Section 4.2 - Friction

Learning Goal: By the end of today, I will be able to recognize and calculate both static and kinetic friction.

Two types of Friction - Kinetic and Static

If you have ever tried to push or pull a heavy object across any significant distance, it always seem to be the most difficult at the start, but once the object is moving, it gets easier to move the object.

Why is that?

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Static friction (F_S) is the force exerted on a stationary object by a surface that prevents the object from starting to move.

Kinetic friction (F_k) is the force exerted on a moving object by a surface, and acts opposite to the direction of motion of the object.

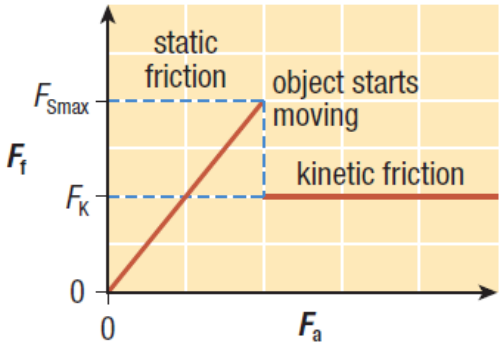

Figure 3 A graph of the magnitude of friction versus the magnitude of the applied force. Once the object starts to move, the friction drops suddenly.

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What factors might affect the amount of friction experienced by an object?

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Coefficients of Friction

Many factors affect the force of friction acting on an object. The magnitude of friction acting on an object may depend on the mass of the object, the type of material the object is made of, and the type of surface the object is in contact with. When dealing with air resistance, the speed of the object and the shape of the object also have an effect. In this section, we will deal only with friction acting on an object in contact with horizontal surfaces. The only applied forces acting on the object will be horizontal.

The Coefficient of Friction is a ratio used to express the degree or level of friction created between an object and the surface it is in contact with.

F_f is the force of friction (kinetic or static), F_N is the Normal Force (contact force) and μ (muu) is the coefficient value (it is unit less).

$$\mu = \frac{F_f}{F_N}$$

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Coefficient of Static Friction

$$\mu_s = \frac{F_{s_{max}}}{F_N}$$

Coefficient of Kinetic Friction

$$\mu_k = \frac{F_K}{F_N}$$

The coefficient of Static Friction is usually greater than the coefficient of Kinetic Friction.

Static Friction can be thought of the force required to make an object "slip".

Different materials generate different coefficients of friction; some typical values are included in the table that follows.

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Table 1 Approximate Coefficients of Kinetic and Static Friction

Material	μ_S	μ_K
rubber on concrete (dry)		0.6–0.85
rubber on concrete (wet)		0.45–0.75
rubber on asphalt (dry)		0.5–0.80
rubber on asphalt (wet)		0.25–0.75
steel on steel (dry)	0.78	0.42
steel on steel (greasy)	0.05–0.11	0.029–0.12
leather on oak	0.61	0.52
ice on ice	0.1	0.03
steel on ice	0.1	0.01
rubber on ice		0.005
wood on dry snow	0.22	0.18
wood on wet snow	0.14	0.10
Teflon on Teflon	0.04	0.04
near-frictionless carbon		0.001
synovial joints in humans	0.01	0.003

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Sample Problem 1

A 3.0 kg block of wood sits on a horizontal wooden floor. The largest horizontal force that can be applied to the block before it will start moving is 14.7 N. Once the block starts moving, it only takes 8.8 N to keep it moving at a constant velocity.

(a) Calculate the coefficient of static friction for the block and the floor.

(b) Determine the force of friction acting on the block if a horizontal force of 6.8 N [E] acts on the block.

(c) Calculate the maximum magnitude of static friction acting on the block if a 2.1 kg object is placed on top of it.

(d) Determine the coefficient of kinetic friction. (of the first block)

Does the block actually "slip" or move from the force?

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Practice

1. Determine the coefficient of friction for each situation. T/I
   (a) It takes a horizontal force of 62 N to get a 22 kg box to just start moving across the floor.
   (b) It only takes 58 N of horizontal force to move the same box at a constant velocity.
2. A 75 kg hockey player glides across the ice on his skates with steel blades. What is the magnitude of the force of friction acting on the skater? Use **Table 1** to help you. T/I
3. A 1300 kg car skids across an asphalt road. Use **Table 1** to calculate the magnitude of the force of friction acting on the car due to the road if the road is
   (a) dry
   (b) wet
   (c) covered with ice T/I

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4.2 Questions

1. For each situation, determine if friction is helpful, makes the action more difficult, or both. Explain your reasoning. K/U
   (a) turning a doorknob
   (b) pushing a heavy box across a rough surface
   (c) gliding across smooth ice to demonstrate uniform motion
   (d) tying a knot
2. A typical bicycle braking system involves a lever that you pull on the handlebars and a brake pad near the rim of the wheel **(Figure 5)**. Describe how the braking system works using the concepts of normal force and friction. K/U C

Figure 5

3. A 1.4 kg block on a horizontal surface is pulled by a horizontal applied force. It takes 5.5 N to start the block moving and 4.1 N to keep it moving at a constant velocity. T/I
   (a) Calculate the coefficients of friction.
   (b) Which changes below will affect the coefficients of friction? Explain.
      (i) turning the block onto another side
      (ii) changing the surface
      (iii) putting an object on top of the block
   (c) What effect will each situation have on the static and kinetic friction acting on each object? Explain.
      (i) putting an object on the block
      (ii) applying an upward force on the block
      (iii) putting slippery grease on the surface
4. Examine the coefficients of friction in **Table 1** on page 170 to answer the following. A
   (a) Roads in Canada are typically made out of asphalt or concrete. Is one material significantly safer than the other? Explain your reasoning.
   (b) Explain why drivers should reduce speed on wet roads.
   (c) Why do we salt roads in the winter, especially when there is freezing rain?
5. You are dragging a 110 kg trunk across a floor at a constant velocity with a horizontal force of 380 N. T/I
   (a) Calculate the coefficient of kinetic friction.
   (b) A friend decides to help by pulling on the trunk with a force of 150 N [up]. Will this help? Calculate the force required to pull the trunk at a constant velocity to help you decide.
   (c) Instead of pulling on the trunk, your 55 kg friend just sits on it. What force is required keep the trunk moving at a constant velocity?
6. A 26 kg desk is at rest on the floor. The coefficient of static friction is 0.25. One person pulls on the desk with a force of 52 N [E] and another pulls with a force of 110 N [W]. Will the desk move? Explain your reasoning. T/I
7. A 12 000 kg bin is sitting in a parking lot. The coefficient of static friction for the bin is 0.50 and the coefficient of kinetic friction is 0.40. A truck pushes on the bin and it starts to move. Determine the minimum force exerted by the truck to
   (a) start the bin moving
   (b) keep the bin moving at a constant velocity T/I
8. A gradually increasing horizontal force is applied to an object initially at rest on a horizontal surface. Draw a graph of the force of friction versus the applied force in each situation. T/I C
   (a) the coefficient of static friction is slightly greater than the coefficient of kinetic friction
   (b) the coefficient of static friction is equal to the coefficient of kinetic friction
9. A doorstop keeps a door open when it is wedged underneath the door. Use the concepts from this section to explain how a doorstop works. C A
10. Describe how to determine each quantity experimentally. T/I C
    (a) the coefficient of static friction
    (b) the coefficient of kinetic friction
11. Explain why the manufacturer of a running shoe might be more concerned about having a high coefficient of friction than the manufacturer of a dress shoe. C A

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