Static and Kinetic Friction

Objective:

1. To find the **coefficient of static friction μ_s**.
2. To find the **coefficient of kinetic friction μ_k**

Theory:

Friction is the force that resists the relative motion of one surface in contact with another. There are two types of friction, **static and kinetic**. When friction acts on an object that is **at rest**, we refer to the frictional force as **static friction**. An object that is in **motion** is subject to **kinetic friction**.

Static friction:

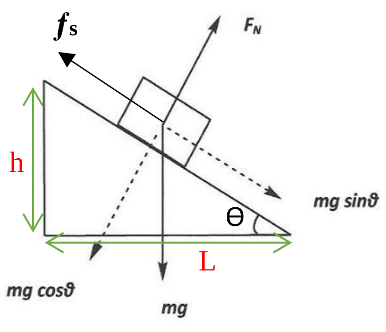
When we want to push a heavy object, static friction is the force that you must overcome to get it moving. The maximum force of static friction $f_{s.max}$ is given by:

$$f_{s,\,max} = \mu_s F_N$$

where,
μ_s is the coefficient of static friction, μ_s is a **dimensionless**.
F_N is the normal force on the body from the surface. (**N**).

A common example of a static friction force is that of a stationary mass on an incline. If the angle at which the mass begins to slide is known, we can determine μ_s. Since if we are interested in the instant at which movement begins, we are dealing with an object in equilibrium. Thus, the **resultant force** in both the x and y directions must be **zero**. Analysis of the forces in the **x-direction**:

$$f_s = mg \sin\theta$$



Following a similar procedure for the **y-direction**:

$$F_N = mg \cos\theta$$

However, we know that at the instant that the mass begins to move:

$$f_s = f_{s,\,max} = \mu_s F_N$$

$$mg \sin\theta = \mu_s mg \cos\theta$$

$$\boxed{\mu_s = \tan\theta = h/L}$$

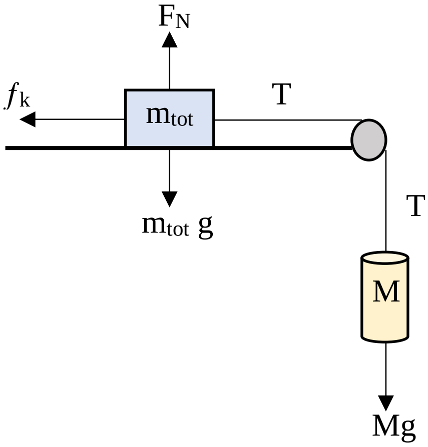
Note that μ_s **depends** on the object and the surface it is laying upon.

Kinetic friction:

Once the force applied on a mass exceeds $\boldsymbol{f}_{\mathbf{s,\,max}}$ and the mass begins to move, a kinetic friction force $\boldsymbol{f}_{\mathbf{k}}$ exists. Kinetic friction coefficients $\boldsymbol{\mu}_{\mathbf{k}}$ are generally **less than** static friction coefficients $\boldsymbol{\mu}_{\mathbf{s}}$, which is the reason that it is much easier to keep a heavy object in motion than it is to start it in motion. The magnitude of the kinetic frictional force is given as follows:

$$f_k = \mu_k F_N$$

In Figure, when the mass M falls, the block m_{tot} slides on the horizontal surface. If the mass M is chosen so that its weight just balances the friction force, then the masses **move at constant speed**. When applying newton's law to the system:



$$\Sigma F = 0$$

For mass $\boldsymbol{m_{tot}}$: $\mathbf{T} = f_k = \mu_k F_N = \boldsymbol{\mu_k m_{tot} g}$

For mass $\boldsymbol{M}$: $\mathbf{T} = Mg$

Therefore, $Mg = \mu_k m_{tot} g$

$$M = \mu_k m_{tot}$$

$$\boxed{M = \mu_k m + \mu_k m_0}$$

Where,

$\mathbf{m_{tot} = m + m_0}$

M is the hanged mass **(g)**

$\mathbf{m_0}$ is the block's mass **(g)**

m are the masses added over the block $\mathbf{m_0}$ **(g)**

$\boldsymbol{\mu}_{\mathbf{k}}$ is the coefficient of kinetic friction, $\boldsymbol{\mu}_{\mathbf{k}}$ is a **dimensionless**.

Then $\boldsymbol{\mu}_{\mathbf{k}}$ and $\mathbf{m_0}$ are given by:

$$\boxed{\mu_k = \text{slope}}$$

$$\boxed{m_0 = \frac{V.I}{\mu_k}}$$

<u>Apparatus</u>:

Static friction		Kinetic friction		
Inclined plane	Block	Table	Block	Small pulley
Support		String	Holder	Masses

Procedure:

- **Static friction:**

1. Measure the high of support **h.**
2. Set up the inclined plane so that the support is the farthest possible point from the pivot. Place the block on the inclined plane with the wooden side down.
3. **Slowly** move the support inward. Keep moving the support inward until the **block starts to slide**.
4. Measure that distance **L** between the angle and the support and find the value of μ_s.
5. Return the support to its original position and repeat the above steps.
6. Find the average value of μ_s.

- **kinetic friction:**

1. Measure the block's mass m_0 and the mass of the holder M_1 by using the **mass balance.**
2. Attach the pulley to the surface keeping the surface horizontal. Set the block m_0 on the surface. Hang a second mass **M** at the end of a string passing over the pulley.
3. Increase M until it causes the system to move with **constant speed**.
4. Add each time **50 g** on top of the block m_0 and add masses to the hanged weight till the block starts moving.
5. Repeat the steps and tabulate the results.
6. Graph the relation between the mass **m** on the **x-axis** and the mass **M** on the **y-axis** and **calculate the slope.**
7. Use the graph to calculate the **coefficient of kinetic friction** μ_k and the block's mass m_0.