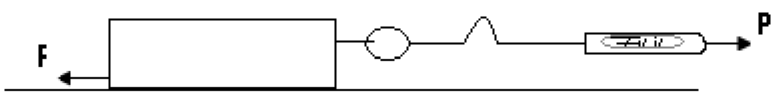
CHAPTER THREE

FRICTION, ATMOSPHERIC AND LIQUID PRESSURE

Friction:

- This is the force, which opposes the relative sliding motion between two surfaces in contact with each other.
- Friction occurs because the surfaces of objects are never perfectly smooth, for microscopic "hills and hallows" or ups and downs on the surface catch into each other and as such oppose the sliding motion, between the two surfaces in contact.

Limiting or static friction:



- A rectangular block of wood placed on a flat surface has a spring dynamometer attached to it, so that a horizontal force, P, can be be applied to it.
- If a gradually increasing force is applied to the block, it will at first continue to remain at rest, since an equally increasing but oppositely directed force of friction F, comes into action at the under surface of the block.
- At this stage, the pull P and the opposing force F are in equilibrium.
- If we continue to increase the pull P, a stage will be reached when the block just begins to slip.
- At this stage or point, the friction brought into play has reached its maximum value for the two surfaces concerned, and it is called the limiting or the static friction.
- In short, the limiting friction is the value of the frictional force, just before the body starts to move.
- Frictional force can be measured using a dynamometer.

Sliding, dynamic or kinetic friction:

- This is the value of the frictional force when the object starts moving or is in motion, and it is always less than the limiting friction.

- In short dynamic friction is the frictional force, acting between two surfaces which have relative motion.

Coefficient of friction:

- Both limiting and dynamic friction are increased roughly in simple proportion to the force, which is perpendicular to the surface pressing them together.
- The ratio of the static and the dynamic friction to the force pressing the surfaces together, are called the coefficient of static and dynamic friction respectively.

- U = $\frac{F}{R}$.

where U = coefficient of friction, F = friction and R = the force pressing the surfaces together i.e. the normal reaction.
- The coefficient of dynamic friction = $\frac{F}{R}$, where F = dynamic friction and R = normal reaction.
- Also, the coefficient of static friction = $\frac{F}{R}$, where F = the static friction and R= the normal reaction.
- The coefficient of static friction has no unit.
- The normal reaction is the force which keeps the two surfaces in contact together, and acts at right angle to the surface.

The principles or laws of friction:

(1)The frictional force between two surfaces oppose their relative motion.
(2)The frictional force is independent of the area of contact of the given surfaces, when the normal reaction is constant.
(3)The frictional force, F, is proportional to the normal reaction R,

=> $F \propto R$ => F = UR => U = $\frac{F}{R}$, where U = the coefficient of friction.

Advantages or uses of friction:

(1) It enables us to walk.
(2)The operation of most brakes depend on friction.
(3)May frictional devices depend on frictional forces. E.g. nails, bolts and nuts.

Disadvantages of Friction:

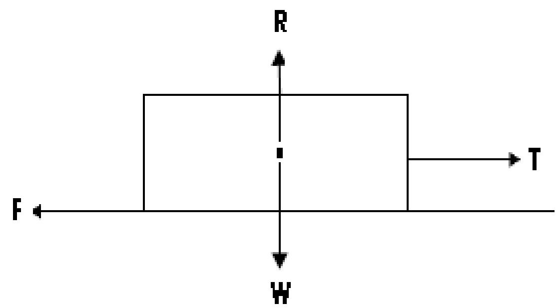
(1) It causes the soles of our shoes to wear out.
(2) Brake lining wears away because of friction.

(3) Friction in machinery causes the loss of useful energy, and possible damage through over heating if care is not take.

Reducing friction:

- By using lubricants such as oil or grease.
- By making the rough surface smooth.
- By the use of small ball bearings.

Objects on horizontal plane:



- Let us suppose that a body of weight W, is pulled with a constant speed along a horizontal plane, by means of a string.
- If the string is parallel to the horizontal plane, then the normal reaction is equal to the weight of the body, and the effort is equal to the frictional force at work.
- This implies that R = W and F = T, but since F = UR => F = UW, where U = the coefficient of friction.

(Q1)(a) State the laws of static friction.

(b) A metal box of mass 200kg, is pulled at a constant speed along a horizontal floor. The coefficient of friction between the floor and the box is 0.5. Find the maximum effort needed to pull the box, when the effort is pulled horizontally.

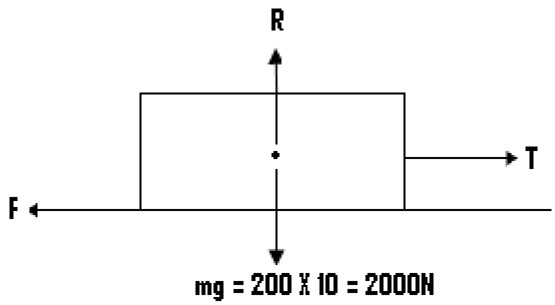
Soln:

(a) (1) The limiting frictional force between two surface in contact, is independent of the areas of the two surfaces in contact.

(2)The limiting frictional force between two surfaces in contact, is directly proportioned to the normal reaction between them i.e. F = UN, where

N = normal reactioon,
F = the limiting friction,
U = a constant referred to as the coefficient of friction

(b)



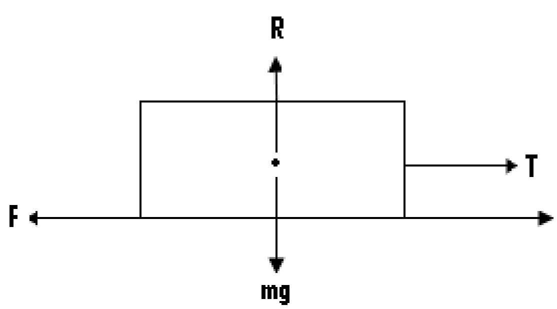
At equilibrium F = T and R = mg.

But since F = UR => F = Umg = $0.5 \times 200 \times 10 = 1000N$. Maximum effort needed = F = 1000N.

(Q2) A box of mass 36kg was pulled along a horizontal surface with a constant speed within a time period of 4 seconds. If it moved through a distance of 3m, and the coefficient of friction between the box and the surface is 0.4, calculate

(i) the effort applied in pulling the box.
(ii) the power used.

Soln:



m = mass of the box = 36kg.
g = 9.81m/s^2.
T = effort applied.
R = the normal reaction = ?
F = friction force = ?
P = power used = ?
S = distance covered = 3m.
U = coefficient of friction = 0.4.

(I) At equilibrium, R = mg, but since F = UR => F = Umg
= 0.4 × 36 × 9.81 = 141.3N.

Also at equilibrium T = F
=> T = 141.3N.

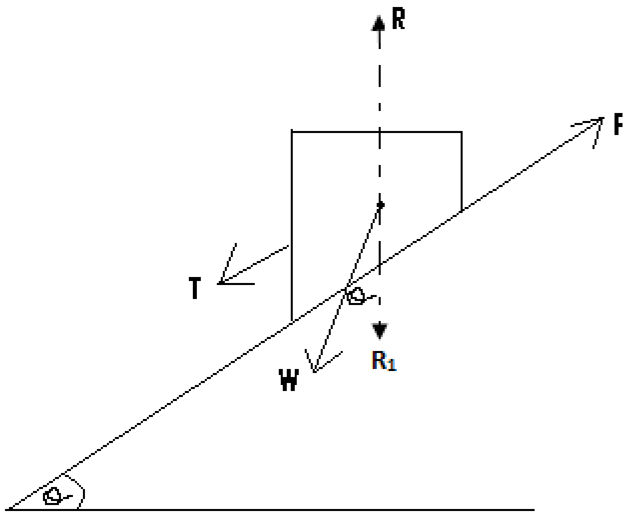
(II) P = $\frac{Force \times distance}{time}$

= $\frac{141.3 \times 3}{4 seconds} = 106W.$

N/B: Effort applied = force.

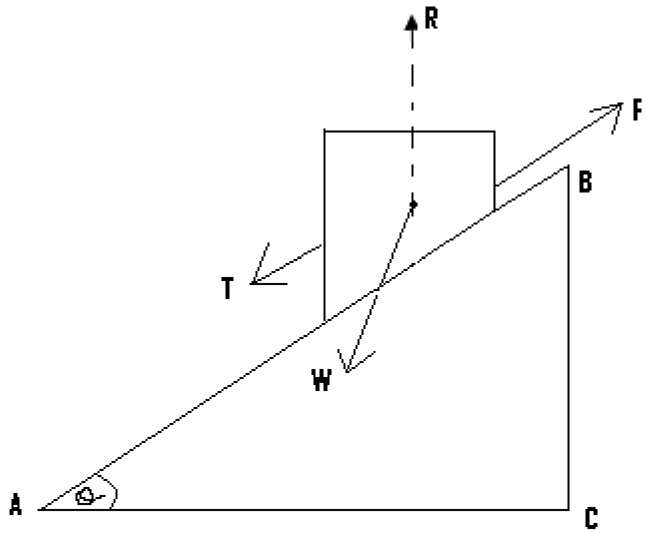
Object on inclined plane:

(1)



- A block of weight W, is placed at the top of a plane which is inclined at an angle θ to the horizontal.
- The block will slip down the plane by its own weight.
- Just at the point the block slips down the plane, the frictional force F, will be equal to the effective effort, T, of the weight which is pulling the block down the plane.
- From the resolution of forces, T = W sin θ and R_1 = W cos θ.
- But just at the point of slipping, F = T = W sin θ => R = W cos θ.
  Since U = $\frac{W sin\theta}{W\, cos\theta}$ = $\frac{sin\theta}{cos\theta}$ = tan θ,
  => U = tan θ.

(2)



- Suppose the block in the diagram moves from A to B, or from B to A, then the work done by the effort T, is given as work done = T x AB = W x BC
  => $\frac{W \times BC}{AB} = W \times \frac{BC}{AB}$, but
  $\frac{BC}{AB} = \sin\theta => T = W\sin\theta$.

Since at equilibrium, the effort, T, is equal to the frictional force => F = W$\sin\theta$

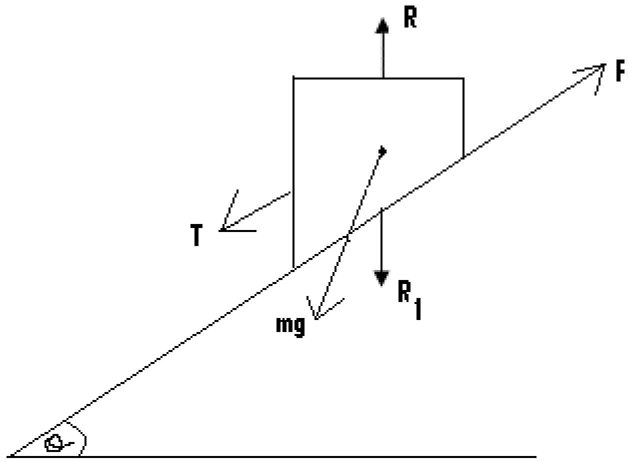
=> F = W $\times$ $\frac{BC}{AB}$.

(Q3) A body of mass 20kg uniformly rolls down a plane, which is included at an angle of 30^0 to the floor.

Calculate

(i) the frictional force.
(ii) the normal reaction.
(iii) the coefficient of friction between the plane and the body.

Soln:



m = mass of the body = 20kg,

g = 9.81m/s^2, R = normal reaction,

F = frictional force, θ = 30^0,

T = the effective part of the weight pulling the body down the plane.

(I) At equilibrium,
F = T = mg sin θ,
=> F = mg sin θ = 20 $\times 9.81 \times sin\ 30^0$
= 20 $\times$ 9.81 $\times$ 0.5 = 98.1N,
=> frictional force = 98.1N.

(II) At equilibrium, R = R_1 = mg cos θ = 20 $\times 9.81 \times cos\ 30^0$,

=> R = 20 $\times$ 9.81 $\times$ 0.866 => R = 169.9.

The normal reaction, R = 169.9N.

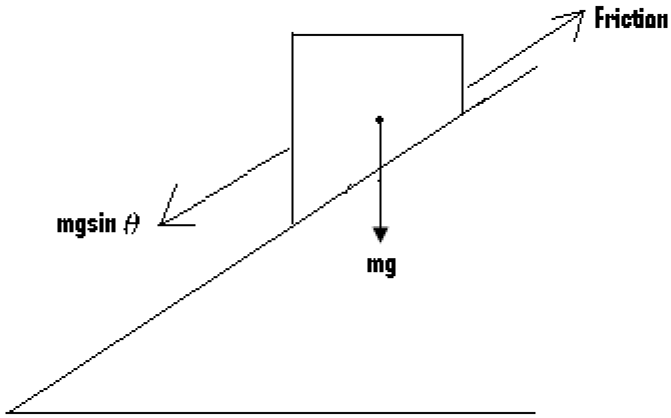
(III) U = $\frac{F}{R} = \frac{98.1}{169.9} = 0.6$,

or U = tan θ = tan 30^0 = 0.6,

=> the coefficient of friction = 0.6.

(Q4) A car of mass 1500kg, is standing on an inclined plane of 20^0 to the horizontal. What must be the frictional force acting along the slope. [Take g = 10ms^{-2}]

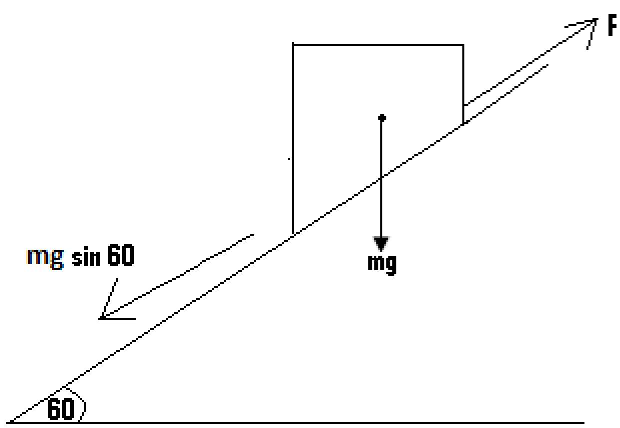
Soln:



If the car is stationary, then the component of the weight down the plane = the friction between the plane and the car.

=> friction = mg sin θ = $1500 \times 10sin20^0$ = 5130N.

(Q5)



Determine the acceleration of the body placed on an inclined plane, which is inclined at an angle of 60^0 to the horizontal, if the coefficient of friction U = 0.5 .

Soln:

The resultant force on the body = mg sin 60^0 – F, but since F = UR => The resultant force = mg sin60 – UR.

Also R = mgcos θ => resultant force = mgsin60^0 - umgcos θ = mgsin60^0 – 0.5mgcos θ

Since force (resultant froce) = ma

Then ma = mgsin 60 – 0.5mg cos θ.

Dividing through using m

=> $\frac{ma}{m} = \frac{mgsin60}{m} - \frac{0.5mgcos\theta}{m}$,

=> a = gsin 60 – 0.5g cos 60,

=> a = $9.8 \times 0.87 - 0.5 \times 9.8 \times 0.5$

=> a = 8.5 – 2.6 = 5.9

=> the acceleration = 5.9m/s^2