Dept. of Medical Instrumentations Engineering

First Stage: **Academic Year: 2020-2021**

Subject: Mechanics **Instructor: Assist. Prof. Dr. Saad Alkhfaji**

==========

LECTURE 7:

Friction

Introduction

Tangential forces generated between contacting surfaces are called friction forces and occur to some degree in the interaction between all real surfaces. Whenever a tendency exists for one contacting surface to slide along another surface, the friction forces developed are always in a direction to oppose this tendency.

In some types of machines and processes we want to minimize the retarding effect of friction forces. Examples are bearings of all types, power screws, gears, the flow of fluids in pipes, and the propulsion of aircraft and missiles through the atmosphere. In other situations we wish to maximize the effects of friction, as in brakes, clutches, belt drives, and wedges. Wheeled vehicles depend on friction for both starting and stopping, and ordinary walking depends on friction between the shoe and the ground.

Types of Friction

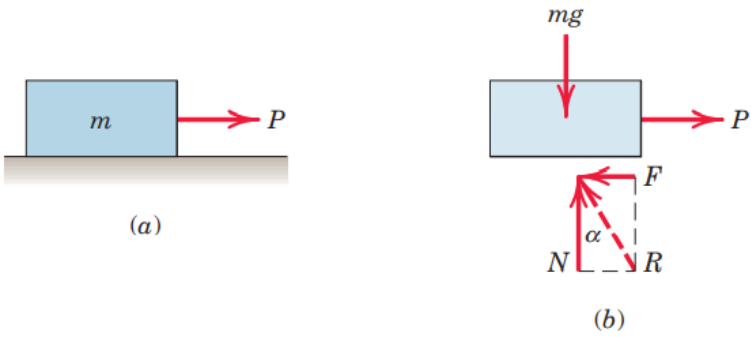
1- Dry Friction. Dry friction occurs when the unlubricated surfaces of two solids are in contact under a condition of sliding or a tendency to slide.

2- Fluid Friction. 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.

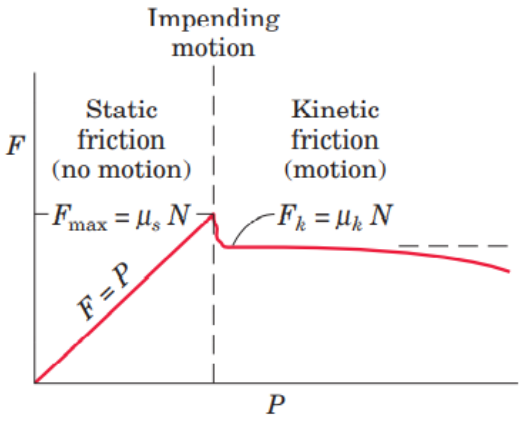
3- Internal Friction. Internal friction occurs in all solid materials which are subjected to cyclical loading. For highly elastic materials the recovery from deformation occurs with very little loss of energy due to internal friction.

Mechanism of Dry Friction

Consider a solid block of mass m resting on a horizontal surface, as shown in Fig. below. We assume that the contacting surfaces have some roughness. The experiment involves the application of a horizontal force P which continuously increases from zero to a value sufficient to move the block and give it an appreciable velocity.



If we perform the experiment and record the friction force F as a function of P, we obtain the relation shown in Fig. below. When P is zero, equilibrium requires that there be no friction force. As P is increased, the friction force must be equal and opposite to P as long as the block does not slip. During this period the block is in equilibrium, and all forces acting on the block must satisfy the equilibrium equations. Finally, we reach a value of P which causes the block to slip and to move in the direction of the applied force.



Static Friction

The region in Fig. above 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. The maximum value of static friction Fmax is proportional to the normal force N. Thus, we may write

$$F_{\max} = \mu_s N$$

where μ_s is the proportionality constant, called the *coefficient of static friction*.

Kinetic Friction

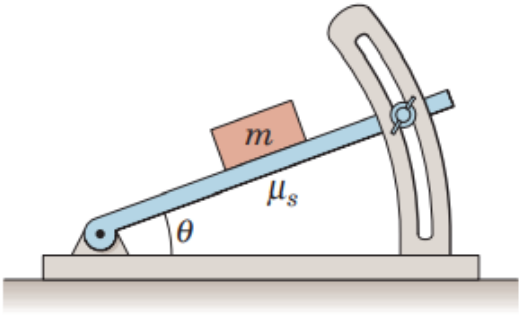
After slippage occurs, a condition of kinetic friction accompanies the ensuing motion. Kinetic friction force is usually somewhat less than the maximum static friction force. The kinetic friction force F_k is also proportional to the normal force. Thus

$$F_k = \mu_k N$$

where μ_k is the *coefficient of kinetic friction*. It follows that μ_k is generally less than μ_s. As the velocity of the block increases, the kinetic friction decreases somewhat, and at high velocities, this decrease may be significant.

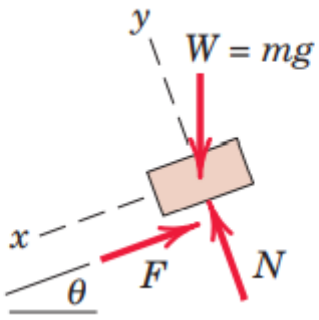
Example 1:

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 μ_s.



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

$[\Sigma F_x = 0]$ $\quad mg \sin\theta - F = 0 \quad F = mg \sin\theta$

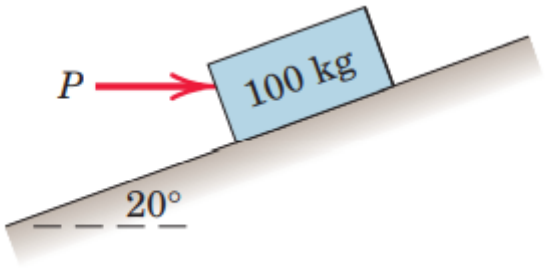
$[\Sigma F_y = 0]$ $\quad -mg \cos\theta + N = 0 \quad N = mg \cos\theta$

Dividing the first equation by the second gives $F/N = \tan\theta$. Since the maximum angle occurs when $F = F_{max} = \mu_s N$, for impending motion we have

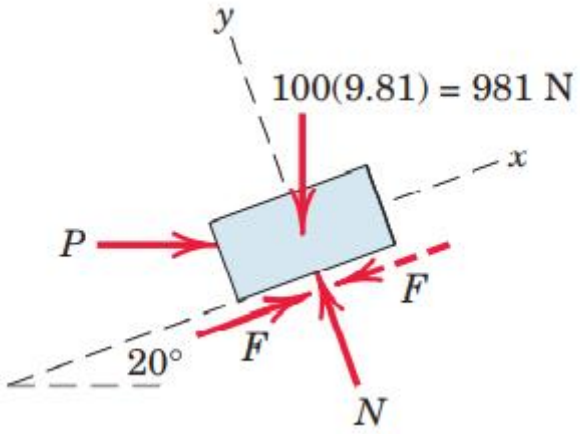
$$\mu_s = \tan\theta_{max} \quad \text{or} \quad \theta_{max} = \tan^{-1}\mu_s \qquad Ans.$$

Example 2:

Determine the magnitude and direction of the friction force acting on the 100-kg block shown if, first, $P = 500$ N and, second, $P = 100$ N. The coefficient of static friction is 0.20, and the coefficient of kinetic friction is 0.17. The forces are applied with the block initially at rest.



Solution:



$[\Sigma F_x = 0]$ $\quad P \cos 20° + F - 981 \sin 20° = 0$

$[\Sigma F_y = 0]$ $\quad N - P \sin 20° - 981 \cos 20° = 0$

Case I. $P = 500$ N
Substitution into the first of the two equations gives

$$F = -134.3 \text{ N}$$

by substituting P = 500 N into the second equation, which gives

N = 1093 N

The maximum static friction force which the surfaces can support is then

$[F_{max} = \mu_s N]$ $\quad F_{max} = 0.20(1093) = 219$ N

Since this force is greater than that required for equilibrium, we conclude that the assumption of equilibrium was correct. The answer is, then,

$F = 134.3$ N down the plane *Ans.*

Case II. $P = 100$ N

Substitution into the two equilibrium equations gives

$$F = 242 \text{ N} \qquad N = 956 \text{ N}$$

But the maximum possible static friction force is

$[F_{max} = \mu_s N]$ $\qquad F_{max} = 0.20(956) = 191.2$ N

It follows that 242 N of friction cannot be supported. Therefore, equilibrium cannot exist, and we obtain the correct value of the friction force by using the kinetic coefficient of friction accompanying the motion down the plane. Hence, the answer is

$[F_k = \mu_k N]$ $\qquad F = 0.17(956) = 162.5$ N up the plane *Ans.*

H.W:

The three flat blocks are positioned on the 30° incline as shown, and a force P parallel to the incline is applied to the middle block. The upper block is prevented from moving by a wire which attaches it to the fixed support. The coefficient of static friction for each of the three pairs of mating surfaces is shown. Determine the maximum value which P may have before any slipping takes place.

