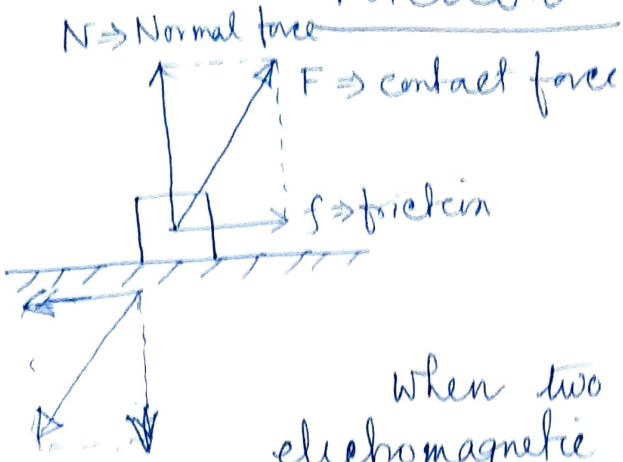
Friction



When two bodies are kept in contact electromagnetic forces act between the charged particles of the bodies at the contact surfaces. As a result each body exerts a contact force on each other. The magnitude of the contact forces acting on two bodies are equal but opposite in directions and hence contact forces obey Newton's 3rd law of motion.

The direction of contact force acting on a particular body is not necessarily perpendicular to the contact surface. We can resolve the force into two components. The perpendicular component is called the normal contact force or normal force and the parallel component is called friction.

Actually whenever the surface of one body slides over the surface of another body, each body exerts a frictional force on the other parallel to the surface of contact. The frictional force on each body is opposite to the direction of motion of that body relative to other. Thus for example when a book slides from left to right along the surface of the table, a frictional force acts on the book right to left direction and an equal force acts on the table from left to right. Frictional forces may also exist between the surfaces when there is no relative motion. This implies that friction arises when the surface of one body moves or tries to move along the surface of another body.

Friction can operate between a given pair of solids, between a solid and a fluid or between a pair of fluids. Frictional force exerted by fluids is called viscous force.

When two solid bodies slip over each other, the force of friction is called kinetic friction. When two bodies are in contact and do not slip over each other, the force of friction is called static friction.

The maximum magnitude of static friction is known as <u>limiting friction</u>.

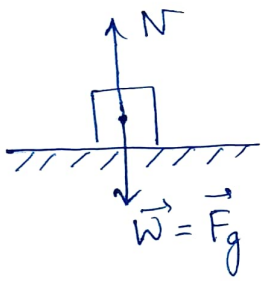


Fig (1)

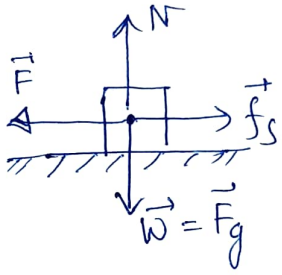


Fig (2)

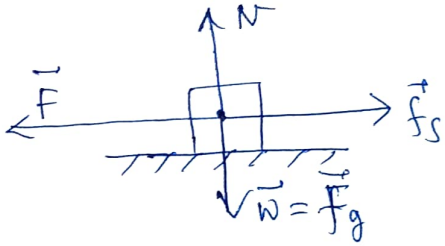


Fig (3)

No motion

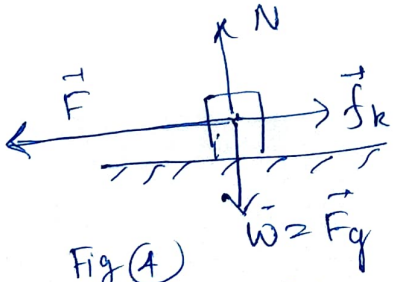


Fig (4)

Acceleration

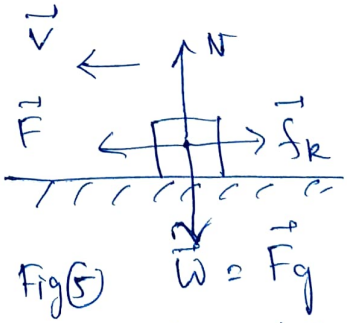


Fig (5)

moving with constant velocity

In Fig (1) a block is kept on the table top, the gravitational force $\vec{F}_g$ is balanced by the normal force $\vec{N}$.

In Fig (2) you exert a force $\vec{F}$ on the block attempting to pull it to the left. In response a frictional force $\vec{f}_s$ is directed towards right exactly balancing your force. And the block does not move. This frictional force is called the static frictional force.

Fig (3) shows that you increase the magnitude of your force, the magnitude of the static frictional force f_s will also increase and will balance your force and the block remain at rest.

Now when the applied force reaches a certain magnitude the frictional force f_s can not increase any more and hence the block just begins to move. The frictional force that then opposes the motion of block is called the kinetic frictional force f_k.

Usually the magnitude of kinetic frictional force which acts when there is motion is less that the maximum magnitude of the static frictional force which acts when there is no motion.

So once the motion starts, the frictional force acting between the surfaces decreases so that a smaller force $\vec{F}$ is required to maintain the uniform motion of the body. This implies that the kinetic frictional force f_k is less than the maximum static frictional force $(f_s)_{max}$.

Laws of friction

We can summarize the laws friction between two bodies in contact as follows:

(1) If the bodies slip over each other, the force of kinetic friction is given by $\vec{f}_k = \mu_k \vec{N}$, $\vec{N}$ = normal contact force. μ_k = coefficient of kinetic fric.

The direction of kinetic friction on a body is opposite to the velocity of this body w.r.t. the body applying the force of friction.

(2) If the bodies do not slip over each other the force of friction is given by

$$\vec{f}_s \leq \mu_s \vec{N}$$

where μ_s is the coefficient of static friction between the bodies and N is the normal force between them.

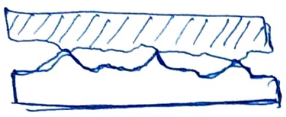
Note: The maximum static friction that a body can exert on the other body in contact with it is called the limiting friction. This limiting friction is denoted by $f_{s,max}$ which is proportional to the normal contact force between the two bodies i.e,

$$\vec{f}_{s,max} = \mu_s \vec{N}.$$

Understanding Friction At Atomic Level

It has already been pointed out that friction appears because of the interaction between the charged particles of the two bodies near the surfaces of contact.

Any macroscopic object like steel plate or a wood piece has irregular surface at atomic scale. A polished steel surface may look plane to naked eyes but if seen under a powerful microscope, its surface is found to be quite irregular.



This figure shows how an apparently plane surface may be at the atomic scale.

When the two bodies are kept one over the other, the real area of contact is much smaller than the total surface area of the bodies. The distance between the particles of the two bodies at the actual point of contact becomes very small and the molecular forces start operating across the surface. Molecular bonds are formed at these contact points. When one of the two bodies is pulled over the other these bonds are broken, the materials under the bond is deformed and new bonds are formed. This local deformation of the bodies send vibration waves in the bodies. This causes the increased random motion of the particles in bodies. Thus the bodies become heated. A force is therefore needed to start the motion or to maintain the motion.