'FRICTION'

Property of oppose b/w Relative motion of two surface.

Property of oppose b/w Relative motion of two surface of same liq. ⇒ viscosity.

Type of friction

* Internal Friction → Friction b/w two surface of same liq. / b/w two layer of solid.
* External Friction → B/w surface of two different solid.
  - (a) → Static Friction → * When body at Rest, friction force b/w two surface of solid.
    * It is self adjusting friction & It max value is called limiting friction.
    * $F_L = (F_s)_{max}$
  - (b) → Dynamic/Kinetic friction → When body move fr. b/w two surface of solid.

Limiting friction depend on →
* It is $\propto$ Normal Rkn. $F_L \propto N$
* It depend on nature of surface.
* Independent from surface or contact Area.

Max value of static friction → $F_L \propto N$

$$F_L = (F_s)_{max} = \mu_s N$$

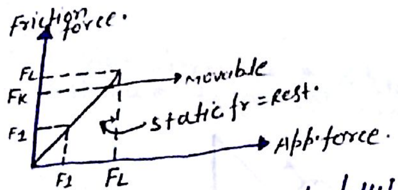
μ_s = static friction coefficient.

kinematic friction →

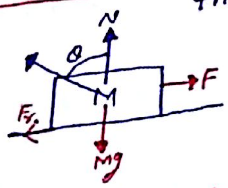
$F_K \propto N$ $F_K = \mu_K N$

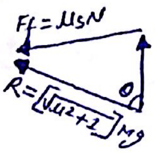
$F_L > F_K \Rightarrow \mu_s > \mu_K$

NOTE →
* $(F_{ex})_{app} < F_L = (F_s)_{max}$ ⇒ Body does not move ⇒ $F.F = (F_{ex})_{app}$.
* $(F_{ex})_{app} = F_L = (F_s)_{max} \Rightarrow F.F = F_L = (F_s)_{max}$
* $(F_{ex})_{app} > F_L \Rightarrow$ body moves on surface ⇒ $F.F = F_K$
* order of friction → $\mu_s > \mu_K > \mu_R$

#


Friction Angle (θ) → Angle b/w Resultant of Normal Rkn. & friction force normal to the surface.

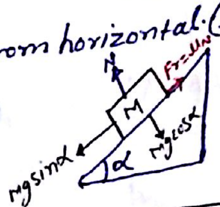




$\tan\theta = \frac{F_f}{N} = \frac{\mu N}{N} = \mu_s$

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

Angle of Repose → Angle of plane surface from horizontal. (If body just slide on surface).



* Just slide on surface.

$Mg\sin\alpha = F_r = \mu_s N$

$Mg\sin\alpha = \mu_s(Mg\cos\alpha)$

$\tan\alpha = \mu_s$

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

Angle of Repose = Angle of friction.

NOTE
* (a) → $\alpha = \theta \Rightarrow$ Just slide on surface ⇒ $F.F \Rightarrow \mu_s Mg\cos\alpha$
* (b) → $\alpha < \theta \Rightarrow$ Body prescent at Rest ⇒ $F.F \Rightarrow Mg\sin\alpha$.
* (c) → $\alpha > \theta \Rightarrow$ Body moving downward ⇒ $F.F \Rightarrow F_K = \mu_K = \mu_K Mg\cos\alpha$

$$a = g\sin\alpha - \mu_K\cos\alpha$$

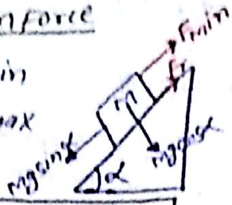
$$Mg\sin\alpha > \mu_s Mg\cos\alpha$$

Minimum & Maximum force Required to hold the object in a incline plan (Force applied parallel to the Incline surface).

* Minimum Force

$Mg\sin\alpha = F_r + F_{min}$

$F_{min} = Mg\sin\alpha - (F_r)_{max}$

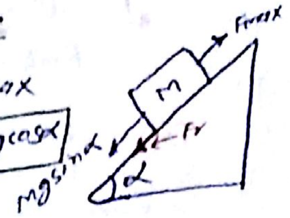


* $F_{min} = Mg\sin\alpha - \mu_s Mg\cos\alpha$

* Maximum Force

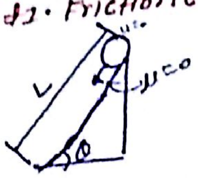
$F_{max} = Mg\sin\alpha + (F_r)_{max}$

* $F_{max} = Mg\sin\alpha + \mu_s Mg\cos\alpha$

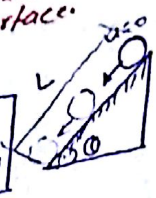


Body is drop from top point of Inclined plane of Angle of Inclination is 'θ'. If time taken by particle to Reached at bottom resp. t_1 & t_2 when surface is smooth & Rough & Relation t_1 & t_2. t_2 = 'n' times of t_1. Friction coefficient of Rough surface.

$$t_1 = \sqrt{\frac{2L}{g\sin\theta}}$$



$$t_2 = \sqrt{\frac{2L}{g\sin\theta - \mu g\cos\theta}}$$



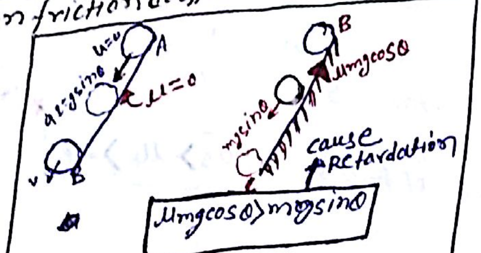
* $$\mu = \tan\theta\left(1 - \frac{1}{n^2}\right)$$

Exemplar:

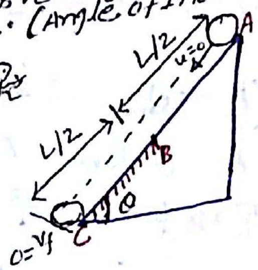
$$\mu = \left(1 - \frac{1}{p^2}\right)$$

First half length of Incline plane is smooth & Remaning half is Rough. If particle is drop from top point of Incline plane along the Incline surface & velocity of particle at bottom point is zero. Then friction coefficient of Rough surface. (Angle of Inclination 'θ')

* $\mu = 2\tan\theta$



$\mu mg\cos\theta > mg\sin\theta$



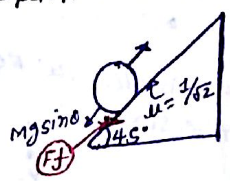
Particle is projected upward along the surface of Inclined plane, friction coefficient is $\frac{1}{\sqrt{2}}$ & Angle of Inclination is 45°. Calculate Retardation of particle Along the Incline plane.

$F = mg\sin\theta + \mu mg\cos\theta$

$a_R = g\sin\theta + \mu g\cos\theta$

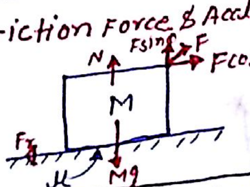
$= g\sin 45° + \left(\frac{1}{\sqrt{2}}\right)g\cos 45°$

* $$R = \frac{g}{\sqrt{2}} + \frac{g}{2} = \frac{g}{2}(\sqrt{2}+1)$$



Friction Force & Accln of Body.

|A| →

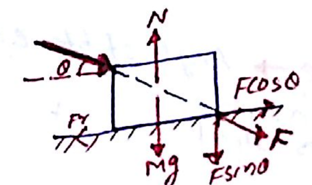


$N = Mg - F\sin\theta$
⇓
$F_r = \mu N$

$F_r = \mu(Mg - F\sin\theta)$

$$a = \frac{F_{net}}{M_{net}} = \frac{F\cos\theta - \mu(Mg - F\sin\theta)}{M}$$

|B| →



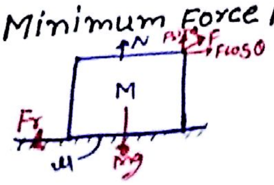
$N = Mg + F\sin\theta$ $\quad$ $F\sin\theta > F_r$ *

$F_r = \mu N = \mu(Mg + F\sin\theta)$ *

$$a = \frac{F_{net}}{M_{net}} = \frac{F\cos\theta - \mu N}{M}$$

NOTE → pull is easier than push.

Minimum Force Required to pull the object.



$\mu_s = \tan\theta$ *

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

* $$F_{min} = \frac{\mu_s Mg}{\sqrt{1+\mu_s^2}}$$

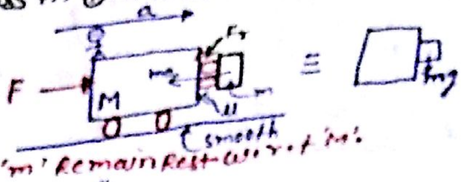
Magnitude of minimum force Required If mass 'm' at Rest w.r.t. M

$N = ma$

$a \geq g/\mu$

$a_{min} = g/\mu$

$$F_{min} = (M+m)a_{min} = \frac{(M+m)g}{\mu}$$



Max value of force applied on mass 'M' so that 'm' remain Rest w.r.t. 'M'

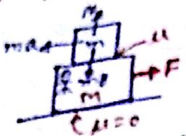
$F_r \geq ma$

$a \leq \mu g$

$a_{min} = \mu g$

$$F_{max} = (M+m)a = \mu(M+m)g$$

$$F > \mu(M+m)g$$



Chain of Length 'L' placed on Rough horizontal surface of friction coefficient 'μ' than Maximum length of its hanging part. If it remain in Rest (mass is uniformally distributed).

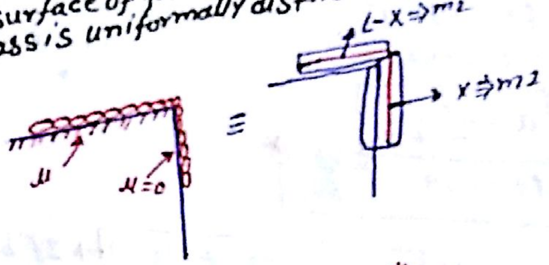
$L = M$

$1 = \frac{M}{L}$

$X = \frac{M}{L}x = m_1$

$L - X = \frac{M}{L}(L-x) = m_2$

$$X = \frac{\mu L}{\mu + 1}$$



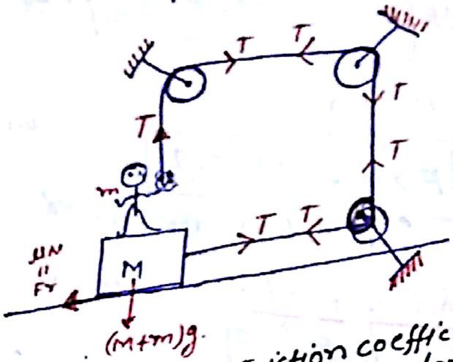
NCERT

Force Applied by person to prevent sliping.

$F \geq T$

$$T \leq \frac{\mu(M+m)g}{\mu+1}$$

$$T_{max} = F_{max} = \frac{\mu(M+m)g}{\mu+1}$$



Vechile of mass 800 kg moves on circular path of Radius 10m. Friction coefficient of surface is 0.5. calculate maximum safe velocity of veachle on circular path.

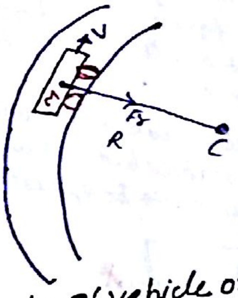
$$F_r \geq \frac{mv^2}{R}$$

$$V \leq \sqrt{\mu R g}$$

$$V_{max} = \sqrt{\mu R g}$$

NOTE → * In a circular path necessary centripetal force is provided from fr. force.

* Magnitude of fr. force ≥ centrifugal force vechle safely turn on circular path.



$$V_{max} = \sqrt{(0.5)^2(10)(10)}$$

$$= \sqrt{50}\ m/sec.$$

Radius of death well is 10 m & minimum safe velocity of vehicle on death well is $5\sqrt{5}$ m/sec. than value of friction coefficient.

$$= \frac{10 \times 10}{(5\sqrt{5})^2} = \frac{100}{125}$$

$$= \frac{4}{5} = 0.8$$

$F_r \geq Mg$

$\mu N \geq Mg$

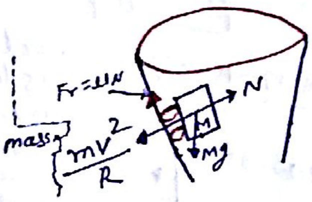
$$V \geq \sqrt{\frac{Rg}{\mu}}$$

$$V_{min} = \sqrt{Rg/\mu}$$

$$\mu_{min} = \frac{Rg}{V_{min}^2}$$

NOTE → * Max safe velocity is independent from of vehicle/man mass.

$V \propto m^0$



Friction in two block system

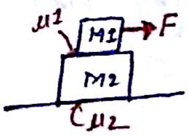
Case-I → Force is applied on upper block

[A] → $\mu = 0$

$$a = \frac{F}{M_1 + M_2}$$

$F - f_1 = M_1 a$ —(I)

$f_1 = M_2 a$ —(II)



* If both block move with some Acceleration.

$F \leq f_1$

⇓

$F \leq \mu_1 M_1 g$

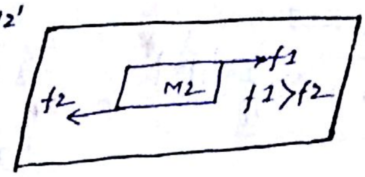
* $F > f_1$ ⇒ Both Block move with diff Acceleration.

[B] → $\mu_2 \neq 0$

sliding condn for 'M2'

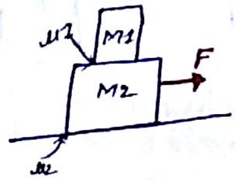
$f_1 \geq \mu_2 (M_1+M_2)g$

$\mu M_1 g \geq \mu_2 (M_1+M_2) g$



Case-II → Force applied on lower block

[A] → $\mu_2 = 0$



$f_1 = M_1 a$ — (I)

$F - f_1 = M_2 a$ — (II)

$a = \frac{F}{M_1+M_2}$

$f_1 = M_1 a = \frac{M_1 F}{M_1+M_2}$ *

$f_1 \geq M_1 a$

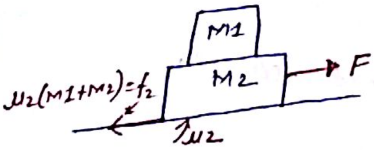
$\mu_1 M_1 g \geq \frac{M_1 F}{M_1+M_2}$ *

$F \leq \mu_1 (M_1+M_2) g$

→ If both block move with same Acceleration.

$F > \mu_1 (M_1+M_2) g$ → If both block move with different Acceleration.

[B] → $\mu_2 \neq 0$



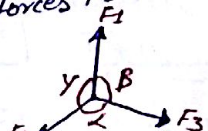
$F > \mu_2 (M_1+M_2) g$

→ Sliding condn for 'M2'

Equilibrium of Body.

$\Sigma \vec{F} = 0$, $\Sigma \vec{\tau} = 0$

Lamm's theorum → When 3-concorrent forces $\vec{F_1}, \vec{F_2}, \vec{F_3}$ act on body in eqm there.

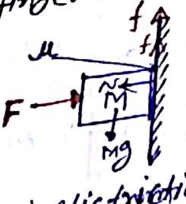


$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$

NOTE → * If 'N' coplaner forces of equal magnitude act on body at equal angle with each other than net force it will be zero. hence body is in eqm.

* If 'N' force act on a body & these forces form closed polygonal then Resultant force will be zero.

A block of mass 'M' is held against a Rough vertical wall by pressing it with a finger. If the coeficient of friction b/w block & wall is 'μ' & Acceleration due to gravity is 'g'. than minimum force Required to be applied by the finger to hold block against the Wall.



$f = Mg$ — (I)

$F = N$ — (II)

$\mu F = Mg$ *

$F = \frac{Mg}{\mu}$

Rolling friction → * oppose of Roling Motion.

* Magnitude is less than from kinetic friction.

Rolling fr. $F_R = \frac{\mu_R N}{r}$ — N: Normal Reaction, r: Radius.

2016 JIMER NOTE → * In case of pure Rolling Motion, Work done by fr. force will be zero, so in this case friction is non-dissipiated. (not loss).

* When body Rool on horrizontal plane the velocity of contact point Remian zero.

NCERT Exemplar # → $m = F/a$

Inertial Mass: $m_i = \frac{F}{a}$ *

Gravitation Mass: $m_g = F/g$ *

$\frac{m_i}{m_g} = 1:1$ *

NOTE → * Every body have Inertia (ie Mass) but its weight (mg) can be zero.

* In a tunnel through the centre of the earth, the object moves only due to Inertia at the centre while its weight becomes zero.

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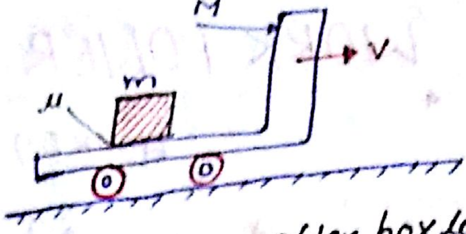
*V_{max} so that block remain stationary with truck.



$V_{max} \geq ma$

$\mu m g \geq Ma$

$\boxed{\mu \geq a}$ $\boxed{\mu_s \geq a/g}$ *

* If truck accelerate & box start Moving backward than time after box leave the truck

$$\boxed{t = \sqrt{\frac{2L + l}{\mu_s g}}}$$ *

[L = Length of truck
l = length of box]