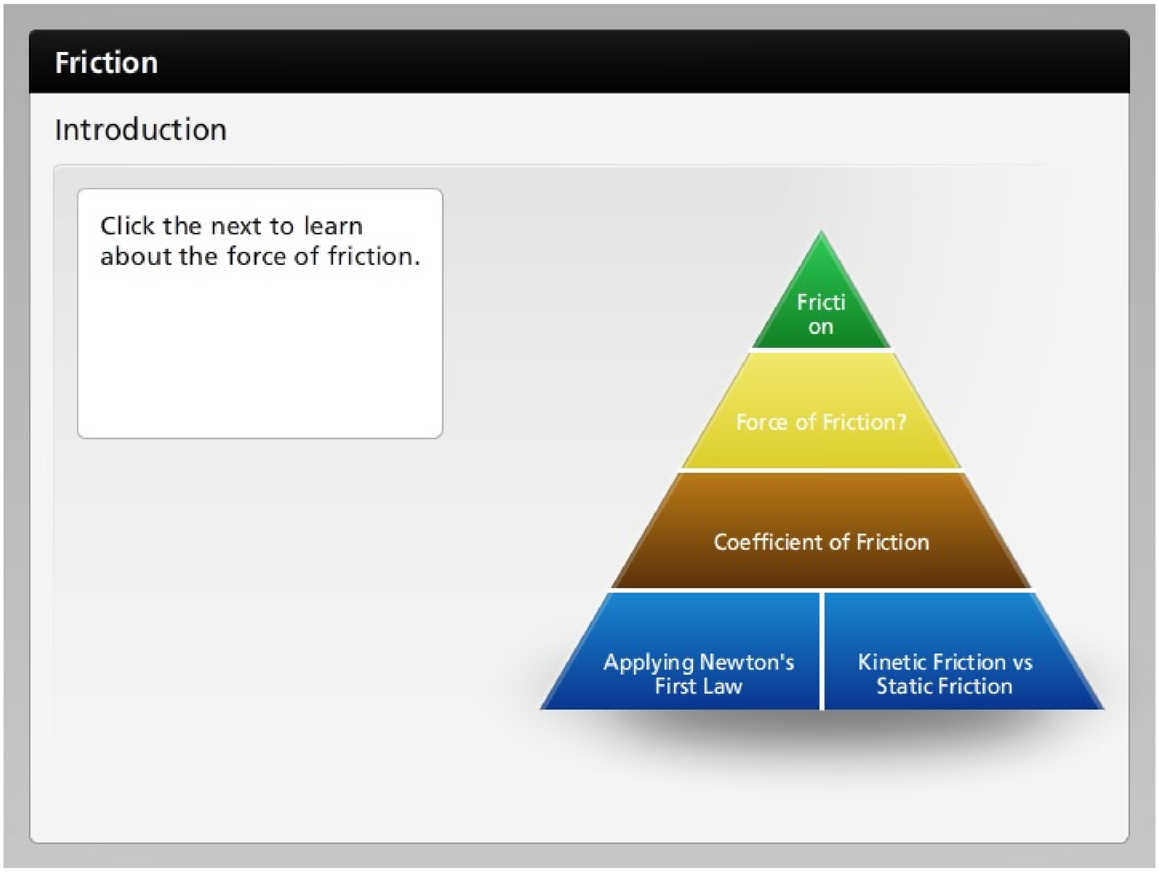
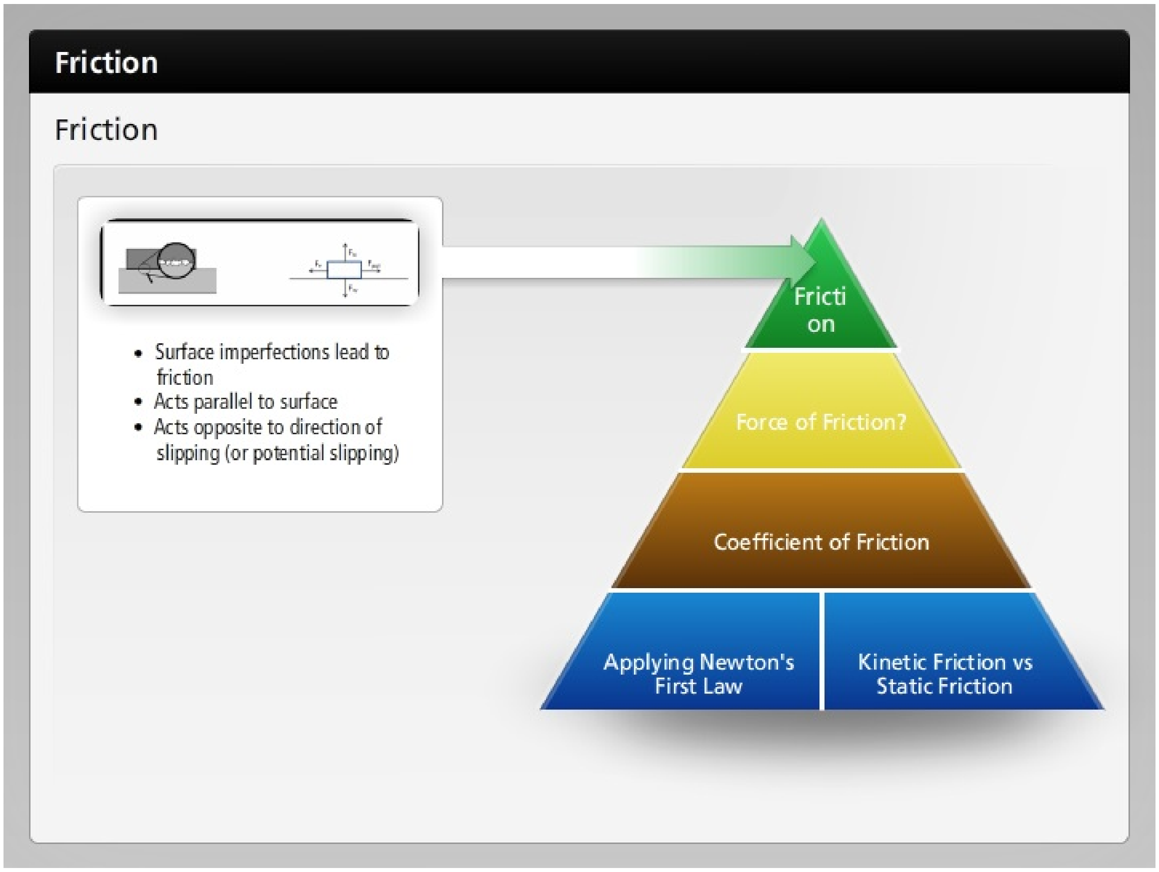
Module 2: Forces and Newton's Laws
Topic 2 Content: Friction

Introduction



Click the next to learn about the force of friction.

Friction



As you learned earlier, friction results from the interaction of two surfaces, and acts in a direct that would oppose the slipping, always parallel to the surface, as opposed to the normal force that always acts in a perpendicular direction. But what determines how much frictional force will be present in a particular situation?

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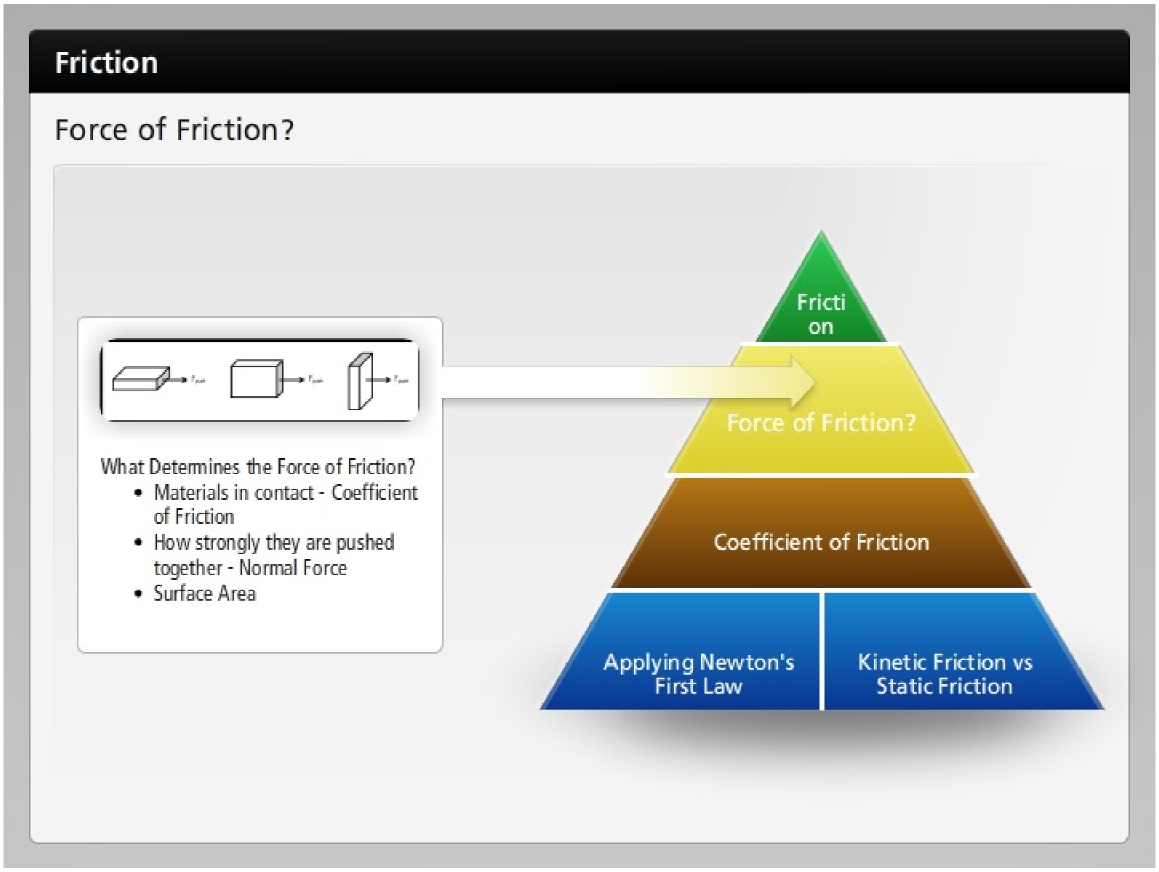
Force of Friction?

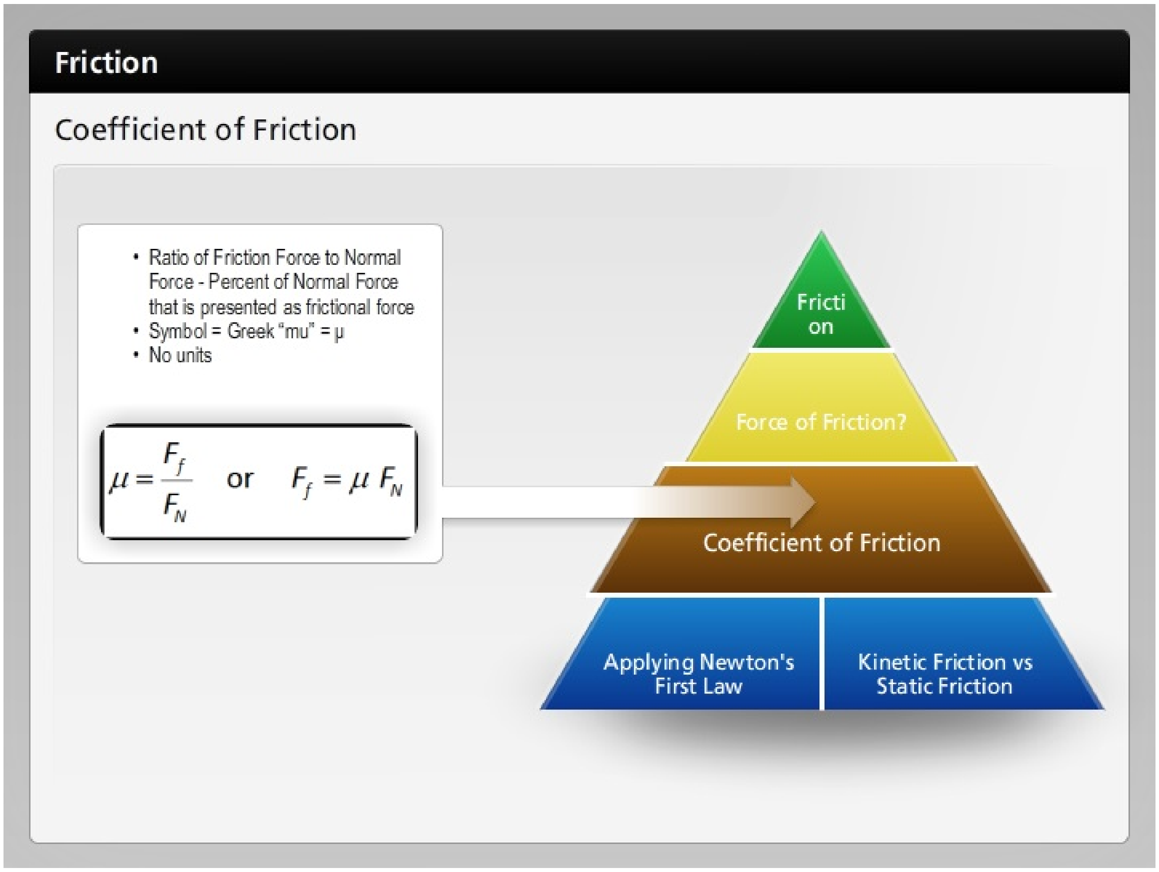


The two characteristics that determine the magnitude of the frictional force are the specific materials that are in contact, which we characterize by something called the coefficient of friction, and how strongly the objects are pushed together., which is the same as the normal force.

If more of the object is in contact with the surface, it seems logical that there would be more friction. However, this is not what really happens. Since the weight is spread over a larger area, every square meter of area has less normal force pushing upward on it. Therefore, the total force of friction is the same, it is just spread out over more area. The force of friction does not depend on whether the object is laying on the large or small side.

So if you place a hardcover book flat on the desk, or put it on its binding edge, or put it up on its edge so that just the thin edges of the cover touch the desk, it should take the same amount of force to push it in each situation.

Coefficient of Friction



The coefficient of friction tells us the ratio of the friction force to the normal force. It can also be thought of as the percent of the normal force that is expressed as friction. So a coefficient of friction of zero point two would mean that 20% of the normal force could be felt as frictional force.

Engineers have created tables of these values for different combinations of surfaces like rubber on asphalt, for example. Each pair of surfaces has its own value of the coefficient of friction. The symbol we use for coefficient of friction is the Greek letter mu. The formula for calculating coefficient of friction is mu equals F F over F N, which can be rearranged to be F F equals mu times F N, which you will use to calculate the force of friction, given the coefficient of friction and the normal force.

Notice that the value of the coefficient of friction will have no units, since it is Newtons divided by Newtons.

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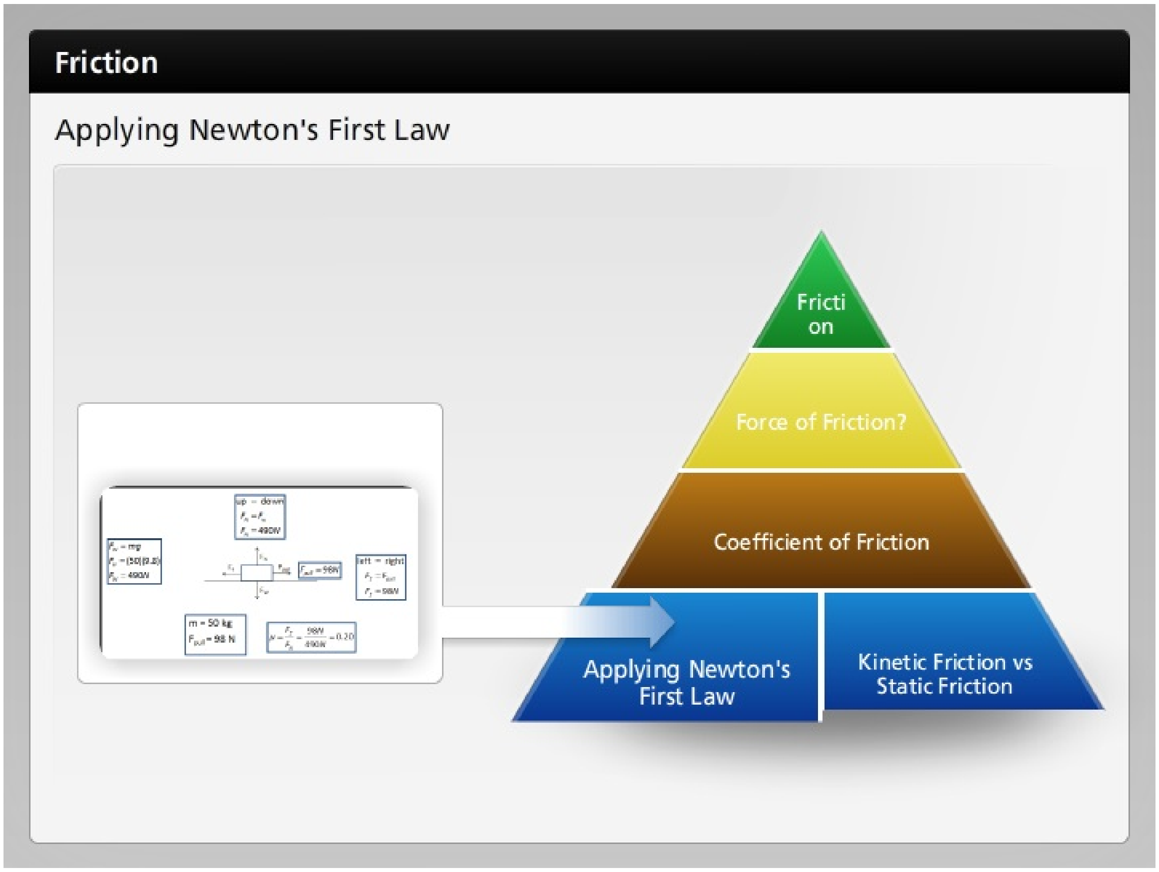
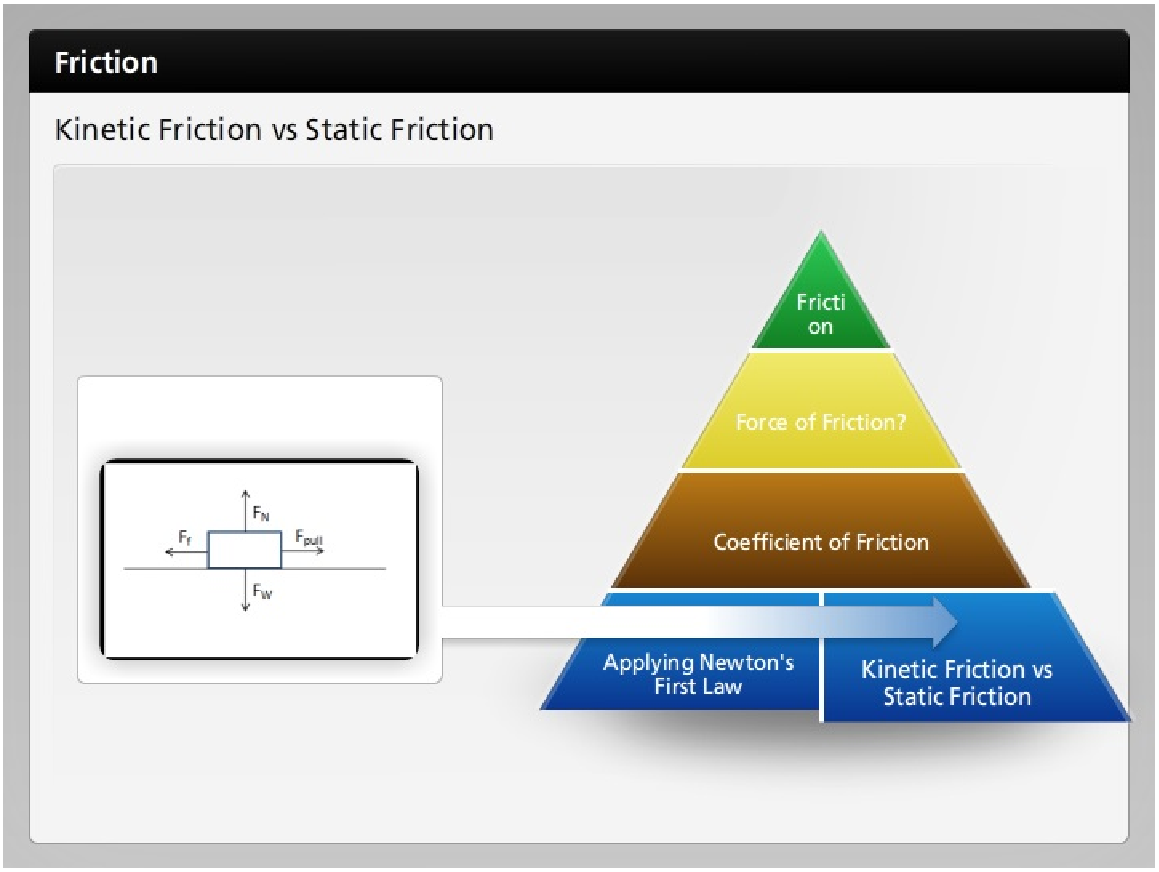
Applying Newton's First Law



We include a discussion of friction within the topic of Newton’s First Law because an understanding of the First Law very much helps us to calculate the force of friction in equilibrium situations, as you saw in an earlier lesson. If we have a block that is being dragged along a surface at a constant velocity with a force applied horizontally to the right, we can identify four forces acting on the block. The gravitational force is pulling straight down, the normal force is responding straight up, the applied force is pulling directly to the right, and the frictional force is pulling directly to the left. Newton’s First Law tells us that if the block is either at rest or moving at a constant velocity, then the vertical forces must balance and the horizontal forces must balance. Or, “up equals down” and “left equals right”. In this situation, with just these four forces, the normal force must be equal in magnitude to the weight of the object and the force of friction must be equal in magnitude to the applied force. Let’s add some numbers to this situation and show how it lets us calculate the coefficient of friction. We’ll set the mass of the block to fifty kilograms, and the pull force equal to ninety-eight Newtons. First, let’s calculate the force of gravity on the block. The weight of the block is equal to the mass times g, the acceleration of gravity. Writing F equals m g, and substituting our values for mass and the gravitational acceleration, we get a weight of forty hundred ninety Newtons. Since the vertical forces add to zero, we know that the magnitude of the gravitational force equals the magnitude of the normal force, or “up equals down”. So we can write F N equals F W and see that the normal force is also equal to forty hundred ninety Newtons. The pull force is ninety eight Newtons to the right. Since the horizontal forces add to zero, we can write “left equals right” and see that the force of friction equals the pull force, or F F equals F pull. So the force of friction is equal to ninety eight Newtons. Finally, we can calculate the coefficient of friction of the surface. Mu is equal to the force of friction divided by the normal force. So we divide ninety eight Newtons by four hundred ninety Newtons and get a coefficient of friction of zero point two. Again, you can see that this means that twenty percent of the normal force shows up as friction.

Kinetic Friction vs Static Friction



So far, we've been talking about friction when two materials are sliding past one another. But there can also be friction when the surfaces in contact are at rest with respect to one another. When an object is sliding, we refer to kinetic friction, and when the surfaces in contact are not moving with respect to one another, we refer to static friction.

Both kinetic friction and static friction have their own coefficients of friction, but the method by which we calculate each will be very much the same. Let's look at a conceptual example of static friction.

Here we have a crate sitting on the floor. At this point, the crate is at rest, so the forces must balance. But we've only got the gravitational force pulling down and the normal force pushing up. There are no other forces on the box, and the gravitational force and normal force are equal in magnitude.

Now, the person starts to push lightly on the box, and the box does not move. Horizontally, we now have the push force and the force of friction, acting in opposite directions. With the box at rest, these two must be the same.

If the person pushes harder, and the crate still doesn't move, you can see that the push force and the force of friction both increase, and remain equal.

At some point, if the applied force is great enough, we get to the point where the crate just begins to move.

This is the point where we calculate the coefficient of static friction. It deals with the maximum amount of friction that the surface can provide before the object starts moving. But the real amount of friction could be less than this if the applied force is less.

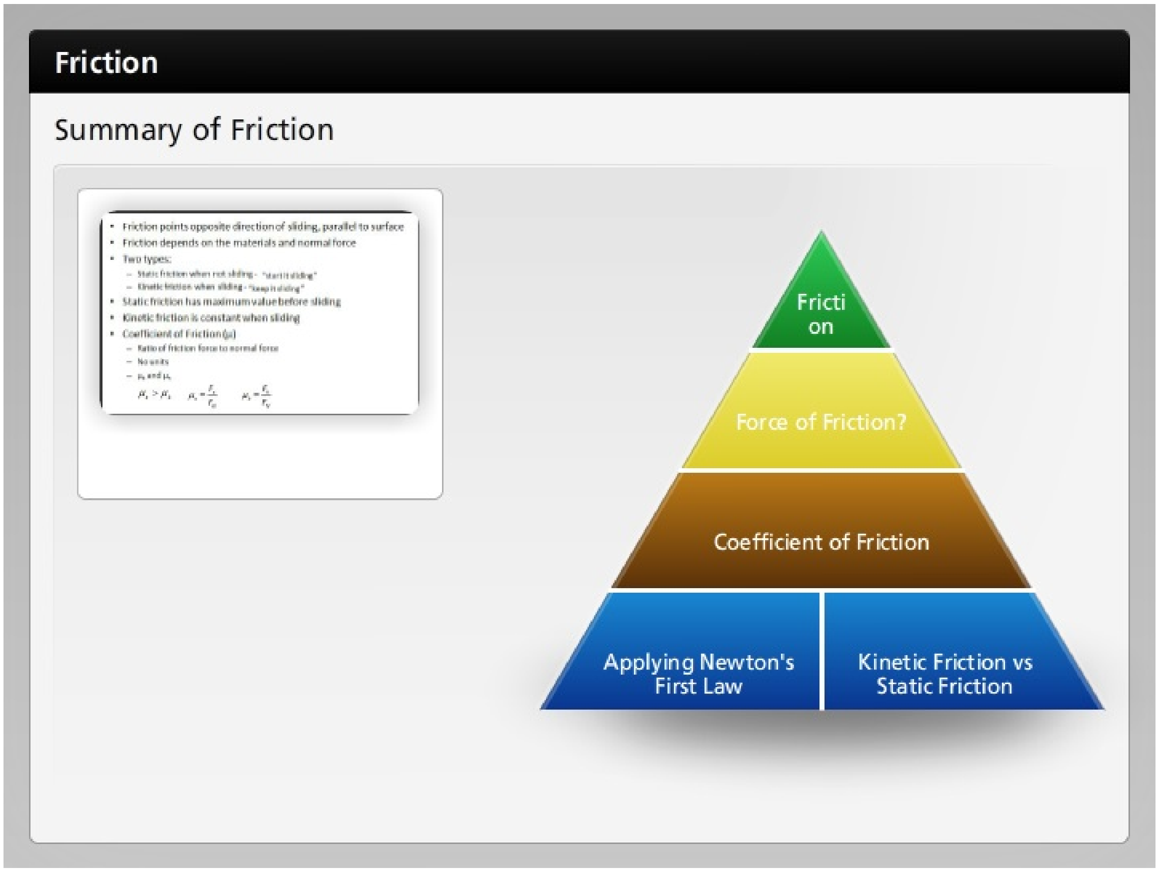
So we calculate the coefficient of static friction by dividing the maximum amount of friction before the object starts moving by the normal force. And we calculate the coefficient of kinetic friction by dividing the amount of friction resulting when the object is sliding by the normal force.

One way to remember this is that you have to overcome static friction to start it sliding and you have to overcome kinetic friction to keep it sliding.

It is interesting to note that the coefficient of static friction is generally greater than the coefficient of kinetic friction. This means that it generally takes more force to start an object slipping than it does to keep an object slipping.

This is an important concept to remember if you drive on wet or icy pavement. When the tires are rolling on the road, the surfaces are not slipping against one another. Your car therefore uses static friction to accelerate as well as to come to a stop when you apply the brakes. Once a car starts to skid, with the tires slipping with respect to the road surface, the ability to accelerate, turn or stop is greatly reduced because then you are dealing with the smaller amount of kinetic friction.

Summary of Friction



The force of friction, when present, points opposite the direction of sliding and is directed parallel to the surface. The force of friction only depends on the materials that are in contact and the normal force that results from the objects being pushed together.

There are two types of friction, kinetic friction that acts when an object is sliding on a surface, and static friction, which acts when the object is not sliding. You have to overcome static friction to start an object sliding and you have to overcome kinetic friction in order to keep an object sliding. Generally, static friction is greater than kinetic friction, so it is harder to start something sliding than it is to keep it sliding.

The value of static friction varies from zero to a maximum just before the object starts sliding. The value for kinetic friction is constant when sliding, regardless of speed or applied force.

The coefficient of friction is the ratio of the force of friction to the normal force. It is a unitless quantity. Since there are both kinetic and static friction, there is also both a coefficient of kinetic friction and the coefficient of static friction. As the value of static friction is generally greater than the value of kinetic friction, the coefficient of static friction is generally greater than the coefficient of kinetic friction