Teacher Tune-up

Quick Content Refresher for Busy Professionals

Can something moving through air encounter friction?

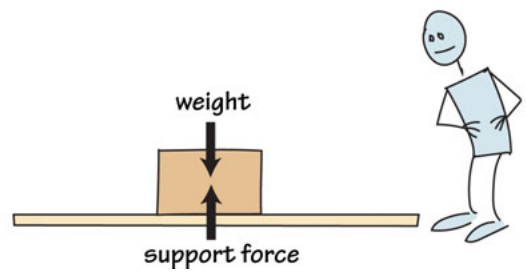
When we think of friction, we usually think first of **sliding friction** between solid surfaces—tires skidding on a road, a child scooting down a playground slide, the squeaky complaint of a chair scraping across a wooden floor. But objects moving through fluids like water and air also encounter frictional forces that oppose their motion. This **fluid friction** differs in several ways from sliding friction.

We'll look first at sliding friction, then compare fluid friction.

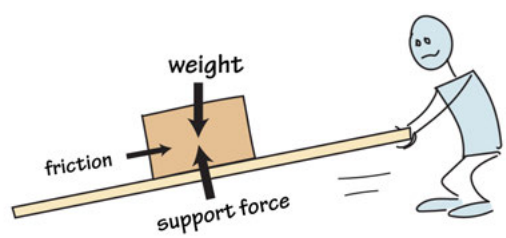
Sliding Friction

Sliding friction results from the "stickiness" between two surfaces that move relative to each other while being pressed together. The pressure between the objects causes points on their surfaces to stick to each other, and force is needed to break those connections as the objects slide.

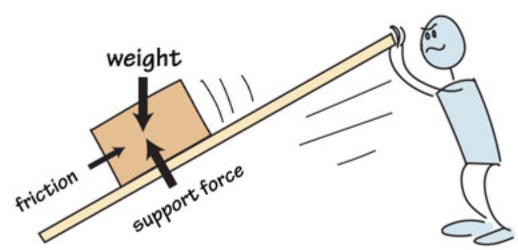
The amount of friction depends on the nature of the surfaces. The same hockey puck that glides across ice with relatively little friction will grind to a halt much more quickly on asphalt. Sandpaper drawn across wood obviously generates more friction than a dust rag drawn across glass.



An object at rest on a surface will not begin to move until more sliding force is applied than the maximum frictional force in the system at rest. Consider a box resting on a level board. The downward force of gravity (i.e. the box's weight) acts on the box, and a support force of equal strength holds it up. So far, there's no friction.



If you tilt the board, making a ramp, the box's weight still pulls down, but now the support force isn't providing as much upward force as before. That's because the support force always acts perpendicular to the board, and so now it doesn't entirely oppose the weight. (In fact, this support force is also called the normal force, because in geometry the word "normal" means perpendicular.) If the box doesn't begin to slide, that means there must be some new, additional force acting against gravity: friction!



The more steeply you tilt the board, the less the support force will counteract the weight of the box, and the more frictional force will be generated in reaction. But this kind of friction has a maximum (depending on the weight of the object and the nature of the surfaces involved—are they rough or smooth, wet or dry, flexible like rubber or rigid like steel?). As you continue to tilt the board, reducing the vertical component of the support force and increasing the frictional reaction, you reach a threshold where the system cannot generate any more friction. From that point onward, any further tilt will give gravity the advantage, and there will be a net downward force on the box. As a result, the box will slide.

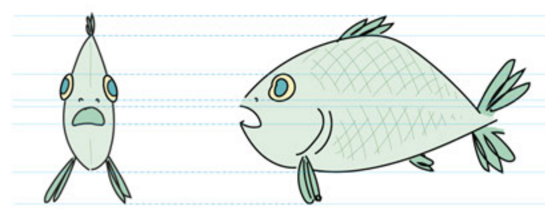
Now here's something about sliding friction that may not be intuitively obvious: once the box is sliding, the frictional force between the bottom of the box and the ramp will remain about the same regardless of how fast the box moves. Double the speed of the box, and the friction force remains the same. That's because as the box slides across the board, the sticky connections between the surfaces are broken just as fast as they are formed, regardless of speed. This indifference of sliding friction to speed means that if you're shoving a heavy object across the floor, once you've got it moving, any increase in your effort goes into speeding up the object, not overcoming additional friction.

Fluid friction

Fluid friction (also called drag) behaves differently than sliding friction, and varies with the speed of an object. Fluid friction depends also on the cross-sectional area of the object (the area it presents in its direction of motion), and the density of the fluid through which the object moves. All fluids cause drag, but the most familiar forms of this kind of friction are air resistance and water drag.

Speed: The faster an object moves relative to a liquid or gas that flows around it, the more molecules it has to push out of its way each second, and so the more resistance it meets. Indeed, drag increases proportionally to the speed squared. This means that when a jet plane doubles its speed (all other things being equal), it will have to push against four times as much air resistance. Similarly, a 50-mph wind exerts 25 times as much force on a tree as a 10-mph wind does (50 mph = 5 × 10 mph, and 52 = 25). If a river's current speeds up because of heavy rainfall, so that it rushes faster against a bridge pier, the increased rate of flow will generate increased water drag on the pier.

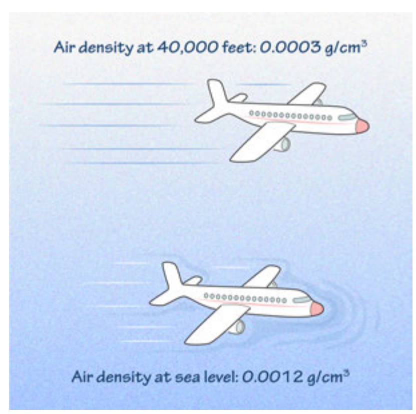
Cross-sectional area: That increased water drag on the bridge pier from speed comes on top of another effect of flooding: when the river's level rises, it will push against a larger surface area on the pier, which increases the drag even more. Airplanes and rockets are designed to present relatively small cross-sections to the air they move through, to increase their speed and their energy efficiency. Same with tennis rackets: their open mesh allows them to hit tennis balls without shoveling more air than necessary. Natural selection also angles for efficiency by reducing cross-sectional area. Most fish have evolved to slice easily through the water, not shove against it like bulldozers.



Sometimes drag is a drag, but other times it's a good thing. Sailboats spread canvas to let the wind drag them across the water, and skydivers bet their lives on the role cross-sectional area plays in air resistance. When a parachute deploys, it has more than 120 times more cross-sectional area than a falling person. This spread of fabric slows a skydiver's fall by about 90 percent.

Density

The greater the density of a fluid, the greater the force with which it opposes an object moving through it. In high-density fluid, there's more mass to shove out of the way, and that takes more work. The water that generates drag for bridge piers and boats is about 1000 times denser than air, which causes it to generate much greater friction. Even variations in air density can make a significant difference. Airplanes can travel twice as fast at their cruising altitudes as they can near sea level because the air at that height is only one-fourth as dense.



Viscosity

In addition to density, the viscosity of a liquid affects how much friction force it generates. Viscosity is a measure of how much the molecules in a liquid are attracted to each other. For example, the molecules in olive oil are about 10 times longer than water molecules, and so they stick to each other more than water molecules do. So it's easier to stir water than olive oil, even though their densities are not very different.

Some differences between fluid and sliding friction

	…will there be more fluid friction?	*…will there be more sliding friction?*
As an object speeds up…	*Yes*	*No*
As an object's weight increases…	*No*	*Yes*
As we enlarge an object's cross-section…	*Yes*	*No*