4.5: Friction

Matches on different tennis court surfaces feel like distinct experiences as a result of friction

Figure 3.2.1

Tennis is played on a variety of court surfaces: grass, clay, hardcourt, and even carpet. Players know that matches on different surfaces are distinctly different games. The ball bounces differently, and shoes slip on some surfaces but stick on others. These differences are a result of friction.

Friction

Friction is the force that resists motion. In most beginning physics classes, friction is ignored. Concepts can be understood and calculations made assuming friction to be nonexistent. Whenever physics intersects with the real world, however, friction must be taken into account. Friction exists between two touching surfaces because even the smoothest looking surface is quite rough on a microscopic scale.

Sliding the two blocks over each other will result in frictional force between the two surfaces

Figure 3.2.2

Every surface has microscopic bumps, lumps, and imperfections, emphasized as in the image above. If we try to slide the top block over the lower block, there will be numerous collisions as the bumps impact each other. The forward motion causes the collisions with bumps which then exert a force in opposite way the block is moving. The force of friction always opposes whatever motion is causing the friction.

The force of friction between these two blocks is related to two factors. The first factor is the roughness of the surfaces that are interacting, which is called the **coefficient of friction**, μ (Greek letter mu). The second factor is the magnitude of the force pushing the top block down onto the lower block. It is reasonable that the more forcefully the blocks are pushed together, the more difficult it will be for one to slide over the other. The force pushing these blocks together is the result of gravity acting on the top block and pressing it against the bottom block, which resists the weight with an equal and opposite force called the **normal force**. The force of friction can be calculated by

> $F_{friction} = \mu \times F_{normal}$ and the normal force will be equal to the force of gravity on the object, if the object is on a flat surface (one parallel to the ground).

This is an approximate but reasonably useful and accurate relationship. It is not exact because **μ** depends on a variety of factors, including whether the surface is wet or dry.

The frictional force we have been discussing is referred to as **kinetic** (or **sliding**) **friction**; it is involved when one surface is sliding over another. If you have ever tried to slide a heavy object across a rough surface, you may be aware that it is a great deal easier to keep an object sliding than it is to start the object sliding in the first place. When the object to slide is resting on a surface with no movement, the force of friction is called **static friction** and it is somewhat greater than kinetic friction. Surfaces that move against one another will have both a coefficient of static friction and a coefficient of kinetic friction, and the two values will not be the same. For example, the coefficient of kinetic friction for ice on ice is 0.03 whereas the coefficient of static friction for ice on ice is 0.10—more than three times as great.

How can we pinpoint the exact amount of force needed to overcome static friction? Use the simulation below to find out:

Examples

Example 3.2.1

A box weighing 2000. N is sliding across a cement floor. The force pushing the box is 500. N, and the coefficient of kinetic friction between the box and the floor is 0.20. What is the acceleration of the box?

Solution

In this case, the box is sliding along the ground, so the normal force for the box is equal to its weight. Using the normal force and the coefficient of friction, we can find the frictional force. We can also find the mass of the box from its weight since we know the acceleration due to gravity. Then we can find the net force and the acceleration.

$$F_F=\mu F_N=(0.20)(2000.\ \mathrm{N})=400.\ \mathrm{N}$$

mass of box=weight/g=2000. N/9.8 m/s^2=204 kg

$$F_{NET}=\text{pushing force}-\text{frictional force}=500.\ \mathrm{N}-400.\ \mathrm{N}=100.\ \mathrm{N}$$

$$a=F_N/m=100.\ \mathrm{N}/204\ \mathrm{kg}=0.49\ \mathrm{m/s^2}$$

Example 3.2.2

Two boxes are connected by a rope running over a pulley, as shown in the figure below. The coefficient of kinetic friction between box A and the table is 0.20. (Ignore the masses of the rope and the pulley and any friction in the pulley.) The mass of box A is 5.0 kg and the mass of box B is 2.0 kg. The entire system (both boxes) will move together with the same acceleration and velocity. Find the acceleration of the system.

Solution

A diagram of a system of two boxes connected by a rope running over a pulley

Figure 3.2.3

The force acting to move the system is the weight of box B, and the force resisting the movement is the force of friction between the table and box A. The mass of the system is the sum of the masses of both boxes. The acceleration of the system can be found by dividing the net force by the total mass.

$$F_N(\text{box A})=mg=(5.0\ \mathrm{kg})(9.8\ \mathrm{m/s^2})=49\ \mathrm{N}$$

$$F_{friction}=\mu F_N=(0.20)(49\ \mathrm{N})=9.8\ \mathrm{N}$$

$$\text{Weight of box B}=mg=(2.0\ \mathrm{kg})(9.8\ \mathrm{m/s^2})=19.6\ \mathrm{N}$$

$$F_{NET}=19.6\ \mathrm{N}-9.8\ \mathrm{N}=9.8\ \mathrm{N}$$

$$a=F_{NET}/\text{mass}=9.8\ \mathrm{N}/7.0\ \mathrm{kg}=1.4\ \mathrm{m/s^2}$$

In the simulation below, you can adjust the type of shoe a runner wears to change the coefficient of static friction between the runner's shoe and the track surface. Play around and observe how a greater static friction coefficient means the sprinter can push off with more force without the danger of slipping.

Summary

- Friction is caused by bodies sliding over rough surfaces.
- The degree of surface roughness is indicated by the coefficient of friction, μ.
- The force of friction is calculated by multiplying the coefficient of friction by the normal force.
- The frictional force always opposes motion.
- The net force is found by subtracting the frictional force from the applied force.

Review

1. A 52 N sled is pulled across a cement sidewalk at constant speed. A horizontal force of 36 N is exerted. What is the coefficient of kinetic friction between the sidewalk and the metal runners of the sled?
2. If the coefficient of kinetic friction between a 25 kg crate and the floor is 0.45, how much force is required to move the crate at a constant velocity across the floor?
3. A smooth wooden 40.0 N block is placed on a smooth wooden table. A force of 14.0 N is required to keep the block moving at constant velocity.
    1. What is the coefficient of kinetic friction between the block and the table top?
    2. If a 20.0 N brick is placed on top of the wooden block, what force will be required to keep the block and brick moving at constant velocity?

Explore More

Use the resource below to answer the following questions.

1. 1 lbf (pound-force) = 4.44 N. Given this information, how many newtons of force did it take to rip the two phonebooks apart?
2. Why do you think there is so much friction between the two phonebooks?

Resources

When you fall thousands of feet from the sky, it seems like something strange is happening with the laws of physics. Turns out, everything relies on a simple force called drag. Though it may seem skydivers are in free fall, air resistance allows skydivers to speed up, slow down, and even change direction.

Additional Resources

Study Guide: Newton's Laws Study Guide

Real World Application: Slippery When Wet

PLIX: Play, Learn, Interact, eXplore: Steel Friction

Video: