Friction

Friction force :
is the force resisting the relative motion of two surfaces in contact
There are two types of friction :
Static friction
Static friction is friction between two objects that are not moving relative to each other. For example, static friction can prevent an object from sliding down a sloped surface. The coefficient of static friction, typically denoted as μ_s, is usually higher than the coefficient of kinetic friction.
Kinetic friction
Kinetic (or dynamic) friction occurs when two objects are moving relative to each other and rub together (like a sled on the ground). The coefficient of kinetic friction is typically denoted as μ_k, and is usually less than the coefficient of static friction.

The **coefficient of friction**:
(also known as the **frictional coefficient**) is a dimensionless scalar value which describes the ratio of the force of friction between two bodies and the force pressing them together. The coefficient of friction depends on the materials used; for example, ice on steel has a low coefficient of friction (the two materials slide past each other easily), while rubber on pavement has a high coefficient of friction (the materials do not slide past each other easily). Coefficients of friction range from near zero to greater than one – under good conditions
The **coefficient of friction** is a dimensionless quantity symbolized by the Greek letter(μ) and is used to approximate the force of friction. Friction can be viewed, again as an approximation, as being of two primary types, *static* or *kinetic*.
The coefficient of *static* friction is defined as the ratio of the *maximum static friction* force (**F**) between the surfaces in contact to the *normal* (**N**) force. The coefficient of *kinetic* friction is defined as the ratio of the *kinetic friction* force (**F**) between the surfaces in contact to the normal force:

$$\mu = \frac{F_f}{N}$$

μ : **coefficient of friction**
F_f : **Friction force**
N : Normal force
Both static and kinetic coefficients of friction depend on the pair of surfaces in contact; their values are usually approximately determined experimentally. For a given pair of surfaces, the coefficient of static friction is *usually* larger than that of kinetic friction; in some sets the two coefficients are equal, such as Teflon-on-Teflon.

Angle of friction (α)

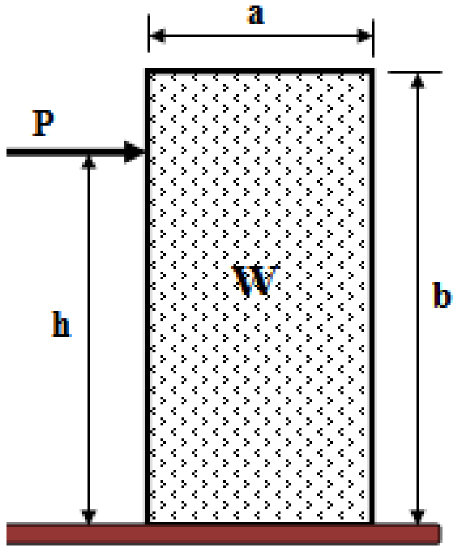
The angle of friction for two surfaces in contact is defined as the angle that the maximum contact force makes with the direction of normal force

$$\mu = \tan(\alpha)$$

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

EX (1) :

In fig. shown , a = 12 cm , b = 18 cm , h = 15 cm ,
W = 100 N , μ = 0.24 , P = 24 N
Is the body sliding or turning over or stay at rest ?



Solution :

$$h_{\max} = \frac{W.a}{2*P} \frac{100(12)}{2(24)} = 2.5cm$$

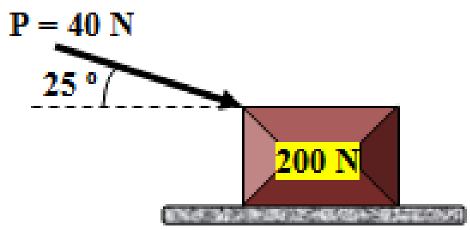
When $h_{\max} > b$ then the force doesn't effect on the body , therefore , the body is not turnover .

$$F_{\max} = \mu.W = 0.24(100) = 24 \quad , \quad F_{\max} = P$$

Then the body tends to slide and doesn't turnover

EX (2) :

A block with (200 N weight rests on a rough horizontal plane , is subjected to the force (P = 40 N) which inclined (25 ^{o}) . Determine the **coefficient of friction**.



Solution :

$$\sum F_x = 0$$

$$F_f = 40\cos 25$$

$$\sum F_y = 0$$

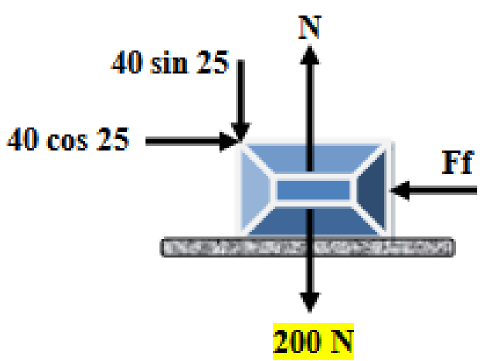
$$N - 40\sin 25 - 200 = 0$$

$$N = 40\sin 25 + 200 = 217N$$

$$F_f = \mu.N$$

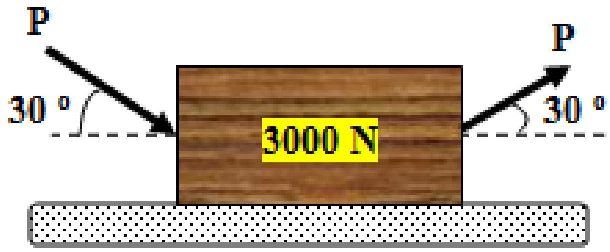
$$36.25 = \mu(217)$$

$$\mu = \frac{36.25}{217} = 0.17$$



EX (2) :

A wooden block (3000 N) weight , the **coefficient of friction** between the block and the floor is (0.35) , Determine whether pushing or pulling process by the force (P) is suitable to make the block tend to move to the right with a least force (P) , (i . e , which is easy pushing or pulling)



Solution :

In case of Pushing

$$\sum F_x = 0$$

$$P \cos 30 - F_f = 0$$

$$F_f = 0.866\ P$$

$$\sum F_y = 0$$

$$N - P \sin 30 - 3000 = 0$$

$$N = P \sin 30 + 3000$$

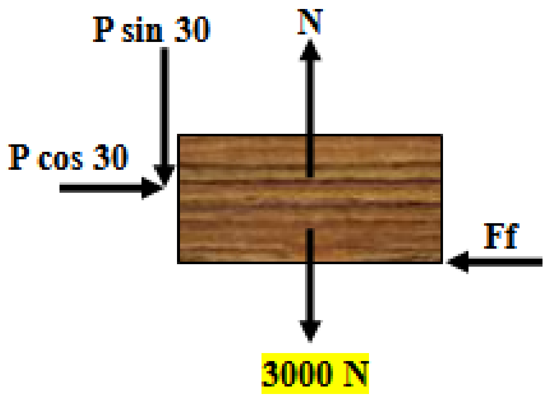
$$F_f = \mu . N$$

$$0.866\ P = 0.35\,(0.5P + 3000\ )$$

$$0.866\ P = 0.175\ P + 1050$$

$$0.691\ P = 1050$$

$$P = \frac{1050}{0.691} = 1519\ .4\,N$$



In case of Pulling

$$\sum F_x = 0$$

$$P \cos 30 = F_f$$

$$F_f = 0.866\ P$$

$$\sum F_y = 0$$

$$N + P \sin 30 - 3000 = 0$$

$$N = -P \sin 30 + 3000$$

$$N = +3000 - 0.5P$$

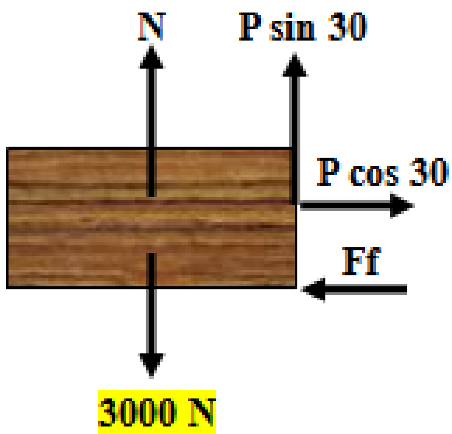
$$F_f = \mu . N$$

$$0.866\ P = 0.35\,(3000 - 0.5P)$$

$$0.866\ P = 1050 - 0.175\ P$$

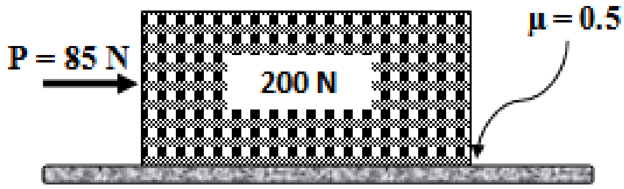
$$1.041\ P = 1050$$

$$P = \frac{1050}{1.041} = 1008\ .6\,N$$



EX (3) :

The (85 N) force (P) is applied to the (200 N) crate . Determine the magnitude and direction of the friction force (F_f) exerted by the horizontal surface on the crate .



Solution :

Assume equilibrium

$$\sum F_x = 0$$

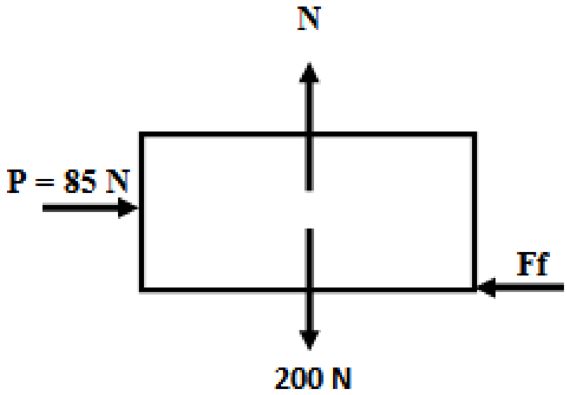
$$F_f = P = 85N$$

$$\sum F_y = 0$$

$$N = 200N$$

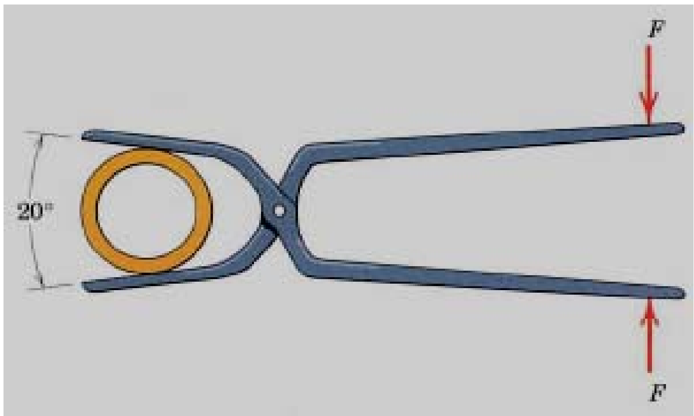
$$F_{f\ \max} = \mu.N = 0.5(200) = 100N$$

$$F < F_f \text{ , assumption volid , F = 85 N}$$



EX (4) :

The tongs are designed to handle hot steel tubes which are being heat- treated in an oil bath , for a (20°) jaw opening . What is the maximum coefficient of friction between the jaws and the tube which will enable the tongs to grip the tube without slipping.

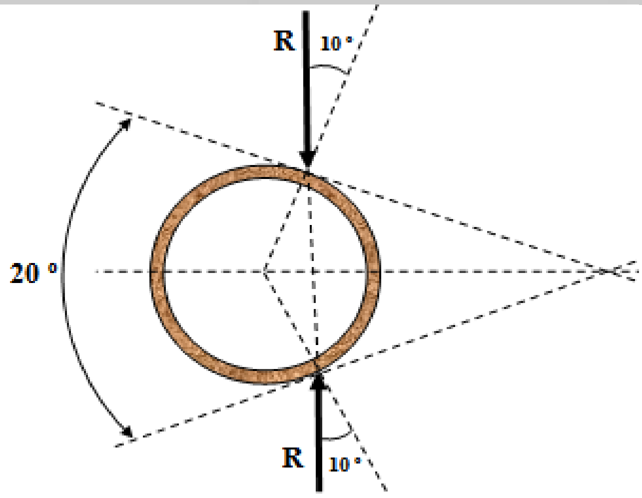


Solution :

$$\mu_{\min} = \tan\phi$$

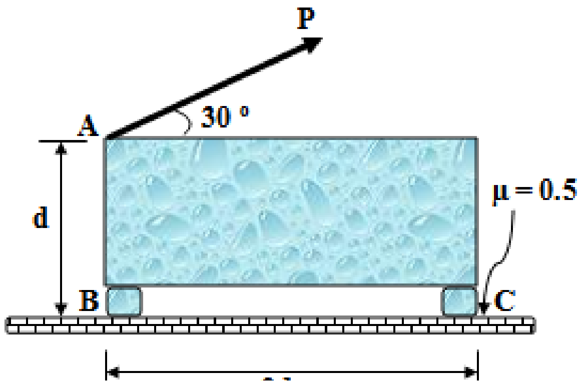
$$= \tan 10$$

$$= 0.176$$

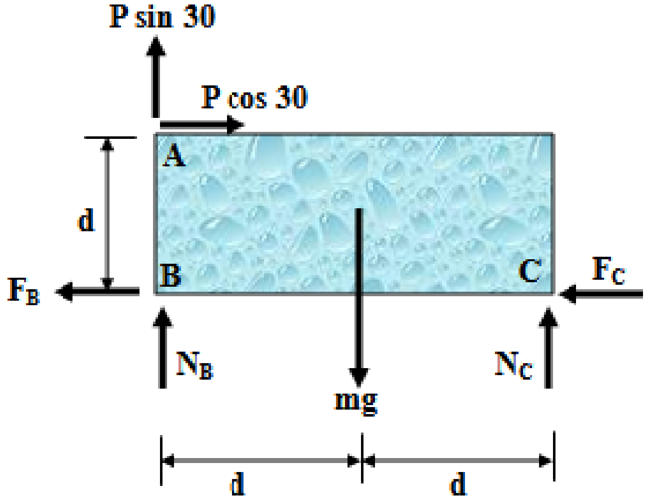


EX (5) :

The magnitude of the force (P) is slowly increased .Does the homogeneous box of mass (m) slip or tip first ? State the value of (P) which would cause each occurrence . Neglect any effect of the size of the small feet .



Solution :



Slips

$\sum F_x = 0$

$-F_B - F_C + P\cos 30 + 0$

$F_B = \mu.N_B \quad , \quad F_C = \mu.N_C$

$-\mu.N_B - \mu.N_C + P\cos 30 = 0$

$P\cos 30 = \mu.N_B + \mu.N_C \;..........(1)$

$\sum F_y = 0$

$N_B + N_C - mg + P\sin 30 = 0$

$N_B = -N_C + mg - P\sin 30 \quad ....(2)$

subst. (2) in (1) :

$P\cos 30 = \mu(mg - N_C - P\sin 30) + \mu.N_C$

$P\cos 30 = \mu.mg - \mu.N_C - \mu.P\sin 30 + \mu.N_C$

$P\cos 30 = \mu.mg - \mu.P\sin 30$

$P\cos 30 + \mu.P\sin 30 = \mu.mg$

$P(\cos 30 + \mu.\sin 30) = \mu.mg$

$$P = \frac{\mu.mg}{\cos 30 + \mu.\sin 30}$$

$$= \frac{0.5 * mg}{0.866 + 0.5 * 0.5} = 0.44mg = P(slip)$$

Tips

$\sum M(C) = 0$

$P\cos 30 * d + P\sin 30 * 2d - mg * d = 0$

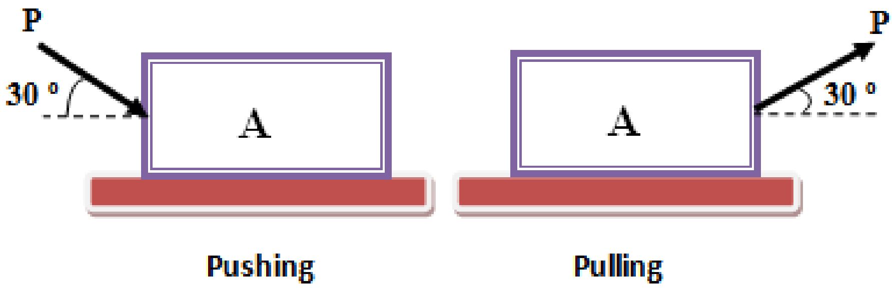
$$P = \frac{mg}{\cos 30 + 2\sin 30} = 0.53mg = P(tip)$$

$\because P(slip) < P(tip)$

then, Slipping will occur

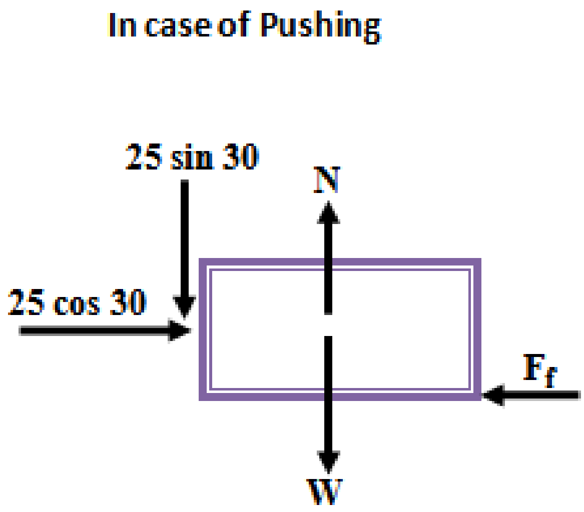
EX (6) :

The body (A) is to be tend to move to the right by the inclined force (P) which is (25 N) in case of pushing and it is (10 N) in case of pulling , Determine the weight of the body and the coefficient of friction between the body and the floor .



Solution :

In case of Pushing



$$\sum F_x = 0 \Rightarrow F_f = 25\cos 30 = 21.65N$$

$$\sum F_y = 0$$

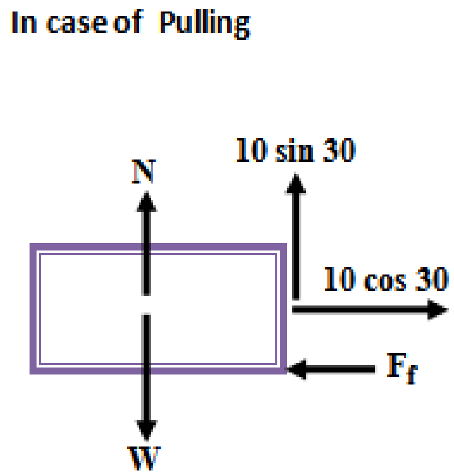
$$N - 25\sin 30 - W = 0$$

$$N = 25\sin 30 + W = 12.5 + W$$

$$F_f = \mu.N \Rightarrow 21.65 = \mu.(12.5 + W)$$

$$\mu = \frac{21.65}{12.5 + W}$$

In case of Pulling



$$\sum F_x = 0 \Rightarrow F_f = 10\cos 30 = 8.66N$$

$$\sum F_y = 0 \Rightarrow N + 10\sin 30 - W = 0$$

$$N = -10\sin 30 + W = W - 5$$

$$F_f = \mu.N \Rightarrow 8.66 = \mu.(W - 5)$$

$$\mu = \frac{8.66}{W - 5}$$

$$\frac{21.65}{12.5 + W} = \frac{8.66}{W - 5}$$

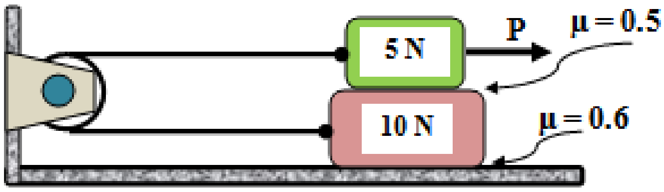
$$8.66(12.5 + W) = 21.65(W - 5)$$

$$W = 16.65 \qquad \text{ans}$$

$$\mu = \frac{8.66}{W - 5} = \frac{8.66}{16.65 - 5} = 0.74 \qquad \text{ans}$$

PROBLEMS

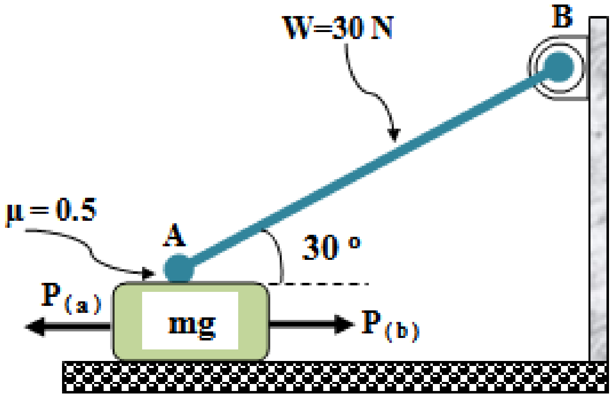
1 - The system of two blocks , cable and fixed pulley is initially at rest . Determine the horizontal force (P) necessary to cause motion , then determine the corresponding tension (T) in the cable .



2 -Determine the magnitude (P) of the horizontal force required to initiate motion of the block of mass (m_o) for the cases :

a – P is applied to the right .

b – P is applied to the lift .



3 – The sliding glass door rolls on the two small lower wheels (A) and (B) . Under normal conditions the upper wheels don't touch their horizontal guide .

a – compute the force (P) required to slide the door at a steady speed if the wheel (A) becomes " frozen " and does not turn in its bearing .

b – Rework the problem if wheel (B) becomes " frozen " instead of wheel (A) . if the coefficient of friction between a frozen wheel and supporting surface is (0.3) , and the center of mass of the (140 N) door is at its geometric center . Neglect the small diameters of the wheel