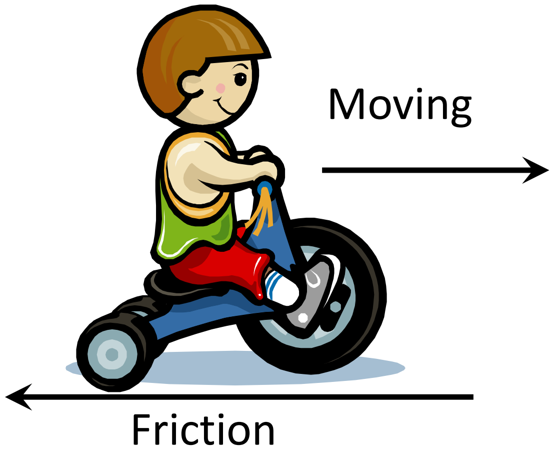
Friction

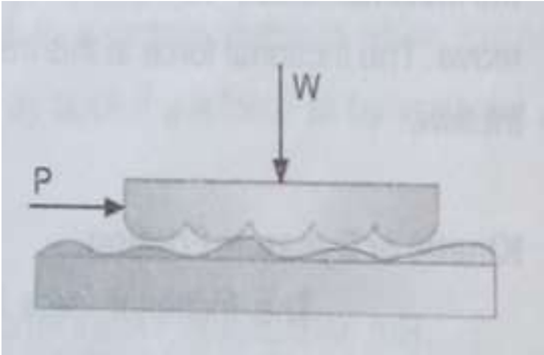
- Friction is a force between two surfaces that are sliding, or trying to slide across one another, for example when you try to push a toy car along the floor.

- Friction always works in the direction opposite from the direction of the motion of the object. It always parallel to the plane of contact.



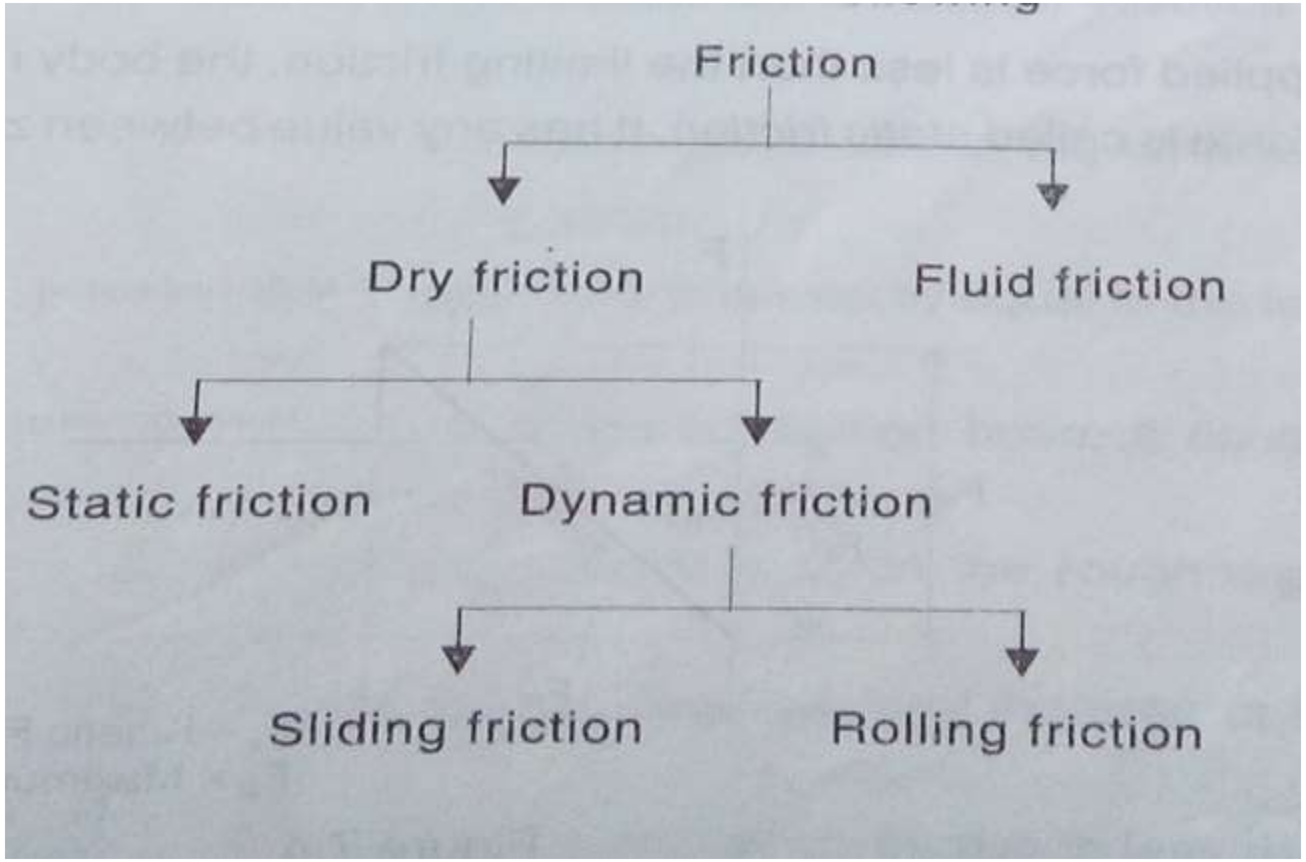
Reason for Friction

- The Major Cause of the friction is the interlocking of minute projections on the surfaces which opposes the relative motion.



The amount of friction depends on the materials from which the two surfaces are made. The rougher the surface, the more friction is produced

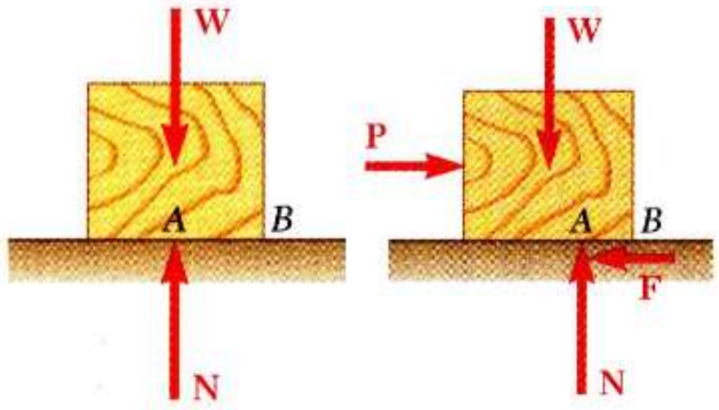
Types of Friction

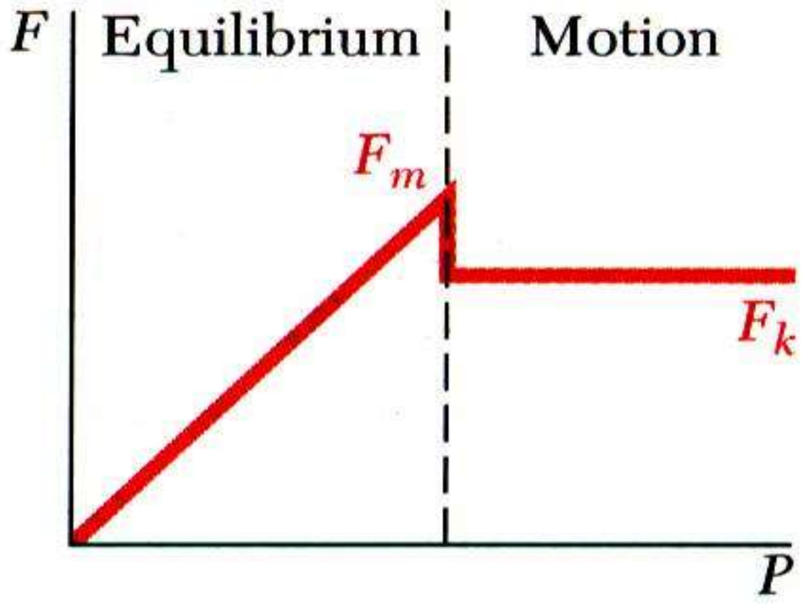


FRICTION

- The Resistance offered by the surface (due to ir-regularities) against motion of a body by the system to moving the system.
- In fluid mechanics, resistance offered by the fluid (within the system layer to layer) itself is known as Viscosity.
- Due to the frictional force our effort to do particular work is being increased.
- Friction is must for the operation of Belt, Clutch, Screw Jack, Brake, Automobile etc.,
- Friction is undesirable in the case of Bearing.
- Power lost due to friction is converted in to heat.

The Laws of Dry Friction





- Maximum static-friction force and kinetic-friction force are:
  - proportional to normal force
  - dependent on type and condition of contact surfaces
  - independent of contact area

Coefficients of Friction

Approximate Values of Coefficient of Static Friction for Dry Surfaces

Metal on metal	0.15–0.60
Metal on wood	0.20–0.60
Metal on stone	0.30–0.70
Metal on leather	0.30–0.60
Wood on wood	0.25–0.50
Wood on leather	0.25–0.50
Stone on stone	0.40–0.70
Earth on earth	0.20–1.00
Rubber on concrete	0.60–0.90

- Maximum static-friction force:

$$F_m = \mu_s N$$

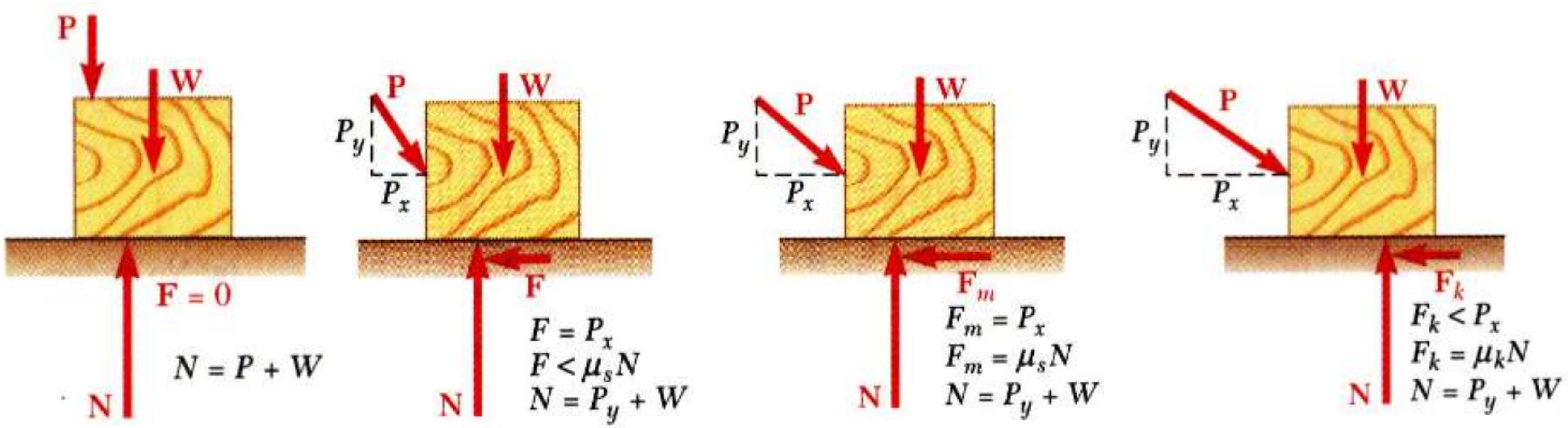
- Kinetic-friction force:

$$F_k = \mu_k N$$

$$\mu_k \cong 0.75\mu_s$$

Friction Vs Applied Force

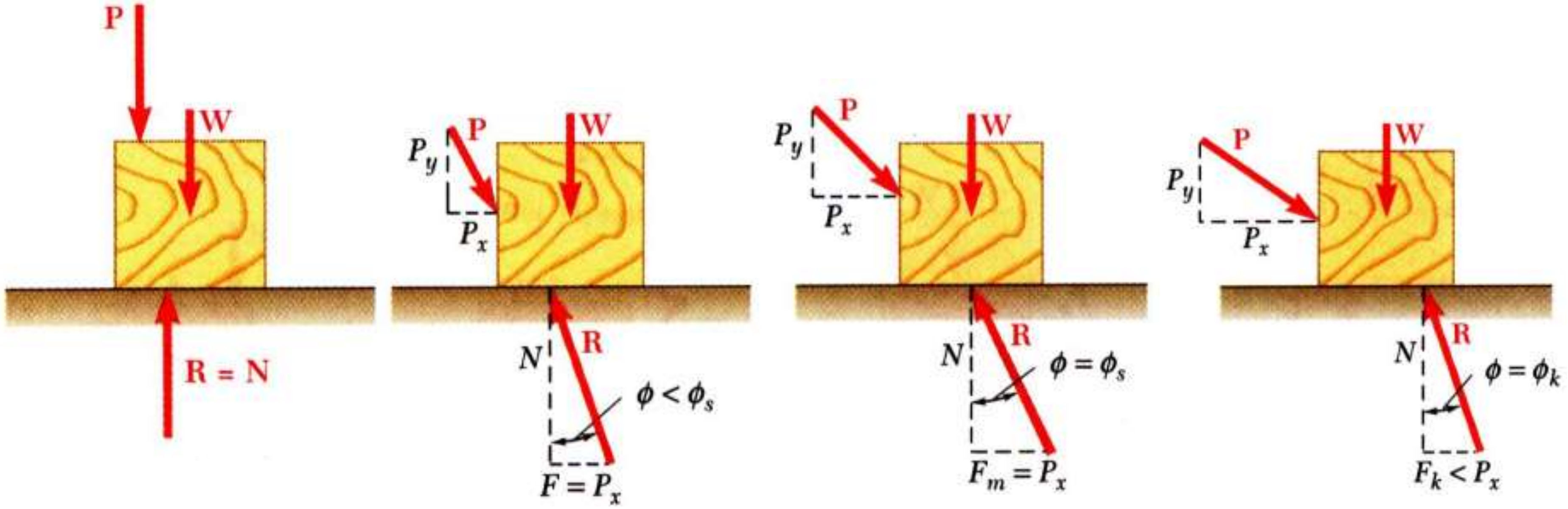
- Four situations can occur when a rigid body is in contact with a horizontal surface:



- No friction, ($P_x = 0$)
- No motion, ($P_x < F_m$)
- Motion impending, ($P_x = F_m$)
- Motion, ($P_x > F_m$)

Angles of Friction

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



- No friction
- No motion
- Motion impending
- Motion

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

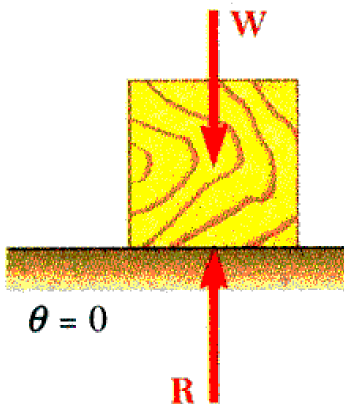
$$\tan\phi_s = \mu_s$$

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

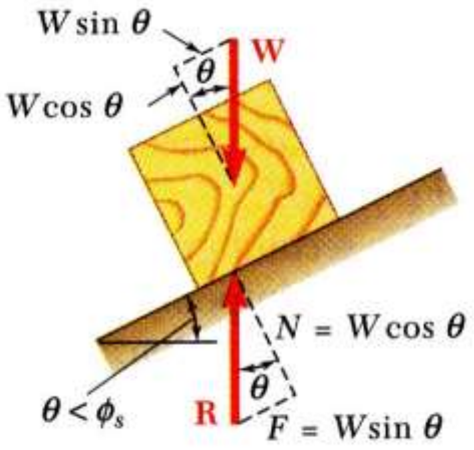
$$\tan\phi_k = \mu_k$$

Friction in Inclined Plane

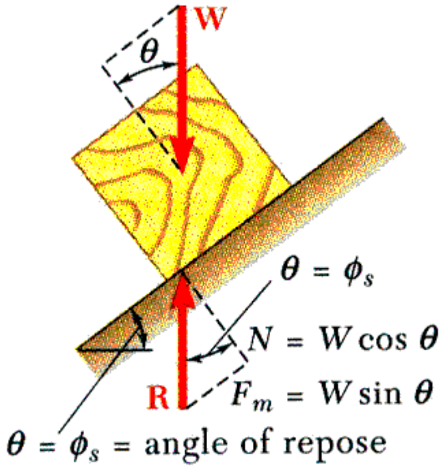
- Consider block of weight W resting on board with variable inclination angle θ.



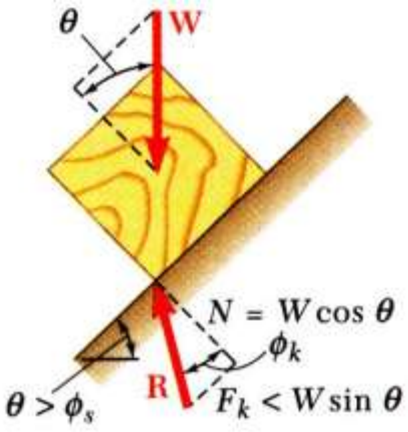
- No friction



- No motion

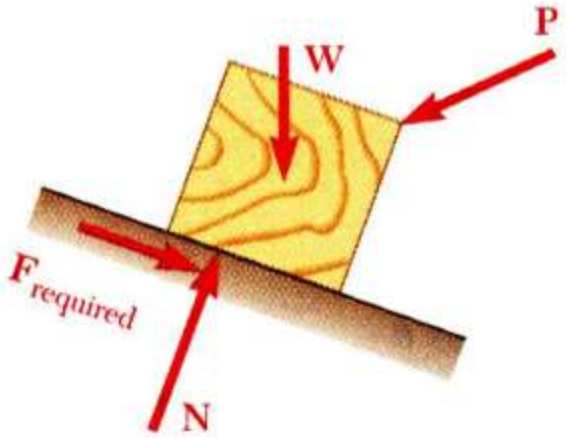


- Motion impending

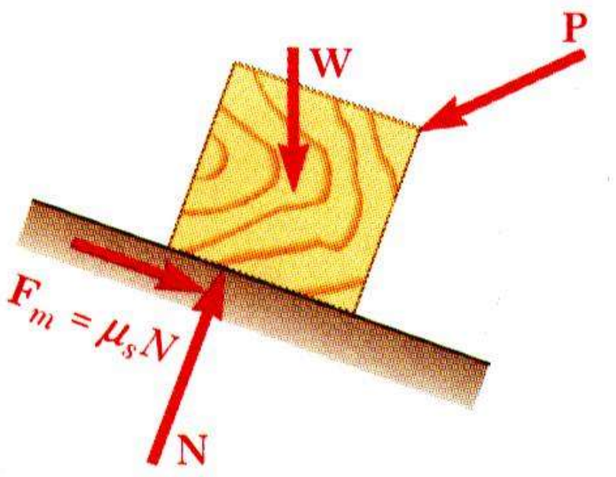


- Motion

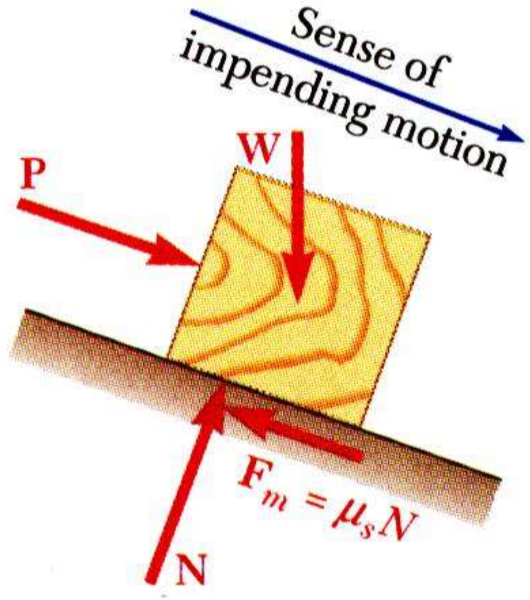
Problems Involving Dry Friction



- All applied forces known
- Coefficient of static friction is known
- Determine whether body will remain at rest or slide

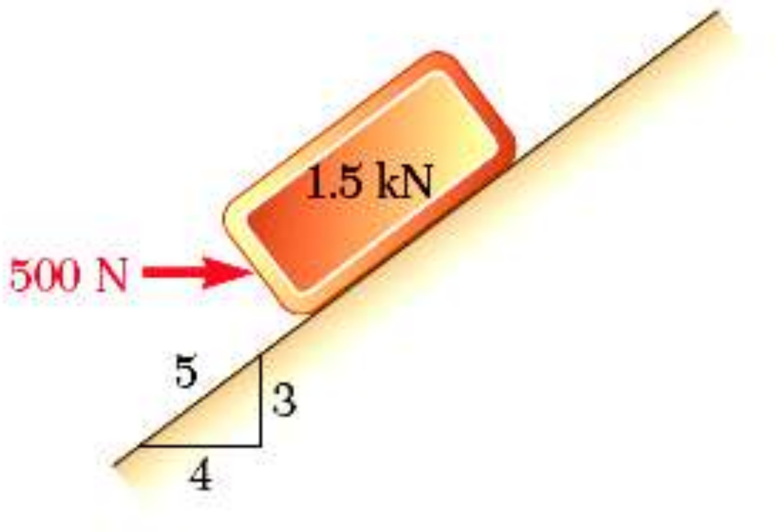


- All applied forces known
- Motion is impending
- Determine value of coefficient of static friction.



- Coefficient of static friction is known
- Motion is impending
- Determine magnitude or direction of one of the applied forces

Problem 1



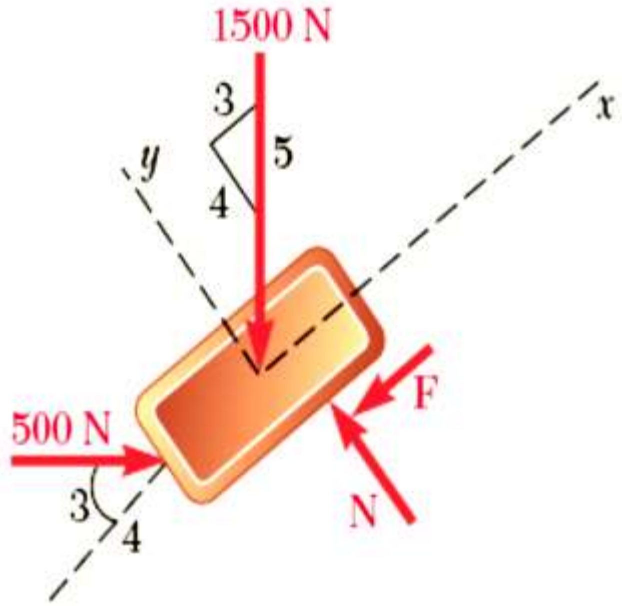
A 500-N force acts as shown on a 1.5 kN block placed on an inclined plane. The coefficients of friction between the block and plane are $\mu_s = 0.25$ and $\mu_k = 0.20$. Determine whether the block is in equilibrium and find the value of the friction force.

- **Calculate maximum friction force and compare with friction force required for equilibrium. If it is greater, block will not slide.**

- **If maximum friction force is less than friction force required for equilibrium, block will slide. Calculate kinetic-friction force.**

S. ThangaKasiRajan, stkrajan@gmail.com

Problem 1



Required friction for Equilibrium

$$\sum F_x = 0: \quad \tfrac{4}{5}(500\text{ N}) - \tfrac{3}{5}(1500\text{ N}) - F = 0$$

$$F = -500\text{ N}$$

Negative sign indicates our assumed direction is wrong. Hence the reverse the direction of force

$$\sum F_y = 0: \quad N - \tfrac{4}{5}(500\text{ N}) - \tfrac{3}{5}(500\text{ N}) = 0$$

$$N = 1500\text{ N}$$

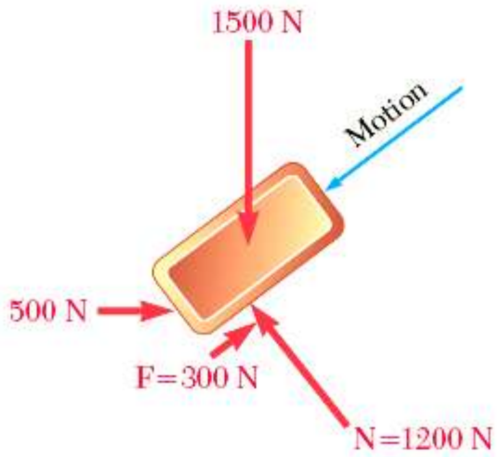
- Maximum Friction

$$F_m = \mu_s N \qquad F_m = 0.25(1500\text{ N}) = 375\text{ N}$$

Since $F_m < F_{req}$ block will slide. Hence Calculate kinetic-friction force.

The block will slide down the plane.

Problem 1



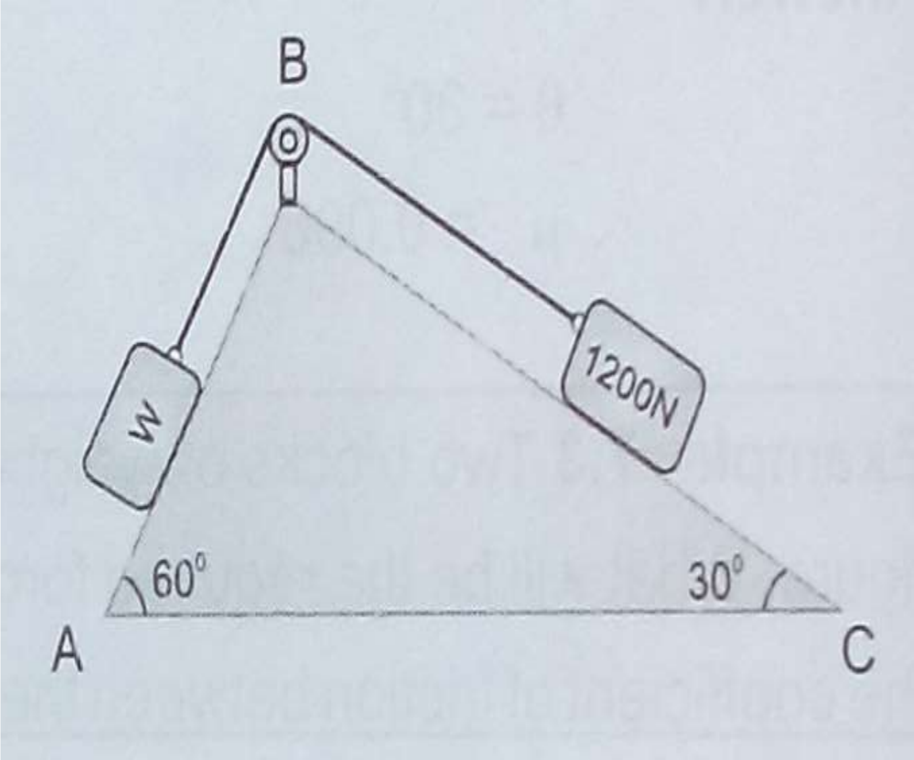
There fore actual friction

$$F_{actual} = F_k = \mu_k N$$
$$= 0.20(1500\ \text{N})$$

$$\boxed{F_{actual} = 300\ \text{N}}$$

Problem 2

Two Blocks of Weight W and 1200N, rests on two identical inclined planes AB and BC inclined at 60º and 30º to the horizontal meeting at the point B, respectively. They are connected by a rope passing over a smooth pulley at B. If the coefficient of friction between the block and the plane AB is 0.23 and that between the block and the plane BC is 0.25, find the least and greatest value of W for the system to be in equilibrium.



Problem 2

a) For the least value of W for equilibrium, the motion of 1200 N block is impending down wards

Considering the 1200 N Block:

From the equations of equilibrium

$\Sigma F_{Y'} = 0$

$N_1 = 1200 \cos 30^\circ = 1039$ N

$F_1 = \mu_1 N_1 = 0.25 \times 1039 = 260$ N

$\Sigma F_{X'} = 0$

$1200 \sin 30^\circ - F_1 - T = 0$

$T = 340$ N

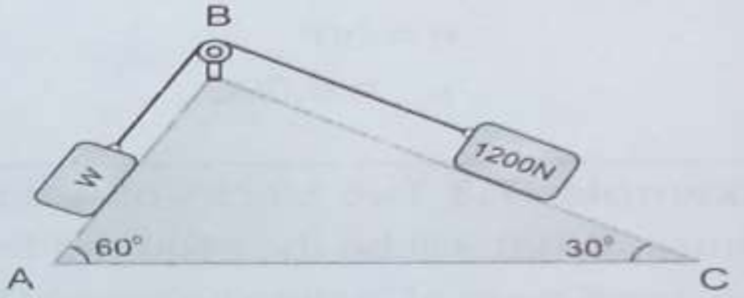


Figure 7.15

Considering weight 'W' Block:

From the equation of equilibrium

$\Sigma F_{Y'} = 0$

$N_2 = W \cos 60^\circ$

$N_2 = 0.5\ W$

$F_2 = \mu_2 N_2 = 0.23 \times 0.5\ W$

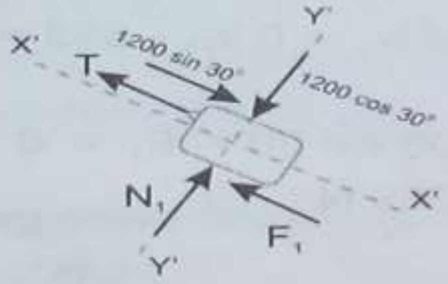
$= 0.115\ W$

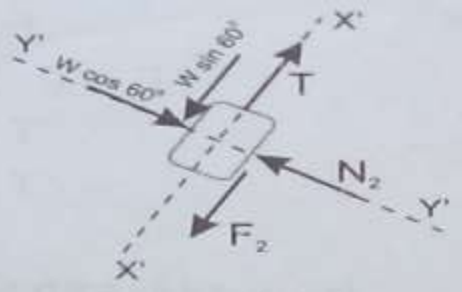
$\Sigma F_{X'} = 0$

$-W \sin 60^\circ - F_2 + T = 0$

$-0.866\ W - 0.115\ W + 340 = 0$

$W = 346.5$ N





Problem 2

b) For the greatest value of W, the motion of 1200 N block is impending motion upwards.

Considering the 1200 N Block

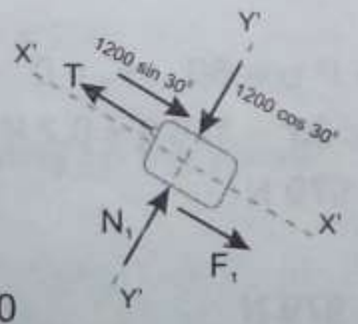
$N_1 = 1039$ N

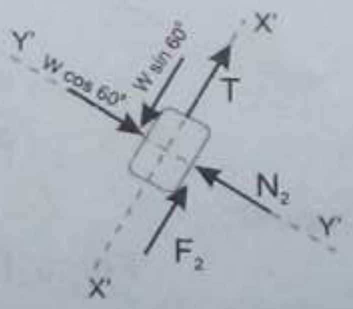
$F_1 = 260$ N

$\Sigma F_{x'} = 0$

$-1200 \sin 30^0 - F_1 + T = 0$

$T = 860$ N





Considering weight 'W' Block:

$N_2 = 0.5$ W

$F_2 = 0.11$W

$\Sigma F_{x'} = 0$

$W \sin 60^o - F_2 - T = 0$

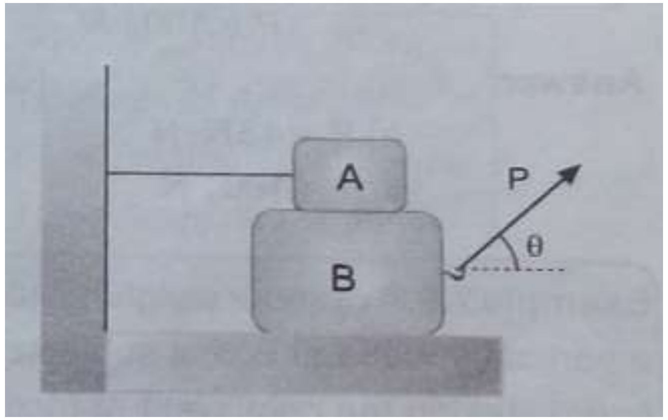
$0.866\ W - 0.115\ W = 860$

$W = 1145$ N

Least value of W = 346.5 N

Greatest value of W = 1145 N

Problem 3



Two Blocks A and B of weight 1500N and 3000N respectively, rest over each other as shown in figure. Block A tied to the wall with a horizontal string. If the coefficient of friction between the blocks A & B is 0.2 and between Block B and the floor is 0.35, what should be the value of P to move the block B (a) When P is Horizontal (b) Force acts 30º upwards.

Problem 3

a) When force P is horizontal

Consider the Block A:

From the equations of equilibrium

$\Sigma F_Y = 0$

$N_1 = 1500\ N$

$F_1 = \mu_1 N_1 = 0.2 \times 1500 = 300\ N$

Consider the Block B:

From the equations of equilibrium

$\Sigma F_Y = 0$

$N_2 - W_2 - N_1 = 0$

$N_2 = 3000 + 1500 = 4500\ N$

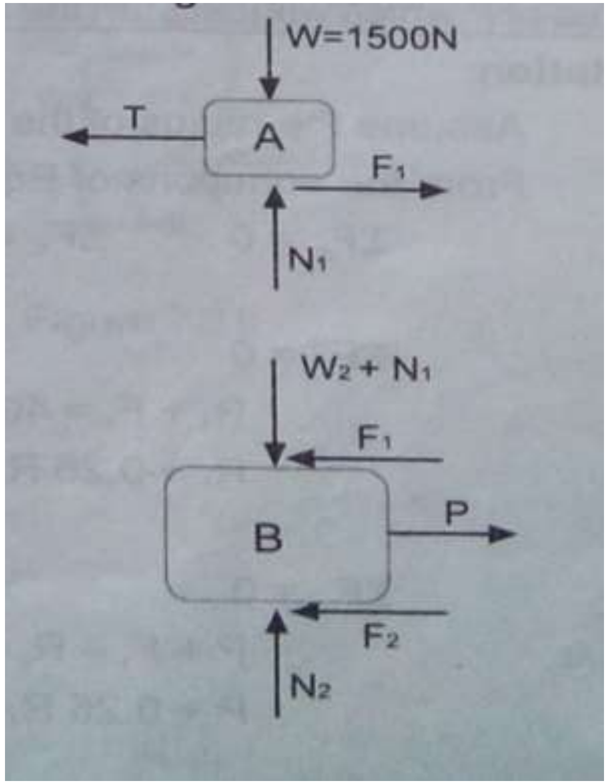
$\Sigma F_X = 0$

$F_2 = \mu_2 N_2 = 0.35 \times 4500 = 1575\ N$

$P - F_1 - F_2 = 0$

$P = 300 + 1575 = 1875\ N$

$P = 1875\ N$



Problem 3

B) When force P in inclined

Consider the Block A:

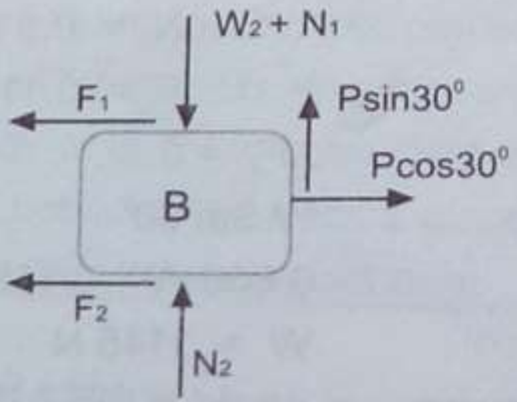
From equations of equilibrium

$\Sigma F_Y = 0$

$N_1 = 1500$ N

$F_1 = 300$ N

Consider the Block B:



From equations of equilibrium

$\Sigma F_Y = 0$

$N_2 - W_2 - N_1 + P \sin 30^\circ = 0$

$N_2 = 3000 + 1500 - 0.5\,P$

$\quad = 4500 - 0.5\,P$

$F_2 = \mu_2 N_2 = 1575 - 0.175\,P$

$\Sigma F_X = 0$

$P \cos 30^\circ - F_1 - F_2 = 0$

$0.886\,P - 300 - 1575 + 0.175\,P = 0$

$P = 1801$ N

Problem 4

Two Blocks of weight 800N and 550 N are connected as shown in fig. What will be the required force P, to start the movement. The pulley is smooth & the coefficient of friction between the other contact surfaces are 0.23

Solution:

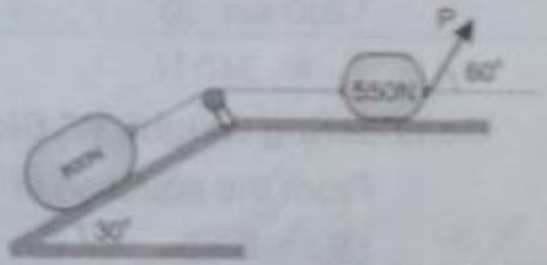


Figure 7.14

Consider 800 N Block:

$\Sigma F_y = 0$

$N_1 = 800 \cos 30^\circ$

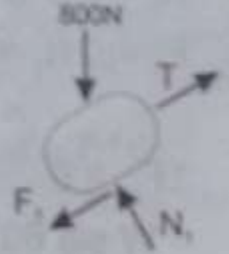
$= 693$ N

$F_1 = \mu N_1 = 0.23 \times 693 = 159$ N

$\Sigma F_x = 0$

$T - 800 \sin 30^\circ - F_1 = 0$

$T = 559$ N



Consider 550 N Block:

$\Sigma F_y = 0$

$N_2 + P \sin 60^\circ = 550$

$N_2 = 550 - 0.866 P$

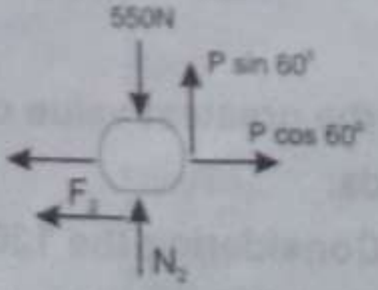
$F_2 = 126.5 - 0.2 P$

$\Sigma F_x = 0$

$-T + P \cos 60^\circ - F_2 = 0$

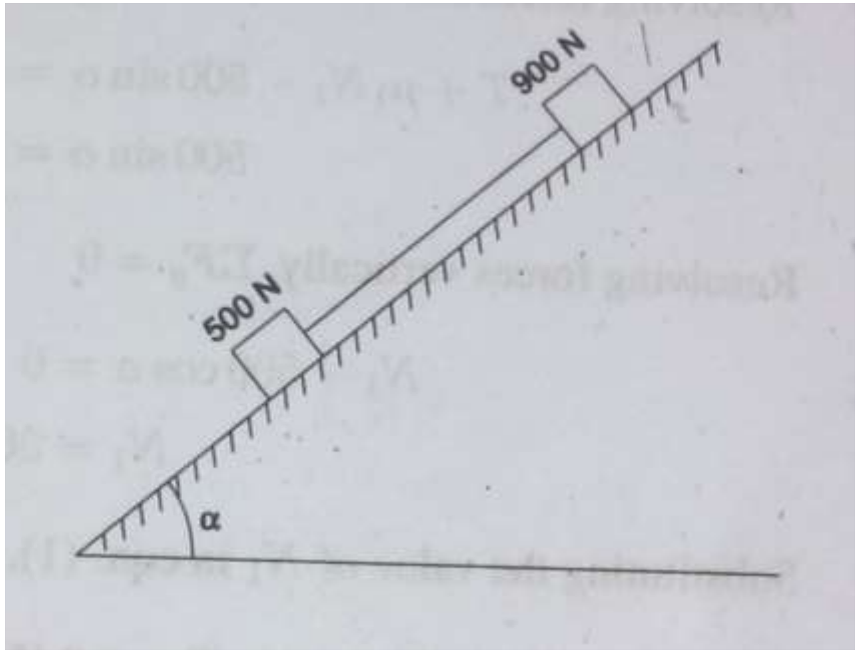
$P \cos 60^\circ - 126.5 + 0.2 P = 559$

$P = 979$ N



Problem 5

Two blocks of weight 500 N and 900N connected by a rod are kept in an inclined plane shown in the figure. The rod is parallel to the plane. The coefficient of friction between 500 N blocks and the plane is 0.3 and that between 900 N blocks and the plane is 0.4. find the inclination of the plane with the horizontal and the tension in the rod when the motion down the plane is just about to start.



Problem 5

Considering equilibrium of 500 N block,

Resolving forces horizontally, $\Sigma F_x = 0$

$$T + \mu_1 N_1 - 500 \sin\alpha = 0$$

$$500 \sin\alpha = T + 0.3 N_1 \qquad (1)$$

Resolving forces vertically, $\Sigma F_y = 0$

$$N_1 - 500 \cos\alpha = 0$$

$$N_1 = 500 \cos\alpha$$

Substituting the value of N_1 in eqn. (1),

$$500 \sin\alpha = T + 0.3\,(500 \cos\alpha)$$

$$T = 500 \sin\alpha - 150 \cos\alpha \qquad (2)$$

Considering equilibrium of 900 N block,

Resolving forces vertically, $\Sigma F_y = 0$

$$N_2 - 900 \cos\alpha = 0$$

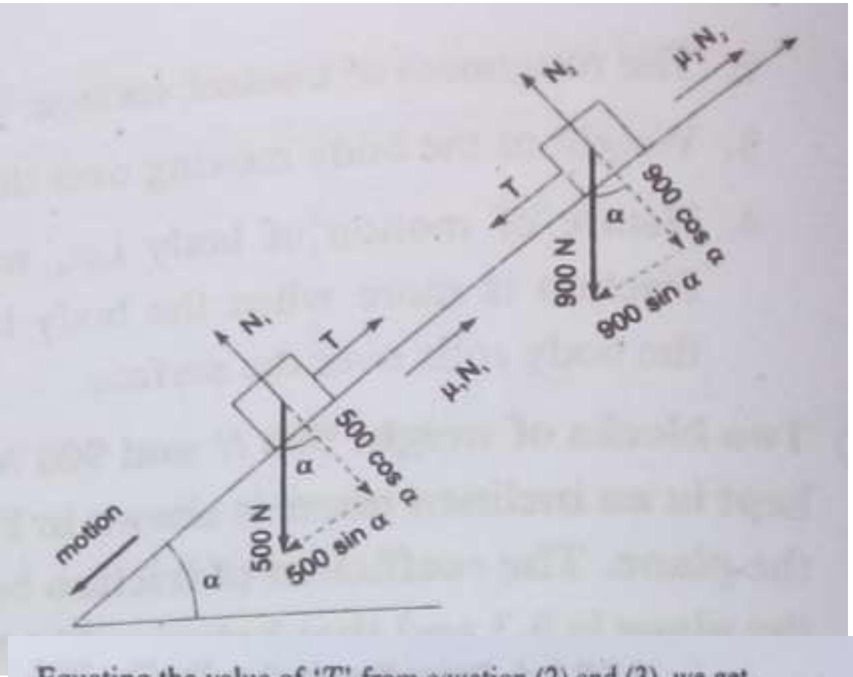
$$N_2 = 900 \cos\alpha$$

Resolving forces horizontally, $\Sigma F_x = 0$

$$\mu_2 N_2 - 900 \sin\alpha - T = 0$$

$$0.4\,(900 \cos\alpha) - 900 \sin\alpha - T = 0$$

$$T = 360 \cos\alpha - 900 \sin\alpha \qquad (3)$$



Equating the value of 'T' from equation (2) and (3), we get

$$500 \sin\alpha - 150 \cos\alpha = 360 \cos\alpha - 900 \sin\alpha$$

$$1400 \sin\alpha = 510 \cos\alpha$$

$$\tan\alpha = \frac{510}{1400} = 0.3642$$

$$\alpha = 20^\circ \qquad \text{(Ans)}$$

Put a = 20° in eqn. (2), we get

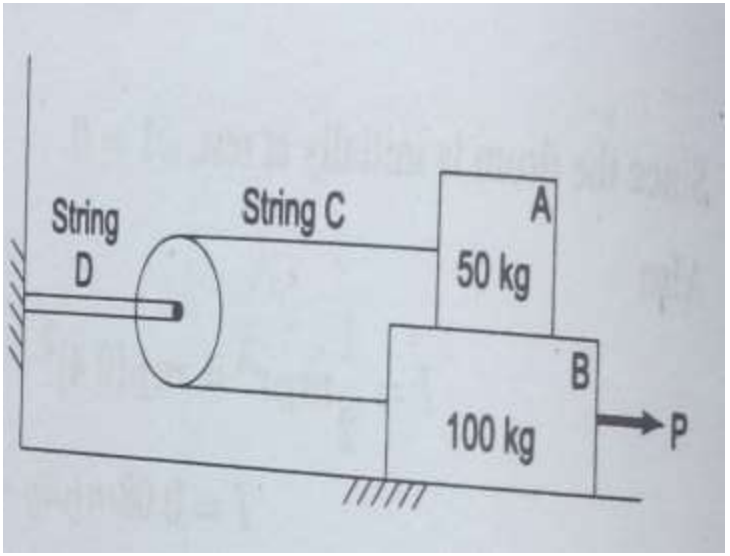
$$T = 500 \sin 20 - 150 \cos 20$$

$$= 171 - 140.95$$

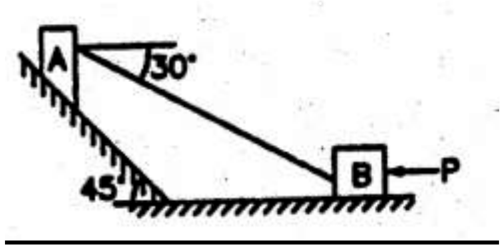
$$T = 30N \qquad \text{(Ans)}$$

Problems for practice

Two blocks of A & B of mass 50 kg and 100 kg respectively are connected by a string C which passes through a frictionless pulley connected with the fixed wall by another string D as shown in the figure. Find the force P required to pull the block B. Also find the tension in the string D. Take coefficient of friction at all contact surfaces as 0.3



Block A weighing 1000 N rests on a rough inclined plane whose inclination to the horizontal is 45°. It is connected to another block B, weighing 3000 N rests on a rough horizontal plane by a weightless rigid bar inclined at an angle of 30° to the horizontal as shown in fig. Find the horizontal force required to be applied to the block B just to move the block A in upward direction. Assume angle of friction as 15° at all surfaces where there is sliding.



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2. Engineering Mechanics – Statics & Dynamics by S.Nagan, M.S.Palanichamy, Tata McGraw-Hill (2001).