INTRODUCTION

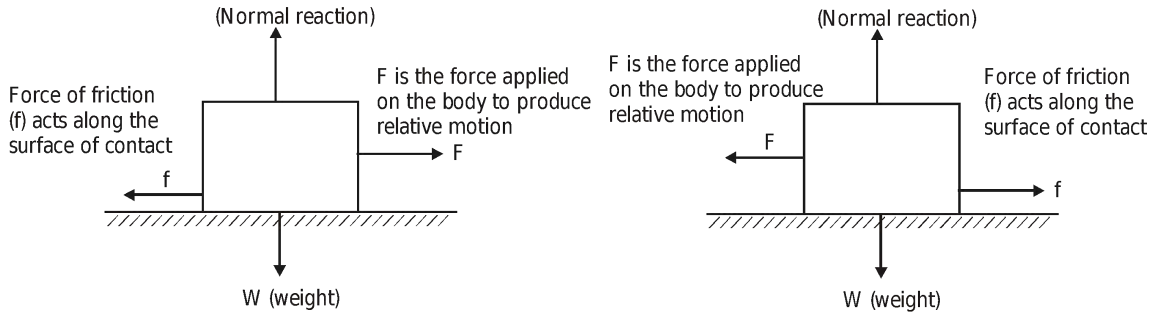
Friction is the opposing force set up between the two surfaces of contact when one body slides or rolls or tends to do on the surface of another body.

FRICTION

Friction is the resistance to motion experienced when two surfaces in contact move with respect to each other.

OR

The force acting along the two surfaces in contact that opposes one body's motion over the other is the force of friction or frictional force.



CAUSES OF FRICTION

1. The force of friction always opposes the relative motion between the two bodies in contact irrespective of the direction of motion. So, for example, when a body is pulled by a force F towards the right, the force of friction acts along the left, and when the applied force acts towards the left, the force of friction acts towards the right.

2. A frictional force always acts to oppose the motion of a body over a surface and is an example of a **contact force.**

COMPETITION WINDOW

1. **STATIC FRICTION**

DEFINITION: The force of friction called into play, which does not allow two bodies to slide upon one another, is called static friction.

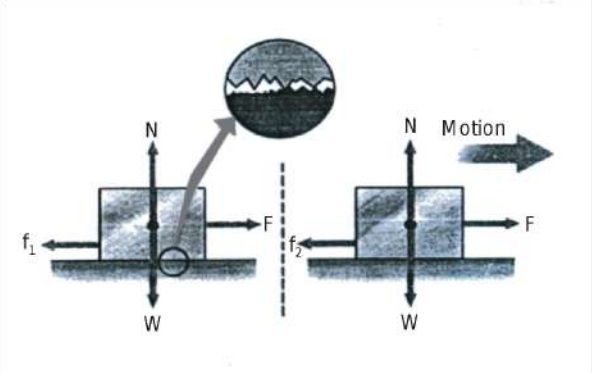
(I) It is a frictional force that is effective before motion start between two planes in contact with each other.

(II) Its nature is self-adjusting.

(III) Numerical value of static friction is equal to external force, which creates the tendency of motion of the body.

(IV) Maximum value of static friction is called limiting friction.

Example: The two surfaces lock into one another. When we have to move any surface over another, the force to break these interlocks on a rough surface, there are many such irregularities. So the force of friction is greater if a rough surface is involved.



LAW OF LIMITING FRICTION

1. The magnitude of the force of limiting friction between any two bodies in contact is directly proportional to the normal reaction between them.

2. The direction of the surface of limiting friction is always opposite to the direction in which one body is on the verge of moving over the other.

3. The force of limiting friction is independent of the apparent contact area, so long as a normal reaction between the two bodies in contact remains the same.

4. Limiting friction between any two bodies in contact depends on the nature of the material of surfaces in contact and their roughness and smoothness.

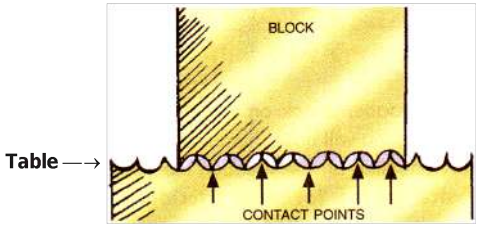
5. Its value is more than the other types of friction force.

HOW FRICTION ORIGINATES

1. Friction is very closely related to the roughness or unevenness of the surfaces in contact. This is because the frictional force increases with the increase in the roughness of the surfaces.

2. A closer look through a microscope reveals that the surfaces have crests and troughs, cracks, bumps, or hills and valleys. These are known as **irregularities** or **imperfections**. Friction is caused by these irregularities found on the two surfaces in contact with each other. It is due to the interlocking of irregularities of the two surfaces that produce friction between them.

3. The force of friction also arises due to **forces of adhesion.** When two rough surfaces come in contact, many contact points are formed. The atoms or molecules present at such contact points give rise to the attractive force of adhesion that opposes the bodies' relative motion. Thus, the force of adhesion between the two surfaces gives rise to friction.



Interlocking of the surfaces of solids sliding over each other

1. Friction depends upon the nature of the surfaces in contact. The smoothness of the contacting surfaces does affect the force of friction between two surfaces in contact.

2. The force of friction is directly proportional to the normal force. When a body moves over a horizontal surface, it presses down against the surface with force equal to its weight, i.e. to the pull of gravity upon it. An increase in the body's weight causes an increase in the amount of resistance offered to the relative motion of the surface in contact.

3. Friction does not depend on the amount of surface area in contact between the moving bodies.

TYPES OF FRICTION

The force of friction not only tends to stop a moving object but also to stop a stationary object from moving. That is why it is difficult to push a stone (or a brick) to get it to move on a rough surface.

The force of friction depends upon two parameters. These are :

(i) Mass.

(ii) Nature of the surface

The force of friction is almost independent of the velocity of the moving body with respect to the surface, as long as the velocity is not too high.

On the basis of its nature frictional force can be divided into three types. They are

(i) Static Friction

(ii) Sliding Friction

(iii) Rolling Friction

(i) Static Friction :

The friction between the two surfaces in contact when there is no relative motion between them is called **Static friction.**

(ii) Sliding Friction :

The friction that exists between a surface sliding on another surface is called **Sliding friction.**

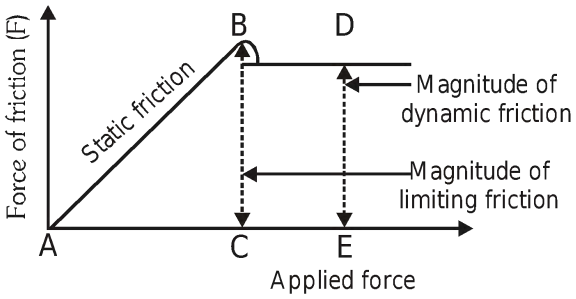
(iii) Rolling Friction :

When a body rolls on the surface of another, the friction that exists between the surfaces is known as **Rolling friction.**

Experimentally, it has been proved that,

Static friction > Sliding or Dynamic Friction > Rolling Friction

Why is dynamic friction slightly lesser than the limiting friction?



You know that friction is caused due to the interlocking of the irregularities on the surface of two bodies in contact with each other. Now, more force is required to unlock the irregularities between the surfaces of two stationary bodies than the force required to keep the irregularities unlocked between the surfaces of two sliding bodies. Thus, the limiting friction is always slightly more than the dynamic friction, or dynamic friction is slightly less than the limiting friction.

Fig. shows a graph between the applied force on the spring balance and the force of friction. The region AB in the graph shows static friction, which is self-adjusting. BC shows the magnitude of limiting friction. DE shows the magnitude of dynamic friction or sliding friction.

DIFFERENCES BETWEEN SLIDING AND ROLLING FRICTION			
Sliding friction		**Rolling friction**	
1.	When a body slides over the other body, then force of friction acting between the two surfaces is called sliding friction	**1.**	When one body roll over the other body, then the frictional force acting between the two is called rolling friction
2.	Small part of the sliding body is always in contact with the other body.	**2.**	Different parts of the rolling body gradually come in contact with the other body

NOTE: Sliding friction and rolling friction are slightly lesser than the limiting friction.

Co-effecient of friction

Static friction

$$\mu_s = \frac{F}{R_n}$$

Sliding friction coefficient

$$\mu_k = \frac{F_k}{R_n}$$

The values of m_S and m_K depend on the nature of both the surface in contact.

The value of m depends on the material of the surface in contact.

m_S and m_K are dimensionless.

Important key points

1. Friction always oppose the tendency of motion.

2. The force of static friction exactly balances the applied force during the stationary state of the body.

3. m_S and m_K can exceed unity, although commonly, they are less than one.

4. Static friction is a self-adjusting force, the kinetic friction is not a self-adjusting force.

5. When two highly polished surfaces are pressed hard, then a situation similar to welding occurs. It is called cold welding.

6. When two copper plates are highly polished and placed in contact with each other. Then instead of decreasing, the force of friction increases. This arises because for two highly polished surfaces in contact, the number of molecules coming in contact increases, and as a result, the cohesive/adhesive forces increase. This, in turn, increases the force of friction.

ADVANTAGES AND DISADVANTAGES OF FRICTION

1. ADVANTAGES

(i) No two bodies will stick to each other without friction.

(ii) Adhesives will lose their purpose without friction.

(iii) When a person pushes the ground backwards. The rough surface of the ground reacts and exerts a forward force due to friction.

(iv) It plays an important role in our daily life. It would be impossible for us to walk if there was no friction between the soles of our shoes and the ground.

(v) Without friction, there would be no reaction from the ground in a forward direction. As a result, we would not be able to move forward.

(vi) It is because of friction that we can hold a pen. It is because of the friction between paper and a pen that we can write.

(vii) Cars and buses can move on the road because of friction between the tyres and the road. Because of the friction between the brake, shoes, and wheels, automobiles slow down and stop when brakes are applied.

(viii) It is the force of friction that holds screws and nails in wooden furniture.

(ix) A matchstick lights due to the force of friction.

1. **DISADVANTAGES**

(i) Friction always opposes the motion, so extra energy has to be spent overcoming the friction.

(ii) Tyres of vehicles and soles of shoes wear out in a few months due to friction.

(iii) Frictional force results in the production of heat, which causes damage to machinery.

(iv) The heat produced in the moving parts of machinery due to friction results in the parts' wear and tear.

(v) Friction causes **wastage of energy.**

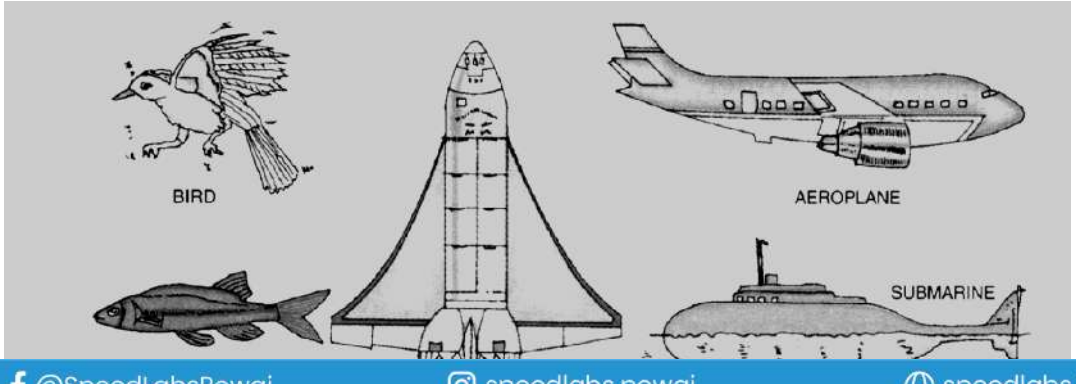
(vi) Friction reduces (retards) the speed of moving vehicles to a great extent.

INCREASING AND REDUCING FRICTION

(A) METHODS OF REDUCING FRICTION.

(I) STREAMLINED BODIES

Air and water offer maximum friction. Objects moving in air or water have streamlined bodies to reduce friction. Birds, cars, aeroplanes and rockets have special streamlined bodies to reduce air resistance. Ships, fishes, boats and submarines are broad in the middle and narrow in front and back.



Streamlined shapes help to reduce friction

(i) **POLISHING** Polishing rough surfaces also reduces friction. If the surfaces that are in contact are rough, there is more friction. Hence to reduce friction, the surfaces in contact are kept smooth and polished. It is worth noting that if the two surfaces in contact are of the same metal, the friction increases on polishing the two surfaces. This is why the bearings and the axle are made of different metals.

(ii) **WHEELS** If a suitcase is fitted with wheels, it is easier to move because the friction between the wheels and the ground is less.

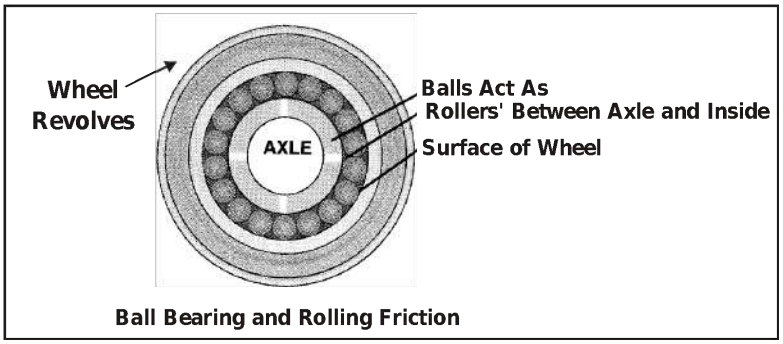
Wheels reduce friction

(III) LUBRICANTS Use of lubricants makes the surface smooth. In machines, friction is reduced by using lubricants such as oil, grease or graphite powder. The lubricant fills the minute unevenness of the two surfaces. It separates them by forming a very thin layer in between. This layer offers very little resistance, and as a result, the friction gets reduced.

(IV) ANTI-FRICTION METALS

When steel slides over an alloy of lead, the friction is less than steel slides on steel. Bearings are sometimes packed with such an alloy.

(V) BALL BEARING Ball bearing changes sliding friction to rolling friction. This is a very useful thing to do since rolling friction is much smaller than sliding friction. Ball bearings are used in most mechanical structures which have moving parts.



Ball Bearing and Rolling Friction

Small metal balls made of stainless steel, brass, ceramic. etc., are placed between moving surfaces, reducing friction.

(A) METHODS OF INCREASING FRICTION

But despite what is given above, there can be times when more friction is better. As we have seen, sometimes it is better for us if friction is greater (as we would like to have when walking on a slippery floor).

There are two methods of increasing friction.

(a) By increasing the roughness of the surface.

(b) By increasing the mass of the object.

- Types have designs and patterns (treads) with grooves on the surface to increase friction (these

  treads also channel away water on the road that, acting as a lubricant, would decrease the friction between tyre and road surface and cause the car to skid off the road).
- Spikes are provided in the soles of the shoes of athletes to increase the friction and prevent them

  from slipping.
- Sand and gravel are strewn on the slippery ground during the rainy season to increase friction.
- The soles of your shoes also have threads, as tyres do. These grooves are there to increase friction

between the sole of the shoe and the floor. You might have noticed that when these grooves wear out, your shoes become slippery.

FLUID FRICTION AND STREAMLINING

Fluid is a substance that can flow. Liquids and gases can flow and are therefore called **fluids**. Fluids also exert friction on bodies moving through them. This friction is called **fluid friction** or **viscous drag**. The fluid friction depends on

(i) Shape of the moving body

(ii) (Velocity of the body

(iii) Nature of fluid.

Have you ever noticed the shape of the bodies of birds and fishes which move in fluids? The shape of their bodies is such that they overcome fluid friction easily using less energy. Such shapes are called **streamlined**.

The shapes of cars, aeroplanes, submarines, and ships that have to move at high speeds in fluids are streamlined to save energy and reduce drag.

ACTIVITY

1. **To prove that limiting friction depends upon the nature of surfaces in contact with each other.**

Materials required: l A wooden block provided with a hook l A spring balance l A sandpaper l Talcum powder.

Method: Place the wooden block on the smooth tabletop. To the hook of the wooden block, attach the spring balance. Pull the spring balance gently towards the right. Go on increasing the pull on the spring balance till it just starts sliding. Read and record the force shown by the spring balance. This force is equal and opposite to the limiting friction between the surface of the wooden block and the tabletop.

Now, place a sandpaper flat on the tabletop and over it, place the wooden block. Repeat the activity as above and again record the force of limiting friction.

Now, sprinkle some talcum powder on the tabletop and over it, place the wooden block. Repeat and again record the force of limiting friction.

You will observe that the force of limiting friction is least in the case of talcum powder, middle-order in the case of smooth tabletop, and maximum in the case of sandpaper.

The activity proves that limiting friction depends upon the nature of surfaces in contact with each other.

2. **To prove that limiting friction increases with the weight of the body.**

Materials required: l A wooden block provided with a hook l A spring balance l Brass weight of 50 gf and 100 gf

Method: Place the wooden block on the smooth table tot. To the hook of the wooden block, attach the spring balance. Pull the spring balance gently towards the right. Go on increasing the pull on the spring balance till it just starts sliding. Read and record the force shown by the spring balance. This force is equal and opposite to the limiting friction between the surface of the wooden block and the tabletop.

Now place 50 gf weight on the wooden block and repeat the activity. Read and record the force of limiting friction. Repeat the activity with 100 gf weight and 150 gf weight.

You will notice that as the weight of the block is increased, the magnitude of limiting friction also increases. The activity proves that limiting friction increases with the increase in the weight of a body.

2. **To prove that limiting friction is independent of the area of the cross-section in contact with the other body.**

Materials required: l A wooden block with a hook having a different length, width and height, such that its all surfaces are similar l A spring balance

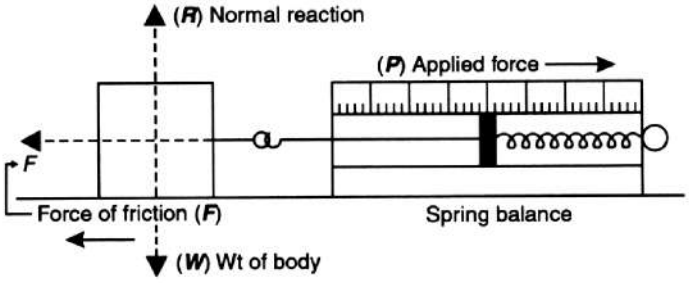
Method: Place the wooden block on the smooth tabletop such that its largest face is in contact with the tabletop. To the hook of the wooden block, attach a spring balance. Pull the spring

balance gently towards the right. Go on increasing the pull on the spring balance till it just starts sliding. Read and record the force shown by the spring balance. This force is

equal and opposite to the limiting friction between the surface of the wooden block and the tabletop.

Repeat the activity by placing a wooden block in such a way on the tabletop that its smallest face is in contact with the tabletop. You will notice that the force of limiting friction required to slide the block remains the same.

The activity proves that limiting friction is independent of the cross-section area in contact with the other body.



The figure for Activity No. 1, 2 and 3

KEY POINTS

Frictional force: The force acting along two surfaces in contact opposes one body's motion over the other.

Self-adjusting: Automatically adjusting itself.

Static friction: The friction between the two surfaces in contact when there is no relative motion between them.

Limiting friction: The maximum value of friction that makes the surface just slide.

Kinetic or dynamic friction: The friction that exists between a surface sliding on another surface.

Rolling friction: The friction that exists between the surfaces when one body rolls over another.

Drag: The frictional force exerted by fluids.

Streamlined shape: The body's shape helps it flow through a fluid easily, offering the least friction.

LOOKING BEYOND

- Alfred Nobel instituted the Noble Prize. Initially, the Nobel Prize was given for outstanding work in Physics, Chemistry, Physiology or Medicine, Literature and most important of all, Peace. In 1969 another Nobel Prize was added for Economics.
- **Alfred Bernhard Nobel (1833-1896)** was a Swedish chemist who invented some powerful explosives. He discovered that nitroglycerine could be handled safely when it had soaked into a powdery rock. This powdery rock was named **dynamite** by Nobel. He went on the develop more powerful explosives and became very wealthy.


Alfred Bernhard Nobel

- **Noble gases** are the most interesting elements existing in nature. The six noble gases are so inert,

or stable, that they hardly react with other materials. In Chemistry, 'noble' means unreactive. None of these gases has any smell, colour or taste, and they do not burn. The noble gases are lightest to heaviest: Helium, Neon, Argon, Krypton, Xenon and Radon. After Hydrogen, Helium is the second most common element in the Universe, and only Hydrogen is lighter than Helium. Since it is lighter than air, Helium is used to fill balloons. Argon and Neon give out brightly coloured light when an electric current is passed through them and is used to produce gas lasers' light beams. Radon is highly radioactive.