Friction

Friction is a force that acts to oppose the sliding motion of two dry bodies in contact. It always acts in opposition to actual or potential sliding motion. The root cause of friction has to do with asperities (bumps) on rough surfaces that tend to lock and possibly also due to interatomic forces that might partially "cold weld" the two surfaces in contact. Without really going into the root causes of friction (which is still an active topic of research), we can do a simple experiment to characterize frictional forces.

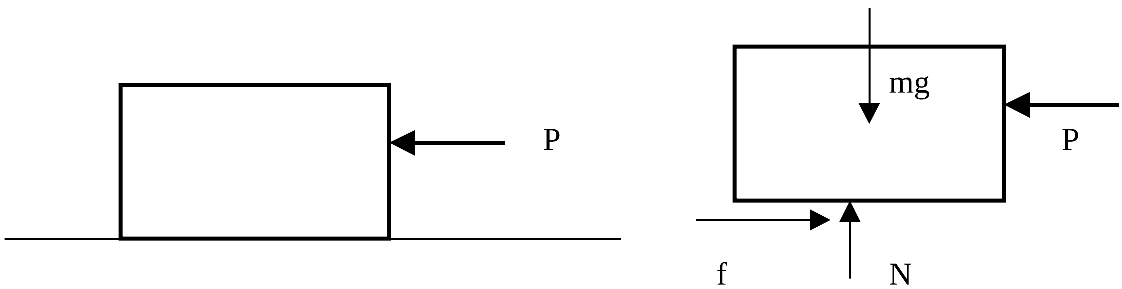

Figure 1: Block sliding over a rough table.

Consider a block of mass m resting on a table with a rough surface (fig. 1). Let us try to push the block by a force P so as to try and slide the block over the surface of the table. More specifically, let us increase this force P from zero and see what happens. We will find the block does not move up to some level of load P. This means that something must be opposing the applied force P and this has to be the frictional force 'f'. Since the block does not move initially we must have f=P in magnitude and acting opposite the direction of P. So, if we plot the frictional force f against the applied load P, we get the curve shown in fig. 2.

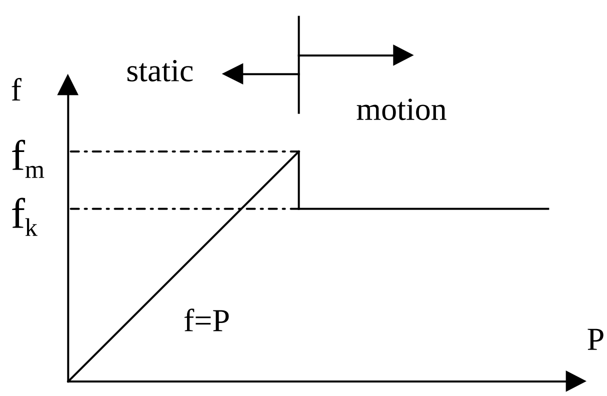

Figure 2: Frictional force as the applied force increases.

The frictional force however cannot indefinitely continue to increase to oppose motion, and eventually the block begins to slide over the table surface. The maximum frictional force turns out to be proportional to the net normal force N exerted by the two bodies on each other:

$$f_m = \mu_s N$$

where μ_s is called the coefficient of static friction. Once the bodies begin to slide over each other, the frictional force drops a bit and stays constant at level:

$$f_k = \mu_k N$$

where μ_k is called the coefficient of kinetic friction. The coefficients of friction are in general functions of the materials that are in contact.

Friction can be shown to be a non-conservative force, and so there is no potential energy that one can associate with it. To see this consider that a body slides from position '1' to position '2' along some path shown in fig. 3. Let $\mathbf{e_t}$ be a unit vector tangent to the path at any point. Then, since the body is in motion, the frictional force must equal the kinetic frictional force: $\mathbf{f} = -\mu_k N \mathbf{e_t}$.

The work done by the frictional force is then obtained as:

$$U = \int_{\mathbf{r}_1}^{\mathbf{r}_2} \mathbf{f}\,.\,d\mathbf{r} = \int_{\mathbf{r}_1}^{\mathbf{r}_2} (-\mu_k N\mathbf{e_t}).(ds\,\mathbf{e_t}) = -\mu_k N \int_{\mathbf{r}_1}^{\mathbf{r}_2} ds = -\mu_k NL$$

where L is the length of the path. Clearly, the work done in going from position '1' to '2' is not path independent, since we can go along different paths of different lengths. Therefore, friction is not a conservative force.