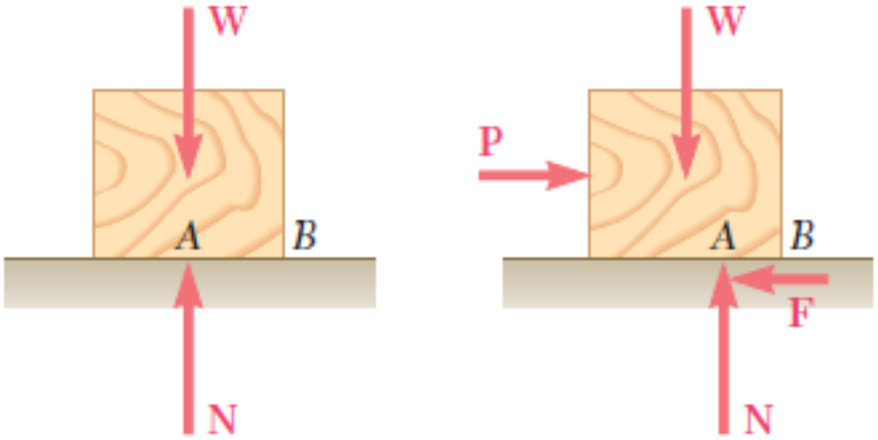
FRICTION

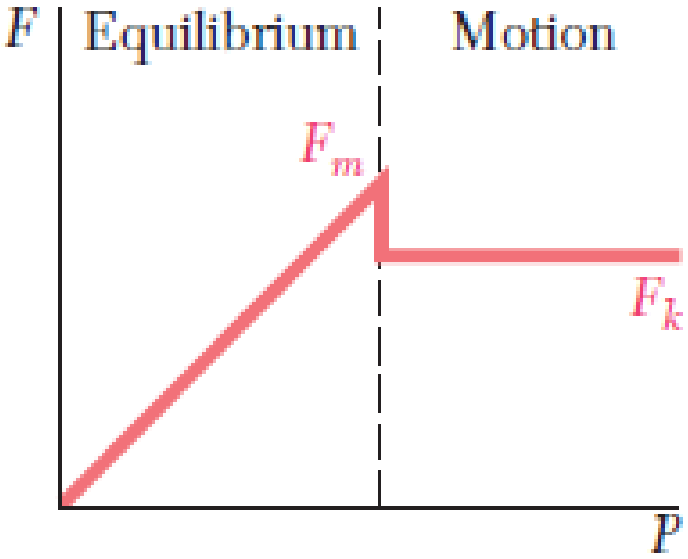
When two surfaces are in contact, tangential forces, called *friction forces*, will always develop if one attempts to move one surface with respect to the other.

TYPES

- Dry Friction (Coulomb Friction)
- Fluid Friction

Laws of Dry Friction/Co-efficient of Friction





$$F_m = \mu_s N$$

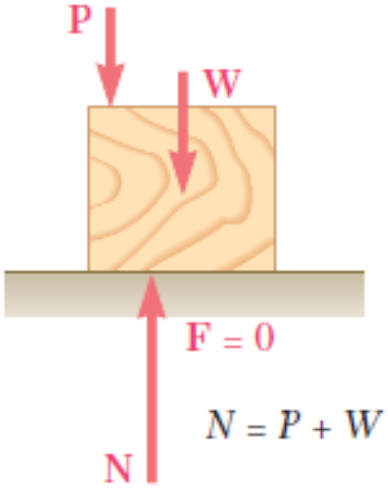
μ_s- Co-efficient of static friction

$$F_k = \mu_k N$$

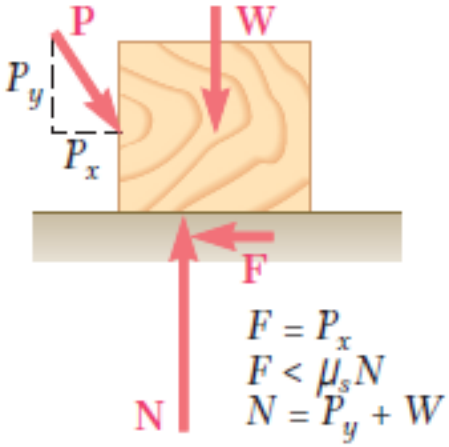
μ_k- Co-efficient of kinetic friction

Both coefficients, however, depend strongly on the nature of the surfaces in contact.

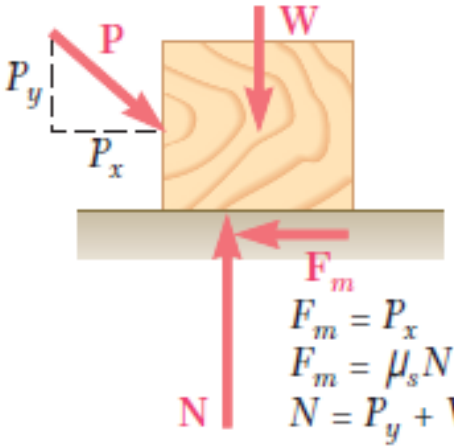
Four Different Situations



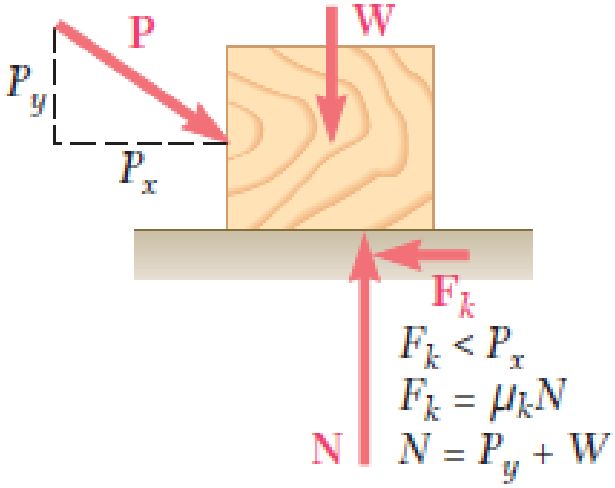
(a) No friction ($P_x = 0$)



(b) No motion ($P_x < F_m$)

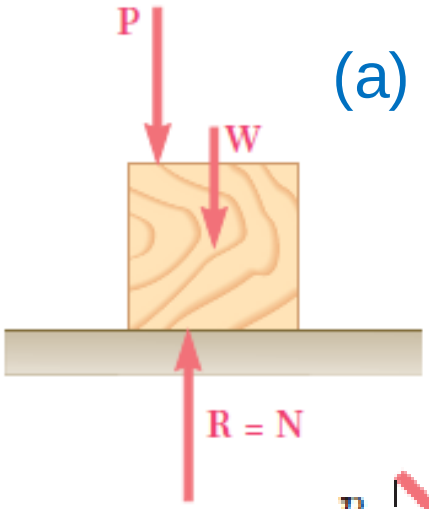


(c) Motion impending ⟶ ($P_x = F_m$)

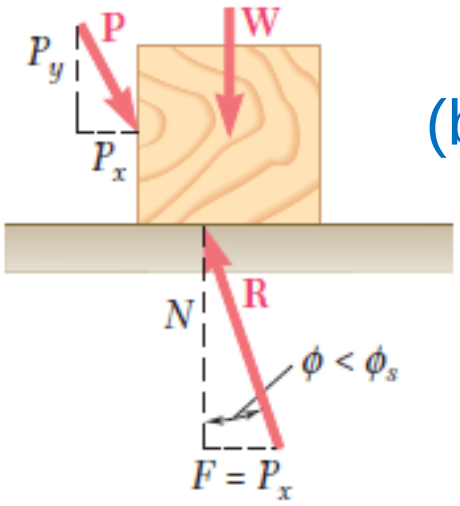


(d) Motion ⟶ ($P_x > F_m$)

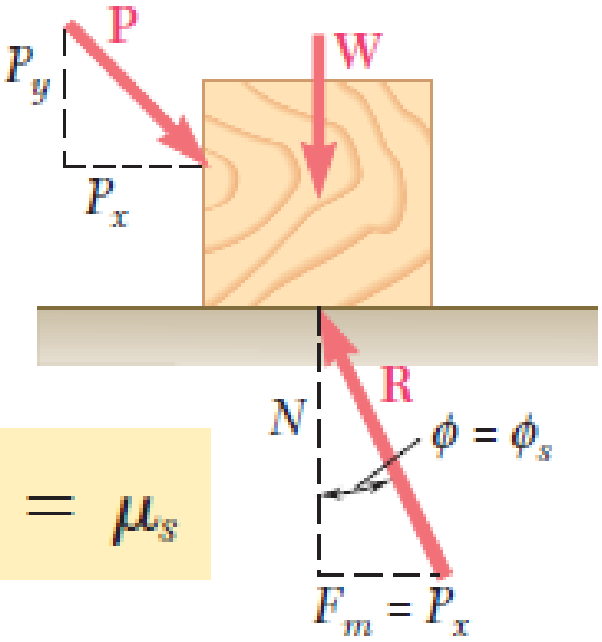
Angles of Friction



(a) No Friction

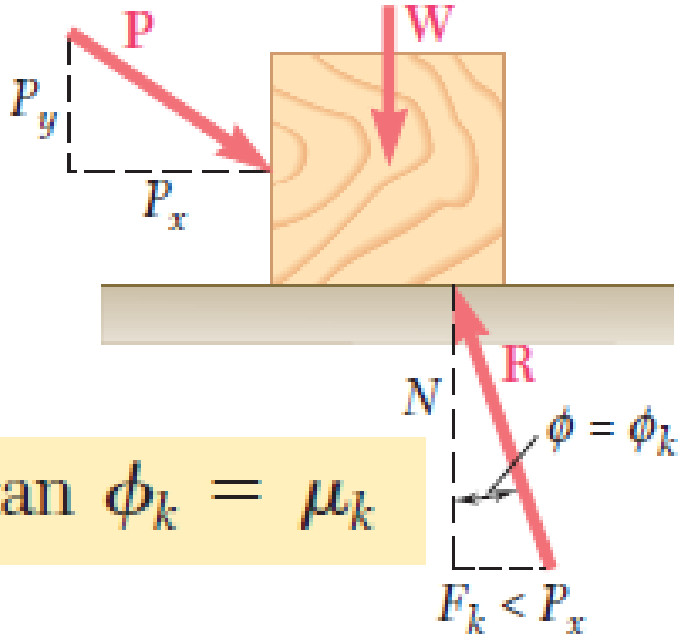


(b) No Motion



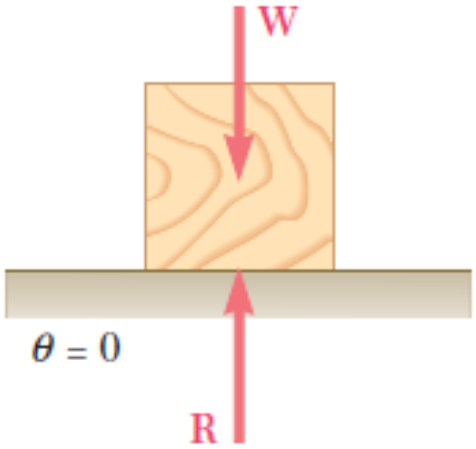
$$\tan \phi_s = \mu_s$$

(c) Motion Impending →

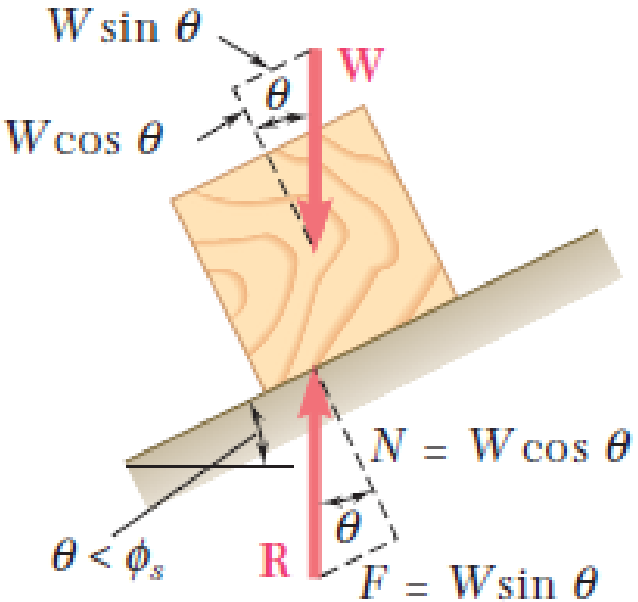


$$\tan \phi_k = \mu_k$$

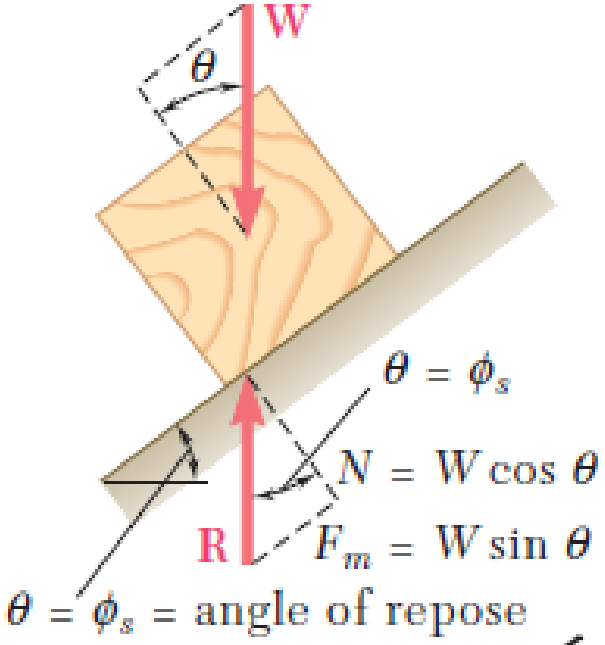
(d) Motion →



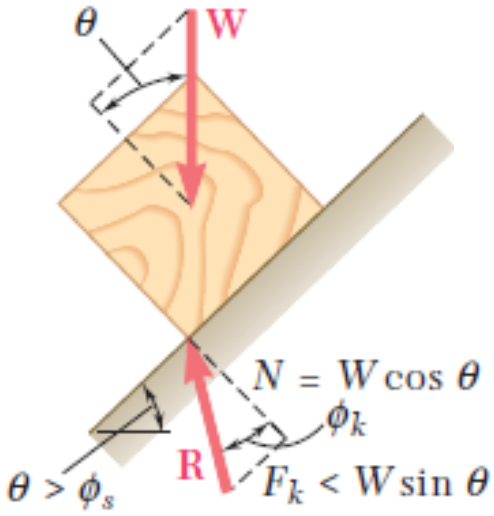
(a) No friction



(b) No motion



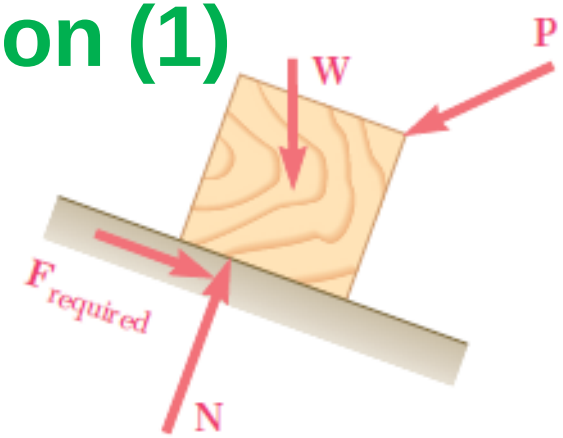
(c) Motion impending



(d) Motion

The value of the angle of inclination corresponding to impending motion is called the *angle of repose*.

Problems Involving Dry Friction (1)



Group 1

All applied forces are given and the coefficients of friction are known

To Find

We are to determine whether the body considered will remain at rest or slide

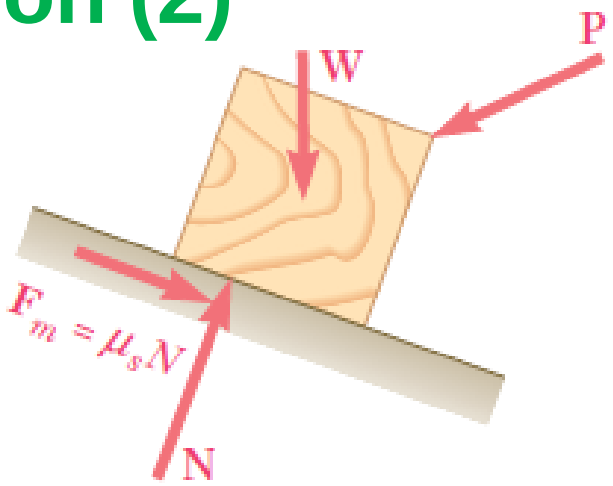
How ?

- Find the value of friction force using equilibrium equations
- Find $F_m = \mu_s N$
- If F< F_m- body is at rest, If F= F_m- Motion impending, If F> F_m- body is in motion
- The actual magnitude of the friction force is $F_k = \mu_k N$

Problems Involving Dry Friction (2)

Group 2

All applied forces are given and the motion is known to be impending



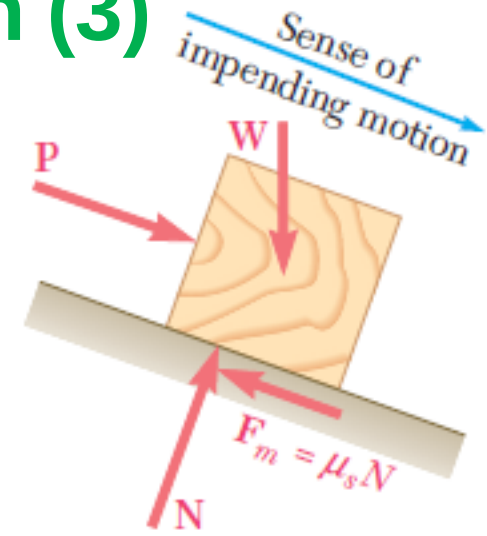
To Find

We are to determine the value of the coefficient of static friction

How ?

- Find the value of F_m and N using equilibrium equations
- Find co-efficient of static friction using $F_m = \mu_s N$

Problems Involving Dry Friction (3)



Group 3

The coefficient of static friction is given, and it is known that the motion is impending in a given direction

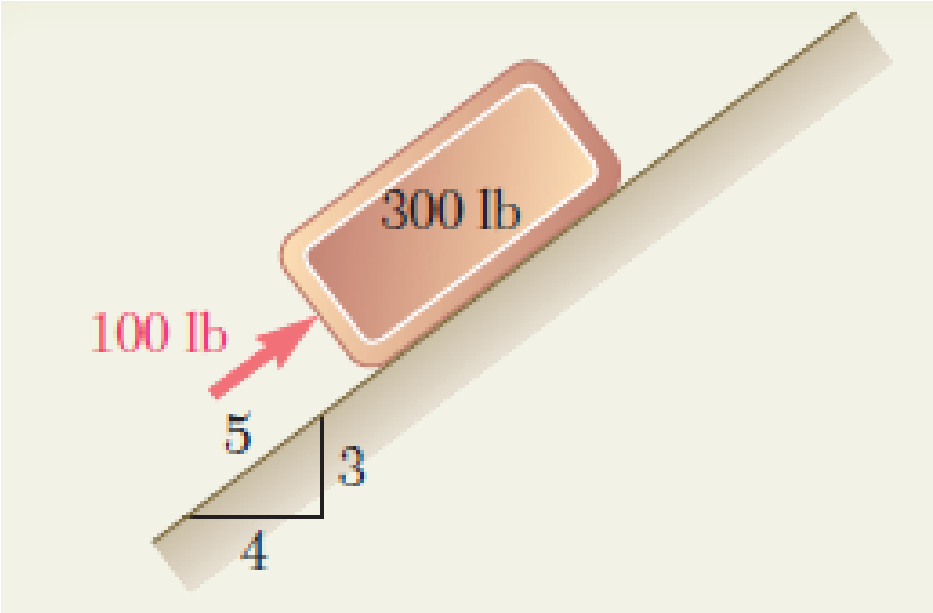
To Find

We are to determine the magnitude or the direction of one of the applied forces

How ?

- Find the unknown force using equilibrium equations
- The direction of F_m is known (*opposite to that of the impending motion*)

Problem 1

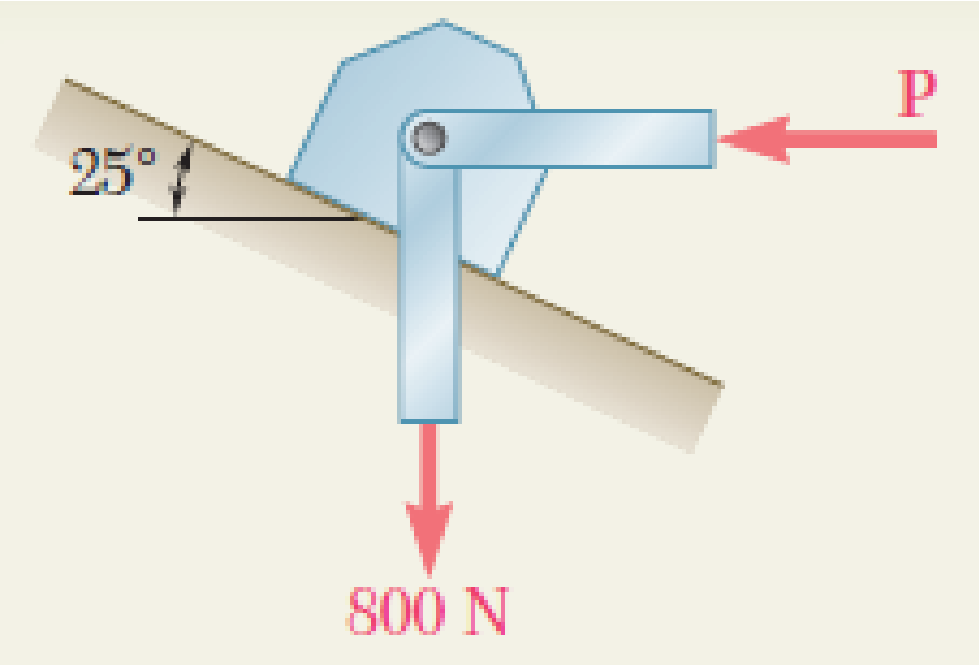


A 100-lb force acts as shown on a 300-lb block placed on an inclined plane. The coefficients of friction between the block and the plane are $\mu_s = 0.25$ and $\mu_k = 0.20$. Determine whether the block is in equilibrium, and find the value of the friction force.

Actual force, F=48 lb

Problem 2

A support block is acted upon by two forces as shown. Knowing that the coefficients of friction between the block and the incline are $\mu_s = 0.35$ and $\mu_k = 0.25$, determine the force **P** required (*a*) to start the block moving up the incline, (*b*) to keep it moving up, (*c*) to prevent it from sliding down.

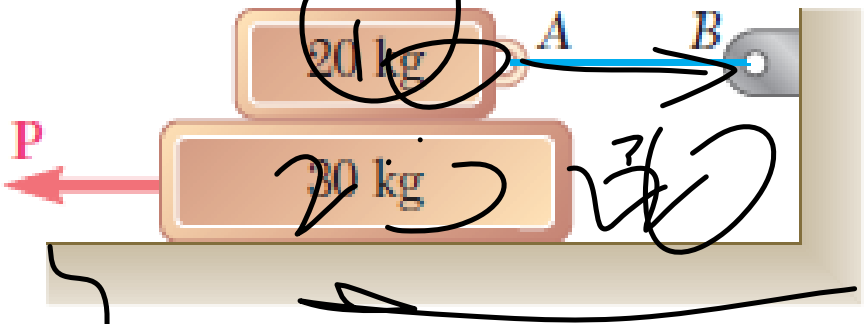


(a) P = 780 N

(b) P = 649 N

(c) P = 80 N

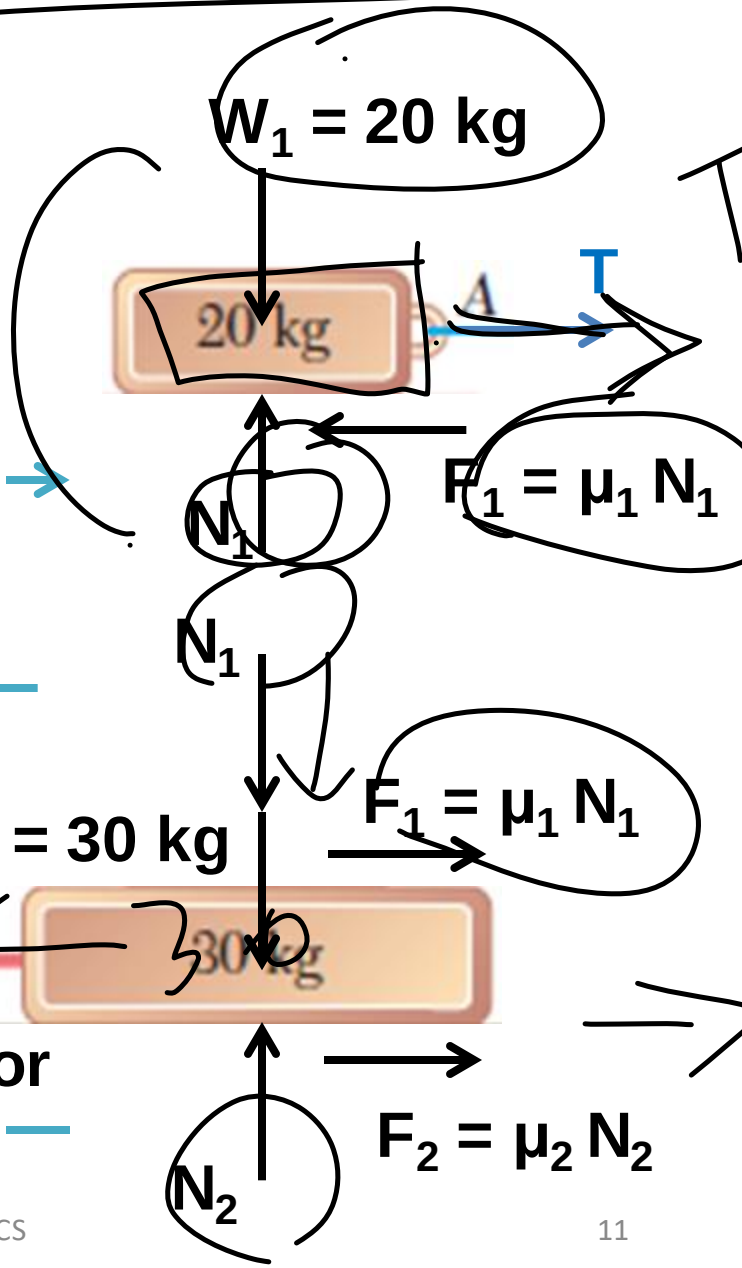
Two Bodies in Contact-Relative Motion

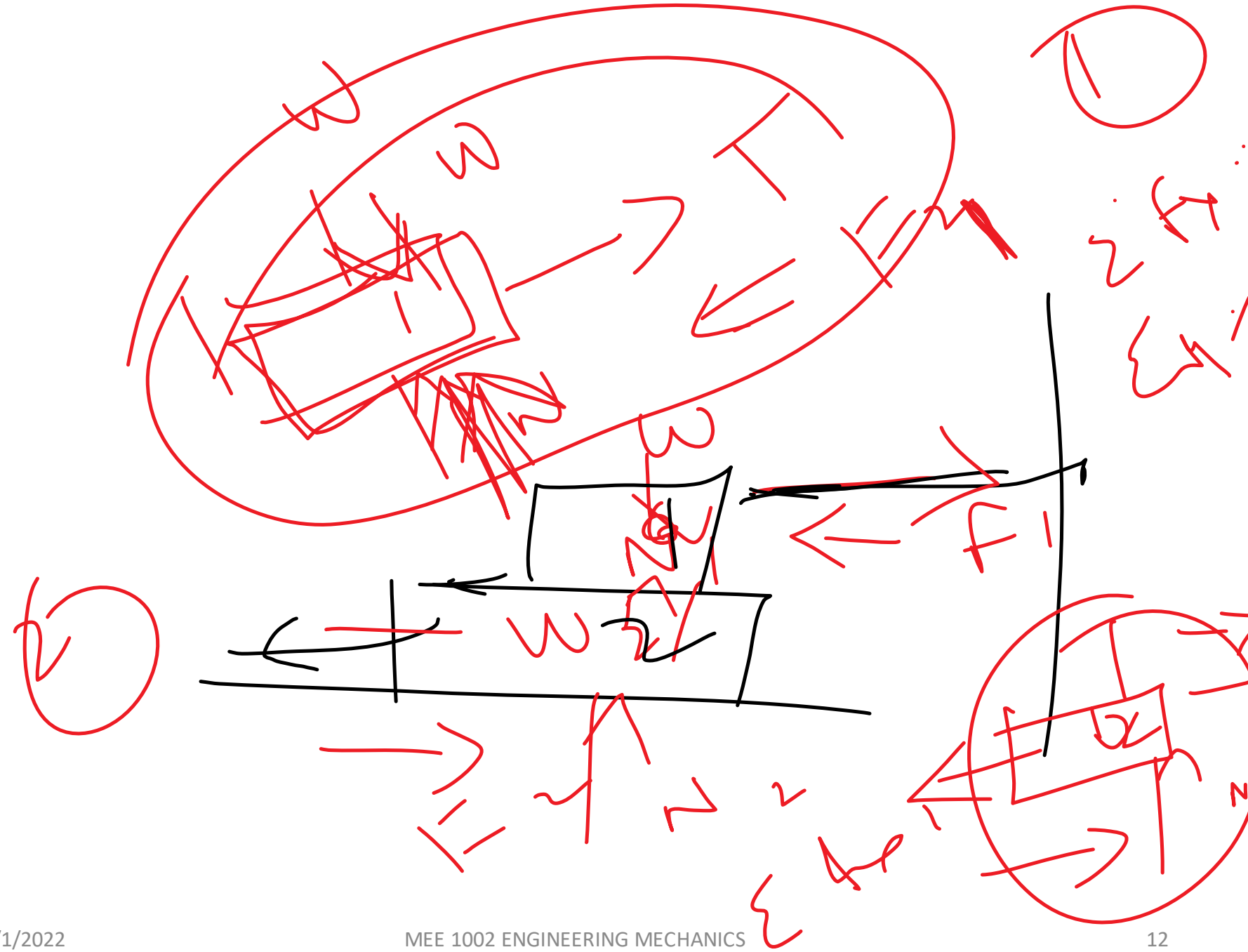


Motion of body 1 with respect to 2

Motion of body 2 with respect to 1

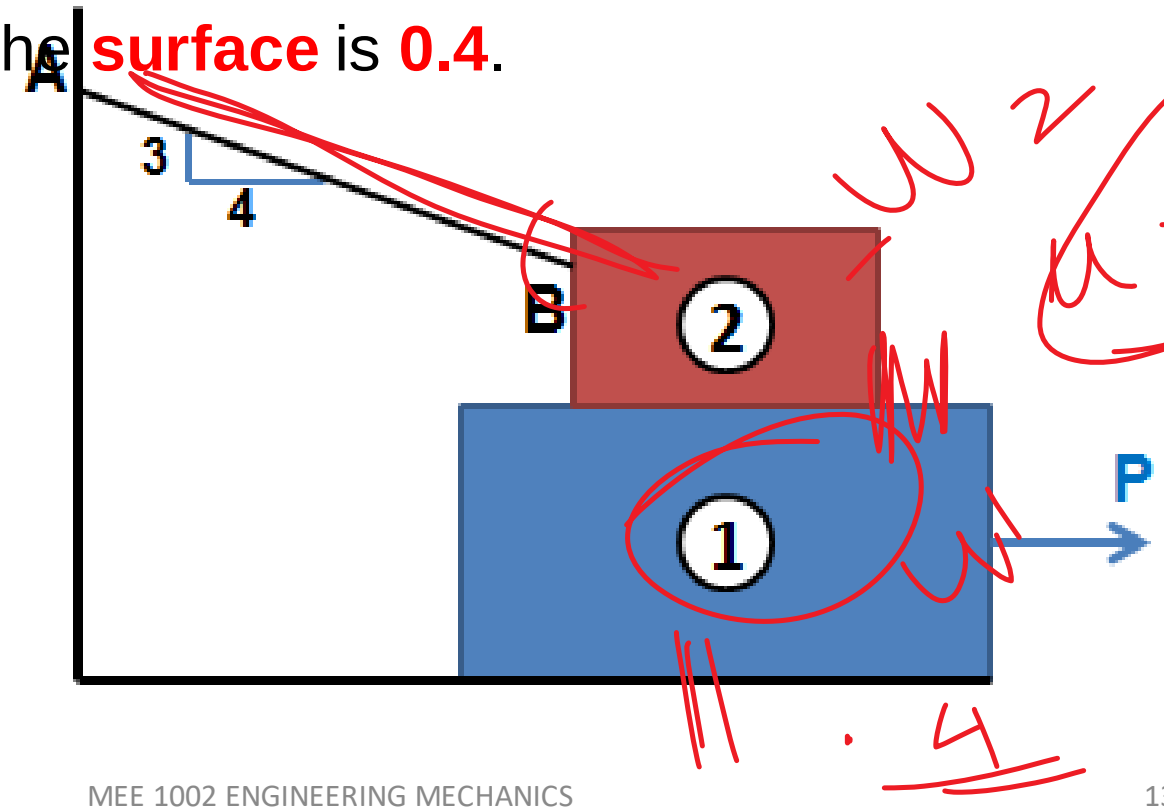
Motion of body 2 with respect to floor



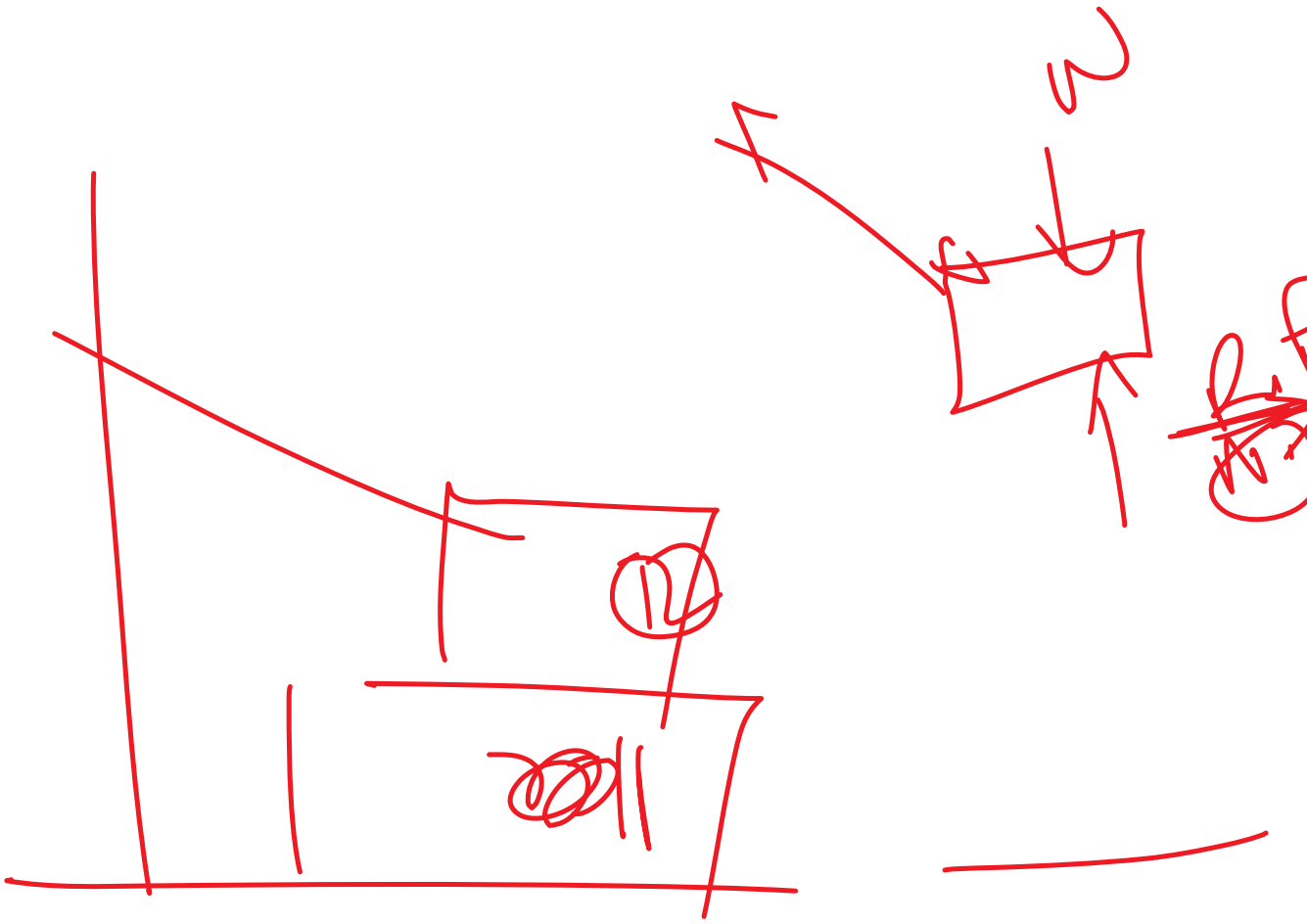


Problem 3

A block of weight W_1=1290N rests on a horizontal surface and supports another block of weight W_2=570N on top of it as shown in figure. Block 2 is attached to a vertical wall by an inclined string **AB**. Find the force **P** applied to the lower block, that will be necessary to cause the slipping to impend. Coefficient of friction between **block 1** and **2** is **0.25** and between **1** and the **surface** is **0.4**.

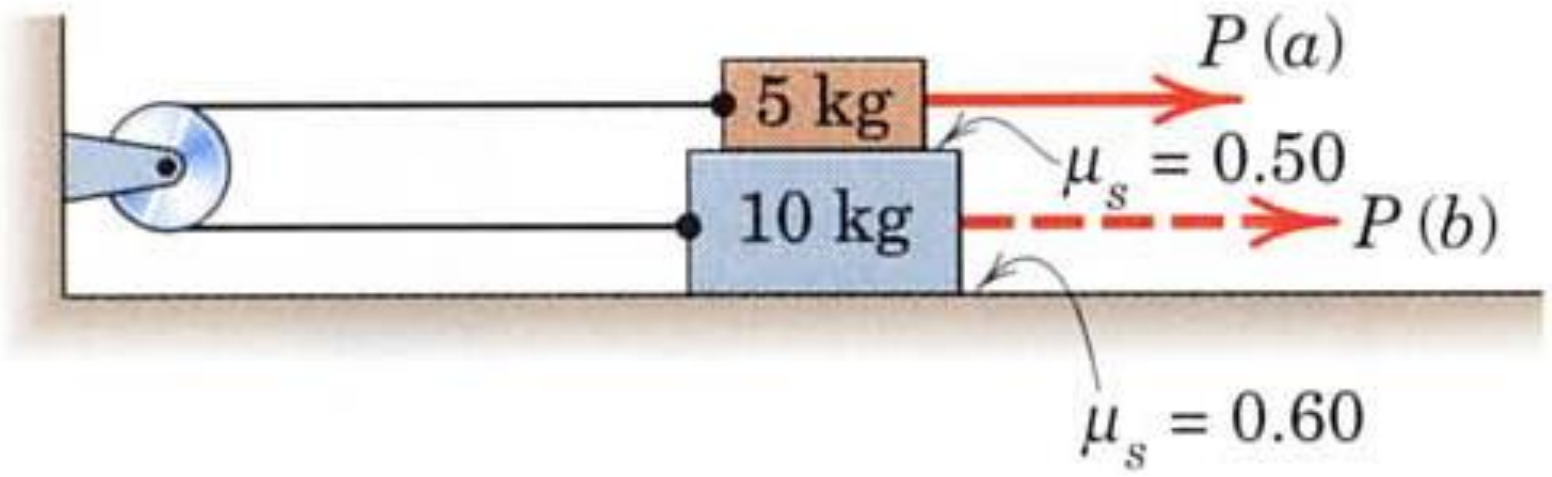


P = 828 N



Problem 4

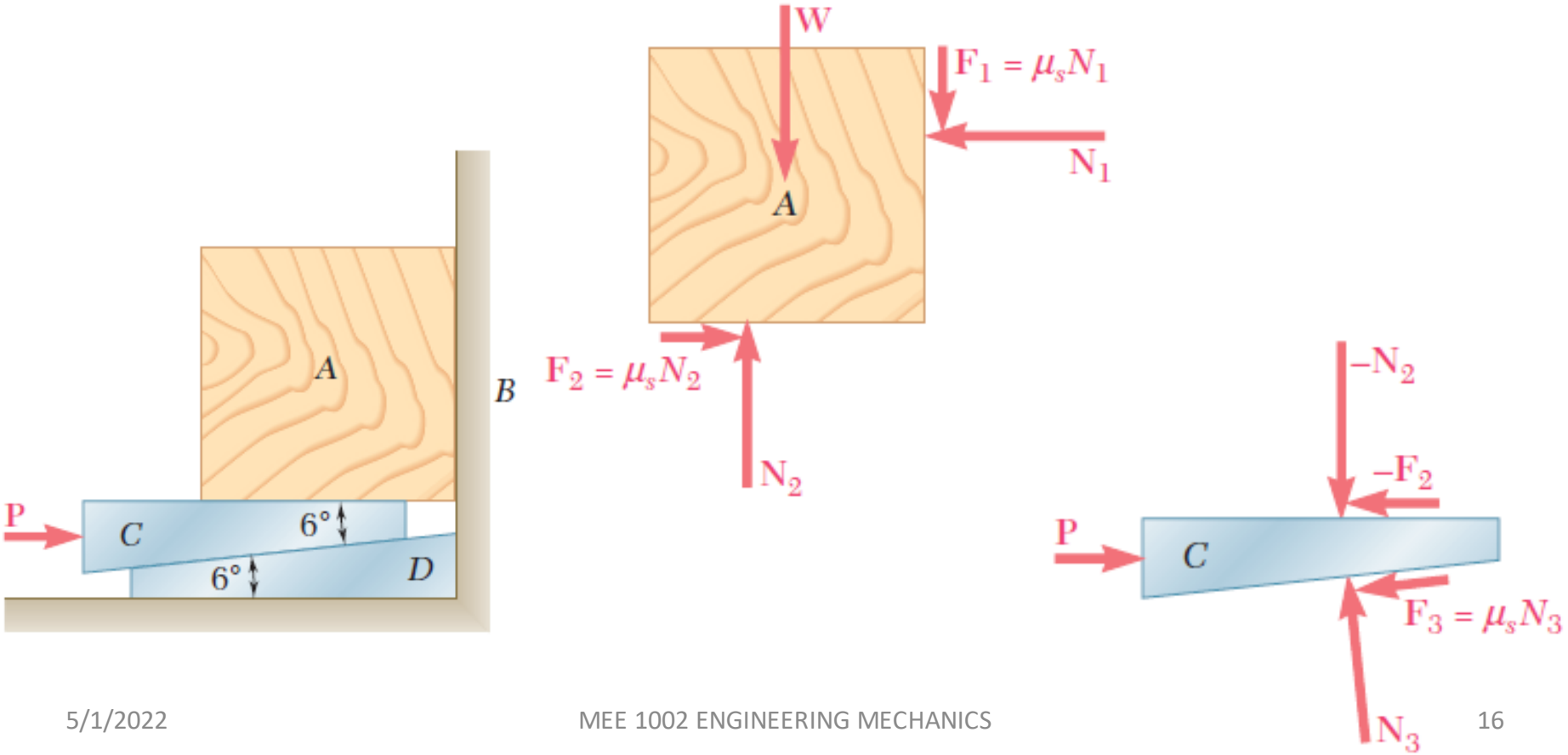
The system of two blocks, cable, and fixed pulley is initially at rest. Determine the horizontal force **P** necessary to cause motion when (a) **P** is applied to the **5 kg block** and (b) **P** is applied to the **10 kg block**. Determine the corresponding tension **T** in the cable for each case.



Ans. (*a*) $P = 137.3$ N, $T = 112.8$ N
(*b*) $P = 137.3$ N, $T = 24.5$ N

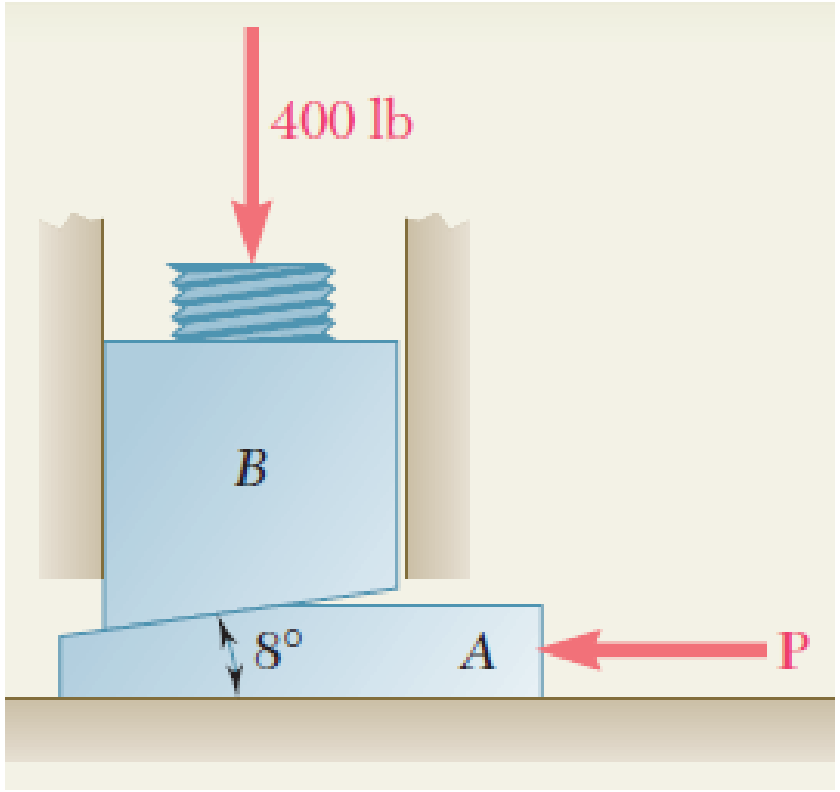
Wedge Friction

- Wedges are simple machines used to raise large stone blocks and other heavy loads by applying considerably smaller force to the wedge.
- Wedges can be used to make small adjustments in the position of heavy pieces of machinery.



Problem 5

The position of the machine block *B* is adjusted by moving the wedge *A*. Knowing that the coefficient of static friction is 0.35 between all surfaces of contact, determine the force **P** required (*a*) to raise block *B*, (*b*) to lower block *B*.



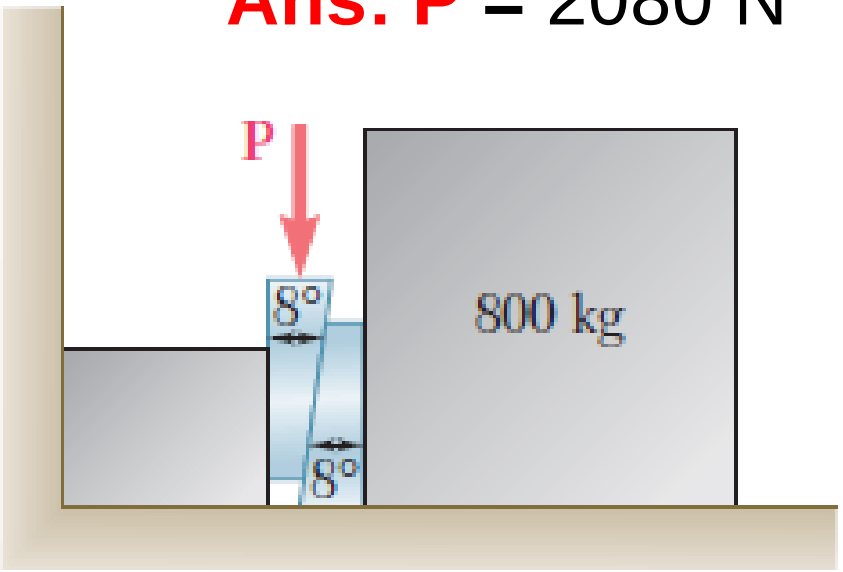
(a) **P** = 423 lb ←

(b) **P** = 206 lb →

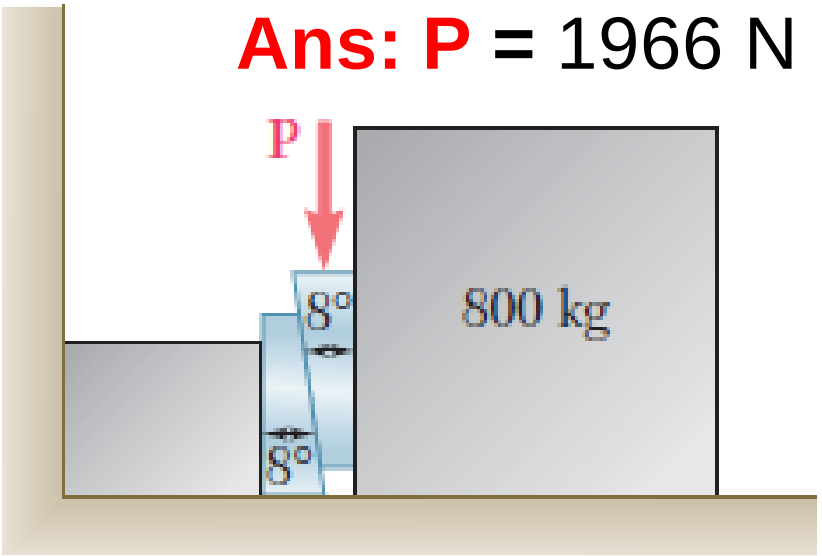
Problem 6

Two 8° wedges of negligible weight are used to move and position the 800-kg block. Knowing that the coefficient of static friction is 0.30 at all surfaces of contact, determine the smallest force **P** that should be applied as shown to one of the wedges.

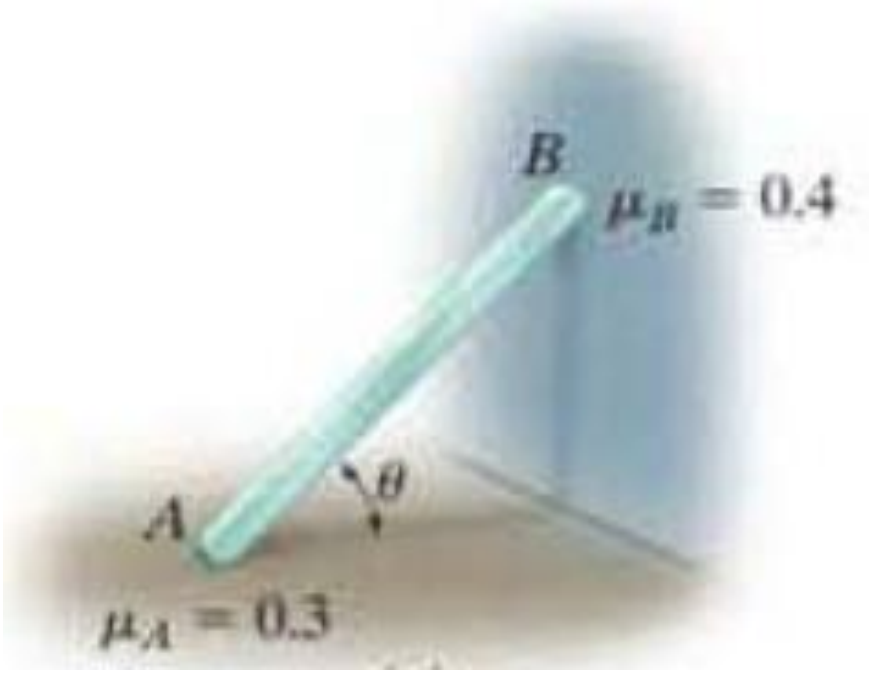
Ans: P = 2080 N

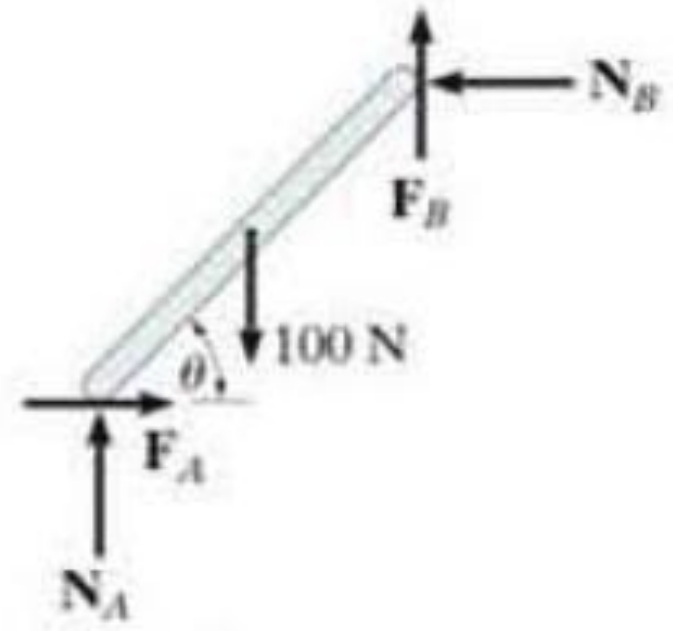


Ans: P = 1966 N



Ladder Friction

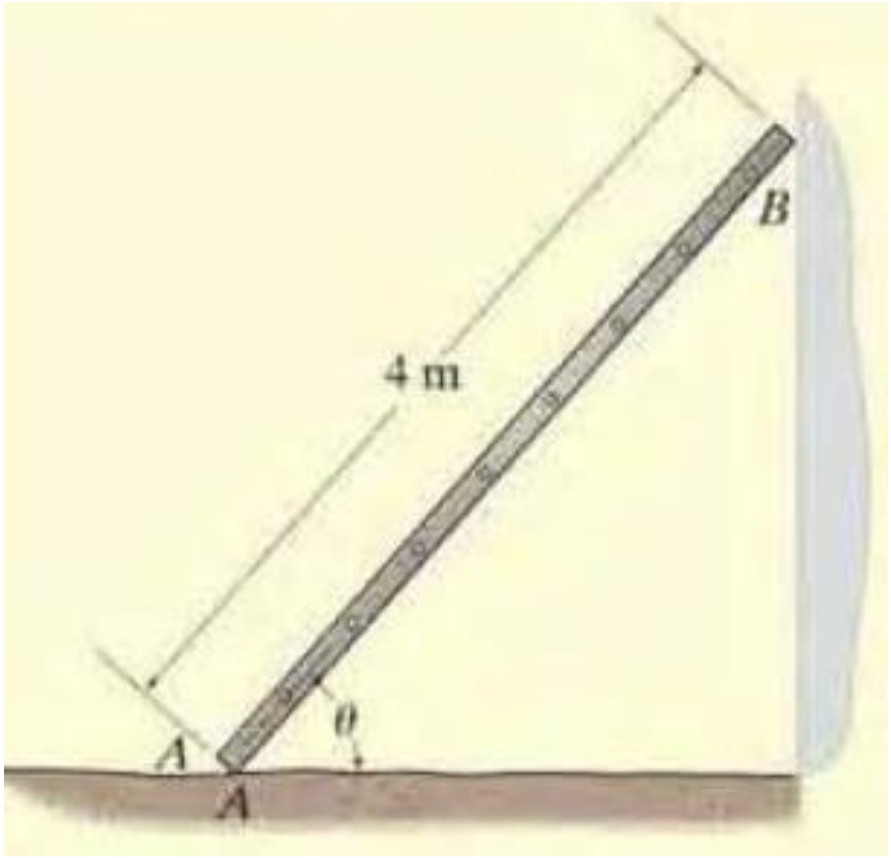




$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma M_Z = 0$

Problem 7

The uniform l0-kg Ladder shown in Figure rests against the smooth wall *B* and the end *A* rests on the rough horizontal plane for which the coefficient of static friction is 0.3. Determine the angle of inclination *θ* of the ladder and the normal reaction at *B* if the Ladder is on the verge of slipping.



Ans: $N_B = 29.4$ N

$\theta = 59°$

Problem 8

A Ladder of length 10 m and weight 300 N is leaning against a vertical wall with an angle of 30° to the vertical. A man of weight 500 N climbs the Ladder. Find the position of the man at the instant the Ladder begins to slip. The coefficient of friction for all surfaces is 0.3.

x = 5.95 m (along the ladder from the ground)

Problem 9

A 4 m long uniform ladder weighing 200 N is placed against a wall making an angle of 55° with the floor. The coefficient of friction between the wall and the ladder is 0.26 and that between the floor and the ladder is 0.36. The ladder in addition to its own weight has to support a man of 900 N at its top end. Calculate the horizontal force *F* applied to the ladder at the floor level to prevent slipping. If force *F* is not applied, what will be the minimum inclination of the ladder so that it does not slip when the man is at its top end.

$F = 250$ N

$\theta = 68.21°$