NEW ZEALAND
MARITIME SCHOOL

STCW 1978 III/2
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MECHANICAL TECHNOLOGY 1

COURSE CODE: 942. 594

ELEMENT 5: FRICTION

Chapter 7.

Friction and Sliding Friction.

7.0 Introduction

This element deals with the effects of friction, when one rigid body slides or tends to slide over another rigid body. These principals are then applied to the solution of the practical problems.

By the end of this module the student will be able to,

- State the laws of dry friction
- Define the terms static friction, sliding friction, normal reaction, plane reaction, friction angle and the limiting force.
- Discuss the forces involved when a body is stationary or sliding at a uniform speed on a plane inclined to the horizontal.
- Solving problems involved in holding, or causing a body to ascend or descend a plane at a uniform speed by means of either force acting parallel with the plane, acting horizontally, and acting at any angle or the least force.

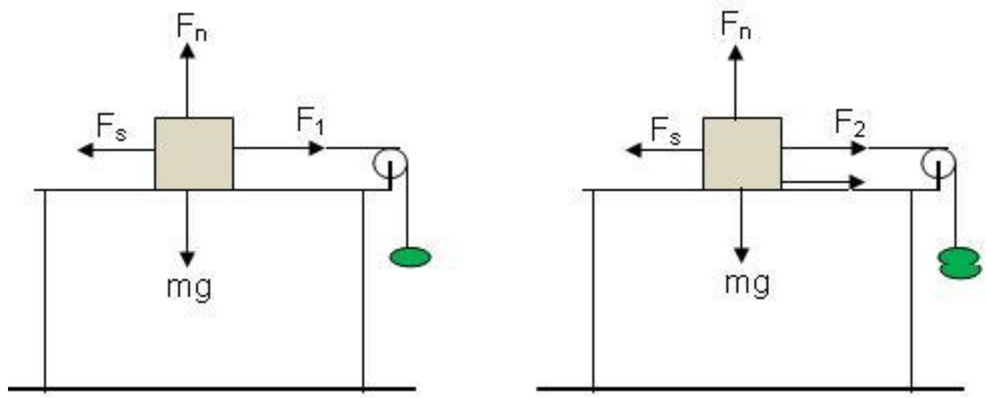
7.1 Defining Friction

You already have a good idea about Force. Friction is what stops that force.. For example, if you're pushing a rock up a hill, there is something that makes that more difficult than pushing that same rock downhill. Well, that FORCE is friction and it is caused by both gravity and the resistance of the material that the object is being pushed along. The gravity, as you well know multiplied by the mass of the object gives its weight. This weight, in terms of friction, is called the normal force or F_N. The resistance of the material is called the coefficient of friction or ***Mu.*** There are two different types of coefficients of friction, static (***Mu_s***) and kinetic ***(Mu_k)***.

If you're sliding a box it will require a force greater than its static coefficient of friction because you need to get the box moving. After the box starts to move it requires a certain force greater than the kinetic coefficient to maintain motion.

When you tend to move an object along a surface, up to certain quantum force, the object does not move. This is because the object tends to be static and tries to oppose any force that is

trying to disturb its static condition. The opposing force is called ***static friction***. It is denoted as F_s. The static friction is so common that the general term friction refers to static friction.



Look at the above diagram. An object of mass ***"m"*** is placed on a table and a string is attached to it which passes through a pulley in such a way that weights can be hung vertically. With a little weight, which tends to slide the object, the static friction F_s exerted by the table on the object is more than the force F_1 that is applied to the object due to the weight supported by the string.

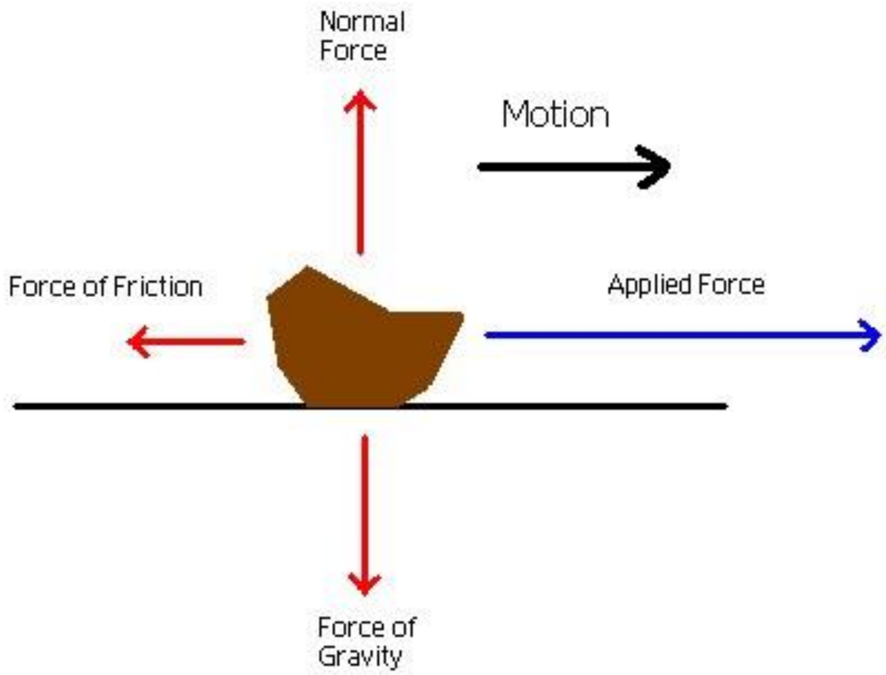
With gradual increase of weights on the string, at one stage, the object just starts sliding. At this condition, the force F_2 applied on the object just balances the static friction F_s.

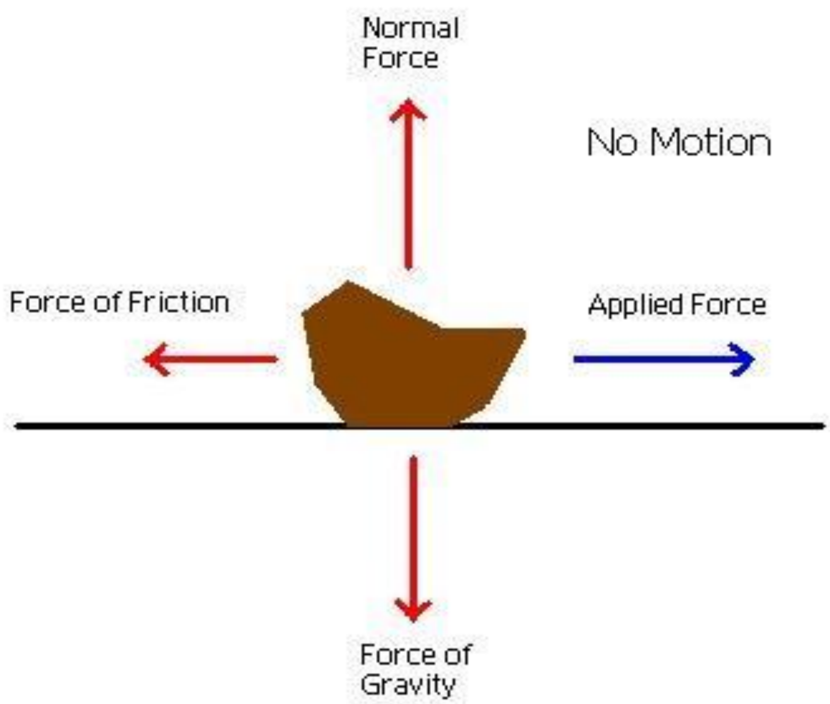
The limiting value of the force to at which the metal block starts is equal to the resistive force offered by the metal block under static condition. Hence that resistive force is called static friction.
The force of sliding friction is directly proportional to the load acting in the direction normal to the surface. ***In a particular case (as shown in the above diagram), if the surface on which the object slides is horizontal, then the normal force equals the weight of the object.***

7.2 Friction

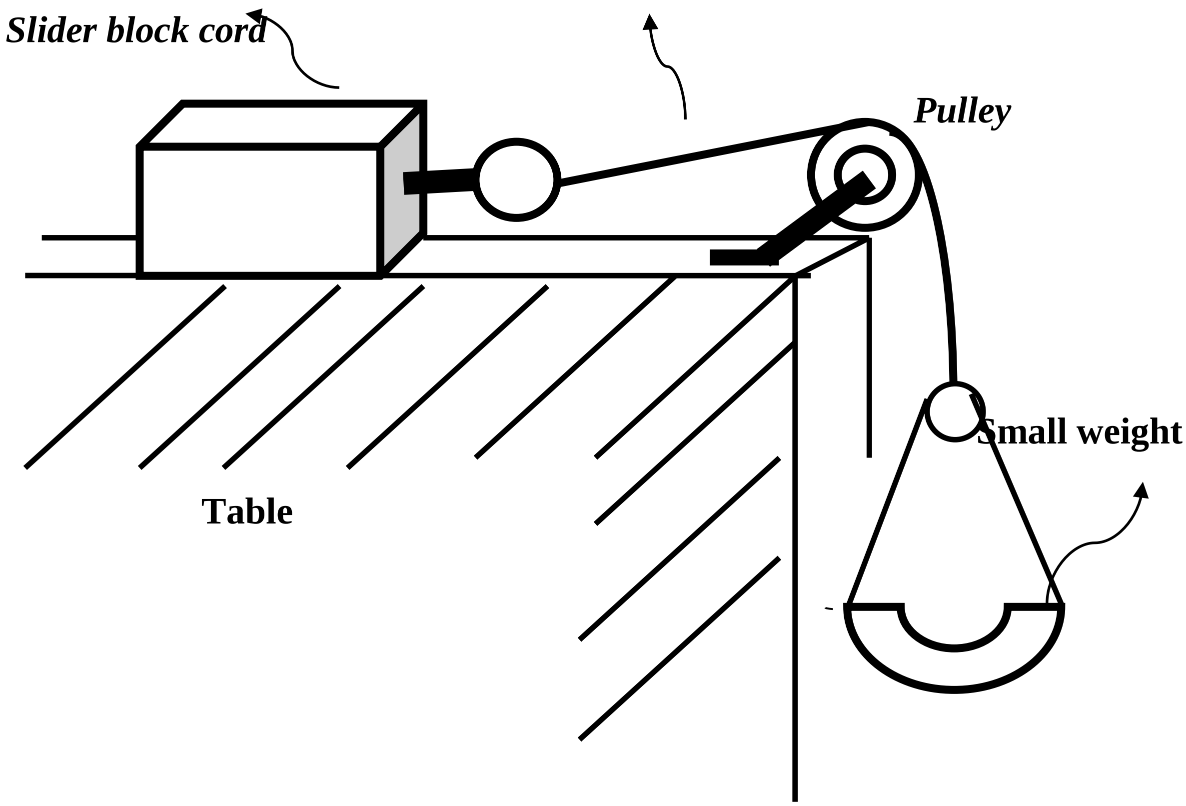
Friction is a force that is created whenever two surfaces move or try to move across each other.

1. **Friction always opposes the motion or attempted motion of one surface across another surface.**
2. **Friction is dependent on the texture of both surfaces and their sizes.**
3. **Friction is also dependent on the amount of contact force pushing the two surfaces together (normal force)**
4. **Friction is proportional to the perpendicular force (with the sliding plane) between the surfaces.**
5. **It is dependent of the speed of sliding at low speeds.**
6. **It opposes motion**.


Normal
Force
Motion
Force of Friction
Applied Force
Force of
Gravity


Normal
Force
No Motion
Force of Friction
Applied Force
Force of
Gravity

Experiment to determine the magnitude of a frictional force



The above shows the equipment that can be used to determine the magnitude of the frictional force of a wooden block. Note the small weight is increased gradually.

7.3 Coefficient of friction **(- pronounced *mu*)**

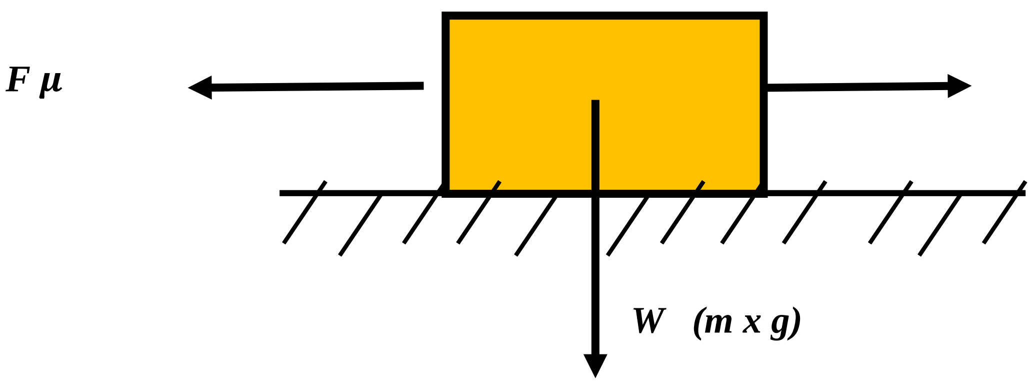


Fig. 3.

In Fig 3 shows a block, with a weight of ***W***newton, resting on a sliding plane. The pulling force for motion, ***F*** must be equal to the frictional force, ***F μ*,**(i.e. the resistance against motion due to friction) to obtain motion.

Coefficient of friction, $\boldsymbol{\mu} = \dfrac{\textbf{friction force}}{\textbf{perpendicular force to the sliding plane}}$ $\quad \boldsymbol{\mu} = \dfrac{F\,\mu}{W}$

And thus: $\quad = \boldsymbol{\mu} \times \boldsymbol{W}$

And thus**:** $\quad \boldsymbol{F} = \mathbf{F}\,\boldsymbol{\mu} = \boldsymbol{\mu} \times \boldsymbol{W}$

From the above we can conclude that:

F = applied force required for motion in new tons.

F μ = frictional force in newton

μ **= coefficient of friction (note there is no unit).**

***W* = perpendicular force to the sliding plane in newton.**

And ***W***= **m** x **g** where

M = mass of object in kg

g = gravitational acceleration of **9.81 m/s^2**

Example: (1)

A block of metal, with a mass of 2 kg, lies on a horizontal metallic surface. A horizontal force of 5 N is required to move the block and a horizontal force of 4 N is required to keep the block in motion.

Calculate:

(a) the coefficient of friction,

(b) the coefficient of sliding friction.

Solution:

(a) Coefficient of static friction = $\dfrac{\textbf{frictional force}}{\textbf{perpendicular force}}$

$$\boldsymbol{\mu} = \frac{\mathbf{5}}{\mathbf{2 \times 9.81}}$$

$$= \mathbf{0.2548}\ \textbf{Ans (i)}$$

(b) **Coefficient of kinetic friction =** $\frac{\textbf{frictional force}}{\textbf{normal reaction}}$

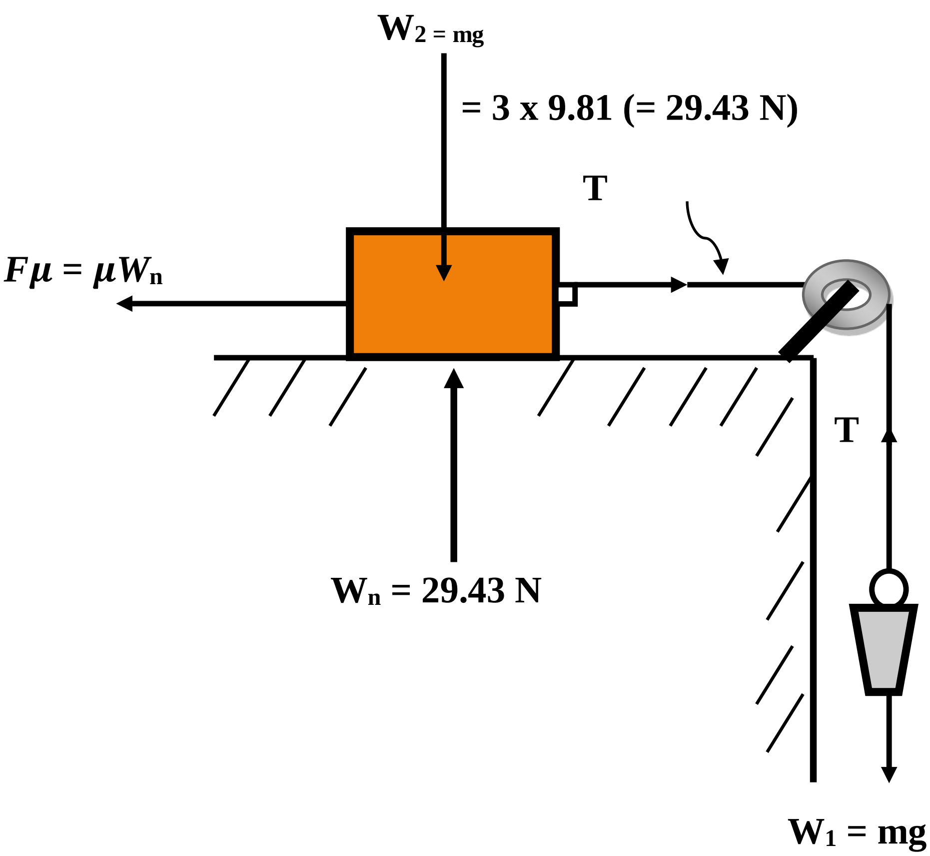
$$\mu = \frac{4}{2 \times 9.81}$$

$$= \textbf{0,2 Ans. (ii)}$$

Example (2)

In a physics lab experiment, two weights of 3 kg and 7kg are attached as shown. When the system is set in motion, an acceleration of 6 m/s^2 is measured for the 7 kg weight. Assuming no mass for the cord and no inertia for the pulley, Calculate,

(1) ***The coefficient of friction between the 3kg weight and the horizontal surface,***
(2) ***And the tension in the cord.***



= 7 x 9,81 = 68.67 N

Solution :

Consider the horizontal motion

$$F\mu = \mu W_n$$

$$= 29.43\,\mu$$

Resultant horizontal force is

$$T - \mu = T - 29.43\,\mu$$

Apply $F = ma$

Where $F = T - 29.43\,\mu$

$M = 3\ kg$ *and* $a = 6\ m/s^2$

Then $F = ma$

$$T - 29.43\,\mu = 3 \times 6\ (= 18)$$

$$\mu = \frac{T-18}{29.43} \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

Now consider vertical motion.

Resultant vertical force is then;

$$W_1 - T = 68.67 - T$$

Applying $F = ma$

Where $F = 68.67 - T$

$m = 7\ kg$ *and* $a = 6\ m/s^2$

Then : $F = ma$

$$68.67 - T = 7 \times 6$$

$$T = 68.67 - 42$$

$$\therefore\ T = 26.67\ N \text{ Ans (ii)}$$

Now to substitute T = 26.67 into equation (i)

$$\mu = \frac{26.67 - 18}{29.43}$$

$$= \frac{8.67}{29.43}$$

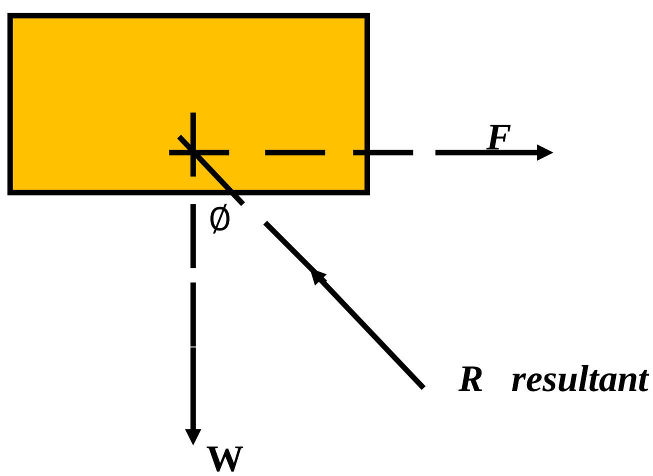
$$\therefore \mu = 0.29 \quad \textit{Ans (i)}$$

In conclusion the tension in the cord is ***26.67*** N and the coefficient of friction between the 3 kg weight and the horizontal surface is ***0.29***

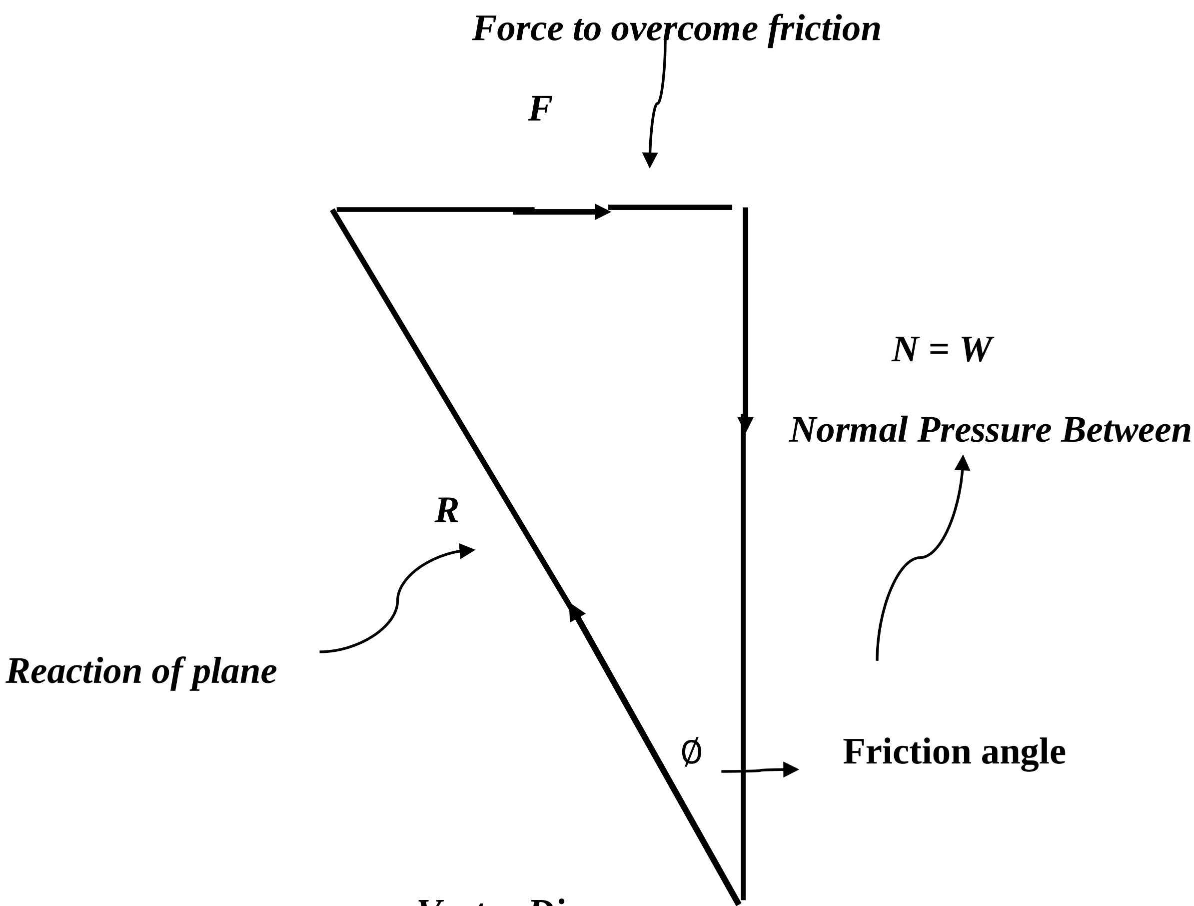
7.4 Friction on a horizontal Plane

The following drawing or illustration shows the forces acting on a body of weight W when a force is applied horizontally to overcome friction on a horizontal plane. Note the reaction of the plane when the body is at rest the plane applies a vertical upward force equal to the magnitude of W to support the weight, but when the body is moving the unseen frictional resisting force comes into action at the surface of the plane;

Thus we say ***R*** is the resultant of these two and swings over in the direction which opposes motion. The magnitude of the angle ∅ between ***R*** and ***N*** depends upon the magnitude of the force required to overcome friction, it is therefore termed the ***Friction angle***



Space Diagram.



Vector Diagram:

From the vector diagram, $\tan \emptyset = \frac{F}{N}$

Also, as stated above, $\boldsymbol{\mu} = \frac{F}{N}$

Therefore, $\quad$ **tan** $\emptyset = \boldsymbol{\mu}$

Stating this in words***, the tangent of the friction angle is equal to the coefficient of friction.***

Example :

If a block of wood weighing 28 newtons requires a horizontal force of 9.8 newtons to pull it along a horizontal plane,

(1) ***What is the coefficient of friction between the block and plane?***
(2) ***And if the block is moved a distance of 5 meters, what is the work done?***

Solution:

Normal pressure between surfaces = weight of block (28 N)

Force to overcome friction, $\boldsymbol{\mu} = \frac{F}{n}$

$= \frac{9.8}{28}$ **= 0.35 Ans (i)**

Work done = force applied x distance moved

= 9.8 [N] x 5 [m]

= 49 joules **Ans (ii)**

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6. Sample Problems
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Here are the quantities you can know from the above explanation.

F= Force
m= Mass
a = Acceleration
g= Gravity
Mu= Coefficient of Friction
M u $_s$= Coefficient of Static Friction
M u $_k$ = Coefficient of Kinetic Friction

F_N = Normal force
These quantities are defined and explained on other pages except for the Coefficient of friction, Static friction, Kinetic friction, and the Normal force which is explained below

New Quantities

The formulas that you already know about dynamics are:

1. $F = ma$
2. $W = mg$

Formulas

So now we have all the formulas we need for determining friction:

1. $F = ma$
2. $W = mg$
3. $F = Mu\ F_N$
4. $F = F_A - F_F$

General Problem Solving Strategy:

1. Read the problem.
2. Go through the problem and figure out what is given or implied
   Make a list, and identify the quantities you know.
3. Find any formula that will allow you to calculate anything that you don't know, and apply it.
4. Add what you just found in the last step to your list of known s.

10.Check to see if you have found the answer. If not, repeat the previous two steps until you are done.

Example problem 1

Since sliding is such a great example, if you have a box that has a mass of 50 kg, what is its normal force?
Here's what we got:

- M = 50 k
- G = 9.8 m/s/s
- F_N=?

Use the formula F_N = mg,
So it would look like F_N = (50 kg)(9.8 m/s/s). Therefore F_N = 490 Newtons.

Now if it takes 156.8 newtons of force to get the box moving, then what is its static coefficient of friction?

Here's what we got now:

- F = 156.8 N
- F_N = 490
- Mu =?

We take the formula F = Mu (F_N)

With 156.8 N = Mu (490 N) we can to this with simple math.

156.8/490 = Mu = .32, which is the static coefficient of friction, and the answer.

Example problem 2

You push a 100 kg rock down the road. If the kinetic coefficient of the rock and the pavement is .25, what is the force required to keep the rock moving?
Here's what we know:

- m = 100 kg
- g = 9.8 m/s/s
- M u_k = .25

Obviously we need to find the F_N for:
F_N = mg

Since we know m and g, F_N = (100 kg)(9.8 m/s/s) = 980 N. Now that we have
F_N we can use
F = Mu (F_N)

Which when plugged in with what we know is

F = (.25) (980 N)

So F = 245 N that need to be continually pressed to keep it moving.

Example Question:

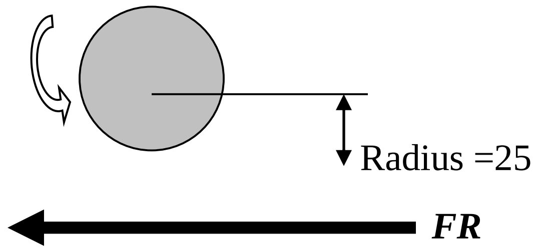
a) ***state four laws of friction for dry sliding surfaces.***

b) ***The coefficient of friction between the running surfaces of a bearing is 0.02 and the normal load on the bearing is 400 N. If the shaft has a diameter of 50 mm and is turning at 1000 rpm, calculate the power lost to friction.***

Solution:

a) *Friction acts to oppose motion*

- *Is proportional to the total pressure between the surfaces in contact*
- *Is dependent of the contact area*
- *Is dependent of the sliding speed (at low speeds)*
- *Depends on the nature of surfaces in contact*



b) $F_R = \mu N$

N=Normal Load = 400N and $\mu = 0.2$

$F_R = 0.02x400 = 8N$

Torque caused by friction

$T_R = F_R xRadius$

$T_R = 8x25x10^{-3} Nm$

$T_R = 0.2Nm$

$$AngularVelocity(\omega) = \frac{2\pi N}{60} = \frac{2\pi x1000}{60}$$

$$\omega = 104.762 rad/s$$

Power lost due to friction $P_L = T_R x \omega$

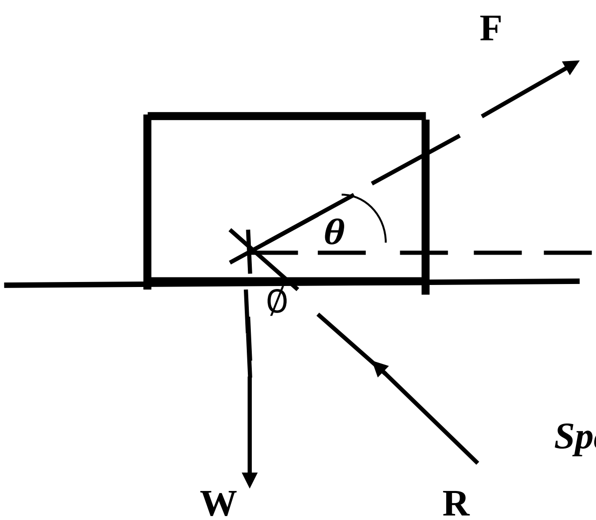
$P_L = 0.2x104.762 Watts$ =20.952 Watts

7.5 Forces not parallel to Plane:

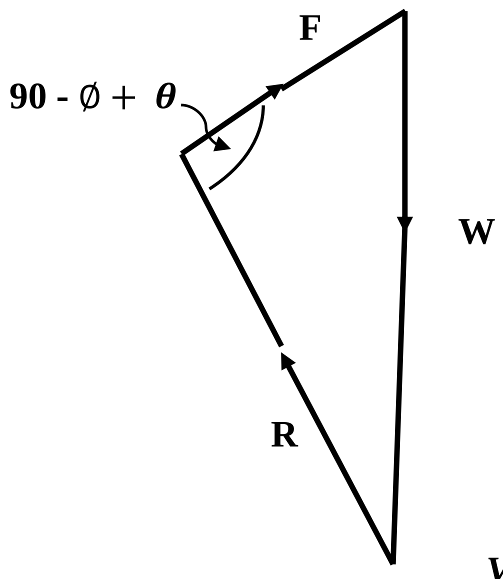
The second part of this topic is looking at forces that not been parallel to the horizontal plane but over which the body is sliding and let it be pulled on an incline of a upward force at $\boldsymbol{\theta}$ degrees. This will be illustrated in the following example drawing. The drawing shows us that Ø is the friction angle (whose tangent is equal to the coefficient of friction), and the angle between F and R in the vector diagram of forces is **90 -Ø +** $\boldsymbol{\theta}$

Then by Sine rule, $$\frac{F}{\sin \emptyset} = \frac{W}{\sin(90 - \emptyset + \theta)}$$

From which any unknown can be calculated.



Space Diagram



Vector Diagram:

Example:

A body of 200 N weight rest on a horizontal plane, the coefficient of friction between the body and the plane is 0.25.Find the force inclined upwards at 30 degrees to the horizontal which will just cause motion.

Solution:

Given: $\tan \emptyset = \mu = 0.25$

$\therefore$**Friction angle** $\emptyset = 14^0\ 2'$

Referring to the above diagram;

Angle opposite $W = (90 - 14^0\ 2' + 30^0) = 105^0\ 58'$

by Sine rule, $\frac{F}{\sin 14^0\ 2} = \frac{200}{\sin 105^0\ 58'}$

$$F = \frac{200 \times 0.2425}{0.9615}$$

$= 50.44\ N$ ***Ans.***

Exercise

1) A casting weighing 750 newtons is pulled along a horizontal workshop floor for a distance of 15 meters by a horizontal force. If the coefficient of friction between the casting and the floor is 0.32, calculate the force applied and the work done……   (ans..240 N (i) 3600 or 3.6 kj (ii))