

FRICTIONAL PROPERTIES

FRICTION

1. Static friction
2. Kinetic friction
3. Internal friction
4. Angle of repose
5. Rolling resistance

The frictional properties of granular materials are important
In designing

- Storage bins, hoppers, chutes,
- Pneumatic conveying system, screw threshers and conveyors,
- Forage harvesters,
- Fruits and Vegetables grader

Friction is a force that resists motion between two objects that are in contact with each other. **Smoother** surfaces exhibit **less** friction, while **rougher** surfaces exhibit **more** friction

Static friction arises between **two objects that are not in motion with respect to each other**. It is measured as the maximum force the bodies will sustain before motion occurs. **Kinetic friction** arises **between bodies that are in motion with respect to each other**, It is measured as the maximum force the bodies will require to keep them in motion

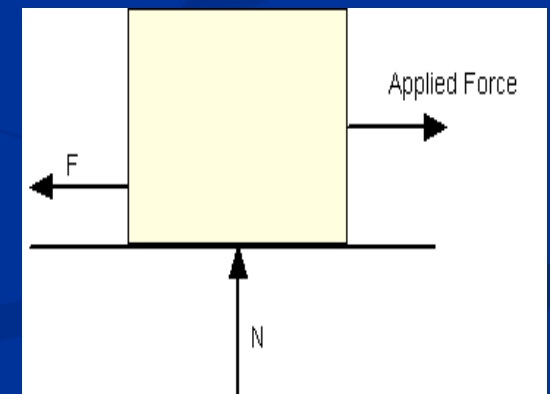
Frictional force can be expressed as

$$F_f = \mu N \quad (1) \quad \text{where}$$

F_f = frictional force (N)

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

N = normal force (N)



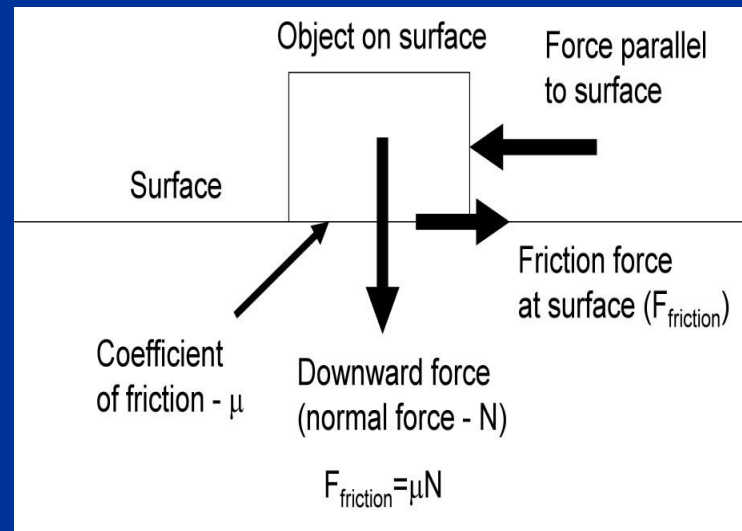
For an object pulled or pushed **horizontally**,
the normal force - N - is simply the weight:

$$N = m g \quad (2)$$

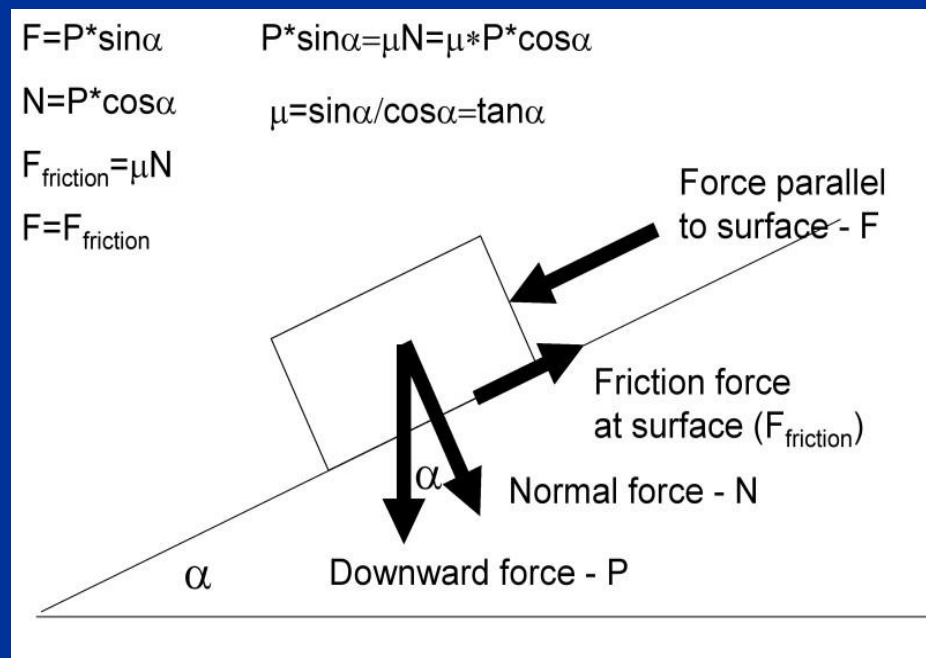
where

m = mass of the object (kg)

g = acceleration of gravity (9.81 m/s^2)



If the **object is on a tilted surface** such as an inclined plane, the normal force is less, because less of the force of gravity is perpendicular to the face of the plane. Therefore, the normal force, and ultimately the frictional force, is determined using **vector analysis**



Coefficient of friction

The **ratio** of the frictional force, parallel to the surface of contact, that opposes the motion of a body which is sliding or rolling over another, to the force, normal to the surface of contact, with which the bodies press against each other.

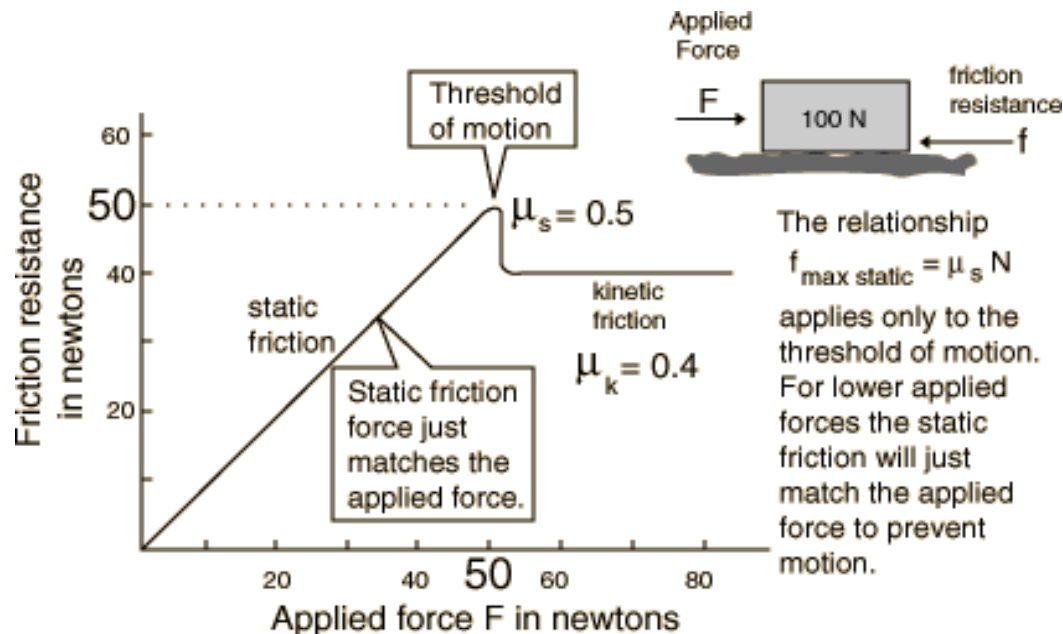
Kinetic (or dynamic) friction occurs when two objects are moving relative to each other and rub together. The coefficient of kinetic friction is usually less than the coefficient of static friction for the same materials meaning that more force is required to set the objects in motion than to keep them in motion.

Factors affecting frictional force

1. Load
2. Actual contact area
3. Sliding velocity
4. Nature of material in contact
5. Moisture content

Static vs Dynamic (kinetic) Friction

The coefficient of friction for a pair of materials is often quoted as STATIC and DYNAMIC values. From the typical diagram below, dynamic friction is usually lower than static (although this is nothing compared to the effect of a little moisture).

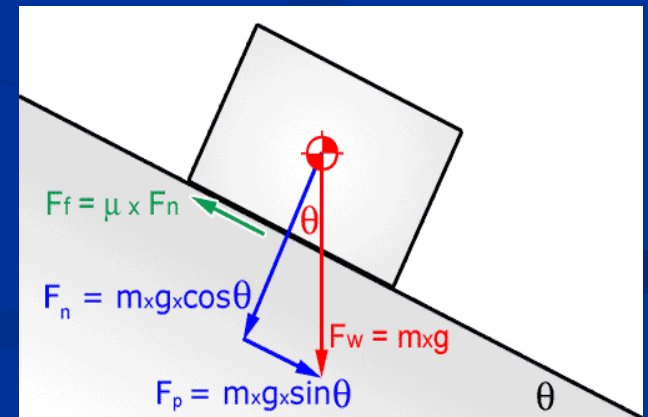


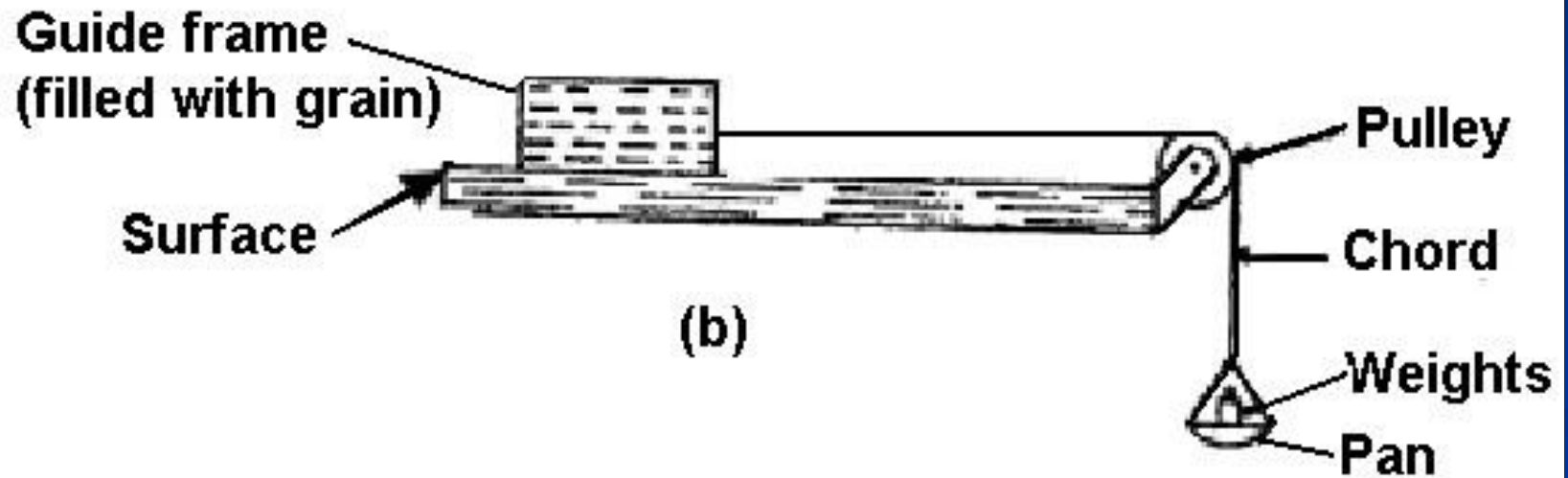
Any force larger than the force of static friction causes sliding to occur.

The instant the sliding occurs, static friction is no longer applicable—the friction between the two surfaces is then called kinetic friction.

Experimental set-up for Coefficient of Friction

A tilting table can be used. The surface to be tested is fixed on the tilting table and the seeds are poured into a cardboard paper ring of diameter 10cm by 2cm deep until the ring is full. Care is taken to raise the ring slightly so that it did not touch the surface. The table is then slowly tilted by a gentle screwing device until movement of the seeds down mounted against the edge of the tilting table. The tangent of the angle of friction is the coefficient of friction





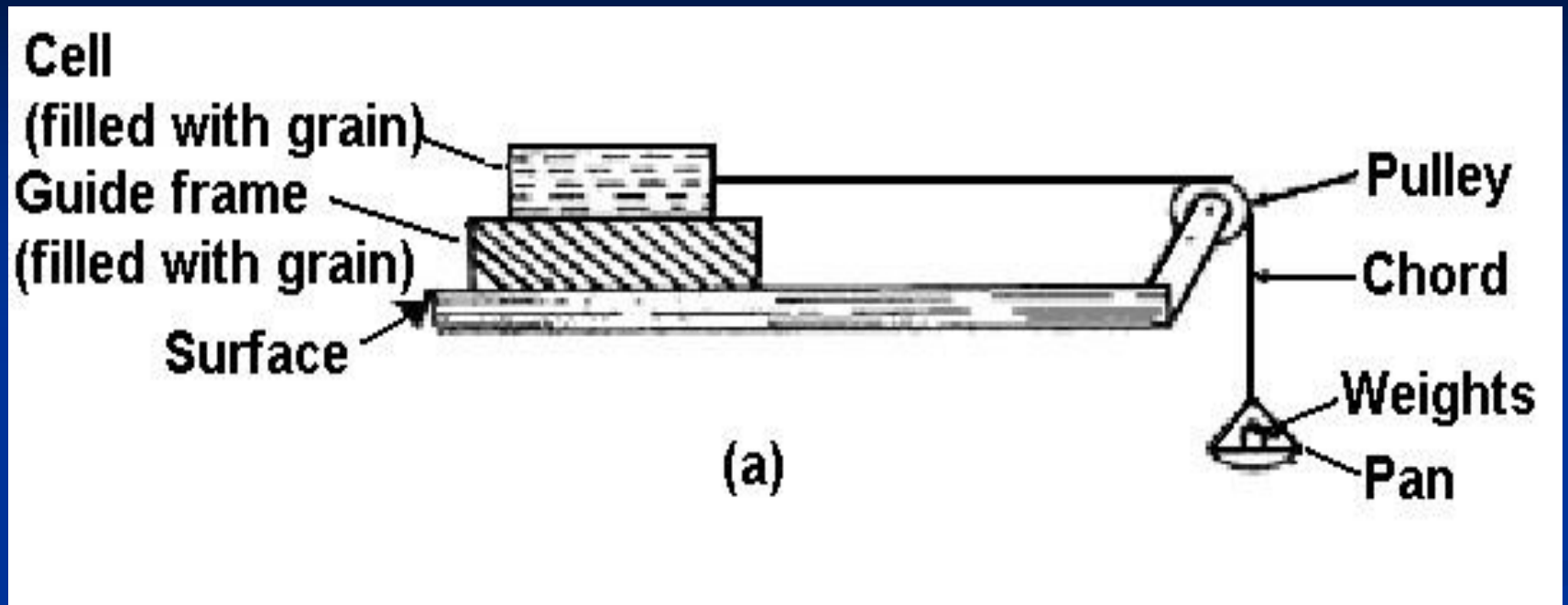
Coefficient of friction on material surface

COEFFICIENT OF INTERNAL FRICTION

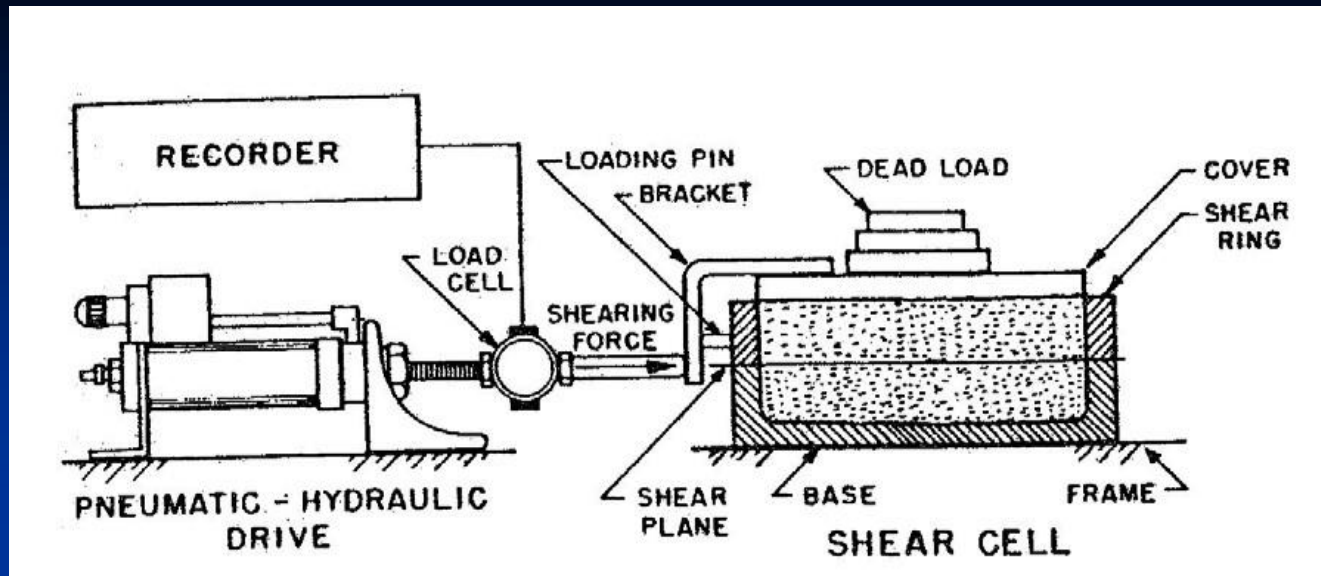
The friction of the **kernels or grains against each other** is known as internal friction where as the friction between the grain mass and the contact surface is known as static friction. The coefficient of the internal friction of the grains is required in predicting the lateral pressure on a retaining wall in silos or design of silos and hoppers for gravity flow.

Factors affecting internal frictional force

1. Moisture content
2. Shape and size of material
3. Amount of consolidation or settling
4. Load
5. Sliding velocity



Coefficient of internal friction



Experimental set up for coefficients of internal friction (Tri-axial compression test apparatus or Shear test apparatus)

The direct shear test apparatus consists of a shear cell, a controlled loading device and a recorder. The normal load is applied by weights acting vertically. The shearing action is provided by means of an electrical or mechanical drive with a load cell or dynamometer in line for force measurement. The shearing force acts in the plane of contact between the base and the ring. The shear cell assures a uniform stress distribution across the specimen sample and shear of solid in the plane between the ring and base.

ANGLE OF REPOSE

Angle of repose is important in designing a structure for storage of food grains in bulk. When a granular material is allowed to flow freely from a point into a pile, the angle which the side of the pile makes with horizontal plane is called the angle of repose (IS: 6663-1972).

The angle of repose is influenced by **size, shape, moisture content and orientation of the particles.**

- ✓ The angle of repose increases with the increase in moisture content.
- ✓ The cohesive materials have larger angle of repose.
- ✓ Lower angle of repose represents easier flowability.

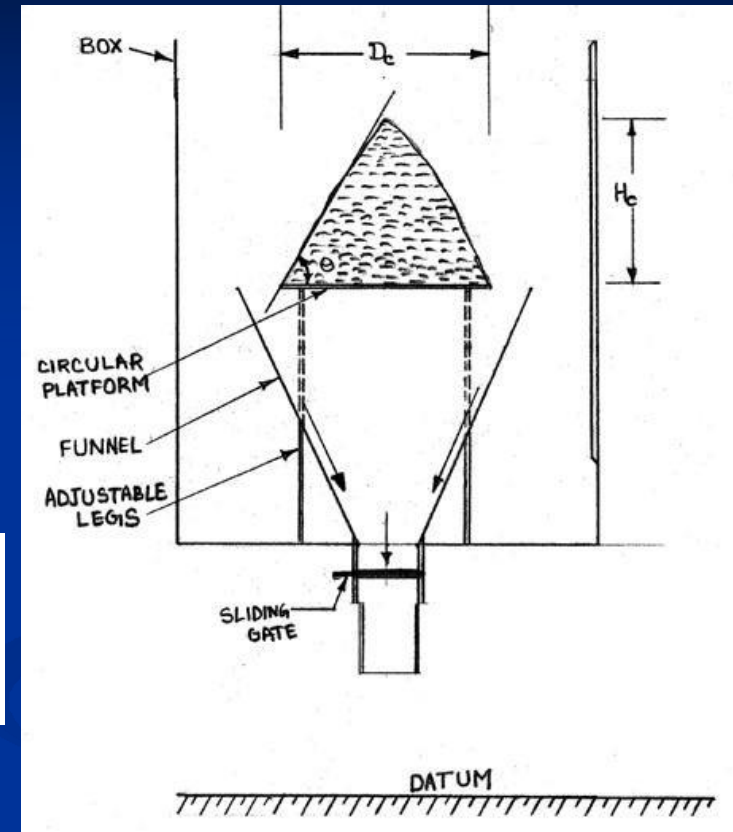
Angle of repose of the grain can be calculated experimentally using the following formulae:

$$\theta = \tan^{-1}\left(\frac{2H_c}{D_c}\right)$$

where,

H_c = height of cone formed measured with depth gauge

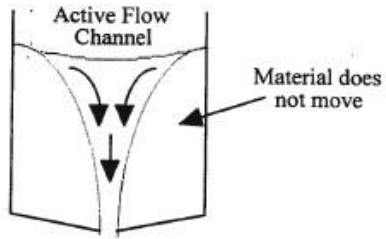
D_c = diameter of the platform on which the cone formed



Line diagram of Experimental Set up for Angle of Repose

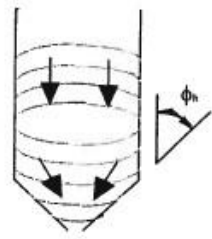
FLOW PATTERNS

A.



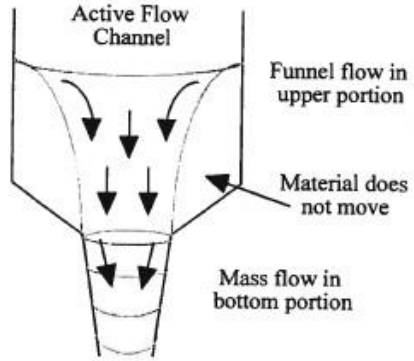
Funnel Flow

B.



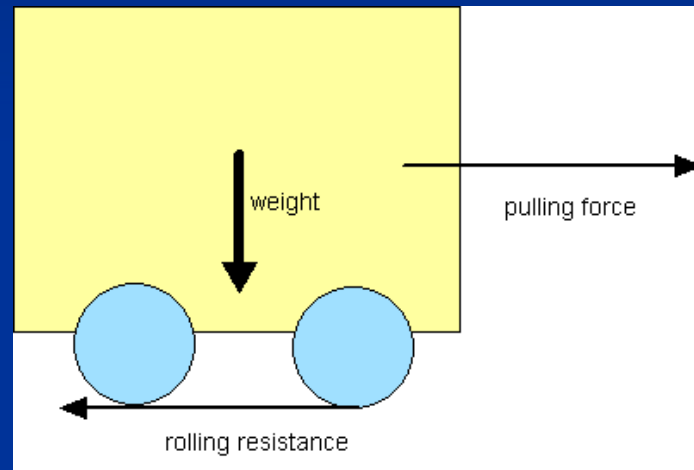
Mass Flow
 $\phi_s =$ hopper angle

C.

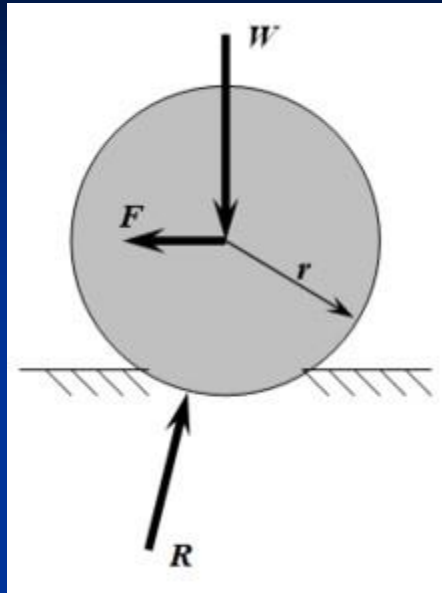


Expanded Flow

Rolling resistance is the force that resists the rolling of a wheel or other circular (rounded) object along a surface caused by deformations in the object and/or surface. Generally the force of rolling resistance is less than that associated with kinetic friction.



Rolling resistance is a measure of the retarding effect of a floor surface at the tread/floor interface of the rounded objects. It is normally expressed in units of force and is a measure of the energy dissipated per unit of distance rolled.



The rolling resistance can be expressed as

$$F_r = c W \quad (1)$$

where

F_r = rolling friction (N,)

c = rolling resistance coefficient - dimensionless
(coefficient of rolling friction - CRF)

$W = m g$ = normal force or weight of body (N,)

m = mass of body (kg,)

g = acceleration of gravity (9.81 m/s²,)

The rolling resistance can **alternatively** be expressed as

$$F_r = c_1 W / r \quad (2)$$

where

c_1 = rolling resistance coefficient with dimension length (coefficient of rolling friction) (mm,)

r = radius of rounded object (mm,)

Rolling resistance is

directly proportional to weight of the rolling object;
inversely proportional to the effective radius and
directly proportional to the coefficient of rolling resistance which is
dependent on supporting surface rigidity.

NB: More rigid is the surface, lower is the 'c' in rolling resistance. Sand is a good example of a soft, rolling-resistant surface. Bicycling across a paved roadway is much easier than across a white sandy beach.

THANK YOU