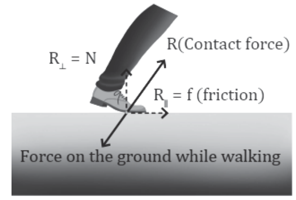
APPLICATIONS OF FRICTION

Role of friction in walking

When an individual walks on the ground, the force of friction aids in their forward movement.

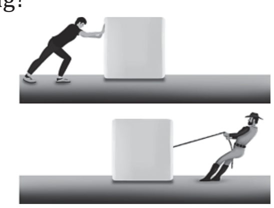
During walking, the foot applies pressure to the ground at an angle. Consequently, the ground exerts a reaction force on the foot.

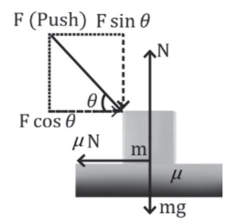


The normal reaction arises from the perpendicular component of this reaction force, while the frictional force stems from its parallel component. This frictional force aids in propelling us forward. When walking forward, there's a natural tendency for our feet to slip backward. Thus, friction acts in the forward direction, facilitating our forward movement.

Pulling – Pushing

Why is pulling easier than pushing?





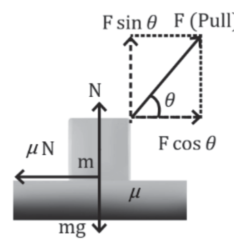
Imagine the block being pushed at an angle θ relative to the horizontal.

Along the vertical, $N = mg + F\sin\theta$

Along the horizontal (just when the sliding starts),

$$F\cos\theta = \mu N = \mu(mg + F\sin\theta)$$

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



Imagine the block being pulled at an angle θ relative to the horizontal.

Along the vertical, $mg = N + F\sin\theta$

$N = mg - F\sin\theta$

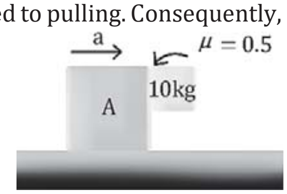
Along the horizontal (just when the sliding starts),

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

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

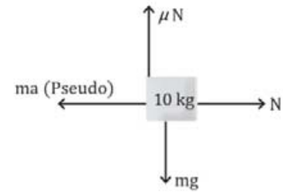
Pushing	Pulling
The pushing force's vertical component points downward.	The pulling force's vertical component is directed upward.
Normal reaction, $N = mg + F\sin\theta$	Normal reaction, $N = mg - F\sin\theta$
Pushing force required to start the motion, $F = \frac{\mu mg}{\cos\theta - \mu\sin\theta}$	Pulling force required to start the motion $F = \frac{\mu mg}{\cos\theta + \mu\sin\theta}$

Therefore, initiating motion requires more force when pushing compared to pulling. Consequently, pulling is comparatively easier than pushing.



Ex. Find the minimum acceleration of the block A so that the 10 kg block does not slip down.

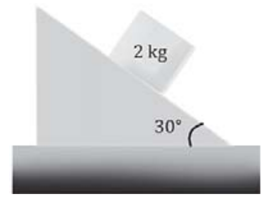
Sol. If the 10 kg mass remains stationary without sliding downward, its weight is countered by the frictional force between block A and the 10 kg block. The normal reaction at the contact surface arises due to the acceleration (a) of block A. Consequently, the normal reaction force equals the pseudo force (ma) of the 10 kg block.



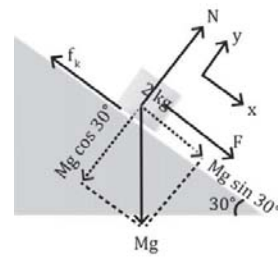
Therefore, as acceleration increases, the normal reaction also increases, leading to an increase in the friction force. The minimum acceleration required to prevent slipping corresponds to the limiting frictional force.
From the FBD of the 10 kg block,
Frictional force $= (f_s)_{max} = \mu N = \mu ma$
Weight is balanced by the frictional force

$$\mu ma = mg$$
$$a = \frac{mg}{\mu m} = \frac{g}{\mu} = \frac{10}{0.5} = 20 ms^{-2}$$

Ex. A block of mass 2 kg slides on an inclined plane that makes an angle of 30° with the horizontal. The coefficient of friction between the block and the surface is $\frac{\sqrt{3}}{2}$.
What force along the plane should be applied on the block so that it moves in the following ways?



(a) Downwards without any acceleration
(b) Upwards without any acceleration (Take $g = 10 ms^{-2}$)



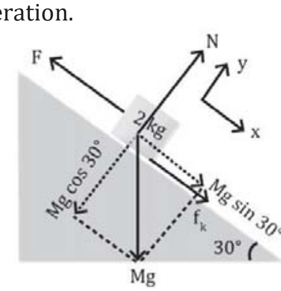
Sol. **(a)** Block slides downwards without any acceleration.
When the block slides downwards, kinetic friction acts up the incline plane.
Balancing forces along the y direction,

$$N = Mg\cos 30° = 20 \times \frac{\sqrt{3}}{2} = 10\sqrt{3} N$$

Balancing forces along the x direction,

$$F + Mg\sin 30° = f_k$$
$$F + 2 \times 10 \times \frac{1}{2} = \mu N (\because f_k = \mu N)$$
$$F + 10 = \left(\frac{\sqrt{3}}{2}\right)(10\sqrt{3})$$
$$F = 5N$$

When the block slides downwards, kinetic friction acts up the incline plane. Hence, a force of 5 N should be applied to move the block down the plane without any acceleration.



(b) Block slides upwards without any acceleration.
When the block slides up the inclined plane, kinetic friction acts down the inclined plane. Balancing forces along the y direction,

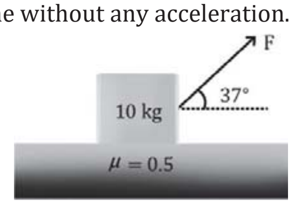
$$N = Mg\cos 30° = 20 \times \frac{\sqrt{3}}{2} = 10\sqrt{3} N$$

Balancing forces along the x direction,

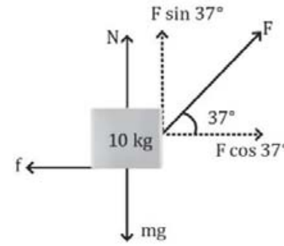
$$F = f_k + Mg\sin 30°$$
$$F = \mu N + 2 \times 10 \times \frac{1}{2} (\because f_k = \mu N)$$
$$F = \left(\frac{\sqrt{3}}{2}\right)(10\sqrt{3}) + 10$$
$$F = 25N$$

Hence, a force of 25 N should be applied to move the block up the plane without any acceleration.

Ex. Force F is gradually increasing from zero. Determine whether the block will slide first or lift up.



Sol. The horizontal component of force F tries to slide the block while the vertical component of F tries to lift the block.



Case 1: The block is lifted up

When the block is lifted, the weight of the block is balanced by the vertical component of the force F. Hence, normal reaction (N) becomes zero.

$$mg = F\sin 37^0$$
$$10 \times 10 = F \times \frac{3}{5}$$
$$F = \frac{500}{3}\,N$$

If $F \geq \frac{500}{3}$ N, the block will be lifted up.

Case 2: The block slides

When the block starts to slide, limiting friction acts on the block, Balancing forces along the vertical direction.

$$N + F\sin 37^\circ = mg$$
$$N = mg - F\sin 37^\circ = 100 - \frac{3F}{5}$$

Balancing forces along the horizontal direction,

$$(f_s)_{mix} = F\cos 37^\circ$$
$$\text{or } \mu N = \frac{4F}{5}$$
$$\text{or } \left(\frac{1}{2}\right)\left(100 - \frac{3F}{5}\right) = \frac{4F}{5}$$
$$F = \frac{500}{11}\,N$$

As the force required to slide the body is less than the force required to lift it up, the body will slide first.