ME3491 THEORY OF MACHINES

UNIT III NOTES

3.Friction

The opposing force, which acts in the opposite direction of the movement of the upper block, is called the force of friction or simply friction

3.1.1 Types of Friction

Friction is of the following two types

1. **Static friction**. It is the friction, experienced by a body, when at rest.

2. **Dynamic friction**. It is the friction, experienced by a body, when in motion. The dynamic friction is also called kinetic friction and is less than the static friction. It is of the following three types :

(a) Sliding friction. It is the friction, experienced by a body, when it slides over another body.

(b) Rolling friction. It is the friction, experienced between the surfaces which has balls or rollers interposed between them.

(c) Pivot friction. It is the friction, experienced by a body, due to the motion of rotation as in case of foot step bearings.

The friction may further be classified as :

1. Friction between unlubricated surfaces, and
2. Friction between lubricated surfaces.

3.1.2. Friction Between Unlubricated Surfaces

The friction experienced between two dry and unlubricated surfaces in contact is known as dry or solid friction. It is due to the surface roughness.

3.1.3 Friction Between Lubricated Surfaces

When lubricant (i.e. oil or grease) is applied between two surfaces in contact, then the friction may be classified into the following two types depending upon the thickness of layer of a lubricant.

1. **Boundary friction** (or greasy friction or non-viscous friction).

   It is the friction, experienced between the rubbing surfaces, when the surfaces have a very thin layer of lubricant. The thickness of this very thin layer is of the molecular dimension. In this type of friction, a thin layer of lubricant forms a bond between the two rubbing surfaces. The lubricant is absorbed on the surfaces and forms a thin film. This thin film of the lubricant results in less friction between them. The boundary friction follows the laws of solid friction.

2.Fluid friction (or film friction or viscous friction).

It is the friction, experienced between the rubbing surfaces, when the surfaces have a thick layer of the lubrhicant. In this case, the actual surfaces do not come in contact and thus do not rub against each other. It is thus obvious that fluid friction is not due to the surfaces in contact but it is due to the viscosity and oiliness of the lubricant.

The oiliness property of a lubricant may be clearly understood by considering two lubricants of equal viscosities and at equal temperatures. When these lubricants are smeared on two different surfaces, it is found that the force of friction with one lubricant is different than that of the other. This difference is due to the property of the lubricant known as oiliness. The lubricant which gives

lower force of friction is said to have greater oiliness.

3.2 Limiting Friction

Consider that a body A of weight W is lying on a rough horizontal body B as shown in Figure a. In this position, the body A is in equilibrium under the action of its own weight W, and the normal reaction RN (equal to W) of B on A.

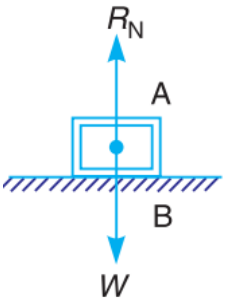


Figure a

Now if a small horizontal force P1 is applied to the body A acting through its centre of gravity as shown in Figure b , it does not move because of the frictional force which prevents the motion. This shows that the applied force P1 is exactly balanced by the force of friction F1 acting in the opposite direction.

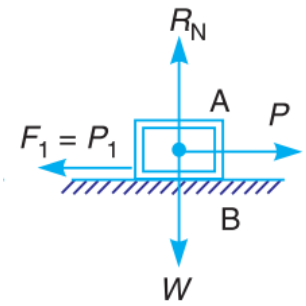


Figure b

If we now increase the applied force to P2 as shown in Figure c, it is still found to be in equilibrium. This means that the force of friction has also increased to a value F2 = P2. Thus every time the effort is increased the force of friction also increases, so as to become exactly equal to the applied force.

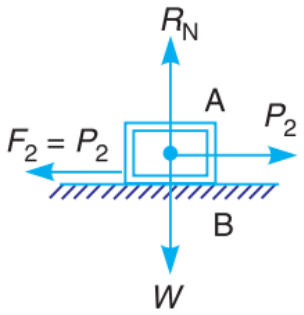


Figure c

There is, however, a limit beyond which the force of friction cannot increase as shown in Figure d

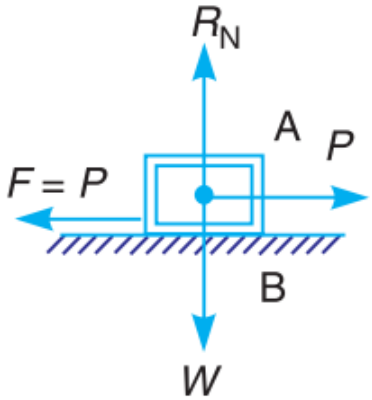


Figure d

After this, any increase in the applied effort will not lead to any further increase in the force of friction, as shown in Figure e. Thus the body A begins to move in

the direction of the applied force. This maximum value of frictional force, which comes into play, when a body just begins to slide over the surface of the other body, is known as limiting force of friction or simply limiting friction. It may be noted that when the applied force is less than the limiting friction, the body remains at rest, and the friction into play is called static friction which may have any value between zero and limiting friction.

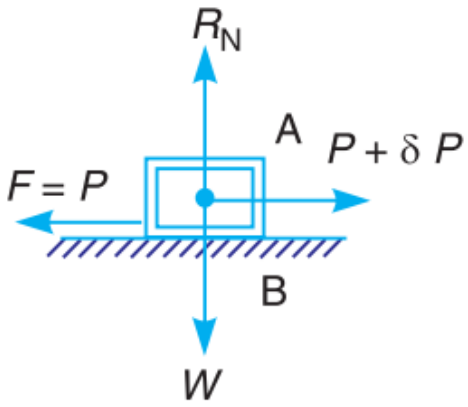


Figure e

3.3. Laws of Static Friction

Following are the laws of static friction :

1. The force of friction always acts in a direction, opposite to that in which the body tends to move.

2. The magnitude of the force of friction is exactly equal to the force, which tends the body to move. 3. The magnitude of the limiting friction (F) bears a constant ratio to the normal reaction (RN) between the two surfaces.

4. The force of friction is independent of the area of contact, between the two

surfaces.

5. The force of friction depends upon the roughness of the surfaces

3.4. Laws of Kinetic or Dynamic Friction

Following are the laws of kinetic or dynamic friction :

1. The force of friction always acts in a direction, opposite to that in which the body is moving.

2. The magnitude of the kinetic friction bears a constant ratio to the normal reaction between the two surfaces. But this ratio is slightly less than that in case of limiting friction.

3. For moderate speeds, the force of friction remains constant. But it decreases slightly with the increase of speed.

3.5. Laws of Solid Friction

Following are the laws of solid friction :

1. The force of friction is directly proportional to the normal load between the surfaces.

2. The force of friction is independent of the area of the contact surface for a given normal load.

3. The force of friction depends upon the material of which the contact surfaces are made.

4. The force of friction is independent of the velocity of sliding of one body relative to the other body

3.6 Laws of Fluid Friction

Following are the laws of fluid friction :

1. The force of friction is almost independent of the load.

2. The force of friction reduces with the increase of the temperature of the lubricant.

3. The force of friction is independent of the substances of the bearing surfaces.

4. The force of friction is different for different lubricants

3.7.Coefficient of Friction

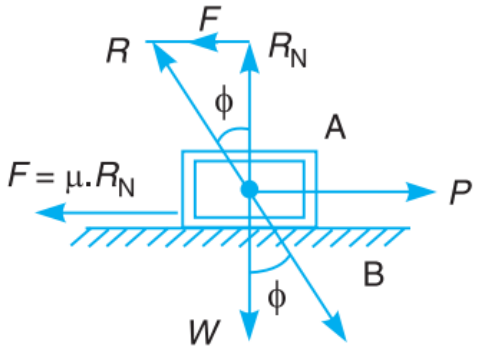
It is defined as the ratio of the limiting friction (F) to the normal reaction (RN) between the two bodies. It is generally denoted by μ.

Mathematically, coefficient of friction, $\mu = F/RN$.

3.8. Limiting Angle of Friction

Consider that a body A of weight (W) is resting on a horizontal plane B, as shown in Figure below. If a horizontal force P is applied to the body, no relative motion will take place until the applied force P is equal to the force of friction F, acting opposite to the direction of motion. The magnitude of this force of friction is $F = \mu.W = \mu.RN$, where RN is the normal reaction.

In the limiting case, when the motion just begins, the body will be in equilibrium under the action of the following three forces : 1. Weight of the body (W), 2. Applied horizontal force (P), and 3. Reaction (R) between the body A and the plane B.



The reaction R must, therefore, be equal and opposite to the resultant of W and P and will be inclined at an angle φ to the normal reaction RN. This angle φ is known as the limiting angle of friction. It may be defined as the angle which the resultant reaction R makes with the normal reaction RN.

3.9 Angle of Repose

Consider that a body A of weight (W) is resting on an inclined plane B, as shown in Figure below. If the angle of inclination α of the plane to the horizontal is such that the body begins to move down the plane, then the angle α is called the angle of repose.