Inclass_Chapter8_Friction.pptx

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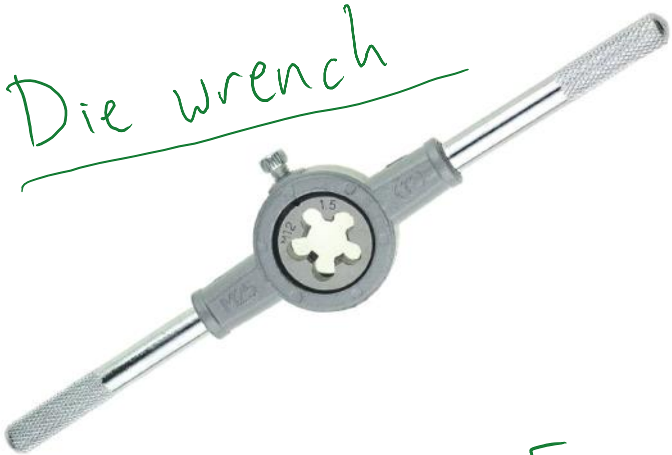
Chapter 8: Friction

Unsolved problems in classical mechanics:

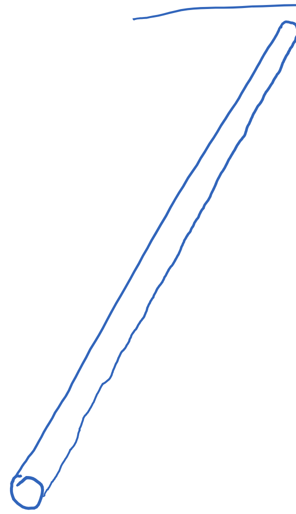
1. Turbulence
2. Friction

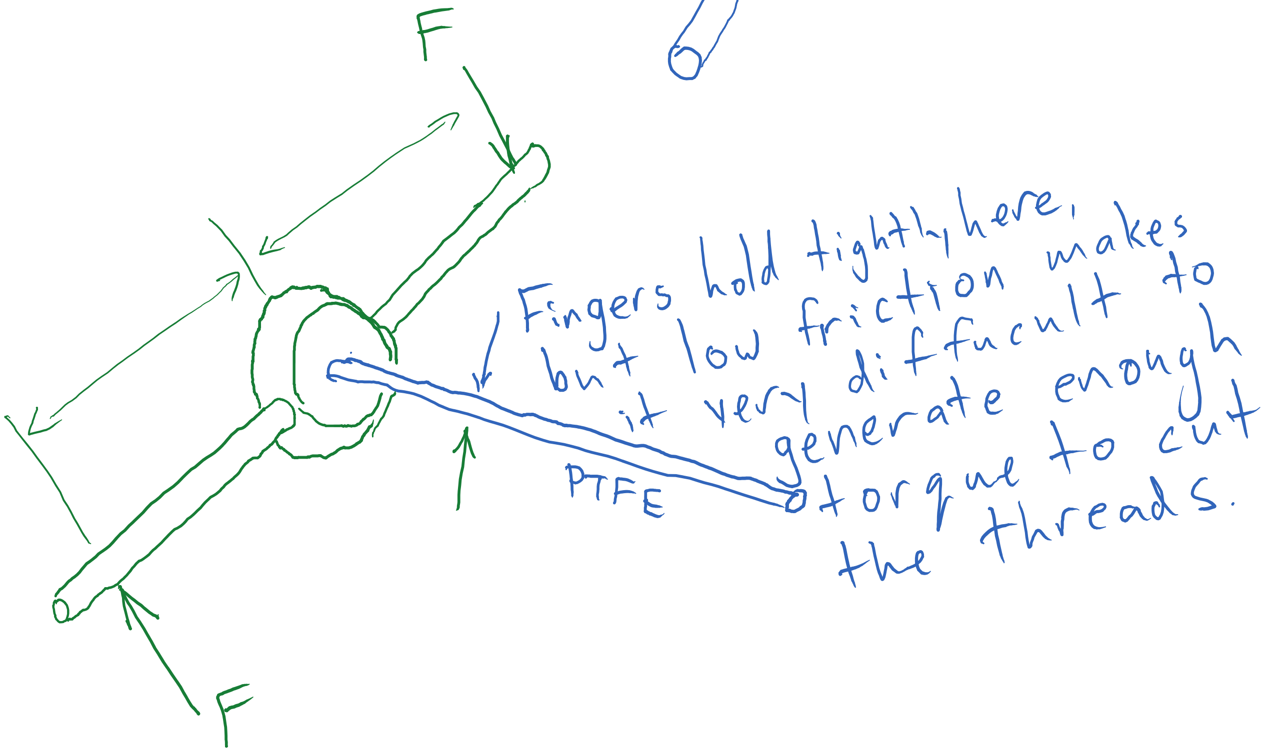
Demo: Why is it so difficult to cut threads on a PTFE (teflon) rod?

Die wrench



PTFE Rod





Friction

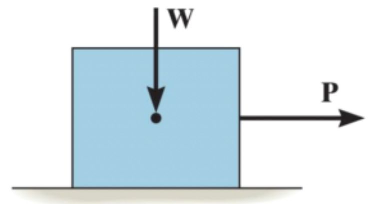
Friction is a force that resists the movement of two contacting surfaces that slide relative to one another. This force acts tangent to the surface at the points of contact and is directed so as to oppose the possible or existing motion between the surfaces.

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

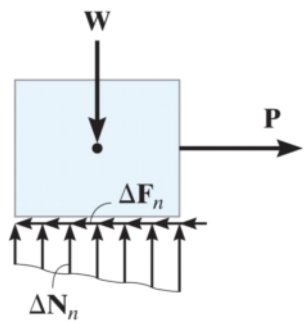
Figure: 08_COC
The effective design of each brake on this railroad wheel requires that it resist the frictional forces developed between it and the wheel. In this chapter we will study dry friction, and show how to analyze friction forces for various engineering applications.

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.



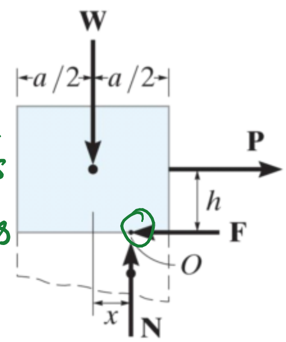
- These distributed loads can be represented by their equivalent resultant normal forces N and frictional forces F

- Equilibrium to avoid tipping:

$$(\Sigma M)_o = 0$$

$$\Rightarrow \quad x \cdot W - h \cdot P = 0$$

$$\Rightarrow \quad x = \frac{P}{W} \cdot h$$



- Impending motion: The maximum force F_s before slipping (movement) begins is given by $|F_s| = \mu_s \cdot |N|$

where μ_s is called the coefficient of static friction

$F_s = \mu_s \cdot N$ gives only the maximum possible static friction force

- The actual friction force may be less!

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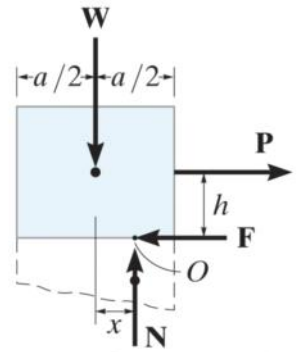
Dry friction

1. If $P=0$, then there is no motion possible and no friction
2. If $P<\mu_s \cdot |W|$ ⟹ No motion and $|F|=|P|$
3. If $P=F_s=\mu_s \cdot W$ ⟹ No motion, but the block is on the verge of sliding
4. If $P>F_s$ ⟹ Box begins to slide



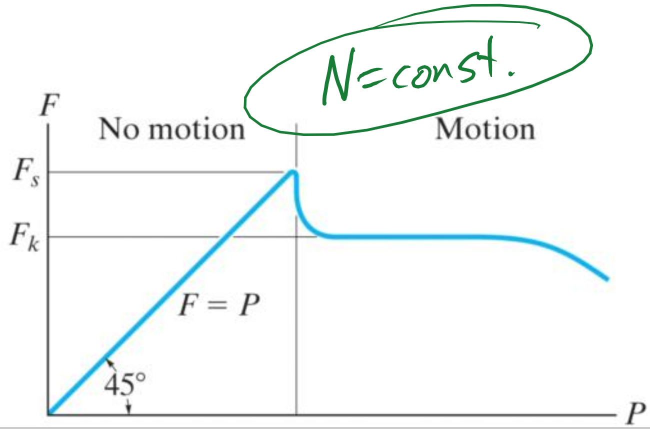


Table 8–1 Typical Values for μ_s	
Contact Materials	Coefficient of Static Friction (μ_s)
Metal on ice	0.03–0.05
Wood on wood	0.30–0.70
Leather on wood	0.20–0.50
Leather on metal	0.30–0.60
Aluminum on aluminum	1.10–1.70
Teflon	~ 0.04

If

$P>F_s$

$\sum F_x \neq 0$ ⟹ acceleration/motion!

F_s no longer is a function of μ_s, but instead will be $F_s=\mu_k \cdot N$

μ_k = coefficient of

kinetic friction

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μ_k is generally ______ μ_s.

A) greater than
B) equal to
C) less than

μ_k typically about 25% less than μ_s.

Use μ_k in cases of motion, but not necessarily acceleration!

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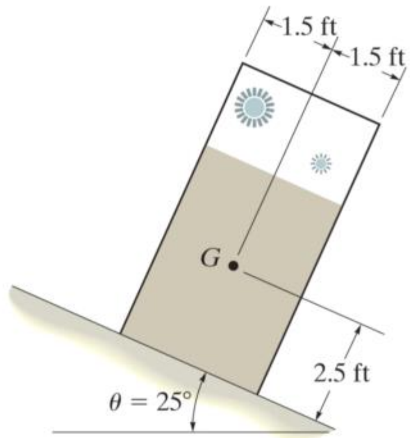
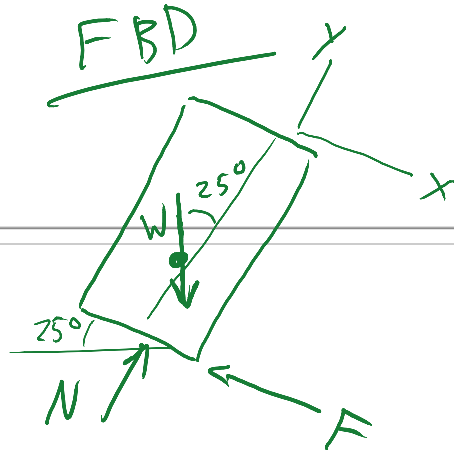
It is observed that when the bed of the dump truck is raised to an angle of $\theta = 25^o$ the vending machines will begin to slide off the bed. Determine the static coefficient of friction between a vending machine and the surface of the truck bed.



Vending machine begins to slide when $F = \mu_s \cdot N$

FBD



$\Sigma F_x = 0 \Rightarrow -F + W \cdot \sin\theta = 0 \quad (\theta = 25°)$

$\Rightarrow F = W \cdot \sin\theta$

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

$\Rightarrow N = W \cdot \cos\theta$

If $F = \mu_s \cdot N$, then $\mu_s \cdot N = W \cdot \sin\theta$

$$\mu_s \cdot N = \left(\frac{N}{\cos\theta}\right)\sin\theta$$

$$\mu_s = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$\boxed{\mu_s = \tan(25°) \approx 0.466}$$

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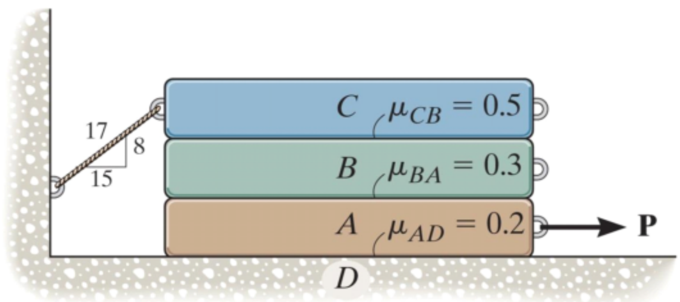
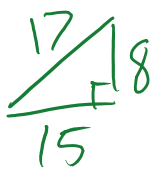
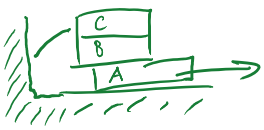


The three bars have a weight $W_A = 20$ lb, $W_B = 40$ lb, $W_C = 60$ lb respectively. If the coefficient of static friction at the surfaces of contact are as shown, determine the smallest horizontal force P needed to move block A.

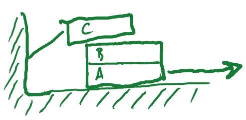


Case 1: A moves, B does not



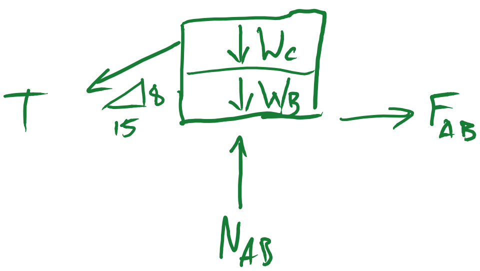
$F_{AD} = \mu_{AD} \cdot N_{AD}$
$F_{AB} = \mu_{AB} \cdot N_{AB}$
} max. static friction before sliding

Case 2: A & B slide together



$F_{AD} = \mu_{AD} \cdot N_{AD}$
$F_{BC} = \mu_{BC} \cdot N_{BC}$
} max. static friction before sliding

Case 1



$\Sigma F_y = 0 \Rightarrow N_{AB} = W_B + W_c + T \cdot \frac{8}{17}$

$\Sigma F_x = 0 \Rightarrow F_{AB} = T \cdot \frac{15}{17}$

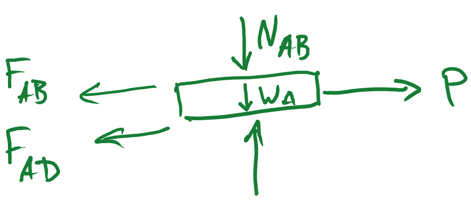
$\hookrightarrow T = \frac{17}{15} \mu_{AB} \cdot N_{AB}$

$T = \frac{17}{15} \mu_{AB} \cdot \left(W_B + W_c + T \cdot \frac{8}{17} \right)$

$\Rightarrow T = 40.48 \text{ lb}$

$\Rightarrow N_{AB} = 40 \text{ lb} + 60 \text{ lb} + (40.48 \text{ lb}) \frac{8}{17}$

$= 119.05 \text{ lb}$



N_{AD}

$$\Sigma F_y = 0 \Rightarrow \boxed{N_{AD}} = W_A + N_{AB}$$

$$= 20\,lb + 119.05\,lb$$

$$= \boxed{139.05\,lb}$$

$$\Sigma F_x = 0 \Rightarrow P = F_{AB} + F_{AD}$$

$$P = \mu_{AB} N_{AB} + \mu_{AD} N_{AD}$$

$$= (0.3)(119.05\,lb) + (0.2)(139.05\,lb)$$

$$P = 63.52\,lb$$

Now, solve P for case 2