



**VISUAL
PHYSICS**

SHORT NOTES

C H A P T E R

Friction

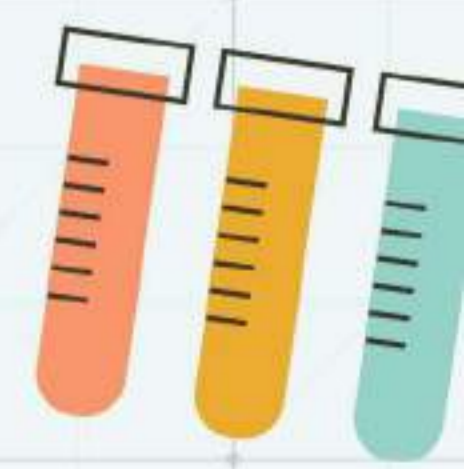
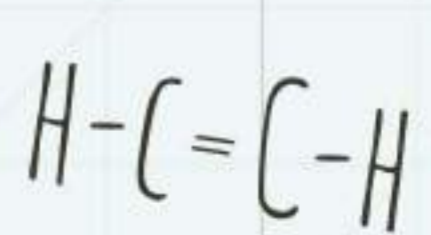
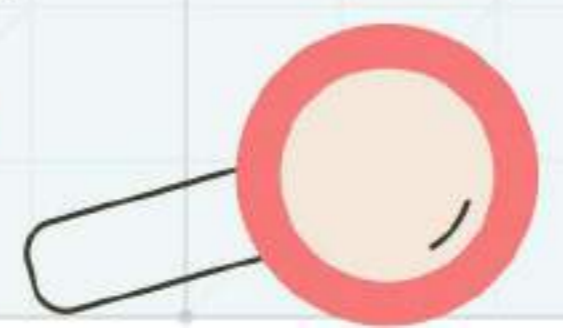
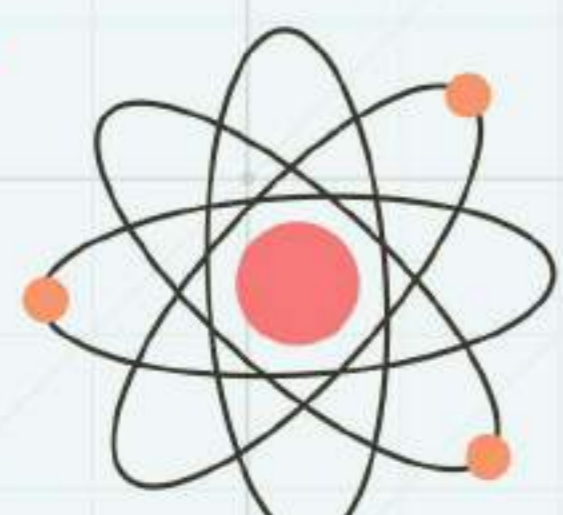
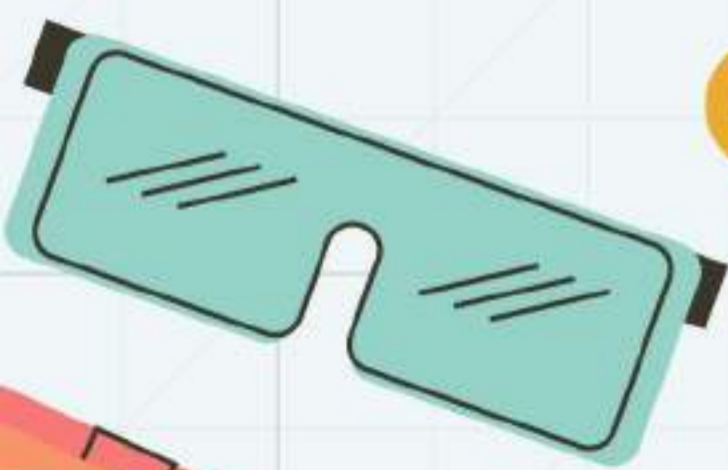
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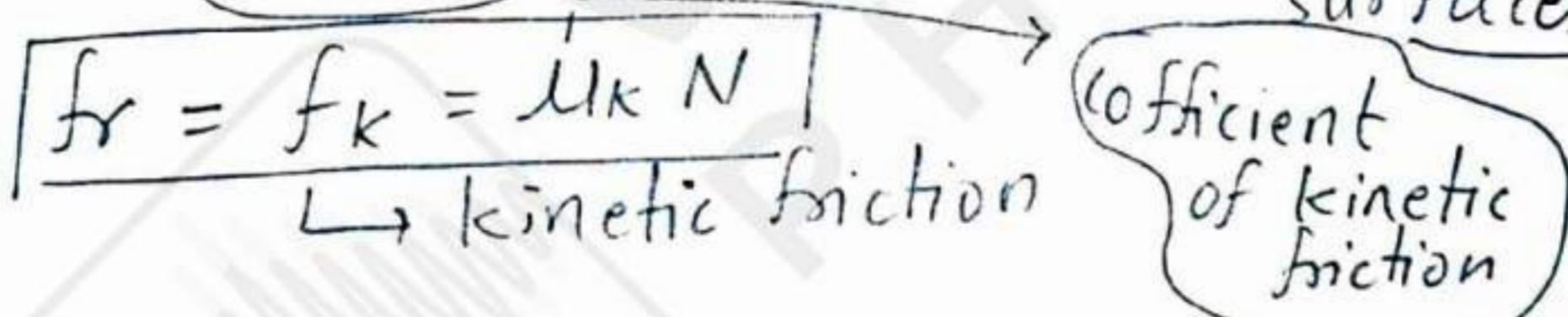
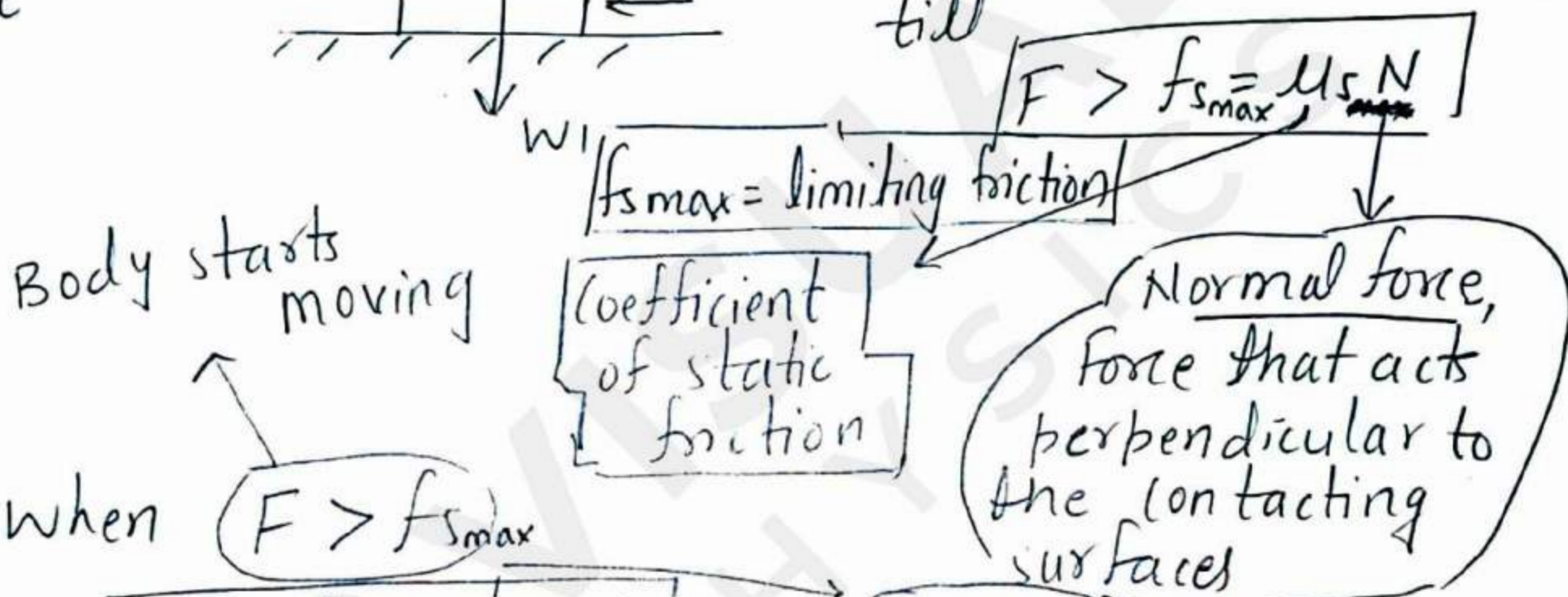
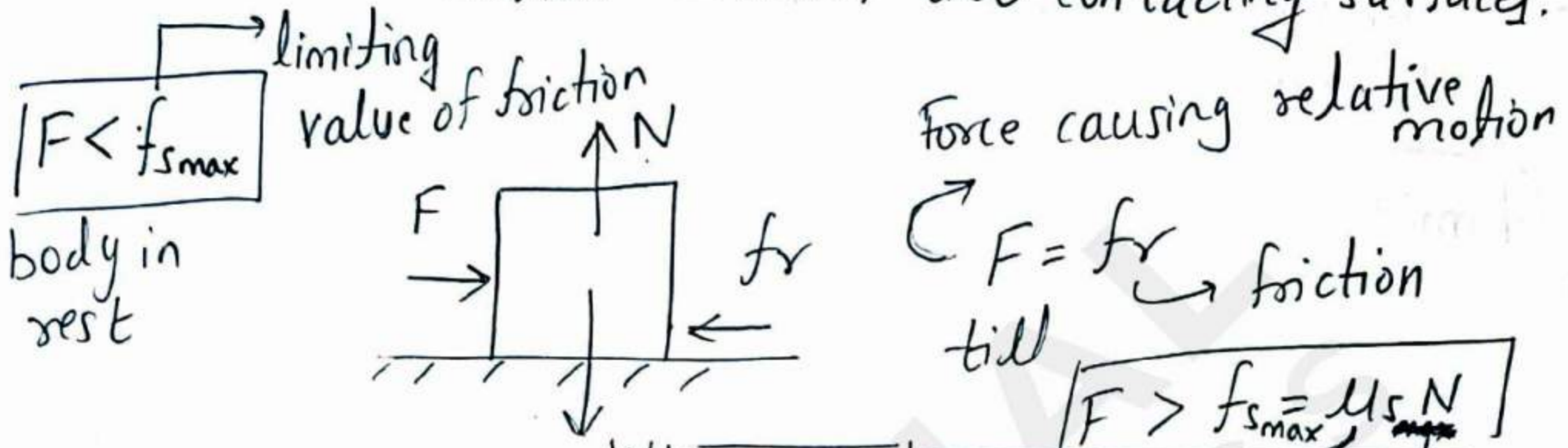


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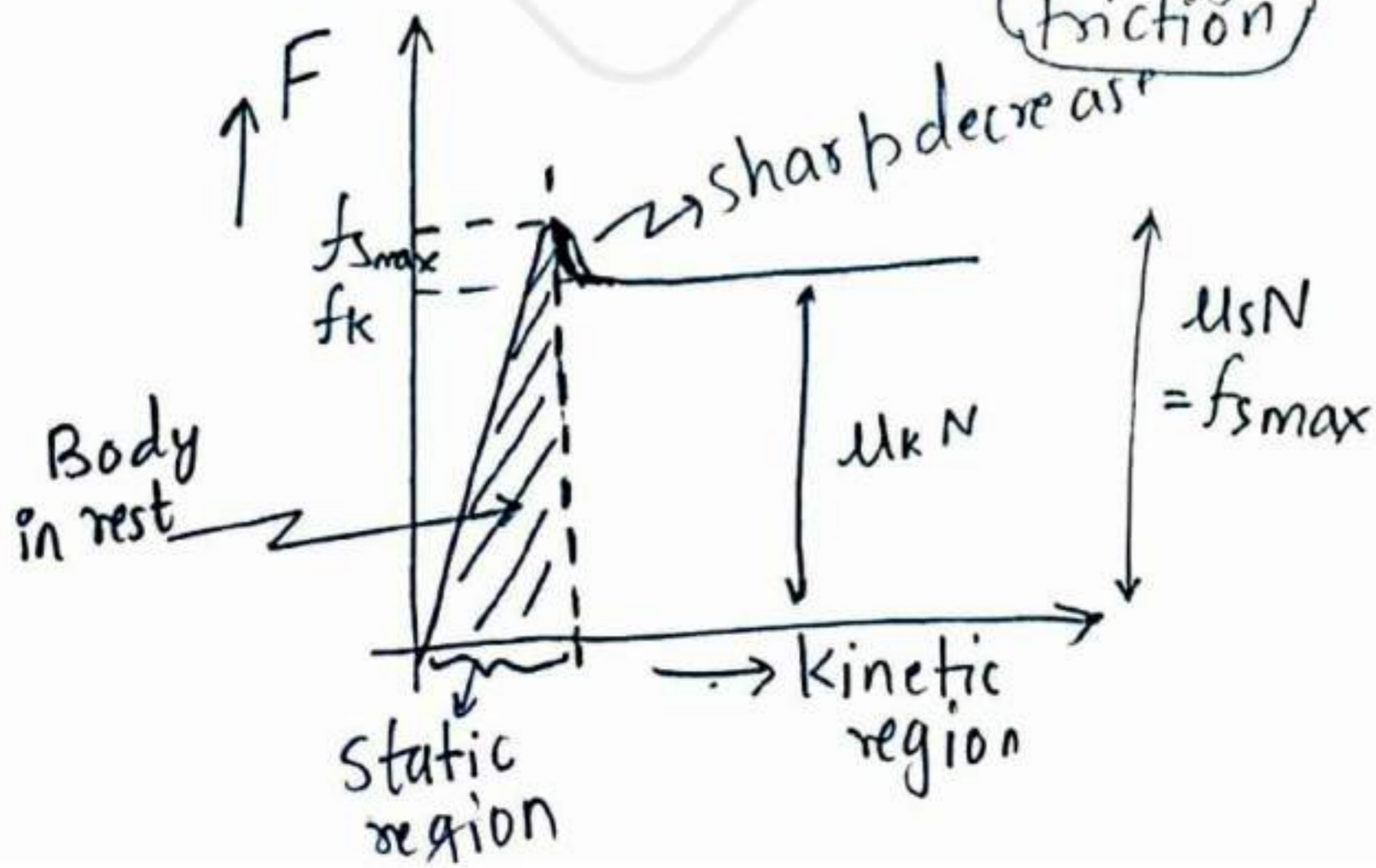
Friction

force which always opposes the relative motion between two contacting surfaces.



Always remember $f_k < f_{smax}$

for given surfaces in contact $\mu_k < \mu_s$



Static friction value varies from f_{smax}

$0 \leq f_s \leq \mu_s N$

when $f_s \leq \mu_s N$

$f_s = F$

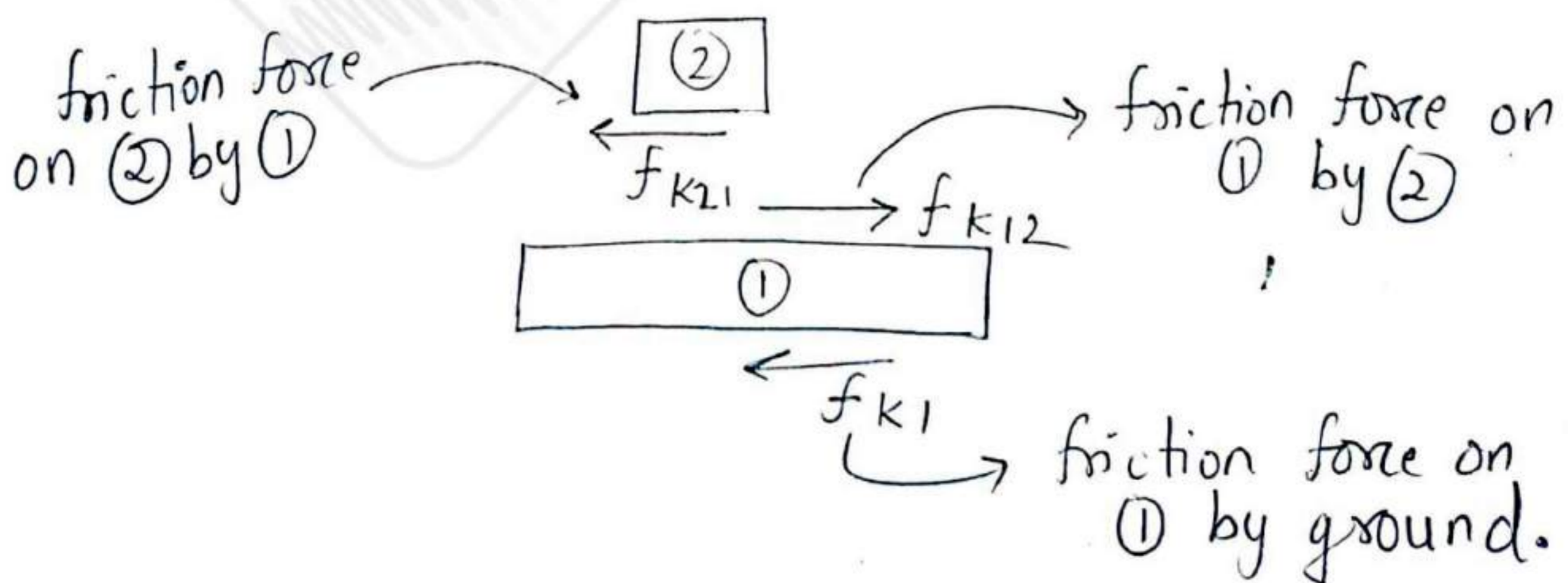
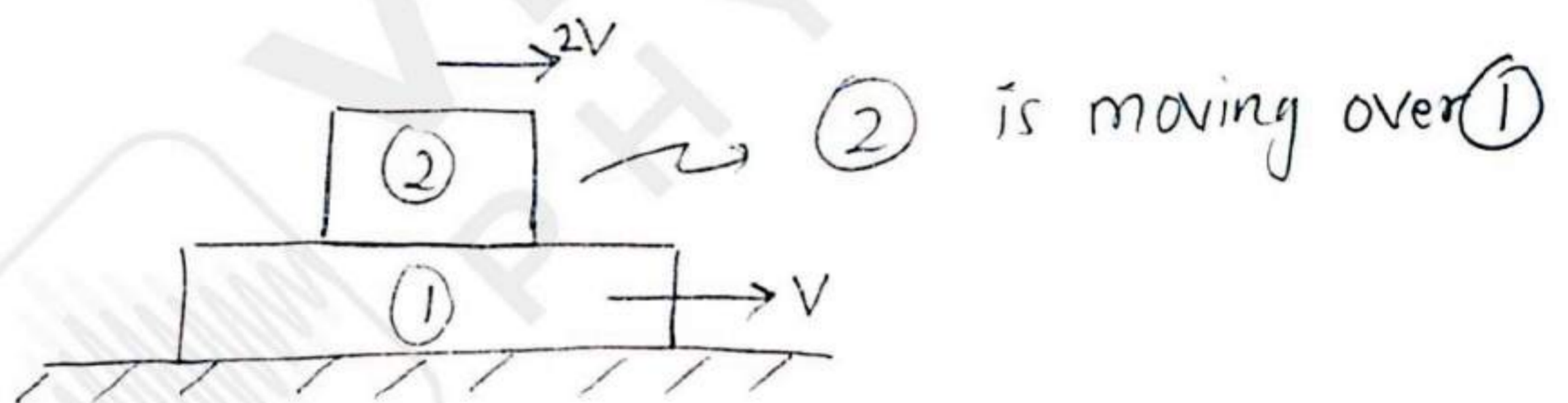
external force

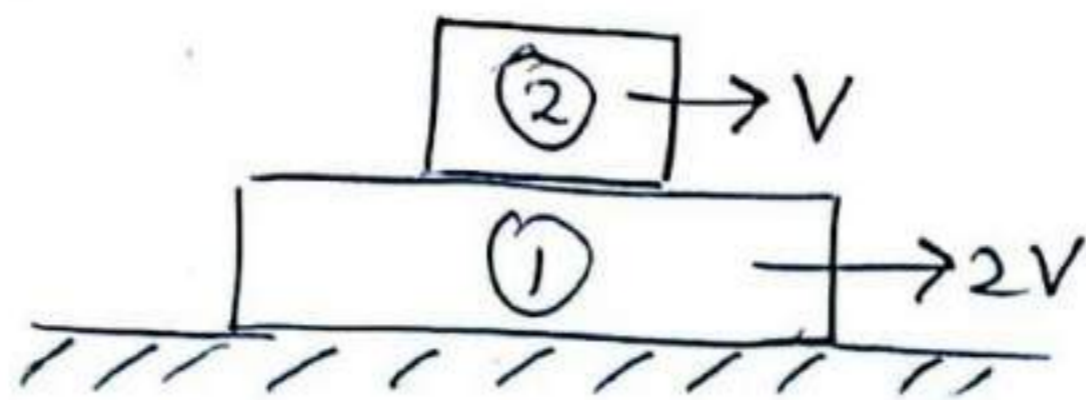
⇒ static friction is an self-adjusting nature and change its magnitude and direction as per requirement.

→ The value of μ_k and μ_s depend on the nature of the surface.

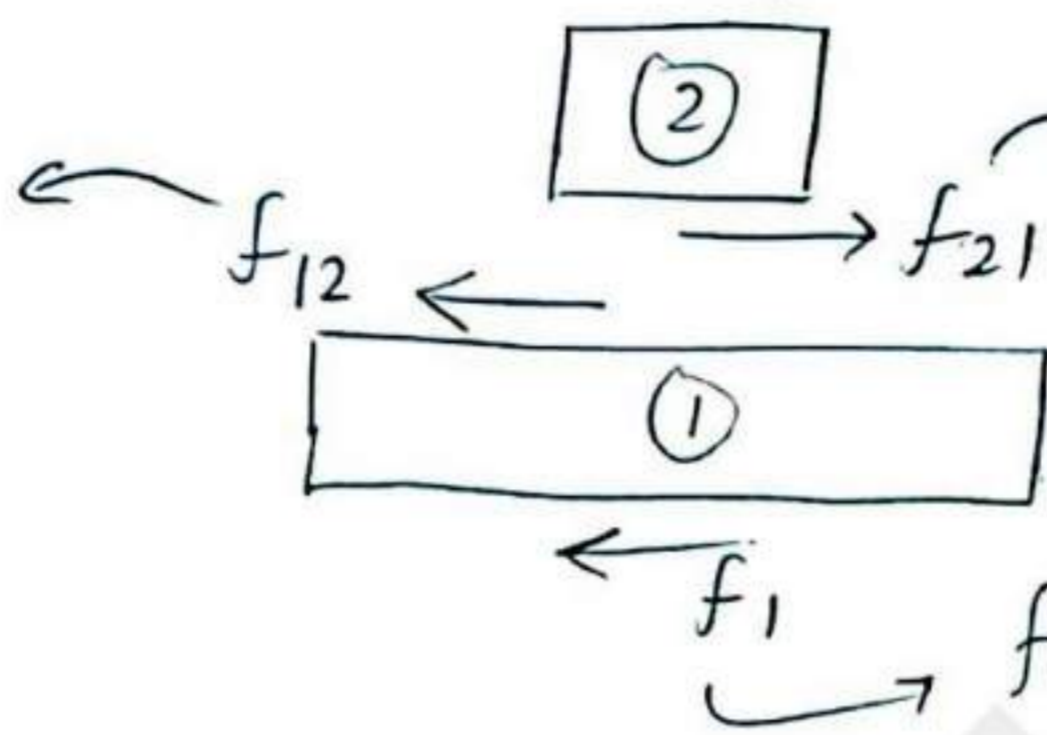
Limiting friction laws: $\rightarrow \mu_s N$

- limiting friction force is independent of the apparent area of contact till N remain same
- direction of limiting force opposite to direction in which one body is on the verge of starting its motion.
- It depends of surface in contact.





friction force on ① by ②

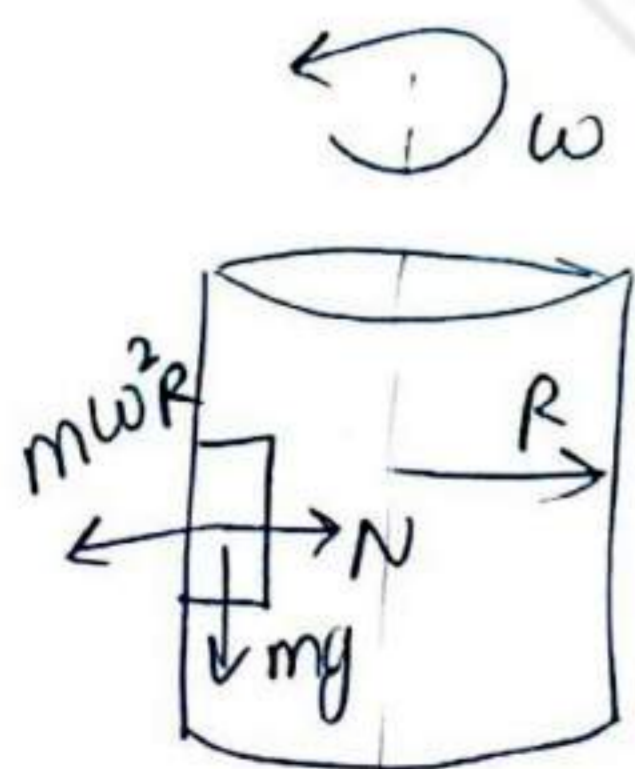
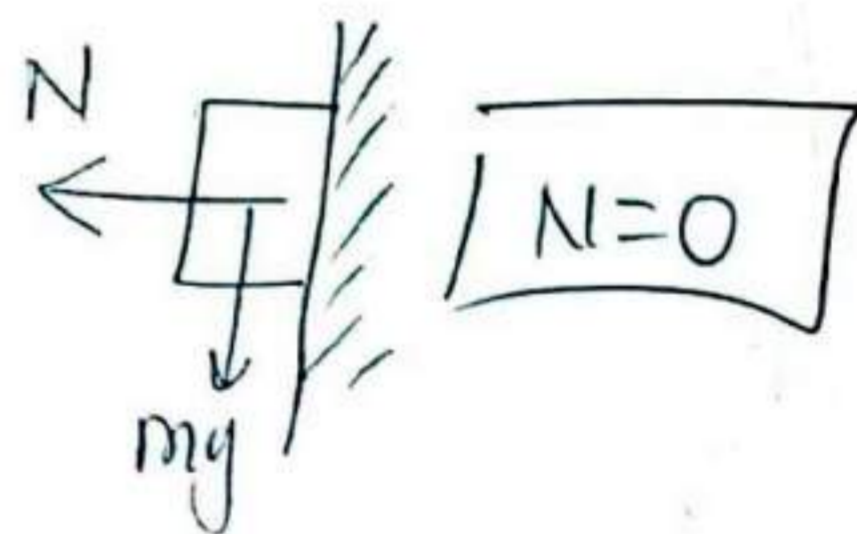
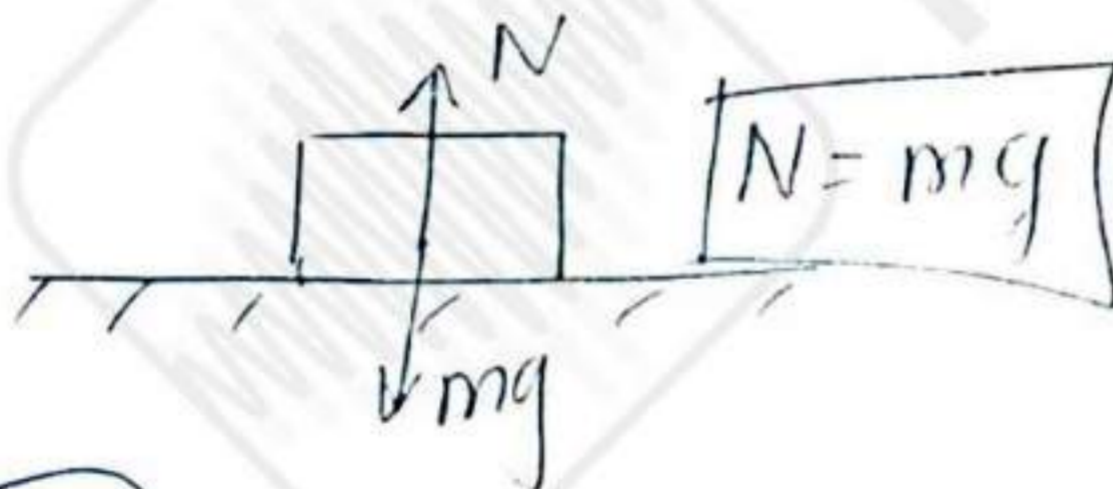


friction on ② by ①

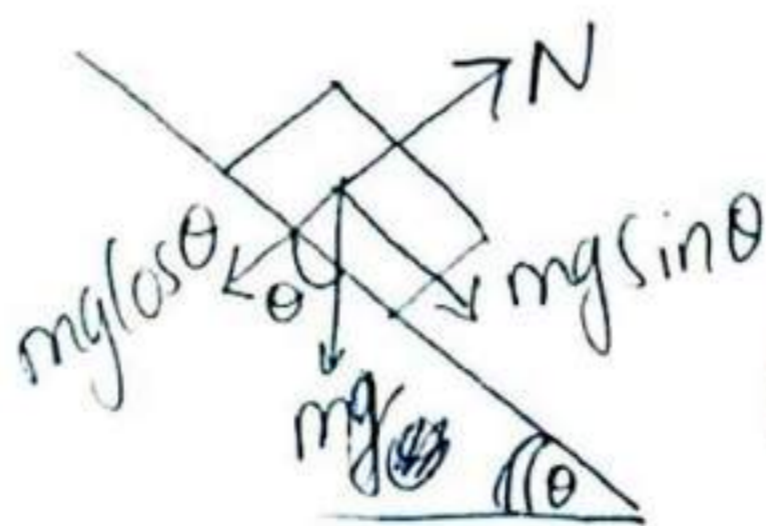
As friction always opposes relative motion

friction by ground on ①

Normal force



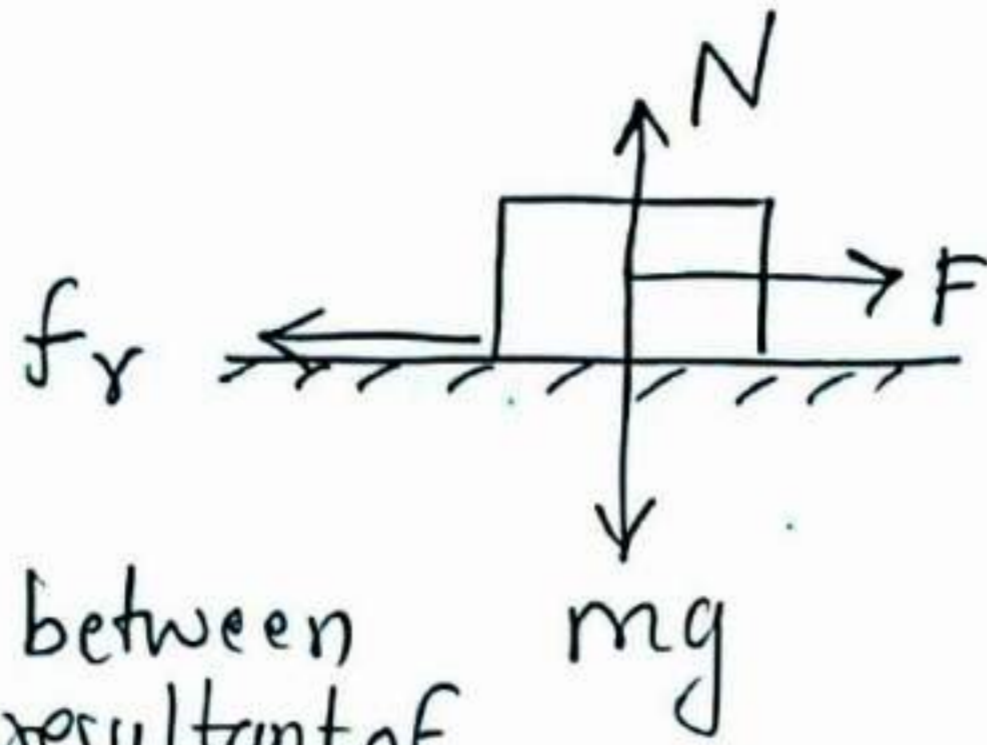
$N = m\omega^2 R$



$N = mg \cos \theta$

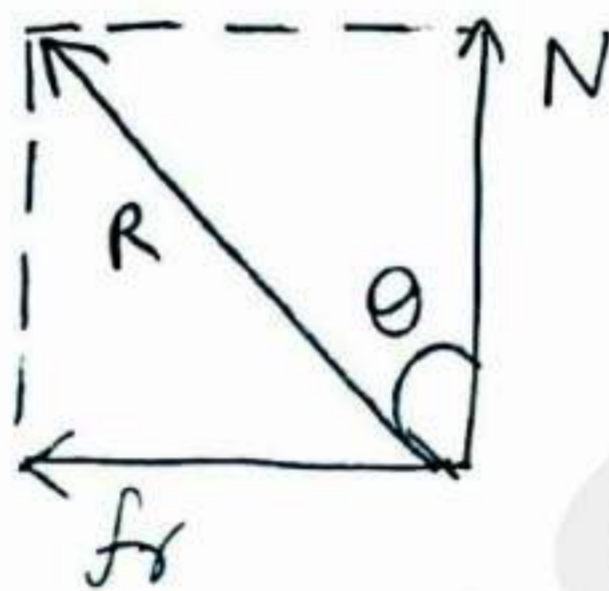
And many more cases.
N is normal force between contact surface.

Angle of friction



Now at condition
 $f_r = f_{lim} = f_s = \mu_s N$

$\theta \rightarrow$ Angle between N and resultant of N & f_r



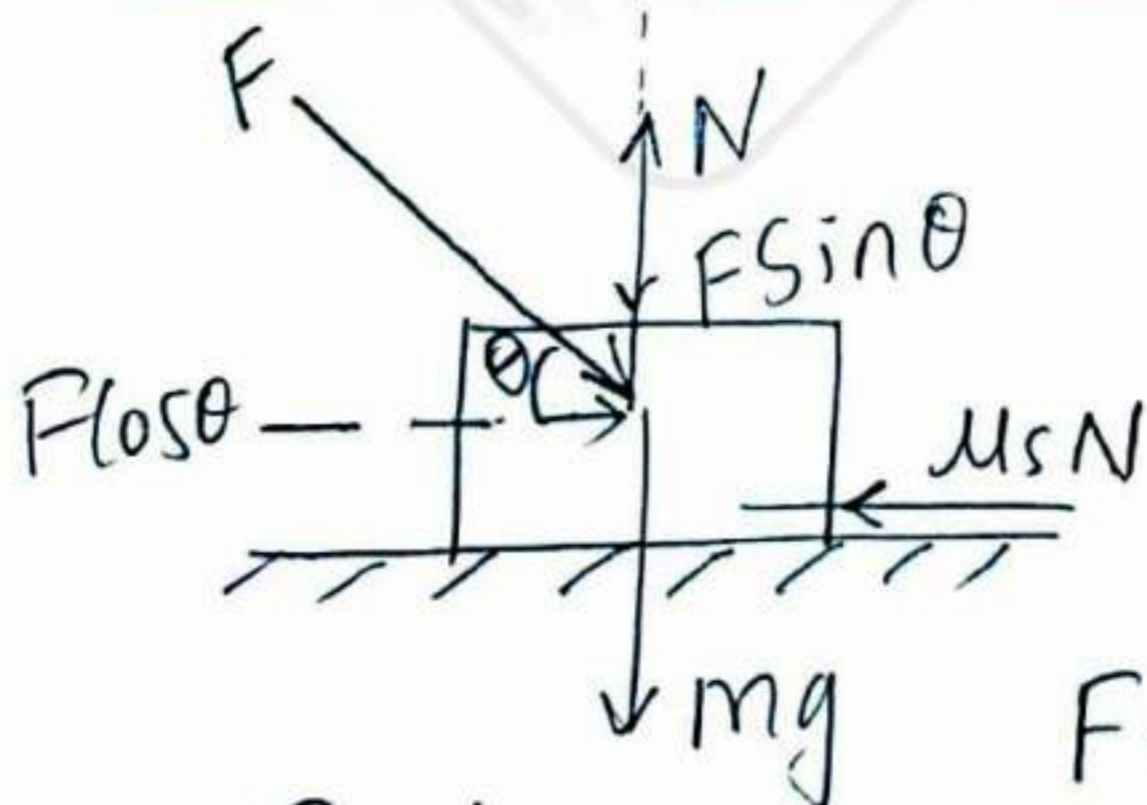
$$\tan \theta = \frac{f_r}{N} = \frac{f_s}{N} = \frac{\mu_s N}{N}$$

$$\boxed{\tan \theta = \mu_s}$$

$$\boxed{\theta = \tan^{-1}(\mu_s)}$$

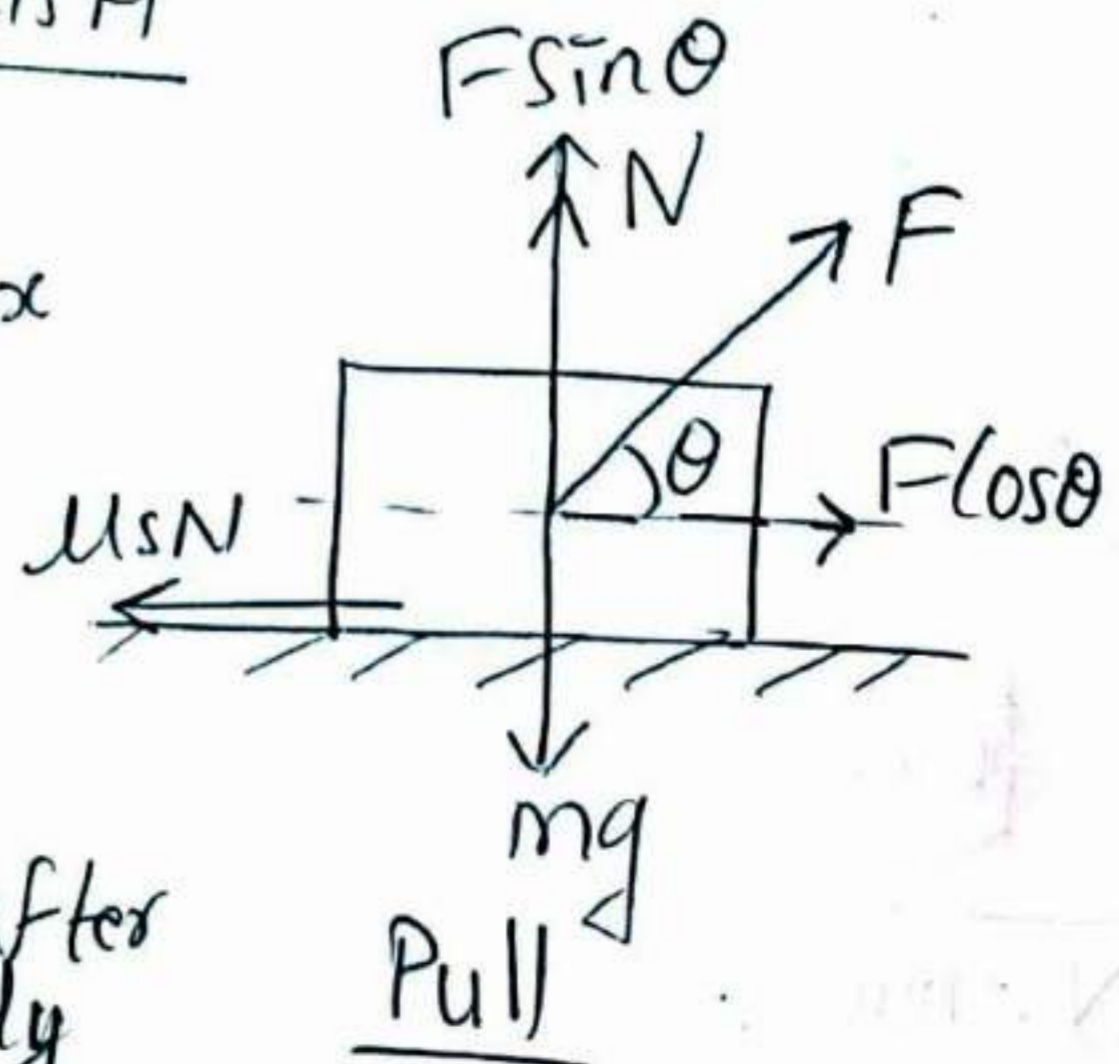
Angle of friction depends on material and nature of surfaces in contact.

PULL IS EASIER THAN PUSH



Push

$F \rightarrow$ max force, after this body starts to move



Pull

Push

In equilibrium

$$\sum F_y = 0 \text{ or } N = mg + F \sin \theta$$

now in limiting case.

$$F \cos \theta = \mu_s N$$

$$F \cos \theta = \mu_s (mg + F \sin \theta)$$

$$F = \frac{\mu_s mg}{\cos \theta - \sin \theta}$$

Pull

$$\sum F_y = 0$$

$$\text{or } N = mg - F \sin \theta$$

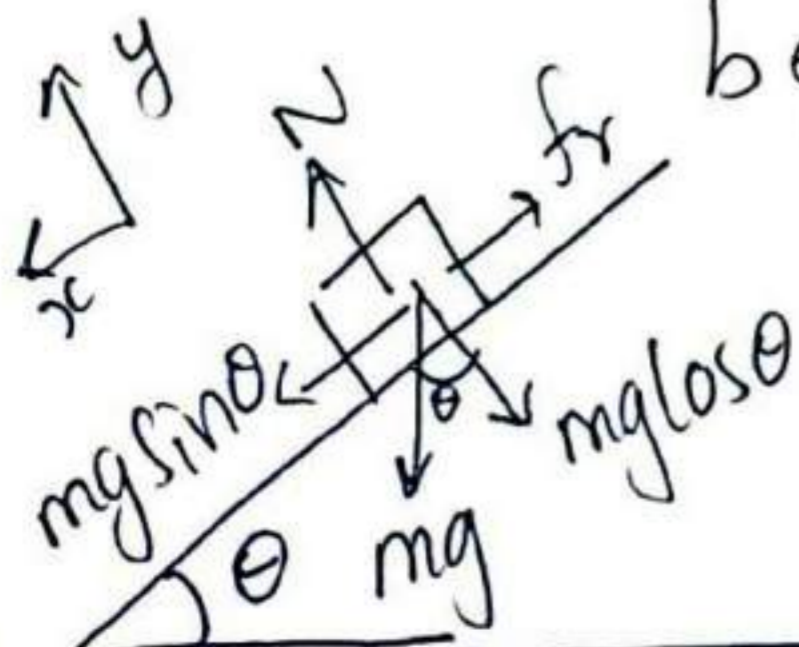
$$F \cos \theta = \mu_s N = \mu_s (mg - F \sin \theta)$$

$$\Rightarrow F = \frac{\mu_s mg}{\cos \theta + \mu_s \sin \theta}$$

"On comparing the force for push is the more than that for pull"

'Angle of Repose' or Angle of Sliding

"minimum angle of inclination of a plane with the horizontal such that a body placed on the plane just begins to slide down"



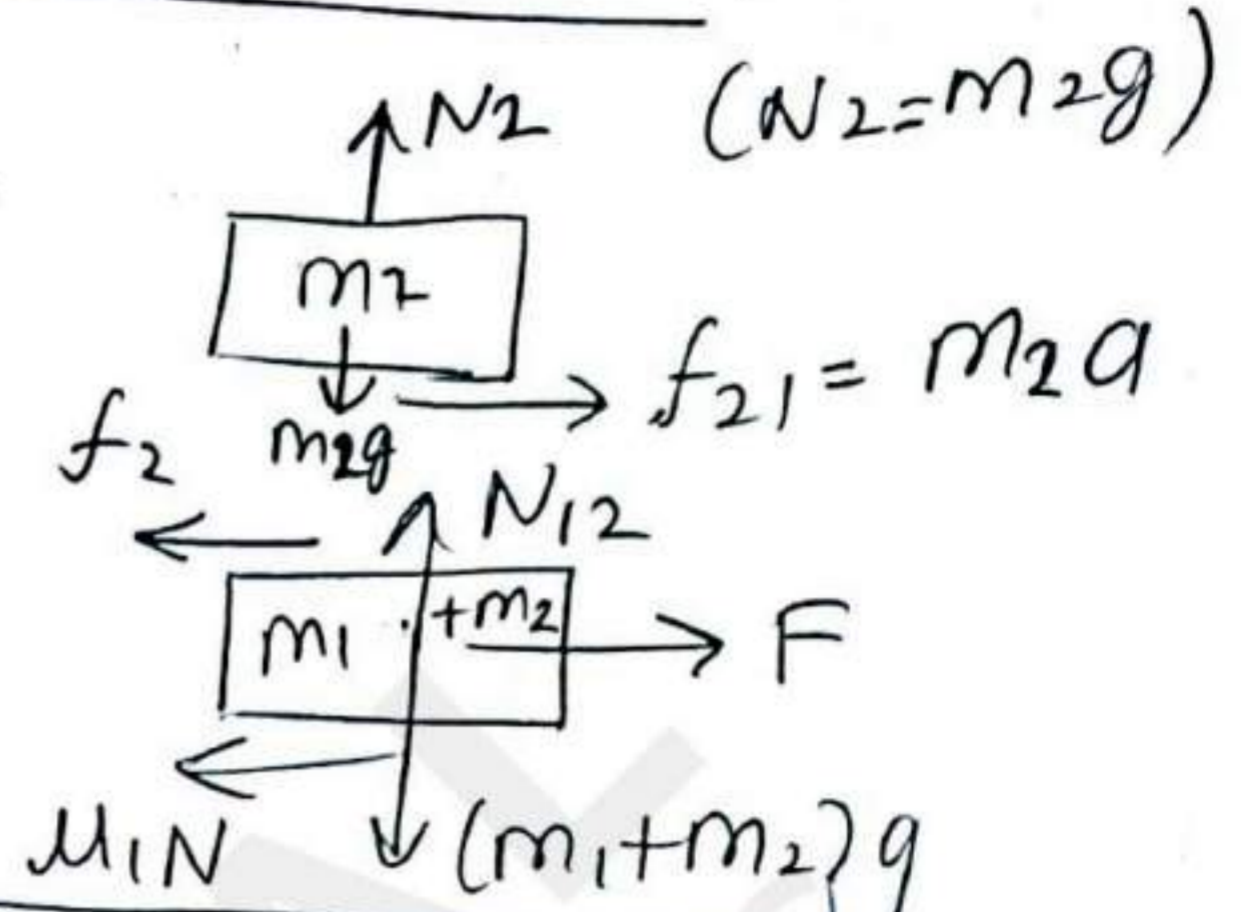
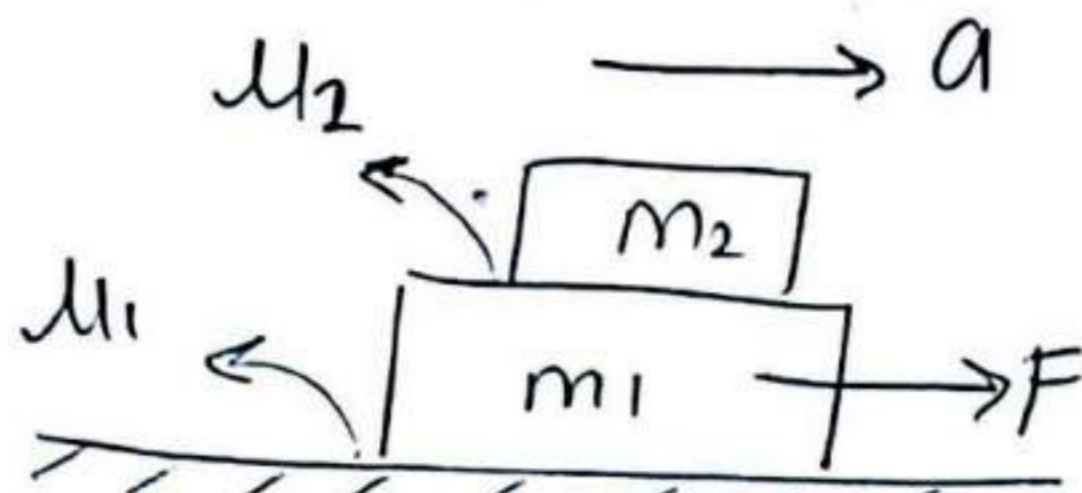
$$f_r = f_s = \mu_s N = mg \sin \theta$$

$$\text{for } \sum F_x = 0$$

$$\Rightarrow \mu_s (mg \cos \theta) = mg \sin \theta$$

$$\star \text{ Angle of repose} = \text{Angle of friction} \quad \tan \theta = \mu_s \rightarrow \text{friction angle at limiting case}$$

Friction acting on multiple surfaces



f_{21} → friction between (1) & (2)
 N_{12} → Normal of (1) & (2) together

$$F - \mu_1(m_1 + m_2)g = (m_1 + m_2)a$$

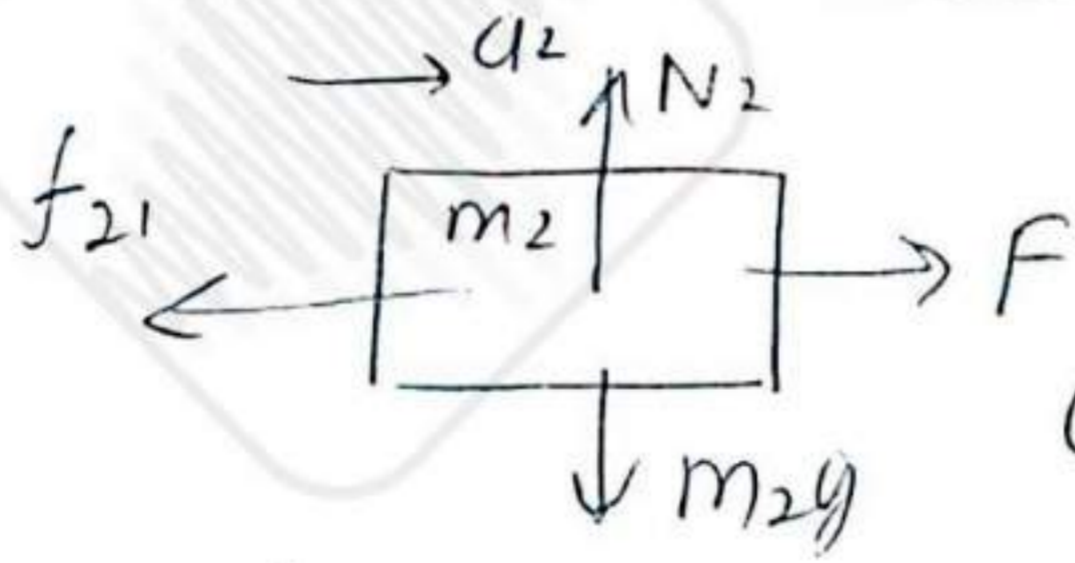
a_{max} → f_{21} → max taking (m_1, m_2) as a system

$$\rightarrow f_{21} = \mu_2 N_2 = m_2 a_{max}$$

$$m_2 a_{max} = \mu_2 m_2 g$$

$$a_{max} = \mu_2 g$$

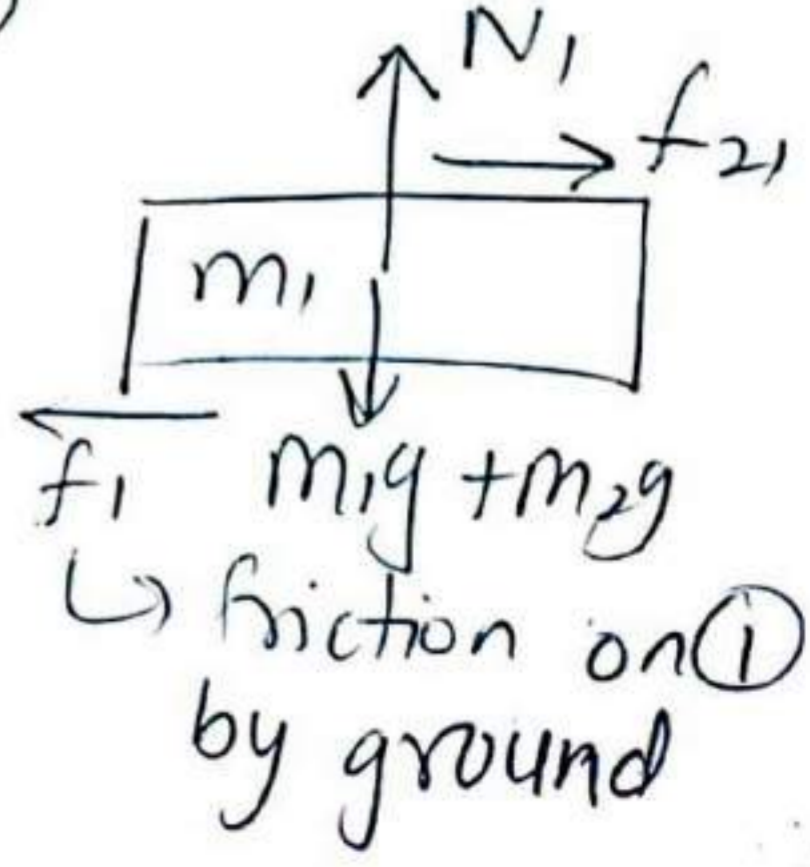
→ " If force were on upper block



f_{21} → friction between (1) & (2)

$$F - f_{21} = m_2 a_2$$

$$F - \mu_2 m_2 g = m_2 a_2$$



↳ friction on (1) by ground

As $N_1 = (m_1 + m_2)g$

$$f_1 = \mu_1 N_1 = \mu_1 (m_1 + m_2)g$$

$$f_{21} = \mu_2 m_2 g$$

if $f_{21} < f_1$, then $m_1 \rightarrow$ rest

if $f_{21} > f_1 \rightarrow m_1$ moves
in direction of f_2
(means forward)

$$\boxed{f_{21} - f_1 = m_1 a}$$

IF $F < f_{21}$, then no slipping in m_1 & m_2
i.e. m_1 & m_2 move together.

IF $F < f_1$, system in rest

IF $F > f_1$, system move with common
acceleration 'a'.

$$F - f_1 = (m_1 + m_2) a$$

$$\text{or } \boxed{F - \mu_1 (m_1 + m_2) g = (m_1 + m_2) a}$$