Experiment No. : 06

Title of Experiment : Determination of Coefficient of Friction using Inclined Plane

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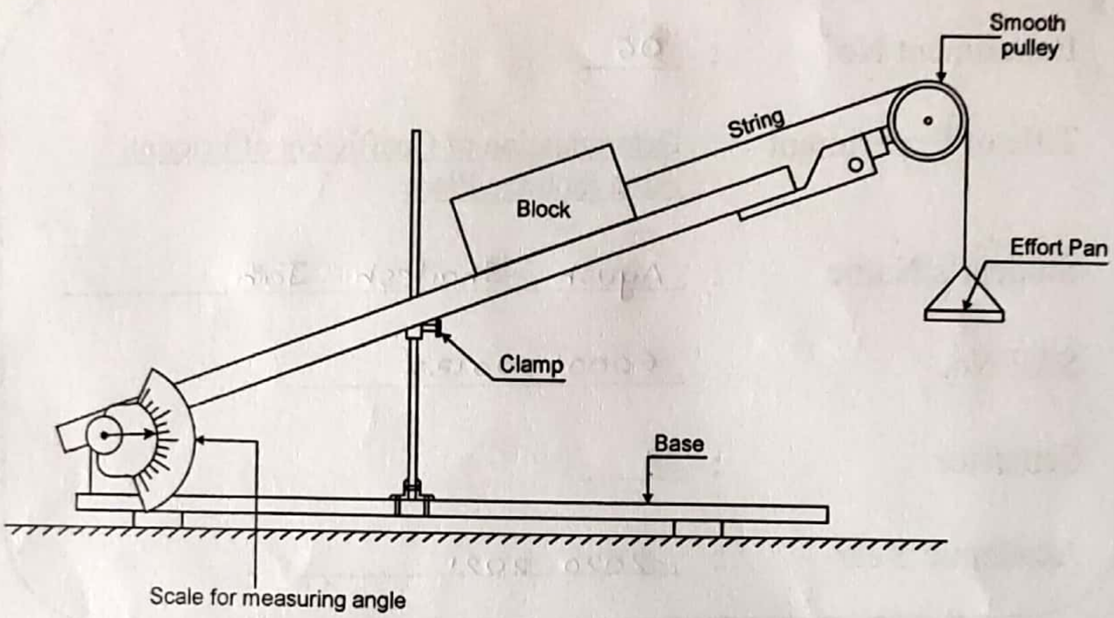
Punctuality	Reading & Understanding	Application	Total	Signature & Date
02	04	04	10	

DJ19FEC104.01	*Illustrate the effect of force and moment and apply the same along with the concept of equilibrium systems with the help of FBD.*
DJ19FEC104.02	*Demonstrate the understanding of Centroid and its significance and locate the same.*
DJ19FEC104.03	*Correlate real life application to specific type of friction and estimate required force to overcome friction.*
DJ19FEC104.04	*Establish relation between velocity and acceleration of a particle and analyze the motion by plotting the relation.*
DJ19FEC104.05	*Analyze general plane motion of rigid bodies using Instantaneous centre.*
DJ19FEC104.06	*Analyze particles in motion using force and acceleration, work-energy and impulse-momentum principles.*

Set-up Diagram



FRICTION PLANE APPARATUS

Experiment No: 06 **Date:** 01/04/2021

Title : **Determination of Coefficient of Friction using Inclined Plane**

Aim: To determine the coefficient of static friction ' μ_s ' between two surfaces by

i. Angle of Repose method

ii. Friction Plane method.

Apparatus :

Friction plane apparatus with glass top and graduated quadrant, weights, box with wooden base, string, effort pan, fractional weights.

Theory :

Friction force is developed whenever there is a motion or tendency of motion of one body with respect to the other body involving rubbing of the surfaces of contact. Friction is therefore a resistance force to sliding between two bodies produced at the common surfaces of contact.

Friction occurs because no surface is perfectly smooth, however flat it may appear. On every surface there are 'microscopic hills and valleys' and due to this the surfaces get interlocked making it difficult for one surface to slide over the other. During static state the friction force developed at the contact surface depends on the magnitude of the disturbing force. When the body is on the verge of motion the contact surface offers maximum frictional force called as 'Limiting Frictional Force'.

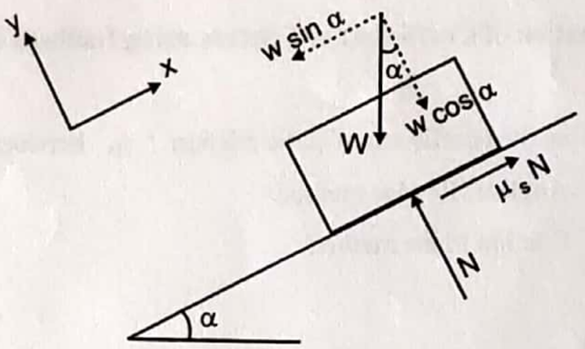
In 1781 the French Physicist Charles de Coulomb found that the limiting frictional force did not depend on the area of contact but depends on the materials involved and the pressure (normal reaction) between them.

Thus frictional force $F \propto N$

or $F = \mu_s N$

Here μ_s is the coefficient of static friction, a term introduced by Coulomb. The value of μ_s lies between 0 and 1 and it depends on both the surfaces of contact.

Angle of Repose Method :



Free Body Diagram

Observation Table:

Surfaces of Contact : wood and Hard board

Sr. No.	Total weight of box W (N)	Inclination of plane α (degrees)	Coefficient of friction $\mu_s = \tan \alpha$
1	4.5	32	0.624
2	6.5	33	0.649
3	8.4	39	0.674
		Mean μ_s=	0.649

Coefficient of static friction 'μ_s' between two surfaces can be found out experimentally by two methods, viz. Angle of Repose method and Friction Plane method.

Angle of Repose Method:

The minimum angle of an inclined plane at which a body kept on it slides down the plane without the application of any external force is known as Angle of Repose. It is denoted by letter α. Angle of repose depends only on the coefficient of static friction μ_s and is independent of the weight of the body. Let us derive the relation between the two.

Let a block of weight W just starts to slide down the inclined plane at a minimum angle α of an inclined plane. Refer F.B.D.

Applying Condition of Equilibrium

$$\Sigma F_x = 0$$

$$\mu_S N - W\sin\alpha = 0 \qquad \text{......... (1)}$$

$$\Sigma F_y = 0$$

$$N - W\cos\alpha = 0 \qquad \text{......... (2)}$$

From equations (1) and (2) we get

$$\mu_S (W\cos\alpha) - W\sin\alpha = 0$$

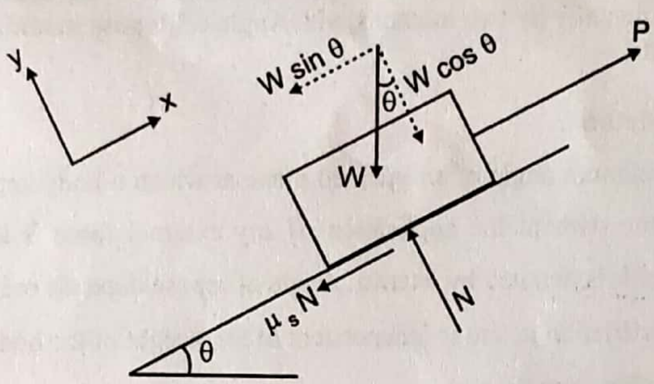
$$\therefore \ \mu_S = \frac{\sin\alpha}{\cos\alpha}$$

Or $\mu_S = \tan\alpha$

Procedure:

1. Initially keep the inclined plane with glass top at horizontal level. Take a box of known weight, note its bottom surface (whether surface is soft wood, or sand paper, or card board etc,) and place the box on the glass surface. Put some known weight in the box.
2. Slowly raise the inclination of the plane till the time when the box starts to slip down the plane.
3. Note the inclination of the plane on the graduated quadrant scale. This is angle of repose α.

Friction Plane Method :



Free Body Diagram

Observation Table:

Surfaces of Contact : Wood and Hard Board

SR. No	θ (degrees)	P (N)	W (N)	Coefficient of friction $\mu_S = \frac{P - W\sin\theta}{W\cos\theta}$
1	20	4.5	4.5	0.7
2	20	5.5	5.5	0.7
3	13	4	4.3	0.72
			Mean μ_s =	0.707

4. Find coefficient of static friction 'μ_s' using $\mu_s = \tan\alpha$
5. Repeat the above steps 1 to 3 by changing the weights in the box for two more sets of observations.

Friction Plane method:

In this method we find the minimum force 'P' required to slide the body of weight W up the inclined plane. Knowing the value of 'P' we relate it to 'μ_s' as below. Refer F.B.D.

Applying Condition of Equilibrium

$$\Sigma F_x = 0$$

$$P - W\sin\theta - \mu_S N = 0 \quad \ldots\ldots\ldots (1)$$

$$\Sigma F_y = 0$$

$$N - W\cos\theta = 0 \quad \ldots\ldots\ldots (2)$$

From equations (1) and (2) we get

$$P - W\sin\theta - \mu_S(W\cos\theta) = 0$$

or $$\mu_S = \frac{P - W\sin\theta}{W\cos\theta}$$

Procedure:

1. Set the inclined plane with glass top at some angle with the horizontal. Note the inclination θ of the plane on the quadrant scale. Take a box of known weight, note its bottom surface (whether surface is soft wood, or sand paper, or card board etc,) and place the box on the glass surface. Put some known weight in the box. Find the total weight W (weight of box + weights in the box)
2. Tie a string to the box and passing the string over a smooth pulley, attach an effort pan to it.
3. Slowly add weights in the effort pan. A stage would come when the effort pan just slides down pulling the box up the plane. Using fractional weights up to a least count of 5 gm, find the least possible weight in the pan that

causes the box to just slide up the plane. Note the weight in the effort pan. This is force 'P'.

4. Repeat the above steps 1 to 3 by changing the weights in the box for two more sets of observations.

Calculations:

Angle of Repose Method

Use $\mu_s = \tan \alpha$

$\mu_s = \tan 33$

$\therefore \mu_s = 0.649$

Friction plane method

Use $\mu_S = \dfrac{P - W\sin\theta}{W\cos\theta}$

$\mu_s = \dfrac{5.5 - 5.5\sin 20}{5.5\cos 20}$

$\mu_s = 0.7$

Result:

For surfaces of Contact : Wood and Hard Board

μ_s by Angle of Repose Method = 0.649

μ_s by Friction Plane Method = 0.707

Precautions:

1. In Angle of Repose method the weights in the box should themselves not slide within the box while the plane is being slowly raised.
2. In Friction plane method the string connecting the box to the effort pan should be parallel to the plane.
3. Oil the pulley at its pin to make it close to being frictionless.