4-2 Friction

Vocabulary **Friction:** The force that acts to oppose the motion between two materials moving past each other.

There are many types of friction between surfaces. They include

Static friction: The resistance force that must be overcome to start an object in motion.

Kinetic or sliding friction: The resistance force between two surfaces already in motion.

Rolling friction: The resistance force between a surface and a rolling object.

Fluid friction: The resistance force of a gas or a liquid as an object passes through. One example of fluid friction is air resistance.

In this chapter, we will deal only with kinetic or sliding friction.

The force of sliding friction between two surfaces depends on the normal force pressing the surfaces together, and on the types of surfaces that are in contact with each other. The magnitude of this force is written as

force of sliding friction = (coefficient of sliding friction)(normal force)

or $F_f = \mu F_N$

If an object is sitting on a horizontal surface, the normal force is equal to the weight of the object. The symbol μ (pronounced "mu") is called the **coefficient of sliding friction.** A high coefficient of friction (in other words, a large number for μ) means that the object is not likely to slide easily, while a low coefficient of friction (or a small μ) is found between very slippery surfaces. Because the coefficient of sliding friction is simply a ratio of the force of sliding friction to the normal force, it has no units.

Solved Examples

Example 6: Brian is walking through the school cafeteria but does not realize that the person in front of him has just spilled his glass of chocolate milk. As Brian, who weighs 420 N, steps in the milk, the coefficient of sliding friction between Brian and the floor is suddenly reduced to 0.040. What is the force of sliding friction between Brian and the slippery floor?

Solution: In order to find the force of sliding friction, you need to know the normal force, or the force the ground exerts upward on Brian. On a horizontal

surface this normal force is equivalent to the object's weight, which in this case is 420 N.

Given: $F_N = 420$ N
$\mu = 0.040$

Unknown: $F_f = ?$
Original equation: $F_f = \mu F_N$

Solve: $F_f = \mu F_N = (0.040)(420\text{ N}) = \mathbf{17\ N}$

Example 7: While redecorating her apartment, Kitty slowly pushes an 82-kg china cabinet across the wooden dining room floor, which resists the motion with a force of friction of 320 N. What is the coefficient of sliding friction between the china cabinet and the floor?

Solution: As in the previous exercise, the normal force is equivalent to the weight of the china cabinet because the cabinet is sitting on a horizontal surface.

Given: $m = 82$ kg
$g = 10.0\text{ m/s}^2$

Unknown: $w = ?$
Original equation: $w = mg$

Solve: $w = mg = (82\text{ kg})(10.0\text{ m/s}^2) = 820\text{ N}$ so F_N is also 820 N.

Given: $F_N = 820$ N
$F_f = 320$ N

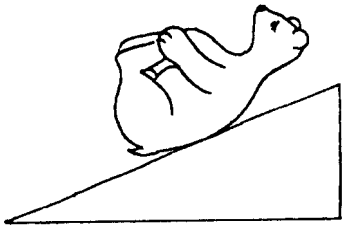
Unknown: $\mu = ?$
Original equation: $F_f = \mu F_N$

Solve: $\mu = \dfrac{F_f}{F_N} = \dfrac{320\text{ N}}{820\text{ N}} = \mathbf{0.39}$

Remember, μ has no units!

Example 8: At the zoo, a 900.-kg polar bear slides down a wet slide inclined at an angle of 25.0° to the horizontal. The coefficient of friction between the bear and the slide is 0.0500. What frictional force impedes the bear's motion down the slide?

Solution: In this example, unlike the previous ones in this section, the polar bear is inclined at an angle to the horizontal so you must find the normal force on the polar bear by using the cosine of this angle. Remember, the normal force, F_N, always acts perpendicular to the surface on which the object is moving.



Given: $m = 900.$ kg
$g = 10.0\text{ m/s}^2$
$\theta = 25.0°$

Unknown: $F_N = ?$
Original equation: $\cos\theta = \dfrac{\text{adj}}{\text{hyp}} = \dfrac{F_N}{mg}$

Solve: $F_N = mg\cos\theta = (900.\text{ kg})(10.0\text{ m/s}^2)\cos 25.0° = 8160\text{ N}$

Given: $F_N = 8160$ N
$\mu = 0.0500$

Unknown: $F_f = ?$
Original equation: $F_f = \mu F_N$

Solve: $F_f = \mu F_N = (0.0500)(8160\text{ N}) = \mathbf{408\ N}$

Practice Exercises

Exercise 7: Unbeknownst to the students, every time the school floors are waxed, Mr. Tracy, the principal, likes to slide down the hallway in his socks. Mr. Tracy weighs 850. N and the coefficient of sliding friction between his socks and the floor is 0.120. What is the force of friction that opposes Mr. Tracy's motion down the hall?

Answer: _____

Exercise 8: Skye is trying to make her 70.0-kg Saint Bernard go out the back door but the dog refuses to walk. If the coefficient of sliding friction between the dog and the floor is 0.50, how hard must Skye push in order to move the dog with a constant speed?

Answer: _____

Exercise 9: Rather than taking the stairs, Martin gets from the second floor of his house to the first floor by sliding down the banister that is inclined at an angle of 30.0° to the horizontal. a) If Martin has a mass of 45 kg and the coefficient of sliding friction between Martin and the banister is 0.20, what is the force of friction impeding Martin's motion down the banister? b) If the banister is made steeper (inclined at a larger angle), will this have any effect on the force of friction? If so, what?

Answer: **a.** _____

Answer: **b.** _____

Exercise 10: As Alan is taking a shower, the soap falls out of the soap dish and Alan steps on it with a force of 500 N. If Alan slides forward and the frictional force between the soap and the tub is 50 N, what is the coefficient of friction between these two surfaces?

Answer: _____

Exercise 11: Howard, the soda jerk at Bea's diner, slides a 0.60-kg root beer from the end of the counter to a thirsty customer. A force of friction of 1.2 N brings the drink to a stop right in front of the customer. a) What is the coefficient of sliding friction between the glass and the counter? b) If the glass encounters a sticky patch on the counter, will this spot have a higher or lower coefficient of friction?

Answer: **a.** _____

Answer: **b.** _____