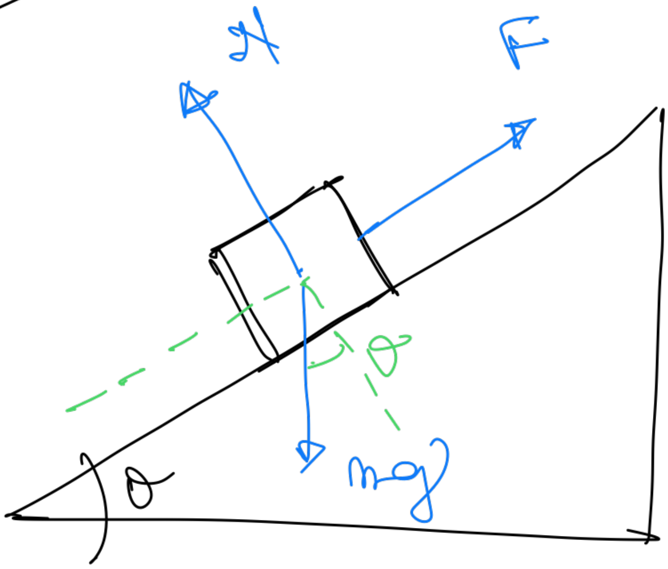
If the inclination is so adjusted that once started, the block continues with uniform velocity on the plank.

Let it be h' etc.

For identical analysis,

$$\mu_k = \frac{f_k}{N} = \tan\theta = \frac{h'}{D'}$$

Example



$\mu_s = 0.3$

① find θ.

② If $\theta = \theta/2$, find f_s.

① $N = mg\cos\theta$

$F_s = mg\sin\theta$

Now, $F_s = \mu_s N$

$mg\sin\theta = 0.3 \times mg\cos\theta$

$\tan\theta = 0.3$

or, $\theta = \tan^{-1}(0.3)$

② for $\theta = \theta/2$,

$F_s = mg\sin\theta/2$