

Friction

Friction is a force that always exists between any two surfaces in contact with each other.

- There is no such thing as a perfectly frictionless environment.
- Even in deep space, bits of micrometeorites will hit a moving object, causing some friction (although it is incredibly small).

Did You Know?

One of the problems that NASA would need to solve before sending astronauts on long journeys (like Mars) is protection from the microdust and micrometeorites in space. One of the most serious problems is that as the spacecraft travels through space at high speeds, the front will be damaged the most. To solve the problem, most spacecrafts would have some kind of ablative shield that would cover the front of the craft (ablative is just what you call any material that you expect to wear away because of some form of damage, while it protects whatever is underneath).

There are two kinds of friction based on how the two surfaces are moving relative to each other:

1. Static friction: the friction that exists between two surfaces that are not moving relative to each other.
2. Kinetic friction: the friction that exists between two surfaces that are moving relative to each other.

In any situation, the static friction is greater than the kinetic friction.

- Have you ever tried to push a really big object? Did you notice that you were pushing harder, and harder, and HARDER, until suddenly it started to move? Then, once you got it moving, it probably felt easier to push than it did to get it started in the first place.
- When the object was at rest, you were trying to overcome the static friction (bigger force).
- When it finally started to move, you were pushing against the kinetic friction (smaller force).

Nobody is exactly sure why friction acts the way it does...

- Some physicists' theories on friction involve the idea of the minute (tiny) imperfections in the surfaces grinding against each other.
- Imagine two pieces of sandpaper rubbing past each other... they'd have a difficult time!
- Now remember that any surface, no matter how smooth it might appear to the naked eye, has tiny bumps.
- These bumps on any surface will grind past other bumps on the other surface and cause friction.
- There is also the hypothesis that there are small electrostatic attractions between atoms of the two surfaces, pulling on each other.
- Think of the electrons in one of the surfaces being attracted to the protons in the other surface.
- As you hold one object against another, billions of these attractions between the electrons and protons of the two objects cause them to stick to each other somewhat.
- This pulling on each other could also be a source of friction.

Did You Know?

Some people think that tarantulas can climb the walls of glass tanks because of some sort of "stickiness" on their feet. Actually, they are using friction more than anything else. A tarantula's feet are covered with thousands of microscopic hairs. When their feet touch the glass, these hairs jam into the micro-cracks in the surface of the glass and hook on. This is why you'll often see tarantulas tap one of their feet against the glass a few times before they take hold and climb.



Friction always acts in the direction opposite to the motion of the object.

- Just look at the direction the object is traveling. The direction of the force due to friction will be exactly 180° opposite.
- Friction is also proportional to the normal force, which is how we'll be able to calculate it.

$$F_f \propto F_N$$

The actual formula for friction is:

$$F_f = \mu F_N$$

F_f = force of friction (Newtons)

F_N = normal force (Newtons)

μ = the coefficient of friction between two surfaces (no units); symbol is the Greek letter "mu".

μ_s = the coefficient of static friction

μ_k = the coefficient of kinetic friction

Some surfaces have less friction than others:

- A rubber hockey puck against ice has less friction than a car tire on an asphalt road.

The static friction that you will soon calculate is a measurement of the maximum it can be. We'll do an example of this soon.

$$F_{fstatic} \leq \mu_s F_N \quad or \quad F_{fs} \leq \mu_s F_N$$

- The kinetic friction is the value of the friction.

$$F_{fkinetic} = \mu_k F_N \quad or \quad F_{fk} = \mu_k F_N$$

- When we measure the coefficient of friction (μ), the smaller the number, the less the friction between the two surfaces.
- By gathering empirical evidence of different combinations of surfaces, physicists have been able to come up with values to use for coefficients of friction.

- "Empirical" evidence means that you actually have to perform the experiment each time to get results. There is no shortcut, regular pattern, or formula that you can use to get the results.
- You are not expected to memorize this table.

Surfaces	μ_s	μ_k
steel on steel	0.74	0.57
aluminum on steel	0.61	0.47
copper on steel	0.53	0.36
rubber on concrete	1.0	0.8
glass on glass	0.94	0.4
waxed wood on wet snow	0.14	0.1
metal on metal (lubricated)	0.15	0.06
ice on ice	0.1	0.03
teflon on teflon	0.04	0.04
synovial joints in humans	0.01	0.003

Example 1

A 12kg piece of copper is placed on top of a piece of steel. There is a 64N maximum static friction measured between them. Determine the coefficient of static friction between the two metals.

- First calculate F_N
- As long as the surface is completely horizontal, we can say $F_N = F_g$. We will calculate it as a positive value, since F_N points up.

#1

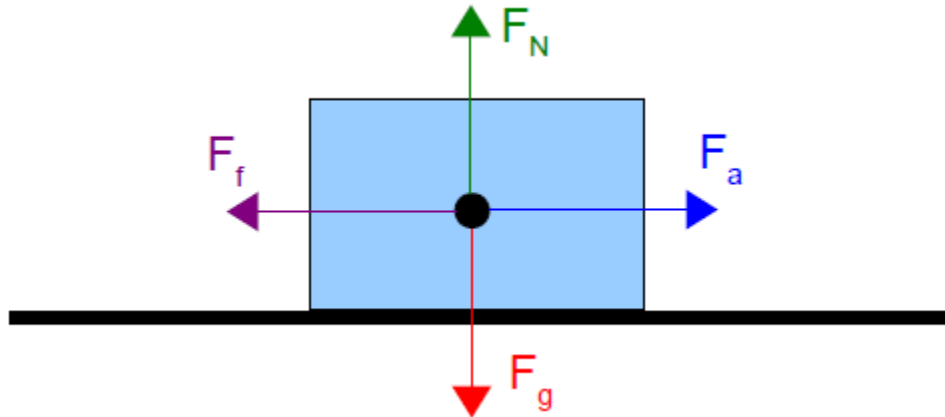
#2

Example 2

I have a steel box (mass of 10 kg) sitting on a steel workbench. I try to push the box out of the way.

a) Sketch a free body diagram of the box.

With no definite information about the amount of force being applied, we'll just draw all the vectors equally for now.



b) I push against the box with a force of 25 N. Determine if anything will happen.

Let's calculate the maximum force due to static friction. First we figure out the normal force.

#3

We'll use this to calculate the maximum static friction. We can get the steel-on-steel value of μ_s from the table above.

#4

So, does this mean that when I push with $F_a = 25$ N, the friction will push back with 73N?

- No. That wouldn't make sense, since that would mean that if you gently pushed the box, it would actually start to accelerate back towards you!
- The force due to static friction can go up to a maximum of 73 N, but can also be less.
- It will be equal to whatever the F_a is, up to the maximum calculated here. In this case the friction only has to be as high as 25N to "beat" my applied force.

#5

With zero net force acting on it, the box will continue to do what it was already doing (Newton's First Law). The box will just sit there motionless.

c) Determine what will happen if I push with a force of 73 N. This exactly equals the maximum static frictional force between these two surfaces.

#6

As above, with no net force acting on it, the box will not start to move.

d) If I push with a force of 100 N, determine if anything will happen. This applied force is greater than the static friction, so it will start to move... but remember that we will now be using kinetic friction!

- Calculate the kinetic friction, which is the value you must use. No more of this “maximum” stuff.

#7

#8

#9