Force and Frictional Forces

Force:

Force is a kind of impact, external or internal which tends to change or in real sense it changes the inertia of any object. Or, force is what we call a push or a pull, or any action that has the ability to change an object's situation.

Forces can be used to increase the speed of an object, decrease the speed of an object, or change the direction in which an object is moving.

The unit of force is Newton (N). All forces in nature are classified into four basic forces:

1. The gravitational force, which originates with the presence of matter.
2. The electromagnetic force, which includes basic electric and magnetic interactions and is responsible for the binding of the atoms and structure of solids
3. The week nuclear force, which causes certain radioactive decay processes and certain reactions among the fundamental particles, and
4. The strong nuclear forces, which operates among the fundamental particles and is responsible for binding the nucleus together.

Friction and frictional forces:

When surfaces of two bodies are in contact whether they are at rest or in relative motion with respect to one another, they developed a force at plane of their contact which opposes their relative motion. This opposition is known as friction and the force which produced at the plane of contact is called frictional force.
Friction forces,

1. Oppose the relative motion
2. Tendency of oppose the relative motion
3. Tangentially along the contact
4. Exist in pair

Frictional force mainly depends on

I. Nature of the surface
II. Degree of their smoothness
III. Presence of foreign materials (Air, oil, water etc.)

IV. Temperature.

Frictional force can be expressed as

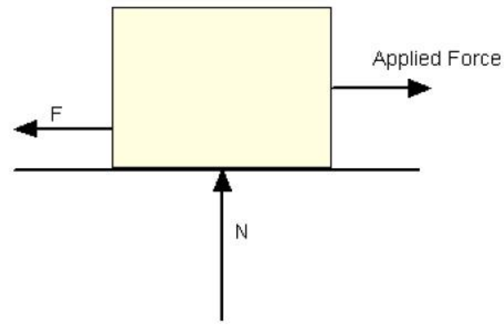
$F_f = \mu$ N -------------------------- (1)

Where,

F_f = frictional force (N)

μ = static (μ_s) or kinetic (μ_k) frictional coefficient

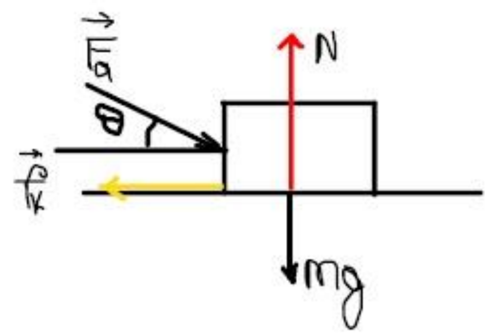
N = normal force (N)



<u>Friction force vary on the same plane due to push of an object on different angle</u>

Suppose a box of mass m is pulled by a force F_a at an angle θ degree with horizontal. The frictional force always oppose the box motion. If μ is the frictional coefficient of the box, then fictional force,

$$\mathbf{F_f} = \mu \, \mathbf{N} \text{ ------------------- (1)}$$



Where, N is the normal force.

In equation (1) μ is a constant coefficient.

So frictional force directly depends on normal force.

The increase in normal force causes an increase in frictional force.

In the figure, the applied force $\mathbf{F_a}$ is divided into two components,

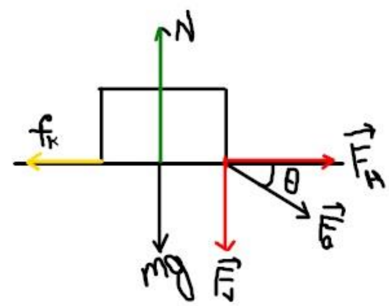
Horizontal component, $\mathbf{F_H} = \mathbf{F_a} \cos\theta$

Vertical component, $\mathbf{F_v} = \mathbf{F_a} \sin\theta$

$\mathbf{F_v}$ is acting directly downward direction.

In this case, $\mathbf{N} = mg + \mathbf{F_v}$

Or, $\mathbf{N} = mg + \mathbf{F_a} \sin\theta$ ------------------------



Putting the value of **N** in equation (1), we can write,

$$\mathbf{F_f} = \mu (mg + \mathbf{F_a} \sin\theta) \text{ ------------------ (3)}$$

$\mathbf{F_f}$ depends on pushing angle θ. With increasing θ friction force increases. That means Friction force vary on the same plane due to push of an object on different angle**.**

Types of frictional forces:

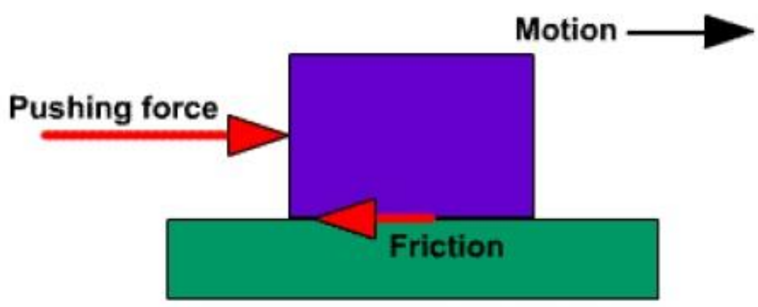
I. Force of kinetic friction:

If the applied/pushing force **F** is greater than the resistive force of friction F_r (written as $\mathbf{F} > \mathbf{F_r}$), then the object will slide or move. The friction is considered kinetic friction, which means moving friction. The frictional force that opposes the relative motion between two surfaces in contact is called kinetic frictional force. It is denoted by $\mathbf{f_k}$,

$$\mathbf{f_k} = \mu_k \mathbf{N}$$

The kinetic frictional force directly proportional to the normal reaction.

Where, $\boldsymbol{\mu_k}$ is the coefficient of kinetic friction, which depends on the properties of surfaces are in contact, N is the magnitude of the normal force.



Pushing force is greater than friction force

II. Force of static friction:

If the pushing force F is less than the resistive force of friction F_r (written as $F < F_r$), there is no motion and the objects remain static with respect to each other. In this case, the friction is considered static friction, which means it is not moving. The frictional force that oppose the tendency of relative motion of a static object is called static frictional force. It is denoted by $f_{s,}$

$$\mathbf{f_s} < \mu_s N$$

Where, μ_s is the coefficient of static friction and N is the magnitude of the normal force.

The equality sign holds only when $\mathbf{f_s}$ has its maximum value. The maximum value of static frictional force is called limiting frictional force $f_{limiting}$. f_s has values ranges from $0 \le f_s \le f_{limiting}$. We can write,

$$\mathbf{f_{limiting}} = \mathbf{f_s^{max}} = \mu_s N.$$

III. Rolling friction:

The opposing force which comes into play when a body rolls over the surface of another body is called rolling friction.

When a wheel of ball is in contact with a solid surface, and a force is applied to the wheel, static friction will prevent the wheel from sliding. Instead, the wheel will start to roll. Once the wheel is rolling, another type of friction takes over. Rolling friction is the resistive force that slows the wheel's motion on the other solid surface. It is different than static or kinetic friction. Much of rolling friction is caused by adhesion between the surfaces.

IV. Fluid friction

When a solid object is in contact with a fluid, such as a liquid or gas, and a force is applied to either the object or to the fluid, there is a friction force that resists the motion. Examples where fluid friction occurs are water flowing through a hose, an airplane flying through the atmosphere and oil lubricating moving parts.

Coefficient of static and kinetic friction:

The ratio of the magnitude of the maximum force of static friction to the magnitude of the normal force is called the coefficient of static friction for the surface involved. We can write,

$$\mu_s = \frac{f_s^{max}}{N}$$

Where, μ_s is the coefficient of static friction, f_s represents the magnitude of the force of static friction and N is the magnitude of the normal force.

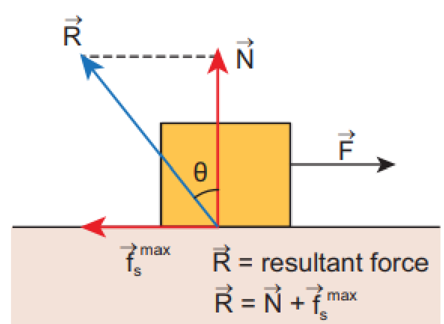
The ratio of the magnitude of the force of kinetic friction to the magnitude of the normal force is called the coefficient of the kinetic friction, then

$$\mu_k = \frac{f_k}{N}$$

Where, μ_k is the coefficient of kinetic friction. F_k represents the magnitude of the force of kinetic friction and N is the magnitude of the normal force.

Both μ_k ***and*** μ_s is dimensionless constants, each being the ratio of (magnitudes of) two forces. Usually, for a given pair of surfaces, $\mu_s > \mu_k$.

Angle of friction



The angle between resultant contact force and the normal force when the body is just about to move.

In figure the resultant force is

$$tan\theta = \frac{f_s^{max}}{N} \text{-----------------}(1)$$

We know,

$$f_s^{max} = \mu_s N$$

Or, $\boldsymbol{\mu_s} = \frac{f_s^{max}}{N}$------------------ (2)

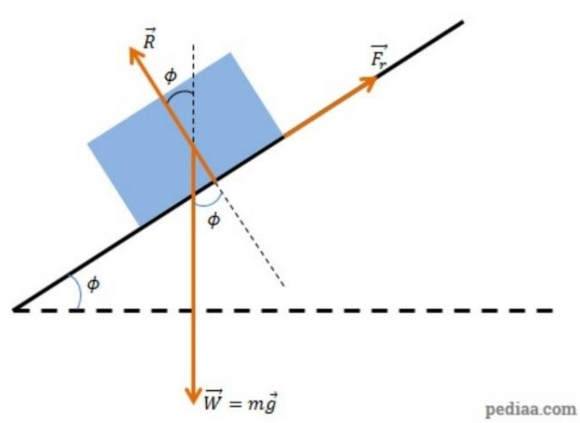
From equations (1) and (2),

$tan\theta = \boldsymbol{\mu_s}$

The coefficient of static friction is equal to tangent of angle of friction.

Angle of repose

The minimum angle between incline plane and horizontal when a body place on it just begin to slide down.



Defining Angle of Repose

Problem:

1. An 80 kg box is pushed by 600 N forces with an angle of 30^0 along to the horizontal line. The box gained velocity 6 m/s starting from rest at 4 seconds. Find the friction coefficient of the box.

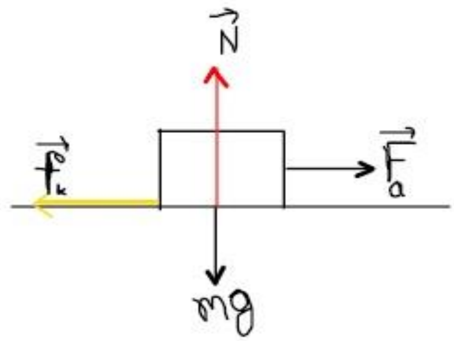
2. A 60 kg box is pushed by 600 N forces with an angle of 45^0 along to the horizontal line. If the sliding friction coefficient of the box is 0.4, find the acceleration of the box.

Math example

Problem 1

A body of mass 4 kg pulled by 10 N force. The kinetic or sliding frictional coefficient is 0.2. Find kinetic frictional force.

Solution:



Given that, $m = 4$ kg

$\mathbf{F_a} = 10$ N

$\mu_k = 0.2$

$g = 9.8$ m/s

So, $mg = 4 \times 9.8 = 39.2$ N

$\mathbf{N} = mg = 39.2$ N

We know, the kinetic frictional force, $\mathbf{f_k} = \mu_k \mathbf{N}$

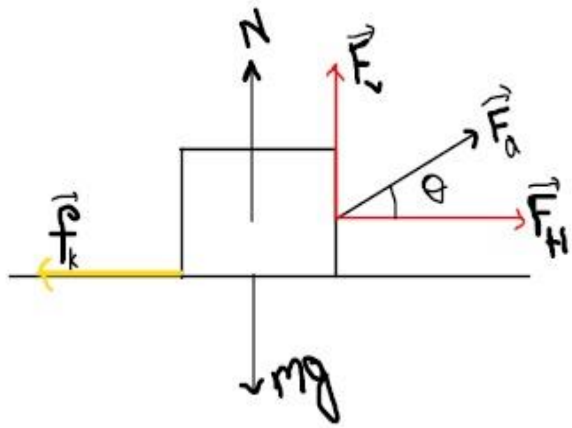
Or, $\mathbf{f_k} = 0.2 \times 39.2 = 7.84$ N

Ans: 7.84 N

Problem 2

A 70 kg box is pulled by 400 N force at an angle 30 deg with horizontal. If the coefficient of sliding friction is 0.5, find the acceleration of the box.

Solution



Given that, $m = 70$ kg

$\mathbf{F_a} = 400$ N

$\mu_k = 0.5$

$g = 9.8$ m/s

$\theta = 30$ deg

So, $mg = 70 \times 9.8 = 686$ N

$\mathbf{F_H} = \mathbf{F_a} \cos\theta = 400 \times \cos 30^0 = 345.4$ N

$\mathbf{F_V} = \mathbf{F_a} \sin\theta = 400 \times \sin 30^0 = 200$ N

Here, $\mathbf{N} + \mathbf{F_V} = mg$

Or, $N + 200 = 686$

Or, N = 486 N

We know, $\mathbf{f_k} = \mu_k \mathbf{N}$

Or, $\mathbf{f_k}$ = 0.5x 486 = 243 N

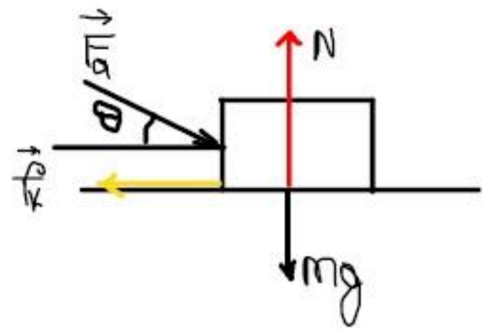
We also have, the net force applied on the box, $F_{net} = \mathbf{F_H} - \mathbf{f_k}$

Or, $m\mathbf{a} = \mathbf{F_H} - \mathbf{f_k}$

Or, $\mathbf{a} = \frac{\mathbf{F_H} - \mathbf{f_k}}{m}$

Or, $\mathbf{a} = \frac{345.4-243}{70}$

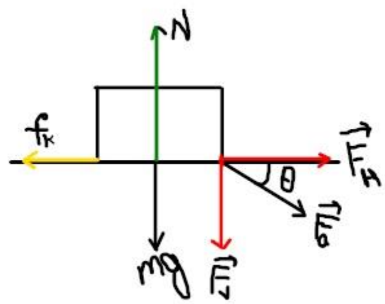
Or, $\mathbf{a}$ = 1.46 m/s^2 (Ans.)



Problem 3

A 4 kg box is pushed by 10✓2 N force at an angle 45 deg with horizontal. If the coefficient of sliding friction is 0.2, find the normal force, frictional force and acceleration. H.W

Solution:



Problem 4

A 4 kg object is at rest, static frictional coefficient is 0.2, what is the value of applied force for which the body start to move.

Solution

The body moves when the applied force is greater than the maximum static frictional force.

Given that, m = 4 kg

μ_s = 0.2

g = 9.8 m/s^2

So, N = mg

Or, N = 4 x 9.8 = 39.2 N

We know,

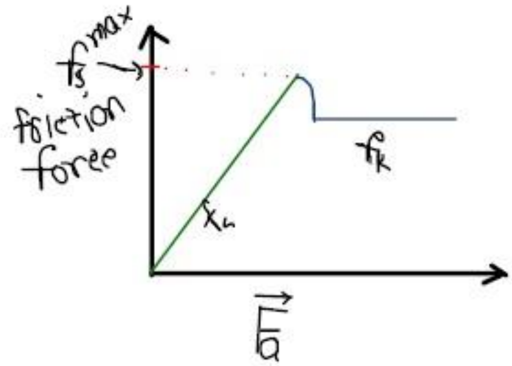
$$f_s^{max} = \boldsymbol{\mu s N}$$

Or, $f_s^{max} = 0.2 \text{ x } 39.2$

Or, $f_s^{max} = 7.84$ N

So, the applied force must be greater than 7.84 N.

Graph of frictional forces vs applied force:



Problem 5

When a force of 450N act on a body horizontally, the body get a velocity 13 m/s within 6 sec. If the friction coefficient is on the surface is 1.27, find mass of the body.

Solution

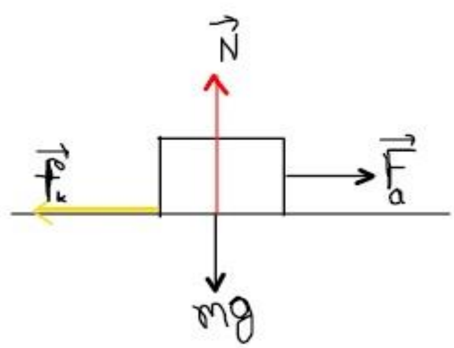
Here given that, Fa = 450 N

v = 13 m/s

t = 6 sec

$\mu_k = 1.27$

m = ?



The net force applied on the box, $F_{net} = F_a - f_k$

Or, $ma = F_a - \mu_k N$

Or, $ma = F_a - \mu_k mg$

Or, $ma + \mu_k mg = F_a$

Or, $m(a + \mu_k g) = F_a$

Or, $m = \frac{F_a}{a+mg}$

Or, $m = \frac{F_a}{(\frac{v-u}{t})+\mu_k g} = \frac{450}{(\frac{13-0}{6})+1.27 \text{ x } 9.8}$

Or, m = 30.8 kg (Ans.)

Possible questions

1. What is friction force?
2. Why it is easy to pull an object then pushed?
3. Show that or explain that Friction force vary on the same plane due to push of an object on different angle.
4. Define static and kinetic frictional coefficient.