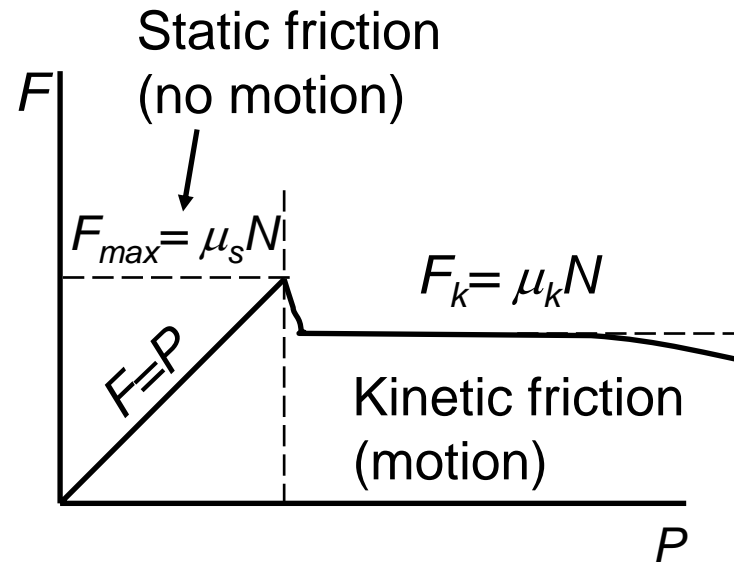
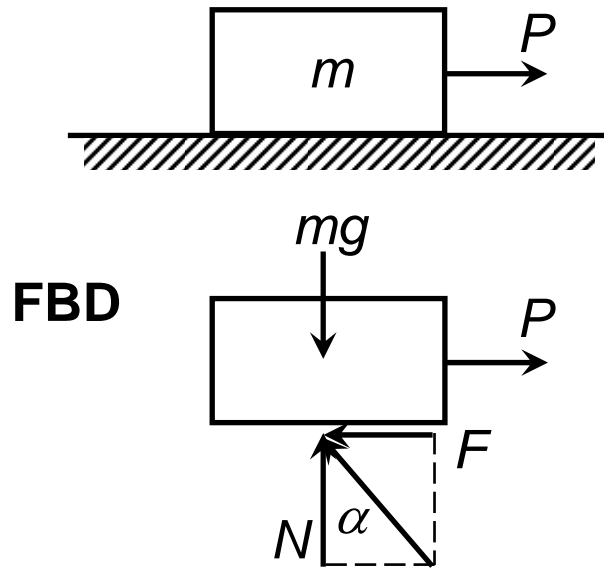


Ch.6 Friction

Types of friction

- a) Dry friction: occurs when non smooth (non ideal) surfaces of two solids are in contact under a condition of sliding or a tendency to slide. (also called *Coulomb friction*)
- b) Fluid friction: occurs when adjacent layers in a fluid are moving at different velocities.
- c) Internal friction: occurs in all solid materials which are subjected to cyclical loading.

Dry friction



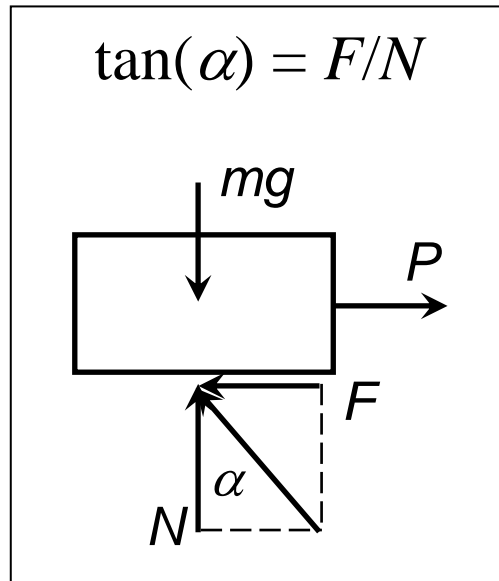
No motion

- Friction force = Force P
- Friction force called static friction
- $F \leq \mu_s N$
- $\mu_s = \text{coefficient of static friction}$

With motion

- $F = \mu_k N$
- $\mu_k = \text{coefficient of kinetic friction}$

Friction angles



At max. static friction

$$F_{max} = \mu_s N$$

α reaches max. value ϕ_s

$$\mu_s = F_{max}/N = \tan(\phi_s)$$

$\phi_s = \arctan(\mu_s) = \textit{angle of static friction}$

In like manner,

$$\mu_k = \tan(\phi_k)$$

$\phi_k = \arctan(\mu_k) = \textit{angle of kinetic friction}$

Types of friction problems (1)

1. Impending motion is known to exist

- $F = F_{max} = \mu_s N$ (in the direction opposing to the impending motion).
- Equations of equilibrium can be used as usual.

2. Relative motion is known to exist

- $F = \mu_k N$ (in the direction opposing to the motion).

Types of friction problems (2)

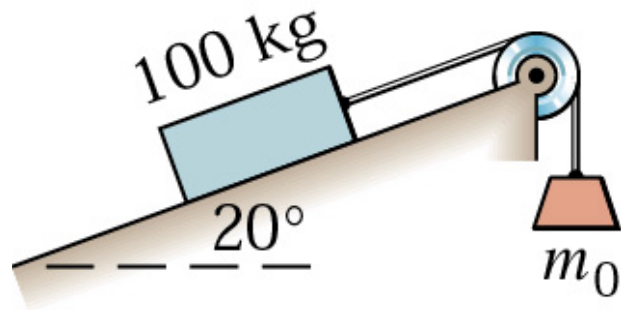
3. Motion condition is unknown

- Assume static equilibrium
- Use equilibrium equation to solve the friction force F
- Check the value of friction force F

- | | |
|-------------------|---|
| (a) $F < \mu_s N$ | <ul style="list-style-type: none">• Friction force necessary for equilibrium can be generated by the surface• The body is in static equilibrium as assumed |
| (b) $F = \mu_s N$ | <ul style="list-style-type: none">• Impending motion is deduced• The body is in static equilibrium as assumed |
| (c) $F > \mu_s N$ | <ul style="list-style-type: none">• Impossible! Assumption of equilibrium is not valid• Motion occurs, $F = \mu_k N$ |

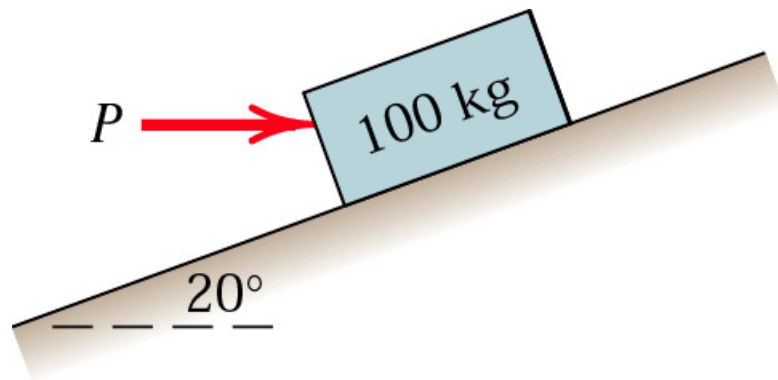
Sample 1

Determine the range of values which the mass m_0 may have so that the 100-kg block shown in the figure will neither start moving up the plane nor slip down the plane. The coefficient of static friction for the contact surface is 0.30



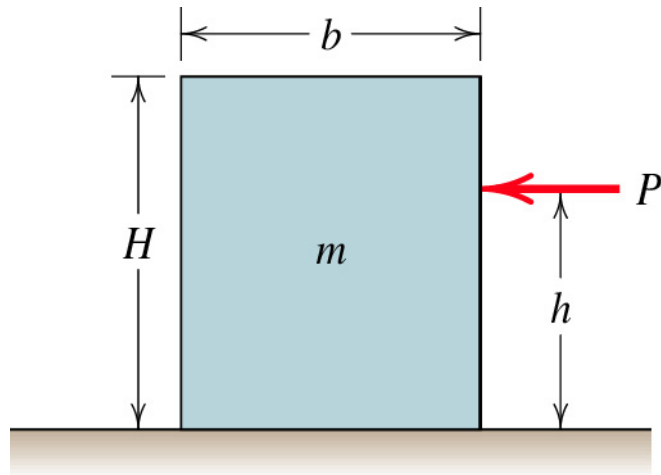
Sample 2

Determine the magnitude and direction of the friction force acting on the 100-kg block shown if, first $P = 500$ N and, second $P = 100$ N. The coefficient of static friction is 0.20, and the coefficient of kinetic friction is 0.17. The forces are applied with the block initially at rest.



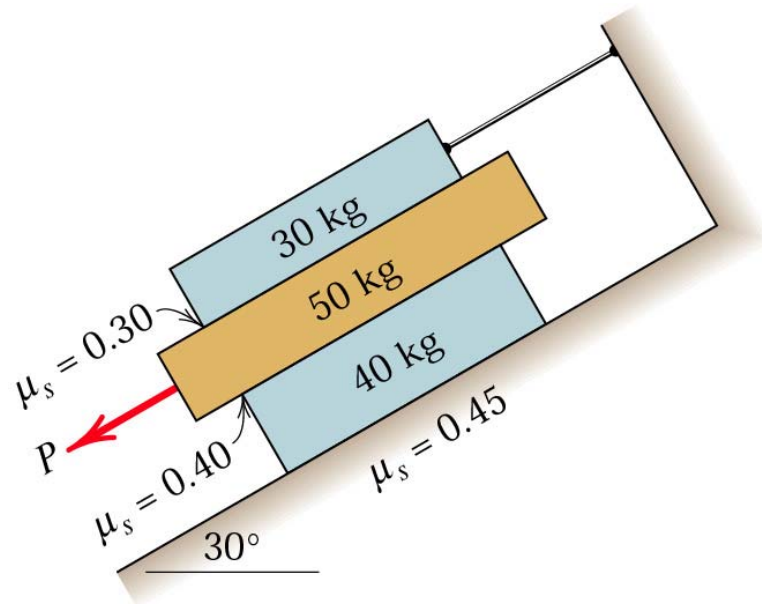
Sample 3

The homogeneous rectangular block of mass m , width b , and height H is placed on the horizontal surface and subjected to a horizontal force P which moves the block along the surface with a constant velocity. The coefficient of kinetic friction between the block and the surface is μ_k . Determine (a) the greatest value that h may have so that the block will slide without tipping over and (b) the location of point C on the bottom face of the block through which the resultant of the friction and normal forces acts if $h = H/2$.



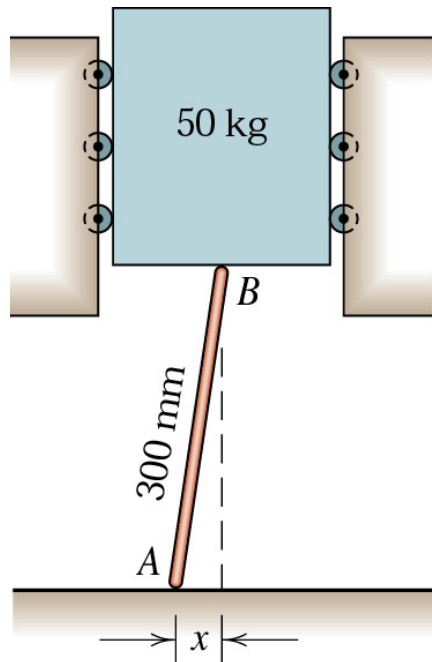
Sample 4

The three flat blocks are positioned on the 30° incline as shown, and a force P parallel to the incline is applied to the middle block. The upper block is prevented from moving by a wire which attaches it to the fixed support. The coefficient of static friction for each of the three pairs of mating surfaces is shown. Determine the maximum value which P may have before any slipping takes place.



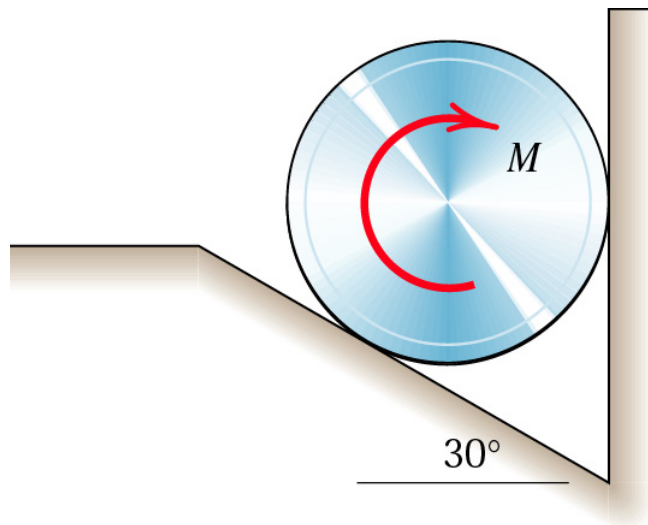
Sample 5

The light bar is used to support the 50-kg block in its vertical guides. If the coefficient of static friction is 0.3 at the upper end of the bar and 0.4 at the lower end of the bar, find the friction force acting at each end for $x = 75$ mm. Also find the maximum value of x for which the bar will not slip.



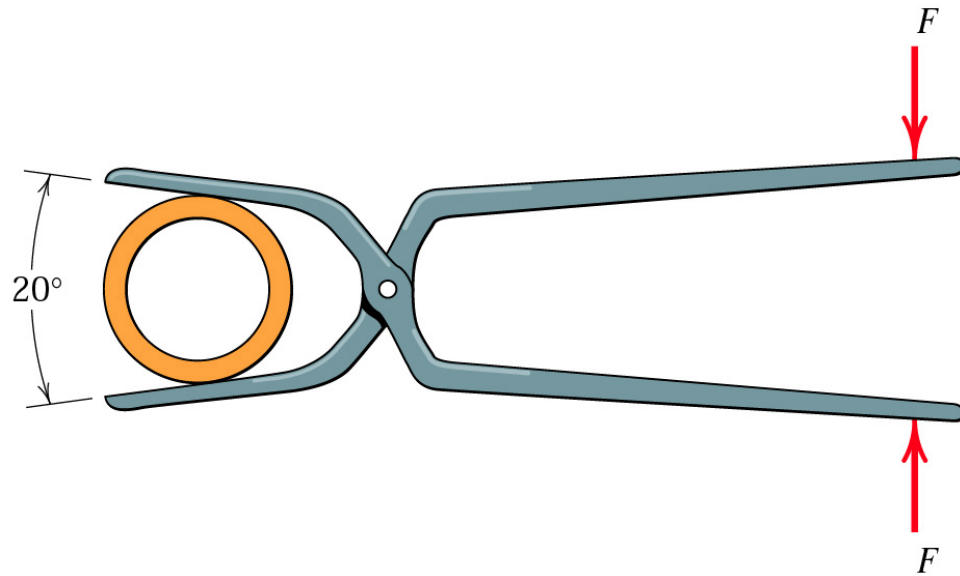
Sample 6

The 30-kg homogeneous cylinder of 400-mm diameter rests against the vertical and inclined surfaces as shown. If the coefficient of static friction between the cylinder and the surface is 0.3, calculate the applied clockwise couple M which would cause the cylinder to slip.



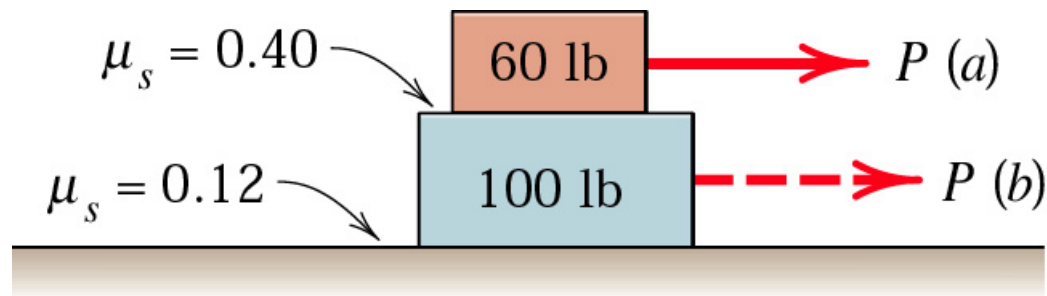
Sample 7

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 minimum coefficient of static friction between the jaws and the tube which will enable the tongs to grip the tube without slipping



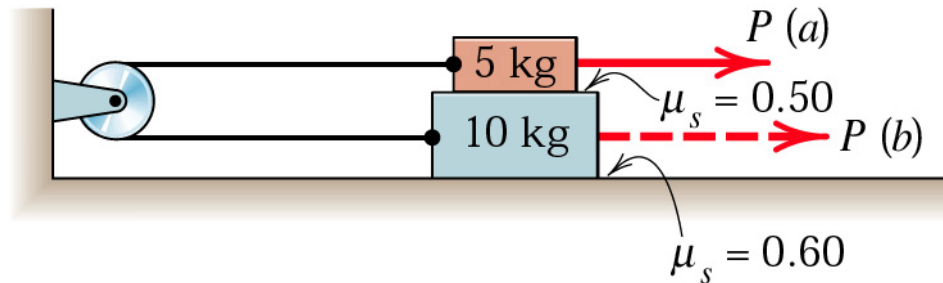
Sample 8

The force P is applied to (a) the 30-kg block and (b) the 50-kg block. For each case, determine the magnitude of P required to initiate motion.



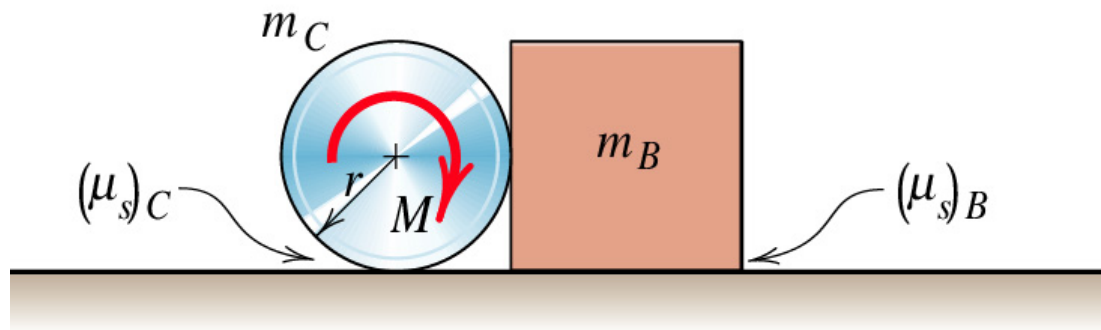
Sample 9

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.



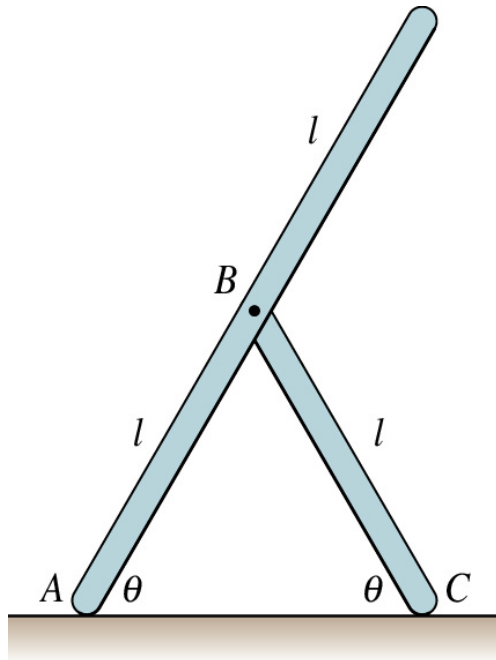
Sample 10

A clockwise couple M is applied to the circular cylinder as shown. Determine the value of M required to initiate motion for the conditions $m_B = 3$ kg, $m_C = 6$ kg $(\mu_s)_B = 0.5$, $(\mu_s)_C = 0.4$, and $r = 0.2$ m. Friction between the cylinder C and the block B is negligible.

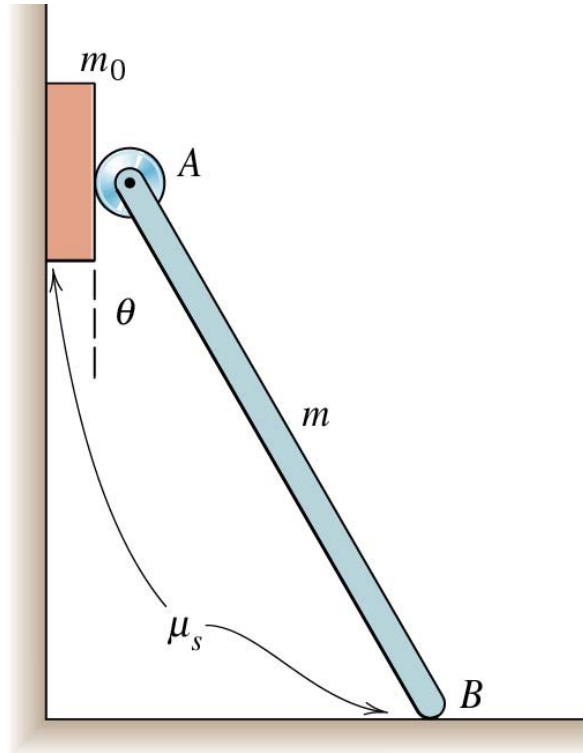


Sample 11

The two uniform slender bars constructed from the same stock material are freely pinned together at B . Determine the minimum angle θ at which slipping does not occur at either contact point A or C . The coefficient of static friction at both A and C is $\mu_s = 0.50$. Consider only motion in the vertical plane shown.



Sample 12



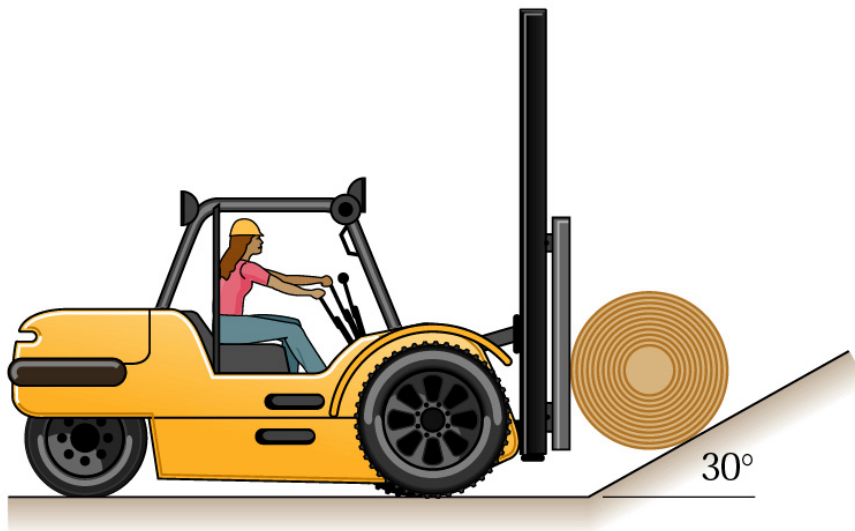
small ideal roller at the upper end A

Determine a general expression for the minimum value θ_{min} of θ for which the block will remain in equilibrium.

Evaluate your expression for $\mu_s = 0.5$ and $m/m_0 = 10$. For these conditions, check for possible slipping at B .

Sample 13

The industrial truck is used to move the solid 1200-kg roll of paper up the 30° incline. If the coefficients of static and kinetic friction between the roll and the vertical barrier of the truck and between the roll and the incline are both 0.40, compute the required tractive force P between the tires of the truck and the horizontal surface.



Sample 14

Three boxes are placed on the incline in contact with each other and released from rest. The coefficients of static friction under boxes *A*, *B*, and *C* are 0.30, 0.20, and 0.35, respectively. Describe what happens.

