Announcements

- Take Optional Evening Matlab Lecture Poll on Piazza
- Quiz 5 next week – CBTF
- TAM210 CBTF Final: Nov. 9-12
- TAM211 CBTF Final: Dec. 14-20 (tentative)

❑ Upcoming deadlines:

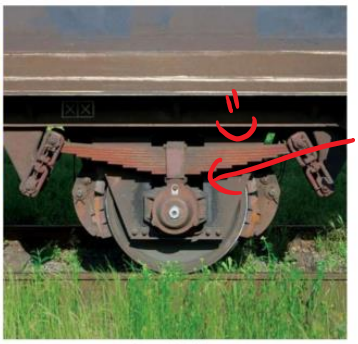
- Tuesday (10/31)
  - PL HW18
- Thursday (11/2)
  - ME HW17
- Friday (11/3)
  - WA#3 – going live tonight!

Friction

Friction is a force that resists the movement of two contacting surfaces that slide relative to one another. This force acts tangent to the surface at the points of contact and is directed so as to oppose the possible or existing motion between the surfaces.

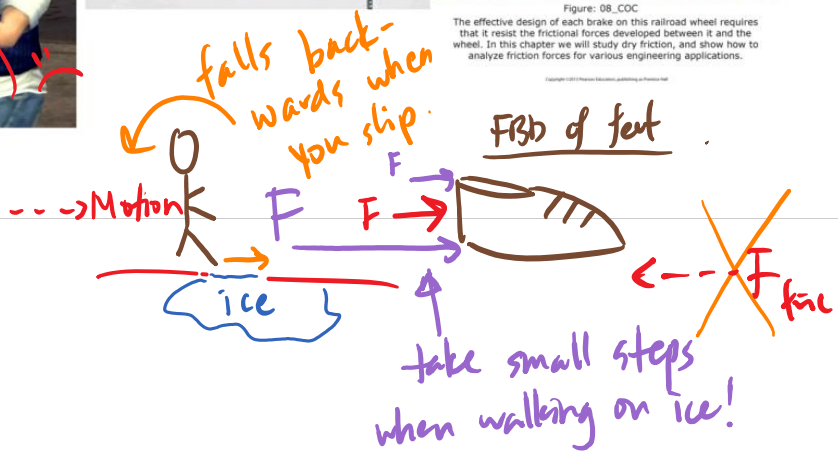
Dry Friction (or Coulomb friction) occurs between the contacting surfaces of bodies when there is no lubricating fluid.

heat.



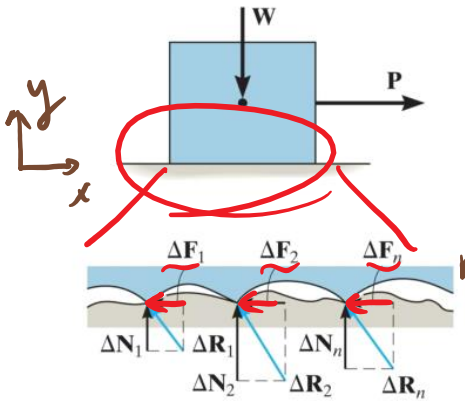
brake.

Figure: 08_COC
The effective design of each brake on this railroad wheel requires that it resist the frictional forces developed between it and the wheel. In this chapter we will study dry friction, and show how to analyze friction forces for various engineering applications.

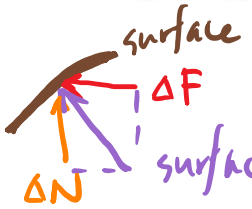


Dry friction

- Consider the effects of pulling horizontally (force **P**) a block of weight **W** which is resting on a **rough** surface.
- The floor exerts an uneven distribution of normal forces ΔN_n and frictional forces ΔF_n along the contacting surface.
- These distributed loads can be represented by their equivalent resultant normal forces N and frictional forces F

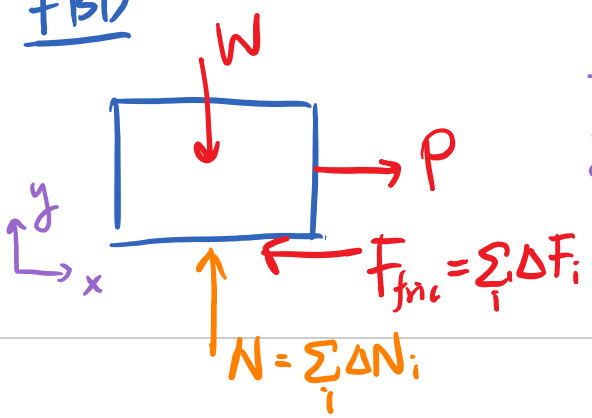


microscopic view



surface reaction force

FBD



EoE

$\sum F_x = P - F_{fric} = 0 \Rightarrow P = F_{fric}$

$\sum F_y = -W + N = 0 \Rightarrow N = W$

Friday, October 27, 2017 11:44 AM

Dry friction

There are 3 regions in the P-F diagram

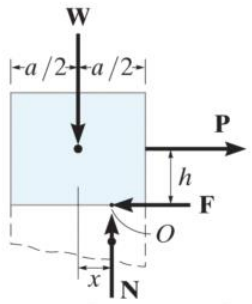
① $P < F_s$: no motion, $F_{friction} = P$

F_s : maximum static friction force $\Rightarrow$ $F_s = \mu_s N$ (coefficient of static friction)

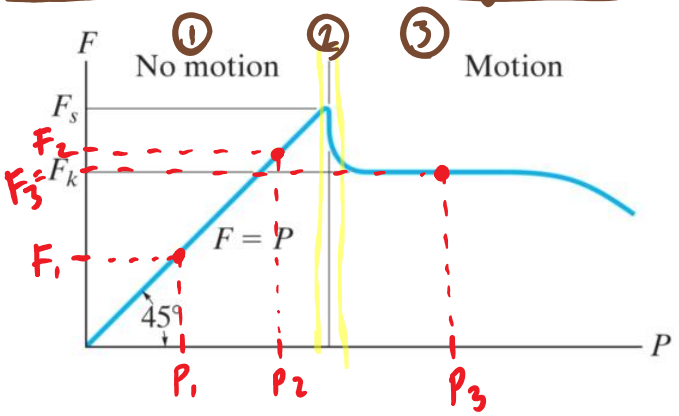
② $P = F_s$: impending motion, unstable

③ $P > F_s$: object in motion, $F_{fric} = F_k$

$F_k = \mu_k N$ (coefficient of kinetic friction)



Force P vs. Friction F Diagram



$P_3 > F_3$: motion occurs

Table 8–1 Typical Values for μ_s	
Contact Materials	Coefficient of Static Friction (μ_s)
Metal on ice	0.03–0.05
Wood on wood	0.30–0.70
Leather on wood	0.20–0.50
Leather on metal	0.30–0.60
Aluminum on aluminum	1.10–1.70

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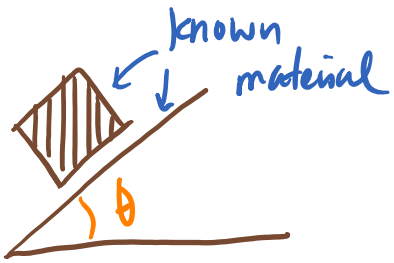
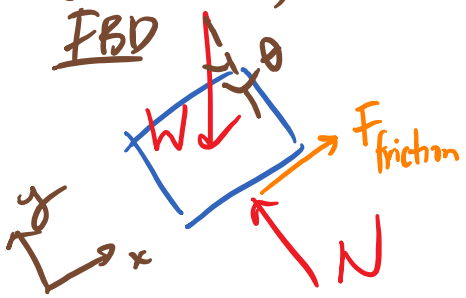
Determine μ_s Experimentally

A block with weight W is placed on an inclined plane. What will happen to the block when the plane is slowly tilted? (increase θ)





~ Solve for relationship between F_{fric} and N using EoE.

EoE

$\Sigma F_x = F_{fric} - W\sin\theta = 0$

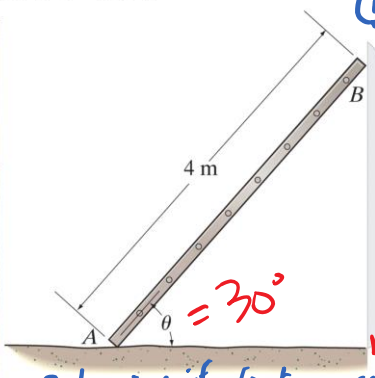
$\Sigma F_y = N - W\cos\theta = 0$

Divide the top eqn by the bottom $\rightarrow \frac{F_{fric}}{N} = \frac{\sin\theta}{\cos\theta} = \tan\theta$

~ Since $F_s = \mu_s N$, $\frac{F_s}{N} = \mu_s = \tan\theta$ when θ = angle at which the box starts to slide.

Example

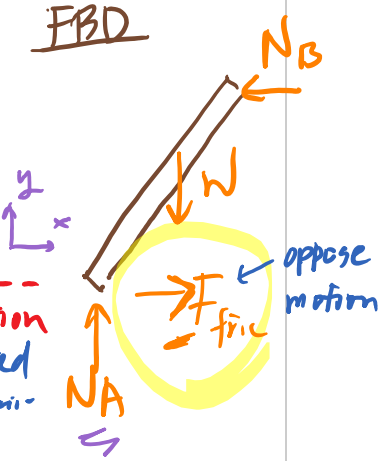
A wooden ladder with a mass of 10 kg is leaning against a smooth wall.
Can it maintain equilibrium if $\theta = 30°$?



No friction

① Draw FBD.

FBD



$\theta = 30°$

motion

~ Determine if friction required to keep the ladder at equilibrium is less than F_s

Find: $F_{fric} \overset{?}{\leq} F_s$

② Use Equations of equilibrium

Eqt

$$\sum F_x = -N_B + F_{fric} = 0 \Rightarrow F_{fric} = N_B$$

$$\sum F_y = N_A - W = 0 \Rightarrow N_A = W$$

$$\sum M_A = -W\left(\frac{4\cos 30°}{2}\right) + N_B(4\sin 30°) = 0$$

$$\Rightarrow N_B = \frac{W}{2\tan 30°}$$

Substitute to express F_{fric} in terms of W and θ.

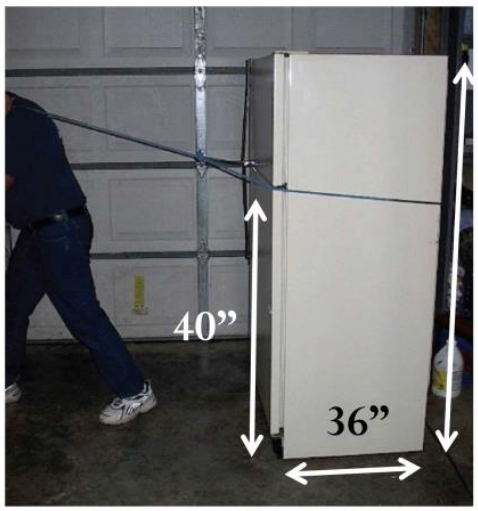
$$\Rightarrow F_{fric} = \frac{W}{2\tan 30°}$$

$$F_s = \mu_s N_A = \mu_s W$$

~ check to see how it compares with F_s.

$$F_{fric} = \frac{W}{2\tan\theta} \leq \mu_s W = F_s$$

$\Rightarrow$ As long $\mu_s \geq \frac{1}{2\tan 30°}$, the ladder will maintain equilibrium.

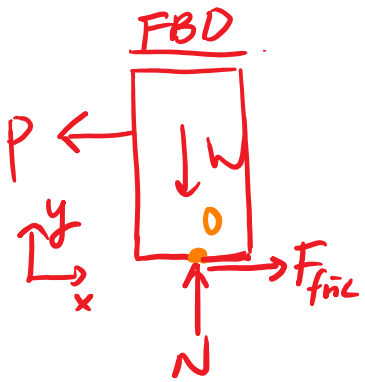


Given: Fridge weight = 250 lb and $\mu_s = 0.4$

Find: The maximum horizontal force P that can be applied at without causing movement of the crate.

① Draw FBD to see what forces are involved

② Check EoE to see what is the required force to overcome friction.



EoE

$\Sigma F_x = -P + F_{fric} = 0$

$\Sigma F_y = N - W = 0$

$\Sigma M_O = P(40\text{ in}) = 0$?

– The moment equation can only be zero if P is zero?