Lecture 3/static and Dynamic

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Friction

Chapter -3

Friction

General Concepts:

***Static friction*: between two bodies is the tangential force that opposes the sliding of one body relative to the other.**

***Friction forces*: Tangential forces generated between contacting surfaces.**

***Limiting friction F':* is the maximum value of static friction that occurs when motion is impending.**

Kinetic friction **: is the tangential force between two bodies after motion begins. It is less than static friction.**

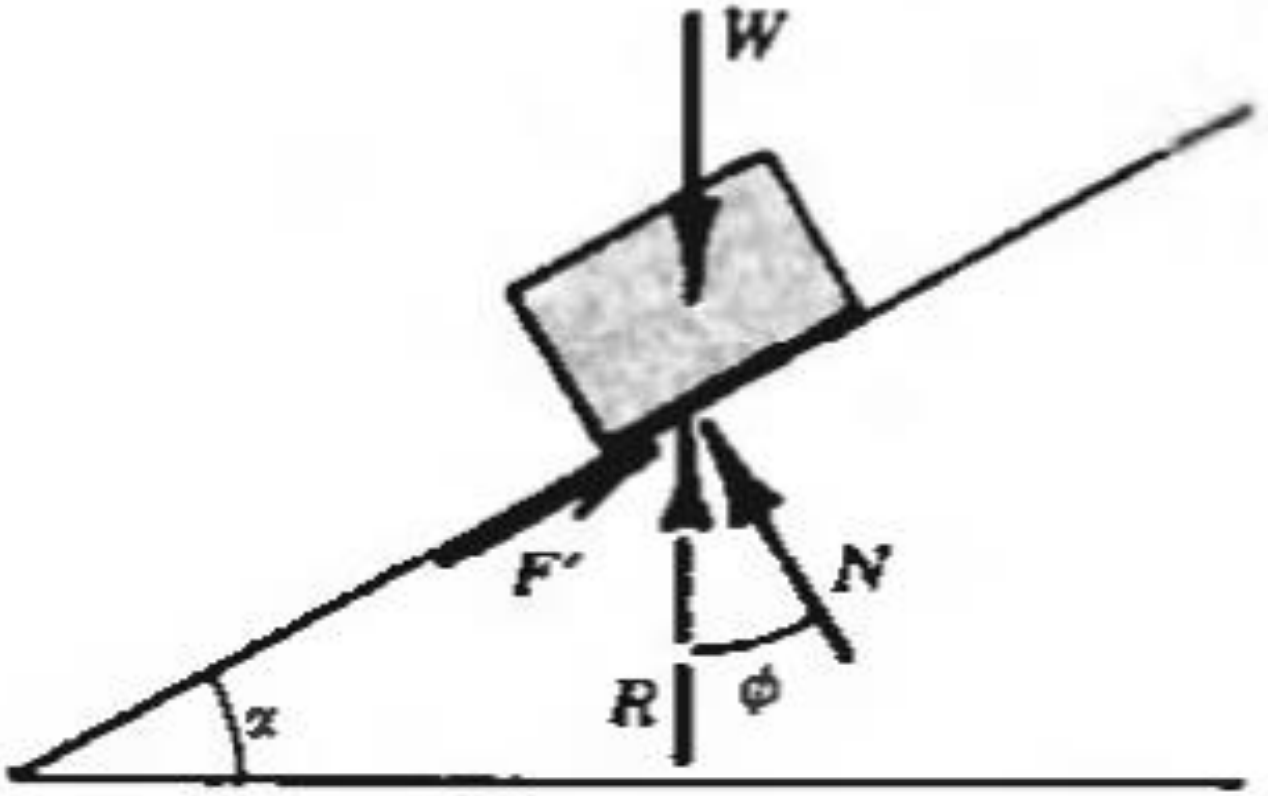
Angle of friction **: is the angle between the action line of the total reaction of one body on another and the normal to the common tangent between the bodies when motion is impending .**

Coefficient of static friction :is the ratio of the limiting friction F' to the normal force N:

$$\mu = \frac{F'}{N}$$

Coefficient of kinetic friction :is the ratio of the kinetic friction force to the normal force .

Angle of respose α : is the angle to which an inclined plane may be raised before an object resting on it will move under the action of the force of gravity and the reaction of the plane. This state of impending motion is shown in Figure:


W
F'
N
R
φ
α

The resultant **R** of **F'** and **N** is shown acting opposite, but equal in magnitude to the force of gravity **W = M g** .Although motion impends ,the body is still in equilibrium. By trigonometry , $\alpha = tan\,\emptyset$

And hence :

$$\mu = \tan \alpha$$

Types of Friction:

a. Dry Friction

b. Fluid Friction

c. Internal Friction

a. Dry Friction:(coulomb friction):

occurs when the lubricated surfaces of two solids are in contact under a condition of sliding or a tendency to slide. A friction force tangent to the surfaces of contact occurs both during the interval leading up to impending slippage and while slippage take place. The direction of this friction force always opposes the motion or impending motion.

b. Fluid Friction

occurs when adjacent layers in a fluid (liquid or gas) are moving at different velocities .this motion causes frictional forces between fluid elements ,and these forces depend on the relative velocity between layers.

When there is no relative velocity , there is no fluid friction .

Fluid friction depends not only on the velocity gradients within the fluid of fluid mechanics, but also on the viscosity of the fluid ,which is a measure of its resistance to shearing action between fluid layers ..

c. Internal Friction

occurs in all solid materials which are subjected to cyclical loading . For highly elastic materials the recovery from deformation occurs with very little loss of energy due to internal friction .For materials which have low limits of elasticity and which undergo appreciable plastic deformation during loading ,a considerable amount of internal friction may accompany this deformation. The mechanism of internal friction is associated with the action of shear deformation .

Laws of friction:

1.The coefficient of friction is independent of the normal force.

Then:

The limiting friction and kinetic friction are proportional to the normal force

2. The coefficient of friction is

independent of the area of contact.

3.The coefficient of kinetic friction is less than that of static friction.

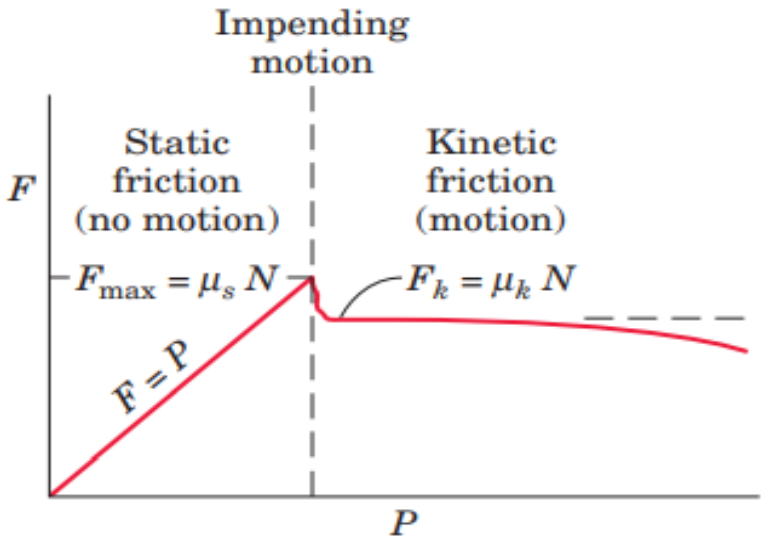
4.At low speeds, friction is independent of the speed. At higher speeds, a decrease in friction has been noticed.

5.hold the body in equilibrium .The static frictional force is never greater than that necessary to hold the body in equilibrium. One may use limiting friction:

$$F' = \mu N .$$

Static Friction

The region in Fig. 6/1*d* up to the point of slippage or impending motion is called the range of *static friction*, and in this range the value of the friction force is determined by the *equations of equilibrium*. This friction force may have any value from zero up to and including the maximum value. For a given pair of mating surfaces the experiment shows that this maximum value of static friction F_{max} is proportional to the normal force N. Thus, we may write


Impending
motion
Static
friction
(no motion)
Kinetic
friction
(motion)
F
$F_{max} = \mu_s N$
$F_k = \mu_k N$
F = P
P

(*d*)

Static Friction :

$$F_{max.} = \mu_s N \quad \ldots\ldots\ldots\ldots 3\text{-}1$$

where μs is the proportionality constant, called the coefficient of static friction. Be aware that Eq. 3-1 describes only the limiting or maximum value of the static friction force and not any lesser value. Thus, the equation applies only to cases where motion is impending with the friction force at its peak value. For a condition of static equilibrium when motion is not impending, the static friction force is:

$$F < \mu_s N$$

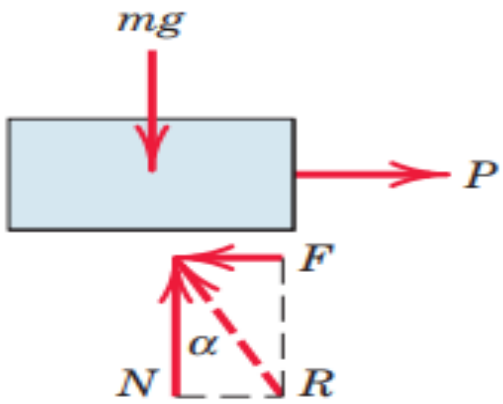
Kinetic Friction:

After slippage occurs, a condition of kinetic friction accompanies the ensuing motion. Kinetic friction force is usually somewhat less than the maximum static friction force. The kinetic friction force F_k is also proportional to the normal force. Thus,

$$F_k = \mu_k N \quad \text{.....3-2}$$

where μ_k is the coefficient of kinetic friction. It follows that μ_k is generally less than μs. As the velocity of the block increases, the kinetic friction decreases somewhat, and at high velocities, this decrease may be significant. Coefficients of friction depend greatly on the exact condition of the surfaces, as well as on the relative velocity, and are subject to considerable uncertainty.

Friction Angles :



(b)

The direction of the resultant R in Fig. b measured from the direction of N is specified by:

tan α = F/N. When the friction force reaches its limiting static value F_{max}, the angle α reaches a maximum value ∅s.

Thus, tan ∅s = μs

When slippage is occurring, the angle α has a value $\emptyset k$ corresponding to the kinetic friction force. In like manner,

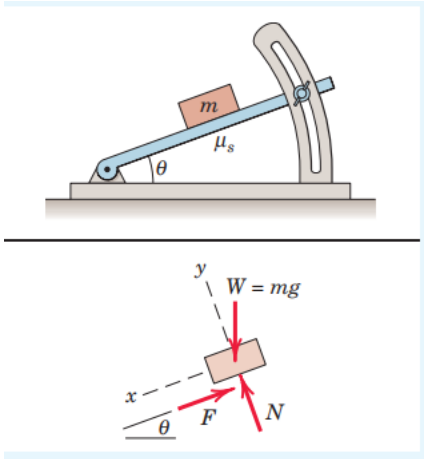
tan ∅k = μk

In practice we often see the expression ,

$$\tan \emptyset = \mu$$

in which the coefficient of friction The angle $\emptyset s$ is called the angle of static friction, and the angle $\emptyset k$ is called the angle of kinetic friction.

***Example 3-1*:Determine the maximum angle θ which the adjustable incline may have with the Horizontal before the block of mass m begins to slip .The coefficient of static friction between the block and the inclined surface is μs.**


m
μ_s
θ
y
W = mg
x
F
N
θ

Solution:

The free-body diagram of the block shows its weight W = mg , the normal force N , and the friction force F exerted by the incline on the block .The friction force acts in the direction to oppose the slipping which would occur if no friction were present. Equilibrium in the x- and –y directions requires :

($\sum Fx = 0$) …⟶..mg sin θ- F = 0 ⟶ F = mg sin θ ……1

($\sum Fy = 0$) …⟶.-mg cos θ+ N= 0 ⟶ N = mg cos θ……2

Dividing eq.1 by eq.2

Gives F/ N = tan θ

Since the maximum angle occurs when $F = F_{max} = \mu s\, N$

,

For impending motion we have

$$\mu s = \tan \theta \, max$$

or $$\theta \, max = \tan^{-1} (\mu s)$$