VISUAL PHYSICS

SHORT NOTES

CHAPTER

Friction

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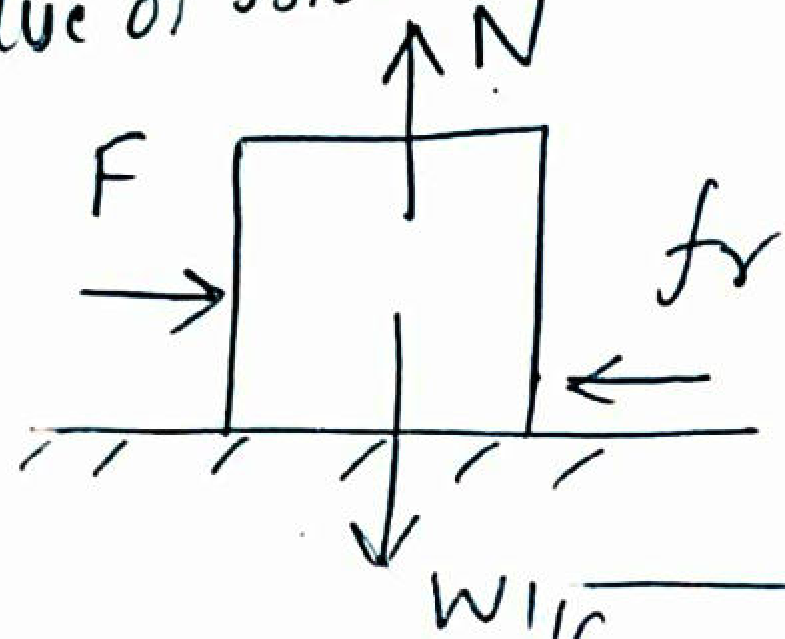
Friction

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

$F < f_{s\,max}$ → body in rest ($f_{s\,max}$ → limiting value of friction)



F → Force causing relative motion

$F = fr$ (fr → friction) till $F > f_{s\,max} = \mu_s N$

$f_{s\,max}$ = limiting friction

μ_s → coefficient of static friction

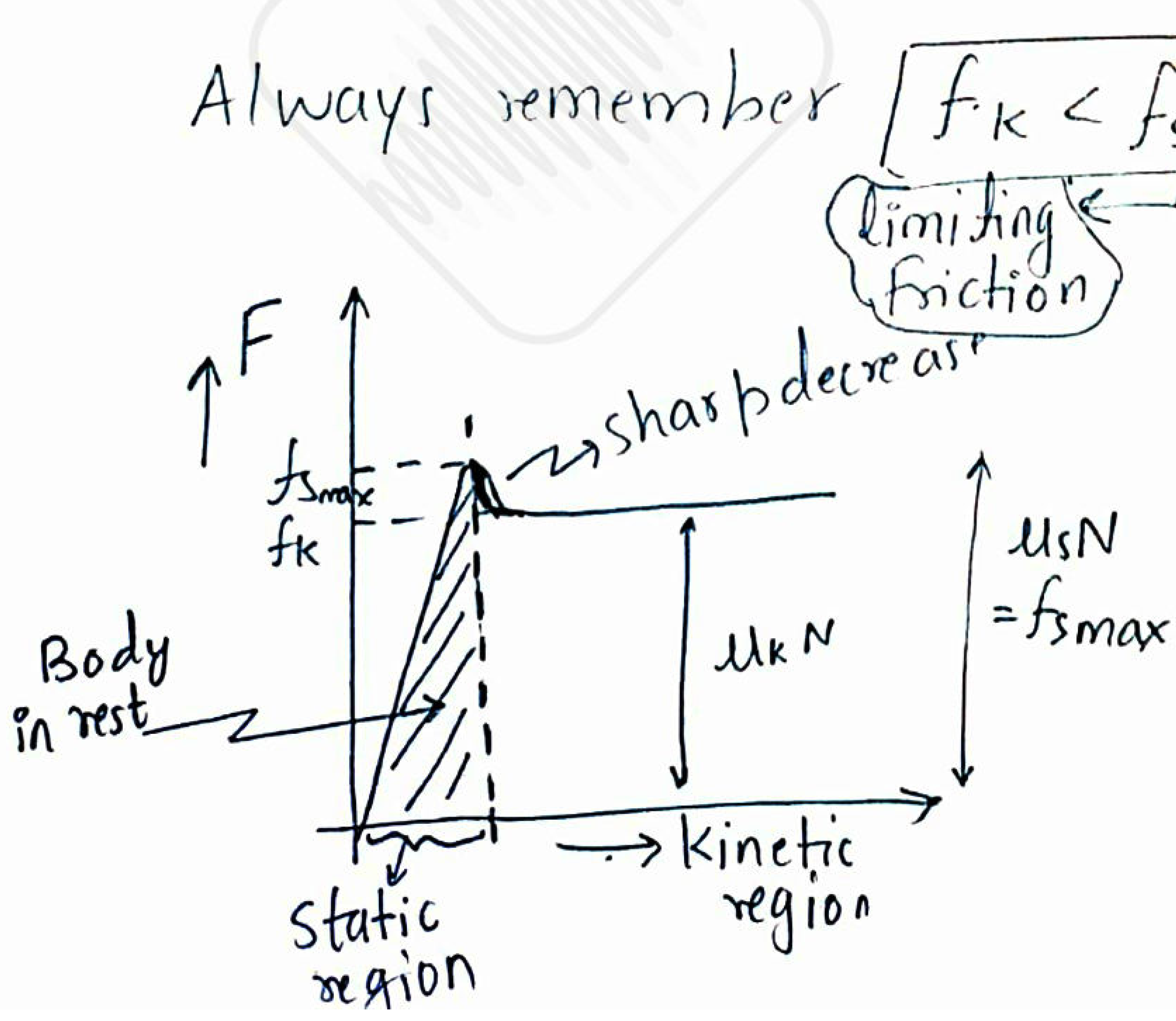
N → Normal force, force that acts perpendicular to the contacting surfaces

When $F > f_{s\,max}$ → Body starts moving

$fr = f_K = \mu_K N$ (f_K → kinetic friction; μ_K → coefficient of kinetic friction)

Always remember $f_K < f_{s\,max}$ ($f_{s\,max}$ → limiting friction)

For given surfaces in contact $\mu_K < \mu_s$



Static friction value varies from

$0 \leq f_s \leq \mu_s N$ ($\mu_s N$ → $f_{s\,max}$)

when $fr \leq \mu_s N$

$f_s = F$ (F → external force)

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

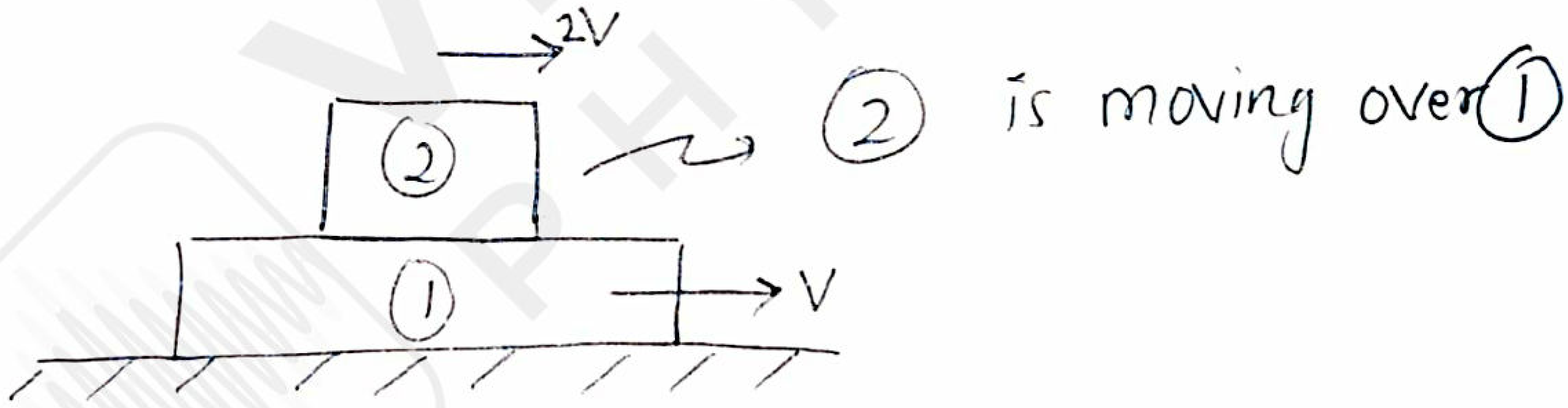
→ The value of μ_K and μ_s depend on the nature of the surface.

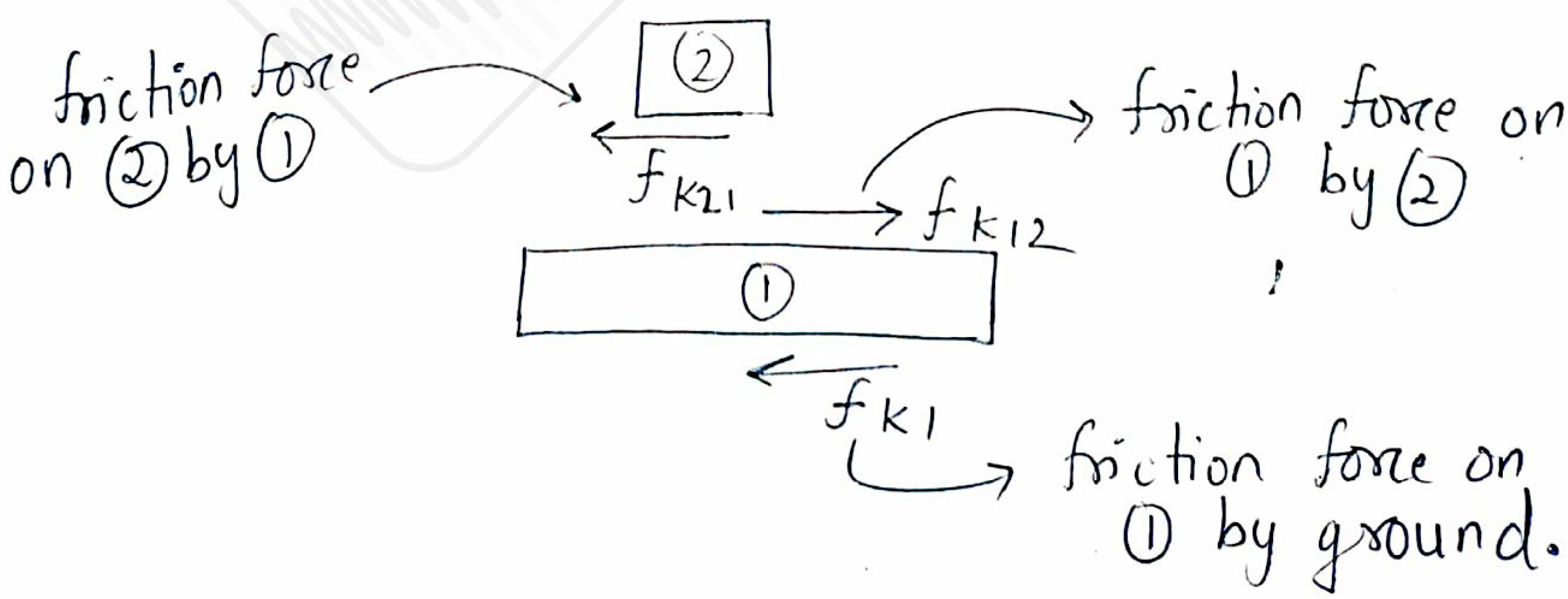
Limiting friction laws: (Limiting friction → $\mu_s N$)

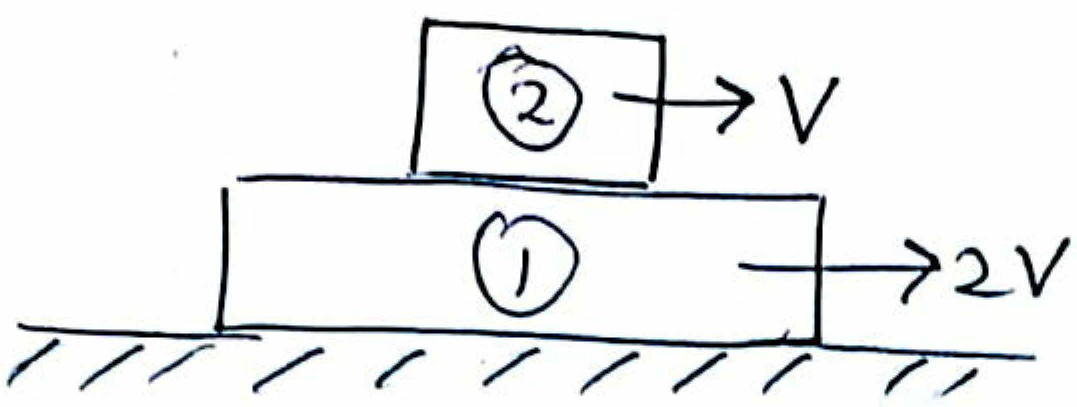
→ limiting friction force is independent of the apparent area of contact till N remain same

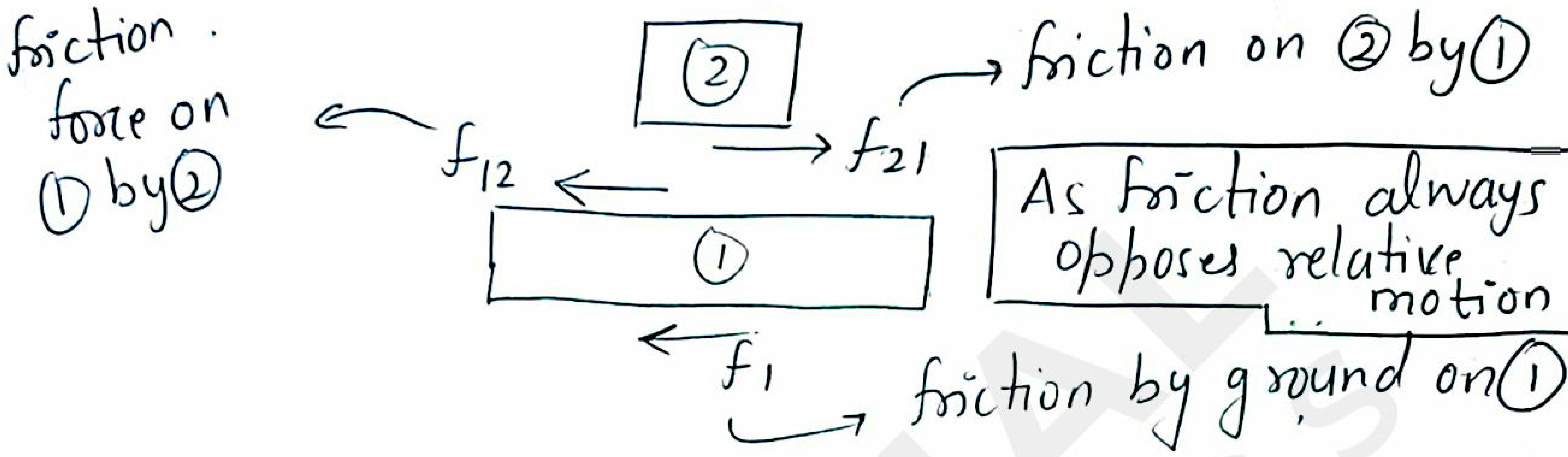
→ direction of limiting force opposite to direction in which one body is on the verge of starting its motion.

→ It depends of surface in contact.



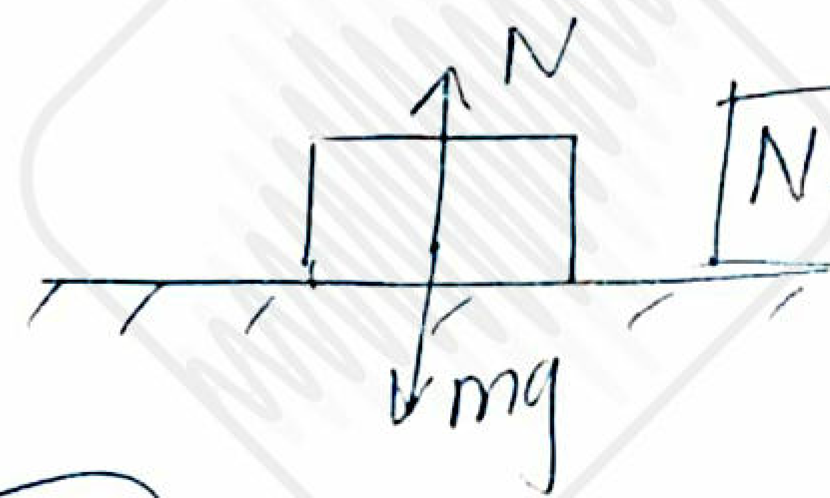




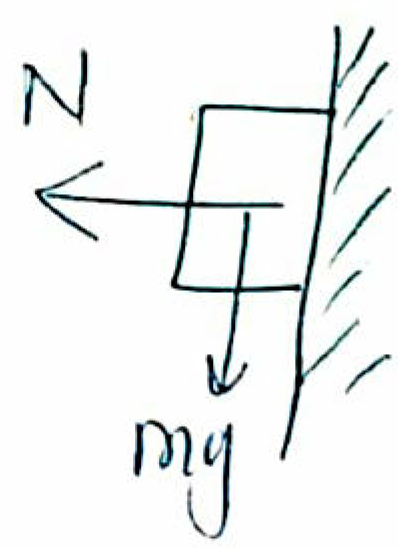


As friction always opposes relative motion

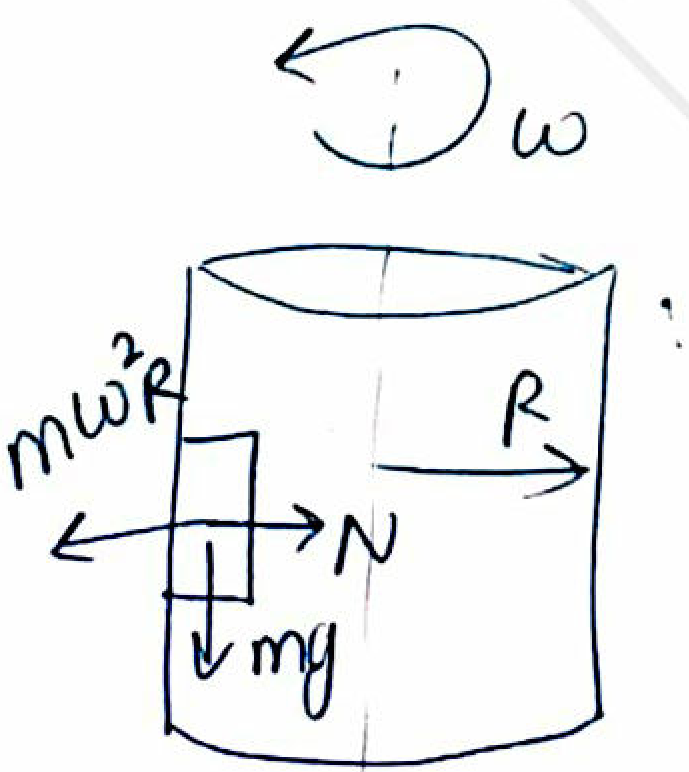
Normal force



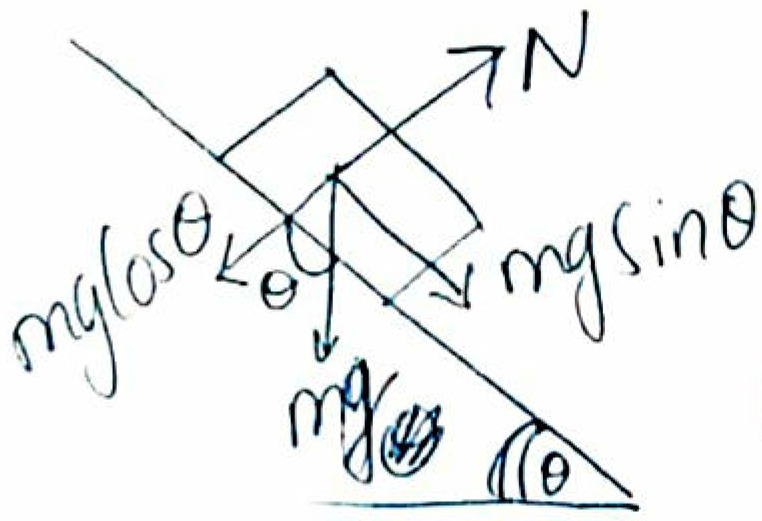
$N = mg$



$N = 0$



$N = m\omega^2 R$

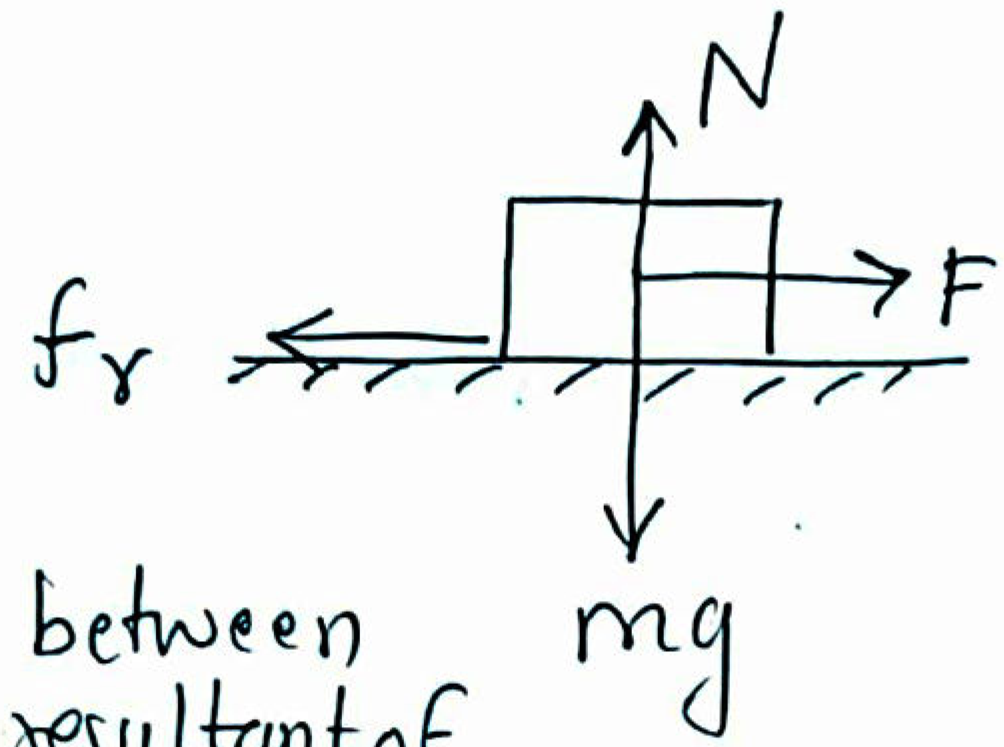


$N = mg\cos\theta$

And many more cases.

N is normal force between contact surface.

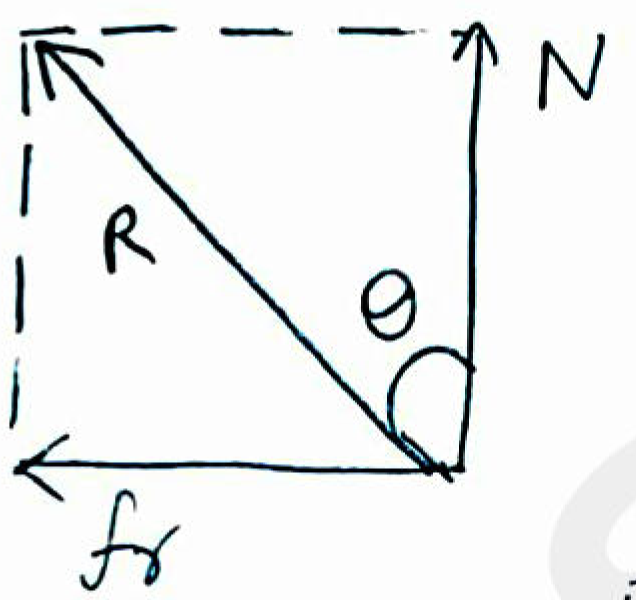
Angle of friction



Now at condition

$f_r = f_{lim} = f_s = \mu_s N$

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



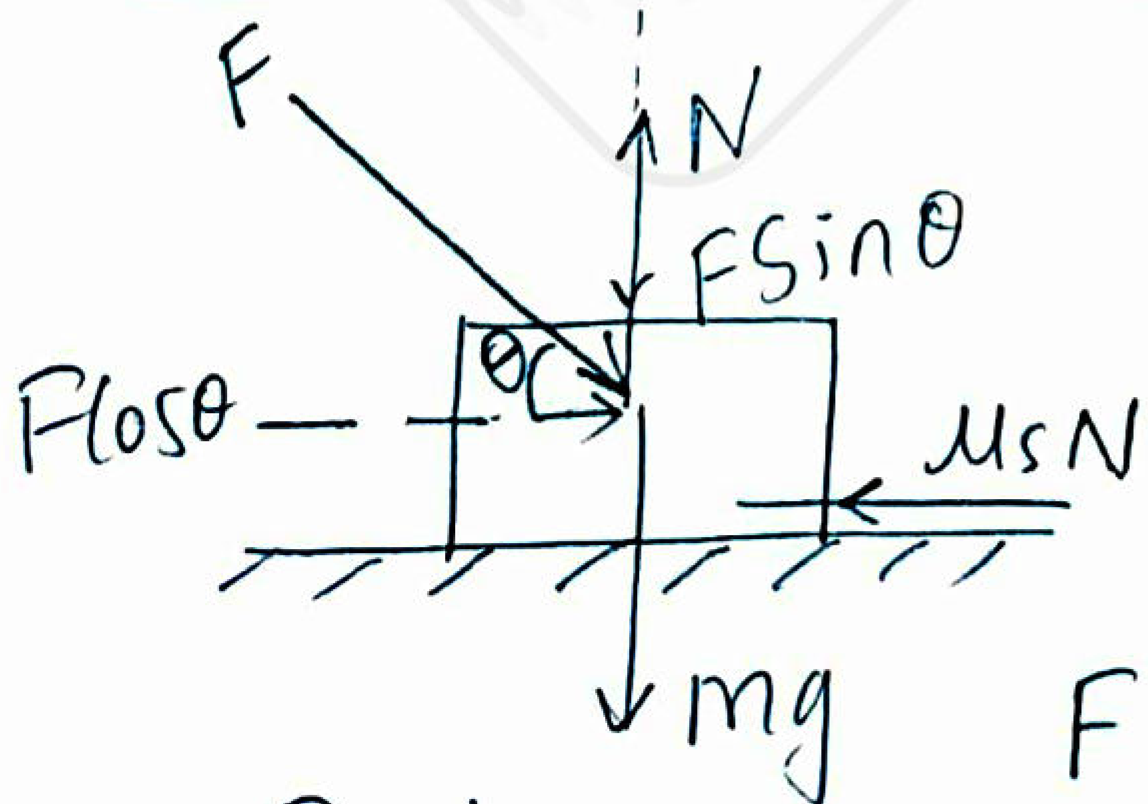
$\tan\theta = \frac{f_r}{N} = \frac{f_s}{N} = \frac{\mu_s N}{N}$

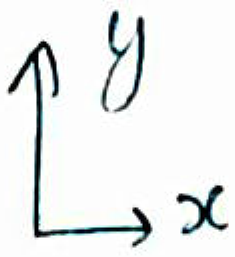
$\boxed{\tan\theta = \mu_s}$

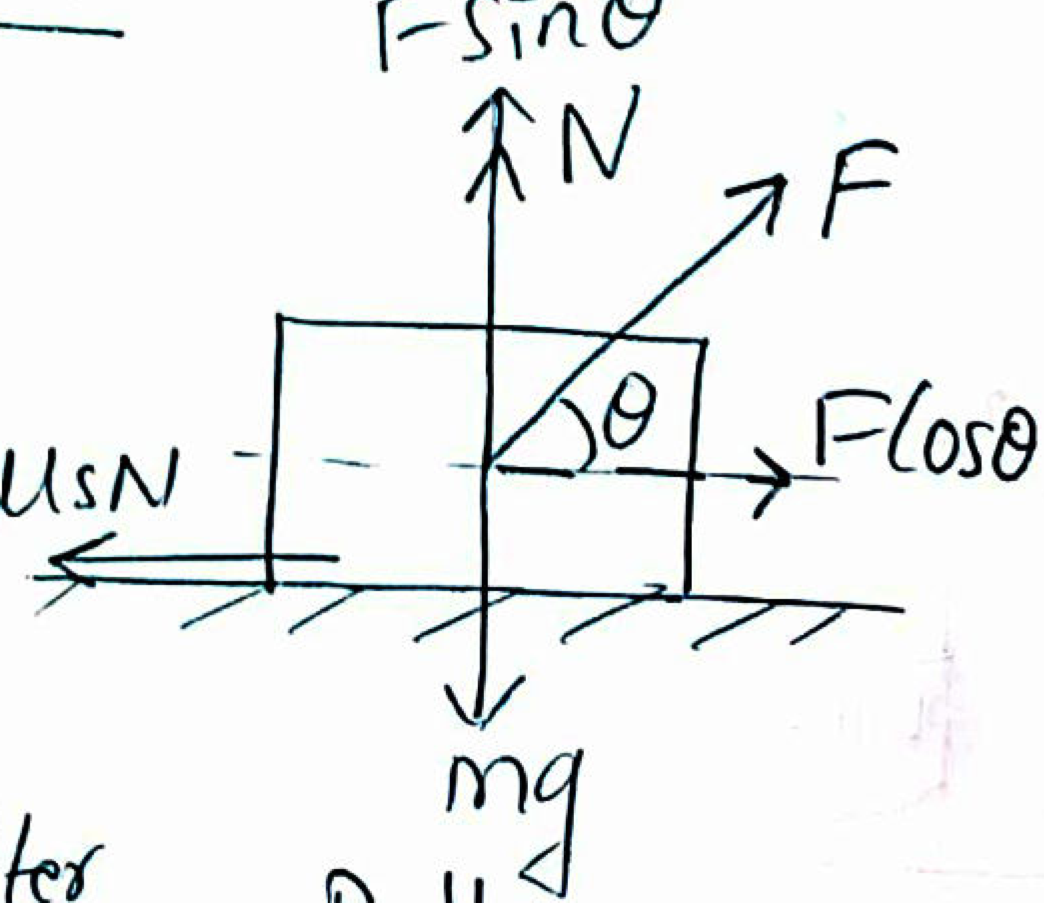
$\boxed{\theta = \tan^{-1}(\mu_s)}$

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.

$\Sigma F_y = 0$ 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

$\Sigma F_y = 0$

or $N = mg - F\sin\theta$

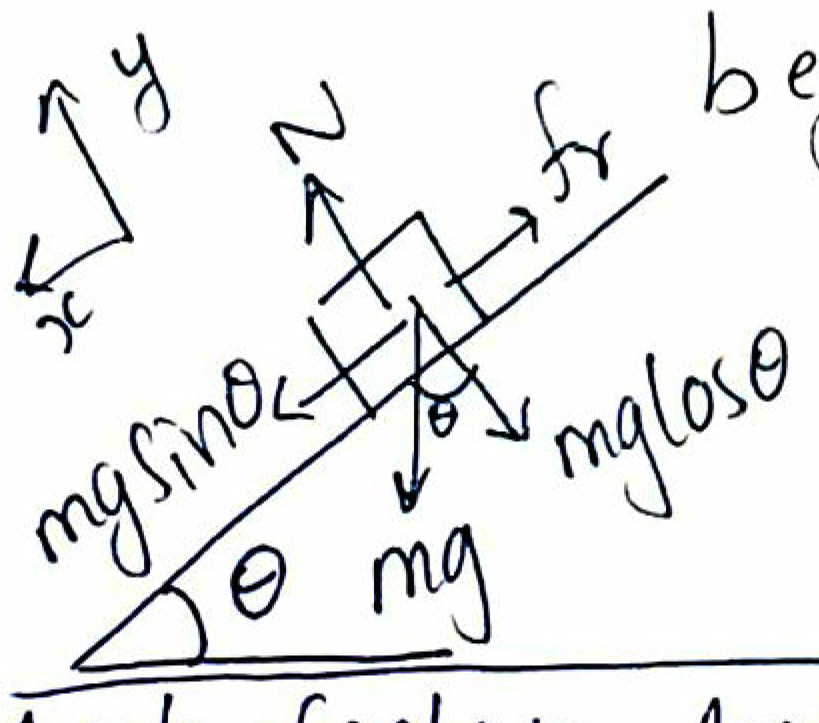
$F\cos\theta = \mu_s N = \mu_s(mg - F\sin\theta)$

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

" On comparing the force for push is 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"



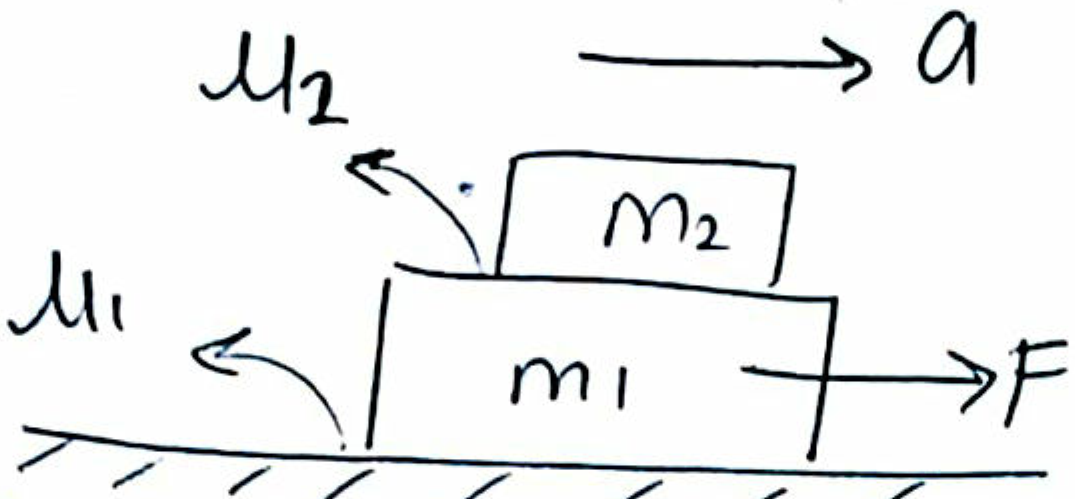
$f_r = f_s = \mu_s N = mg\sin\theta$ for $\Sigma F_x = 0$

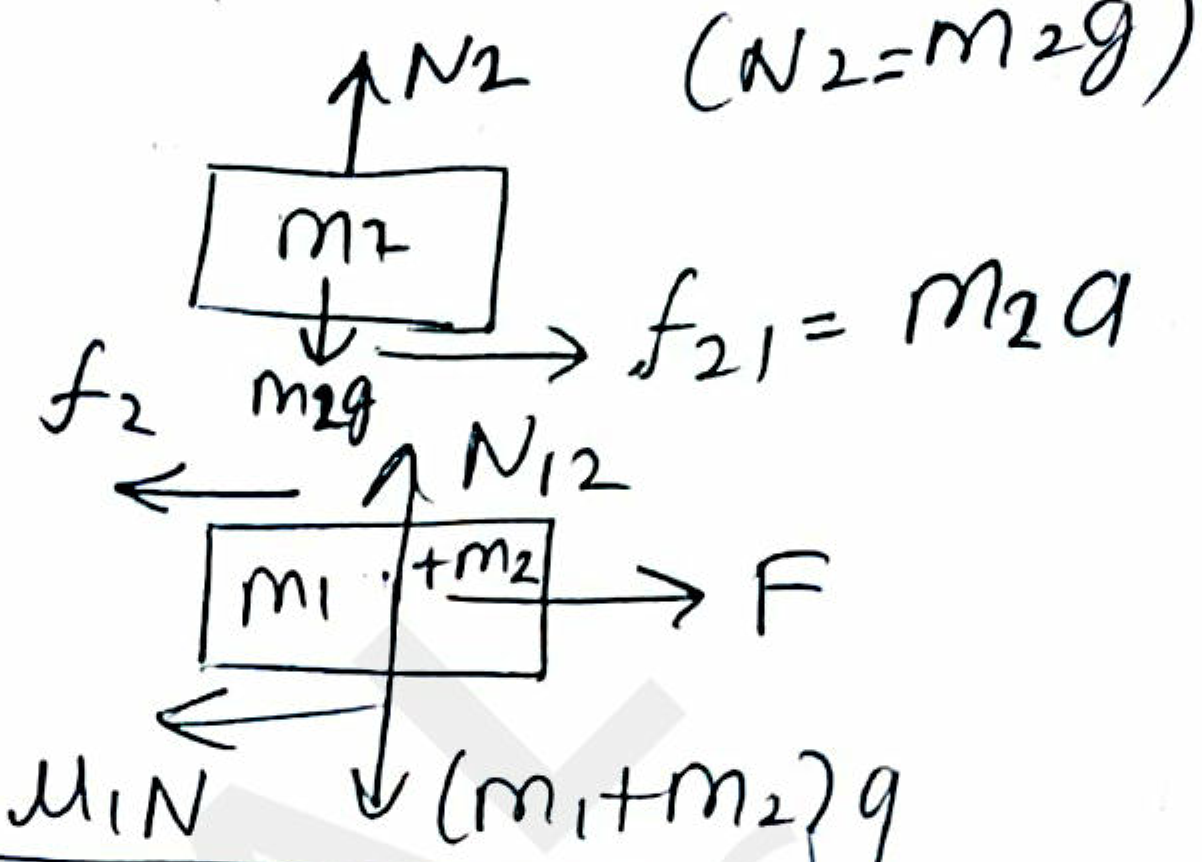
$\Rightarrow \mu_s(mg\cos\theta) = mg\sin\theta$

$\tan\theta = \mu_s$ → friction angle at limiting case

★ Angle of repose = Angle of friction

Friction acting on multiple surfaces





$f_{21} \rightarrow$ friction between ① & ②

$N_{12} \rightarrow$ Normal of ① & ② together

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

taking (m_1 & m_2) as a system

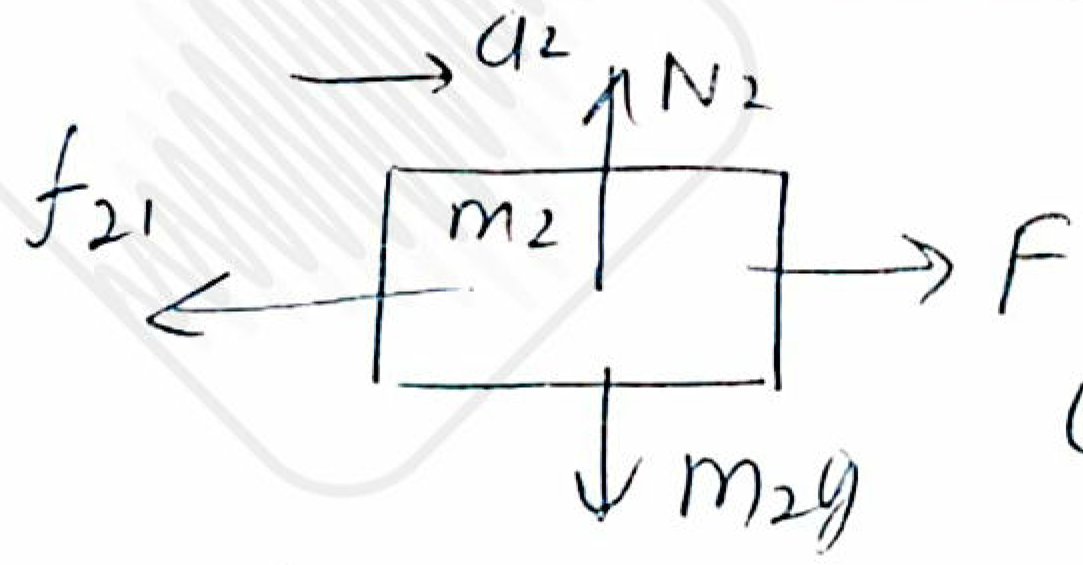
$a_{max} \rightarrow f_{21} \rightarrow max$

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

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

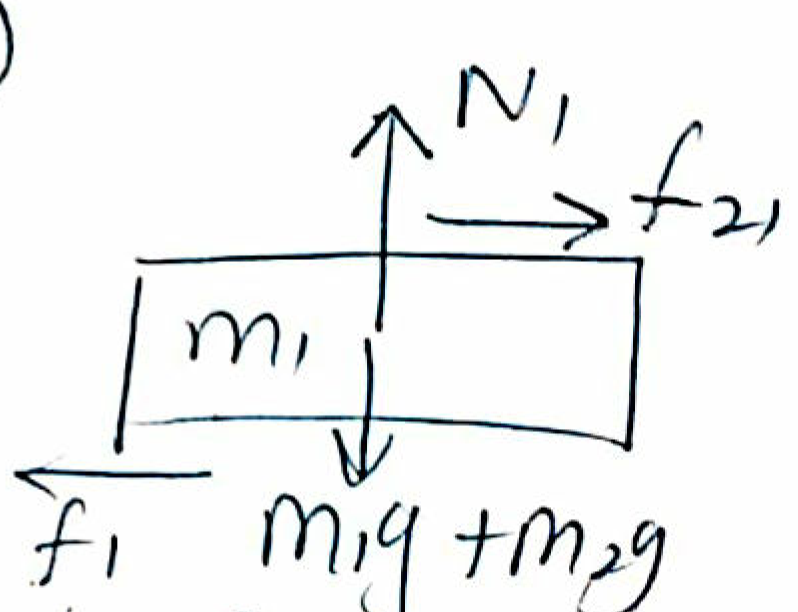
$$\boxed{a_{max} = \mu_2 g}$$

→ " If force were on upper block



$f_{21} \rightarrow$ friction betwee ① & ②

$(N = m_2 g)$



f_1 ↳ friction on ① by ground

$F - f_{21} = m_2 a_2$

$$\boxed{F - \mu_2 m_2 g = m_2 a_2}$$

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)

$$\boxed{f_2 - f_1 = m_1 a}$$

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'.

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

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