NOTES

With Assignments, Sessional Papers with Solution and Model Question Papers

ON

ENGINEERING MECHANICS

(B.tech-1st year)

(ENGINEERING MECHANICS)

Index

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Unit 1: Two Dimensional Concurrent Force Systems

Engineering Mechanics is that branch of science, which deals with the behavior of a rigid body, when the body is at rest or in motion. The Engineering Mechanics is divided into

- Statics (study of body at rest) and
- Dynamics (study of body in motion)

Definitions:

- **Vector Quantity**: A quantity, which is completely specified by magnitude and direction, is known as a vector quantity. Some examples: Velocity, Momentum, Force, and Acceleration.

- **Scalar Quantity**: A quantity, which is completely specified by magnitude only, is known as a scalar quantity. Some examples: Mass, Length, Time, Temperature.

- **Body**: A body has a definite shape and consists of number of particles.

- **Particle**: A particle is a body of infinitely small volume, whose mass is considered to be concentrated at a point.

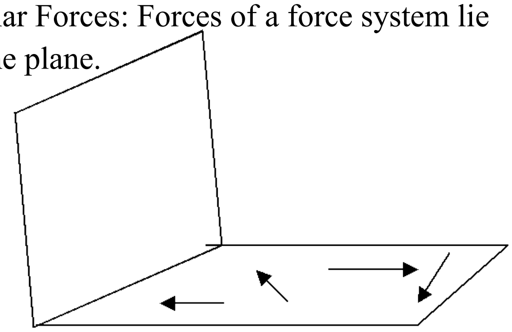
- **Mass**: Mass is an indication of the quantity of matter present within a system. (m)

- **Weight**: Weight is a force, which the system exerts due to gravitational acceleration. Weight is actually the force with which the system is attracted towards the earth. (W = m x g)

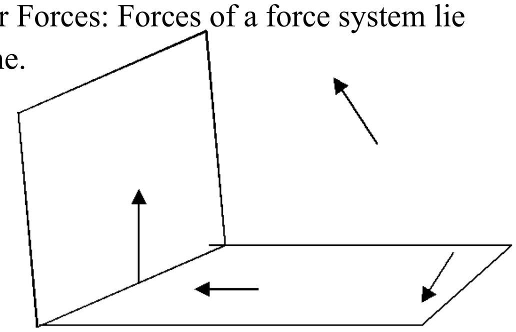
Force System:

Different forces acting on a body can be termed as a Force system and it can be further classified as:

1. Coplanar Forces: Forces of a force system lie in same plane.



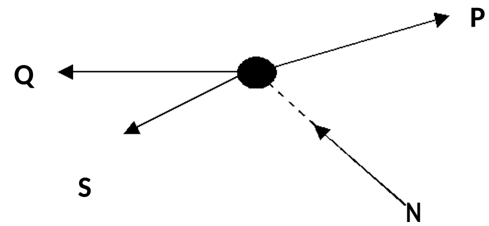
2. Non Coplanar Forces: Forces of a force system lie in different plane.



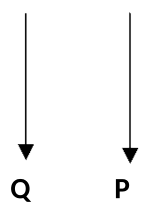
Forces are also classified as:

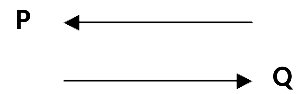
a. **Collinear forces**: Forces acting in same line of action. They may be in same direction (Like forces) or in opposite direction (Unlike forces).

b. **Concurrent Forces**: Forces intersecting / acting at a common point.



c. **Parallel forces**: Forces acting parallel to each other. They may be in same direction (Like forces) or in opposite direction (Unlike forces).





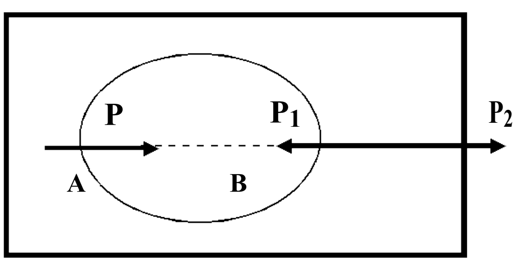
External forces include the applied force, normal force, tension force, friction force, and air resistance force. And for our purposes, the **internal forces** include the gravity forces, magnetic force, electrical force, and spring force.

Resultant and Equilibrant of a Force System:

The resultant is a trigonometric function, usually using the Law of Cosines in two dimensional solutions by vector resolution, of two or more known forces while equilibrant is equal in magnitude to the resultant, it is in the opposite direction because it balances the resultant. Therefore, the equilibrant is the negative of the resultant.

Principle of Transmissibility:

When the point of application of force acting on a body is shifted to any other point on the same Line of Action of the force without changing its direction, there occur no change in the Equilibrium State of the body.



$$P = P_1 = P_2$$

Free Body Diagram: A **free body diagram** is a graphical representation of an object, after isolating it from the surroundings to analyze the forces and moments acting on a body.

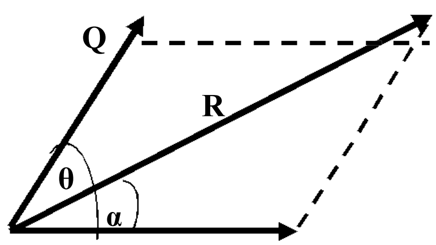
Methods to find the resultant of coplanar and concurrent forces as under:

a. Triangle Law of Forces:

If two forces (P and Q) are acting simultaneously on a body are represented by the sides of a triangle taken in order, the closing side of the triangle (R) taken in the opposite order represents their resultant.

b. Law of Parallelogram of Forces:

If two coplanar forces (P and Q) are acting at a point (i.e. concurrent force) be represented in magnitude and direction by the two adjacent sides of a parallelogram, then there resultant (R) is represented in magnitude and direction by the diagonal of the parallelogram passing through that point. The position of Resultant (R) with P is **α.**

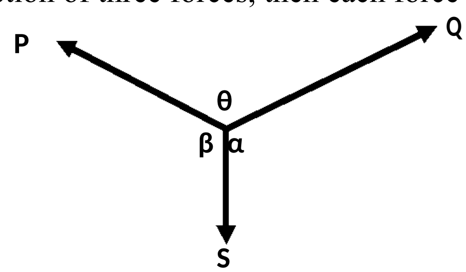


$$R^2 = P^2 + Q^2 + 2PQ \cos\theta;$$

$$\tan\alpha = Q \sin\theta / (P + Q\cos\theta)$$

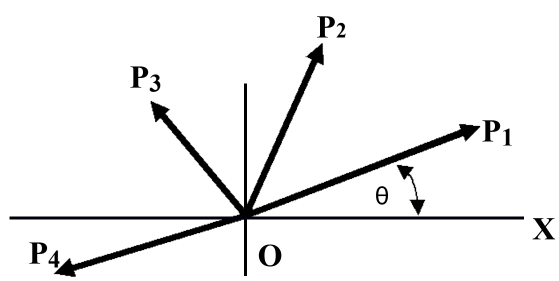
c. Lami's Theorem:

Lami's theorem states that if a body is in equilibrium under the action of three forces, then each force is proportional to the Sine of angle between the other two forces.



$$\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{S}{\sin\theta}$$

d. Resolution of Forces: The forces are making angle θ_1, θ_2, θ_3, and θ_4, with OX



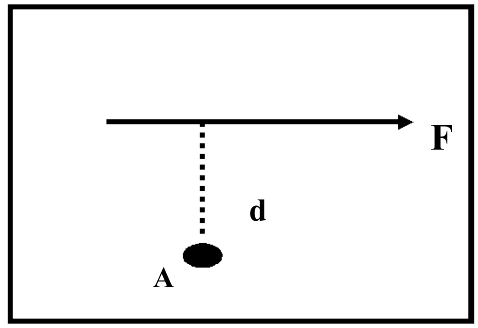
Components of Resultant Force along X axis	Components of Resultant Force along Y axis
$R_H = P_1\cos\theta_1 + P_2\cos\theta_2 + P_3\cos\theta_3 + P_4\cos\theta_4$	$R_V = P_1\sin\theta_1 + P_2\sin\theta_2 + P_3\sin\theta_3 + P_4\sin\theta_4$
Resultant $R^2 = R_H^2 + R_V^2$	$\tan\alpha = R_v / R_H$

Unit II: Two Dimensional Non-Concurrent Force Systems

Moment of a Force:

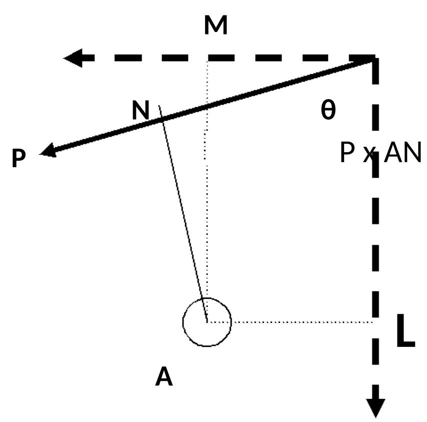
The product of a force and the perpendicular distance of the line of action of the force from a point is known as moment of the force about that point.

» **M = F x d**



Varignon's Theorem (Law of Moments):

Varignon's theorem states that the moment of a force about any point is equal to the algebraic sum of the moments of its components about that point.



Moment of Force **P** about **A** =

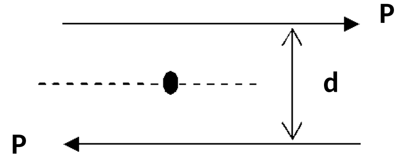
This can be calculated as per **Varignon's theorem**:

Principle of Moments:

Principle of Moments states that the moment of the resultant of a number of forces about any point is equal to the algebraic sum of the moments of all the forces of the system about the same point.

∑ Clockwise moment = ∑ Anti-clockwise moment for equilibrium condition

Couple: When two forces equal in magnitude and opposite in direction and separated by a definite distance are set to form a couple. **C = P x d**

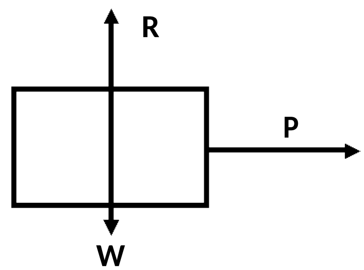


Friction

Introduction:

In the previous chapters it is assumed that the contact surface between two bodies is perfectly smooth in nature, so the bodies freely slide tangentially over one another but have no movement in the normal direction. To find an ideal condition of perfect smooth surface is not possible, even a glass surface or highly polished metal surface has some sort of surface irregularities, which can be seen through powerful magnification.

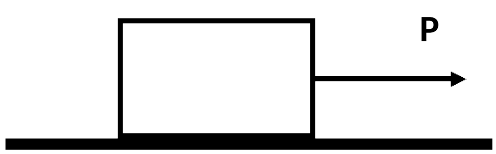
With such irregularities when one body slides or tends to slide over another body, a resistance is offered to its motion in opposite direction (tangential). This tangential resisting force is known as the force of friction, frictional force or simply friction and generally represented by "F".

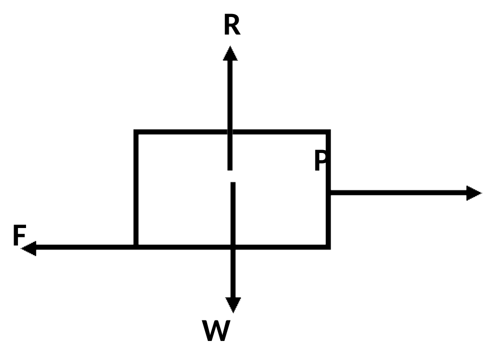


Perfectly smooth surface

Figure: Tangential Force (P) applied on a body kept on a perfectly smooth surface

From above figure it is clear that if a body is kept on as perfectly smooth surface, it will not be stable / equilibrium if a force P in tangential direction is applied on the body.





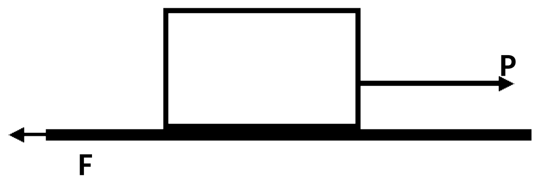
Rough surface

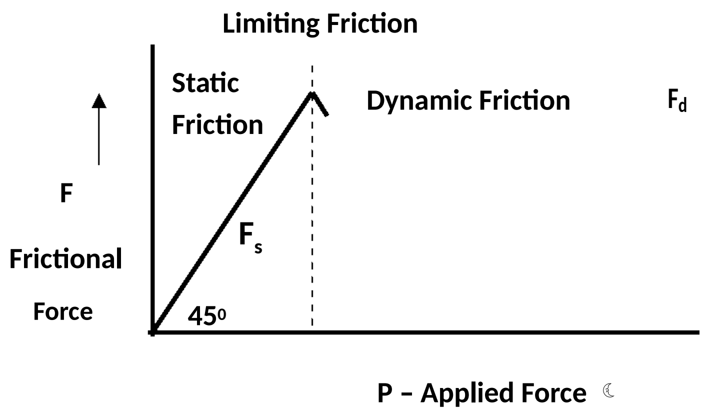
Figure: Tangential Force (P) applied on a body kept on a rough surface

Friction is considered as a necessary devil. In our day to day life we experience friction everywhere. Wear and tear of all parts having relative velocity causes loss of energy and power and reduces efficiency of machine parts resulting in financial losses. But at the same time friction is very much needed for our day to activities such as Friction between meteorite and air helps to increase its temperature and ignite it, protecting the living things on Earth. We can hold objects in our hand due to friction between finger prints and object. Foot prints increase friction and helps to stand up, and engineering equipments like belt and pulley, brakes and clutch systems, lifting machines etc.

Friction & its features:

Let's assume a body of weight W is placed on a rough surface, and we gradually apply a force P as shown in the figure. The frictional force F will act in opposite direction and the start opposing motion.





The above figure shows the graph drawn between applied force "P" and frictional force "F". Under static condition (no motion) there will a linear relationship between P and F. The friction under static friction is known as static friction (F_S) such as $F_S = P$. The maximum value of static friction is known as limiting friction, beyond which it can't increase further. At this stage the body is just start to move (impending motion). As the body starts moving, the friction force reduces and known as dynamic friction (F_d). The main characteristics of frictional force are listed as under:

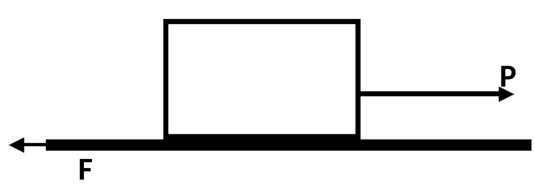
1. It always opposes the direction of motion
2. It is a passive force, if there is no applied force, there will be no frictional force

Nature of friction:
Friction is classified into two categories:

a. Dry friction
b. Fluid friction

Dry friction: It is also known as coulomb friction. It appears when the contact surfaces are dry, and there is tendency for relative motion. It is further classified into:

a. **Sliding Friction:** Sliding friction is the friction produced between surfaces, which slide over each other.



b. **Rolling Friction: Rolling friction is the f**riction produced between two surfaces, which are separated by balls or rollers.

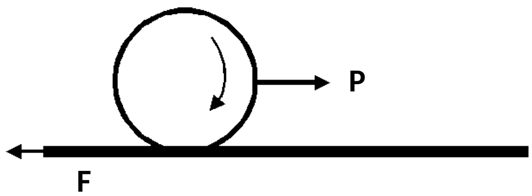


Figure: Rolling Friction

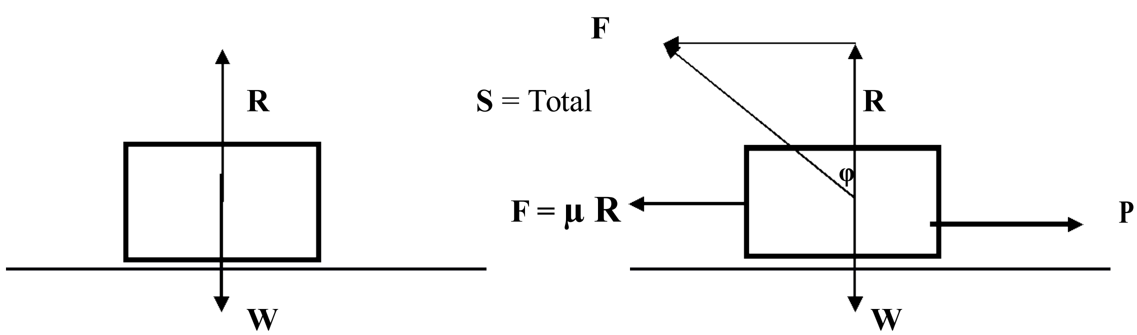
It is experienced that the sliding friction is always greater than rolling friction.

2. Fluid Friction: This is the friction between two surfaces when one is fluid (Gas or liquid). It exists when a lubricating fluid is introduces between the two contact surfaces

Friction is further classified based on motion as under:

1. **Static Friction:** It is developed between two mating surfaces, which are subjected to an external force, but there is no relative motion between them.
2. **Dynamic Friction:** It is also known as kinetic friction and developed between developed two mating surfaces, which are subjected to an external force, but there is relative motion between them.

3.4: Various terms related to friction:



1. Coefficient of Friction (μ): The coefficient of friction is defined as the ratio of force of friction (F) to the normal reaction (R) between the contact surfaces.
If the contact surfaces are smooth coefficient of friction is low and it increases with the increase in roughness between the two contact surfaces.

Following Table shows the approximate coefficient of friction between various materials

Sr. No.	Materials		Static friction, μ_s
1	Aluminium	Steel	0.61
2	Copper	Steel	0.53
3	Brass	Steel	0.51
4	Cast iron	Copper	1.05
5	Cast iron	Zinc	0.85
6	Concrete (wet)	Rubber	0.30
7	Concrete (dry)	Rubber	1.0
8	Concrete	Wood	0.62
9	Copper	Glass	0.68
10	Glass	Glass	0.94
11	Metal	Wood	0.2 to 0.6
12	Steel	Steel	0.80
13	Wood	Wood	0.25–0.5
14	Rope	Wood	0.5 to 0.70
15	Leather	Metal	0.3 to 0.5

2. Angle of Friction: It is defined as the angle, which the resultant of normal reaction and limiting force of friction makes with the normal reaction, and denoted by **φ,** as shown in the figure 3.7.

R is the normal reaction and F is the limiting force of friction. With the help of law of parallelogram of forces the resultant S can be calculated as underA:

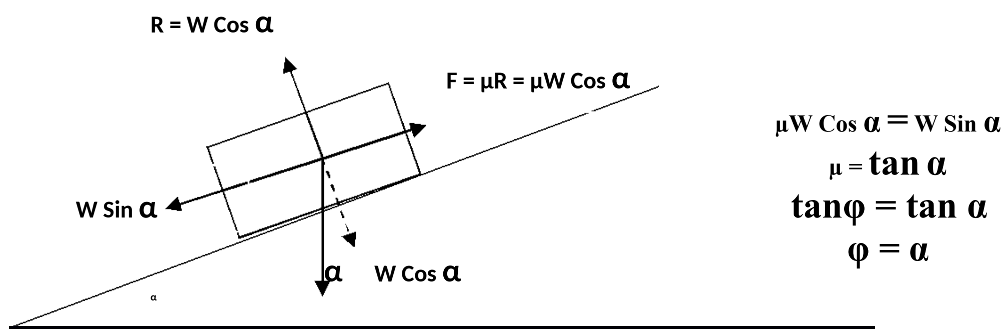
$S^2 = R^2 + F^2$

And $\tan \varphi = F / R$

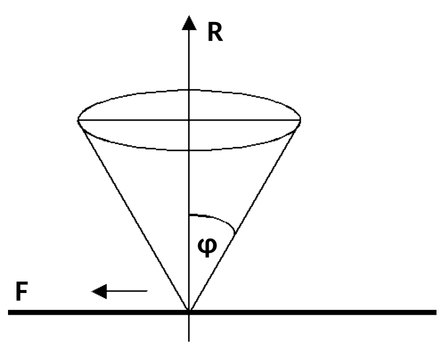
so

$\mu = \tan \varphi = F / R$

3. **Angle of Repose:** The angle **α** of the inclined plane at which a block resting on it is about to slide down is called the angle of repose and it is equal to the angle of friction.



4. Cone of Friction: When the total reaction is revolved around the normal reaction a Cone Shape is formed. The apex angle is **2 φ**. This cone is called Cone of friction.



Laws of Limiting friction (Laws of Coulomb friction):

The laws of coulomb friction which are based on experimental evidences are listed as under:

1. The magnitude of the limiting (maximum) static frictional force depends upon the nature of the surfaces in contact and on their roughness (or smoothness). It does not depend upon the size or area of the surfaces.
2. The force of friction is tangential (parallel) to the surfaces in contact and its direction is opposite to the direction in which the body would start moving.
3. For the given surfaces, the limiting frictional force f_s is directly proportional to the normal reaction R:

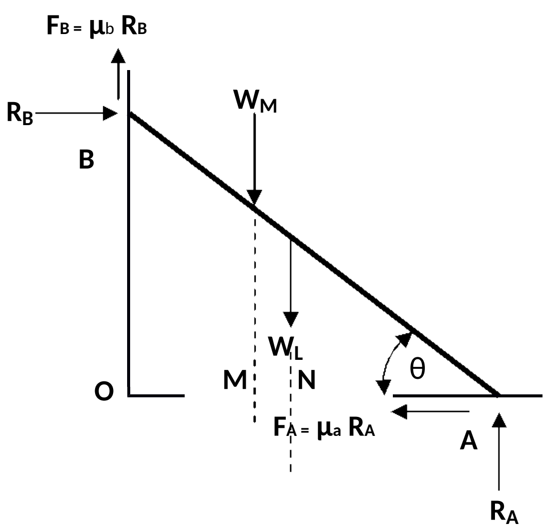
$$F \propto R$$

$$F = \mu R$$

$$F/R = \mu$$

Ladder Friction:

Ladders are commonly used to climb the walls or roofs and many a times we have experienced that the ladders gets slipped causing harm to the person using it. To understand this phenomenon we must check the equilibrium status of all acting forces in this non concurrent force system. Following is the mathematical model for few cases of a ladder.



A Ladder of Length "**L**" m and weight "W_L" is resting against a wall making an angle **'θ'.** The coefficient of friction between ladder & floor is μ_a wall & between ladder and wall is μ_b.

A person of weight W_M starts climbing on the wall

*{If the wall is mentioned as **SMOOTH WALL** it means that there is no friction, hence Coefficient of friction (**μ**) between wall & Ladder is **zero**. But the floor will not be smooth, in such case the ladder will slip}*

Given

AB = L meter; Hence OA = L Cos θ and OB = L Sin θ

As the weight of ladder will act at its centre: AN = ½ OA = ½ L Cos θ

Let's assume the person will climb up to a height of X meters from A and at that point the Ladder will start sliding / slipping. Hence **OM = X Cos θ**

Considering the whole system we apply

$$\Sigma F_Y = 0 \Rightarrow \quad \mu_b R_B + R_A = W_L + W_M \quad \text{------ } 1$$

$$\Sigma F_x = 0 \Rightarrow \quad \mu_a R_A = R_B \quad \text{-------------- } 2$$

From equation 1 and 2: $R_A = (W_L + W_M) / (1 + \mu_a \times \mu_b)$

Hence $R_B = \mu_a \{(W_L + W_M) / (1 + \mu_a \times \mu_b)\}$

Now let's apply the Moment Equation $\Sigma M_A = 0$,

$$W_L \times AN + W_M \times AM = R_B \times OB + \mu_b R_B \times OA$$

By putting value we will get "X" - the distance travelled by person on the Ladder.

Case II: If the person is standing at a known distance (say X meters) from "A" the angle of inclination is to be calculated with the help of three equations we can get the sin θ /cos θ = tan θ in moment equation.

CASE III: The person is standing at a known distance (say X meters) from "**A**" and a horizontal Force "P" is applied at "A" (or a rope/ string / Rod is tied with Tension "T" to prevent the ladder to slide / slip. The three equations will be

$$\Sigma F_Y = 0 \Rightarrow \quad \mu_b R_B + R_A = W_L + W_M \quad \text{------ } 1$$

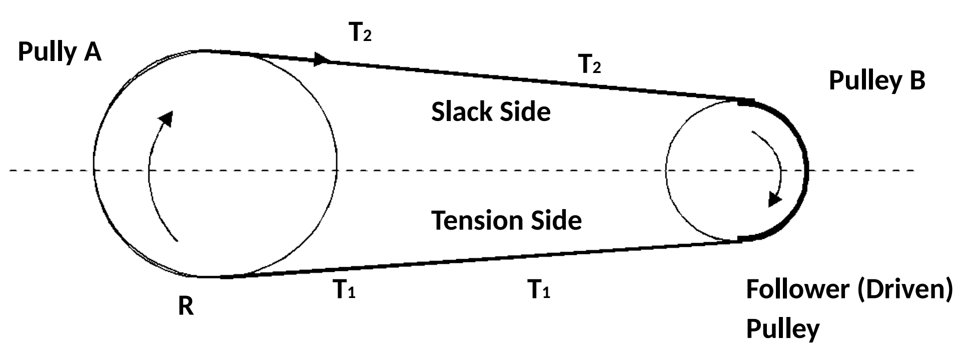
$$\Sigma F_x = 0 \Rightarrow \quad P + \mu_a R_A = R_B \quad \text{-------------- } 2$$

$$\Sigma M_A = 0 \Rightarrow \quad W_L \times AN + W_M \times AM = R_b \times OB + \mu_b R_b \times OA \text{ ------------- } 3$$

R_B will be calculated from equation 3 and by putting the value in I and II we will get the value of "P" or Tension in the String / Chain / Rod.

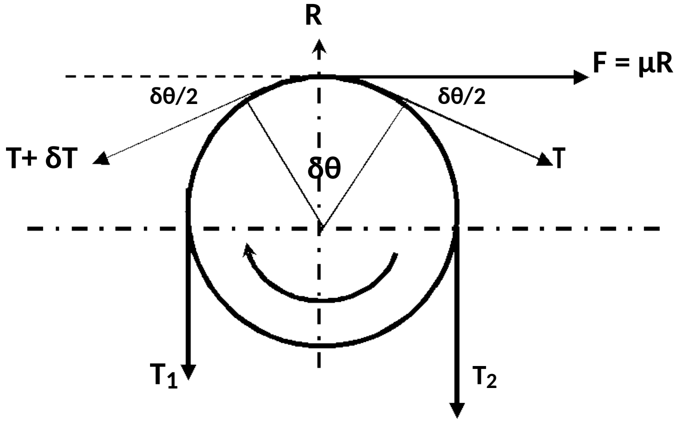
Rope and Belt Friction:

Belt and pulley system is a popular means of power transmission. Pumps with diesel engines, flour mills, machines such as centre lathe, uses belt and pulley system.



The pulley A which is attached to the shaft of prime over (electric motor or diesel engine in most of the cases) is known as driver and the other pulley which is driven is known as follower or driven pulley. The belt is carried by the driver pulley along with it due to friction between the pulley and belt. Which results in belt carries the follower with it. The driver pulls the belt from one side, which is known as tension side and delivers it to the other side known as slack side4. The belt tension in tension side (T_1) is more than the slack side (T_2).

Belt Friction: The ratio of driving tension in Flat type Belts.



A belt driven pulley rotating in anti clockwise direction is shown in figure.

Let's take

T_1	=	Tension in Tight Side
T_2	=	Tension in Slack Side
θ	=	Contact angle of belt with pulley
$\boldsymbol{\mu}$	=	Coefficient of friction between Belt & Pulley

Let's consider a small portion of the belt making an angle $\boldsymbol{\delta\theta}$ with the center of pulley.
Let's **T** and **(T + δT)** are the tensions in slack and tight sides respectively.

Now it is clear from the above figure that the Belt is under equilibrium under the action of forces:

a. Tension **T** in slack side

b. Tension **T + δT** in tight side

c. Normal reaction **R**

d. Frictional Force **μR**

Now we will resolve the forces in horizontal direction (Tangential Direction)

$\mu R + T\cos\delta\theta/2 \quad = \quad (T + \delta T)\cos\delta\theta/2$ {Since $\delta\theta$ is very small $\cos\delta\theta/2 = 1$}

$\mu R + T \quad = \quad (T + \delta T)$, hence $\mu R = \delta T$ - --------- (1)

Now we will resolve the forces in Vertical direction (Radial Direction)

$R \quad = T\sin\delta\theta/2 + (T + \delta T)\sin\delta\theta/2$ {Since $\delta\theta$ is very small $\sin\delta\theta/2 = \delta\theta/2$}

$R \quad = T\,\delta\theta/2 + T\,\delta\theta/2 + \delta T\,\delta\theta/2 \quad = T\,\delta\theta$ ----- (2) {$\delta T\,\delta\theta/2$ is neglected}

Equating (1) and (2) we get,

$\mu\,(T\,\delta\theta) \quad = \quad \delta T$ so $\delta T/T = \mu\,\delta\theta$ on integrating we get

$$\int_{T_1}^{T_2} \delta T/T = \int_0^{\theta} \mu\,\delta\theta$$

$\mathrm{Log}_e\,(T_1 / T_2) \quad = \quad \mu\theta$; taking antilog we get $T_1 / T_2 = e^{\mu\theta}$

Structural Mechanics: Trusses

Engineering Structures:

Engineering Structures may be defined as systems of number of members connected to one another to support or transfer forces acting on them and to withstand these forces safely. When heavy loads are to be resisted or the Span is very high then a Beam cannot work. In such cases steel members such as Bars, Angles, Channels etc, are used and joined together to design Framed Structure to carry the heavy Loads.

Engineering Structures may be broadly divided into (a) Trusses (b) Frames (c) Machines

(a) **Trusses:** A truss may be defined as a system of uniform members joined together at their ends by riveting etc. The truss is formed from *two-force members*, i.e., members of truss are straight members with end point connections, And loads are applied only at joints. Simplest truss is triangular truss. The individual part of the structure is called Member. The members are joined either by welding or riveting / nut & bolts. The members are Slender (cross sectional dimensions are quite small compared to the length) and are usually of angle section, T-section, I-section etc. The roofs of sheds at Railway platforms, workshops and Industrial buildings, and bridges etc are some of examples of a TRUSS. A truss is shown in below figure.

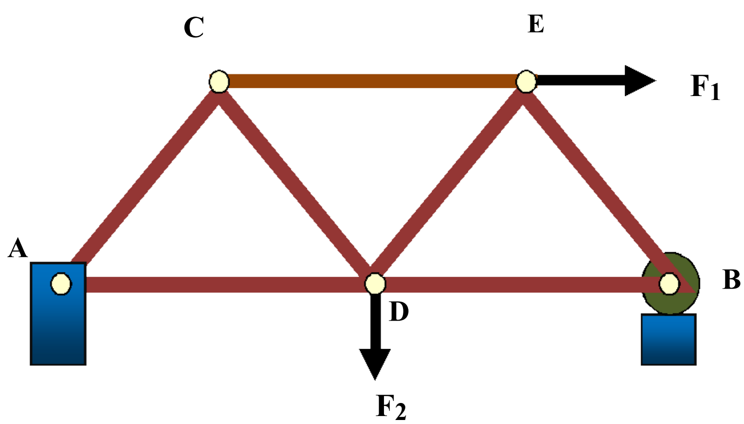
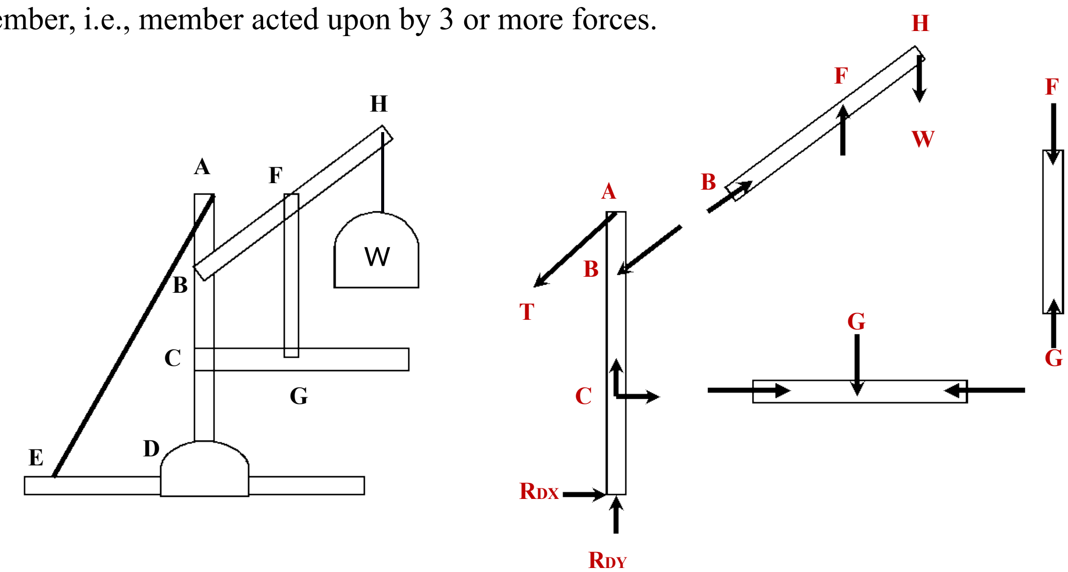


Figure: Truss

(b) **Frames:** In frames, forces may act anywhere on the members. Trusses and frames are used in roofs of sheds of railway stations (platforms), workshops, buildings, bridges etc. Frames contain at least one multi-force member, i.e., member acted upon by 3 or more forces.



(c) **Machines:** Machines are structures designed to transmit and modify forces and they contain some moving parts. For example Centre lathe, drilling machine etc

In this chapter only analysis of plane Trusses is considered.

Classification

Types of Trusses: Trusses may be of following types:

a) **Plane Truss or Space Truss:** In plane truss all the members lie in the same plane and the forces act along the plane of the truss, e.g. Bridge Trusses and roof trusses. In Space truss all the members do not lie in the same plane, e.g. suspension tower, Tripod etc.

b) **Statically Determinate and Statically Indeterminate Truss:** The force analysis can be done by equation of static in the case of S.D.F. Only static equations are not sufficient there is need of considering their deformation also in case of SIF.

c) **Perfect or Rigid Truss:** This is non-collapsible when external supports are removed. A perfect truss is the one, which contains such number of members as are just sufficient to prevent distortion of its shape when loaded externally. A perfect truss should satisfy the equation, $m = 2j - 3$, where m = no. of members, j = no. of joints.

Note: Equation gives only a necessary but not a sufficient condition of a perfect truss. The only necessary and sufficient condition of a perfect truss is that it should retain its shape when load is applied at any joint in any direction.

d) **Imperfect Truss:** Imperfect Trusses are of two types:

(i) **Deficient or Collapsible Truss:** A truss that contains less members than required to be just rigid and is collapsible, is known as Deficient truss. It cannot resist distortion/ retain its shape under external load. $m < 2j - 3$.

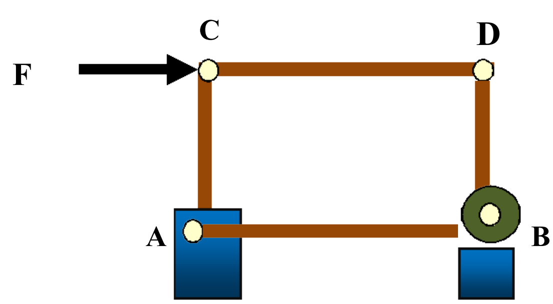


Figure: Deficient / Collapsible Truss

(ii) Redundant or Over Rigid Truss: A truss that contains more members than required to be just rigid, is known as redundant or over rigid truss. $m > 2j - 3$, since number of unknowns $(m+3)$ are more than number of equations $(2j)$ hence such a truss is statically indeterminate.

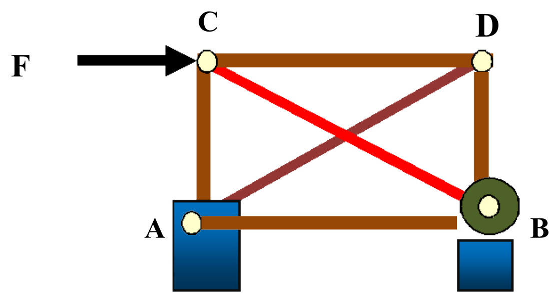


Figure: Redundant / over rigid Truss

Nature of Forces:

Members can either experiences tensile force or compressive force. To phenomenon is explained through this illustration. Force P (Tensile) is applied on member AB as shown in the figure (a)

Figure (a): A pull of P is applied at Member AB.

Now to maintain the equilibrium status an equal and opposite reaction ($F_{AB} = F_{BA}$) will be developed.

Now if we see only reaction in the member, it may look like that the member has a compressive force, but as reaction is always opposite in direction the member is under the influence of a tensile force equivalent to the reaction i.e. $F_{AB} = F_{BA}$

And member under compressive force will look like

Members under compressive forces are called Strut, while members under tensile force are known as Tie rod. Members with no force are known as Null members.

Reactions at Supports of Truss:

Trusses are usually supported on hinged support at both the ends or hinged support at one end and Roller support at the other end. One support must be hinged. Otherwise the truss is of Cantilever type.

Basic Assumptions of Truss Analysis:

Following assumptions are made while making such analysis:

1. All members of truss are pin joined. The forces are transmitted from one member to another through smooth pins (no friction).
2. The truss is a perfect one and statically determinate.
3. All the members are straight, rigid, slender, and uniform in cross section and lie in same plane.
4. The external loads and reactions are acting at Joints only.
5. The self-weight of members is neglected.
6. Every joint is treated separately as a free body in equilibrium, i.e., the sum of all the vertical forces as well as the horizontal forces acting on the joint is equated to zero.

$\Sigma Fx = 0$ and $\Sigma FY = 0$

Methods of Truss Analysis:

To analyze a truss means finding the forces in various members. There are two methods to find the forces in members:

a. **Graphical Method**
b. **Analytical Method**

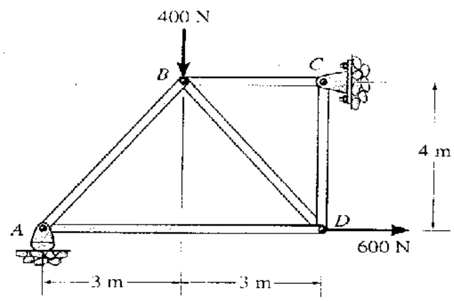
The analytical method is further classified into two methods:

1. **Method of Joints**
2. **Method of Sections**

Method of joints: The following procedure is used for analysis of trusses

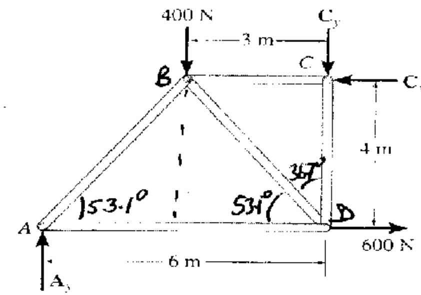
i. Check that truss is a perfect truss ($m = 2j - 3$)
ii. Consider the free body diagram of entire truss and compute the support reactions using the equations of equilibrium ($R_x = 0$, $R_y = 0$, $M_A = 0$). Determination of support reaction may not be necessary in case of cantilever type of truss.
iii. Assume and mark directions of the axial forces in the members away from the joint on the diagram.
iv. Consider equilibrium of each joint independently and calculate magnitude of axial forces in members. Conditions of equilibrium are $Rx = 0$, $R_y = 0$. Hence at a time only two unknown forces can be determined. Therefore start from a joint at which not more than 2 unknown forces appear.
v. If the magnitude of the force comes out to be negative, the nature of force in that member is compressive and if it is positive than nature of force in that member is tensile.
vi. If the force is pushing the joint, it is compressive and if it is pulling the joint, it is of tensile nature.

Example 1: Determine the force in each member of the truss shown. Indicate whether the members are in tension or compression.



(a)

Space diagram



(b)

Free-body Diagram.

External Forces Determination

$\sum$ Fx = 0 i.e. 600 N - Cx = 0 , Cx = 600 N

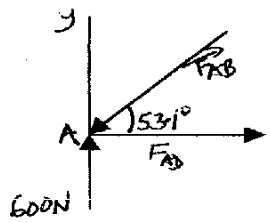
$\sum$ Mc = 0 i.e. - Ay (6 m) + 400 N (3 m) + 600 N (4 m) = 0

6 Ay = 1200 + 2400 = 3600 N, Ay = 600 N

$\sum$ Fy = 0 i.e. 600 N - 400 N - Cy = 0 , Cy = 200 N

Choose a joint where there are no more than two unknowns. Start from A or C.

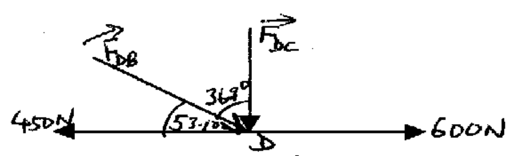
Joint A



$\sum$ Fy = 0 i.e. 600 N = F_{AB} sin 53.1°; **F_{AB} = 750 N (C)**

$\sum$ Fx = 0 i.e. F_{AD} = F_{AB} cos 53.1° = 750 cos 53.1° = **450 N (T)**

Joint D



$\sum$ Fx = 0 i.e. - 450 + F_{DB} cos 53.1° + 600 = 0

0.6 F_{DB} = - 150 N i.e. F_{DB} = - 250 N

The negative sign indicates that F_{DB} acts in the opposite sense to that shown:

Hence **F_{DB} = 250 N (T)**

Method of Sections:

In this method, the equilibrium of a portion of truss is considered which is obtained by cutting the truss by some imaginary section

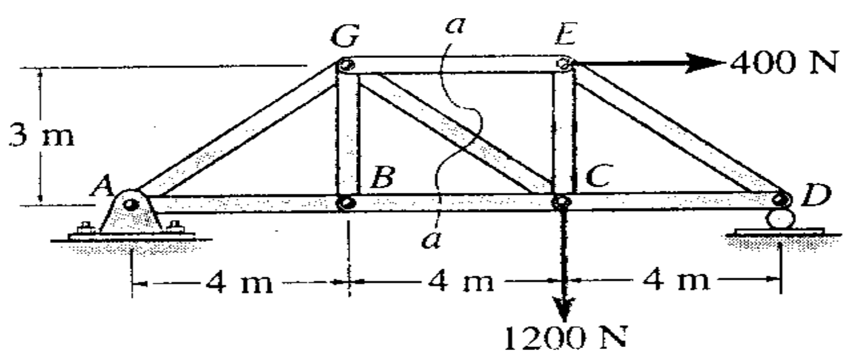
Points to be considered:

- The section should pass throug h the members and not through joints.
- A section should divide the truss into two clearly separate and unconnected portion s.
- A section should cut only three members since only three unknowns can be d etermined. (In special cases, a section may cut more t han three members.)
- When using moment equation s, the moment can be taken about any convenient point, which may or may not lie on the section undeer consideration.

The following steps are carried out to find forces in members through method of se ctions.

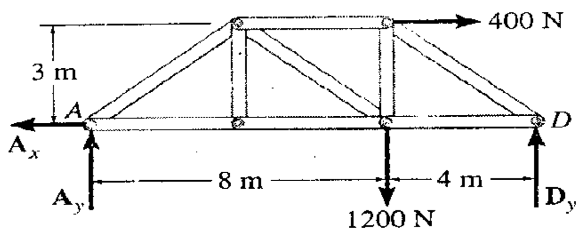
ii. Check that truss is a perfect truss ($m = 2j - 3$)
iii. Consider the entire truss as a free body and determine reactions at the supports.
iv. Cut the truss into two separate portions by passing an imaginary section through tho se members in which forces are to be determined. (More than one such sections are possible)
v. The internal forces in these members become external forces acting on the two portio ns of the truss.
vi. Assume and mark directions of t he axial forces in the cut members away from the joi nt on the diagram.
vii. Consider equilibrium of one port ion of the truss and calculate magnitude of three unknown axial forces in members using equations of equilibrium $Rx = 0$, $R_y = 0$, $M_A = 0$.

Example 2: Determine the force in members GE, GC and BC of the truss shown in the Figure. Indicate whether the members are i n tension or compression.

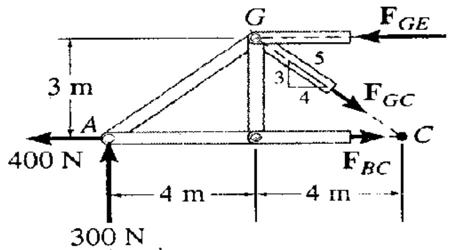


(a)

(a)



(b)



(c)

4.7 Special Conditions:

External Forces Determination

$\sum$ **Fx = 0 i.e. A_x = 400 N**

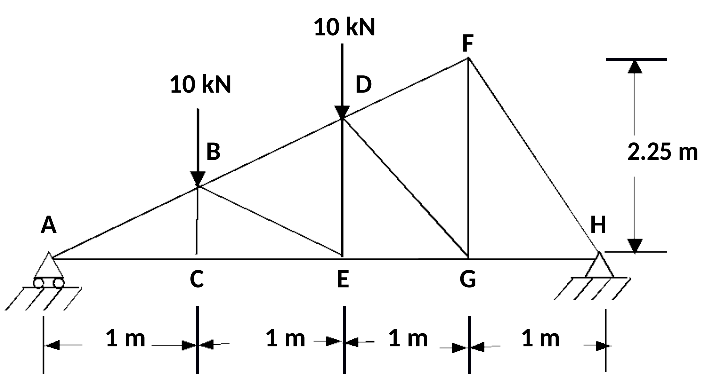
$\sum$ **M_A = 0 ; i.e. - 1200 x 8 - 400 x 3 + 12 D_y = 0; D_y = 900 N**

$\sum$ **Fy = 0 i.e. A_y - 1200 + 900 = 0; A_y = 300 N**

Important Note:

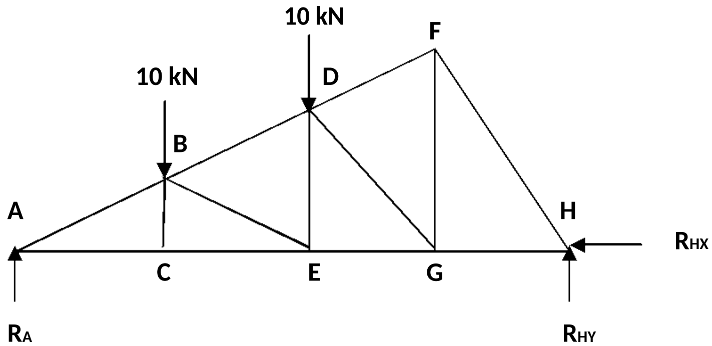
When two members meeting at a joint are not collinear and there is no externa force acting at the joint, then forces in both the me mbers are zero. (2) When there are three me mbers meeting at a joint, of which two are collinear an d third be at an angle and if there is no load at the joint, the force

Example 3: For the simply supported truss shown in figure, find the force in memb ers BD, DE, EG and CE using the method of sections. **(U PTU 2003, Jan'2011)**



Solution:

First we will calculate the reactions at support A and H. as A is a roller support it will have only one upward reaction R_A, whereas at H (Hinged support) the inclined reaction will be converted into Horizontal and Vertical component s R_{HX} and R_{HV}. The free body diagram of the truss will be as under:



These reactions will be calculated with the equations of equilibrium as under:

$\sum Fx = 0$, so $R_{HX} = 0$ ------ (1)

(as there was no horizontal or inclined force was acting on the truss, it was oblivious that horizontal component of reaction at hinged support is ZERO)

$\sum Fy = 0$, so $R_A + R_{HY} = 10 + 10 = 20$ ------ (2)

$\sum M_A = 0$, so $4\ R_{HY} = 10 \times 1 + 10 \times 2 = 30$

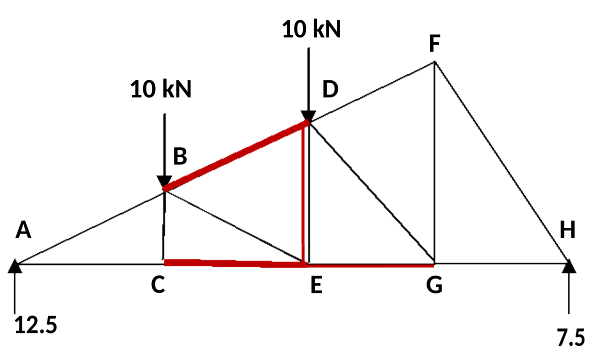
$R_{HY} = 30 / 4 = 7.5$------ (3)

$\sum M_H = 0$, so $4\ R_A = 10 \times 3 + 10 \times 2 = 50$

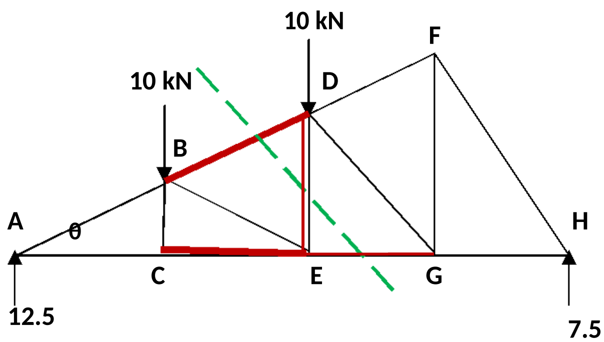
$R_A = 50 / 4 = 12.5$------ (4)

We can crosscheck our answer with the help of equation (2).

To find the force in members BD, DE, EG and CE using the method of sections, we will mark these members for easy identification.

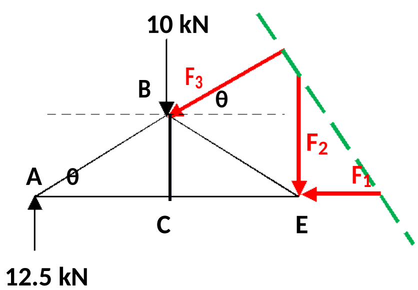


In Method of section generally we can find forces in three members at a time. We have to cut the sections twice. First sections BD, DE and EG will be cut as shown in figure to divide the truss into two sections.



As we can consider LHS or RHS, LHS is selected and the forces in member BD, DE and EG are considered as Compressive.

$\theta = \tan^{-1}(2.25/3) \quad = \quad 36.9^0$



We can find F_1, F_2 and F_3 by three equations of equilibrium or by moment equation only.

$\sum Fx = 0$

$F_3 \cos 36.9 + F1 = 0 \quad (1)$

$\sum F_Y = 0$

$F_3 \sin 36.9 + F_2 + 10 = 12.5$

$F_3 \sin 36.9 + F_2 = 2.5 \quad (2)$

$\sum M_A = 0$

$10 \text{ x } 1 + F_2 \text{ x } 2 = 0$

$F_2 \text{ x } 2 = -10 / 2 \qquad = -5$ kN (Tensile Force) (Member DE)

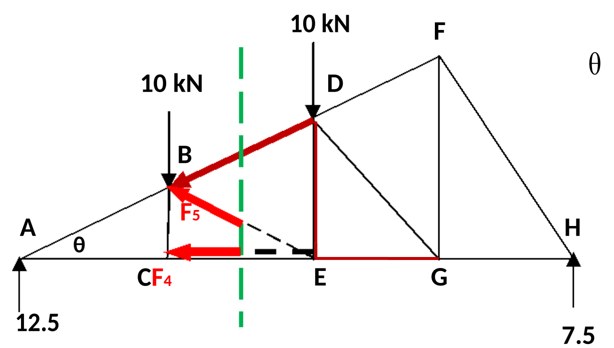
$F_3 \sin 36.9 + (-5) = 2.5 \qquad (2)$

So $F_3 = 7.5 / \sin 36.9 =$ 12.5 kN (Compressive) (Member BD)

$12.5 \cos 36.9 + F1 = 0 \qquad (1)$

$F_1 = - 12.5 \cos 36.9 = - 10$ kN (Tensile) (Member EG)

To find the force in the section will be cut as under:



Let’s assume the force in cut members CE and BE are F4 and F5 respectively (both Compressive). We have already calculated force in member BD (12.5 kN, Comp.)

$\sum M_B = 0$

$12.5 \times 1 + F_4 \times 0.75 = 0$

By similarity of triangles FG / AG = BC / AC

BC = (2.25/3) x 1= 0.75

$F_4 =$ (- 12.5 x 1) /0.75 = -16.67 kN (Tensile) in Member CE.

The final answer is tabulated as under:

Sr. No.	Member	Force	Magnitude (kN)	Nature
1	EG	F_1	**10**	Tensile
2	DE	F_2	**5**	Tensile
3	BD	F_3	**12.5**	Compressive
4	CE	F_4	**16.67**	Tensile

)

Unit III – Centroid and Moment of Inertia

Centre of Gravity: C.G. of a body is defined as the point through which resultant of the gravitational force (weight) acts for any orientation of the body. It depends upon the shape of the body and may or may not necessarily be within the boundary of the body.

1. **A body has only one C.G.**
2. **Its location doesn't change even with a change in the orientation of the solid body.**
3. **It lies in a plane of symmetry, if any of a body.**
4. **It is an imaginary point.**

Location of C.G. / Centroid: The coordinates of C.G. (X, Y) are determined as under

$$A \times X = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + \ldots\ldots\ldots + a_4x_4$$

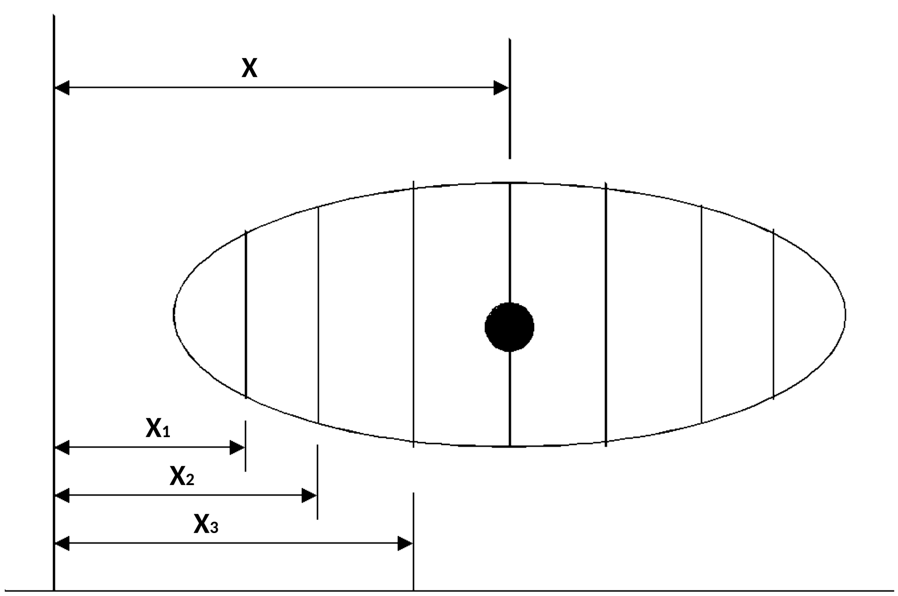
$$X = (a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + \ldots\ldots\ldots + a_nx_n) / A$$

$$= \Sigma\, a * x / A$$

Similarly

$$Y = (a_1y_1 + a_2y_2 + a_3y_3 + a_4y_4 + \ldots\ldots\ldots + a_ny_n) / A$$

$$= \Sigma\, a * y / A$$



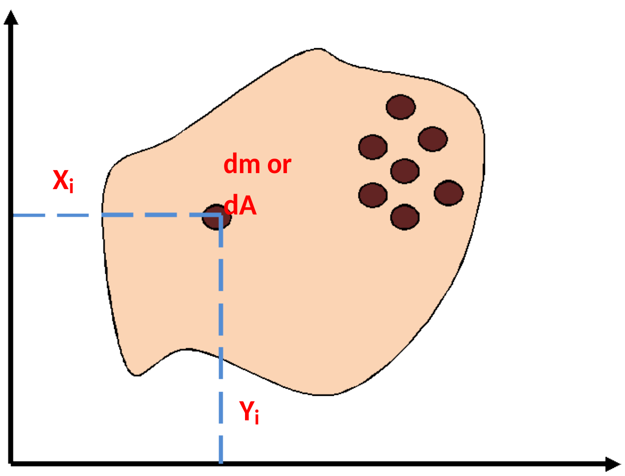
Similarly for solids (Mass)

X $=\Sigma\, m * x / A$

Y $=\Sigma\, m * y / A$

Location of C.G. / Centroid:

The CG / Centroid is obtained by dividing the object into very small pieces of mass / area dM / dA and multiplying these pieces of mass / area by their distance to the x (and y) axis, summing over the entire object, and finally dividing by the total mass of the object to obtain the CG / Centroid.



$X = \sum X_i * dA_i / (\sum dA_i)$ **and** $Y = \sum Y_i * dA_i / (\sum dA_i)$ **(in case of area)**

Figure 1: Centroid

Note:

1. It is assumed that the object has uniform density (homogeneous).
2. The centre of mass and centre of gravity coincides, when the acceleration due to gravity is same throughout the object.
3. Hollowed pipes, L shaped section have Centroid located outside of the material of the section
4.

Centroid of Composite Area:

We know the Centroid of regular geometrical shapes, but in real life the objects are not similar to these shapes, in real life these objects are formed from several regular geometrical areas, such as rectangles, triangles, etc. (Figure 2). In such cases the Centroid of the composite bodies may be found by taking the sum of the produce of each simple area and the distance its Centroid is from the reference axis, divided by the sum of the areas. For the composite area shown in figure 2, the location of its x - Centroid would be given by:

$$X_{ct} = (A_1 * x_1 + A_2 * x_2 + A_3 * x_3 + A_4 * x_4 + A_5 * x_5) / (A_1 + A_2 + A_3 + A_4 + A_5)$$

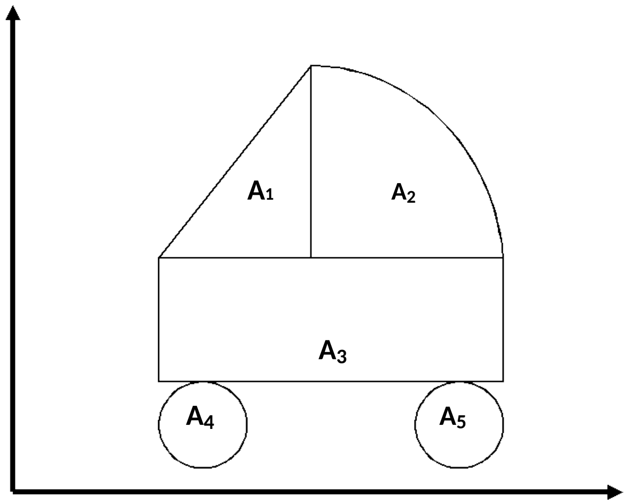


Figure 2:

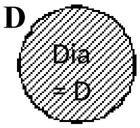
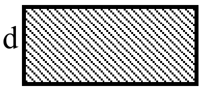
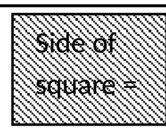
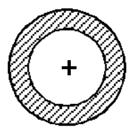
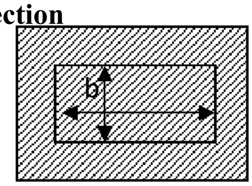
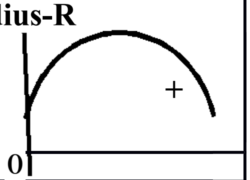
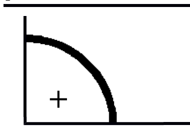
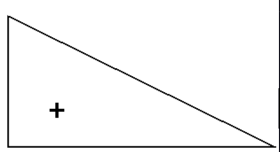
Where x_1, x_2, x_3, and x_4 are the distances from the Centroid of each simple area to the y-axis as shown in the Diagram 3. The location of the y - Centroid would be given in like manner.

$$Y_{ct} = (A_1 * y_1 + A_2 * y_2 + A_3 * y_3 + A_4 * y_4 + A_5 * y_5) / (A_1 + A_2 + A_3 + A_4 + A_5)$$

Important Note:

1. In above example all these figures i.e. rectangle, circle, triangle and quarter circle are added to form the composite / complex shape, so their areas are added in the above equation. In case any shape is removed from the composite shape, its area will be subtracted respectively.
2. The coordinates are in I quadrant, hence taken both (x and y) as positive. For easy calculation it is recommended that the whole body should be placed in I quadrant.

Centre of Gravity / Centroid and Area Moment of Inertia for different Cross Section is as under

Cross Section	**Centre of Gravity**	I_{xx}	I_{yy}
Circular Cross Section of diameter D 	D / 2	$\Pi/64\ (D^4)$	$\Pi/64\ (D^4)$
Rectangular Cross Section of Width – b and Depth – d 	At crossing of both diagonals d / 2 and b / 2	$1/12\ (bd^3)$	$1/12\ (db^3)$
Square Cross Section Side – a 	At crossing of both diagonals a / 2 and a / 2	$1/12\ (a^4)$	$1/12\ (a^4)$
Hollow Circular Cross Section Outer Diameter – D_2 Inner Diameter - D_1 	D_2 /2	$\Pi/64\ (D_2^4 - D_1^4)$	$\Pi/64\ (D_2^4 - D_1^4)$
Hollow Rectangular Cross-section **1.** Width Outer – B; Inner – b 2. Depth Outer-D, Inner–d 	At crossing of both diagonals D / 2 and B / 2	$1/12\ (BD^3 - bd^3)$	$1/12\ (DB^3 - db^3)$
Half Circle (Semi Circle)Radius-R  0	At (4R / 3 п) from Base on Y axis and R/2 on X axis	$0.11\ R^4$	$\Pi/128\ (D^4)$
Quarter Circle (Radius R)  o	At 4R / 3 п from Base on X and Y axis	$0.055\ R^4$	$0.055\ R^4$
Triangle (height = h, base = b))  **O**	From O at h / 3 in vertical b/3 from O	$1/36\ (bh^3)$	$1/36\ (hb^3)$

Moment of Inertia (MOI):

The **Moment of Inertia (I)** is a ter m used to describe the capacity of a cross-sectio n to resist bending.

Inertia refers to the property of a body by virtue of which the body resists any change in its state of rest or uniform motion. Area moment of inertia is essentially a measure of resistance to bending. The mass moment of inertia gives a measure of the resistance that the body offers to change in angular velocity.

It is always considered with respect to a reference axis such as X-X or Y-Y. It is a mathematical property of a section concerned with a surface area and how that area is distributed about the reference axis. The reference axis is usually a centroidal axis.

The moment of inertia is also k nown as the **Second Moment of the Are a** and is expressed mathematically as:

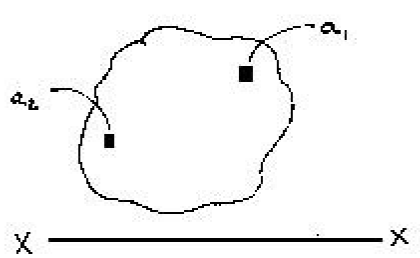
$$\mathbf{I_{xx} = \Sigma\ (A)\ x\ (y^2)}$$

In which:

$\mathbf{I_{xx}}$ = the moment of inertia around the x Axis

A = the area of the plane of the obje ct

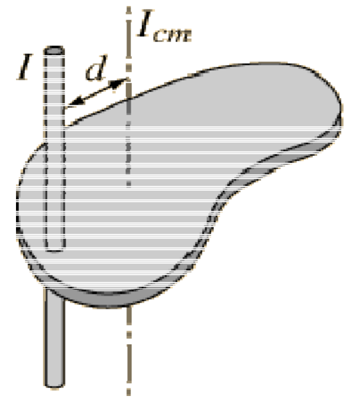
y = the distance between the centroi d of the object and the x axis



The Moment of Inertia is an important value which is used to determine the state o f stress in a section, to calculate the resistance to buckli ng, and to determine the amount of deflection in a beam.

Parallel axis theorem:

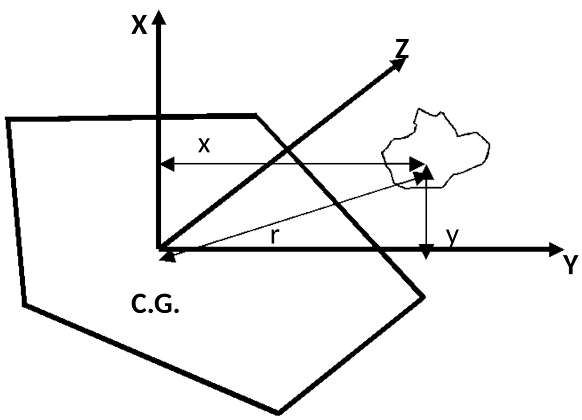
The moment of inertia of any object of area "**A**" (and mass – m, in case of Mass Moment of inertia) about an axis through its center of Area (mass in case of Mass moment of inertia) is the minimum moment of inertia (**I_{cm}**) for an axis in that direction in space. Th e moment of inertia about any axis parallel to that axis through the cent er of Area (mass) is given by



$$\mathbf{I = I_{cm} + Ad^2}$$

Perpendicular axis theorem:

For a Planar object, the moment of inertia about an axis perpendicular to the plane is the sum of the moments of inertia of two perpendi cular axes through the same point in the plane of the object.



$r^2 = x^2 + y^2$

MOI about ZZ = dA * r^2

$I_{zz} = \int dA * r^2$

$= \int dA * (x^2 + y^2)$

$= \int dA\, x^2 + dA\, y^2$

MASS MONMENT OF INERTIA OF VARIOUS VOLUMES

Mass Moment of Inertia:

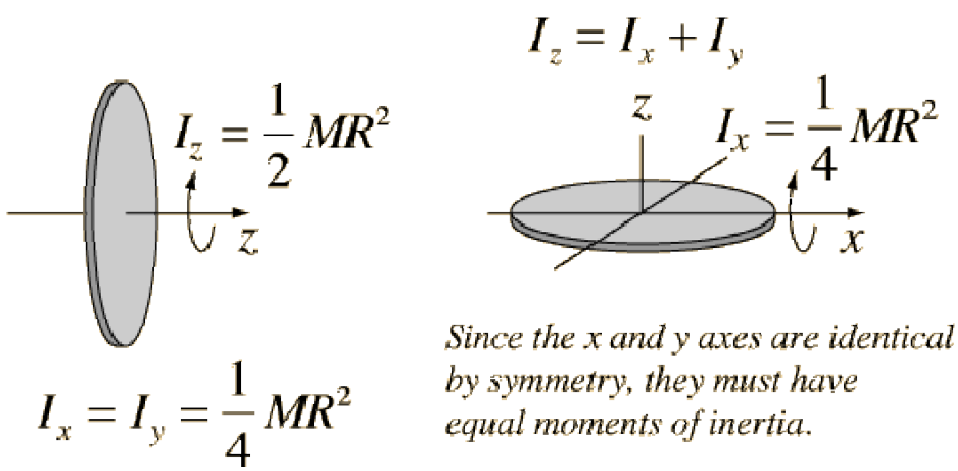
Mass moment of Inertia is defined as the product of the mass and the square of the distance between the mass centre of the body and the axis.

1. Mass Moment of Inertia of a Circular Ring of uniform Cross Section:

$\mathbf{I_{ZZ}} = MR^2$; $\mathbf{I_{xx} = I_{yy} = I_{ZZ}/2} = \frac{1}{2} MR^2$

2. Mass Moment of Inertia of a Circular Disc of radius R and thickness t about its centroidal axis:

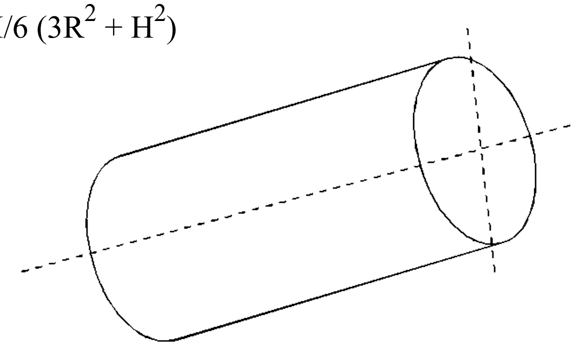
$\mathbf{I_{ZZ}} = \frac{1}{2} MR^2$; $\mathbf{I_{xx} = I_{yy} = I_{ZZ}/2} = \frac{1}{4} MR^2$



3. Mass Moment of Inertia of a Solid Cylinder of radius "R" and height "H":

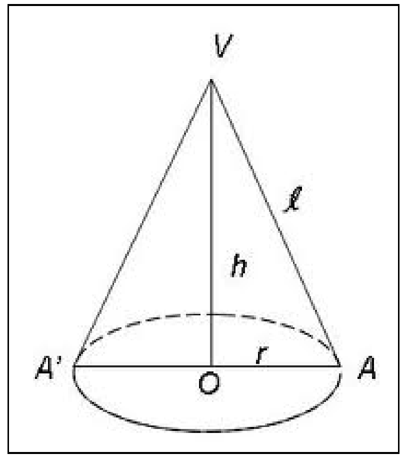
$\mathbf{I_{xx} = I_{yy}} = M/12\ (3R^2 + H^2)$

$\mathbf{I_{ZZ} = I_{xx} + I_{yy}} = M/6\ (3R^2 + H^2)$



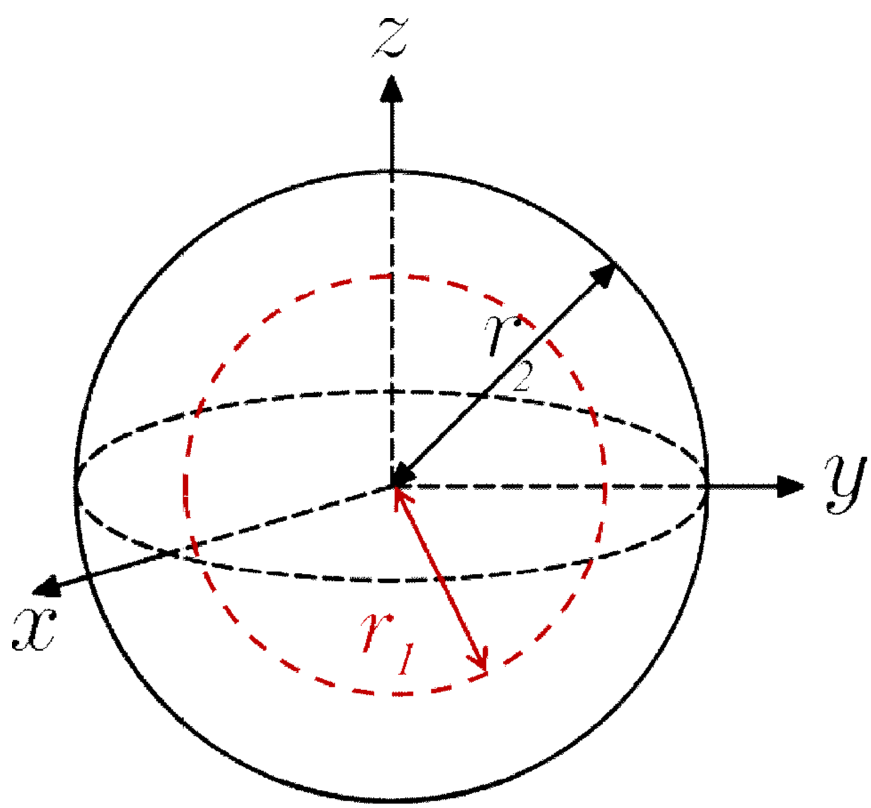
4. Mass Moment of Inerti a of a Right Circular Solid Cone of radius "R" and height "H" about its axis of rotation:

$I_{ZZ} = 3/10\ MR^2$



5. Mass Moment of Inertia of a Solid sphere of radius "R" about its diametral axis:

$I_{XX} = I_{YY} = I_{ZZ} = 2/5\ MR^2$



Unit IV & V Kinematics and Kinetics of Rigid Body

Kinematics is the study of motion of a body without considering the cause of motion i.e. force.

Kinetics is the study of motion as well as the action of forces which change the motion of a body.

Distance normally refers to the total distance an object moves during a particular journey.

Displacement refers to the distance from the starting point at a particular instant in time. We normally use *s* for displacement. In other words displacement is the change in the position of a particle or a body with respect to a certain fixed reference point is referred as displacement.

Velocity: The rate of change of body with respect to time is called velocity.

Acceleration: The rate of change of velocity of a body with respect to time is called acceleration.

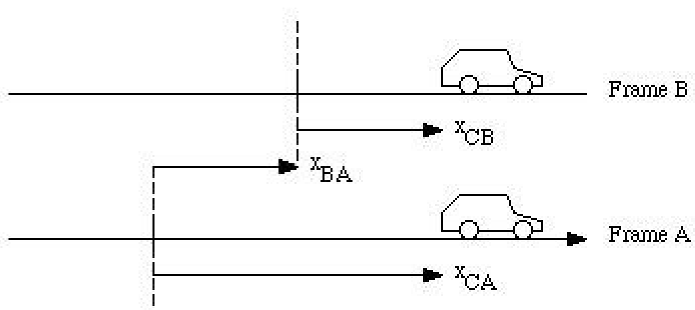
Motion is classified as General Plane motion, Absolute motion, relative motion, rectilinear motion, curvilinear motion, and uniform motion. The major motions are discussed below:

1. **<u>Rectilinear Motion (Linear motion)</u>**: A motion along straight line is called rectilinear motion.

Equations of rectilinear motion:

v	=	$u + at$	Where	u	=	Initial velocity in m/s
v^2	=	$u^2 + 2as$		v	=	Final velocity in m/s
s	=	$ut + \frac{1}{2} at^2$		a	=	Acceleration in m /s^2
				s	=	displacement in meters
				t	=	time in sec

Relative velocity: The relative velocity of a Body "A" with respect to another body "B" will always be the algebraic difference between their velocities.



1. **Rotation and General Plane motion**: In the rotary (circular) motion, the movement of the particle is along a circular path. The particle repeats its journey along the same path about the same centre of rotation.

   a. **Angular displacement (θ):** The displacement of a body in rotation is called angular displacement and it is measured in radians.

   b. **Angular Velocity (ω)**: The rate of change of angular displacement of a body with respect to time is called angular velocity. It is measured in radian per sec.

   $$\omega = d\theta / dt$$

   c. **Angular acceleration ($\acute{\alpha}$)**: The rate of change of angular displacement of a body with respect to time is called angular velocity. It is measured in radian per sec.

   $$\acute{\alpha} = d\,\omega / dt \quad = d\,(d\theta\,)\_/\,dt \times dt = d^2\theta / dt^2$$

   or

   $$\acute{\alpha} = d\,\omega / d\theta \;\times d\theta / dt \quad = \omega \times d\,\omega/d\theta$$

Equations of Circular motion:

$$\omega = \omega_o + \acute{\alpha}t$$

Where ω_o = Initial velocity in rad/s

$$\omega^2 = \omega_o^2 + 2\,\acute{\alpha}\theta$$

ω = Final velocity in rad/s

$$\theta = \omega_o t + ½\,\acute{\alpha}t^2$$

Laws of Motion:

Force: The force is an external effort in the form of a push or pull, which either changes or tends to change the state of rest or of uniform motion of a body along a straight line.

Inertia: The inherent property of all the objects that they do not change their state of rest or of uniform motion along a straight line unless acted upon by an external force, is called inertia.

a. **Inertia at rest**: It is inability of a body not to change by itself its position of rest.

b. **Inertia of Motion**: It is in the inability of a body not to change by itself its state of uniform motion along a straight line.

Newton's First Law of Motion: (Law of Inertia)

If a body is at rest then it will remain at rest, or if it is moving along a straight line with a uniform speed then it will continue to move as such, unless an external force is applied on it to change its present state.

Linear Momentum: The product of the mass and the velocity of a body is called the linear momentum of the body.

$$\vec{P} = m\,\vec{v}$$

Newton's Second Law of Motion:

The rate of change of linear momentum of a body is equal to the net external force acting on the body; and the change in momentum takes place in the direction of the force. Thus a force applied to a body equals the mass of the body multiplied by the acceleration produced in the body in the direction of the force.

(1 Newton force is the force, which produces an acceleration of 1 m / s^2 in a body of a mass 1 kg.)

Newton's Third Law of Motion:

Whenever a body exerts a force on another body, the second body also exerts an equal and opposite force on the first body

Force, Impulse and Momentum:

Force: Force is an external agent, which tends to change the state of rest or uniform motion of a system. It is a vector quantity. It's unit is Newton. Newton's II law states that force is proportional to the rate of change of momentum.

Force is specified by a) magnitude b) direction c) Point of application and line of action

Momentum: Momentum is the product of mass and velocity of a body and represents the energy of motion stored in a moving body.

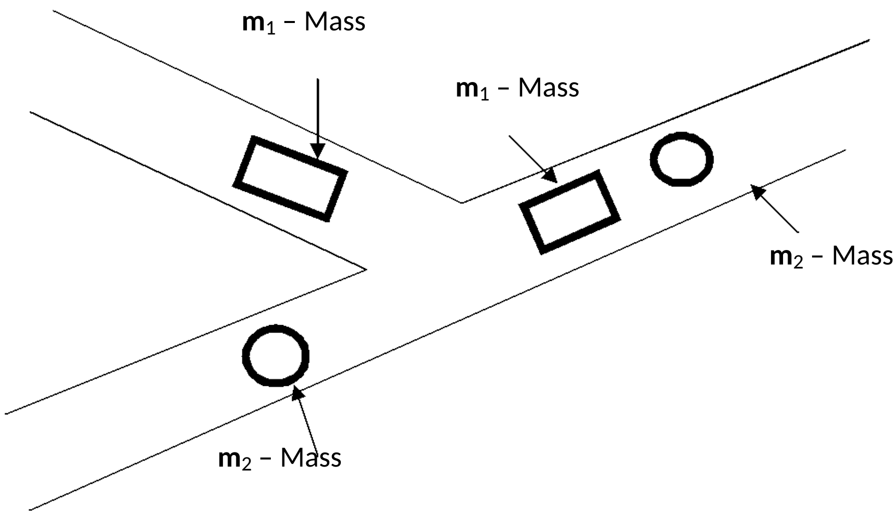
The product of mass and velocity **Force**: is known as momentum of the body. Also the change in the linear momentum per unit time is proportional to the impressed force and takes place in the direction of the force.

Momentum = m x v in kg-m / sec

Impulse: The product of force and the time during which it acts (f x t) is called impulse of force.

$$\mathbf{F \times t = mV_f - mV_i = m(V_f - V_i)}$$

The Law of Conservation of Momentum states that "Total momentum of any group of objects always remain same if no external force acts on it"



Momentum before collision = Momentum after collision

D'ALEMBERT'S PRINCIPLE:

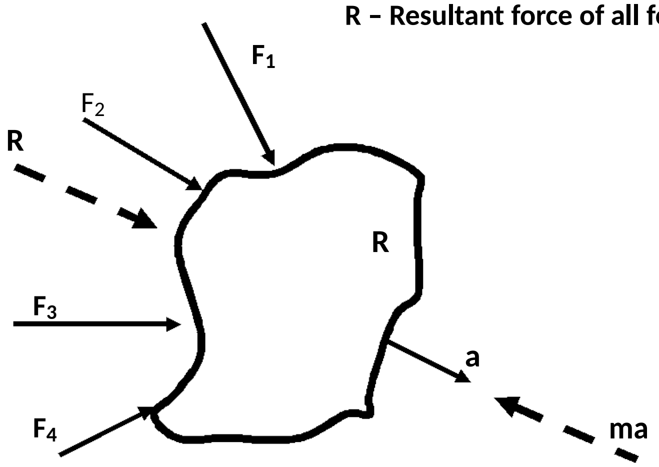
It states that the system of forces acting on a body in motion is in dynamic equilibrium with the inertia force of the body.

Let's consider a Body subjected to four forces as shown in the figure. It will move with acceleration "**a**" because of the resultant of these forces. It will remain static if a force = **ma** acts in the **reversed direction.** Now for the dynamic equilibrium of the body sum of the reversed force and resultant force should be zero. As

$$\Sigma F = 0; \qquad R - ma = 0 \qquad R = ma$$

The force (-ma) is termed as the inertia force or reverse effective force.

R – Resultant force of all forces



Work done by a force on a moving body is defined as the **product of the force** and the **distance moved** in the direction of the force.

Energy is defined as the capacity to do the work. **Potential energy** (mgh) is the capacity to do work due to the position of the body and **kinetic energy** (**½ mv^2**) is the capacity to do the work due to the motion of the body.

Power is defined as the time rate of doing work. Power is F * d/t = Force * Velocity

Work Energy Principle: The work energy principle states that the work done by a system of forces (resultant force) acting on a body during a displacement is equal to the change in kinetic energy of the body during the same displacement.

$$\textbf{Net force (F) x d} = \tfrac{1}{2} m (v^2 - u^2)$$

Virtual Work: The principle of virtual work (or principle of virtual displacements) I: if a particle is in equilibrium under the action of a number of forces (including the inertial force) the total work done by the forces for a virtual displacement is zero

The principle of virtual work (or principle of virtual displacements) II: a particle is in equilibrium under the action of a system of forces (including the inertial force) if the total work done by the forces is zero for any virtual displacement of the particle

Radius of Gyration:

If the entire area (or mass) of the given lamina is considered to be concentrated at a point such that there is no change in the moment of inertia about a given axis, then distance of that point from the given axis is called the Radius of Gyration.

$I = Ak^2$ (in case of Area MOI) or Mk^2 (in case of mass MOI)

And radius of Gyration "K_{xx}" = $\sqrt{(I_{XX} / A)}$ or $\sqrt{(I_{XX} / M)}$

"K_{yy}" = $\sqrt{(I_{yy} / A)}$ or $\sqrt{(I_{yy} / M)}$

Important Formulae

1. **$R^2 = P^2 + Q^2 + 2PQ\cos\theta$; $\tan\alpha = Q\sin\theta / (P + Q\cos\theta)$**
2. **$P / \sin\alpha = Q / \sin\beta = R / \sin\gamma$ (Lami's theorem)**
3. **$\Sigma F_X = 0$; $\Sigma F_Y = 0$; $\Sigma M = 0$ (conditions of equilibrium)**
4. **$T_T / T_S = e^{\mu\theta}$ (T_T = Tension in Tight Side, T_S= Tension in Slack Side, θ = Angle of ontact)**
5. **Initial Tension = Net Driving Tension = Effective Tension in Belt = ($T_T - T_S$)**
6. **P (Power in kW) = $\{(T_T - T_S) * \pi DN\} / (60 * 1000)$ = $(T_T - T_S)$ * Velocity in m/s**

(Where - D – Diameter of Pulley & N – RPM of pulley)

7. Angle of contact on case of Open Belt System: $\theta = 180^0 - 2\alpha$;

Where $\sin\alpha = (R_2-R_1) / L$

SESSIONAL PAPERS with SOLUTION

B.TECH – FIRST SESSIONAL EXAMINATION, 2013 – 14

SEMESTER – FIRST **SECTION – K to S**

SUBJECT – ENGINEERING MECHANICS **SUBJECT CODE –ME 101**

NAME OF STUDENT: **CLASS ROLL NO.:**

Time: 2.00 Hours **Max Marks: 60**

Notes: (i) This paper is in three sections. Draw neat sketches to support your answer

(ii) Marks are indicated against each section. Attempt questions from each section as per instructions. Assume missing data suitably, if any.

SECTION – A

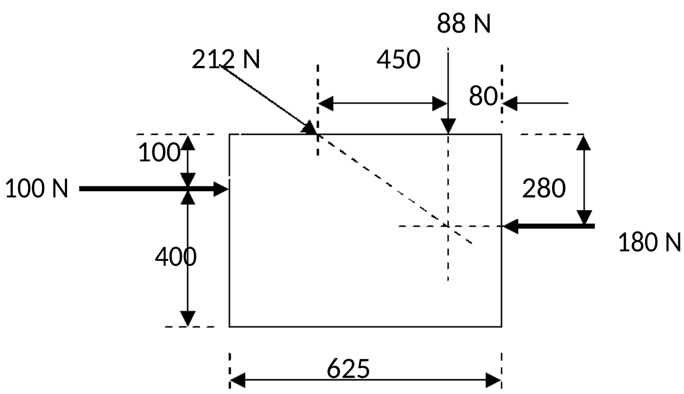
1. Attempt ALL parts of this question: **(2X6 = 12)**

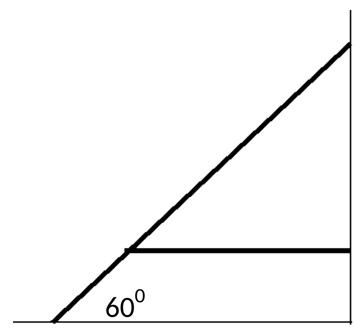
a) Explain the various systems of forces with suitable examples.
b) State the principle of transmissibility of force with its limitation.
c) What do you mean by Free Body Diagram (FBD)? Illustrate with examples.
d) What is equilibrium? Explain the conditions of coplanar forces.
e) Classify trusses?
f) State the varignon's theorem.

SECTION – B

2. Attempt ANY THREE questions. Each part has equal marks. **(6X3 = 18)**

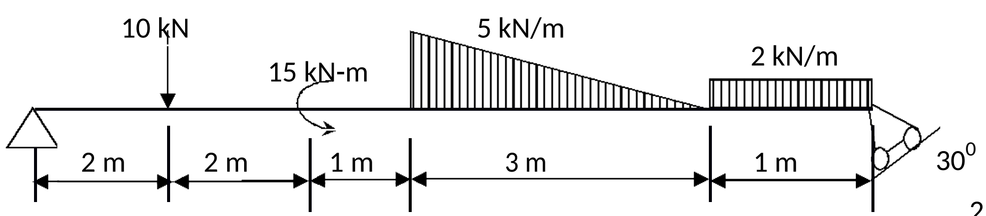
a. For the given force system, find the resultant and its point of application and direction. All dimensions are in mm.





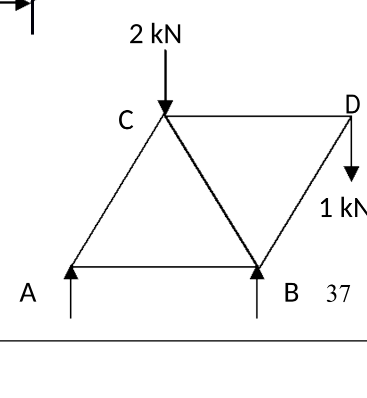
b. A ladder of weight 900 N and length 10 m is held in impending motion towards the right by a rope at 2.5 meter along the length from bottom end and tied to the wall as shown in figure. The coefficient of friction between the floor and the ladder is 0.25 and that between the wall and ladder is 0.40. Determine the tension in the rope.

c. Find reactions at the support for the given beam as shown in figure.



d. Determine the forces in the members AB, BC and CD of the truss (each member length is 4 m) by section method.

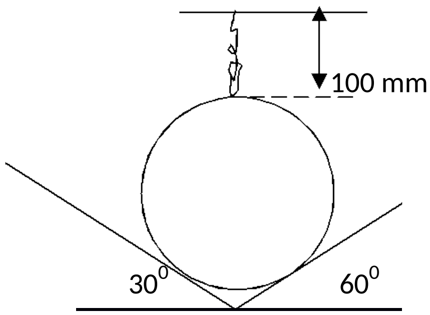
e. Determine an expression for the ratio of belt tensions in a flat belt drive.

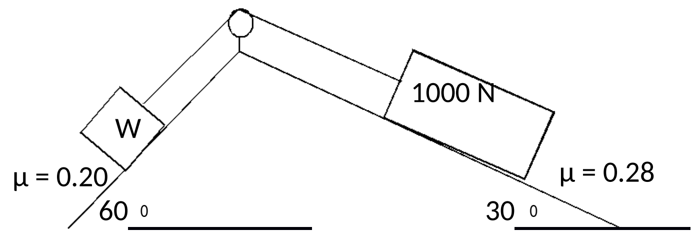


SECTION – C

3. ALL questions are compulsory. **(10 x 3 = 30)**

a) State the Lami's theorem. A sphere (weight = 40 N) is resting in a V shaped groove as shown in the figure and is subjected to a **spring** force. The **spring** is compressed to a length of 100 mm from the free length of 150 mm. If the stiffness 2 N/mm. determine the contact reactions at support.



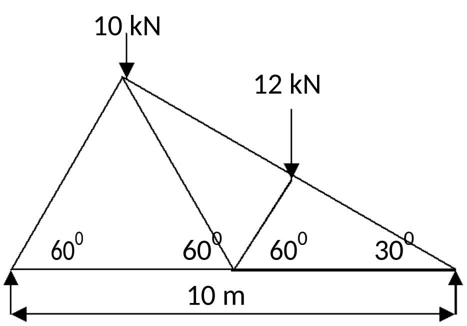


b) Find the least and greatest value of "W" for the equilibrium of above system. The pulley is frictionless.

OR

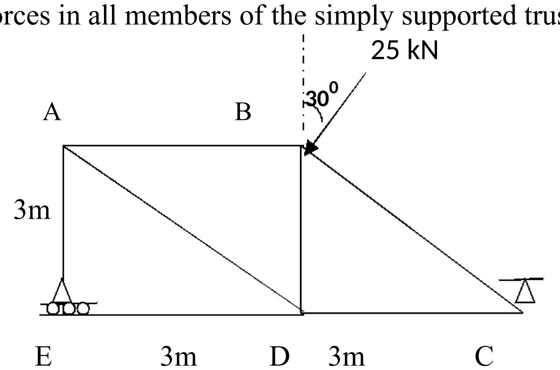
State the laws of Coulombs friction? An open belt drive connects two pulleys 120 cm and 50 cm diameter, on parallel shafts 4 meter apart. The maximum tension in the belt is 1855.3 N. The coefficient of friction is 0.3. The driver pulley of the diameter 120 cm runs at 200 rpm. Calculate (i) the power transmitted and (ii) torque on each of the two shafts.

c) Find the axial forces in all members of following truss.



OR

Find the axial forces in all members of the simply supported truss as shown in below fig.



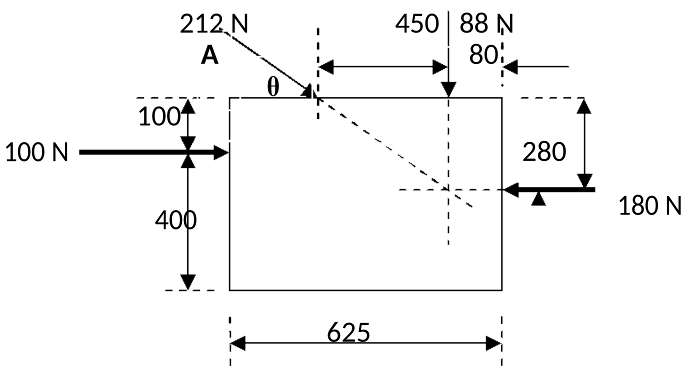
*** All the Best ***

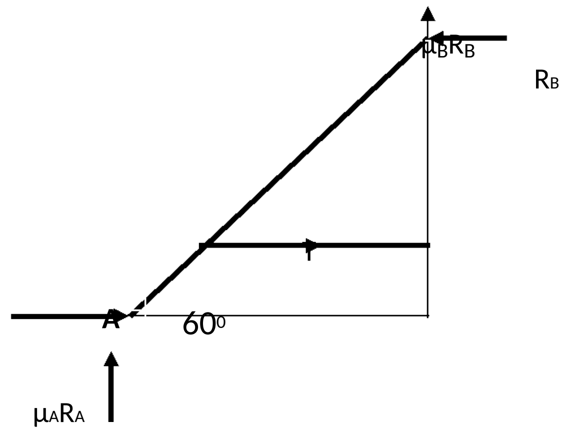
Solution

SECTION – B

2. Attempt ANY THREE questions. Each part has equal marks. **(6X3 = 18)**

a. For the given force system, find the resultant and its point of application and direction. All dimensions are in mm.





θ = tan (280/450) = 31.89

$\sum fx = -180 + 100 + 212 \cos (31.89)^0 = 99.825$ N $\rightarrow$

$\sum fy = -212 \sin(31.89)^0 - 88 = 200$ N $\downarrow$

$R = \sqrt{}\, (\sum fx)^2 + (\sum fy)^2 = \sqrt{}\, (99.825)^2 + (200)^2 = 223.53$ N

$\tan \alpha = \sum fy / \sum fx = 200 / 99.825$ i.e. $\alpha = 63.47^0$ in 4^{th} quadrant

This resultant will give the same moment about any point say "A"

$R . x = 100*100 - 212 \sin 31.89^0 * 95 - 88*545 -$

$180*280$ x = 99 N m / 223.53 = **0.442** m from **"A"**

Ladder:

$\sum fx = \mu_a R_A + T = R_B$ -------- (1)

$\sum fy = R_A + \mu_b R_B = 900$ ------- (2)

From equations (1) and (2)

$T = 1.1\, R_B + 225$

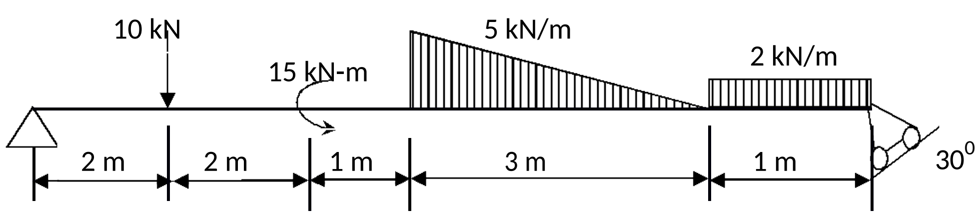
$\sum M_A = 0$

$R_B *10 \sin 60 + \mu_b R_B * 10 \cos 60 = T$ (2.5 sin60) + 900*5 cos60

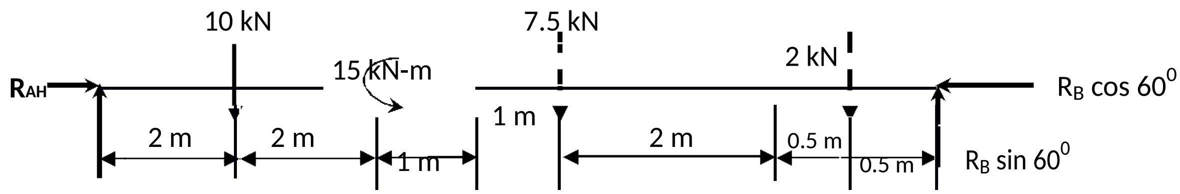
T = 588.76 N

b. A ladder of weight 900 N and length 10 m is held in impending motion towards the right by a rope at 2.5 meter along the length from bottom end and tied to the wall as shown in figure. The coefficient of friction between the floor and the ladder is 0.25 and that between the wall and ladder is 0.40. Determine the tension in the rope.

c. Find reactions at the support for the given beam as shown in figure.



FBD of Beam:



$\sum M_A = 0$ **R_{AV}**

$R_B \sin 60^0 * 9 = 10*2 - 15 + 7.5*6 + 2*8.5$ i.e. $\mathbf{R_B = 8.6\ kN}$

$\sum fx \Rightarrow$ $R_{AH} = R_B \cos 60^0 =$ **4.3 kN** ------- (1)

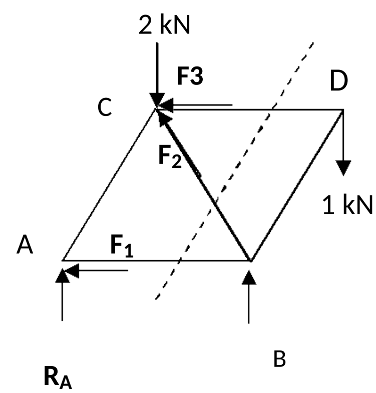
$\sum fy \Rightarrow$ $R_{AV} + R_B \sin 60^0 = 10 + 7.5 + 2 = 19.5$ ------- (2)

$R_{AV} =$ **12.05 kN**

$R_A = \sqrt{(4.3)^2 + (12.05)^2} = 12.79$ kN

$\tan \alpha = \sum fy / \sum fx = 12.05 / 4.3$ i.e. $\boldsymbol{\alpha = 70.36^0}$ in 3rd quadrant

d. Determine the forces in the members AB, BC and CD of the truss (each member length is 4 m) by section method.



$\sum M_B \Rightarrow 2*2 = 1*2 + R_A*4;$ i.e. $R_A = 0.5$ kN
$\sum M_A \Rightarrow 2*2 + 1*6 = R_B*4;$ i.e. $R_B = 2.5$ kN
(R_B not needed as taking left side)

Considering all forces in cut members as Compressive
$\sum fx = 0$
$F_1 + F_2 \cos 60 + F_3 = 0$ ---(1)
$\sum fy = 0$
$\mathbf{R_A} + F_2 \sin 60 = 2$ ------ (2)
$F_2 = (2-0.5) / \sin 60$; $\mathbf{F_2 = 1.732\ kN}$ (Compressive)
$\sum M_C = 0$
$0.5*2 + F_1 * 2\sqrt{3} = 0$; $\mathbf{F_1 = -(1/3.464) = 0.289\ kN}$ (Tensile)

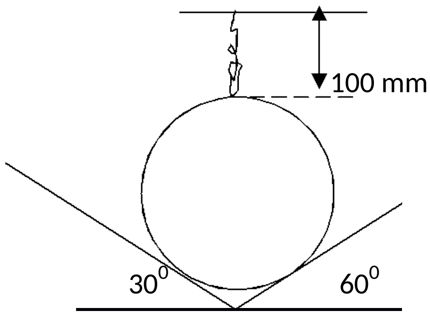
From equation (1) $\mathbf{F_3 = 0.577\ kN}$ (Tensile)

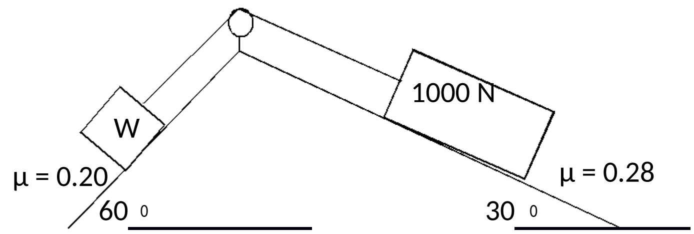
e. Determine an expression for the ratio of belt tensions in a flat belt drive. (SEE THE NOTES)

SECTION – C

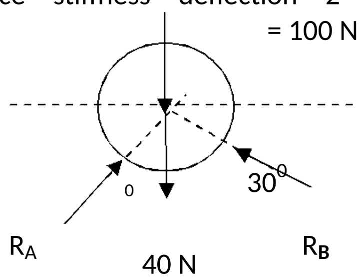
3. ALL questions are compulsory. **(10 x 3 = 30)**

a) State the Lami's theorem. A sphere (weight = 40 N) is resting in a V shaped groove as shown in the figure and is subjected to a **spring** force. The **spring** is compressed to a length of 100 mm from the free length of 150 mm. If the stiffness 2 N/mm. determine the contact reactions at support.





Spring force = stiffness * deflection = 2 * (150-100)
= 100 N



∑Fx => R_A Cos60 = R_B Cos 30 ------- (1)

∑Fy => R_A Sin60 + R_B sin 30 = 140 ------ (2)

From(1) and (2)

R_A = 121.24 N and R_B = 70 N

Power Transmission by a Belt Pulley system:

for open belt

Sin α = (R_1-R_2)/ L = (0.6 -0.25) / 4 ; i.e. α = 5.02^0 Angle of contact θ = 180 - 2α = 169.96^0 = 2.967 radian

$T_1 / T_2 = e^{(0.3*2.967)} = 2.435$

T_2 = 761.8 N as T_1 = 1855.3 N given

Power (watt) = 2*π N_2 (T1-T2) R_2 / 60 = (T1-T2) *V

(V = 2*π N_2 * R_2 / 60)

P = 13.73 kW = 13730 W

Torque = (T1-T2) R

Driving side = (1855.3-761.8)*0.6 = 656.1 Nm

Driven side = (1855.3-761.8)*0.25= 273.4 Nm

For least value of "W", 1000 N block impending downwards

For 1000 N block side FBD

∑Fy => R_1 = 1000 cos 30 = 866.03 N ----- (1)

∑Fx => T + μ_1 R_1 = 1000 sin 30 ------- (2)

T = 500 - 0.28 (866.03) = **257.51 N**

For W N block side FBD

∑Fy => R_2 = W cos 60 ----- (1)

∑Fx => T = μ R_2 + W sin 60 ------- (2)

257.51 = 0.2 (0.5W) + 0.866 W

W = 266.57 N (Least Value)

For GREATEST value of "W", 1000 N block impending UPWARDS

For 1000 N block side FBD

∑Fy => R_1 = 1000 cos 30 = 866.03 N ----- (1)

∑Fx => T - μ_1 R_1 = 1000 sin 30 ------- (2)

T = 500 + 0.28 (866.03) = **742.49 N**

For W N block side FBD

∑Fy => R_2 = W cos 60 ----- (1)

∑Fx => T + μ R_2 = W sin 60 ------- (2)

742.49 = - 0.2 (0.5W) + 0.866 W

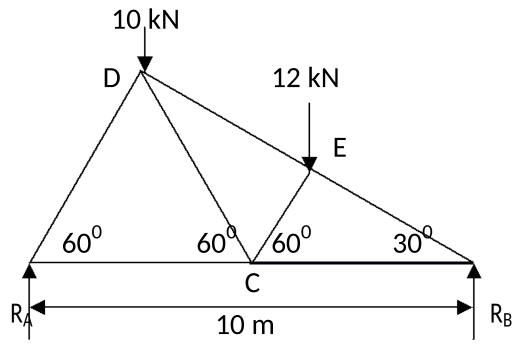
W = 969.28 N (Greatest Value)

b) Find the least and greatest value of "W" for the equilibrium of above system. The pulley is frictionless.

OR

State the laws of Coulombs friction? An open belt drive connects two pulleys 120 cm and 50 cm diameter, on parallel shafts 4 meter apart. The maximum tension in the belt is 1855.3 N. The coefficient of friction is 0.3. The driver pulley of the diameter 120 cm runs at 200 rpm. Calculate (i) the power transmitted and (ii) torque on each of the two shafts.

c) Find the axial forces in all members of following truss.



$\sum M_A = 0$

R_B *10 = 10*2.5 + 12*6.25; **R_B = 10 kN**

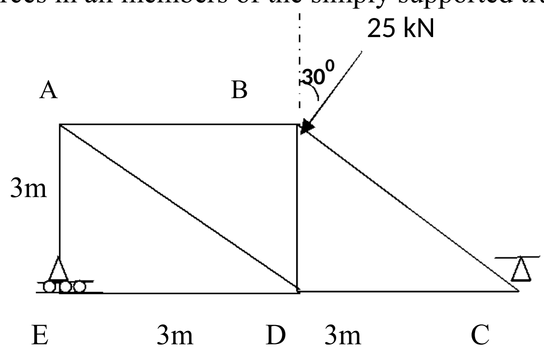
Hence **R_A** = 22 - 10 = **12**

kN By Joint method

F_{AC}	6.928 kN (T)
F_{AD}	13.856 kN (C)
F_{BC}	17.32 kN (T)
F_{BE}	20 kN (C)
F_{CE}	10.392 kN (C)
F_{CD}	10.392 (T)
F_{ED}	14 kN (C)

OR

Find the axial forces in all members of the simply supported truss as shown in below fig.



$\sum M_E = 0$

R_{CV} *6 = 25* cos 30 *3 - 25* sin 30 *3; **R_{CV} = 4.575 kN**

$\sum Fx = 0$

R_{CH} = - 25 sin 30 **= -12.5 kN**

$\sum Fy = 0$

R_E = 25 cos 30 – R_{CV} = 21.65- 4.575 = **17.075 kN**

By Joint method

F_{AE}	17.075 kN (C)	
F_{ED}	0	(Null Member)
F_{AD}	24.140 kN (T)	
F_{AB}	17.070 kN (C)	
F_{BD}	17.075 kN (C)	
F_{CD}	17.075 kN (T)	
F_{BC}	6.469 kN (C)	

SUBJECT – ENGINEERING MECHANICS **SUBJECT CODE –ME 101**
NAME OF STUDENT: **CLASS ROLL NO.:**
Time: 3.00 Hours **Max Marks: 100**

Notes: (i) This paper is in three sections. Draw neat sketches to support your answer
(ii) Marks are indicated against each section. Attempt questions from each section as per instructions. Assume missing data suitably, if any.

SECTION – A

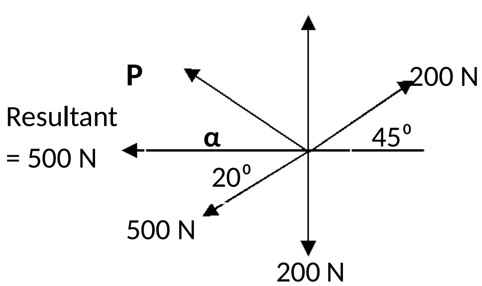
4. Attempt ALL parts of this question: **(2X10 = 20)**

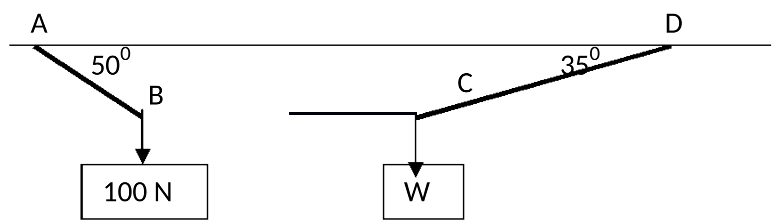
g) Define Force. List three characteristics to describe a force.
h) The resultant of two concurrent forces P = 100 N and Q = 150 N is R= 210 N. Find the angle between P and R and Q and R.
i) Write the various assumptions made in analysis of a truss.
j) Define angle of repose and angle of friction.
k) Define centroid and centre of gravity.
l) Moment of Inertia of a semicircular lamina about its both centroidal axis is = _____ and _____
m) A wheel rotating with 60 rpm accelerates with uniform angular acceleration of 1 rad / sec. Find its rpm after 2 minutes.
n) State Work energy principle in brief.
o) Define Work, energy, impulse and momentum.
p) State and explain principle of Virtual work.

SECTION – B

5. Attempt ANY THREE questions. Each part has equal marks. **(10X3= 30)**

a) (i) The four coplanar forces are acting at a point as shown in the figure. One force is unknown (P). The resultant is 500 N and acting along X axis. Determine the unknown force (P) and its inclination (**α**) with X axis.

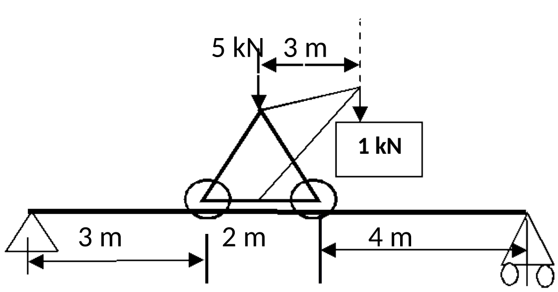


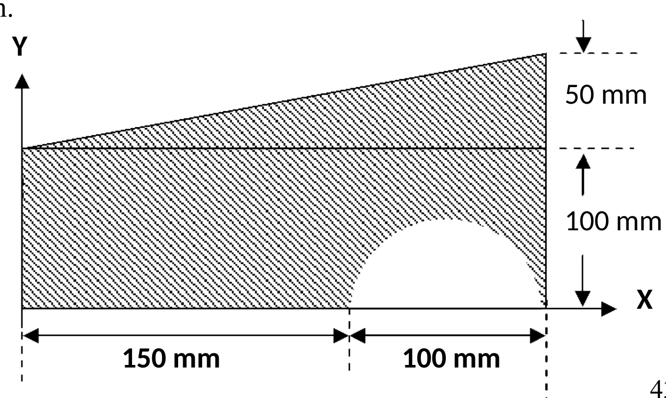


(ii) Three members AB, BC and CD are joined as shown in the above figure. A vertical weight (100 N) is hanged at B. Find the weight "W" to be attached at C to maintain the member BC in horizontal position.

b) (i) A ladder 12 m length (weight = 500 N) is resting against a smooth wall. Find the coefficient of friction between floor and ladder if ladder starts slipping when the angle between ladder and floor is $\leq 50^0$.

(ii) Find the reactions at support for the following beam.





c) Determine the Centroid of the shaded area of above lamina.

(d) (i)The initial angular velocity of a rotating body is 2 rad / sec. And initial angular acceleration is zero. The rotation of the body is according to the relation $\alpha = 3t^2 - 3$. Find (i) angular velocity and (ii) angular displacement when t = 5 sec.

(ii) A train starts from rest and moves along a curved track of radius 800 m with uniform acceleration until it attains a velocity of 72 kmph at the end of 3 minute. Determine the tangential , normal and total acceleration in m/s^2 of the train at the end of second minute.

(e) (i) A cylindrical roller 50 cm in diameter is in contact with two horizontal conveyor belts running at uniform speed of 10 m/s and 6 m/s in LH figure below . Assuming that there is no slip at point of contact, determine (i) position of the instantaneous centre, (ii) Linear velocity of centre of roller.

2 kN / m 1 kN

10 m/s

+

2 m 1 m

6 m/s

(ii) Find the reactions at the support by the **Virtual Work method in above RH figure**.

SECTION – C

Attempt all questions of this section. Each question carries 10 marks. (10 x 5 = 50)

6. What should be the value of the angle θ so that the motion of the 90 N blocks impends downward? The coefficient of friction for all the surfaces is 1/3.

10 kN

6 kN

30 kN

90 kN

60^0 60^0 60^0 60^0

θ

10 m

7. Find the forces in the members of the above truss. The truss is hinged supported at left end and roller supported at right end.

8. (i) A semicircle is removed from a square lamina of side 25 mm as shown in the figure. Find the moment of inertia of the remaining area about its base.

(ii) Find the mass moment of inertia of a solid sphere

9. i) List various types of motion with suitable examples.

(ii) A Ship is approaching a port in due East direction with a velocity of 15 kmph. When this was 50 km from port, ship B sails in N 45^0 W direction with a velocity of 25 kmph from the port. After what time the two ships are at a minimum distance and how far each has travelled.

SOLUTION

SUBJECT – ENGINEERING MECHANICS **SUBJECT CODE –ME 101**

SECTION – A

Note: For theory parts see notes / reference books.
Attempt **ALL** parts of this question: **(2X10 = 20)**

b) The resultant of two concurrent forces P = 100 N and Q = 150 N is R= 210 N. Find the angle between P and R and Q and R. (P and Q = 67.25^0, P & R = 41.20^0 hence Q & R = 26.05^0)

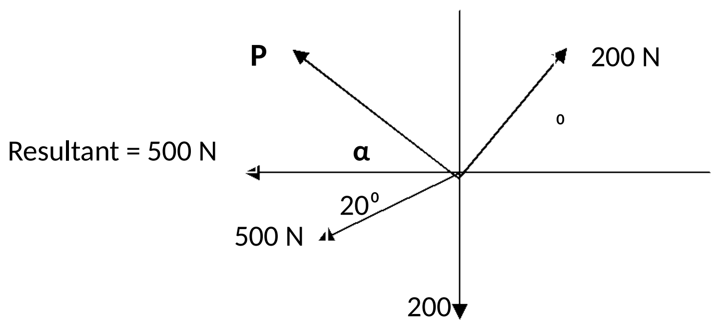
f) MOI of a semicircular lamina about its both centroidal axis is = $0.11\ R^4$ and $(\pi / 128)\ D^4$

A wheel rotating with 60 rpm accelerates with uniform angular acceleration of 1 rad / sec. Find its rpm after 2 minutes. **$\omega = \omega_0 + \alpha t$; $\omega = 2\pi$** N / 60 hence **$\omega_0 = 2\pi$** 60 / 60 = **2π** so **ω_{120} = 126.28 rad / sec. So N120 = 126.28 x 60 / (2π) = 1205.9 RPM Ans.**

SECTION – B

Attempt ANY THREE questions. Each part has equal marks. **(10X3= 30)**

a) (i) The four coplanar forces are acting at a point as shown in the figure. One force is unknown (P). The resultant is 500 N and acting along X axis. Determine the unknown force (P) and its inclination (**α**) with X axis.



Solution:

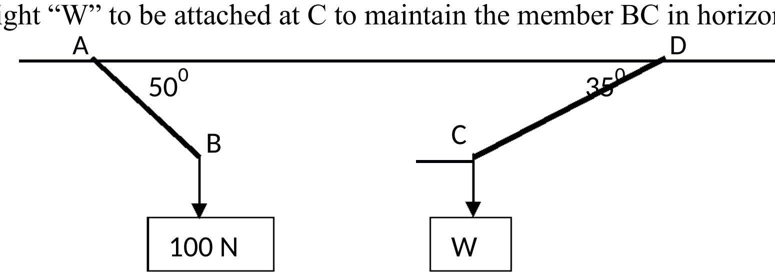
$\sum F_x \Rightarrow \quad 500 = P\cos\alpha + 500\cos 20 - 200\cos 45$ ------ (1)

$\sum F_y \Rightarrow \quad P\sin\alpha + 200\sin 45 = 500\sin 20 + 200$ -------- (2)

From (1) and (2) **P = 286.5 N and α = $53^0 15'$**

(ii) Three members AB, BC and CD are joined as shown in the figure. A vertical weight (100 N) is hanged at B. Find the weight "W" to be attached at C to maintain the member BC in horizontal position.

Solution:



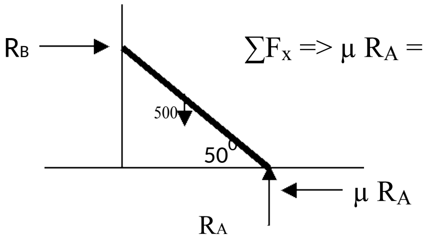
Applying Lami's

At B T_{BC} = (100 / sin 130) x sin 140 = 83.9 N at C At B T_{BC} = (W / sin 145) x sin 125 = 83.9 N

So W = (83.9 x sin 125) / sin 145 = 58.74 N

b (i) A ladder 12 m length (weight = 500 N) is resting against a smooth wall. Find the coefficient of friction between floor and ladder if ladder starts slipping when the angle between ladder and floor is $\leq 50^0$.

Solution: As the wall is smooth friction is zero.

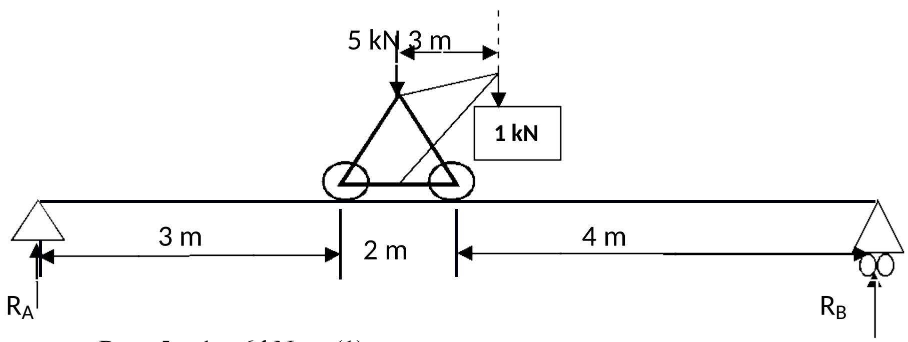


$\sum F_x \Rightarrow \mu R_A = R_B$ --- (1) and $\sum F_Y \Rightarrow R_A = 500$ --- (2)

$\sum M_A \Rightarrow 500 * 6 \cos 50 = R_B * 12 \sin 50$ so $R_B = 209.77$

from (1) $\boldsymbol{\mu = 209.77 / 500 = 0.4195}$ Ans

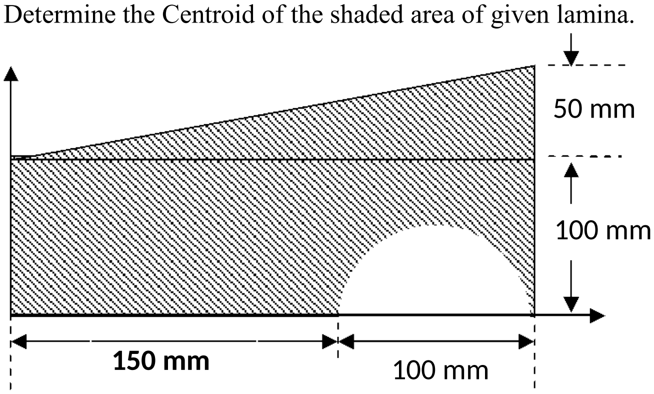
(ii) Find the reactions at support for the following beam.



$\sum F_Y \quad {}_A + R_B = 5 + 1 = 6$ kN --- (1)

$\sum M_A \Rightarrow 5 * 4 + 1 * 7 - R_B * 9 = 0$; $\mathbf{R_B = 3}$ **kN** **--- (2) and from (1)** $\mathbf{R_A = 3}$ **kN** Ans.

c) Determine the Centroid of the shaded area of given lamina.



Sr. No.	Section	Area	X_i	Y_i
01	Rectangle	250 x 100	125	50
02	Triangle	½ x 250 x 50	250 x 2/3	100 + 50 x 2/3
03	Semicircle	$\pi (50^2) / 2$	150 +50	$4 (50) / (3 \pi)$
		$\sum A = 27325$		

$\overline{X} = A_1X_1 + A_2X_2 - A_3X_3 / (A_1 + A_2 - A_3) = 3381666.667 / 27325 =$ **123.75 mm**

$\overline{Y} = A_1Y_1 + A_2Y_2 - A_3Y_3 / (A_1 + A_2 - A_3) = 1895791.667 / 27325 =$ **69.38 mm**

Ans: Centroid of the given shaded portion is (**123.75 mm, 69.38 mm**).

d) (i)The initial angular velocity of a rotating body is 2 rad / sec. And initial angular acceleration is zero. The rotation of the body is according to the relation $\alpha = 3t^2 - 3$. Find (i) angular velocity and (ii) angular displacement when t = 5 sec.

Solution:

Initial angular velocity $\boldsymbol{\omega_0 = 2}$ **rad / sec**

(1) Angular Velocity (**ω**)

We know $\boldsymbol{\alpha = d\omega / dt}$ **or** $\boldsymbol{d\omega = \alpha dt}$; $\boldsymbol{d\omega} = (3t^2 - 3)dt$

Integrating, we get $\int \boldsymbol{d\omega = \int \alpha dt = \int (3t^2 - 3)dt}$

$$\boldsymbol{\omega = (3t^3)/3 - 3t + C}$$

as at t = 0, $\boldsymbol{\omega = 2}$ **rad / sec so** $\boldsymbol{2 = 0 + 0 + C ; C = 2}$

$$\boldsymbol{\omega = t^3 - 3t + 2}$$

when t = 5; $\boldsymbol{\omega_5 = 5^3 - 3*5 + 2 = 112}$ **rad / sec and**

(2) Angular Displacement (**θ**)

We know $\boldsymbol{\omega = d\theta / dt}$ **or** $\boldsymbol{d\theta = \omega dt}$

Integrating, we get $\int \boldsymbol{d\theta = \int \omega dt = \int (t^3 - 3t + 2)\, dt}$

$$\boldsymbol{\theta = \tfrac{1}{4} t^4 - 3/2\, t^2 + 2t +}$$

$\boldsymbol{C_1}$ as $\boldsymbol{\theta = 0}$ **when t was 0**

so $\boldsymbol{C_1 = 0}$ **hence general equation** $\boldsymbol{\theta = \tfrac{1}{4} t^4 - 3/2\, t^2 + 2t}$

so at t = 5 $\boldsymbol{\theta_5 = \tfrac{1}{4}\, 5^4 - 3/2\, 5^2 + 2(5) = 128.75}$ **radians.**

(ii) A train starts from rest and moves along a curved track of radius 800 m with uniform acceleration until it attains a velocity of 72 kmph at the end of 3 minute. Determine the tangential , normal and total acceleration in m/s^2 of the train at the end of second minute.

Solution: As train starts from rest u = $\boldsymbol{\omega_0 = 0}$ **and radius = 800 m**

Velocity after 3 minutes v = 72 km per hour = 72 *5/18 = 20 m/s

So ω_{180} = V/ R = 20 / 800 = 1/40 rad / sec

As train is moving with uniform acceleration, we can use the motion equations:

$\omega_{180} = \omega_0 + \alpha t$; $1/40 = 0 + \alpha * 180$ so $\alpha = 1/7200$ rad / sec^2

so the angular velocity after 2 minutes

$\omega_{120} = \omega_0 + \alpha t$ = $0 + 1/7200 * 120 = 1/60$ rad / sec.

Tangtential acceleration (a_t) = R * α = 800 * 1/7200 = 0.111 m / sec^2

Normal acceleration (a_n) = $\omega^2 R$ = (1/60)2 * 800 = 0.222 m / sec^2

Acceleration (a^2) = $a_t^2 + a_n^2$ so a = 0.246 m/ sec^2

e) (i) A cylindrical roller 50 cm in diameter is in contact with two horizontal conveyor belts running at uniform speed of 10 m/s and 6 m/s as shown in figure. Assuming that there is no slip at point of contact, determine (i) position of the instantaneous centre, (ii) Linear velocity of centre of roller.

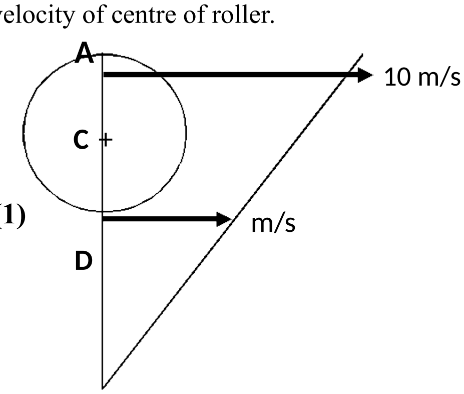
As I is the instantaneous centre

so **ω is uniform about I**

so V_A = 10 m/s = $\boldsymbol{\omega * IA}$

$\boldsymbol{= \omega * (ID + 0.5) - (1)}$

V_D = 6 m/s = $\boldsymbol{\omega * ID}$ **-- (2)**



From equations (1) and (2) ID = 0.75 m and **ω** = 8 rad / sec

so $\mathbf{V_C = \omega * IC = 8 * 1 = 8}$ **m/sec** ---- Ans.

(ii) Find the reactions at the support by the **Virtual Work method**.

1 kN

2 kN / m

2 * 3 = 6

1 kN

$Y_2 Y_1$ y

2 m 1 m 1.5 m

2 m 1 m

Solution:

R_A

R_B

By similar triangle ratio: $Y / 3 = Y_1 / 2 = Y_2 / 1.5$

Total Virtual Work done = 0

$R_A * 0 + (-6) *(Y_2) + R_B * Y_1 + (-1) * Y = 0;$ Hence $\mathbf{R_A = 1}$ **kN and** $\mathbf{R_B = 6}$ **kN** as $R_A + R_B = 7$

SECTION – C

Attempt all questions of this section. Each question carries 10 marks. (10 x 5 = 50)

3 (i) What should be the value of the angle θ so that the motion of the 90 kN blocks impends downward? The coefficient of friction for all the surfaces is 1/3.

30 kN

90 kN

θ

Solution:

From FBD of upper block:

$\sum F_y \Rightarrow R_1 = 30 \cos\theta$ -------- (1)

$\sum F_x \Rightarrow T = 30 \sin\theta + 1/3 (R_1) = 30 \sin\theta + 1/3 (30 \cos\theta)$ ------ (2)

From FBD of Lower block:

$\sum F_y \Rightarrow R_2 = R_1 + 90 \cos\theta = 30 \cos\theta + 90 \cos\theta = 120 \cos\theta$ ------ (3)

$\sum F_x \Rightarrow 90 \sin\theta = \mu R_1 + \mu R_2 = 1/3 [30 \cos\theta + 120 \cos\theta]$ ---- (4)

$90 \sin\theta = 50 \cos\theta$ ------ (4)

So $\sin\theta / \cos\theta = 50 / 90$; hence $\theta = \tan^{-1} (0.5555) = \mathbf{29.05^0}$ **= θ Ans**

g) Find the forces in the members of the following truss. The truss is hinged supported at left end and roller supported at right end.
Solution: Considering all member forces as compressive in nature.

10 kN

D **F_4** **E** 6 kN

F_3 **F_5**

F_2 **F_7**

60^0 **F_1** 60^0 60^0 **F_6** 60^0

A 10 m **C** **B**

R_{AV} **R_B**

$\sum F_x \Rightarrow R_{AH} = 6$ ------------ (1)

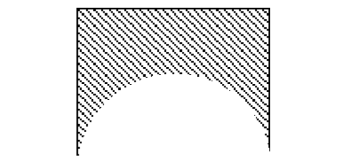
$\sum F_y \Rightarrow R_{AV} + R_B = 10$ ------ (2)

$\sum M_A \Rightarrow 10*2.5 + 6*4.33 = 10 R_B$ ------ (3)

So $R_B = 5.10$ kN and $R_{AV} = 4.10$ kN

Joint (A)	Joint (B)	Joint (C)	Joint (D)
$\sum F_x$ => $6 + F_2 + F_1 = 0$ - (1) $\sum F_y$ => $F_2 \sin 60 = 4.9$ --- (2) So F_1 = -8.829 kN (T) and F_2 = 5.658 kN (C)	$\sum F_x$=> $F_7 \text{ Cos } 60 + F_6 = 0$ (1) $\sum F_y$ => $F_7 \sin 60 = 5.1$ --- (2) So F_6 = - 2.945 kN (T) and F_7 = 5.89 kN (C)	$\sum F_x$ => $F_3\text{Cos}60 - 8.829 = F_5 \text{ Cos } 60 - 2.945$ (1) $\sum F_y$ => $F_3 \sin 60 + F_5 \sin 60=0$ So F_3 = 5.884 kN (C) and F_5 = - 5.884 kN (T)	$\sum F_x$=> 5.658 Cos 60 – 5.884 cos 60 = F_4 So F_4 = -0.113 kN (T)

5 ((ii) A semicircle is removed from a square lamina of side 25 mm as shown in the figure. Find the moment of inertia of the remaining area about its base.



MOI of square about base = $1/12\ (25^4) + 25^2 * 12.5^2$ ---(1)

MOI of semicircle about its base = $0.11\ (12.5)^4 + \pi\ (12.5)^2/2 * (4*12.5/3\ \pi)^2$ – (2)

MOI of shaded portion = MOI of square – MOI of Semicircle = 120,620.95 mm^4

II Method:

MOI of shaded portion about base = $1/3\ (25^4) - \pi / 128\ (25^4) = 120{,}620.95$ mm^4

6) (i) A Ship is approaching a port in due East direction with a velocity of 15 kmph. When this was 50 km from port, ship B sails in N 45^0 W direction with a velocity of 25 kmph from the port. After what time the two ships are at a minimum distance and how far each has travelled.

Solution:

V_{BX} = 25 sin 45 = 17.678 kmph and V_{BY} = 25 sin 45 = 17.678 kmph

V_{AX} = - 15 kmph and V_{AY} = 0

V_{RX} = 17.678 - (-15) kmph = 32.678 kmph and V_{RY} = 17.678 - 0 = 17.678 kmph

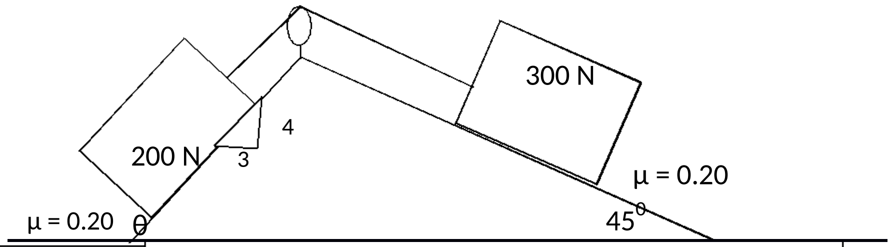
$V_R^2 = 32.678^2 + 17.678^2$ = 37.153 kmph

$\alpha = \tan^{-1}(17.678 / 32.678) = 28.41^0$

$V_R * t = 50 \cos \boldsymbol{\alpha}$; $37.153 * t = 50 \cos \mathbf{28.41}$

So t = 1.1837 hours ---- Ans.

7. Explain .D'Alembert's principle. In what distance will body of 300 N attains a velocity of 3 m/s staring from rest. What is the tension in the chord? Consider frictionless pulley.



<table>
<tr>
<td>From Free Body Diagram of 200 N Block (Considering block going upward):

Sin θ = 4/5 and cos θ = 3/5

$\sum F_y \Rightarrow R_1 = 200 \cos \theta$ --- (1)

$\sum F_x \Rightarrow T = 200 * \sin\theta + \mu R_1 + 200/9.8 * a$ -- (2) $T = 200*4/5 + 0.2(200 \cos \theta) + 20.41a$

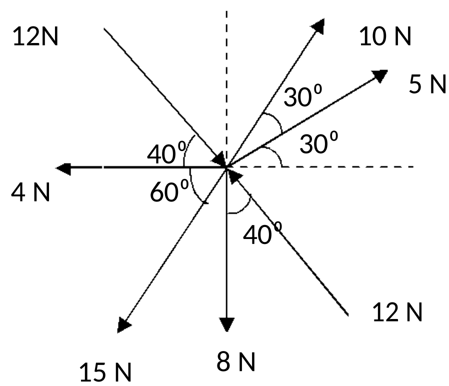
So $T = 160 + 24 + 20.41\ a$</td>
<td>From Free Body Diagram of 300 N Block (Considering block going downward):

$\sum F_y \Rightarrow R_2 = 300 \cos \theta$ --- (3)
$\sum F_x \Rightarrow 300 * \sin\theta = T + \mu R_2 + 300/9.8 * a$ -- (4)
$212.13 = T + 42.43 + 30.61\ a$
So $T = 169.7 - 30.61\ a$ --- (4)
From (2) and (4)
$a = -0.2799\ m / sec^2$ and $T = 178.26\ N$</td>
</tr>
<tr>
<td colspan="2">Negative acceleration shows that the direction of motion is just opposite to what we have considered.
Now as u = 0; $V^2 - u^2 = (2\ a * S)$ $\Rightarrow V^2 = (2\ a * S)$
so to attain the velocity of 3 m/s the blocks will move
$S = V^2 / 2\ a = 3^2 / 2*0.2799$
S = 16.07 m ----- Answer</td>
</tr>
</table>

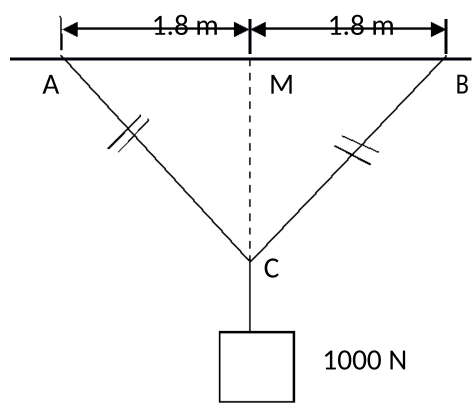
ASSIGNMENTS

ASSIGNMENT-TWO DIMENSIONAL FORCE ANALYSIS

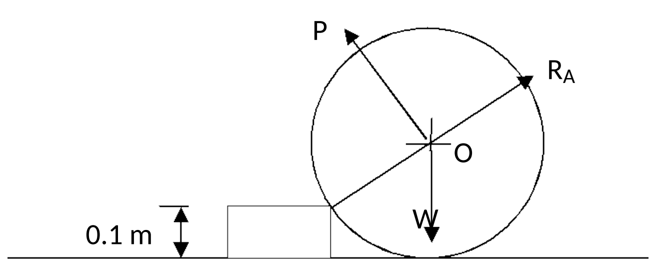
1. Explain various force systems giving examples.
2. State and explain Principle of transmissibility of a force.
3. State and prove Lami's theorem.
4. The forces 20N, 30N, 40N, 50N are acting at one of the angular points of a regular hexagon, towards the other five angular points, taken in order. Find the magnitude and direction of the resultant force.
5. Determine the resultant of following force system as shown in fig.



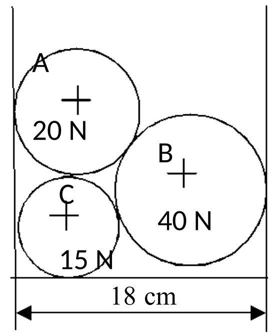
6. Determine the shortest length of cable which can be used to support a load of 1000 N if tension in the cable is not to exceed 720 N. Take Length of AC equal to BC



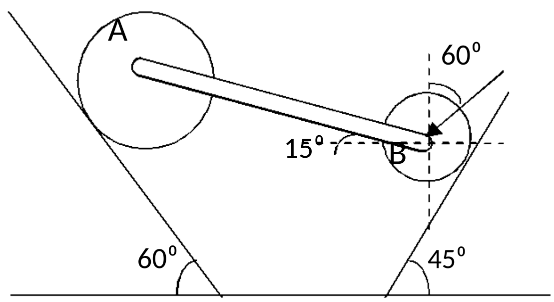
7. A uniform wheel of 0.4 m diameter, weighing 8 kN, rests against a rigid rectangular block 0.1 m thick as shown in fig.. Find the least pull through the centre of the wheel to just turn it over the corner of the block. All surfaces are smooth. Find the reaction of the block as well.



8. Three cylinders are piled in a rectangular ditch as shown in fig. Neglecting friction, determine the reaction between cylinder C and the vertical wall. The radius of cylinders A= 5cm, B=6 cm, C=4 cm.

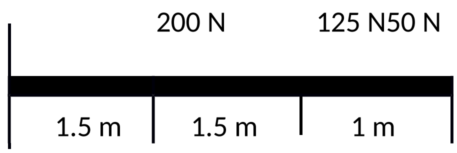


9. In fig., two cylinders A of weight 400 N and B of weight 200 N, rest on smooth inclines. They are connected by a bar of negligible weight hinged to each cylinder at its geometric center by smooth pins. Find the force P acting as shown that will hold the system in the given position.



ASSIGNMENT-TWO DIMENSIONAL FORCE ANALYSIS (II)

1. State and explain the Principle of moments.
2. State and prove Varignon's theorem.
3. Define the terms: a) Moment b) moment of a force c) Couple
4. A system of parallel forces acting on a lever is as shown. Determine the magnitude, direction and position of the resultant.



5. Four forces equal to 10 N, 20 N, 30 N and 40 N are respectively acting along four sides (1 m each) of a square ABCD, taken in order. Determine the magnitude, direction and position of the resultant.

20 N

30 N

10 N

40 N

6. A cylinder of weight W and radius r is supported in horizontal position against a vertical wall by a bar LM of negligible weight. The bar is hinged to the wall at L and supported at M by a horizontal rope MN. Find the value of the angle ϴ that the bar should make with the wall so that the tension in the rope is minimum. Assume frictionless conditions.

M

N

S

U

I

L

7. Three cables attached to a disk exert on it the forces as shown in fig. Determine resultant and specify its point of application on line AD.

110 N

140 N C 20^0

45^0 B

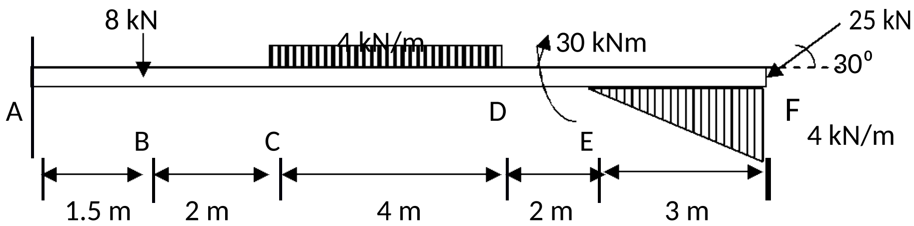
A

D

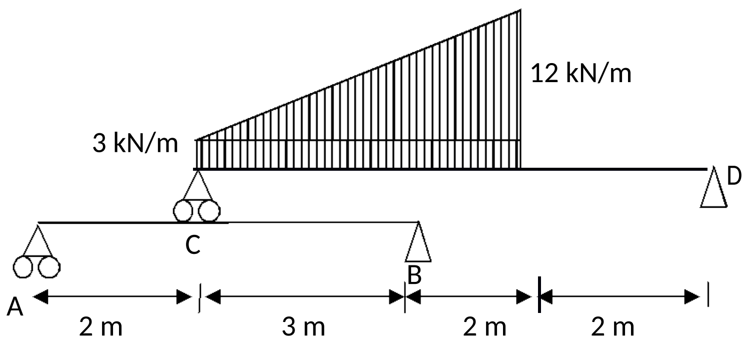
45^0

140 N

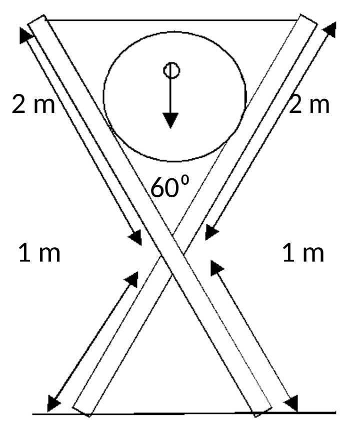
8. A Cantilever beam has been loaded as shown in fig. Determine the reaction at cantilever end A.



9. Determine the reactions at A, B and D of the system shown.



10. A cylinder of diameter 1m weighing 500 N is supported by two crossbars each 3 m long and hinged together at 1m from lower ends as shown. A horizontal string connects upper ends of bars and thus prevents opening out of bars. Find tension in string and reaction components at hinge. Assume frictionless conditions.



Assignment on Beam and Truss

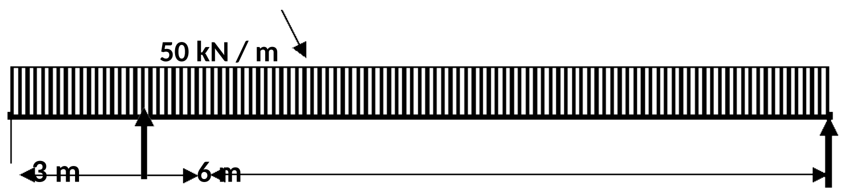
Theoretical questions:

2. Define Beam. List various types of beams and loads with neat sketches.
3. Write any four assumptions considered while analyzing a truss.
4. Define perfect, imperfect (deficient and redundant) Frames.

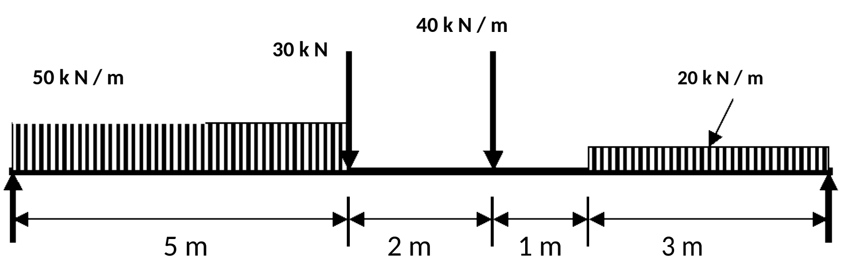
Numerical Questions:

1. A simply supported beam of span 12 m is loaded with a uniformly varying load of 50 kN / m at left end and 110 kN / m at right end. Find reactions at support.

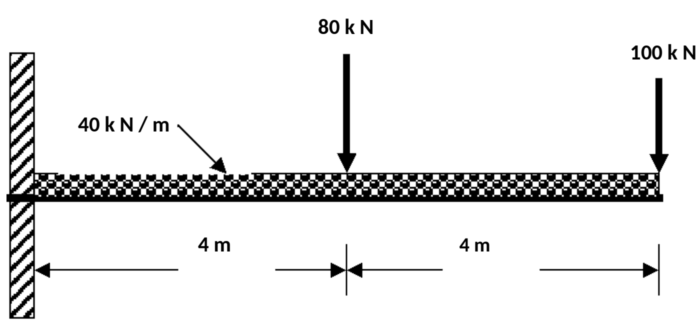
2. Find reactions at support for the following beam .

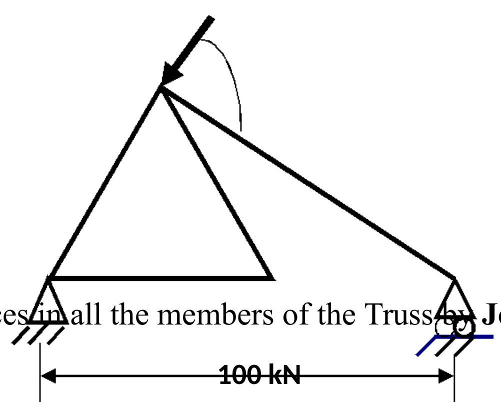


3. Find reactions at support for the following beam.



4. Find reactions at the fixed support for the following beam.





5. Determine the forces in all the members of the Truss by **Joint Method** as shown in figure.

D

90

60° 60° 30°

A C

8 m

6. Determine the forces in the members of the truss by **Methods of Section**, shown in figure.

- FE, AE, AB and DE, DB and BC

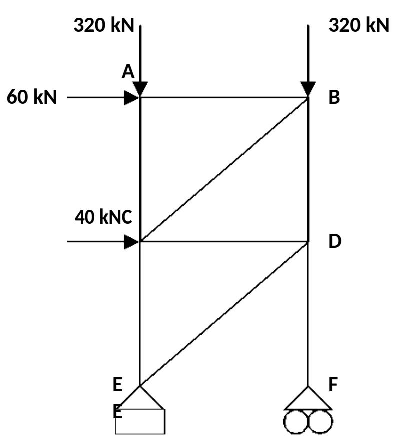
D **50 kN** **E** **80 kN** **F**

60^0 60^0

A 12 m **B** 12 m **C**

60 kN **100 kN**

7. Find the forces of the members of following Truss.

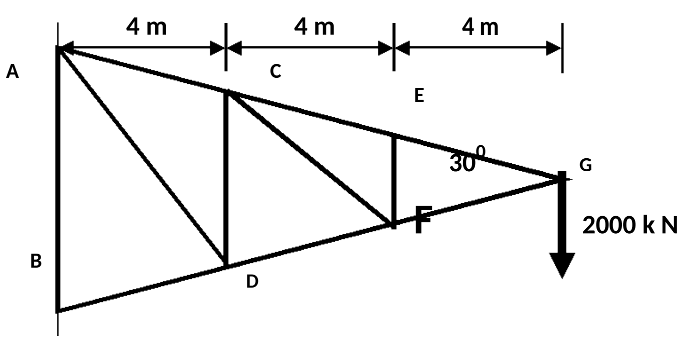


Given

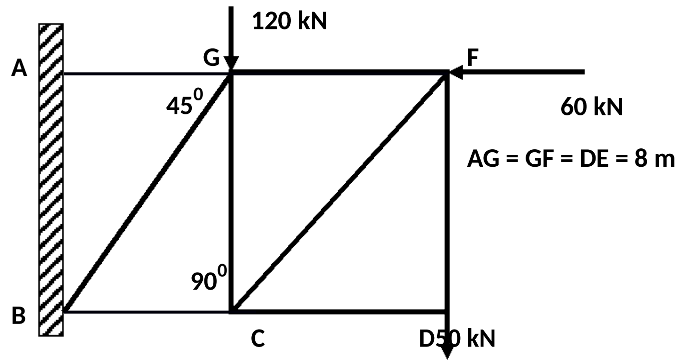
AB = 3 m

AC = CE = 4 m

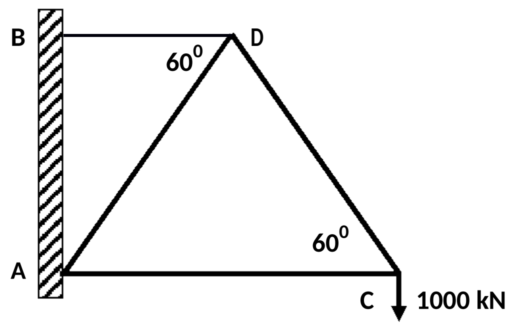
8.



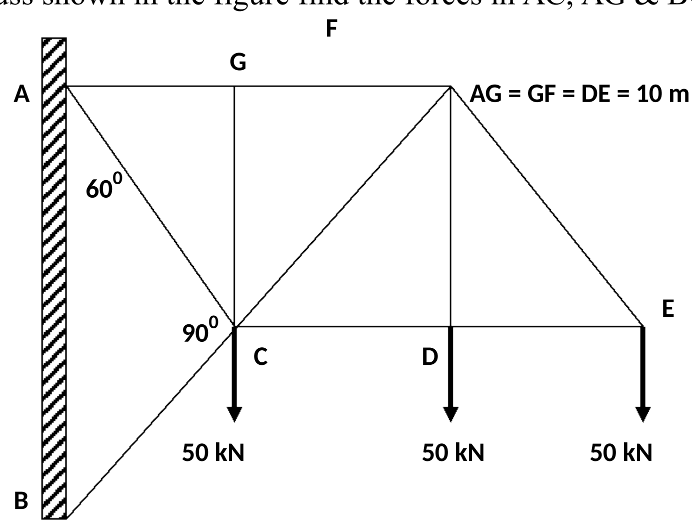
9) For the truss shown in the figure find the forces in GF, CD & CF members by section method.



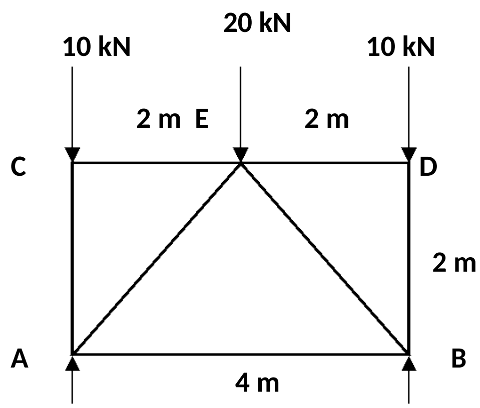
10) Analyse the following truss by Joint method.



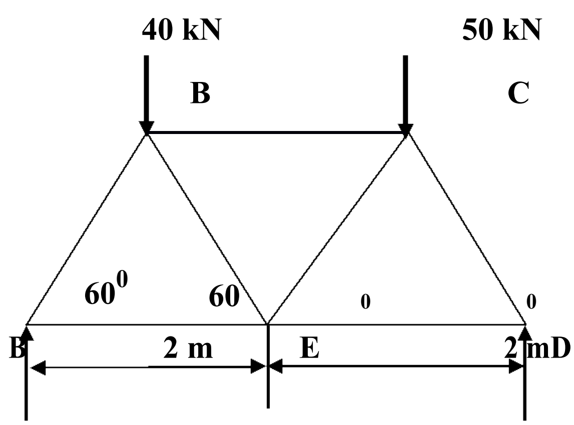
11. For the truss shown in the figure find the forces in AC, AG & BC and GF, CD & CF.



12. Find out the forces in all members of the following truss: (10 marks)



13. Find out the forces in BC, CE and DE members of the following truss:



Assignment: Friction

1. A uniform ladder of length 10 m and weighing 20 N is placed against a smooth vertical with its lower end 8 m from the wall. In this position the ladder is just to slip. Determine the coefficient of friction between the ladder and the floor.

2. A uniform ladder 20 m long weighs 1800 N. It is placed against a wall making an angle of 60^0 with floor. The coefficient of friction between the wall and the ladder is 0.38 and that between the floor and the ladder is 0.33. The ladder in addition to its own weight has to support a man weighing 900 N at the top of the ladder. Calculate the horizontal force F to be applied to the ladder at the floor level to prevent slipping.

3. A uniform ladder 5 m long weighs 300 N. It is placed against a wall making an angle 60^0 with floor. The coefficient of friction between the wall and the ladder is 0.25 and that between the floor and the ladder is 0.35. The ladder in addition to its own weight has to support a man weighing 900 N at the top of the ladder. Calculate the horizontal force F to be applied to the ladder at the floor level to prevent slipping.

4. A uniform ladder 3 m long weighs 18 N. It is placed against a wall making 60^0 with floor. The coefficient of friction between the wall and the ladder is 0.25 and that between the floor and the ladder is 0.35. The ladder in addition to its own weight has to support a man weighing 90 N at the top of the ladder. Calculate the horizontal force F to be applied to the ladder at the floor level to prevent slipping.

5. Calculate the push required to keep a ladder (length 8 m, weight = 750 N) in equilibrium, while a person (weight 1000 N) standing at the top. The ladder makes an angle of 20^0 with wall and take coefficient of friction for wall and surface = 0.3.

6. Determine the minimum angle which can be made by a ladder with the floor and leaning against a smooth wall without slipping under its own weight while supporting a person at top, whose weight is double the weight of the ladder. Take $\mu = 0.35$ wherever applicable.

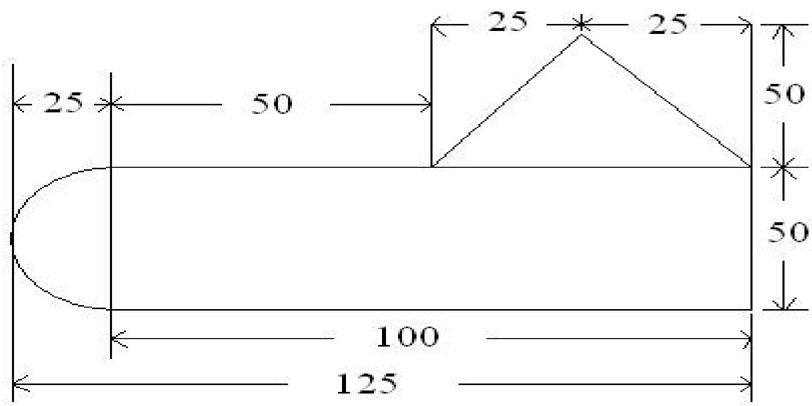
7. The weight of a 12 m long ladder is 2000 N and it is placed against a wall making an angle of 58^0 with floor. The coefficient of friction between wall and ladder is 0.30 and floor and ladder is 0.32. Calculate up to what length a person of weight 800 N can climb the ladder.

8. Derive $T_1 / T_2 = e^{\mu\theta}$ for an open belt drive system.

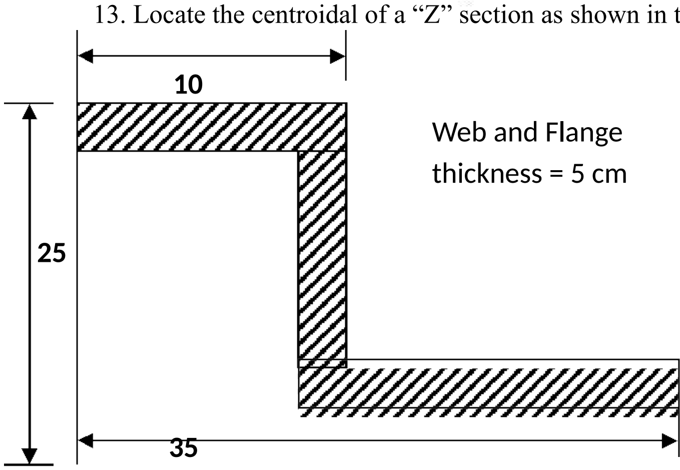
9. A belt is running over a pulley of diameter 120 cm at 200 rpm. The angle of contact is 165^0 & coefficient of friction between the belt & pulley is 0.3. If the maximum tension in the belt is 3000 N. Find the power transmitted by the belt.

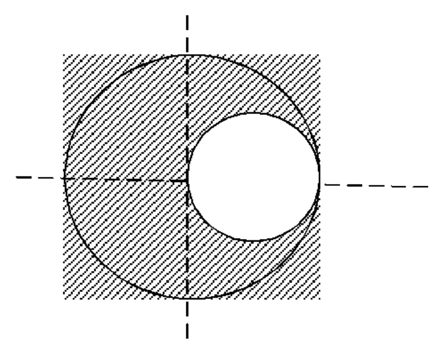
Assignment Unit III (CG, Centroid & Moment of Inertia)

1. Define Centriod, Centre of gravity, and moment of inertia.
2. Derive the equtaion of mass moment of inertia for a circular Ring.
3. Derive the equation for the Mass MOI for a uniform Circular plate.
4. Derive an expression for the mass moment of inertia of a solid uniform circular cone.
5. Derive an expression for the mass moment of inertia of a Sphere.
6. Derive an expression of the moment of inertia of a rectangular section about an axis passing through its centroid.
7. Two equal circular plates of maximum possible diameters are being cut from a square metalic sheet (size 800 x 800 mm). Calculate the moment of inertia of the reamining shape.
8. Calculate the Polar MOI of an equilateral triangle (side = 20 cm) about its vertex.
9. Locate the centroidal of a "Z" section as shown in the figure. All dimensions are in cm.
10. Calculate the Polar MOI of an equilateral triangle (side = 20 cm) about its vertex.
11. Show that the product of inertia of an area about two mutually perpendicular axes is zero, if the area is symmetrical about one of these axes.
12. A uniform lamina as shown in fig. on page no.5 consists of a rectangle, a semicircle & a triangle. Determine the CG of the lamina. All dimensions are in mm.



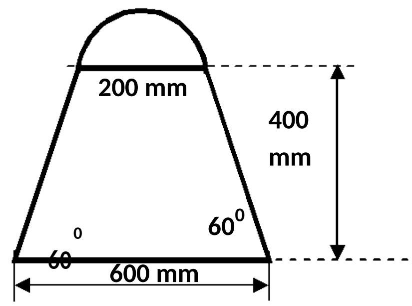
13. Locate the centroidal of a "Z" section as shown in the figure. All dimensions are in cm.





14. A circle is cut from a circle of diameter 450 mm as shown in the above figure. Calculate the polar moment of Inertia of the remaining shape.
15. Find the moment of inertia of an **"L"** shaped body of height and base as 200 mm each and web and flange thickness 20 mm about X axis.
16. From a circular plate of diameter 100 mm a circular part is cut out whose diameter is 50 mm. Find the centroid of the remainder.

17. Determine the moment of inertia of the section about an axis passing through the base of a equilateral triangle (side 150 mm).
18. Find the centroid of the given figure:



ASSIGNMENTS

ASSIGNMENT-KINEMATICS (RECTILINEAR, CURVILINEAR AND ROTARY MOTION)

1. Distinguish between :
   a) Statics and dynamics
   b) Kinematics and kinetics
   c) Rectilinear motion and curvilinear motion.
2. Express the acceleration of a particle in tangential and normal components.
3. The position of a particle in rectilinear motion is defined by the relation $x=t^3+t^2+t+1$, where x is in metres and t is in seconds. Determine its position, velocity and acceleration at time t=2 s.
4. The acceleration of a particle in rectilinear motion is defined by the relation $a=kt^2 -3$. Given that at $t=0$ s, $v=0$ m/s and $x=0$ and at $t=3$ s, $v=9$ m/s, determine its position, velocity and acceleration at $t=2$s.
5. Two trains start at same time from stations A and B (6 km apart) respectively in opposite tracks. Train A accelerates uniformly at the rate of $0.5 m/s^2$ until it reaches a speed of 54 kmph. While train B accelerates uniformly at the rate of $0.6 m/s^2$ until it reaches a speed of 72 kmph and then travels at this speed. Determine when and where both will cross each other.
6. A balloon is ascending from the ground at a constant acceleration of $0.5 m/s^2$. After 30 seconds from the start, a ball is released from the balloon. Determine the velocity with which it will strike the ground and the time taken to reach the ground.
7. Track repairs are going on a 2 km length of a railway track. The maximum speed of the train is 90 km/h. The speed over the repair track is 36 km/h. If the train on approaching the repair track decelerates uniformly from the full speed of 90 km/h to 36 km/h in a distance of 200 m and after covering the repair track accelerates uniformly to full speed from 36 km/h in a distance of 1600 m, find the time lost due to reduction of the speed in the repair track.
8. A wheel starting from rest is accelerated at the rate of $5 rad/s^2$ for an interval of 10 sec. If it is then made to stop in the next 5 sec by applying brakes, determine

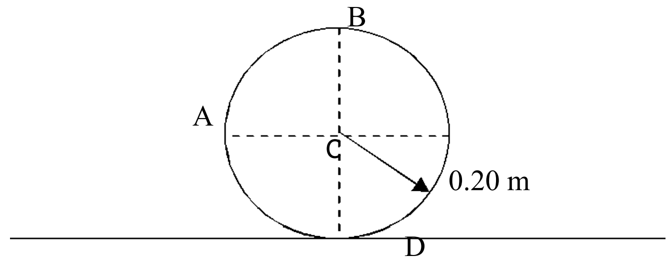
(i) The maximum velocity attained

(ii) Total angle turned.

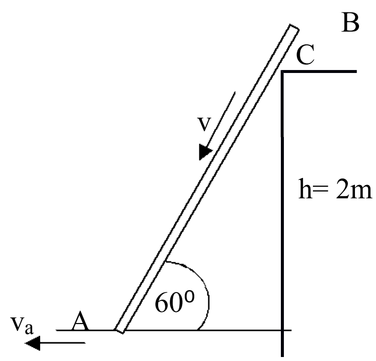
9. A wheel rotates with uniform angular acceleration. If the angles turned during the third and the sixth second be 8 radians and 11 radians respectively, determine the initial angu~~la~~r velocity of the wheel and the angular acceleration.
10. The angular rotation in radians of an accelerated flywheel is given by $\Theta = {}_{32}{}^{9}t^2$. Find the linear velocity and acceleration of a point at a distance of 0.75m from the axis of rotation at the instant when its tangential and normal accelerations are equal.
11. The angular acceleration of the disc is defined by the relation $\alpha = 3t^2-2t$. Determine the expressions for angular velocity and displacement given that the disc is initially at rest at $\Theta=0$.
12. A motorist is driving at 80 km/hr on a curved position of a highway of 400 m radius. He suddenly applies brakes and that causes the speed to decrease to 45 km/hr at a constant rate in 8 sec. Determine the tangential and normal components of acceleration immediately after the application of brakes and 4 seconds later.

ASSIGNMENT-KINEMATICS (RELATIVE VELOCITY AND GENERAL PLANE MOTION)

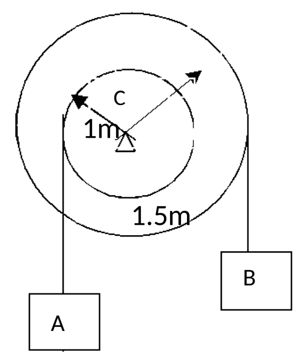
1. Define General plane motion and give examples.
2. What are the various methods used to analyze the general plane motion. Discuss them.
3. Define instantaneous center of rotation.
4. Hailstones fall vertically at a velocity of 5 m/s on to the deck of a ship steaming at 8 m/s. Find the direction of motion of hailstone as felt by an observer on the deck and its apparent velocity.
5. When a cyclist is riding west at 24 km/h he finds the rain meeting him at an angle of 45^0 with the vertical. When he rides at 16 km/h he meets the rain at an angle of 30^0 with the vertical. What is the actual velocity in magnitude and direction of the rain.
6. A cylinder of radius 20 cm rolls without slipping along a horizontal plane PQ. Its center has a uniform velocity of 25 m/s. Find the velocity of the points A and B on the circumference of the cylinder.



7. A string is wound round at a pulley 250 mm in diameter. One of its end is fixed to the pulley while the other is fixed to the weight hanging freely. This weight describes a distance of 10 m after starting from rest, in five seconds. Find the angular velocity reached at the end of the above displacement. Also find the distance moved by the weight to make the pulley rotate at 300 rpm.
8. A long rod AB is supported at the upper edge of a wall of height h= 2m, and on a horizontal floor as shown in the figure. If the lower end of the rod moves with a velocity of v_a= 1 m/s, find the velocity of the contact point C of the rod and the angular velocity of the contact point C of the rod and the angular velocity of the rod, when the rod is at 60^0 to the horizontal.



9. A pulley and two loads are connected by inextensible strings as shown in fig. The load A has uniform acceleration of 3 m/s^2 and an initial velocity of 4.5 m/s both directed downwards. Find
(a) The number of revolutions executed by pulley in 4 sec.
(b) The velocity and position of load B after 4 sec.
(c) The acceleration of point C at t=0.



ASSIGNMENT-KINETICS OF RIGID BODIES

a. Write brief note on

a) D'Alembert's Principle and its applications.
b) Principle of conservation of Energy and its application.
c) Principle of conservation of momentum and its applications.

b. Define the terms:

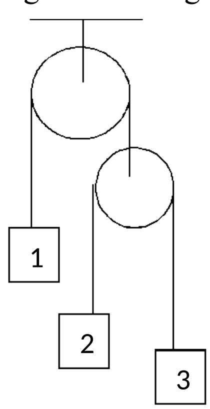
a) Work-energy principle
b) Impulse
c) Momentum

3. Two bodies directly in line and 10m apart are held stationery on an inclined plane having inclination of 20⁰. The coefficient of friction between plane and lower body is 0.08 and that between the plane and upper body is 0.05. If both the bodies are set in motion at the same instant, calculate the distance through which each body travels before they meet together.

10. An elevator together with the passengers weighing 2 tons is supported by a cable. Determine the acceleration of the lift when the tension in the cable is

a) 23 kN when the lift is moving upwards
b) 18 kN when it is moving upwards
c) 16kN when the lift is moving downwards
d) 21 kN when it is moving downwards

11. Determine the acceleration of the system of blocks shown in fig. Assume the pulleys to be massless and frictionless. Take m_1 = 8kg, m_2= 2 kg and m_3= 3 kg. Also, determine the tension in the strings connecting the blocks.

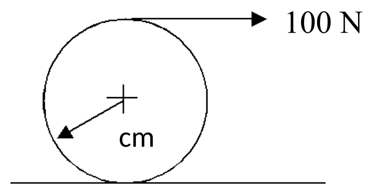


12. Two bodies of weights 40 N and 25 N are connected to the two ends of a light inextensible string, which passes over a smooth pulley. The weight 40 N is placed on a rough inclined plane, while the weight 25 N is hanging free in the air. If the angle of the plane is 15⁰, and coefficient of friction between the weight 40 N and the inclined surface is 0.2, determine :

a) Acceleration of the system Tension in the string c) Distance moved by the weight 25 N in 3 sec starting from rest

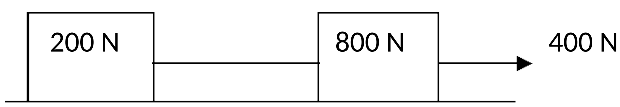
.

13. A constant force of 100 N is applied as shown tangentially on a cylinder at rest, whose mass is 50 kg and radius is 10 cm, for a distance of 5 m. Determine the angular velocity of the cylinder and the velocity of its center of mass. Assume that there is no slip.



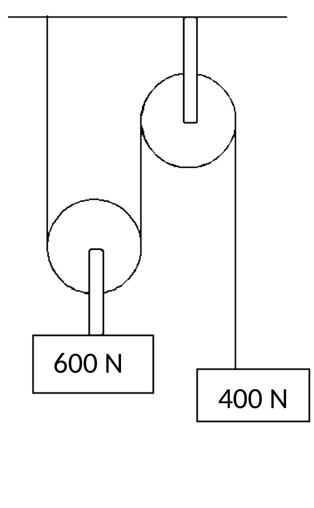
14. A 10 gm bullet is shot horizontally in a wood block of mass 1 kg. The bullet gets embedded in the block and the block is displaced on a rough horizontal table ($\mu = 0.2$) through 1 m. What was the velocity of the bullet?

15. Two weights 800 N and 200 N are connected by a thread and move along a rough horizontal plane under the action of a force 400 N applied to the first weight of 800 N as shown in fig. The coefficient of friction between the sliding surfaces of the weights and the plane is 0.3. Determine the acceleration of weights and the tension in the thread using D'Alembert's principle.



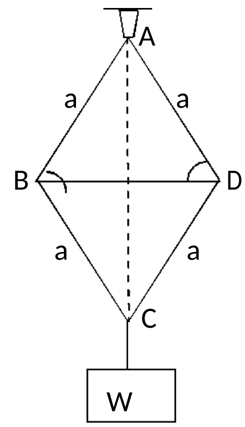
16. A block of 10 kg mass slides down an inclined plane with a slope angle of 35^0. It is stopped by a spring of stiffness 1 kN/m. If the block slides down 5 m before hitting the spring then determine the maximum compression of the spring. The coefficient of friction between the block and the inclined plane is 0.15.

17. Two blocks are connected by inextensible wires as shown in fig. Find by how much distance block 400 N will move in increasing its velocity to 5m/s from 2 m/s. Assume pulleys are frictionless and weightless.

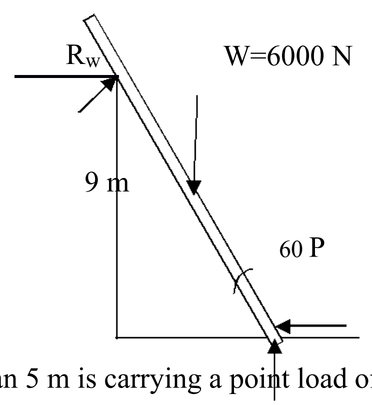


ASSIGNMENT-VIRTUAL WORK

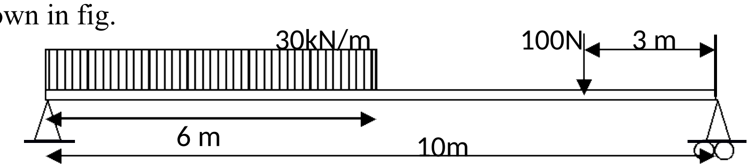
1. Define virtual displacement and virtual work.
2. State the principle of virtual work.
3. Discuss the advantages of the method of virtual work over the method of equilibrium equations to determine the unknown forces in a system of forces acting on the body.
4. Five rods AB, BC, CD, DA and BD each of equal length and equal cross-section are pin-jointed together so as to form a plane frame ABCD. The frame ABCD has a rhombus shape with one horizontal diagonal BD. The frame is suspended from topmost joint A. A weight W is attached at the lowermost joint C. Neglecting the self-weight of the frame and using the method of virtual work, find the magnitude of thrust in member BD.



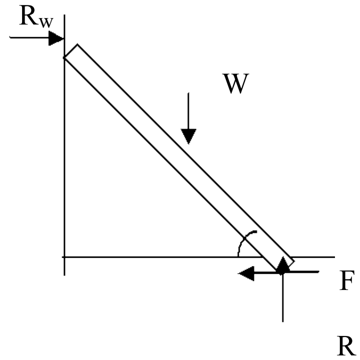
5. A weightless ladder AB is supported as shown in fig. carries a vertical load of 6000N. Find the force P required horizontally at B to keep the ladder in equilibrium, by the principle of virtual work. Assume all contact surfaces as smooth.



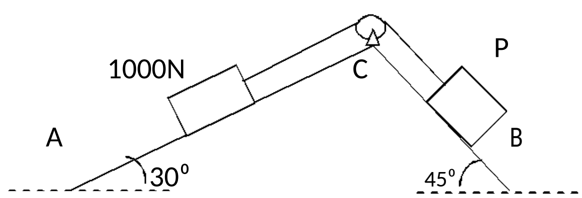
6. A beam AB of span 5 m is carrying a point load of 2 kN at a distance of 2m from A. Determine the beam reactions, by using the principle of virtual work.
7. Using the method of virtual work, find the support reactions for the simply supported beam AB loaded as shown in fig.



8. A uniform ladder of weight 250 N rests with its upper end against a smooth vertical wall and its foot on a rough horizontal ground making an angle of 45^0 with the ground. Find the force of friction of ground using the method of virtual work.



9. A weight of 1000 N resting over a smooth surface inclined at 30^0 with the horizontal is supported by an effort P resting on a smooth surface inclined at 45^0 with the horizontal as shown in fig.



MODEL QUESTION PAPERS

ENGINEERING MECHANICS ME 101 (MODEL PAPER (1))

B.Tech. I Year (SEM. I) EXAMINATION, 2013-14

Time: 3 Hours Total Marks: **100**

Note: (1) This paper is in three sections. Section **A** carries **20 marks**. Section **B** carries **30 marks** and Section C carries **50 marks**.

(2) Attempt all questions. Marks are indicated against each question / part.

(3) Assume **missing data suitable** if any.

SECTION – A

1. Attempt all parts of this question [2x10=20]

a) Discuss the equilibrium condition for coplanar force system.

b) Find the weight of the block placed on a inclined plane making an angle of 30^0 with horizontal. The component of this block parallel to the inclined plane is 100 N.

c) Explain the laws of static friction

d) What is a zero force member (Null Member) in a truss. How you will identify it.

e) State parallel axis theorem

f) State perpendicular axis theorem

g) A car starts from rest with uniform acceleration of 1.2 m/sec^2. After achieving 100 kmph a sudden brake is applied to stop the car with retardation of 1.4 m/sec^2. Find the distance travelled during this period.

h) What is the relationship between angular velocity and revolutions per minute (r.p.m.) of a body?

i) Explain principle of conservation of momentum with neat sketches

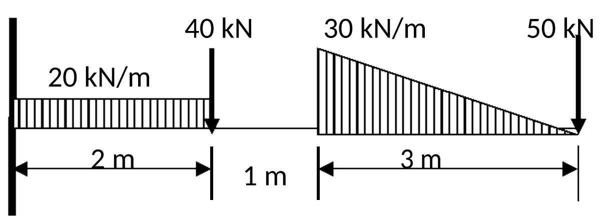
j) Find the force required to pull a block of 1 kN on a rough horizontal plane (μ = 2/5) with an acceleration of 2 m/sec^2.

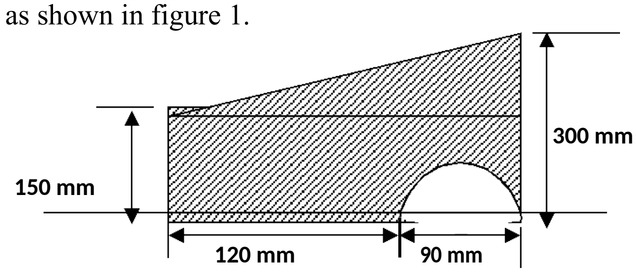
SECTION – B

2 Answer any three parts of the following: [10x3=30]

a) A uniform ladder of weight 1000 N and of length 8 m rests on a horizontal ground and leans against a smooth vertical wall. The angle made by the ladder with the horizontal is 60^0. When a men of weight 800 N stands on the ladder at a distance of 7 meters from the bottom of the ladder, the ladder is at the point of sliding. Determine the coefficient of friction between the ladder and the floor.

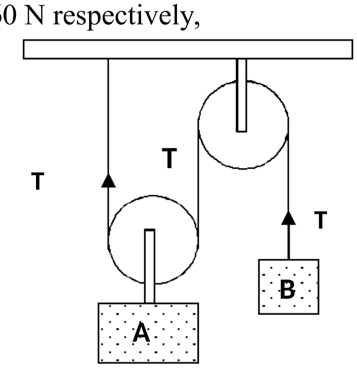
c) Calculate the resultant at the fixed end of the cantilever beam as shown in figure 1.





d) Find Centroid of the area shaded shown in the above figure.

e) Find the tension in string and accelerations of block A and B weighing 300 N and 60 N respectively, connected by a string and frictionless and weightless pulleys as shown in figure:



f) A train of weight 2000 kN is ascending (i.e. going upwards) a slope of 2.5 in 200 with a uniform speed of 45 km/hr. Find the power exerted by the engine, if the road resistance is 6 N per KN weight of the train,

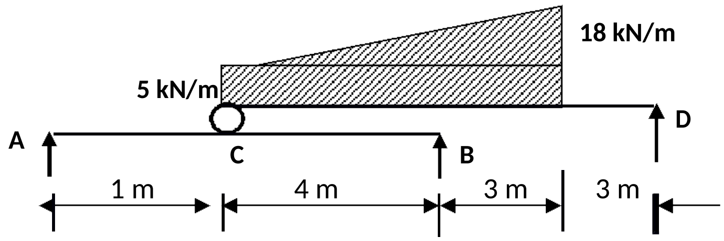
SECTION C (Attempt all parts)

3. Answer any two parts of the following: (5 x 2)

a) Explain the following: Law of transmissibility of forces, Varignon's theorem, Lami's theorem.

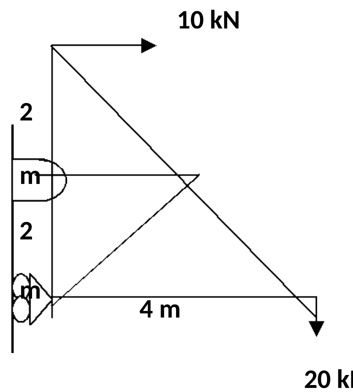
b) Derive the relationship for the tensions in a tight side and slack side of a belt pulley arrangement.

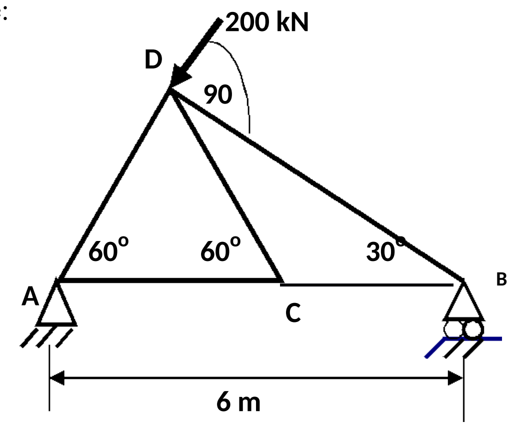
c) Determine the reactions at A, B and D of the system shown in the figure:



4) Attempt any one of the following: (10 x 1)

a) Find the forces in the members of the Truss shown in the left figure:

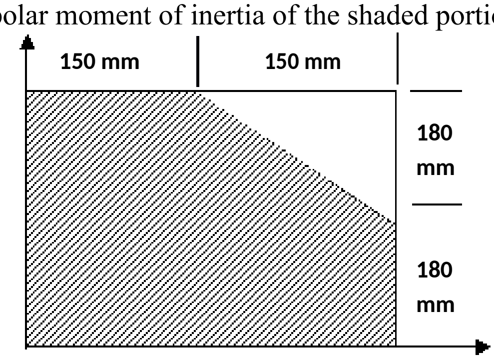




(b) Determine the forces in **DB, DC and AC** members of the Truss by **Section Method** as shown in right figure.

5) **Answer any one part of the following: (10)**

(a) Determine the polar moment of inertia of the shaded portion as shown in figure.



b) Derive an expression of mass moment of inertia of a right circular cone about the longitudinal axis.

6) **Answer any one part of the following: (10)**

(a) Explain the following terms with examples: Linear motion, uniform motion, and uniform accelerated motion and Define D'Alembert's principle.

(b) a particle moves along a straight line with a velocity given by the equation $v = 4t^3 - 2t^2 - 3t + 8$. Where v is the velocity in m/s and t is time in sec. When t = 3 seconds, the particle is found to be at a distance of 20 m from station A. Determine (1) the acceleration and displacement of the particle after 8 seconds.

7. **Answer any and part of the following: (10)**

(a) A train of weight 2000 kN is pulled by an engine on a level track at a constant speed of 36 kmph. The resistance due to friction is 10 n per kN of the trains weight. Find the power of the engine. Now if the train has to move with an acceleration of 0.5 m/s^2 find the power of engine.

(b) A bullet of mass 25 gm is fired with a velocity of 400 m/s. What is the KE of the bullet? If the bullet can penetrate 20 cm in a block of wood, what is the average resistance of wood. Find the distance travelled by both on a rough surface of μ= 0.3 before coming to rest. What will be the exit velocity of the bullet if fired into a similar block of 10 cm thick?

B.TECH – MODEL QUESTION PAPER (2) 2013 – 14

SEMESTER –1st **YEAR - FIRST** **SECTION – K to S**

SUBJECT – ENGINEERING MECHANICS **SUBJECT CODE - ME 101**

Time: 3.00 Hours **Max Marks : 100**

Notes: (i) This paper is in three sections. Draw neat sketches to support your answer
(ii) Marks are indicated against each section. Attempt questions from each section as per instructions. Assume missing data suitably, if any.

SECTION – A

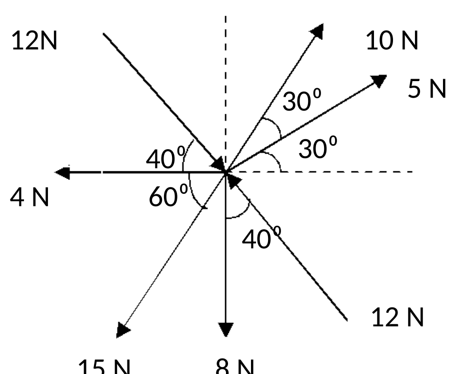
10. Attempt all parts of this question: (2X10 = 20)

q) Discuss the parallelogram law of force addition and polygon law of forces.
r) Explain principle of transmissibility of force.
s) State and Prove the Varignon's Principle.
t) What do you mean by angle of repose, Limiting friction and coefficient of friction.
u) What are the assumptions made in the analysis of a simple truss.
v) Differentiate between centroid and centre of gravity.
w) Explain transfer formula for determining the MOI.
x) Explain Polar moment of inertia & Radius of gyration.
y) Explain the difference between kinematics and kinetics.
z) Explain the types of motion.

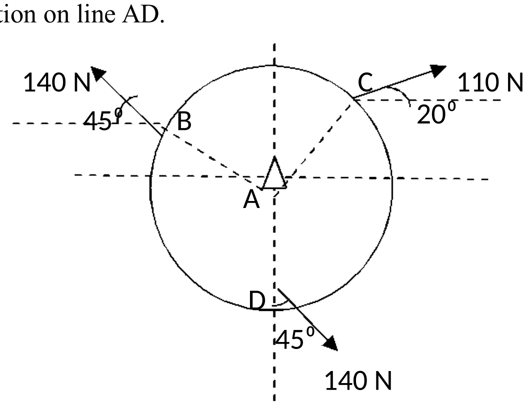
SECTION – B

Note : Attempt any three questions. Each part carry equal marks. **(10X3 = 30)**

a) (i) Determine the magnitude and direction of the resultant of following force system as shown in fig.



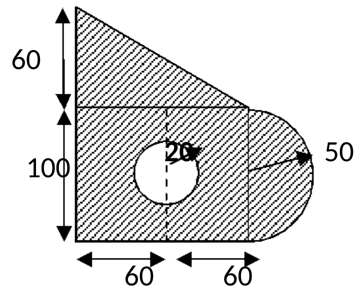
(ii) Three cables attached to a disk exert on it forces as shown in fig. Determine resultant and specify its point of application on line AD.



b) (i) In a lifting machine, an effort of 500 N is to be moved by a distance of 20 m raise a load of 10000 N by a distance of 0.8 m. Determine the velocity ratio, mechanical advantage and efficiency of the machine. Determine also ideal effort, effort lost in friction, ideal load and frictional resistance.

(ii)Derive the relation $T_2/T_1 = e^{\mu\Theta}$ for a belt drive.

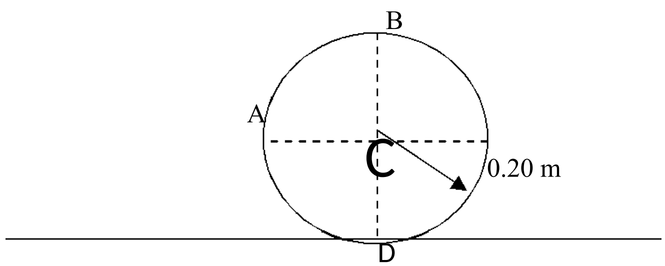
c) Determine the centroid of the composite section shown in fig.3. All dimensions are in mm.



d) (i) The angular acceleration of the disc is defined by the relation $\alpha = 3t^2 - 2t$. Determine the expressions for angular velocity and displacement given that the disc is initially at rest at $\Theta=0$.

(ii) Define the terms tangential acceleration, normal acceleration and total acceleration in kinematics.

e) (i) A cylinder of radius 20 cm rolls without slipping along a horizontal plane PQ. Its center has a uniform velocity of 25 m/s. Find the velocity of the points A and B on the circumference of the cylinder.

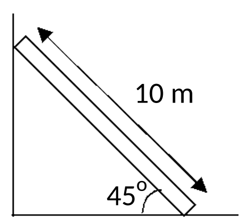


(ii) Explain the virtual displacement and virtual work in detail.

SECTION – C

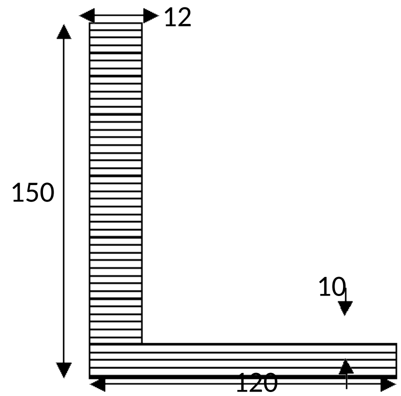
Note : Answer all the following questions. (Each question carry 10marks) (10X5 = 50)

1) A ladder of length 10m rests against a vertical wall,angle of inclination being 45° .If the coefficient of friction between ladder and wall and ladder and ground be 0.5 each.What will be the maximum distance along ladder to which the man whose weight is 1.5 times the weight of ladder may ascend before ladder begins to slip.(Take weight of ladder as W).



2) Find the magnitude and nature of the forces in all the members of the cantilever truss as shown in fig.

3) Determine the moment of inertia of the L-section shown in fig .about its centroidal axis. Also determine the radius of gyration with respect to centroidal x – x axis and y – y axis. All dimensions are in “m”.



4) (i) Derive the expression for mass M.I for a right circular cone of base radius R ,height H and mass M about its axis of rotation.
(ii)Discuss the various forms of Energies.

5) (i) What do you mean by the translational and rotational motion of rigid body?
(ii) In the mechanism as shown in fig. (A), determine the horizontal force P required to be applied to hold the system in equilibrium. The length of each link is L and that of weight is W.

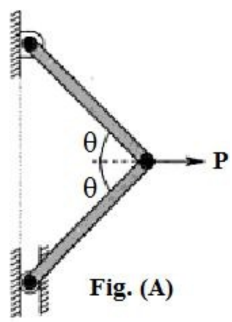


Fig. (A)

6) Explain the D’Alembert principle, work energy principle and impulse momentum method.

A bullet weighs 0.5N and moving with the velocity of 400m/s hits a centrally 30N block of wood moving away at 15m/s and gets embedded in it. Find the velocity of the bullet after the impact and the amount of kinetic energy lost.

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B.TECH – MODEL QUESTION PAPER (3) 2013 – 14

SEMESTER –1st **YEAR - FIRST** **SECTION – K to S**

SUBJECT – ENGINEERING MECHANICS **SUBJECT CODE - ME 101**

Time: 3.00 Hours **Max Marks : 100**

Attempt *all* questions. Marks are indicated against each question part.

(ii) Assume missing data suitably, if any.

Section-A

1. You are required to answer briefly *all* the parts : $10 \times 2 = 20$

(a) State principle of transmissibility of a force.

(b) What is equilibrium? State the necessary and sufficient conditions for a system of coplanar forces to be in equilibrium.

(c) Write down assumptions made in the analysis of truss.

(d) Explain the difference between coefficient of friction and angle of friction.

(e) Define polar moment of inertia. What is its use ?

(f) Differentiate between centroid and centre of gravity.

(g) Define tangential, normal and resultant acceleration.

(h) Distinguish between relative velocity and resultant velocity.

(i) State D'Alembert principle. What is its importance?

(j) State the principle of conservation of momentum and give some of its practical example.

Section-B

2. Answer any *three* parts of the following : $3 \times 10 = 30$

(a) A 600 N cylinder is supported by the frame BCD as shown in Fig. 2a.The frame is hinged at D. Determine reactions at A, B, C and D.

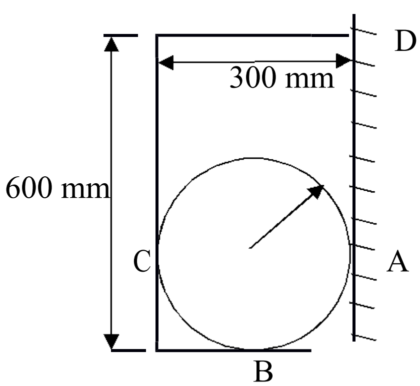


Fig. 2a

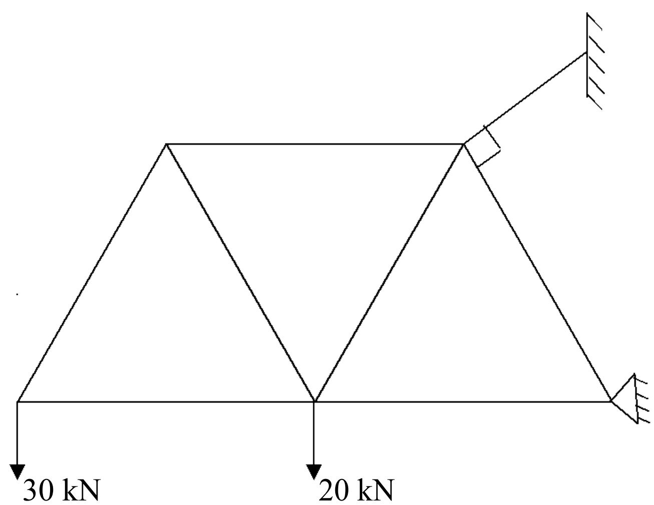


Fig. 2b

(b) Compute the forces in each member of the loaded cantilever truss shown in fig. 2b. Take length of each member 5 m.

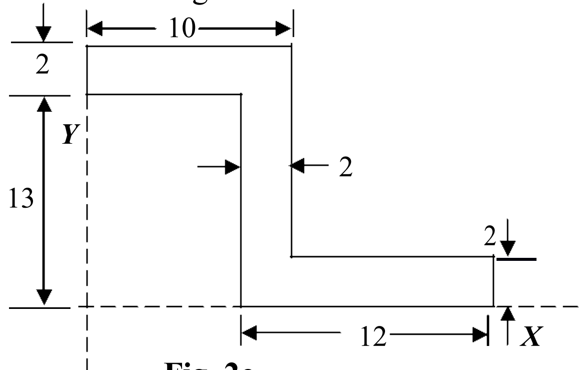


Fig. 2c

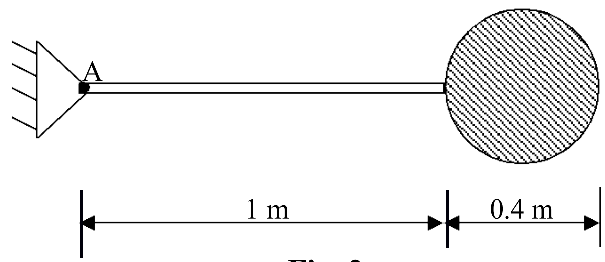


Fig. 2e

(c) Determine the centroidal polar moment of inertia of Z-section shown in fig. 2c. All dimensions are in cm.

(d) **(i)** A motorist enters a curved road with a 90 m radius of curvature with a velocity of 90 kmph and reduces the speed uniformly to 60 kmph in 10 s. determine the total acceleration at the end of 5 seconds.
(ii) Two ships move from a port at the same time. Ship A has velocity of 30 kmph and is moving in N 30° W while ship B is moving in south-west direction with a velocity of 40 kmph. Determine the relative velocity of A with respect to B and the distance between them after half an hour.

(e) A cylinder weighing 500 N is welded to a 1 m uniform bar of 200 N as shown in fig. 2e. Determine the acceleration with which the assembly will rotate about point A, if released from rest in horizontal position. Determine reaction at A at this instant.

Section-C

3. Answer any *two* part of the following : $2 \times 5 = 10$

(a) State and prove Lami's theorem.

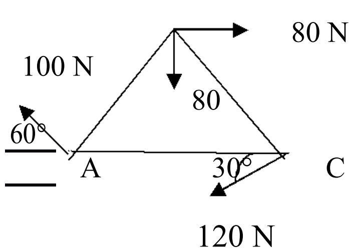


Fig. 3c

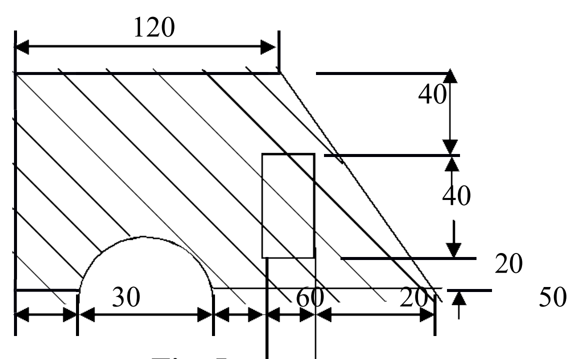


Fig. 5a

(b) Classify two dimensional force system with example.

(c) Find the resultant of the force system shown in fig. 3c acting on a lamina of equilateral triangular shape.AC = BC= AB = 100 mm

4. Answer any *two* part of the following : $2 \times 5 = 10$

(a) A uniform ladder weighing 800 N and 10 m long is resting on a rough horizontal floor and inclined at an angle of 30° with the vertical wall. The ladder would just slip if a man of 100 N weight reaches a point that is 8 m from the lower end of the ladder.If the coefficient of friction between the wall and the ladder is 0.4, determine the coefficient of friction between the ladder and the floor.

(b) Prove $T_1/T_2 = e^{\mu\theta}$

(c) State and prove Varignon's theorem.

5. Answer any *two* part of the following : $2 \times 5 = 10$

(a) Determine centroid of shaded area shown in fig . 5a

(b) Determine the centroid of a circular sector of radius R and central angle 2α.

(c) Derive an expression for the moment of inertia of a cylinder of length L, radius R and density ρ about its centroidal axes.

6. Answer any *two* part of the following : $2 \times 5 = 10$

(a) The acceleration of a particle in rectilinear motion is defined by the relation $a = 3t^2 + 2$. Given that the initial velocity and displacement are respectively 2 m/s and 3 m, write the equation of motions. Also, determine the position, velocity and acceleration at t=2s.

(b) A flywheel, which accelerate at uniform velocity is observed to have made 100 revolution to increase its velocity from 120 rpm to 160 rpm. If the flywheel originally started from rest, determine

(i) the value of acceleration (ii) time taken to increase the velocity from 120 rpm to 160 rpm and (iii) revolution made in reaching a velocity of 160 rpm, starting from rest.

(c) Determine the velocities of the points B and D given in fig. 6 c by instantaneous centre method. Given angular velocity $\omega = 5$ rad/sec, Wheel radius = 1 m.

7. Answer any *two* part of the following : $2 \times 5 = 10$

(a) Explain principle of work energy and principle of virtual work.

(b) Determine the tension in the string and acceleration of blocks A and B weighing 1500N and 500 N connected by an inextensible string as shown in fig. 7b.

(c) A ladder having weight 200 N is supported by a smooth wall and a rough floor (μ = 0.3) as shown in figure 7c. The ladder is in equilibrium. Find the friction force at point B of floor using virtual work method

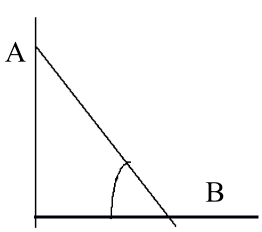
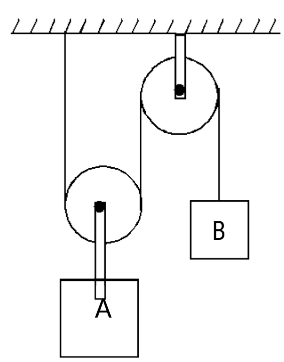
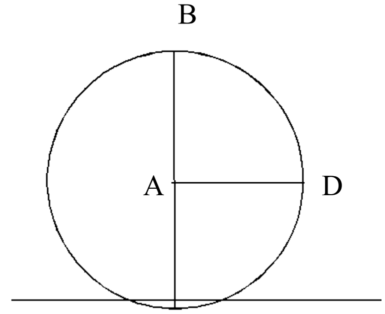


Fig. 7c

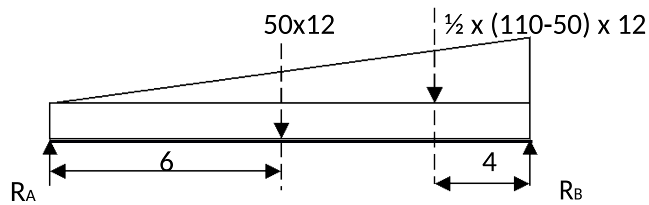




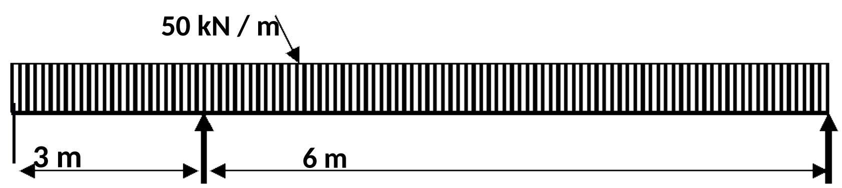
SOLUTION of Assignment on Beam and Truss

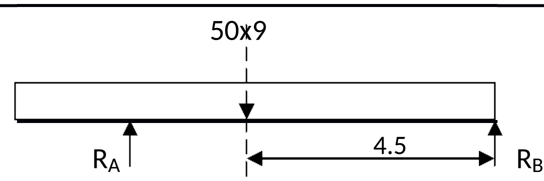
Numerical Questions:

A simply supported beam of span 12 m is loaded with a uniformly varying load of 50 kN / m at left end and 110 kN / m at right end. Find reactions at support.

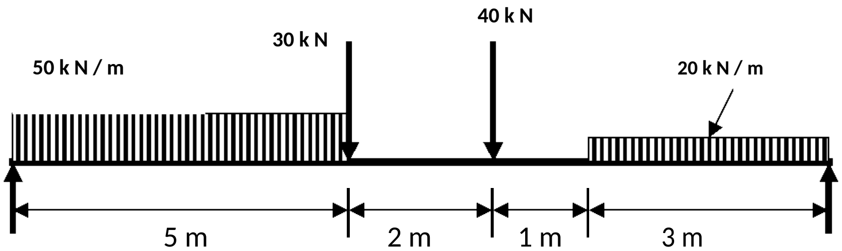
FBD	
$\sum F_x$	Not applicable
$\sum F_y$	$R_A + R_B = 50x12 + ½ (60x12) = 960$ ------ (1)
$\sum M_A$	R_B x 12 = 600 x 6 + 360 x 8; R_B = 540 kN and from (1) so R_A = 420 kN
For checking the answer $\sum M_B$	R_A x 12 = 600 x 6 + 360 x 4 R_A = 420 kN
Answer	R_A= 420 kN ; R_B = 540 kN

Find reactions at support for the following beam .



FBD	
$\sum F_x$	Not applicable
$\sum F_y$	$R_A + R_B = 50x9 + 450$ ------ (1)
$\sum M_A$	R_B x 6 = 450 x 1.5; R_B = 112.5 kN and from (1) so R_A = 337.5 kN
For checking the answer $\sum M_B$	R_A x 6 = 600 x 4.5 R_A = 337.5 kN
Answer	R_A= 337.5 kN ; R_B = 112.5 kN

Find reactions at support for the following beam.



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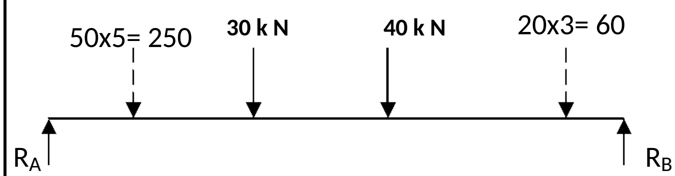
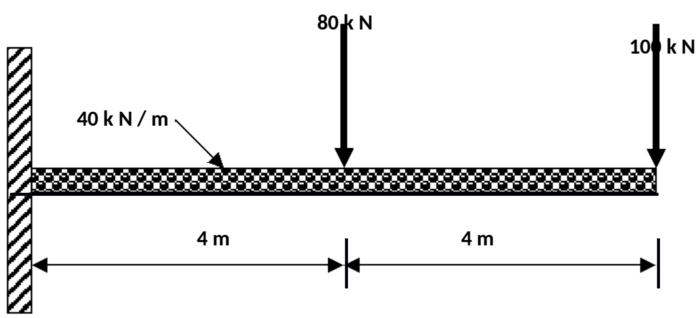
<tr><td>FBD</td><td>
</td></tr>
<tr><td>$\sum F_x$</td><td>Not applicable</td></tr>
<tr><td>$\sum F_y$</td><td>$R_A + R_B = 250 + 30 + 40 + 60 = 380$ ------ (1)</td></tr>
<tr><td>$\sum M_A$</td><td>R_B x 11 = 250 x 2.5 + 30 x 5 + 40 x 7 + 60 x 9.5;
R_B = 1625 / 11 = 147.72 kN and from (1) so R_A = 232.28 kN</td></tr>
<tr><td>For checking the answer
$\sum M_B$</td><td>R_A x 11 = 250 x 8.5 + 30 x 6 + 40 x 4 + 60 x 1.5
R_A = 232.28 kN</td></tr>
<tr><td>Answer</td><td>R_A= 232.28 kN ; R_B = 147.72 kN</td></tr>
</table>

Find reactions at the fixed support for the following beam.



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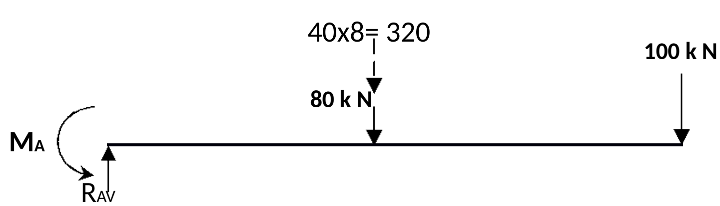
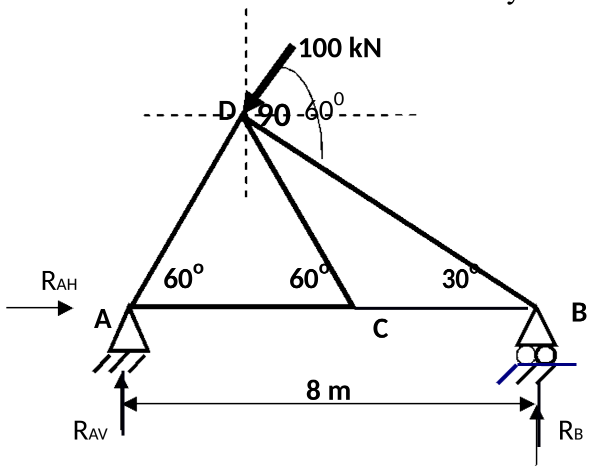
<tr><td>FBD</td><td>
</td></tr>
<tr><td>$\sum F_x$</td><td>Not applicable</td></tr>
<tr><td>$\sum F_y$</td><td>R_{AV} = 80 + 320 +100 = 500 kN ------ (1)</td></tr>
<tr><td>$\sum M_A$</td><td>M_A = (80 + 320) x 4 + 100 x 8 = 2400 kN-m anticlockwise</td></tr>
<tr><td>Answer</td><td>R_{AV}= 500 kN ; M_A = 2400 kN-m anticlockwise</td></tr>
</table>

Determine the forces in all the members of the Truss by **Joint Method** as shown in figure.

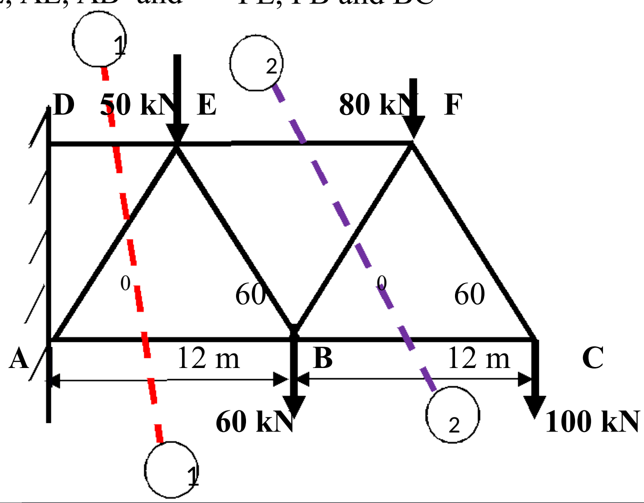


Considering all members as compressive

Reactions at support		
$\sum F_x$	$R_{AH} = 100 \cos 60 = 50$ ------ (1)Not applicable	
$\sum F_y$	$R_{AV} + R_B = 100 \sin 60 = 86.60$ ------ (1)	
$\sum M_A$	$R_B \times 8 = 0$ hence $R_B = 0$; $R_{AV} = 86.60$	
At Joint A	$\sum F_x = 0$ $F_{AC} + F_{AD} \cos 60 = R_{AH}$ i.e 50 $F_{AC} = 50 - F_{AD} \cos 60$ $F_{AC} = 50 - 100 \cos 60 = 0$ (Null Member)	$\sum F_y = 0$ $F_{AD} \sin 60 = R_{AV}$ i.e 86.60 $F_{AD} = 86.60 / \sin 60 = 100$ kN (Comp.)
At Joint B	$\sum F_x = 0$ $F_{BC} + F_{BD} \cos 30 = 0$ $F_{BC} = 0 - F_{BD} \cos 30$ $F_{BC} = 0 - 0 = 0$ (Null Member)	$\sum F_y = 0$ $F_{BD} \sin 30 = 0$ $F_{BD} = 0$ (Null)
At Joint C	-	$\sum F_y = 0$ $F_{CD} \sin 60 = 0$ $F_{CD} = 0$ (Null)
Answer	$F_{AC} =$ 0 (Null Member) $F_{AD} = 100$ kN (Comp.) $F_{BC} =$ 0 (Null Member)	$F_{BD} = 0$ (Null member) $F_{CD} = 0$ (Null member)

Determine the forces in the members of the truss by **Methods of Section**, shown in figure.

- DE, AE, AB and FE, FB and BC



SECTION 1-1 and taking Right Hand Side Section		
$\sum F_x$	$F_{DE} + F_{AE} \cos 60 + F_{AB} = 0$ ---- (1)	
$\sum F_y$	$F_{AE} \sin 60 = 50 + 80 + 60 + 100 = 290 / \sin 60$; $F_{AE} = 334.86$ kN ------ (2)	
$\sum M_E$	$F_{AB} \times 6\sqrt{3} = 60 \times 6 + 80 \times 12 + 100 \times 18$; $F_{AB} = 265.68$ kN ---- (3) From (1), (2) and (3) $F_{DE} = - 433.11$ kN i.e 433.11 (Tensile) $F_{AE} = 334.86$ kN (Comp.) $F_{AB} = 265.68$ kN (Comp.)	
Answer	$F_{DE} = 433.11$ (Tensile) $F_{AE} = 334.86$ kN (Comp.)	$F_{AB} = 265.68$ kN (Comp.)

SECTION 2-2 and taking Right Hand Side Section		
$\sum F_x$	$F_{EF} + F_{BF} \cos 60 + F_{BC} = 0$ ---- (1)	
$\sum F_y$	$F_{BF} \sin 60 = 80 + 100 = 180 / \sin 60$; $F_{AE} = 207.84$ kN ------ (2)	
$\sum M_F$	$F_{BC} \times 6\sqrt{3} = 100 \times 6$; $F_{BC} = 57.73$ kN ---- (3) From (1), (2) and (3) $F_{EF} = -161.65$ kN i.e 161.65 (Tensile)	
Answer	$F_{EF} = 161.65$ (Tensile) $F_{AE} = 207.84$ kN (Comp.)	$F_{BC} = 57.73$ kN (Comp.)