UNIT - 3

FRICTION

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Friction

Wedge
Belt Friction
Screw Thread
Vehicle friction on inclined plane

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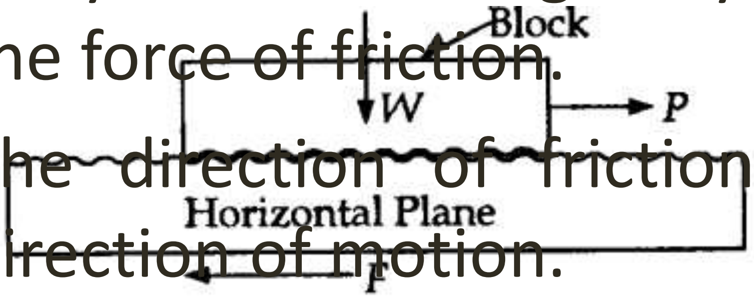
Friction

- When a body slides over another body, a force is exerted at the surface of contact by the stationary body on the moving body. This resisting force is called the force of friction.



- The direction of friction force is opposite to the direction of motion.

Characteristics of friction force

- The main characteristics of friction force are:
  - It always acts on the body in a direction opposite to that in which motion is intended;
  - It always opposes the tractive force, It is a passive force;
  - It exists as long as the tractive force acts. It is a self-adjusting force; only that much comes into play as is just sufficient to prevent motion.

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Types of Friction

- There are essentially two types of friction,
- Nature of friction
  - Static and Dynamic friction
    - Dry friction (coulomb friction)
    - Fluid friction (Wet friction)
      - Sliding friction
      - Rolling friction

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Laws of dry Friction

- Based upon experimental evidence, the following laws of friction have been established for dry contact surfaces.
  - Friction acts tangential to the surfaces in contact and is in a direction opposite to that in which motion is to impend, i.e., take place.
  - Friction force is maximum at the instant of impending motion. Its variation from zero to maximum value (limiting friction) depends upon the resultant force tending to cause motion.
  - The magnitude of limiting friction bears a constant ratio to the normal reaction between the mating surfaces. This ratio drops to a slightly lower value when the motion starts.

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Laws of dry Friction

- Limiting friction is independent of the area and shape of contact surfaces.
- Limiting friction depends upon the nature (roughness or smoothness) of the surfaces in contact.
- At low velocities between sliding surfaces, the friction force is practically independent of the velocity. However, slight reduction in friction occurs when the speeds are high.

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Defined Terminology in friction

- Limiting friction:
  - Friction force is maximum at the instant of impending motion. Its variation from zero to maximum value (limiting friction) depends upon the resultant force tending to cause motion.

- "The limiting friction is the maximum frictional force exerted at the time of impending motion "

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Defined Terminology in friction

Coefficient of friction(μ):

The coefficient of friction is defined as the ratio of force of friction to the normal reaction between the contact surfaces.

$\mu_s = F_R / R_N.$

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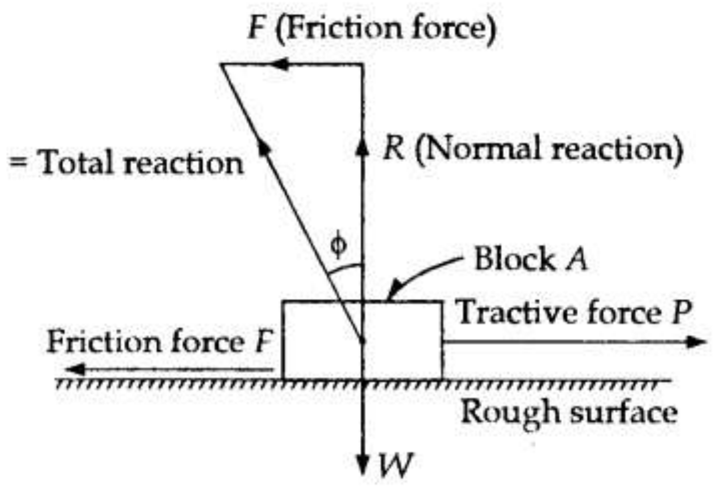
Defined Terminology in friction

Angle of friction(ϕ):

It is defined as the angle which the resultant of normal reaction and limiting force of friction makes with the normal reaction.



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Defined Terminology in friction

Angle of repose (α):

The angle between inclined plane with horizontal at the time impending motion or limiting condition, is known as angle of repose.

Thus $\alpha = \Phi = \theta$

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Friction

Wedge

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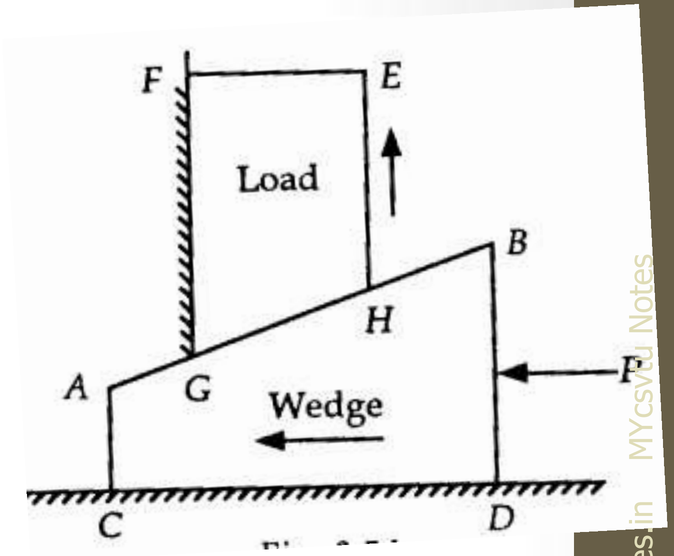

Wedge

A wedge is a piece of metal or wood in the shape of a prism whose section is usually triangular or trapezoidal. It is used for lifting load, for tightening fits or keys for shafts.

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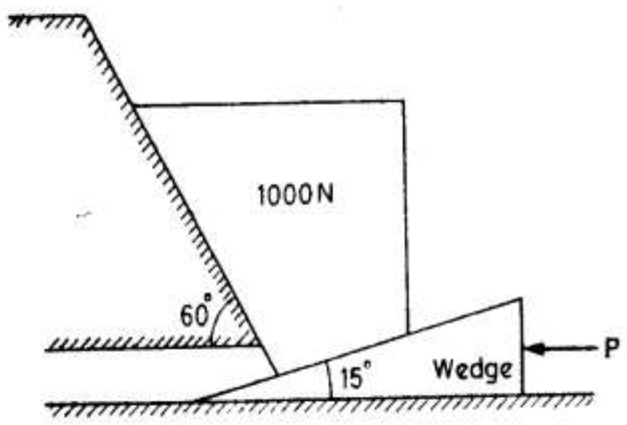
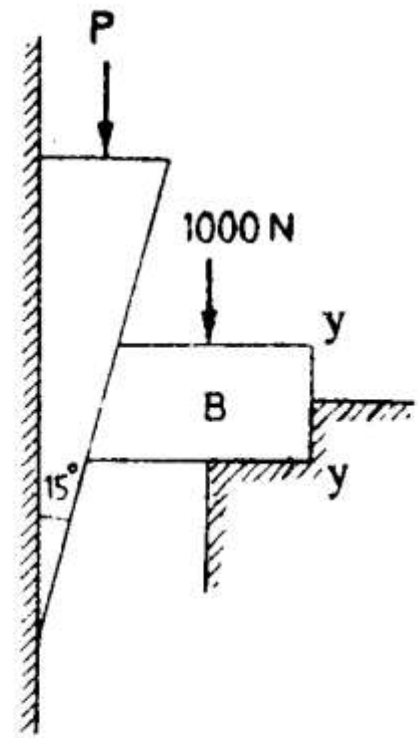
Problem - 1

- A block weighing 1000N is to raised against a surface inclined at 60^0 to the horizontal by means of a 15^0 wedge. Find the horizontal force P which will just start the block to move if the coefficient of friction between all the surface of contact be 0.2. assume the wedge to be negligible weight.



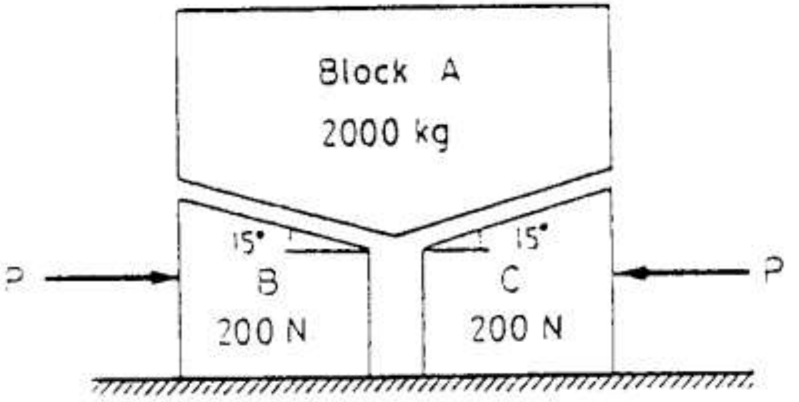
Problem - 2

- A 15^0 wedge of negligible weight is to be driven to tighten a body B which is supporting a vertical load of 1000 N. If the coefficient of friction for all contacting surfaces be 0.2. find the minimum force P required to drive the wedge.



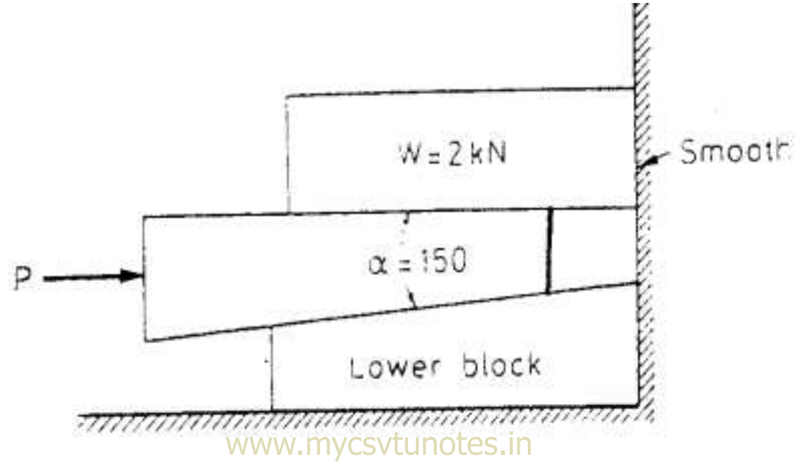
Problem -3

- A block of mass 2000 kg is to be raised upward by simultaneously pushing two identical wedges B and C under it. Each wedge weighs 200 N and the wedge angle is 150, if the coefficient of friction at all surfaces of contact is 0.3, find the minimum force P required for doing the job

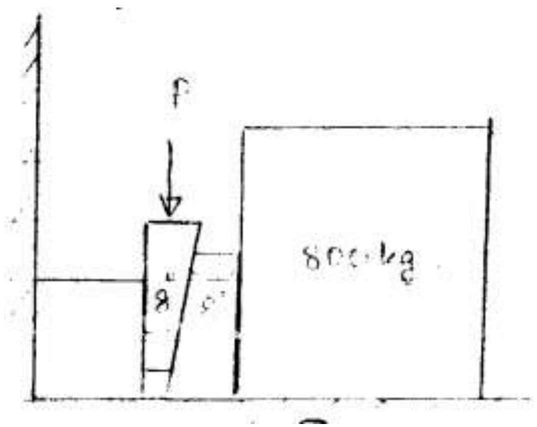


Problem -4

- Determine the horizontal force P to be applied to the wedge so as to raised the weight W of 2 KN. Assume the weight to be negligible weight and the contact surfaces between weight W and vertical wall are smooth. The coefficient of friction between weight W and the wedge is 0.25 and between wedge and lower block is also 0.25. is the system is self locking one?



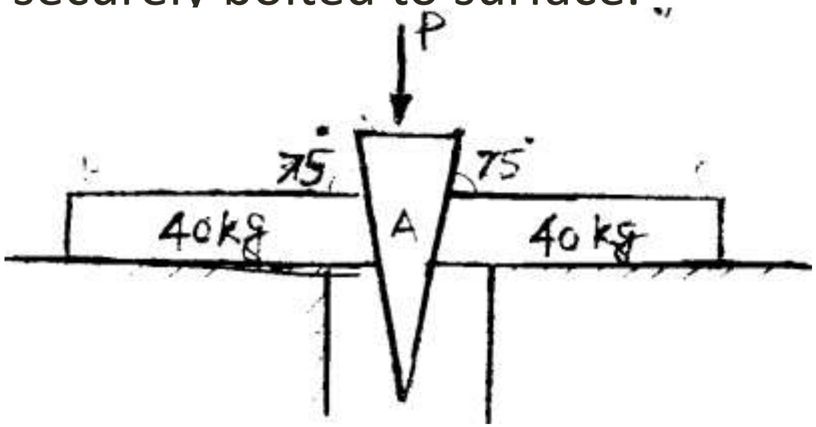
Problem - 5



- Two 8 degree wedge of negligible weight are used to move and position the 800 Kg block. Knowing that the Coefficient of static friction is 0.25 at all surfaces of contact, determine the smallest force P which should be applied as shown to one of the wedge.

Problem - 6

- A wedge A of negligible weight is to be driven between two 40 Kg plates B and C. The Coefficient of static friction between all surfaces of contact is 0.35. Determine the magnitude of force P required to start moving the wedge
  - If the plates are equally free to move.
  - If plate c is securely bolted to surface.



Friction

Belt friction

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Belt drive

- Open belt drive
- Cross belt drive

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Speed ratio of the shaft

$$\frac{N_2}{N_1} = \frac{D_1}{D_2}$$

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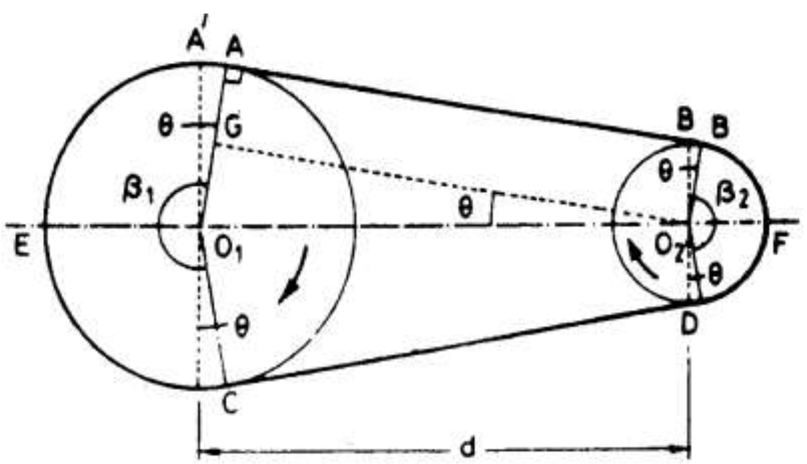
Length of belt for Open Belt Drive

Open belt drive

$$L = \left[\pi(r_1 + r_2) + 2d + \left(\frac{(r_1 - r_2)}{d} \right)^2 \right]$$



Angle of lap of open belt drive

- Angle of Lap:
  - For Larger Pulley : $\beta_1 = \pi + 2\theta$
  - For Smaller Pulley : $\beta_2 = \pi - 2\theta$

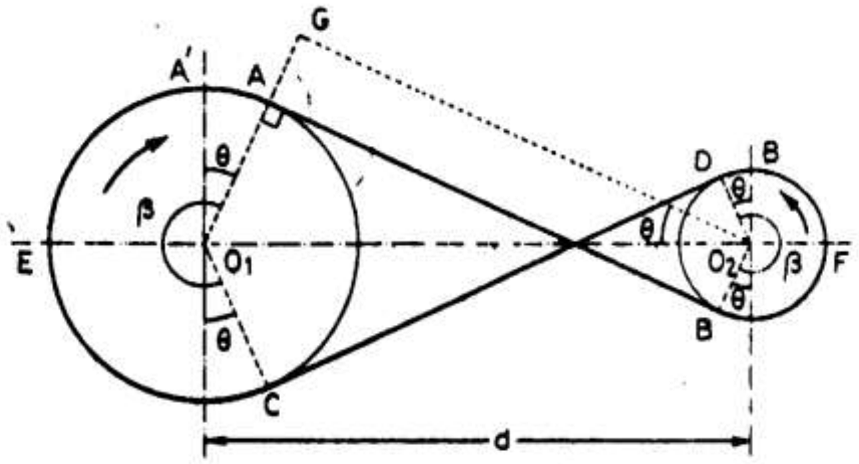
Where

$$\sin\theta = \frac{r_1 - r_2}{d}$$

Length of belt for cross belt drive

Cross belt drive

$$L = \left[\pi(r_1 + r_2) + 2d + \left(\frac{(r_1 + r_2)^2}{d} \right) \right]$$



Angle of lap for cross belt drive

- Angle of lap for both pulley : $\beta_1 = \pi + 2\theta$

where

$$\sin\theta = \frac{r_1 - r_2}{d}$$

Ratio of Tensions

Flat belt

$$\frac{T_1}{T_2} = e^{\mu\beta}$$

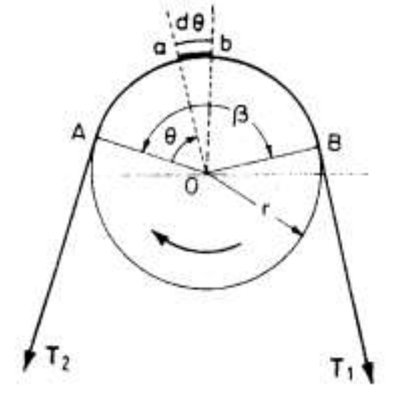
Where

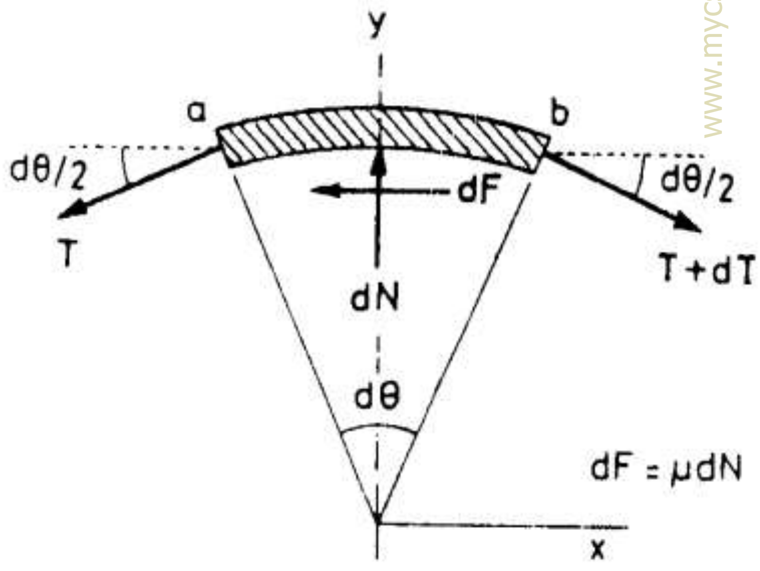
T_1 = tension in tight side

T_2 = Tension in slack side

μ = coefficient of friction

β = Angle of lap





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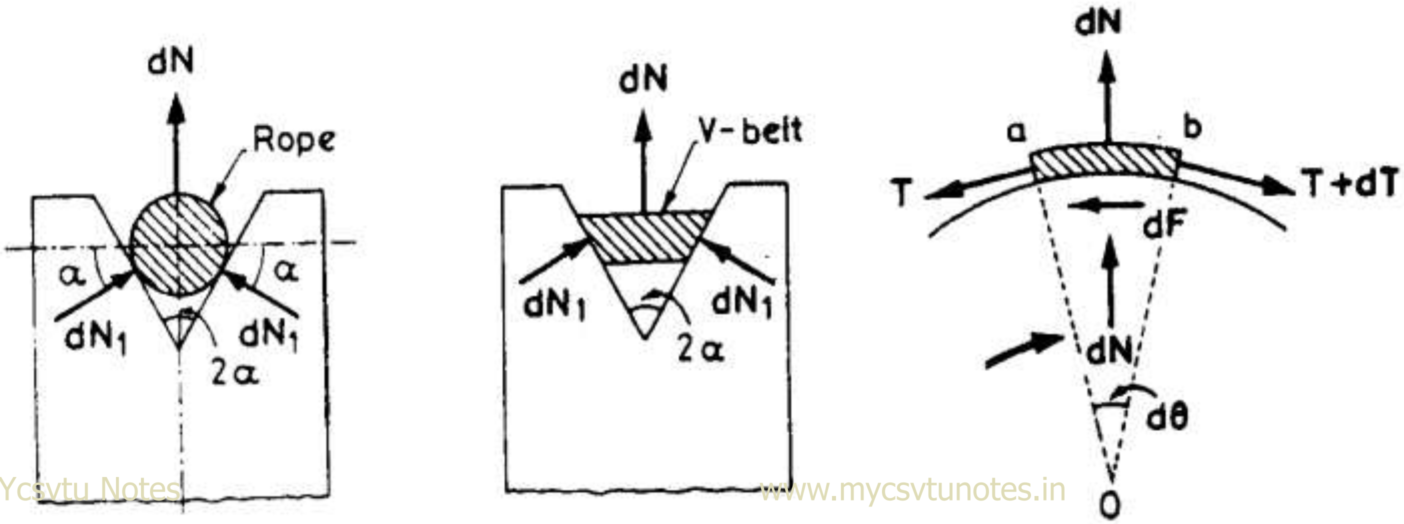
Ratio of Tensions

- V- Belt Drive

$$\frac{T_1}{T_2} = e^{\mu \beta \operatorname{cosec} \alpha}$$



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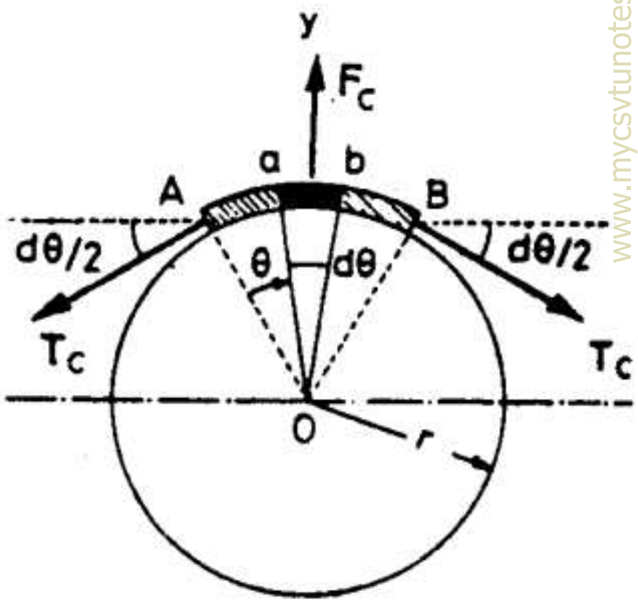
Centrifugal Tension in the belt

A belt running over a pulley experiences a centrifugal force similar to what a body experiences while moving in a circular path. This centrifugal force changes the values of the tensions on the two sides of the belt but it comes into play only when the belt is moving.

Centrifugal tension is given by

$$T_c = mv^2$$



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Centrifugal Tension in the belt

- Following points may be noted

  - Centrifugal tension is the additional tension in the belt due to the centrifugal force. So when the belt is in motion;

  The tension in tight side = $T_1 + T_c$
  The tension in slack side = $T_2 + T_c$

- Centrifugal tension depends only on the mass of the belt per unit length and the speed of the belt, so the expression for centrifugal tension is same for the flat belt and cross belt drive

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Initial Tension in belt

- When the belt is laid on the pulleys and is stationary, the tensions on the two sides of the belt are same. This tension T_o is called the initial tension in the belt.
- Some initial tension has to be given to the belt so that it grips the pulleys.
- As the belt comes into motion, tensions on the two sides become different. They are called driving tension.
- Let us assume,
  - (i) That the material of the belt is perfectly elastic
  - (ii) That the total length of the belt remains unchanged.
- Initial Tension is given by

$$T_0 = \frac{T_1 + T_2}{2}$$

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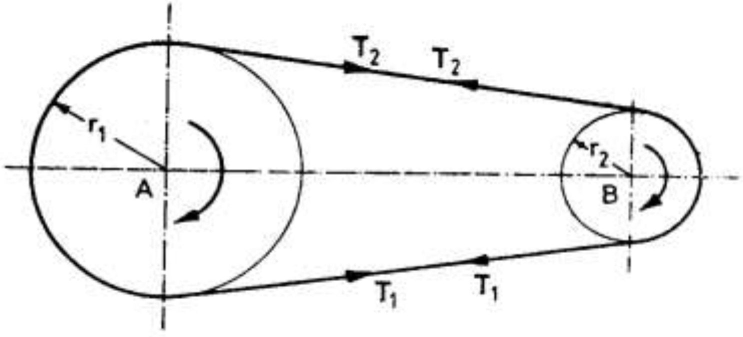
Power Transmitted by belt

- Power transmitted by belt:

$$P = (T_1 - T_2)v$$



Condition for the Transmission of maximum power

- The power transmitted is maximum when the centrifugal tension in the belt is one third the maximum permissible tension T_m in the belt.

$$T_c = \frac{T_m}{3}$$

- Thus the maximum power transmitted

$$P_{\max} = \frac{2}{3} T_m \left(1 - \frac{1}{K}\right) v$$

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Mechanical Strength of the belt

- The maximum tension that can be permitted in a belt shall depend upon the mechanical strength of the belt.

  $T_{max} = \sigma_m$ x (the area of cross-section area of the belt)

  - Where,

    σ_m =Maximum permissible stress allowed in the belt

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Problem - 1

- Find the power transmitted by a cross belt drive connecting two pulley of 45.0 cm and 20.0 cm diameters which are 1.95 m apart. The maximum permissible tension in the belt is 1 KN, coefficient of friction is 0.2 and the speed of larger pulley is 100 r.p.m.

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Problem - 2

- A belt 100 mm wide and 8.0 mm thick is transmitting power at a belt speed of 1600 m/minute. The angle of lap for the smaller pulley is 165° and the coefficient of friction is 0.3. The maximum permissible stress in the belt is 2 MN/m^2 and the mass of the belt is 0.9 kg/m. Find
  1. The power transmitted and the initial tension in the belt.
  2. maximum power that can be transmitted and the corresponding belt speed

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Problem - 3

- 86 kW of power is to be transmitted between two equal pulleys of 30.0 cm diameter and rotating at 1500 rpm by using an open V-belt drive. The angle of the groove is 30°, the density of the belt material is 1.2 Mg/m^3, the safe stress in the belt is $7 MN/m^2$ and the coefficient of friction is 0.12. Determine the cross-sectional area of the belt that is required.

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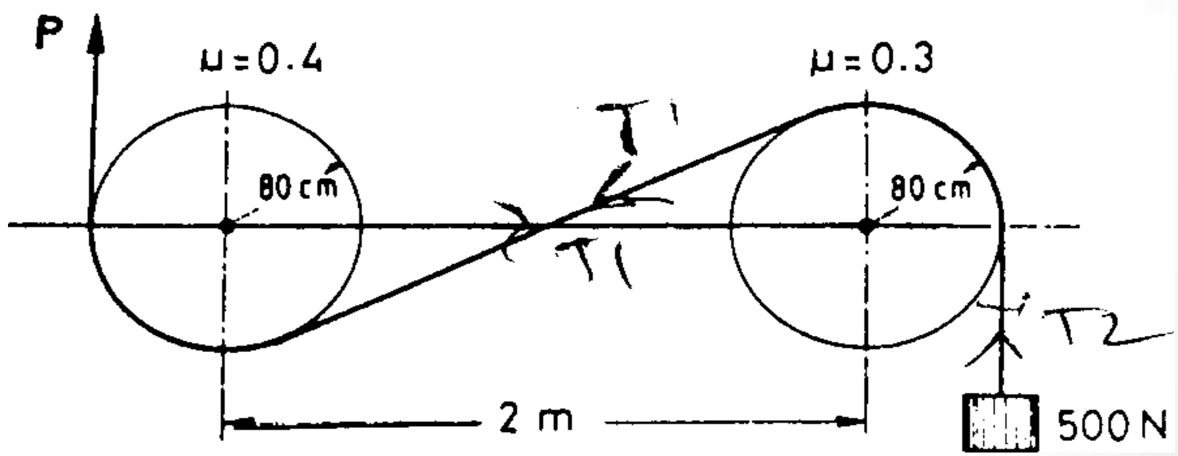
Problem - 4

- A rope is looped around two pulleys as shown in Fig. P. 7.1. Determine force P required to hold the weight of 500 N.



Problem - 5

- Two parallel shafts 6 meters apart are fitted with 30 cm and 40 cm diameter pulleys which are connected by means of a cross belt. If the direction of rotation of the driven pulley is to be reversed by changing over to an open belt drive,, determine the length of the belt that must be reduced

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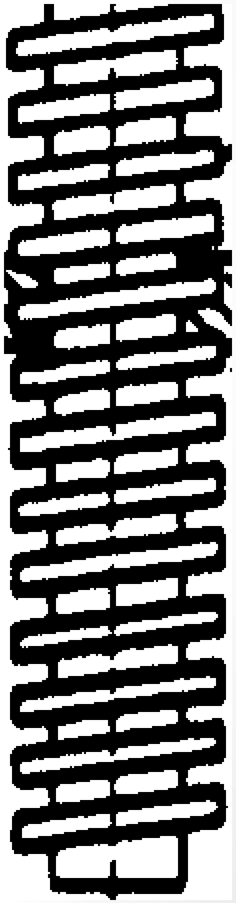
Friction

Screw friction



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Types of thread

- V-Thread
- Square Threaded Screw

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Defined Terms in Screw Friction

Pitch:

It is the axial distance measured between two consecutive threads

Lead:

It is the axial distance advancement in one complete revaluation

Lead = pitch x n

Where n = No. of start

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Defined Terms in Screw Friction

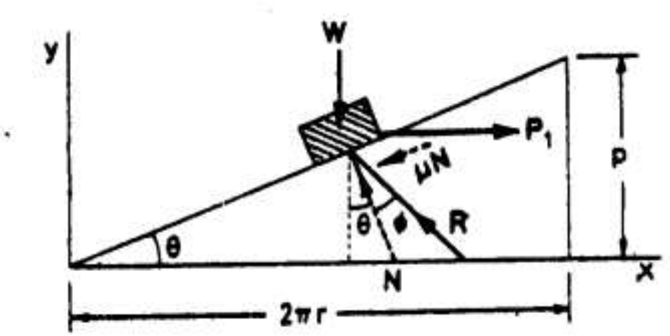
Helix:

It is the curve trace by a point in such a manner that a point moves in constant radius in a plane as well as same time there is uniform axial advancement

Helix angle:

$$Tan\theta = \frac{Lead}{\pi D} = \frac{n \times Pitch}{\pi D}$$

An angle made by any one of the thread from horizontal



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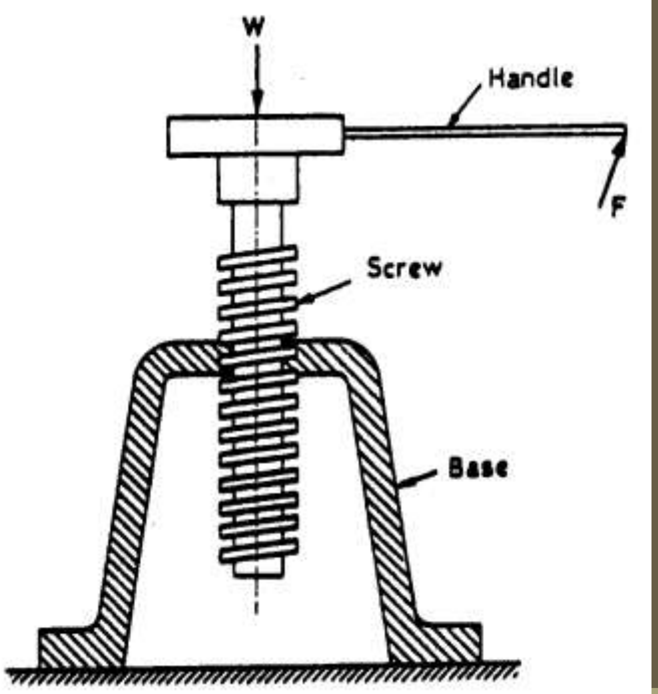
Effort required to lifting and lowering the load

Effort required to lifting load

$$P = W \tan(\phi + \theta)$$

Effort required to lowering load

$$P = W \tan(\phi - \theta)$$



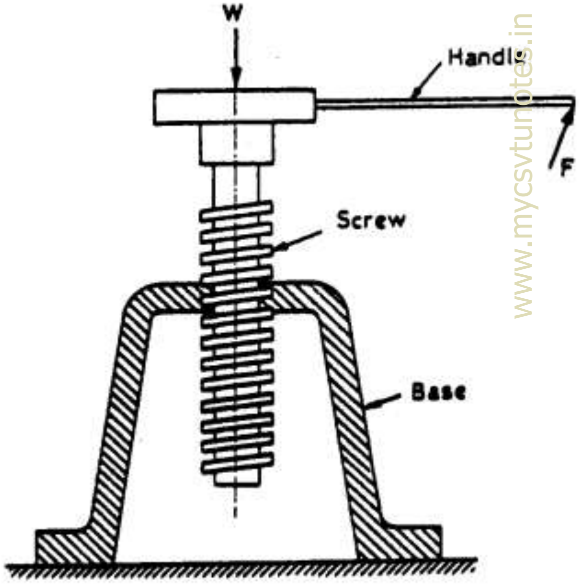
Effort required at the end of lever

Torque required to lift load

$$M_t = P \times \frac{D}{2} = W \tan(\phi + \theta) \times \frac{D}{2}$$

Torque required at the end of lever

$$M_t = P \times \frac{D}{2} = Q \times L$$



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Efficiency of screw

Efficiency of screw is given by

$$\eta = \frac{P_{ideal}}{P_{actual}} = \frac{\tan(\theta)}{\tan(\phi + \theta)}$$

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Condition for max. Efficiency

Condition for the maximum efficiency of the screw

$$\theta = \frac{\pi}{4} - \frac{\phi}{2}$$

Max. efficiency is given by

$$\eta_{max} = \frac{1-\sin\phi}{1+\sin\phi}$$

Self Locking machine and Efficiency of self locked screw

- When the load W on the screw remains in place even after the effort is removed (i.e. when effort is zero), it is called a self locking machine.
- Condition for self locking

$$\Phi > \theta$$

- Self locking Efficiency

$$\eta = (1/2) - (\tan^2\theta)/2$$

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Problem - 1

- A screw jack has square threads of mean diameter 6 cm, of helix angle 10° and coefficient of friction 0.3. Determine the force that must be applied to the end of 60 cm lever to (i) raise (ii) lower a weight of 3000 N.

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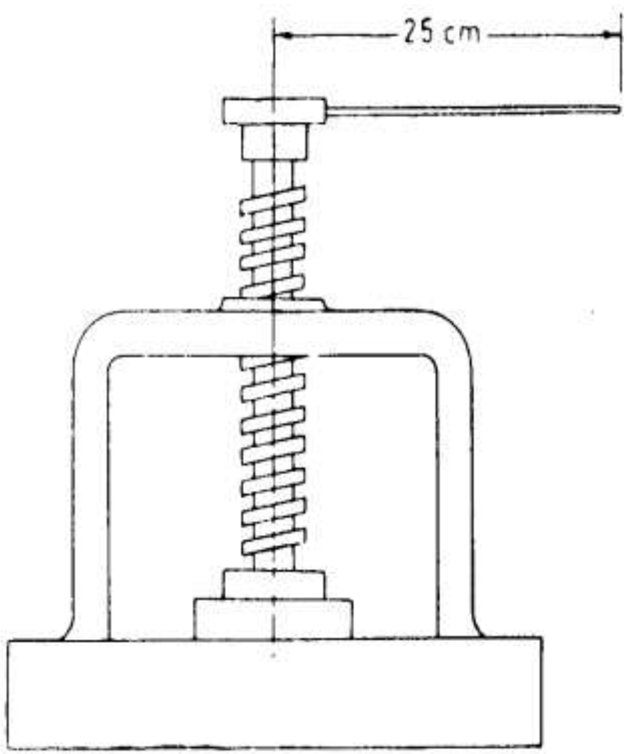
Problem - 2



- A wooden block is to be compressed by a force of 18 kN by a device shown in Figure The screw used has double start square threads of mean diameter 10 mm with a pitch of 2 mm and coefficient of friction 0.30. Find the force required to be applied at the end of the lever 25 cm long.

Problem - 3

- A screw jack having square threads of mean diameter 6.25 cm and the pitch of 12.5mm has a coefficient of friction $\mu = 0.05$. find
  - The tangential force which should be applied at the end of 30 cm long handle to raise a load of 5000 N.
  - Whether the jack is self-locking? If not find the torque required to keep the load from descending.

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Friction

Vehicle friction on inclined plane

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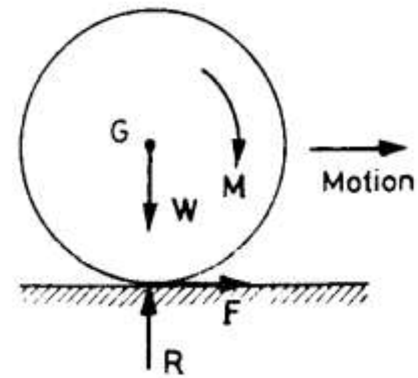
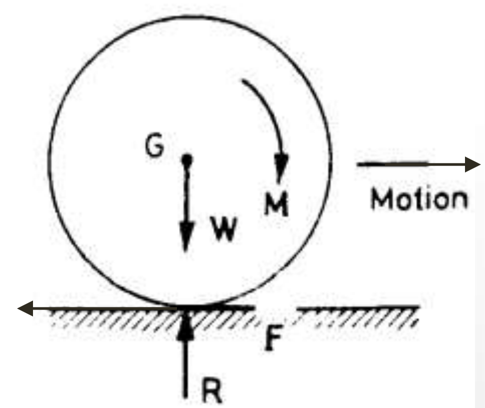
Vehicle friction on inclined plane

- when rolling on a plane



- when braked on a plane



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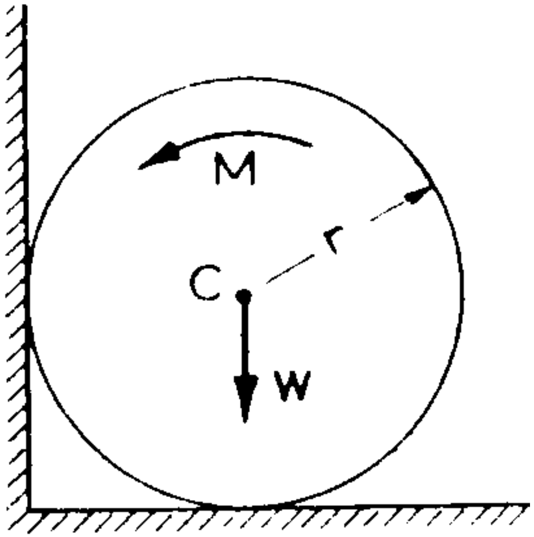
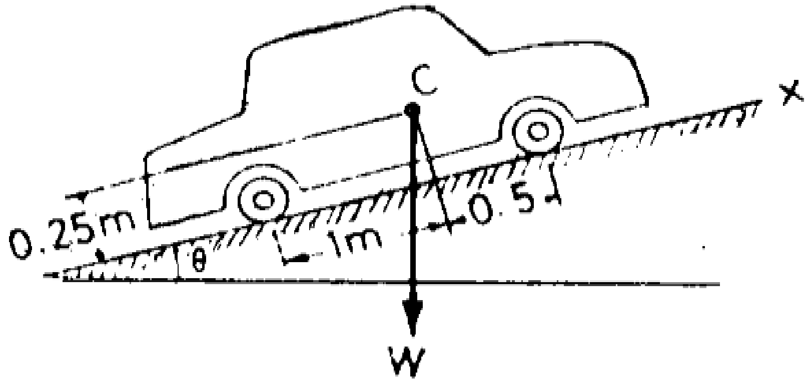
Problem - 1



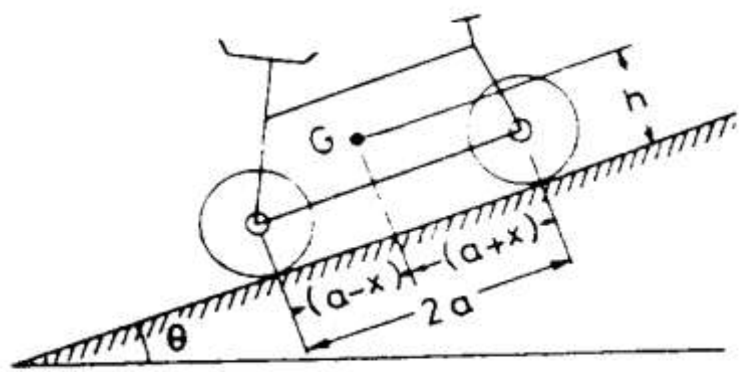
- A homogenous cylinder of weight It rests on a horizontal floor in contact with a wall. If the coefficient of friction for all contact surfaces be μ. Determine the couple M acting on the cylinder which will start counter clockwise rotation.

Problem - 2

- **A** rear wheel drive car of mass 2000 kg is shown in Fig. The road is inclined at an angle θ with the horizontal. If the coefficient of friction between the tyres and the road is 0.3, what is the maximum inclination θ that the car can climb?



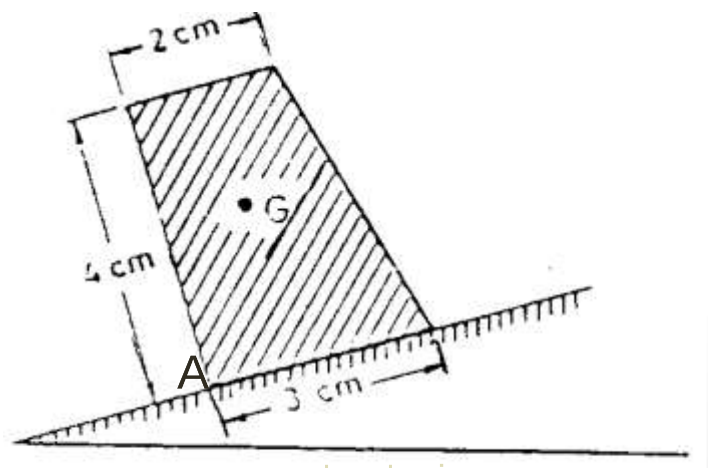
Problem - 3



- The distance between the centres of the wheels of a bicycle is 2 a and its centre of gravity is at a height h above the ground and at a distance x in front of its middle point. Find the greatest slope of the incline on which the bicycle can rest without slipping if
  - (a) the rear wheel is braked
  - (b) the front wheel is braked. The coefficient of friction between the tyre and the ground is μ.

Problem -4

- A block shown in Figure weighing 1000 N is resting on a rough horizontal plane. The plane is gradually lifted to increase the angle θ. Determine whether sliding of block or overturning about A will occur first and the angle at which it occurs. Assume $\mu = 0.3$.



Problem - 5

- A right cone of the height *h* and the base of radius *r* rests on an inclined plane as shown in Fig. The coefficient of friction between the plane and the cone is μ.If the angle of the inclination of the plane is slowly increased till the cone is just at the point of toppling over find the relation between μ, r and *h.*