

## 5.1 Nature of friction

If we place an object such as a pencil on a table and tap on it so that it starts to move on the table, we know from experience that its speed would gradually decrease until it ultimately comes to rest. If we place the same object on a surface smoother than that of the table, the object would move a longer distance on the surface before coming to rest.

An object moving on a surface gradually slows down and comes to rest as described above, because the surface exerts a force on the object to oppose its motion. This opposing force is known as a frictional force. Friction always opposes the motion of an object.

Let us consider a situation where a table needs to be pushed along a horizontal floor as shown in Figure 5.1.



Figure 5.1 – Pushing a table

If we try to move the table with a very small force, it might not move. This is because the floor exerts a force on the table which opposes the force that we apply. The two forces have equal magnitudes but opposite directions. Therefore they cancel out.

Now suppose that we slightly increase the force that we apply on the table. If the table still does not start to move, it means that the frictional force exerted by the floor has automatically increased in order to balance the force that we applied. The frictional force is a force which automatically adjusts to balance the force we apply. However, if we keep on increasing the force on the table, at some instant, the table will begin to move. This happens because the frictional force cannot automatically adjust beyond a certain limit. When the force that we apply exceeds that limit, an unbalanced force that is equal to the difference between the two opposite forces remains. This unbalanced force starts the motion of the table.

The forces that act between the surfaces of two objects in contact with each other, to oppose the relative motion when the objects are moving relative to each other or, to oppose the tendency to move when the objects have a tendency to move relative to each other, are called frictional forces.

Frictional forces exist in the motion of liquids and gasses too, However, in this lesson we discuss only the frictional forces that act between solid bodies.

## 5.2 Static, limiting and dynamic states of frictional forces

Frictional forces can be divided into three categories, depending on the situations they act on a body

They are:

1. The frictional forces that act when there is no relative motion, even though, a force is applied on the body.
2. The frictional forces that act on a body as it just begins to move. This force includes the small additional force that is necessary to give it a velocity.
3. The frictional forces that act on bodies when they are in relative motion.

In order to investigate differences among the three types of frictional forces mentioned above, let us do the following activity.

## Activity 1

**Items required :** A block of wood weighing 60 N, a Newton balance

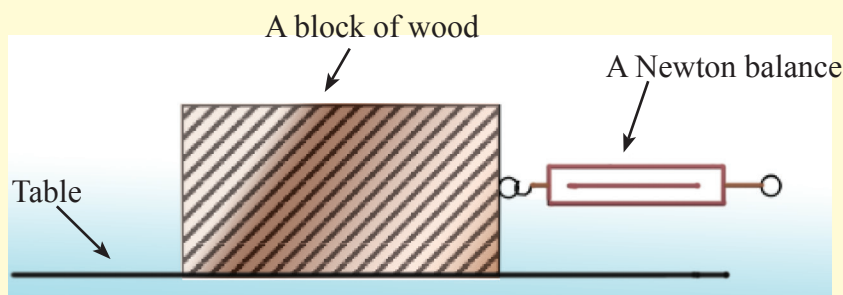


Figure 5.2 – Finding the maximum frictional force exerted on the object

### Procedure :

- Fix a small ring to the block of wood and attach the balance to the ring.
- Place the block of wood on a horizontal table and pull the block as shown in Figure 5.2, with a very small force. You would be able to read the magnitude of the applied force from the Newton balance. Initially, the force would be insufficient to move the block.
- Gradually increase the force on the object. When the force is gradually increased, at some point it will just begin to move. Find the force at the moment it just about to move.

The body begins to move because the table surface is not capable of further increasing the frictional force in order to balance the force that you exerted. In other words, the frictional force does not exceed that force. The maximum frictional force exerted by the surface of the table to oppose the motion is equal to the force necessary to just start the motion.

Whenever the force applied on the body is smaller than this maximum frictional force, the surface of the table exerts a frictional force on the body that is equal and opposite to the applied force. This frictional force exerted on the body before the motion starts is called **static friction**.

When the applied force is gradually increased, the static friction acting on the body also increases with it. However, the static frictional force can increase only up to a certain maximum value. When the applied force exceeds this maximum value the frictional force is incapable of increasing further in order to keep the body in equilibrium. Therefore the body begins to move and acquires a small velocity. This maximum frictional force between the surfaces of two bodies in contact with one another is known as the **limiting frictional force** between the two bodies.

The frictional force acting on the body after the body starts to move, is known as **dynamic friction** between the two surfaces. In other words, dynamic friction is the frictional force acting on bodies that are in motion. Dynamic friction is slightly less than the limiting frictional force.

### 5.3 Factors affecting the limiting frictional force

Frictional forces act between objects that are in contact with one another. Therefore, let us now investigate how the frictional forces depend on the nature and area of contact surfaces and the reaction forces perpendicular to the contact surfaces (normal reaction).

Let us first do the following activity in order to investigate how the limiting frictional force depends on the nature of the contact surfaces.

#### Activity 2

**Items required :** A block of wood weighing 60 N, a Newton balance, several sheets of sand paper of various roughness

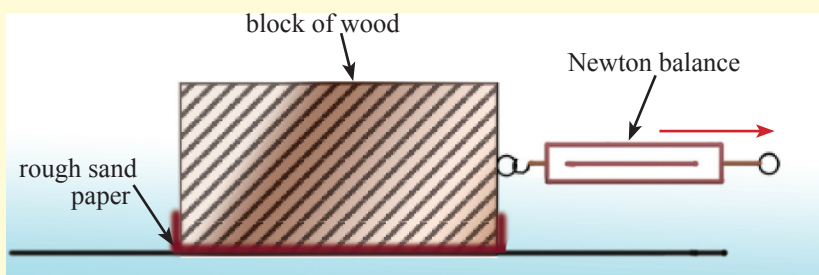


Figure 5.3 – Investigation of the influence of surface roughness on friction

### Procedure :

- Fix the block of wood with the sand paper having the lowest roughness with rough side facing out and completely covering the bottom surface.
- Place the block of wood on the table so that the rough surface of the sand paper is in contact with the surface of the table. Next pull the Newton balance attached to the block with a very small horizontal force at first and then increasing the force gradually.
- When the block of wood just begins to move, record the reading of the Newton balance. This is the limiting frictional force.
- Next use a sand paper which is rougher than the first and fix it again to cover the bottom surface of the block, and find the limiting frictional force that is just enough to set the block of wood in motion.
- Repeat the above procedure using several sand papers of increasing roughness and record the limiting frictional force each time.
- Compare the results you obtained. You will observe that the limiting frictional force increases gradually with increasing roughness of the sand paper used to cover the block of wood.

**This activity shows that the limiting frictional force depends on the nature of the surfaces in contact.**

Now let us investigate the dependence of the limiting frictional force on the surface area of the contact surfaces through the following activity.

### Activity 3

**Items required :** A block of wood with a weight of 60 N and different dimensions for length, width and height, a Newton balance, several pieces of sand paper of equal roughness.

Procedure :

- Paste the sand paper on the surfaces of the block of wood which have different areas.
- Next place the surface with the largest area in contact with the table top and find the force that is just enough to move the block (the limiting frictional force) as before.

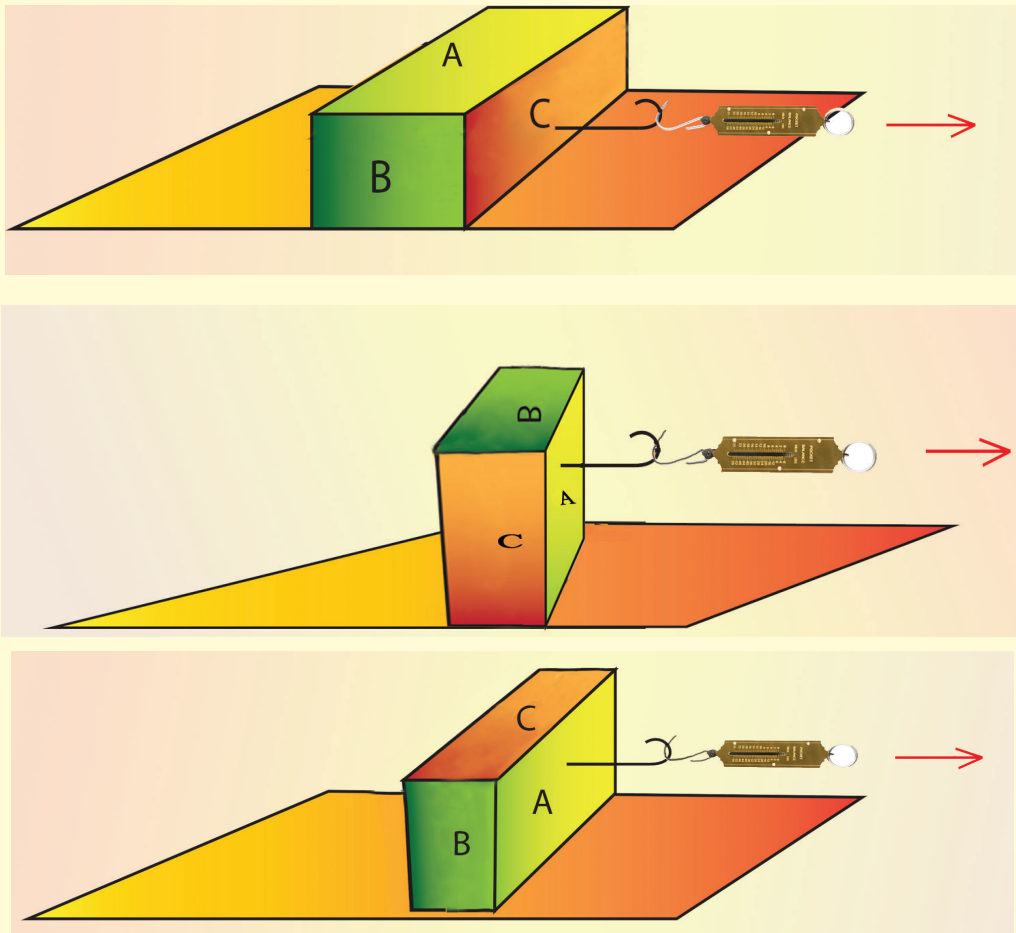


Figure 5.4 – Investigation of the influence of surface area on friction

- Repeat the above step, placing different surfaces of the block in contact with the table as shown in Figure 5.4, to find the limiting frictional force corresponding to each surface.
- You will find that the limiting frictional force is the same for all surfaces of the block of wood in contact with the table. This shows that the limiting frictional force **does not depend** on the surface area.

Our next activity is the investigation of the dependence of the normal reaction between bodies in contact, on the limiting frictional force.

#### Activity 4

**Items required:** Three blocks of wood each having a weight of 20 N, a Newton balance

Procedure :

- As in the previous experiment, place one block of wood on the table and find the force required to just move the block. That is the limiting frictional force.
- Next, place another block of wood on the first one and find the limiting frictional force as before.
- Repeat the above step with the third block placed on the other two and record the limiting frictional force.

This experiment can also be done by placing various other objects on the first block of wood instead of the other blocks of wood.

You will notice that the readings obtained for different weights are not the same and that the limiting frictional force increases with increasing weights.

That is, when the weight ( $W$ ) is increased, the normal reaction exerted on the weight by the table (perpendicular reaction force  $R$ ) also increases.

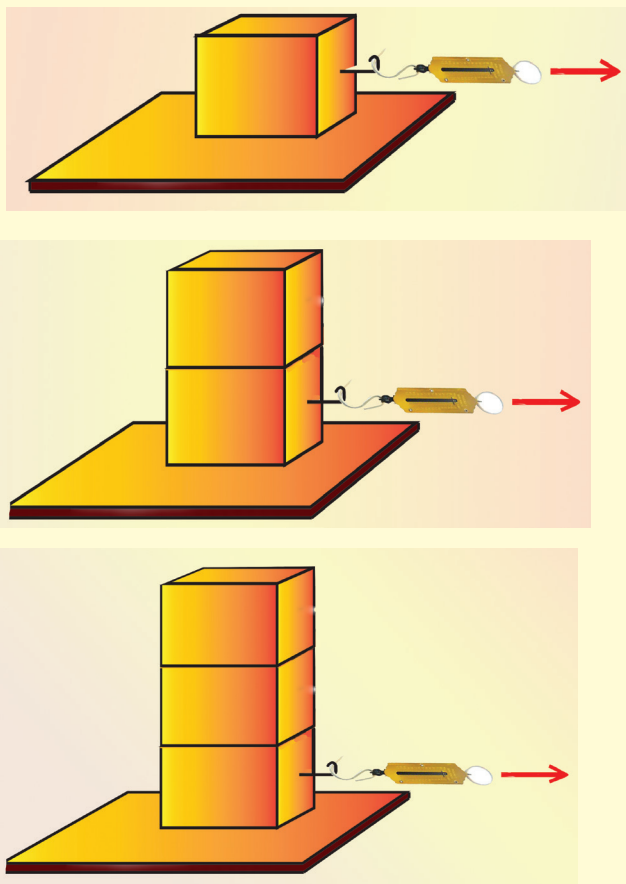


Figure 5.5 – Investigation of the influence of normal reaction on frictional force

That is, weight of the object = perpendicular reaction force.

**This activity shows that the limiting frictional force increases when the normal reaction between the two forces increases.**

The above activities show that the limiting frictional force depends on the nature of the contact surfaces and the normal reaction between the surfaces while it does not depend on the area of the contact surfaces.

## 5.4 Practical applications of friction

Various parts of most of the machines and instruments that we use daily are in contact with other parts. When we operate these machines and instruments, these parts slide on one another, giving rise to frictional forces. Therefore, when machines are operated, an excessive amount of additional work has to be done against frictional forces, causing a loss of energy. This loss of energy appears as heat, raising the temperature of the object. If we could reduce frictional forces, then we would be able to minimize the energy loss and the rise in temperature.

### Methods of reducing friction

- Reducing the roughness of contact surfaces or polishing them.
- Applying lubricators such as graphite, lubrication oil or grease between the contact surfaces.
- Inserting balls that could roll between the contact surfaces. Such balls can prevent the two contact surfaces from sliding on each other. Ball bearings used to connect most of the rotating parts of vehicles and machines to stationary parts such as axles are fabricated in this manner. A few different types of bearings are shown in Figure 5.6.





Figure 5.6 – Some types of bearings

### Advantages of frictional forces

So far we discussed only some disadvantages of frictional forces and how to minimize them. Sometimes friction is useful to us. A few such examples are given below.

- We can walk on a surface only because of the frictional force exerted by that surface on our feet prevents slipping. If we try to walk on a wet surface or an oily surface, we tend to slip and fall, due to lack of friction.
- Grooves are etched on the surface of tire as shown in figure 5.7 in order to increase the friction between the tire and the road surface. If a sufficient amount of friction is not exerted on the tire, the wheels would tend to skid on the road, causing accidents. Sometimes, when a motor vehicle is travelling on mud or sand, the wheels tend to rotate in the same place, without moving forward because the friction is insufficient for the wheels to move forward. On wet roads a water layer that exists between the road and the tire tends to reduce the friction between the two surfaces causing the vehicles to skid.



Figure 5.7 – Tires with grooves to increase friction

- Coir ropes are formed by twisting a large number of coir fibers together. Even when a large force is applied on a rope, the fibres do not separate because of the friction among them. It is easier to untie a knot made with a nylon string than a knot made with a coir string. This is because the frictional forces among the coir fibers are stronger than those among the nylon fibers.
- Moving vehicles can be brought to rest by applying brakes because of friction. As shown in figure 5.8, breaks of a bicycle operate by pressing the break-pads which are made of rubber on the wheel rim. The bicycle stops because of the friction between the surfaces of the rubber break-pads and the wheels.



Figure 5.8 – Break system of a bicycle

- In modern motor vehicles, disc-brakes are used to stop the vehicle. Such a break system is shown in figure 5.9. In such systems, the frictional forces caused by pressing the break-pads against a disc attached to the wheel, are used to stop the wheels from rotating.

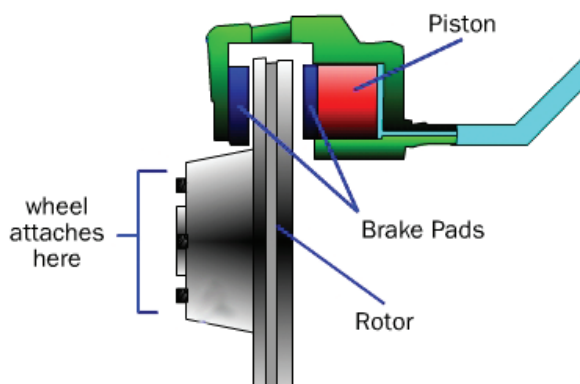


Figure 5.9 - Disk brake system of a car

### Exercise

- (1)
  - (i) Briefly state what is meant by friction.
  - (ii) Briefly explain what is meant by static friction.
  - (iii) Briefly explain what is meant by limiting friction.
  - (iv) Under what circumstances does dynamic friction act?
  - (v) What are the two main factors that limiting friction depends on?
  - (vi) State a factor on which friction does not depend?
- (2)
  - (i) Give two benefits of friction.
  - (ii) Give two disadvantages of friction.
  - (iii) It is dangerous to drive vehicles with tires that have worn out grooves on rainy days. Explain why.
  - (iv) Write down two methods used to reduce friction.

## Summary

- When one of two bodies in contact with one another moves or tries to move relative to the other, the second body exerts a force that tends to stop this relative motion. This phenomenon is known as friction.
- The frictional force that acts before the body begins to move is the static friction. Static friction between the bodies varies with the external force that tries to cause the relative motion.
- The frictional force that acts when the relative motion between the two bodies just starts.
- Limiting friction between two bodies depends on the nature of the contact surfaces and the normal reaction.
- Limiting friction does not depend on the surface areas of the contact surfaces.
- The frictional force acting on a moving body is the dynamic friction.

## Technical terms

Friction	ஈர்ப்பு	உராய்வு
Static friction	சுரீகிரக ஈர்ப்பு	நிலையியல் உராய்வு
Limiting friction	கிழிவாலை ஈர்ப்பு	எல்லை உராய்வு
Dynamic friction	கிழிவாலை ஈர்ப்பு	இயக்கவியல் உராய்வு
Weight	பொருள்	நிறை
Normal Reaction	அகிலமீடு புகிழியாவி	செவ்வன் மறுதாக்கம்