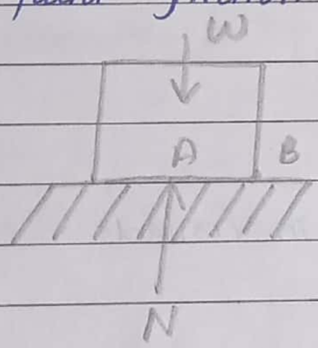
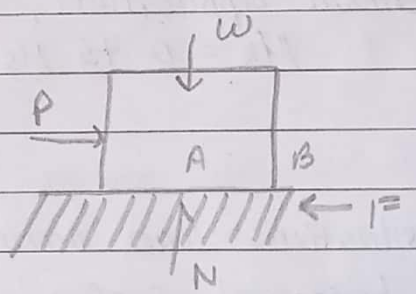
Friction:

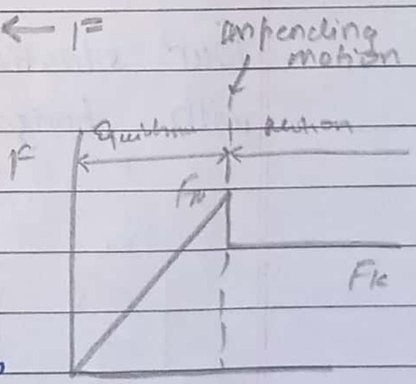
When two surfaces are in contact with each other, tangential forces will always developed when one surface tends to move with respect to other. The tangential forces are called frictional forces.

Frictional forces are limited in magnitude and don't prevent motion if you apply sufficient large force.

Friction are of two types: dry friction and fluid friction.







Firstly, the block of weight 'W' placed on horizontal surface. In this condition, the forces acting on the body are its weight and ~~to~~ reaction N.

When some horizontal force P is applied to block, the block remains stationary, the block experiences ~~F~~ horizontal component F of the surface reaction which is static friction force.

As P increases, the static friction force keeps increasing until it reaches a maximum value Fm.

i.e, $F_m = \mu_s N$

Further increase in P cause block to begin to move, the value of F drops to smaller kinetic friction force F_K.

$$F_K = \mu_K N$$

So,

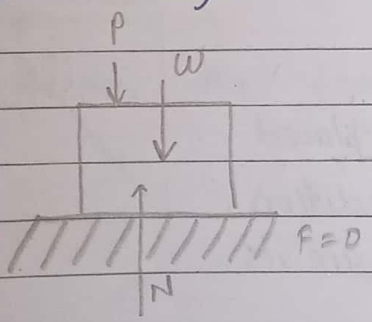
Static friction force (F_m) = $\mu_s N$

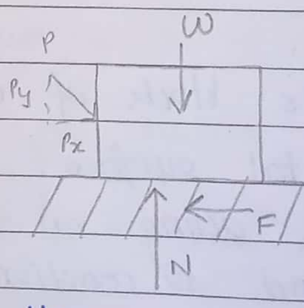
Kinetic friction force (F_K) = $\mu_K N$

In general application,

$$\mu_K = 0.75\ \mu_s$$

Four situations can occur when body is in contact with horizontal surface.





Here,

$N = P + W$

No friction ($P_x = 0$)

Here,

$F = P_x$

$F < \mu_s N$

$N = P_y + W$

No motion ($P_x < F_m$)

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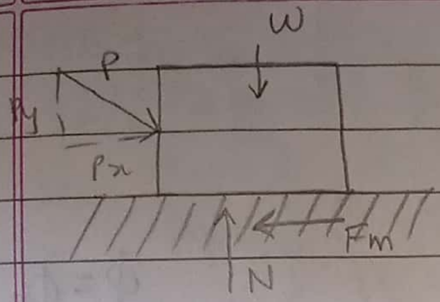


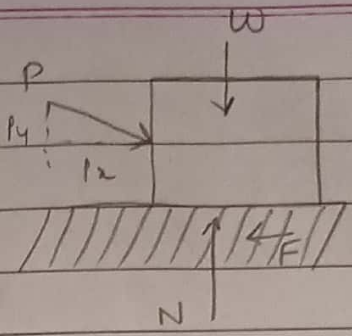
Here,

$F_m = P_x$

$F_m = \mu_m N$

$N = P_y + W$

Impending motion ($P_x = F_m$)



Here,

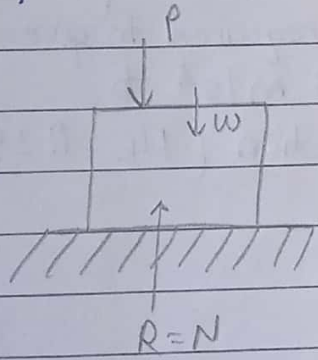
$F_k < P_x$

$F_k = \mu_k N$

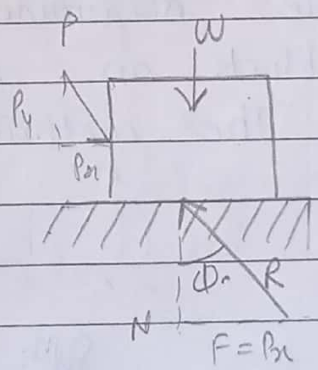
$N = P_y + W$

Motion ($P_x > F_k$)

It is sometimes convenient to replace normal force N and friction force F by resultant R:



No friction ($P_x = 0$)



$\phi < \phi_s$

No motion ($P_x < F_m$)

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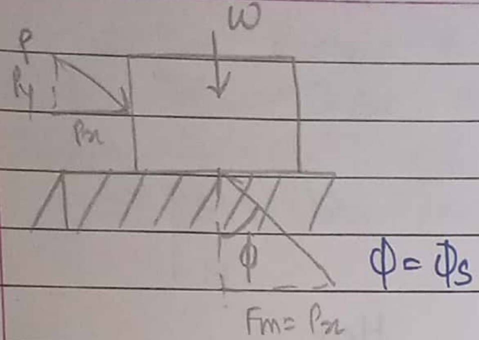
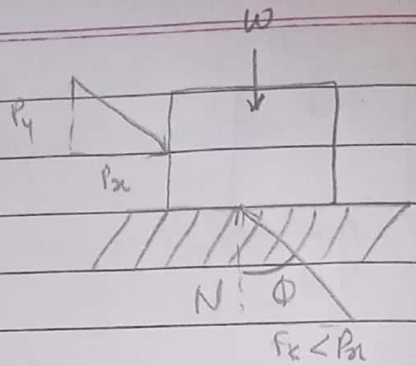


$\phi = \phi_s$



$\phi = \phi_k$

Impending motion
$(P_x = F_m)$

$\tan\phi_s = \frac{F_m}{N} = \frac{\mu_s N}{N}$

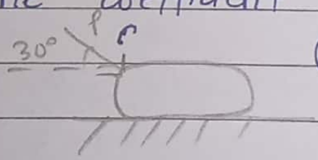
$\therefore \tan\phi_s = \mu_s$

Motion
$(P_x > F_k)$

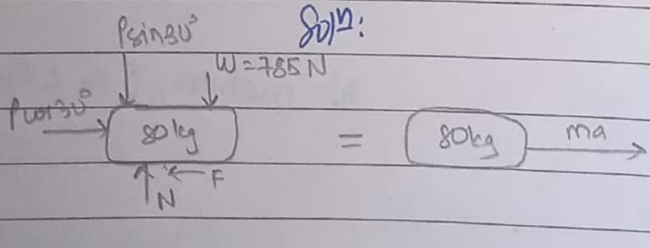
$\tan\phi_k = \frac{F_k}{N}$

$\therefore \tan\phi_k = \mu_k$

<Q.1>: An 80 kg block rests on horizontal plane. Find the magnitude of the force P required to give the block an acceleration of 2.5 m/s² to right. The coefficient of kinetic friction ($\mu_k = 0.25$).



Soln:



Given,
$m = 80$ kg
$g = 9.81$ m/s² $\therefore W = 785$ N
$a = 2.5$ m/s²
$F = ma = 80 \times 2.5 = 200$ N

We know,

$(\overset{+}{\rightarrow}) \sum F_x = ma$

or, $P\cos 30^\circ - F = 200$

or $P\cos 30^\circ - 0.25N = 200$ — (i)

Also,

$(+\uparrow) \sum F_y = 0$

or, $N - P\sin 30^\circ - W = 0$

or $N - P\sin 30^\circ - 785 = 0$

or $N = P\sin 30^\circ + 785$ — (ii)

Putting eqn (ii) in eqn (i), we get.

$P\cos 30^\circ - 0.25(P\sin 30^\circ + 785) = 200$

or. $P\cos 30^\circ - 0.25 P\sin 30^\circ + 0.25 \times 785 = 200$

or $P = \dfrac{200 + 0.25 \times 785}{\cos 30^\circ - 0.25 \times \sin 30^\circ}$

$\therefore P = 535$ N

<Q.2>: Two blocks A and B of masses 280 kg and 420 kg respectively are joined by an inextensible cable as shown. Assume pulley is frictionless and $\mu = 0.3$. The system is at rest initially.

i) Accleration of block

ii) velocity after 3.5 m

iii) velocity after 1.5 sec.

Soln.

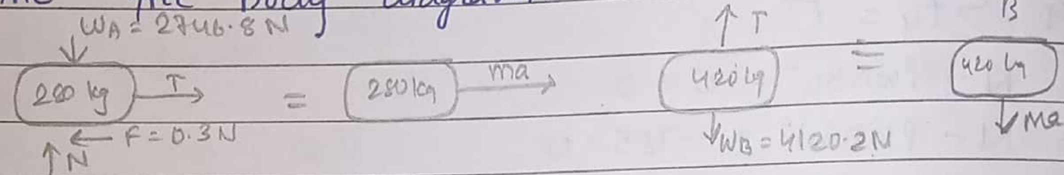
Given;

$m_A = 280$ kg $g = 9.81$ m/s^2

$m_B = 420$ kg $\therefore W_A = 2746.8$ N

$\therefore W_B = 4120.2$ N

The free body diagram.



For (i):

For body A;

$(+\uparrow)\ \sum F_y = 0$

or, $-W_A + N = 0$

$\therefore N = 2746.8$ N

$(\overset{+}{\rightarrow})\ \sum F_x = ma$

or, $T - 0.3 \times 2746.8 = 280a$

or, $T - 280a = 824.04$ —— (i)

For body B;

$(\uparrow +)\ \sum F_y = -m_B a$

or, $T - 4120.2 = -420 \times a$

or, $T + 420a = 4120.2$ —— (ii)

Solving (i) and (ii),

$a = 4.709$ m/s^2

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for (ii):

$s = 3.5\ m$

$a = 4.709\ m/s^2$

$v_0 = 0\ m/s$ (rest)

Using eq^n of linear motion;

$v^2 = v_0^2 + 2as$

or $v = \sqrt{2 \times 4.709 \times 3.5}$

$\therefore v = 5.741\ m/s.$

for (iii)

$t = 1.5\ s$

$a = 4.709\ m/s^2$

$u = 0\ m/s$

Using eq^n of linear motion

$v = u + at$

or $v = 0 + 4.709 \times 1.5$

$\therefore v = 7.064\ m/s^2$

<Q.3> A block weighing 800 N, lying on horizontal floor is just dragged by a force inclined at 35° to the floor.

Find the (a) value of P

(b) inclination with 'p' with horizontal. so that 'p' is minimum.

(c) the value of P_{min} $(\mu = 0.25)$.

Sol^n:

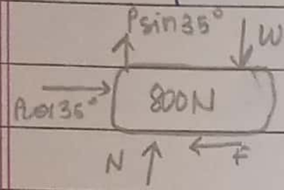
Given,

$W = 800\ N$

$\theta = 35^\circ$

$\mu = 0.25$

The free body diagram:



for (i):

$(\overset{+}{\rightarrow})\ \sum F_x = 0$

or, $P\cos 35^\circ - F = 0$

or $P\cos 35^\circ - 0.25N = 0$ — (i)

$(\uparrow +)\ \sum F_y = 0$

or, $N + P\sin 35^\circ - 800 = 0$

or $N = 800 - P\sin 35^\circ$ — (ii)

Solving eq^n (i) and (ii), we get.

$$P\cos 35^\circ - 0.25(800 - P\sin 35^\circ) = 0$$

or $$P = \frac{0.25 \times 800}{\cos 35^\circ + 0.25 \times \sin 35^\circ}$$

$$\therefore P = 207.782\ N$$

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For (ii);

Let angle betn minimum P and horizontal F be α.

$$P = \frac{0.25 \times 800}{\cos\alpha + 0.25 \times \sin\alpha}$$

For P to be minimum, denominator must be maximum.

$$\frac{d}{d\alpha}(\cos\alpha + 0.25 \times \sin\alpha) = 0$$

or $0.25\cos\alpha - \sin\alpha = 0$

or $\tan\alpha = 0.25$

$\therefore \alpha = 14.04^\circ$

Taking second derivative,

$$\frac{d^2}{d\alpha^2}(\cos\alpha + 0.25 \times \sin\alpha)$$

$= -(\cos\alpha + 0.25\sin\alpha)$

$= -(\cos 14.04 + 0.25 \times \sin 14.04)$

$= -1.0377 < 0$

feeling most comfortable.

So, at 14.04°, $\cos\alpha + 0.25 \times \sin\alpha$ is maximum so,

~~Pmin =~~ P is minimum at 14.04°

So,

$$P_{min} = \frac{0.25 \times 800}{\cos 14.04^\circ + 0.25 \times \sin 14.04^\circ}$$

$\therefore P_{min} = 194.03$ N