Friction is the force resisting the relative motion of solid surfaces, fluid layers, and/or material elements sliding against each other. There are several types of friction: dry, fluid (between layers of viscous fluid moving relative to each other), lubricated (fluid separates two solid surfaces), skin (drag), and internal (the force resisting motion of solid undergoing deformation) friction.

In this unit we are only looking at the type of friction called dry friction. **Dry friction** resists relative lateral motion of two solid surfaces in contact. Dry friction is subdivided into *static friction* between non-moving surfaces, and *kinetic friction* between moving surfaces.

When surfaces in contact move relative to each other, the friction between the two surfaces converts kinetic energy into heat. This property can have dramatic consequences, as illustrated by the use of friction created by rubbing pieces of wood together to start a fire. Kinetic energy is converted to heat whenever motion with friction occurs, for example when a viscous fluid is stirred. Another important consequence of many types of friction can be wear, which may lead to performance degradation and/or damage to components. Friction is a component of the science of tribology.

Friction is not a fundamental force but occurs because of the electromagnetic forces between charged particles which constitute the surfaces in contact. Because of the complexity of these interactions friction cannot be calculated from first principles, but instead must be found empirically.

Static friction Static friction is friction between two solid objects that are not moving relative to each other. For example, static friction can prevent an object from sliding down a sloped surface. The coefficient of static friction, typically denoted as μ_s, is usually higher than the coefficient of kinetic friction. The static friction force must be overcome by an applied force before an object can move. The maximum possible friction force between two surfaces before sliding begins is the product of the coefficient of static friction and the normal force: $f = \mu_s F_n$. When there is no sliding occurring, the friction force can have any value from zero up to F_{max}. Any force smaller than F_{max}attempting to slide one surface over the other is opposed by a frictional force of equal magnitude and opposite direction. Any force larger than F_{max}overcomes the force of static friction and causes sliding to occur. The instant sliding occurs, static friction is no longer applicable—the friction between the two surfaces is then called kinetic friction. An example of static friction is the force that prevents a car wheel from slipping as it rolls on the ground. Even though the wheel is in motion, the patch of the tire in contact with the ground is stationary relative to the ground, so it is static rather than kinetic friction. The maximum value of static friction, when motion is impending, is sometimes referred to as **limiting friction**, although this term is not used universally. It is also known as traction.

Kinetic friction Kinetic (or dynamic) friction occurs when two objects are moving relative to each other and rub together (like a sled on the ground). The coefficient of kinetic friction is typically denoted as μ_k, and is usually less than the coefficient of static friction for the same materials.[However, Richard Feynman comments that "with dry metals it is very hard to show any difference." New models are beginning to show how kinetic friction can be greater than static friction. Kinetic friction is now understood, in many cases, to be primarily caused by chemical bonding between the surfaces, rather than interlocking asperities;[17] however, in many other cases roughness effects are dominant, for example in rubber to road friction.[16] Surface roughness and contact area, however, do affect kinetic friction for micro- and nano-scale objects where surface area forces dominate inertial forces.

Angle of friction For the maximum angle of static friction between granular materials, see Angle of repose. For certain applications it is more useful to define static friction in terms of the maximum angle before which one of the items will begin sliding. This is called the *angle of friction* or *friction angle*. It is defined as:

$$\tan\theta = \mu$$

where θ is the angle from vertical and μ is the static coefficient of friction between the objects.[19] This formula can also be used to calculate μ from empirical measurements of the friction angle.

Reducing friction

Devices: Devices such as wheels, **ball bearings**, **roller bearings**, and air cushion or other types of **fluid bearings** can change sliding friction into a much smaller type of rolling friction. Many **thermoplastic** materials such as **nylon**, **HDPE** and **PTFE** are commonly used in low friction **bearings**. They are especially useful because the coefficient of friction falls with increasing imposed load.[*citation needed*] For improved **wear** resistance, very high **molecular weight** grades are usually specified for heavy duty or critical bearings.

Lubricants: A common way to reduce friction is by using a **lubricant**, such as oil, water, or grease, which is placed between the two surfaces, often dramatically lessening the coefficient of friction. The science of friction and lubrication is called **tribology**. Lubricant technology is when lubricants are mixed with the application of science, especially to industrial or commercial objectives.

Superlubricity, a recently-discovered effect, has been observed in graphite: it is the substantial decrease of friction between two sliding objects, approaching zero levels. A very small amount of frictional energy would still be dissipated.

Lubricants to overcome friction need not always be thin, turbulent fluids or powdery solids such as graphite and talc; acoustic lubrication actually uses sound as a lubricant.

Another way to reduce friction between two parts is to superimpose micro-scale vibration to one of the parts. This can be sinusoidal vibration as used in ultrasound-assisted cutting or vibration noise, known as dither.

Laws of dry friction

The properties of sliding friction were discovered by experiment in the 15th to 18th centuries and were expressed as three empirical laws:

- **Amontons' First Law**: The force of friction is directly proportional to the applied load.
- **Amontons' Second Law**: The force of friction is independent of the apparent area of contact.
- **Coulomb's Law of Friction**: Kinetic friction is independent of the sliding velocity.

Amontons' 2nd Law is an idealization assuming perfectly rigid and inelastic materials. For example, wider tires on cars provide more traction than narrow tires for a given vehicle mass because of surface deformation of the tire.

Approximate coefficients of friction

Materials		Static friction, μ_s	
		Dry & clean	Lubricated
Aluminum	Steel	0.61	
Copper	Steel	0.53	
Brass	Steel	0.51	
Cast iron	Copper	1.05	
Cast iron	Zinc	0.85	
Concrete (wet)	Rubber	0.30	
Concrete (dry)	Rubber	1.0	
Concrete	Wood	0.62[9]	
Copper	Glass	0.68	
Glass	Glass	0.94	
Metal	Wood	0.2–0.6[9]	0.2 (wet)[9]
Polythene	Steel	0.2[10]	0.2[10]
Steel	Steel	0.80[10]	0.16[10]
Steel	Teflon	0.04[10]	0.04[10]
Teflon	Teflon	0.04[10]	0.04[10]
Wood	Wood	0.25–0.5[9]	0.2 (wet)[9]