

2.3 FRICTION

The property by virtue of which a resisting force is created between two rough bodies that resists the sliding of one body over the other is known as friction.

The force that always opposes the motion of one body over the other body in contact with it is known as the **force of friction or frictional force**.

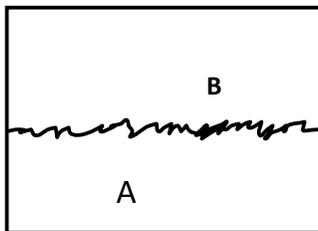
Frictional force operates between

- a) two solids in contact
- b) a solid and a fluid
- c) two fluids.

Causes of friction:

The surface of any body is never perfectly smooth. Even a polished surface which appears to be smooth shows irregularities when observed under a microscope.

When one body is placed in contact with another body there will be interlocking of a large number of irregularities. Many points of contact between A and B get cold-welded due to a high pressure at sharp points. The phenomenon is called surface adhesion.



The external force tending to produce a relative motion between A and B has to rupture these interlocking. As a result there is an opposition to the relative motion between the two bodies.

The opposing force is the force of friction. The frictional force always acts opposite to the direction of motion or the direction of the applied force.

Properties of frictional forces:

1. Frictional force always acts parallel to two planes in contact with each other and in a direction opposite to that of relative motion of the two bodies.
2. Frictional forces are caused due to intermolecular interactions between the bodies.
3. Frictional force always decreases the relative motion between two bodies or surface.
4. Frictional force is more for rough surface and less for smooth surfaces.

There are four types of friction, they are

- 1).Static friction
- 2) Dynamic friction
- 3) Sliding friction
- 4) Rolling friction

Static Friction:

The maximum frictional force present when a body just tends to slide over the surface of another body is known as the static friction.

Dynamic Friction:

The frictional force which is effective when two surfaces in contact with each other are in relative motion with respect to each other is known as dynamic friction.

Sliding Friction:

The frictional force present when one body slides over the other body is known as kinetic friction or sliding friction.

Rolling Friction:

It is defined as the opposing force between the surface of a rolling body and the another.

Coefficient of Static Friction:

The maximum force of static friction F_S is directly proportional to the normal force R acting on the body, i.e.

$$F_S \propto R \quad F_S = \mu_S R$$

Therefore, $\mu_S = F_S / R$

$$= \frac{\text{maximum force of static friction}}{\text{Normal}}$$

Where, μ_S is known as coefficient of static friction.

Hence coefficient of static friction is defined as the ratio of magnitude of limiting friction to the normal reaction between the two surfaces in contact. Similarly, when the body is in motion, $f_K \propto R$ or

$$f_K = \mu_K R,$$

Where f_K is the force of kinetic friction μ_K is coefficient of kinetic friction

$$\mu_K = f_K / R$$

Thus coefficient of kinetic friction is defined as the ratio of magnitude of kinetic friction to the normal reaction between the surfaces in contact.

Rolling Friction:

When a body rolls over a surface, both the rolling body and the surface on which it rolls are compressed to a small extent. As a result it has to move against a gradient moreover as the body rolls it has to continuously detach itself from the surface over which it rolls.

The adhesive force between the two surfaces in contact opposes this separation. Consequently a force which opposes the rolling motion of the body comes into play. This opposing force is called rolling friction and denoted by f_r

It is quite difficult to pull a heavy iron box on a rough floor. However if the box is provided with four wheels, also made of iron, it becomes easier to move the box on the same floor.

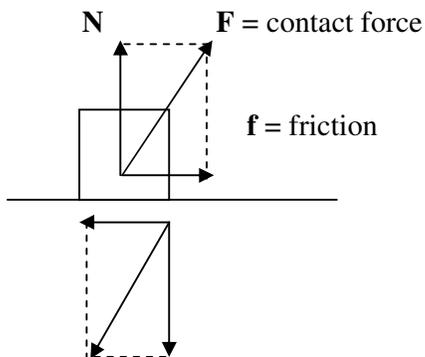


$$f_r = \mu_r \times R / r, \quad \text{where, } r \text{ is radius of the rolling body, } R \text{ is the normal reaction}$$

μ_r is a constant called coefficient of rolling friction.

Friction as the component of contact force:

When two bodies are kept in contact, electromagnetic forces act between the two contact surfaces of the bodies. As a result, each body exerts a contact force on the other. The component of this contact force normal to the plane of contact is called the normal force and the component along the tangent to the contact plane is called the friction.



Advantages and disadvantages of friction:

Friction plays an important part in our life and it is very useful.

- Friction enables us to walk, without friction it will not be possible for us to walk.
- Vehicles can run only when there is adequate friction between the road and tire.
- Nails and screws hold the board together because of friction.
- The transfer of power from one machine to another is possible because of friction between the belt and the wheels.

Disadvantages of Friction:

- Due to friction, the wear and tear of the machine parts increases.
- Work is done to overcome friction. This results in large amount of energy loss.
- Heat generated because of friction may damage the machinery.

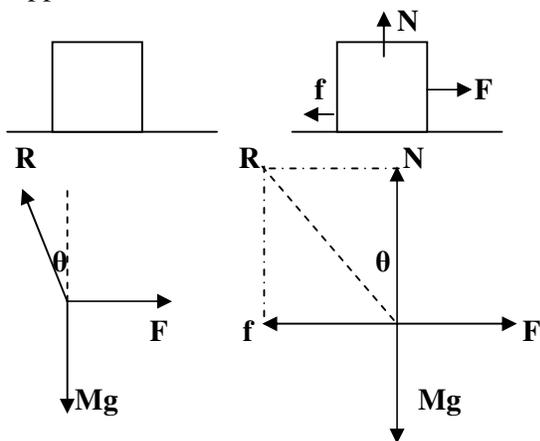
Methods of reducing Friction:

Following are the methods to minimize friction.

- By polishing the surfaces the friction can be reduced.
- By using the lubricants in the machine parts the friction can be reduced.
- By using the ball bearing the kinetic friction is replaced by rolling friction which is considerably less than the kinetic friction.
- Materials of low coefficient of friction can be used.

Angle of Friction:

Consider a block of mass 'm' placed on a horizontal surface. When no horizontal force is applied on the block the contact force 'c' acts along the vertical. On applying a horizontal force 'F' the contact force deviates from the vertical so as to balance both the weight of the block and the applied force F. Thus the angle between the contact force and the vertical increases with the magnitude of the applied force F and reaches a maximum when the motion is impending.



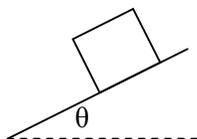
From the figure,

$$N = R \cos \phi \text{ and } f = R \sin \phi$$

$$\mu = f / N = \frac{R \sin \phi}{R \cos \phi} \quad \text{Therefore, } \mu = \tan \phi$$

Angle of Repose:

If a block is kept on an inclined plane and inclination is gradually increased, the block will not immediately slide down. It requires certain minimum inclination to slide.



The minimum inclination at which the block starts sliding down is called **angle of repose**.

FRICION

Frictional force act along the surface between two bodies whenever one moves or tries to move over the other and in a direction so as to oppose relative motion on the surfaces.

Sliding friction
The force of friction which comes into play when one body slides or tends to slide on the surface of another body is known as sliding friction.

Rolling friction
The force of friction which comes to play when one body rolls or tends to roll on the surface of another body is known as rolling friction.

Types of sliding friction

- Static friction
- Limiting

Experiment shows that when a body is at rest, the frictional force to be overcome before it moves, called limiting friction, is greater than that which acts once it is moving, and called sliding, kinetic or dynamic friction.

Laws of friction

- The limiting frictional force f is directly proportional to the normal force N exerted by the surface on the body. i.e. $f \propto N$ or $f / N = \text{constant}$
- The dynamic frictional force f^d is directly proportional to the normal force, N , i.e. $f^d \propto N$ or $f^d / N = \text{constant}$ and is reasonably independent of the speed of motion.
- The frictional force does not depend on the area of contact of the surfaces if the normal reaction is constant.

2.3 Questions:

1. What is the direction of frictional force?
2. What is the effect of frictional force on the relative motion between two surfaces?
3. Why do we slip on a muddy road?
4. Mention one factor on which the coefficient of friction depends?
5. Carts with rubber tyres are easier to ply than those with iron tyres. Why?
6. What are lubricants?
7. How is fuel saved by keeping proper air pressure in the tyres of an automobile?
8. Arrange the coefficient of friction (μ_k , μ_r & μ_s) in the increasing order of magnitude?
9. Why is it difficult to climb up a greasy pole?
10. Automobile tyres have generally irregular projection over their surfaces. Why?
11. What is limiting friction?
12. Which frictional force is least?
13. A body of mass m is moving with constant velocity v on a horizontal surface, what is the force on the table.
14. Which friction is self-adjusting?
15. A block of mass 2 kg is placed on a table. If horizontal force of 10 N is applied and the body does not move, what is the value of frictional force acting on the body?

ANSWERS

2.3 FRICTION

1. Direction of frictional force is always opposite to the motion of the body.
2. It always reduces the relative motion of the body.
3. Due to lack of frictional force.
4. It depends on the nature of surface.
5. Due to less friction.
6. Materials which reduce the frictional force are called lubricants.
7. When tyres are filled with air properly, torque required is less to turn and frictional force is less hence fuel is saved.
8. $\mu_s > \mu_k > \mu_r$
9. Grease reduces the frictional force and are called lubricants.
10. To provide enough friction for stability.
11. Maximum value of static friction is called limiting friction.
12. Rolling friction.
13. Force on the table is mg .
14. Static friction.
15. Frictional force is 10 N