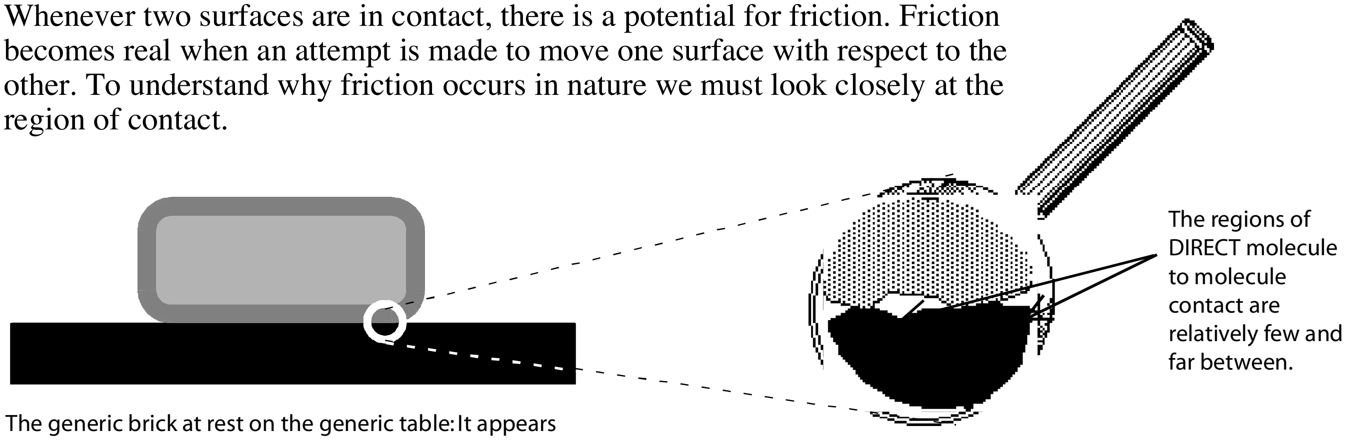
PhyzGuide: Friction

THE SMALL PICTURE

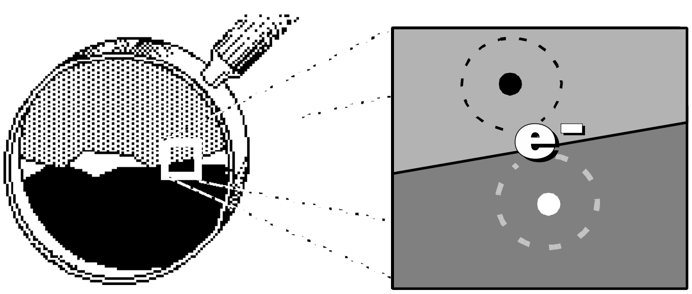
Whenever two surfaces are in contact, there is a potential for friction. Friction becomes real when an attempt is made to move one surface with respect to the other. To understand why friction occurs in nature we must look closely at the region of contact.



The generic brick at rest on the generic table: It appears that the entire bottom surface of the brick is in contact with the table-top.

A magnification of a small portion of the region of "apparent" contact.

If you were to magnify the apparent contact region of two surfaces, you would find that even polished surfaces appear as rough "hills and valleys." Where there are spaces between the surfaces, there is no friction problem. At the points of direct molecular contact, however, electrons become confused. They forget which object they belong to, and wind up trying to orbit nuclei in molecules of both! The resulting bond is called molecular adhesion or a "cold-weld."



An electron torn between two nuclei.

Thoughts of an electron with an identity crisis...

"Whoa! Which molecule am I a part of: the molecule in the brick or the one in the table???

I guess I'll just have to orbit both nuclei!"

When two highly polished metal surfaces are brought together in a highly evacuated chamber, one might think that the friction would be small because the surfaces are so smooth. In reality, the surfaces "cold-weld" and won't slide across each other at all. Again, this is due to the confusion of the electrons in the surface molecules. On a highly polished metal surface, many, many surface molecules will be in contact, and there will be a large number of adhering molecules.

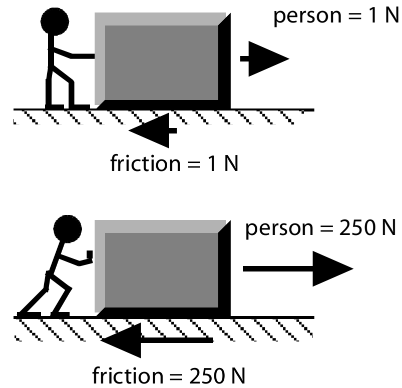
If our brick on the table is pushed with a small force, it won't move—the molecular adhesion is too strong. This is known as static (stationary) friction. If the pushing force is increased, the cold-welds are broken and the brick moves. As it moves, new cold-welds are formed and then broken in rapid succession. This is known as kinetic (moving) or sliding friction.

THE BIG PICTURE

Now that we understand the molecular nature of friction, we can step back and deal with friction on a macroscopic basis. On the large scale, friction is a force that comes in two flavors: **static friction** and **kinetic friction.** Both flavors act in the direction opposite to the motion (or intended motion) of an object.

Static friction is a force that balances an external force that would otherwise set an object in motion. The static friction force can vary in magnitude. Consider a heavy crate at rest on the floor. If you push it with your pinky, it won't go anywhere. If your pushing force is 1N, the static friction force is 1N in the opposite direction. If you push with a force of 20N and the crate still refuses to budge, the static friction force must have increased to 20N. The static friction force adjusts to maintain equilibrium. You push east, friction acts to the west. You *can* move the crate if you push hard enough. But how hard do you have to push? Good question.

The static friction force varies to maintain equilibrium.

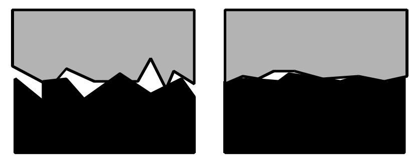


In both cases above, the net force is zero: F = 0.

The **static friction** force varies as mentioned above: it will adjust to counter-act any force that would move the crate. But static friction has a limit. This limit depends on two factors.

1) The "stickiness" of the surfaces in contact. Quantitatively, this "stickiness" translates into a number called the **coefficient of static friction** (pretty catchy, eh? Get it? "Catchy?"—"Friction?" Oh forget it...) and is denoted by the lowercase Greek letter mu: μ_s [*s* for "static"].

2) The compressive force of the object on the surface that supports it. This is what we've come to know and love as the **normal force**. A greater normal force indicates that the surfaces in contact are being "squashed" together, thus more regions of molecular adhesion (cold-welding). Often, the normal force is equal to the object's weight, *but this is not always the case*.



Rough surface: higher coefficients of static and kinetic friction.

Smooth surface: lower coefficients of static and kinetic friction.

3) The surface area of the contact region—*whoops!* I said there were only *two* factors and there are only two factors. So guess what? *The area of the contacting surfaces is not a factor!* (You may need a lab activity to convince you of this.)

Taken together, and acknowledging the variable nature of the static friction force, we write this relation:

(NOTE: The "N" in the equation is for "normal," not for "newtons.")

$$f_s \le \mu_s N$$

It is legal to use the equation $f_s = \mu_s N$ **only** when considering the **maximum** value of the static friction force.

When an object is *in* motion, friction does not go away. But it does take on a single value. The **kinetic friction** force depends on two factors.

1) The **coefficient of kinetic friction**, μ_k. This factor, like the coefficient of static friction, depends on surface characteristics.

2) The **normal force** (again).

3) The speed *v* of the object. Whoops, there I go again. *Speed is not a factor!*

Taken together, we write this relation:

$$f_k = \mu_k N$$