CHARACTERISTICS OF DRY FRICTION & PROBLEMS INVOLVING DRY FRICTION

Today's Objective:

Students will be able to:

a) Understand the characteristics of dry friction

b) Draw a FBD including friction.

c) Solve problems involving friction.

In-Class Activities:

- Check Homework, if any
- Reading Quiz
- Applications
- Characteristics of Dry Friction
- Problems involving Dry Friction
- Concept Quiz
- Group Problem Solving
- Attention Quiz

READING QUIZ

1. A friction force always acts _____ to the contact surface.

   A) Normal B) At 45°

   C) Parallel D) At the angle of static friction

2. If a block is stationary, then the friction force acting on it is ________ .

   A) $\leq \mu_s N$ B) $= \mu_s N$

   C) $\geq \mu_s N$ D) $= \mu_k N$

APPLICATIONS

In designing a brake system for a bicycle, car, or any other vehicle, it is important to understand the frictional forces involved.

For an applied force on the bike tire brake pads, how can we determine the magnitude and direction of the resulting friction force?

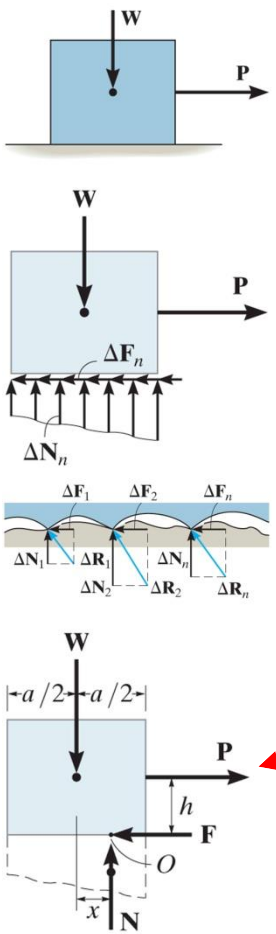
APPLICATIONS (continued)

The rope is used to tow the refrigerator.

In order to move the refrigerator, is it best to pull up as shown, pull horizontally, or pull downwards on the rope?

What physical factors affect the answer to this question?

CHARACTERISTICS OF DRY FRICTION (Section 8.1)



Resultant Normal and Frictional Forces

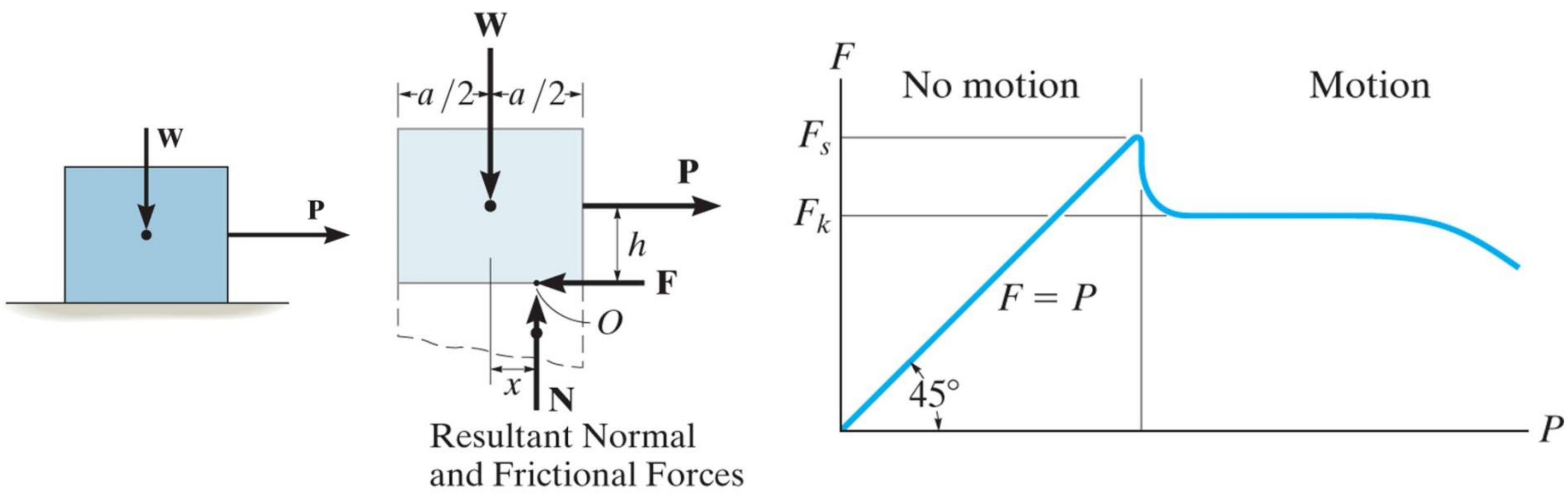
Friction is defined as a force of resistance acting on a body which prevents or resists the slipping of a body relative to a second body.

Experiments show that frictional forces act tangent (parallel) to the contacting surface in a direction opposing the relative motion or tendency for motion.

For the body shown in the figure to be in equilibrium, the following must be true:

$F = P$, $N = W$, and $W*x = P*h$.

CHARACTERISTICS OF DRY FRICTION (continued)

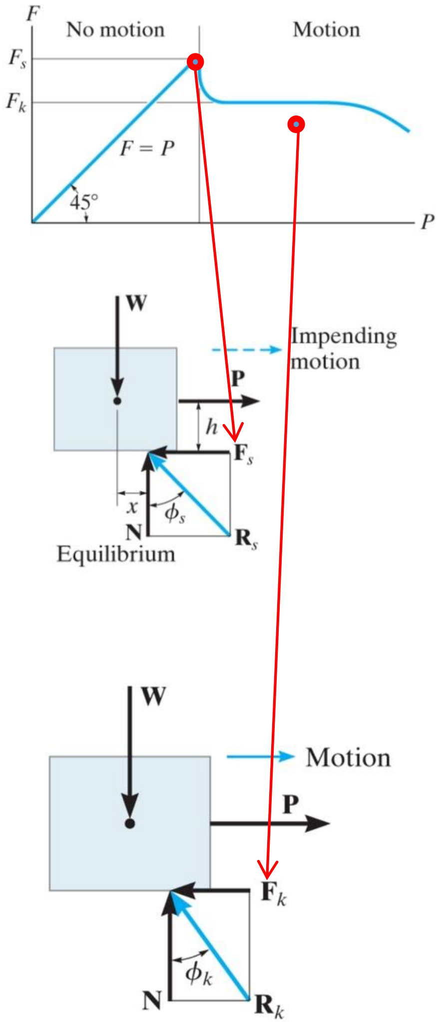


To study the characteristics of the friction force F, let us assume that tipping does not occur (i.e., "h" is small or "a" is large).

Then we gradually increase the magnitude of the force P.

Typically, experiments show that the friction force F varies with P, as shown in the right figure above.

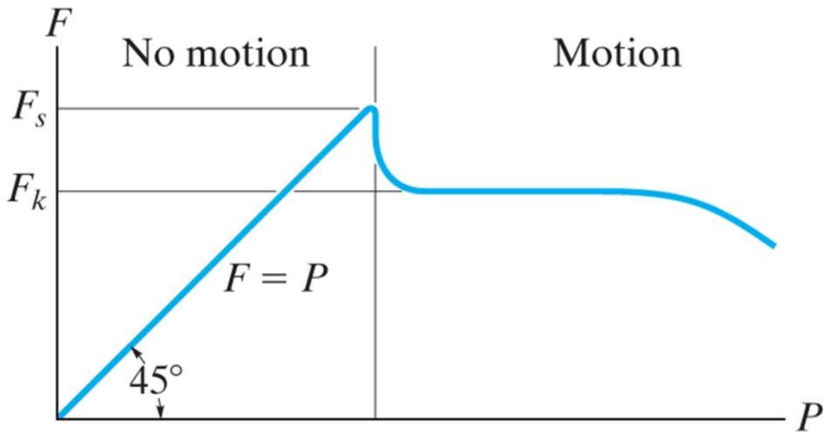
CHARACTERISTICS OF DRY FRICTION (continued)



The maximum friction force is attained just before the block begins to move (a situation that is called "impending motion"). The value of the force is found using $F_s = \mu_s N$, where μ_s is called the coefficient of static friction. The value of μ_s depends on the two materials in contact.

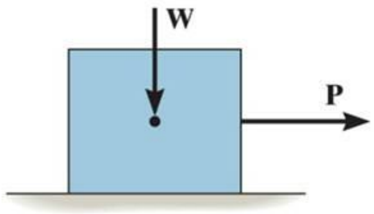
Once the block begins to move, the frictional force typically drops and is given by $F_k = \mu_k N$. The value of μ_k (coefficient of kinetic friction) is less than μ_s .

CHARACTERISTICS OF DRY FRICTION (continued)

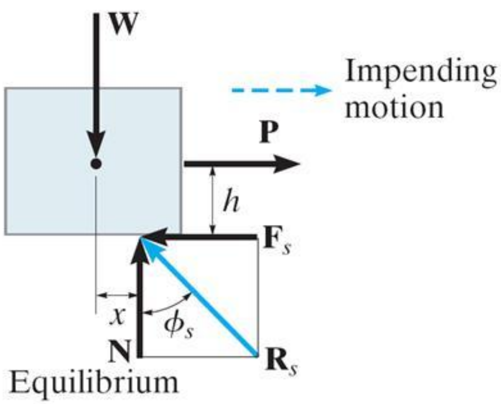


It is also very important to note that the friction force may be less than the maximum friction force. So, just because the object is not moving, don't assume the friction force is at its maximum of $F_s = \mu_s N$ unless you are told or know motion is impending!

DETERMINING μ_s EXPERIMENTALLY



If the block just begins to slip, the maximum friction force is $F_s = \mu_s N$, where μ_s is the coefficient of static friction.

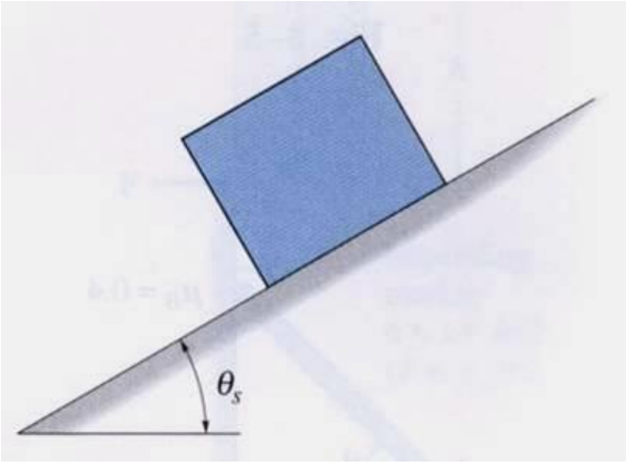


Thus, when the block is on the verge of sliding, the normal force N and frictional force F_s combine to create a resultant R_s.

From the figure,

$\tan \phi_s = (F_s / N) = (\mu_s N / N) = \mu_s$

DETERMINING μ_s EXPERIMENTALLY (continued)

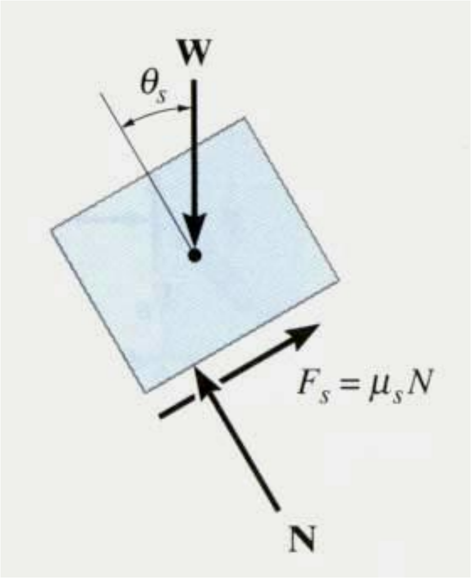


A block with weight w is placed on an inclined plane. The plane is slowly tilted until the block just begins to slip.

The inclination, θ_s, is noted. Analysis of the block just before it begins to move gives (using $F_s = \mu_s N$):

$$\nwarrow + \quad \sum F_y = N - W \cos \theta_s = 0$$

$$\nearrow + \quad \sum F_X = \mu_S N - W \sin \theta_s = 0$$



Using these two equations, we get

$\mu_s = (W \sin \theta_s) / (W \cos \theta_s) = \tan \theta_s$

This simple experiment allows us to find the μ_S between two materials in contact.

PEARSON

PROBLEMS INVOLVING DRY FRICTION (Section 8.2)

Steps for solving equilibrium problems involving dry friction:

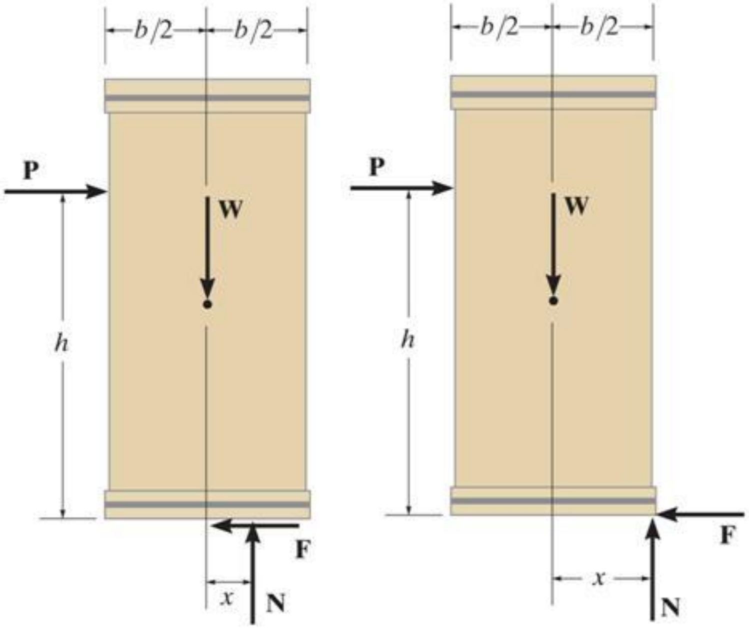
1. Draw necessary free body diagrams. Make sure that you show the friction force in the correct direction (it always opposes the motion or impending motion).

2. Determine the number of unknowns. Do not assume that $F = \mu_S N$ unless the impending motion condition is given.

3. Apply the equations of equilibrium and appropriate frictional equations to solve for the unknowns.

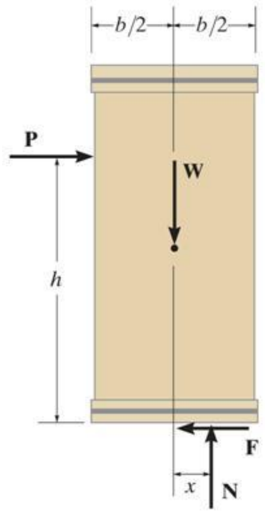
IMPENDING TIPPING versus SLIPPING

For a given W and h of the box, how can we determine if the block will slide or tip first? In this case, we have four unknowns (F, N, x, and P) and only the three E-of-E.



Hence, we have to make an assumption to give us another equation (the friction equation!). Then we can solve for the unknowns using the three E-of-E. Finally, we need to check if our assumption was correct.

IMPENDING TIPPING versus SLIPPING (continued)



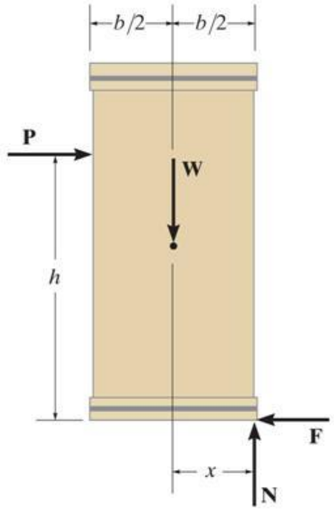
Assume: Slipping occurs

Known: $F = \mu_s N$

Solve: x, P, and N

Check: $0 \leq x \leq b/2$

Or



Assume: Tipping occurs

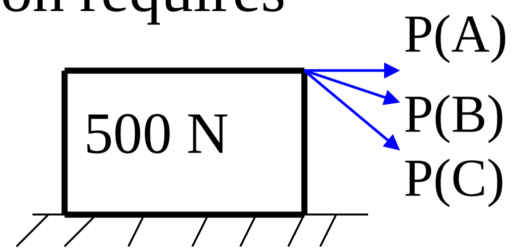
Known: $x = b/2$

Solve: P, N, and F

Check: $F \leq \mu_s N$

CONCEPT QUIZ

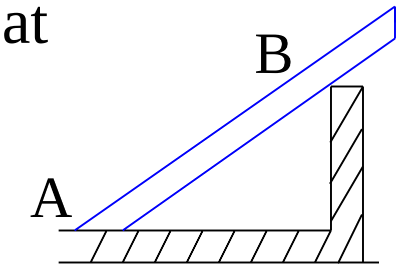
1. A 500-N (≈ 50-kg) box with a wide base is pulled by a force P and $\mu_s = 0.4$. Which force orientation requires the least force to begin sliding?



A) P(A) B) P(B)

C) P(C) D) Can not be determined

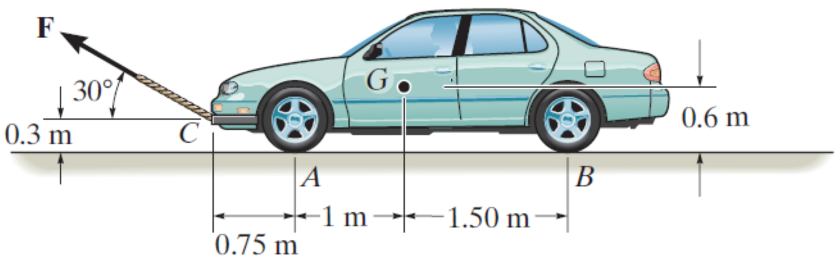
2. A ladder is positioned as shown. Please indicate the direction of the friction force on the ladder at B.



A) ↑ B) ↓

C) ↗ D) ↙

GROUP PROBLEM SOLVING



Given: Automobile has a mass of 2000 kg and $\mu_s = 0.3$.

Find: The smallest magnitude of **F** required to move the car if the back brakes are locked and the front wheels are free to roll.

Plan: a) Draw FBDs of the car.

b) Determine the unknowns.

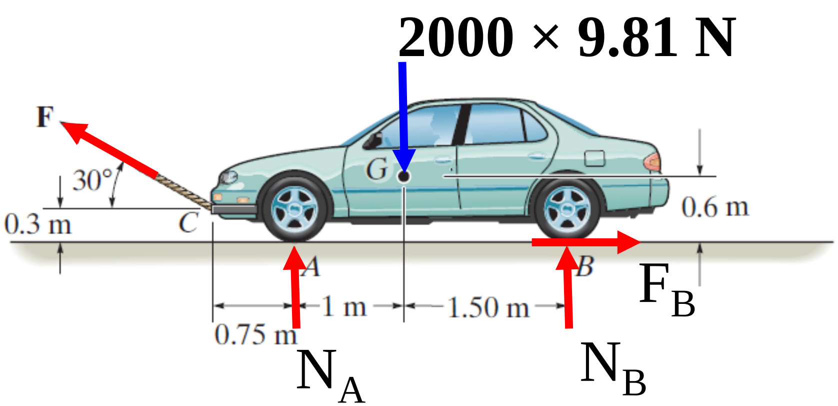
d) Apply the E-of-E and friction equations to solve for the unknowns.

GROUP PROBLEM SOLVING (continued)

Here is the correct FBD:

Note that there are four unknowns: F, N_A, N_B, and F_B.

FBD of the car



Equations of Equilibrium:

$$+\rightarrow \sum F_X = F_B - F(\cos 30°) = 0 \qquad (1)$$

$$+\uparrow \sum F_Y = N_A + N_B + F(\sin 30°) - 19620 = 0 \qquad (2)$$

$$\circlearrowleft + \sum M_A = F\cos 30°(0.3) - F\sin 30°(0.75) + N_B(2.5) - 19620(1) = 0 \qquad (3)$$

Assume that the rear wheels are on the verge of slip. Thus

$$F_B = \mu_s N_B = 0.3\, N_B \qquad (4)$$

GROUP PROBLEM SOLVING (continued)

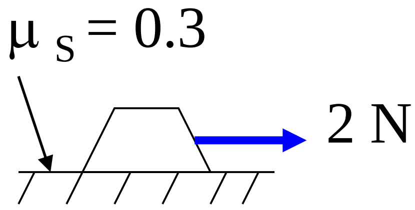
Solving Equations (1) to (4),

$F = 2762$ N

and $N_A = 10263$ N, $N_B = 7975$ N, $F_B = 2393$ N.

ATTENTION QUIZ

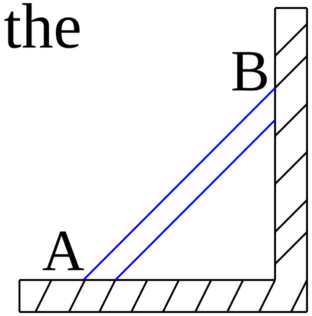
1. A 10-N block is in equilibrium. What is the magnitude of the friction force between this block and the surface?



A) 0 N B) 1 N

C) 2 N D) 3 N

2. The ladder AB is positioned as shown. What is the direction of the friction force on the ladder at B.



A) ↗ B) ↙

C) ← D) ↑

End of the Lecture

Let Learning Continue