Lecture 8: Friction Part 1 – Friction Phenomena

Friction is a force which is generated _____ between _____. Its direction is always _____ to that of the motion, or tendency for a motion.

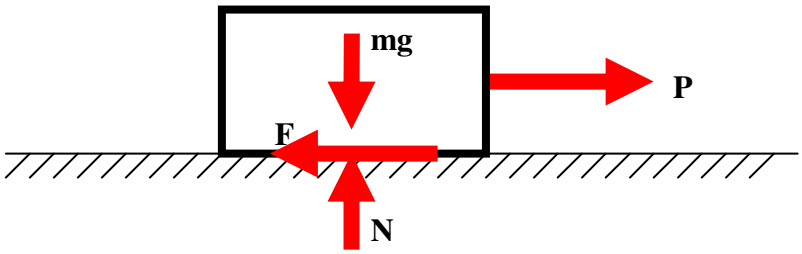


Figure 1

Figure 1 shows a block of mass *m* being pulled horizontally by a fore *P*. The _____ surface exerts a normal force *N* to support the weight of the block and a friction force *F* to resist the motion in the direction of *P*.

Friction forces exist everywhere in both nature and man made objects, both intentionally or not. Friction can be beneficial, or even essential in certain applications such as _____. On the other hand, some applications such as _____ _____ require minimum friction.

Types of friction

1. _____ (also known as Coulomb friction). It occurs when unlubricated (nonsmooth or rough) surfaces of _____ are in contact under a condition of _____. An example of this type of friction is shown in figure 1. This type of friction will be explained in details in the next section.
2. _____. It occurs when adjacent layers in a moving viscous fluid are moving at different velocities. The shearing action

caused by the relative velocity between the layers account for the fluid friction.

3. _____. It occurs in all solid materials subjected to cyclic loadings. Internal friction is present during deformation and causes a loss of energy.

In this course, we will only concentrate on _____.

Dry Friction

As stated before, dry friction occurs at the contact between two rough surfaces during a sliding motion or under a tendency to slide. The friction force is always tangent to the surface and its direction always opposes the motion or the impending motion.

Mechanism of Dry Friction

Let us consider the block in figure 1 (redrawn in figure 2a). The block is vertical equilibrium as the force N is equal to its weight mg. However, the block may or may not slide horizontally depending on the magnitudes of the force P and the friction F.

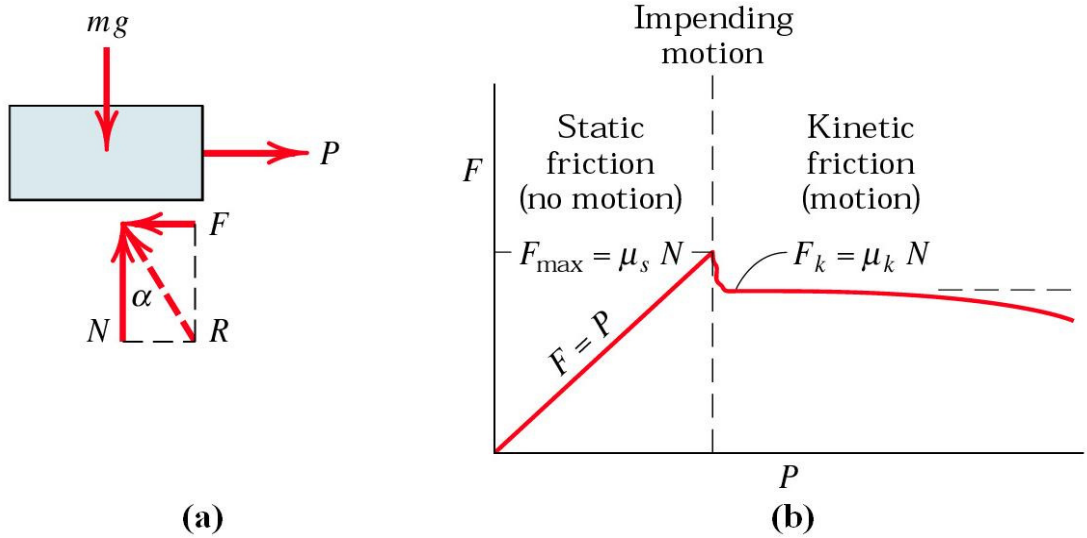


Figure 2

The curve in figure 2b shows us two regions on either side of the vertical dotted line labeled '_____'. These regions correspond to the types of behavior of the block upon the application of force P.

Stationary Block – No motion is present

If the magnitude of the force P is less than that required for the block to move, the system lies in the region to the _____ of the dotted line. In this region, the friction force is called the _____, as _____ in the system.

The main characteristic of this region is the linear relationship _____, which is expected because the forces must be in equilibrium in order for the block to be stationary.

The block will remain stationary as long as the _____ _____, which is defined as

_____

where μ_s is a constant called the _____.

When $P=F_{max}$, the block is said to _____.

Moving Block – Motion is present

After slipping has occurred and the block is now _____, the friction that the block is now experiencing is called the _____. Kinetic friction is somewhat less than the maximum static friction force (at the point of impending motion) as shown in figure 2b.

For $P > F_{\max}$, the kinetic friction F_k is also proportional to the normal force, as shown by the relationship

_____

where μ_k is a constant called the _____ and usually _____.

However, as the velocity of the block increases and $P >> F_{max}$, the kinetic friction decreases quite significantly. This effect is shown in figure 2b.

Friction Angles

The direction of the resultant force R in figure 2a makes an angle α with the vertical component. The magnitude of this angle can be computed via the relationship _____.

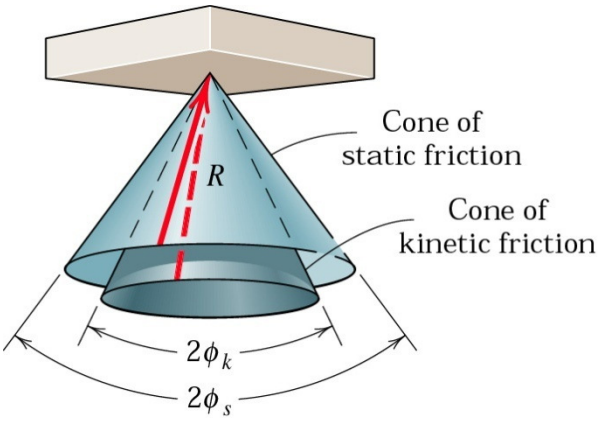
When the friction force reaches the _____, the angle reaches a _____, where

_____

The angle ϕ_s is called the _____.

Similarly, the *angle of* _____ is given by

_____



Both kinetic and static friction angles clearly define the limit of direction (or the maximum angle) of the reaction force R as shown in the figure. For reaction forces whose direction is _____ the static friction cone, _____ is present and vice versa.

Coefficients of friction

Given below is a table of coefficients of friction between typical types of surfaces found in engineering applications. Note that these only represent typical values under normal working conditions. They may vary depending on the exact nature of the contact surfaces and working environment.

CONTACTING SURFACES	TYPICAL VALUES OF COEFFICIENT OF FRICTION	
	STATIC, μ_s	KINETIC, μ_k
Steel on steel (dry)	0.6	0.4
Steel on steel (greasy)	0.1	0.05
Teflon on steel	0.04	0.04
Brass on steel (dry)	0.5	0.4
Brake lining on cast iron	0.4	0.3
Rubber tyres on smooth pavement (dry)	0.9	0.8
Wire rope on iron pulley (dry)	0.2	0.15
Hemp rope on metal	0.3	0.2
Metal on ice		0.02