As long as the jug does not move, the force of static friction is always equal to and opposite in direction to the component of the applied force that is parallel to the surface ($F_s = -F_{applied}$). As the applied force increases, the force of static friction also increases; if the applied force decreases, the force of static friction also decreases. When the applied force is as great as it can be without causing the jug to move, the force of static friction reaches its maximum value, $\mathbf{F_{s,max}}$.

Kinetic friction is less than static friction

When the applied force on the jug exceeds $\mathbf{F_{s,max}}$, the jug begins to move with an acceleration to the left, as shown in **Figure 13(c).** A frictional force is still acting on the jug as the jug moves, but that force is actually less than $\mathbf{F_{s,max}}$. The retarding frictional force on an object in motion is called the force of **kinetic friction** **($\mathbf{F_k}$).** The magnitude of the net force acting on the object is equal to the difference between the applied force and the force of kinetic friction ($F_{applied} - F_k$).

kinetic friction

the force that opposes the movement of two surfaces that are in contact and are sliding over each other

At the microscopic level, frictional forces arise from complex interactions between contacting surfaces. Most surfaces, even those that seem very smooth to the touch, are actually quite rough at the microscopic level, as illustrated in **Figure 14.** Notice that the surfaces are in contact at only a few points. When two surfaces are stationary with respect to each other, the surfaces stick together somewhat at the contact points. This *adhesion* is caused by electrostatic forces between molecules of the two surfaces.

TIP *In free-body diagrams, the force of friction is always parallel to the surface of contact. The force of kinetic friction is always opposite the direction of motion. To determine the direction of the force of static friction, use the principle of equilibrium. For an object in equilibrium, the frictional force must point in the direction that results in a net force of zero.*

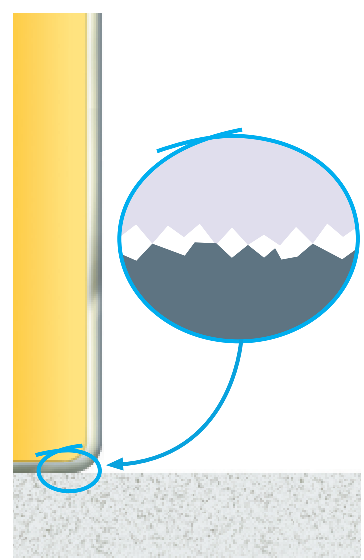

Figure 14
On the microscopic level, even very smooth surfaces make contact at only a few points.

The force of friction is proportional to the normal force

It is easier to push a chair across the floor at a constant speed than to push a heavy desk across the floor at the same speed. Experimental observations show that the magnitude of the force of friction is approximately proportional to the magnitude of the normal force that a surface exerts on an object. Because the desk is heavier than the chair, the desk also experiences a greater normal force and therefore greater friction.

Friction can be calculated approximately

Keep in mind that the force of friction is really a macroscopic effect caused by a complex combination of forces at a microscopic level. However, we can approximately calculate the force of friction with certain assumptions. The relationship between normal force and the force of friction is one factor that affects friction. For instance, it is easier to slide a light textbook across a desk than it is to slide a heavier textbook. The relationship between the normal force and the force of friction provides a good approximation for the friction between dry, flat surfaces that are at rest or sliding past one another.