INTELLIGENT OBJECTIVE QUESTIONS IN MECHANICS

1) A cantilever beam of square cross-section (100 mm X 100 mm) and length 2 m carries a concentrated load of 5 kN at its free end. What is the maximum normal bending stress at its mid-length cross-section?

(a) 10 N/mm^2
(b) 20 N/mm^2
(c) 30 N/mm^2
(d) 40 N/mm^2

2) A hollow shaft of outside diameter 40 mm and inside diameter 20 mm is to replaced by a solid shaft of 30 mm diameter. If the maximum shear stresses induced in the two shafts are to be equal, what is the ratio of the maximum resistible torque in the hollow to that of solid shaft?

(a) 10/9
(b) 20/9
(c) 30/9
(d) 40/9

(3) A cannonball is fired from a tower 80 m above the ground with a horizontal velocity of 100 m/s. Determine the horizontal distance at which the ball will hit the ground. (take $g=10\ m/s^2$)

(a) 400 m,
(b) 280 m,
(c) 200 m,
(d) 100 m.

(4) Water drops from a tap at the rate of four droplets per second. Determine the vertical separation between two consecutive drops after the lower drop attained a velocity of 4 m/s. Take $g=10\ m/s^2$.

(a) 0.49 m
(b) 0.31 m
(c) 0.50 m
(d) 0.30 m

Q.1) The example of Statically indeterminate structures are,
a. continuous beam,
b. cantilever beam,
c. over-hanging beam,
d. both cantilever and fixed beam.

Q.2) A redundant truss is defined by the truss satisfying the equation,
a. $m = 2j - 3$,
b. $m < 2j + 3$,
c. $m > 2j - 3$,

d. m > 2j + 3

http://subhankar4students.blogspot.in/p/lecture-notes.html

Q.3) The property of a material to withstand a sudden impact or shock is called,
a. hardness
b. ductility,
c. toughness,
d. elasticity of the material

Q.4) The stress genarated by a dynamic loading is approximately _____ times of the stress developed by the gradually applying the same load.

Q.5) The ratio between the volumetric stress to the volumetric strain is called as
a. young's modulus
b. modulus of elasticity
c. rigidity modulus,
d. bulk modulus

Q.6) In a Cantilever beam, the maximum bending moment is induced at
a. at the free end
b. at the fixed end
c. at the mid span of the beam
d. none of the above

Q.7) The forces which meet at a point are called
a. collinear forces
b. concurrent forces
c. coplanar forces
d. parallel forces

Q.8) The coefficients of friction depends upon
a. nature of the surface
b. shape of the surface
c. area of the contact surface
d. weight of the body

Q.9) The variation of shear force due to a triangular load on simply supported beam is
a. uniform
b. linear
c. parabolic
d. cubic

Q.10) A body is on the point of sliding down an inclined plane under its own weight. If the inclination of the plane is 30 degree, then the coefficient of friction between the planes will be

a. $1/\sqrt{3}$
b. $\sqrt{3}$
c. 1
d. 0

Unit: 1 (Force System)

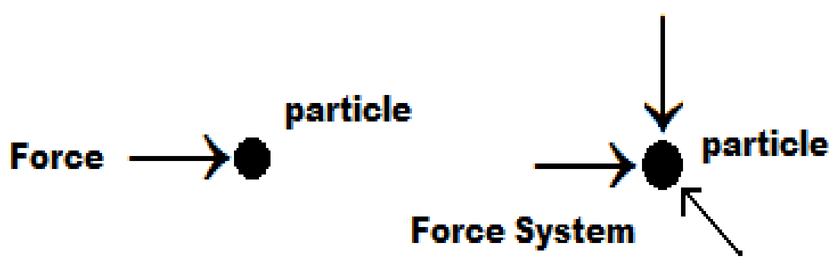
VERY SHORT QUESTIONS (2 marks):

1) **What is force and force system?**

Ans: A force is a physical quantity having magnitude as well as direction. Therefore, it is a vector quantity. It is defined as an "external agency" which produces or tends to produce or destroys or tends to destroy the motion when applied on a body.

Its unit is Newton (N) in S.I. systems and dyne in C.G.S. system.

When two or more forces act on a body or particle, it is called force system. Therefore, a force system is a collection of two or more forces.



2) **What is static equilibrium? What are the different types of static equilibrium?**

Ans: A body is said to be in static equilibrium when there is no change in position as well as no rotation exist on the body. So to be in equilibrium process, there must not be any kind of motions ie there must not be any kind of translational motion as well as rotational motion.
We also know that to have a linear translational motion we need a net force acting on the object towards the direction of motion, again to induce an any kind of rotational motion, a net moment must exists acting on the body. Further it can be said that any kind of complex motion can be resolved into a translational motion coupled with a rotating motion.

"Therefore a body subjected to a force system would be at rest if and only if the net force as well as the net moment on the body is zero."

There are three types of Static Equilibrium

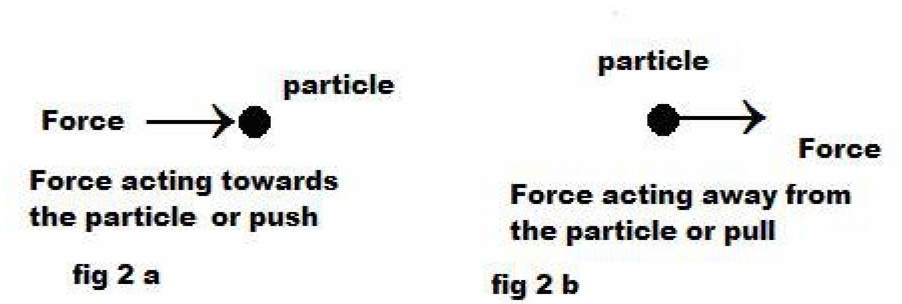
1. Stable Equilibrium
2. Unstable Equilibrium

3. Neutral Equilibrium

3) What are the characteristics of a force?

Ans: A force has four (4) basic characteristics.

- **Magnitude**: It is the value of the force. It is represented by the length of the arrow that we use to represent a force.
- **Direction**: A force always acts along a line, which is called as the “line of action”. The arrow head we used to represent a force is the direction of that force.
- **Nature or Sense**: The arrow head also represent the nature of a force. A force may be a pull or a push. If a force acts towards a particle it will be a push and if the force acts away from a point it is pull.
- **Point of Application**: It is the original location of a point on a body where the force is acting.



4) What are the effects of a force acting on a body?

Whenever a force acts on a body or particle, it may produce some external as well as internal effects or changes.

- A force may change the state or position of a body by inducing motion of the body. (External effect)
- A force may change the size or shape of an object when applied on it. It may deform the body thus inducing internal effects on the body.
- A force may induce rotational motion into a body when applied at a point other than its center of gravity.
- A force can make a moving body into an equilibrium state at rest.

5) What is composition and resolution of forces?

Ans: **Composition of forces:** Composition or compounding is the procedure to find out single resultant force of a force system

Resolution of forces: Resolution is the procedure of splitting up a single force into number of components without changing the effect of the same.

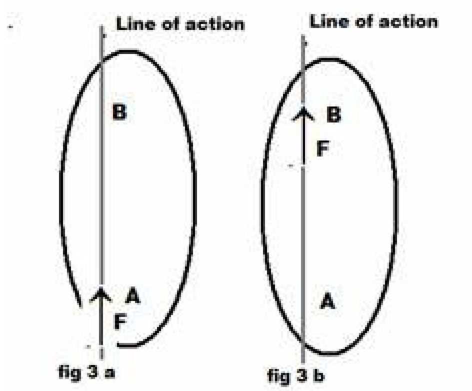
6) What is Resultant and Equilibrant?

Ans: **Resultant:** The resultant of a force system is the Force which produces same effect as the combined forces of the force system would do. So if we replace all components of the force by the resultant force, then there will be no change in effect.
The Resultant of a force system is a vector addition of all the components of the force system. The magnitude as well as direction of a resultant can be measured through analytical method.

Equilibrant: Any concurrent set of forces, not in equilibrium, can be put into a state of equilibrium by a single force. This force is called the Equilibrant. It is equal in magnitude, opposite in sense and co-linear with the resultant. When this force is added to the force system, the sum of all of the forces is equal to zero.

7) Explain the principle of Transmissibility?

Ans: The principle of transmissibility states "the point of application of a force can be transmitted anywhere along the line of action, but within the body."



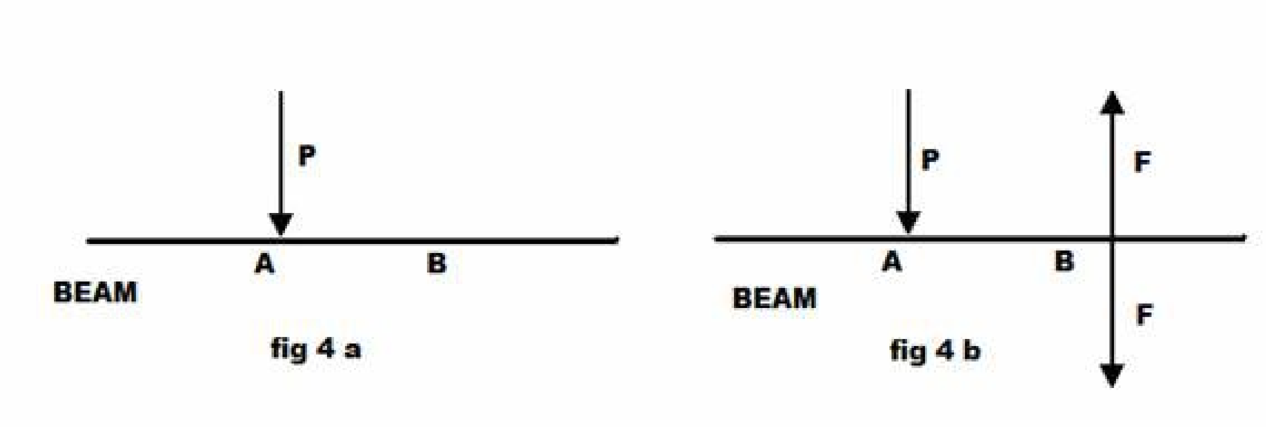
The fig 3 a shows a force F acting at a point of application A and fig 3 b, the same force F acts along the same line of action but at a different point of action at B and both are equivalent to each other.

QUESTIONS BANK 2: FORCE AND FORCE SYSTEM

(I am going to publish a question bank for EME-102/EME-202 of 1st yr. MTU; Greater Noida. Some pages from the book ....Subhankar Karmakar)

1) Explain the principle of Super-position.

Ans: The principle of superposition states that "The effect of a force on a body does not change and remains same if we add or subtract any system which is in equilibrium."

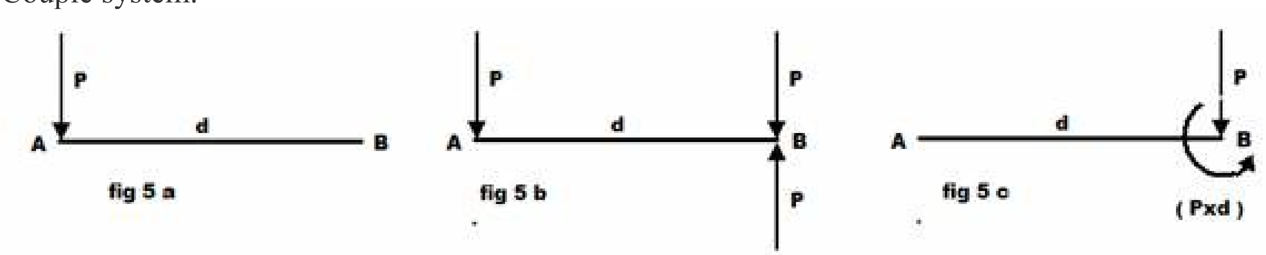


In the fig 4 a, a force P is applied at point A in a beam, where as in the fig 4 b, force P is applied at point A and a force system in equilibrium which is added at point B. Principle of super position says that both will produce the same effect.

2) What is "Force-Couple system?"

Ans: When a force is required to transfer from a point A to point B, we can transfer the force directly without changing its magnitude and direction but along with the moment of force about point B.

As a result of parallel transfer a system is obtained which is always a combination of a force and a moment or couple. This system consists of a force and a couple at a point is known as Force-Couple system.

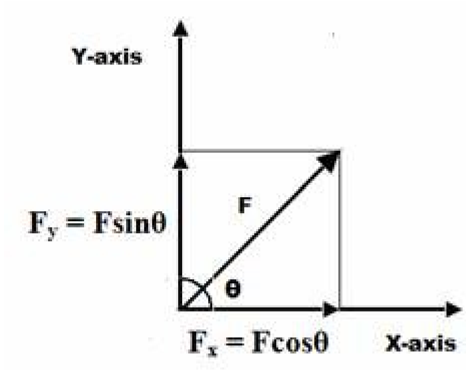


In fig 5 a, a force P acts on a bar at point A, now at point B we introduce a system of forces in equilibrium (fig 5 b), hence according to principle of superposition there is no change in effect of the original system. Now we can reduce the downward force P at point A and upward force P at point B as a couple of magnitude Pxd at point B (fig 5 c).

3) What do you understand by Equivalent force systems?

Ans: Two different force systems will be equivalent if they can be reduced to the same force-couple system at a given point. So, we can say that two force systems acting on the same rigid body will be equivalent if the sums of forces or resultant and sums of the moments about a point are equal.

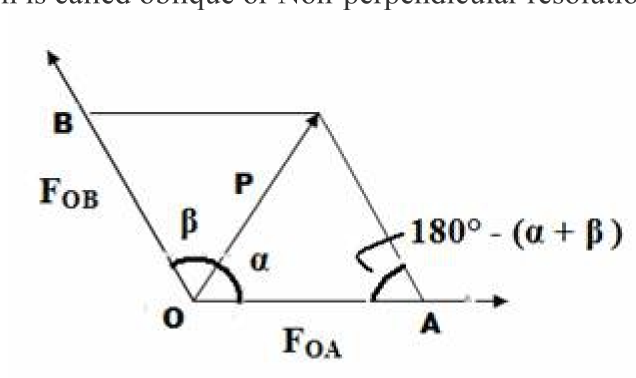
4) What is orthogonal or perpendicular resolution of a force?



Ans: The resolution of a force into two components which are mutually perpendicular to each other along X-axis and Y-axis is called orthogonal resolution of a force.
If a force F acts on an object at an angle θ with the positive X-axis, then its component along X-axis is $\mathbf{F_x = F\cos\theta}$, and that along Y-axis is $\mathbf{F_y = F\sin\theta}$

5) What is oblique or non-perpendicular resolution of a force?

Ans: When a force is required to be resolved in to two directions which are not perpendiculars to each other the resolution is called oblique or Non-perpendicular resolution of a force.



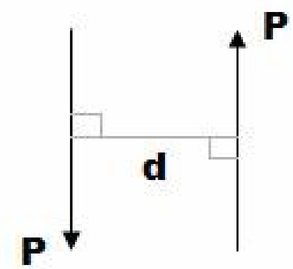
$$\mathbf{F_{OA} = (P \sin \beta)/ \sin (\alpha + \beta)}$$
$$\mathbf{F_{OB} = (P \sin \alpha)/ \sin (\alpha + \beta)}$$

QUESTIONS BANK 3 : FORCE AND FORCE SYSTEM

(I am going to publish a question bank for EME-102/EME-202 of 1st yr. MTU; Greater Noida. Some pages from the book ....Subhankar Karmakar)

8) What is a couple?

Ans: Two unlike parallel, non-collinear forces having same magnitude form a couple. The distance between two forces (d) is known as arm or lever of the couple.



The magnitude of the couple is the product of one of the forces and the distance between them.

Therefore, moment **M = P x d**

Moment produced by couple is called **Torque.**

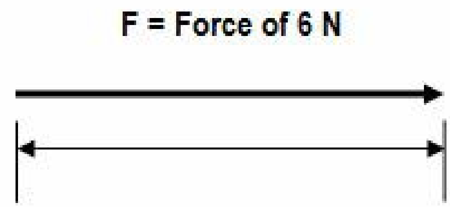
9) What are the properties of a couple?

Ans: The properties of a couple are

1. Two unlike parallel, non-collinear forces having same magnitude form a couple.
2. The resultant of a couple is always zero.
3. The moment of a couple is the product of one of the forces and the distance between them.
4. A couple can not be balanced by a single force.
5. It can be balanced only by another couple of opposite nature.
6. The moment of couple is independent of the moment center.

10) What is a vector?

Ans: A vector is a physical quantity which has magnitude as well as direction. The examples of vector quantity are force, momentum, acceleration, moment etc. A vector quantity is represented by an arrow, where the length of the arrow represents magnitude of the vector and the arrow head represents the direction of the vector.



11) What are the basic vector operations?

Ans: The basic vector operations are

- Vector Addition
- Vector Subtraction
- Vector Resolution
- Vector Dot Product
- Vector Cross Product

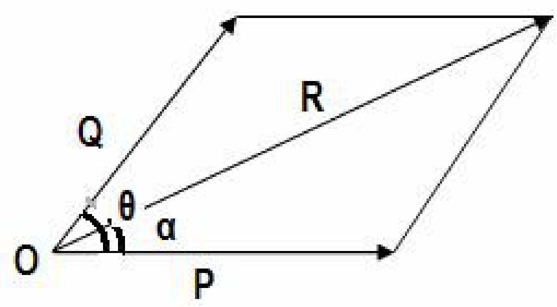
12) How can two vectors be added by vector addition?

Ans: Any two vectors of similar kind can be added by the principle of vector addition.
Two vectors P and Q can be added by either by

- Triangle's law of vector addition
- Parallelogram law of vector addition

For more than two vectors, they can be added by

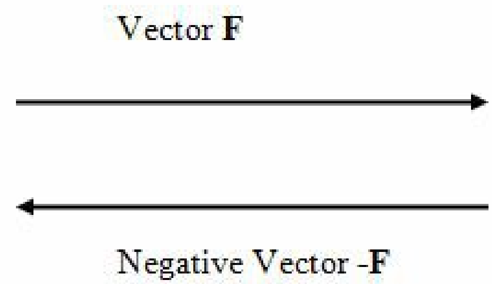
- Polygon law of vector addition
- Force resolution method



13) What is a negative vector?

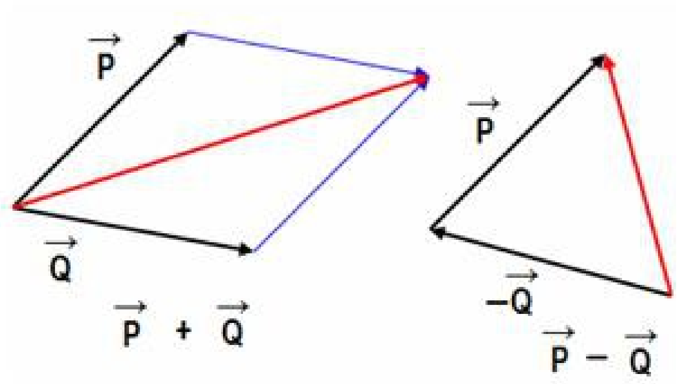
Ans: Suppose we have a vector **F** whose direction is towards right. Then the negative vector −**F** will be the same vector but in opposite direction i.e. towards left as shown in the figure.

The length of the arrow remains same and it indicates the magnitude of the vector remains same, just direction becomes opposite.



14) Explain the vector subtraction.

Ans: Addition of a negative vector may be represented as a vector subtraction. In the figure first two vectors **P** and **Q** are added by Parallelogram law and where as the second diagram represents addition of **P** and −**Q**.

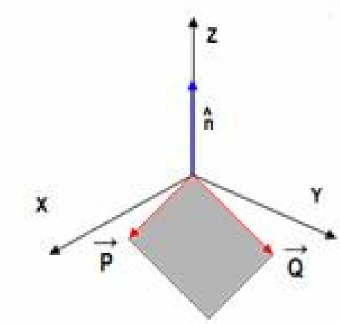


P − Q = P + (− Q)

15) Explain product of two vector quantities.

Ans: There are two types of vector product. One is called dot product, which is also called as scalar product and represented as **P.Q = |P||Q|cos θ**; where **θ** is the angle between two vectors and it produces a scalar quantity.

The other is called crossed product or vector product of two vectors and represented as
P X Q = P.Q = |P||Q|sin θ n; where **θ** is the angle between two vectors and it produces a vector quantity.



Vector cross product

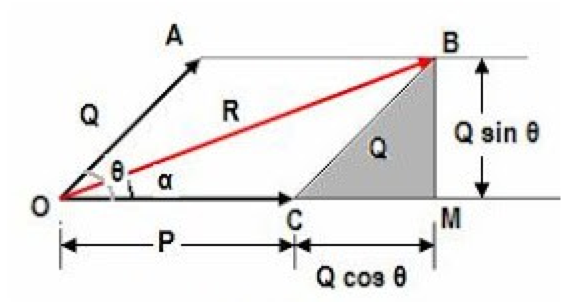
The new product vector is along the normal direction **n** to the plane containing vectors **P** and **Q**. The magnitude of the cross product represents the area of the parallelogram made by the two vectors P and Q as shown by the shaded area in the figure.

QUESTIONS BANK 4 : FORCE AND FORCE SYSTEM

(I am going to publish a question bank for EME-102/EME-202 of 1st yr. MTU; Greater Noida. Some pages from the book ....Subhankar Karmakar)

20) Describe the law of parallelogram of forces.

Ans: It states "If two forces simultaneously acting at a point be represented in magnitude and direction by two adjacent sides of a parallelogram, the diagonal will represent resultant in magnitude and direction, passing through the point of intersection of two forces.



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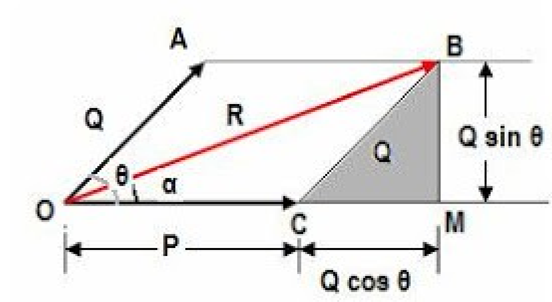
21) Describe the analytical method to find the resultant of two concurrent forces.

Ans: Consider two concurrent forces P and Q acting at a point O and represented by two sides OA and OC of a parallelogram OABC.



Let θ be the angle between two forces P and Q, and α be the angle between P and resultant R.
Now, we draw perpendicular BM on the line OM.
In ΔCMB, we have BM=Q sin θ and CM= Q cos θ

Magnitude of resultant R:

In ΔOMB,

$(OB)^2 = (OM)^2 + (BM)^2$

» $(OB)^2 = (OC + CM)^2 + (BM)^2$

» $R^2 = (P + Q\cos\theta)^2 + (Q\sin\theta)^2$

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

» $R^2 = P^2 + 2PQ\cos\theta + Q^2(\cos^2\theta + \sin^2\theta)$

» $R^2 = P^2 + 2PQ\cos\theta + Q^2$

Direction of the Resultant

In ΔOMB,

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

$$\tan\alpha = \frac{BM}{OM} = \left(\frac{Q\sin\theta}{P + Q\cos\theta}\right) \text{- - - - - - - - - (i)}$$

22) What is static equilibrium? What are the different types of static equilibrium?

Ans: A body is said to be in static equilibrium when there is no change in position as well as no rotation exist on the body. So to be in equilibrium process, there must not be any kind of motions ie there must not be any kind of translational motion as well as rotational motion.

We also know that to have a linear translational motion we need a net force acting on the object towards the direction of motion, again to induce an any kind of rotational motion, a net moment must exists acting on the body. Further it can be said that any kind of complex motion can be resolved into a translational motion coupled with a rotating motion.

"Therefore a body subjected to a force system would be at rest if and only if the net force as well as the net moment on the body is zero."

There are three types of Static Equilibrium

1. Stable Equilibrium
2. Unstable Equilibrium
3. Neutral Equilibrium

QUESTIONS BANK 5 : FORCE AND FORCE SYSTEM

(I am going to publish a question bank for EME-102/EME-202 of 1st yr. MTU; Greater Noida. Some pages from the book ....Subhankar Karmakar)

23) What are the conditions of static equilibrium for (i) con-current force system, and (ii) coplanar non concurrent force system?

Ans: For **Concurrent force system**, the equilibrium conditions are as follows

$$\text{(i) } \Sigma \mathbf{F_x} = \mathbf{0}; \text{ (ii) } \Sigma \mathbf{F_y} = \mathbf{0}$$

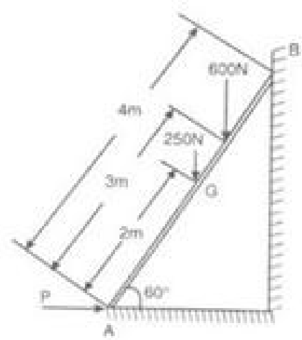
and for coplanar **non concurrent force system**, the equilibrium conditions are as follows

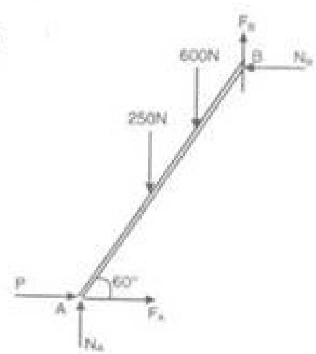
$$\text{(i) } \Sigma \mathbf{F_x} = \mathbf{0}; \text{ (ii) } \Sigma \mathbf{F_y} = \mathbf{0}; \text{ (iii) } \Sigma \mathbf{M_i} = \mathbf{0}$$

24) What is free body diagram?

Ans: When a force system acts on a body or connected bodies, for force analysis, we take one body at a time and isolate the body from all other connected bodies or surfaces. This isolated body is called free body.

Free Body Diagram or FBD is an isolated view of the body showing all the forces and reactions acting on the body with their magnitudes and direction.

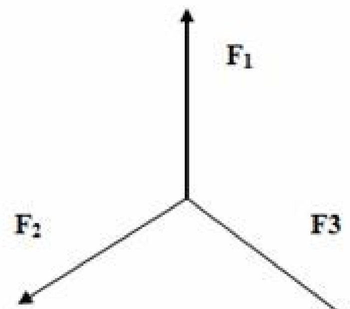




In the figure, the ladder is isolated from the surfaces (ground and wall) and replaced with the reactions given by ground and wall. In the next figure the ladder is shown with all the forces and reactions acting on it and this figure is called FBD.

25) What is a concurrent force system?

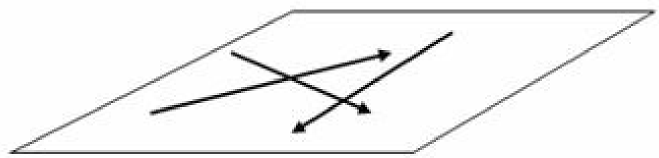
Ans: If the line of actions of two or more forces passes through a certain point simultaneously then they are called concurrent forces. Concurrent forces may or may not be coplanar.



A concurrent force system

26) What is a coplanar force system?

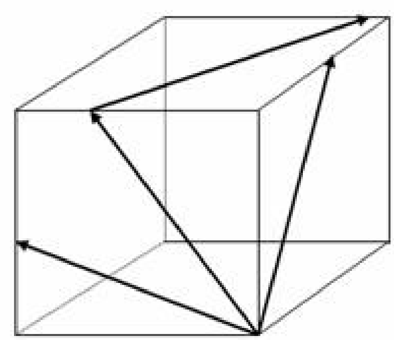
Ans: If all the forces of a force system are acting in the same plane, then the force system is called as coplanar force system. A coplanar force system may be concurrent, non-concurrent or parallel.



Coplanar Force System

27) What is non-coplanar force system?

Ans: A force system in which the forces acting in different planes is called as non-coplanar force system. When a force changes its plane it has to pass through space so non coplanar force system is also known as space forces or spatial force system.

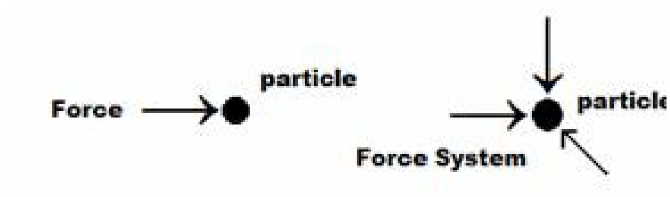


QUESTIONS BANK 6 : FORCE AND FORCE SYSTEM

(I am going to publish a question bank for EME-102/EME-202 of 1st yr. MTU; Greater Noida.
Some pages from the book ....Subhankar Karmakar)

BROAD QUESTIONS:

Q1) Explain the concept of force and force system. Classify force system. Also explain the concept of Resultant of a force system with proper examples and sketches.



Ans: A force is a physical quantity having magnitude as well as direction. Therefore, it is a vector quantity. It is defined as an "external agency" which produces or tends to produce or destroys or tends to destroy the motion when applied on a body.

Its unit is Newton (N) in S.I. systems and dyne in C.G.S. system

When two or more forces act on a body or particle, it is called force system. Therefore, a force system is a collection of two or more forces.

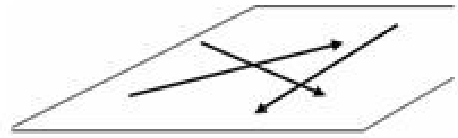
Force System Classification:

There are mainly seven types of system of forces.

(i) Coplanar forces **(ii) Non coplanar forces**
(iii) Collinear forces **(iv) Non collinear forces**
(v) Concurrent forces **(vi) Non concurrent forces**

Coplanar force system:

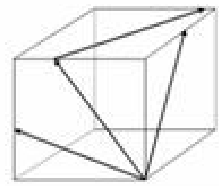
If all the forces of a force system are acting in the same plane, then the force system is called as coplanar force system. A coplanar force system may be concurrent, non-concurrent or parallel.



Coplanar Force System

Non coplanar force system:

If forces of a force system act at different planes, they are called non coplanar force system.



Collinear force system:

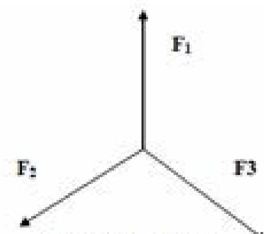
The forces which are acting along a straight line are called as collinear forces.

Non collinear force system:

The forces which are not acting along a straight line are called as non collinear forces.

Concurrent force system:

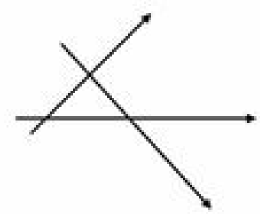
If the line of actions of two or more forces passes through a certain point simultaneously then they are called concurrent forces. Concurrent forces may or may not be coplanar.



A concurrent force system

Non concurrent force system:

If the forces of a force system are such that their lines of action do not intersect at a common point, they are called non concurrent force system.



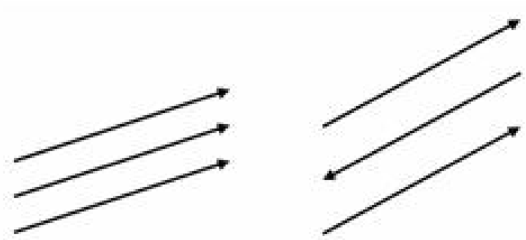
Coplanar non concurrent forces

Parallel force system:

If the line of actions of all the forces of a force system is parallel to each other, they are called as Parallel forces or parallel force system.

A parallel force system may be of two types

1. Like parallel forces or force system
2. Unlike parallel forces or force system



Like parallel force system Unlike parallel force system

Q2) What are the different methods of Force Addition? Explain them with proper sketches and geometrical derivation.

Ans: Any two forces can be added by the principle of vector addition.
Two forces P and Q can be added by either by

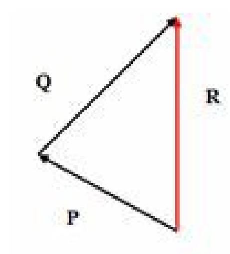
- **Triangle's law of vector addition**
- **Parallelogram law of vector addition**

For more than two forces, they can be added by

- **Polygon law of vector addition**
- **Force resolution method**

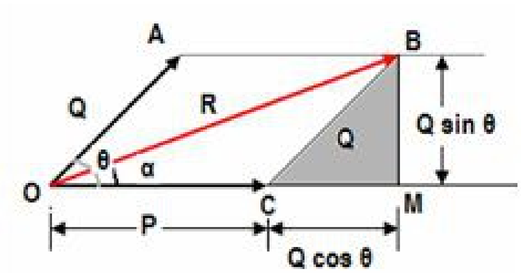
Triangle's law of force addition:

When two concurrent forces are in order, they are added by triangle's law of force addition. Let two concurrent forces act on a particle as shown in the figure. They can be represented by the two sides of a triangle in order. Then the third side of the triangle opposite the order will represent resultant of both the forces. The resultant is generally denoted by R.



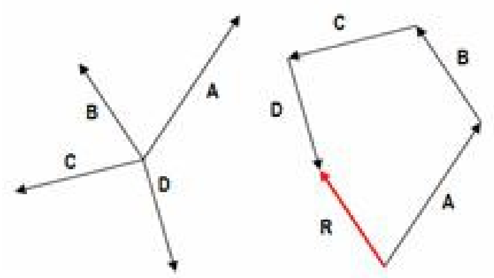
Parallelogram law of force addition:

It states "If two forces simultaneously acting at a point be represented in magnitude and direction by two adjacent sides of a parallelogram, the diagonal will represent resultant in magnitude and direction, passing through the point of intersection of two forces.



Polygon's law of force addition:

The polygon's law of force addition states "If a number of force acting at a point are such that they can be represented in magnitude and direction by the sides of a open polygon taken in order, then their resultant is represented in magnitude and direction by the closing side of the polygon but taken in the opposite order".



Force resolution method of force addition:

If a force system has n number of forces, then the resultant can be found by determining the horizontal components and vertical components of all the forces.

If the sum of all the horizontal components be ΣF_{xi} and the sum of all the vertical components be ΣF_{yi}, then the resultant force can be determined by

$$R = \sqrt{(\Sigma F_{xi}^2 + \Sigma F_{yi}^2)}$$

COURSE FILE:

INSTITUTE NAME : VIVEKANAND INSTITUTE OF TECHNOLOGY AND SCIENCE
SUBJECT NAME : ENGINEERING MECHANICS
SUBJECT CODE : EME-102
FACULTY NAME : SUBHANKAR KARMAKAR
DEPARTMENT : MECHANICAL ENGINEERING DEPARTMENT
YEAR : FIRST YEAR

INDEX:

LESSON PLAN : EME-102 / 202 : ENGINEERING MECHANICS

UNIT	TOPICS SYNOPSIS	No. of	DATE

		Lectures	
UNIT I	Two Dimensional Force Systems: Basic concepts, Laws of motion, Principle of Transmissibility of forces, Transfer of a force to parallel position , Resultant of a force system, Simplest Resultant of Two dimensional concurrent and Non-concurrent Force systems, Distributed force system, Free body diagrams, Equilibrium and Equations of Equilibrium, Applications.	5	date
UNIT I	Friction: Introduction, Laws of Coulomb Friction, Equilibrium of Bodies involving Dry-friction, Belt friction, Application.	3	date
UNIT II	Beam: Introduction, Shear force and Bending Moment, Differential Equations for Equilibrium, Shear force and Bending Moment Diagrams for Statically Determinate Beams.	5	date
UNIT II	Trusses: Introduction, Simple Truss and Solution of Simple truss, Method f Joints and Method of Sections.	3	date
UNIT III	Centroid and Moment of Inertia: Centroid of plane, curve, area, volume and composite bodies, Moment of inertia of plane area, Parallel Axes Theorem, Perpendicular axes theorems, Principal Moment Inertia, Mass Moment of Inertia of Circular Ring, Disc, Cylinder, Sphere and Cone about their Axis of Symmetry.	6	date
UNIT IV	Kinematics of Rigid Body: Introduction, Plane Motion of Rigid Body, Velocity and Acceleration under Translation and Rotational Motion, Relative Velocity.	4	date
UNIT IV	Kinetics of Rigid Body: Introduction, Force, Mass and Acceleration, Work and Energy, Impulse and Momentum, D'Alembert's Principles and Dynamic Equilibrium.	4	date
UNIT V	Simple Stress and Strain: Introduction, Normal and Shear stresses, Stress- Strain Diagrams for ductile and brittle material, Elastic Constants, One Dimensional Loading of members of varying cross-sections, Strain energy.	3	date
UNIT V	Pure Bending of Beams: Introduction, Simple Bending Theory, Stress in beams of different cross sections.	3	date
UNIT V	Torsion: Introduction, Torsion of shafts of circular section, torque and twist, shear stress due to torque.	3	date

Text books:

1. Engineering Mechanics by Irving H. Shames, Prentice-Hall

2. Mechanics of Solids by Abdul Mubeen, Pearson Education Asia.

3. Mechanics of Materials by E.P.Popov, Prentice Hall of India Private Limited.

TIME TABLE:

DAY	9.30	10.20	11.10	12.00	LUNCH	1.40	2.30	3.20	4.10
MON	9.30	ME-D	11.10	ME-F	LUNCH	1.40	ME-D	3.20	ME-D
TUE	9.30	ME-D	11.10	12.00	LUNCH	ME-F	2.30	ME-D	4.10
WED	ME-F	10.20	ME-D	12.00	LUNCH	1.40	2.30	3.20	4.10
THU	ME-D	10.20	11.10	ME-F	LUNCH	1.40	2.30	3.20	4.10
FRI	9.30	ME-F	11.10	ME-D	LUNCH	1.40	2.30	3.20	4.10
SAT	ME-D	10.20	ME-F	12.00	LUNCH	ME-F	2.30	3.20	4.10

COURSE PLAN:

SUBJECT NAME: ENGINEERING MECHANICS

SUBJECT CODE : EME-102

SCOPE : The course aims to provide deeper knowledge, a wider scope and improved understanding of the study of motion and the basic principles of mechanics and strength of materials. It is a concept based subject and it needs the application capabilities of the concepts on the part of the students.

SESSIONAL EVALUATION SCHEME:

PARTICULAR	WEIGHTAGE	MARKS
TWO SESSIONALS	60%	30
ATTENDANCE	20%	10
TEACHER'S ASSESSMENT(TA)*	WEIGHTAGE	MARKS

*TA will be based on the Assignments given, Unit test Performances and Attendance in the class for a particular student.

Lecture Schedule of Unit – 1

Total Number of Lectures: 8

• Lecture Details & Synopsis :

• Lecture- 1: Introduction, mass, particle, rigid body, position vector, change of position, velocity, momentum, change of momentum, force acceleration, Newton's law of motion, conservation of momentum, conservation of energy.

• Lecture- 2: Definition of force, characteristics of force, Force as a vector, Force addition, triangle's & parallelogram laws of force addition, magnitudes & direction of resultant force, negative force, resolution of force, oblique and orthogonal resolutions, component of a vector along a line, classification of a force system, force system in one dimension, like & unlike forces, two dimensional force system, co-planar force system, non coplanar force system, concurrent force system, coplanar concurrent force system, coplanar parallel force system

• Lecture- 3: The concepts of rigid body, principle of transmissibility of forces, resultant of coplanar concurrent force system, equilibrium of forces, conditions of static equilibrium for concurrent force system, actions & reactions in case of equilibrium in (i) spherical balls in a channel, (ii) blocks of mass in an inclined plane, (iii) reactions in strings, wires & ropes. Types of force (i) tension (ii) compression. Concepts of free body diagrams. Lami's theorem.

• Lecture- 4: Applications of the conditions of static equilibrium in case of concurrent forces in the analysis of a concurrent force system & numericals based on this. Numericals based on the resultant of a force system. Numericals based on Lami's theorem.

•Lecture- 5: Normal reactions, concepts of friction, angle of friction, coefficient of friction, angle of repose, laws of coulomb friction, limiting friction, coefficient of static friction & kinematics friction, Equilibrium of bodies involving dry friction. Use of Friction, Friction as a necessary

EVIL.

• Lecture- 6: Numericals based on static friction, ladder friction, friction in inclined plane, numericals on ladder friction & friction in inclined plane. Objective type questions in friction.

• Lecture- 7: Theory of Belt Friction, Slack & tight side of a belt, Concepts of Included angle, power delivered by belt drive, Numericals on Belt friction & objective type Questions.

• Lecture- 8: Doubt clearing Sessions on Unit- 1, (Static Equilibrium Analysis, Resultant Forces, Resolution of Forces, Lami's Theorem, Concepts of Dry & belt Friction.)

Reference books:
•(i)Engineering Mechanics by Timoshenko & Young
(ii)Engineering Mechanics by R. K. Rajput
(iii) Engineering Mechanics by Irving H. Shames

Lecture Schedule of Unit – 2

Total Number of Lectures: 8

• Lecture Details & Synopsis:

• Lecture- 9: Concepts of Beam, Classification of Beams, simply supported beam, cantilever beam, over hanging beam, continuous beam,Types of Support Reactions, Pin/hinged joints, Roller joints, fixed joints, determination of support reactions in beam, types of loading in beams, concentrated load, distributed load on the beam, uniformly distributed load (UDL), uniformly varying load (UVL), pure moment loading.

• Lecture- 10: Concepts of Shear Force, sign convention for shear force, determination of shear force at each point of the beam over the complete length of the beam, shear force diagrams (SFD), differential equations for equilibrium, concepts of bending moments, sign conventions for bending moments, determination of bending moments at each point of the beam over the complete length of the beam, bending moment diagrams (BMD), maximum bending moment, point of contra-flexure and its importance.

• Lecture- 11: SFD & BMD in case of (i) simply supported beam, (ii) cantilever beam, (iii) over-hanging beam with (a) concentrated loading, (b) uniformly distributed loading, (c) uniformly varying loading.

• Lecture- 12: Numericals on SFD & BMD for all types of beam.

• Lecture- 13: Numericals on SFD & BMD for all types of beam and to find point of contra-flexure.

• Lecture- 14: Concepts of Truss, Linkages, and Joints, Classification of Trusses, Perfect Truss, Deficient Truss, Redundant Truss, Simple Truss, Analysis of a Truss by (i) Method of Joints (ii) Method of Sections.

• Lecture- 15: Numericals on Truss analysis by method of joints & method of Sections.

• Lecture- 16: Numericals on Truss analysis by method of sections.

Lecture Schedule of Unit – 3

Total Number of Lectures: 6

• Lecture Details & Synopsis:

• Lecture- 17: Concepts of geometrical Centroid, Center of Mass & Center of Gravity, Centroid of Plane, Curve, Area, & Volume, determination of centroid of composite bodies.

• Lecture- 18: Numericals on determination of Centroid of composite bodies.

• Lecture- 19: Concepts of Rotation & Moment of Inertia, concepts of area moment of inertia & mass moment of inertia, Determination of moment of Inertia with the help of calculus, Parallel axis theorem & Perpendicular axis theorem of Moment of Inertia.

• Lecture- 20: Concepts of Principal Moment of Inertia, determination of Mass Moment of Inertia of (i) Circular Ring, (ii) Disc, (iii) Cylinder, (iv) Sphere & (v) Cone about their axis of symmetry

• Lecture- 21: Numericals on determination of Moment of Inertia of different objects.

• Lecture- 22: Numericals on determination of M.O.I of different objects.

Lecture Schedule of Unit – 4

Total Number of Lectures: 8

• Lecture Details & Synopsis:

• Lecture- 23: Introduction of rigid body, Motion of Rigid Body, Velocity & Acceleration under Translational Motion, Equation of motion due to gravity, concepts of Relative Velocity, Problems on Projectile Motion.

• Lecture- 24: Concepts of Rotational Motion, Angular Displacement, Angular Velocity, Laws of Motion for Rotation, Concepts of Moment, Torque & Couple, Angular Acceleration, Relations between angular velocity & linear velocity, Relation between angular acceleration & linear acceleration, concepts of centripetal acceleration, concepts of Pseudo Force ie. Centrifugal acceleration.

• Lecture- 25: Motion on Level road, Banking of road & Super elevation of rails, Analysis of Slider-crank mechanism (Four bar mechanism) & numericals on rotational motion.

• Lecture- 26: Numericals on Rotational motion & its application.

• Lecture- 27: Concepts of Force, Newton's Laws of Motion, Definition of Mass, Gravitational Mass & Inertial Mass, Concepts of Work & Energy, Conservation of Mass Principle, Principle of Conservation of Momentum.

• Lecture- 28: Principle of Conservation of Energy, Work- Energy Theorem, Concepts of Conservative Force & Potential Energy. Collision of two bodies, Elastic & Inelastic Collision, Impulse & Impulsive Force, Impulse & change of Momentum. Power.

• Lecture- 29: Concepts of Dynamic Equilibrium, Inertial Mass & D' Alembert's Principle of Dynamic Equilibrium, Motion on an Inclined Plane, Analysis of Lift Motion, Analysis of Motion of Connected Bodies (i) System of Pulleys (ii) Two Bodies connected by a string.

• Lecture- 30: Numericals on Dynamic Equilibrium & System of Pulleys.

Lecture Schedule of Unit – 5

Total Number of Lectures: 10

• Lecture Details & Synopsis:

• Lecture- 31: Deformation of Rigid Bodies under the action of External Force, Resistance against deformation & induction of internal resistive force, Unit deformation & strain, internal force & stress, linear deformation and normal stress, Hooke's Law & Modulus of Elasticity (E, Young's modulus), angular deformation, Shear Strain, & shear Stress, Modulus of Rigidity (G), Complimentary Shear Stress.

- Lecture-32: Simple Stress-Strain Diagrams for (i) Ductile Materials, (ii) Brittle Materials, One Dimensional Loading of members of Varying Cross Sections (i) Circular Bar of Uniform Taper, (ii) Bar of Uniform Strength (iii) Bar of (a) Uniform & (b) Taper Cross section due to Self Weight, (iv) Composite Bar, Impact loading (i) Gradually Applied load, (ii) Suddenly Applied Load.

- Lecture- 33: Concepts of Strain Energy & Resilience, Concepts of (i) Longitudinal & (ii) Lateral Strain, Poisson's Ratio, Hydro-static Compression & Volumetric Strain, Bulk Modulus (K), relation between (i) E, G, & K, (ii) E, K, m (iii) E, G, m. simple numericals on stress & strain.

- Lecture- 34: Numericals on Simple Stress & Simple Strain, Shear Strain & Shear Stress, numericals on composite bars.

- Lecture- 35: Concepts of Pure Bending, Assumptions in simple theory of bending, Concepts of Bending Stress, Neutral Layer & Neutral Axis, Bending Stress Diagrams, Difference between Simple Stress & Bending Stress, Derivation of Bending Equation, Section Modulus (Z), Relation between max. Tensile & max. Compressive Stress,

- Lecture- 36: Stress in Beams of different cross sections, Numericals on Bending Stresses.

- Lecture- 37: Doubt clearance class on (i) stress, strain (ii) pure bending

- Lecture- 38: Introduction of Shaft & Torsion, concept of pure torsion, Polar Moment of Inertia (J), Section Modulus (Z), Polar Modulus (Zp), Assumption for Deriving the Torsional Formulas, Torsional Equation,

• Lecture- 39: Torsional Rigidity or Torsional Stiffness (K), Comparison of strength of (i) Solid & (ii) Hollow Circular Shaft (Tmax), Power Transmission by a Shaft, Importance of Angle of Twist, numerical based on Torsion in Shaft.

• Lecture- 40: Doubt clearing classes on Torsion.

• Reference Books:

• Engineering Mechanics by R. S. Khurmi

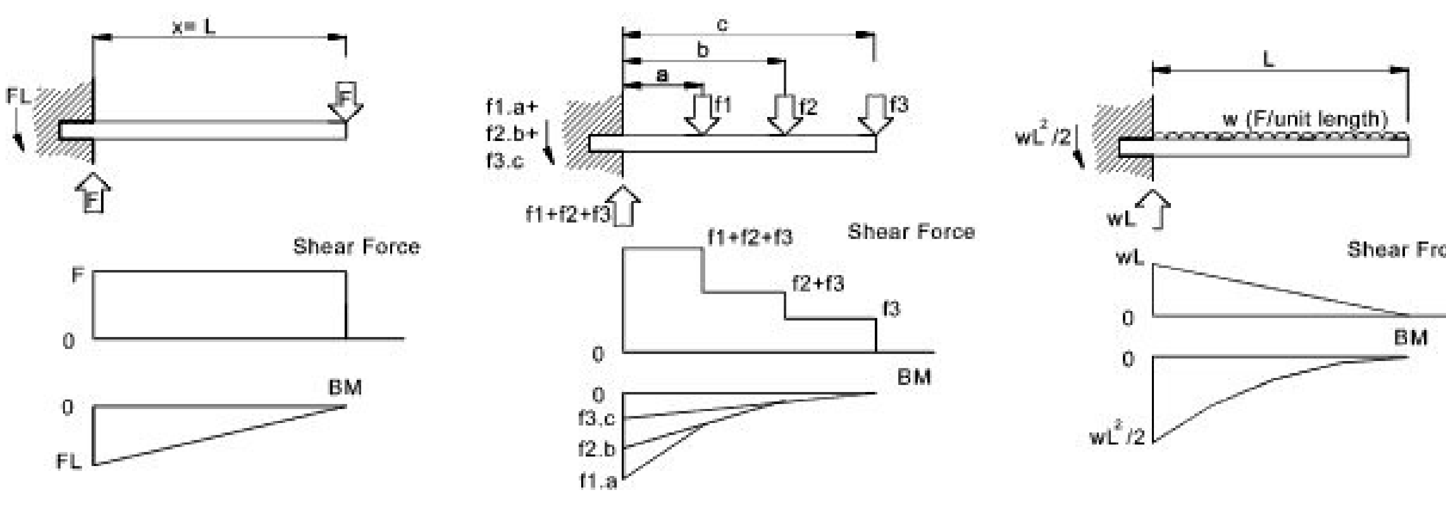
• Engineering Mechanics by Bhavikatti

• Engineering Mechanics by D. S. Kumar.

• Engineering Mechanics by Timoshenko & Young.

S.F.D. for CANTILEVER BEAMS

SHEAR FORCE DIAGRAMS OF THREE DIFFERENT TYPES OF CANTILEVER LOADING



CANTILEVER BEAM

This is the most common beam in our surroundings. It is supported at one end with Fixed Joint and is known as Fixed End. The other end remains without any support and known as Free End. At the fixed end, there are a vertical reaction (R_V), a horizontal reaction (R_H)

and a reaction moment (M_R).

How To Draw the Shear Force Diagram of a Cantilever.

(i) replace the fixed joint by a vertical, a horizontal reaction force and a reaction moment.

(ii) then divide the beam into different segment depending upon the position of the loads on the beam.

(iii) take the left most segment of the beam and draw a movable section within the segment.

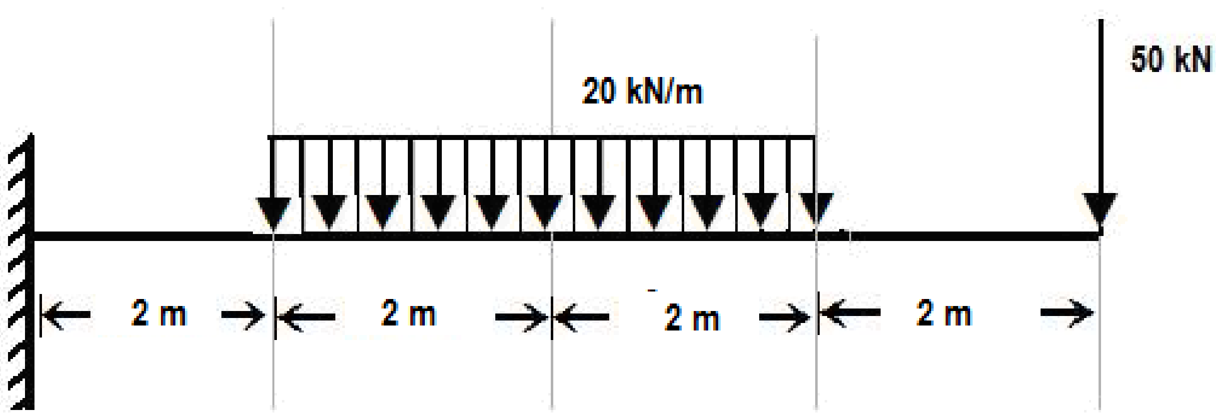
(iv) let the distance of the extreme left end of the beam from the movable section line be X

(v) let the upward (vertical) forces or reactions are positive and the downward forces are negative. Now the sum of the total vertical forces left to the section line is equal to the shear force at the section line at a distance X from the left most end of the beam.

(vi) as positive SF produces positive Bending Moment, hence if we multiply all the forces those are in the left side of the section line with the distances of each force from the section line added with concentrated moment (clockwise as +ve, anti-clockwise as -ve) we get bending moment. So the sum of the products of each force that is in the left side of the section with the distance of it from section line added with pure moment on this section is equal to the Bending Moment at the section line.

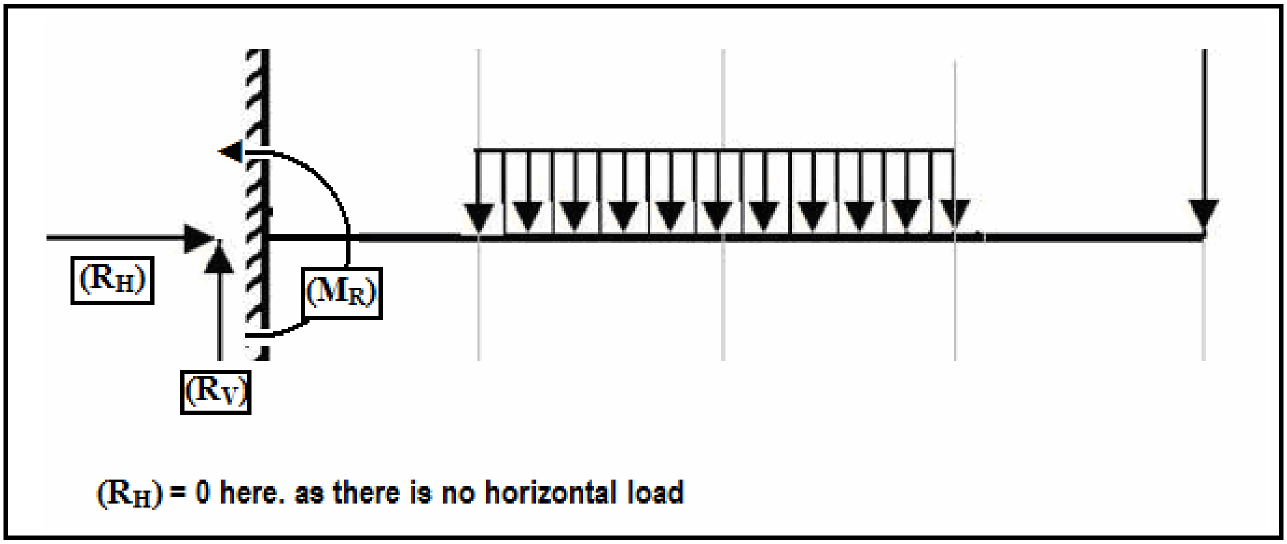
CANTI-LEVER BEAM

Draw shear force & bending moment diagrams and equations

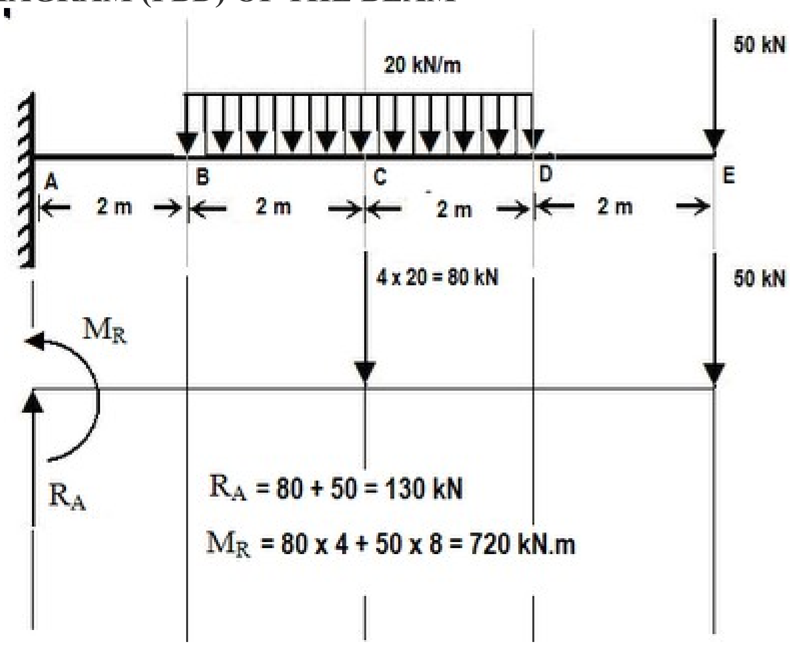


Solution: At first we shall find the reaction of the canti-lever beam.
A canti-lever beam is a common type of beam which is supported on a single fixed joint at one end. A fixed joint can provide a horizontal reaction, a vertical reaction and a reaction moment. While finding reaction we should transform a distributive load (UDL, UVL) to their equivalent

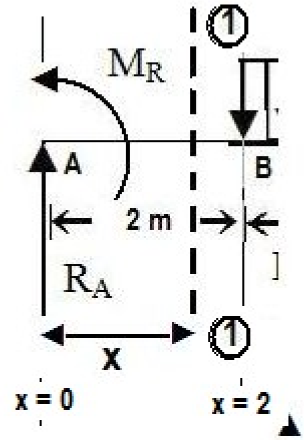
concentrated or point load. An equivalent load of a distributed load can be found by placing the total load at the centroid of the distributed load diagram.



FREE BODY DIAGRAM (FBD) OF THE BEAM



<u>SF and BM Equations:</u>



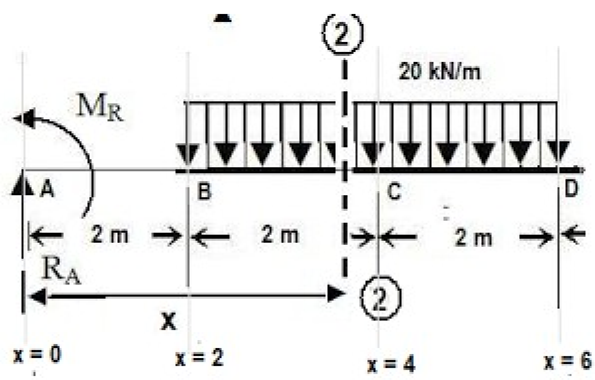
Section AB ($0 \le X \le 2$)

$SF = R_A = 130$ kN

$BM = -M_R + R_AX = -720 + 130X$ kN.m

At $X = 0$; SF = 130 kN and BM = – 720 kN.m

At $X = 2$; SF = 130 kN and BM = – 720 + 260 = – 460 kN.m



Section BD ($2 \le X \le 6$)

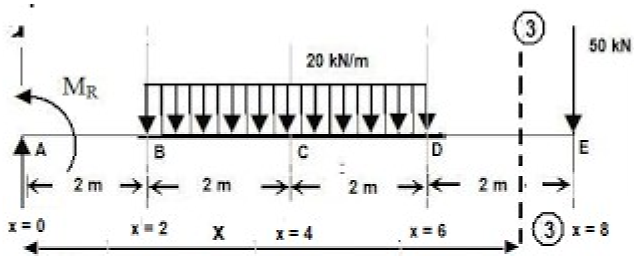
$SF = R_A - 20(X-2) = 130 - 20(X-2)$

$BM = -M_R + R_AX - \{20(X-2)^2\}/2$

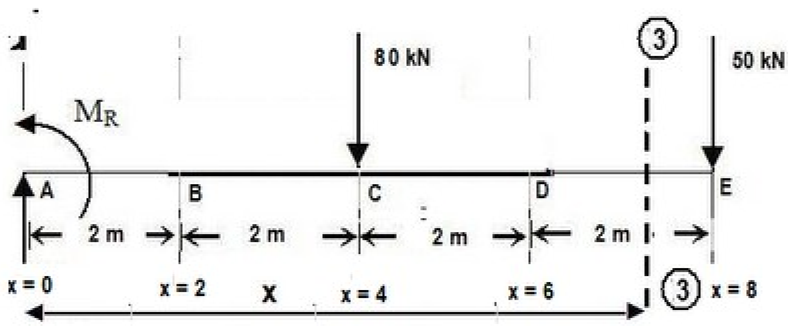
$= -720 + 130X - \{20(X-2)^2\}/2$

At $X = 2$; SF = 130 kN and BM = – 460 kN.m

At $X = 6$; SF = 130 – 80 = 50 kN and BM = – 720 + 780 – 160 = – 100 kN.m



When a distributive load remains fully on the left side of the section line as it is in the above diagram, we should use an equivalent point load in the place of Distributive load of UVL and UDL.



Section DE ($6 \leq X \leq 8$)

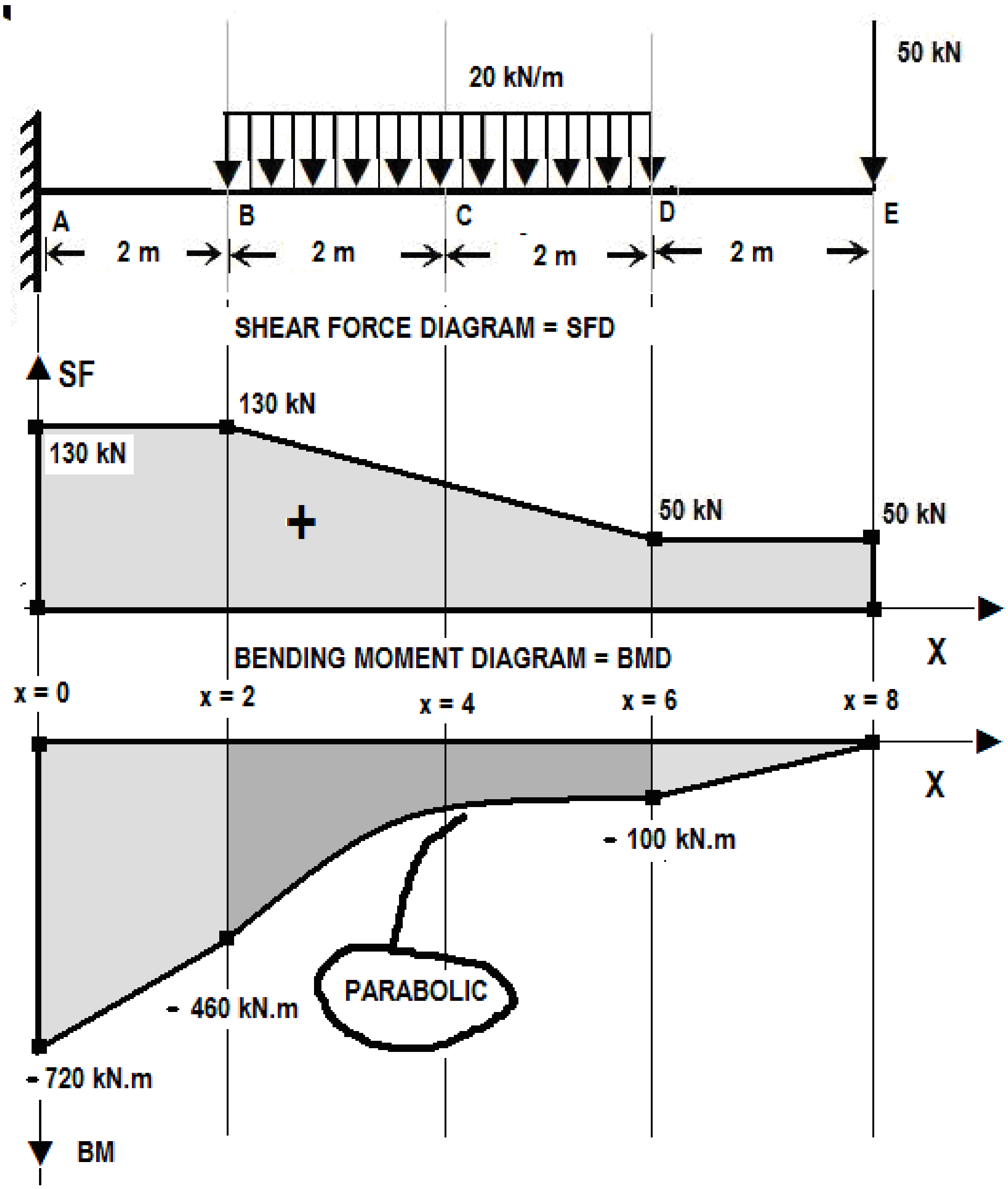
$SF = R_A - 80 = 130 - 80 = 50$ kN

$BM = -M_R + R_A X - 80(X - 4) = -720 + 130X - 80(X - 4)$

At $X = 6$; $SF = 130 - 80 = 50$ kN and $BM = -720 + 780 - 160 = -100$ kN.m

At $X = 8$; $SF = 130 - 80 = 50$ kN and $BM = -720 + 1040 - 320 = 0$ kN.m

SFD and BMD



ENGINEERING MECHANICS LECTURE NOTES:
Topic: Introduction of the Concept of Force.

CHANGE IN POSITION:

To know force well, first we have to understand what do we mean by Change. What does it mean when we say the position of the body has been changed? Whenever we find the state of object becomes different than that of the same object before some time say Δt, then we say that there exists a change in the state of the object. Suppose the change occurs in the position of the body. But to find the initial position of a body, we need a co-ordinate system.

THE CAUSE OF CHANGE:

It has been seen that to induced a change or to make a change in the position of an object we must have to change the energy possess by the body. To transfer energy into the object we shall have to apply FORCE on the body. Therefore Force is the agency that makes a change in position of a body.

THE CONCLUSION: GALILEO'S LAW OF INERTIA OR NEWTON'S FIRST LAW OF MOTION.

So, if there is no force on an object the position of the object won't change with respect to time. It means if a body at rest would remain at rest and a body at uniform motion would remain in a steady motion. This law is known as Galileo's Law of Inertia or Newton's first law of motion.

Topic: **FORCE SYSTEM**

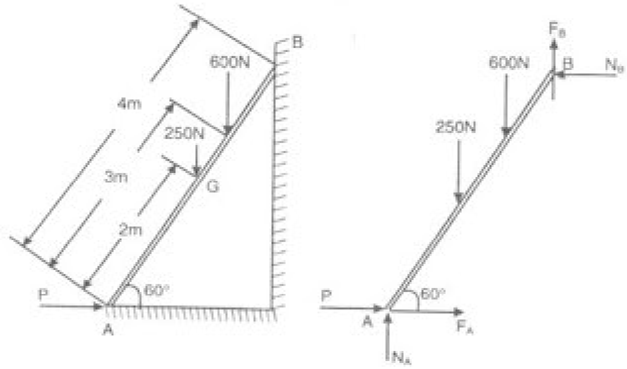
Q: **WHAT IS A FORCE SYSTEM? CLASSIFY THEM WITH EXAMPLES.**

ANSWER:

A force system may be defined as a system where more than one force act on the body. It means that whenever multiple forces act on a body, we term the forces as a force system. We can further classify force system into different sub-categories depending upon the nature of forces and the point of application of the forces.

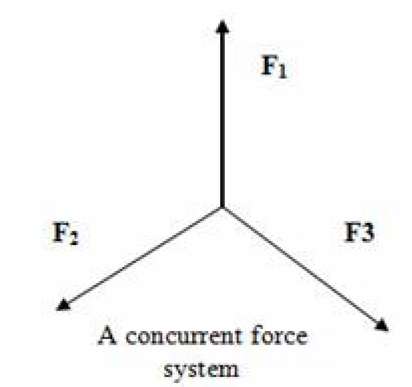
Different types of force system:

(i) **COPLANAR FORCES:**



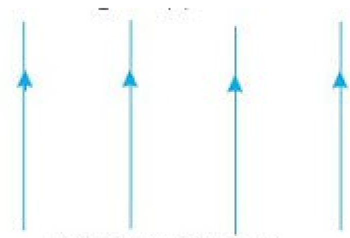
If two or more forces rest on a plane, then they are called coplanar forces. There are many ways in which forces can be manipulated. It is often easier to work with a large, complicated system of forces by reducing it an ever decreasing number of smaller problems. This is called the "resolution" of forces or force systems. This is one way to simplify what may otherwise seem to be an impossible system of forces acting on a body. Certain systems of forces are easier to resolve than others. Coplanar force systems have all the forces acting in in one plane. They may be concurrent, parallel, non-concurrent or non-parallel. All of these systems can be resolved by using graphic statics or algebra.

(ii) **CONCURRENT FORCES:**



A concurrent coplanar force system is a system of two or more forces whose lines of action ALL intersect at a common point. However, all of the individual vectors might not actually be in contact with the common point. These are the most simple force systems to resolve with any one of many graphical or algebraic options. If the line of actions of two or more forces passes through a certain point simultaneously then they are called concurrent forces. Con-current forces may or may not be coplanar.

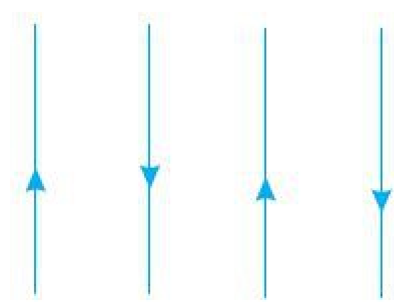
(iii) **LIKE FORCES:**



(*a*) Like parallel forces

A parallel coplanar force system consists of two or more forces whose lines of action are all parallel to one another. This is commonly the situation when simple beams are analyzed under gravity loads. These can be solved graphically, but are combined most easily using algebraic methods. If the lines of action of two or more forces are parallel to each other, they are called parallel forces and if their directions are same, then they are called LIKE FORCES.

(iv) **UNLIKE FORCES:**

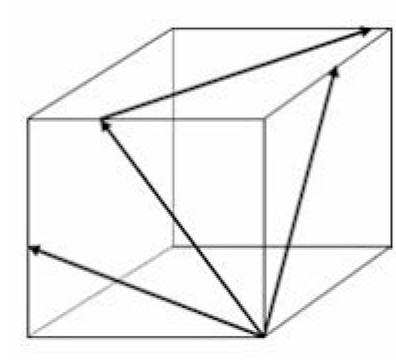


(*b*) Unlike parallel forces.

If the parallel forces are such that their directions are opposite to each other, then they are termed as **"UNLIKE FORCE"**.

For more notes on force system click here

(v) **NON COPLANAR FORCES:**



The last illustration is of a "non-concurrent and non-parallel system". This consists of a number of vectors that do not meet at a single point and none of them are parallel. These systems are essentially a jumble of forces and take considerable care to resolve.

Q.) **WHAT IS FORCE ADDITION? WHAT ARE THE OPERATIONS OF FORCE?**

A.) Force is a vector quantity. It has magnitude and as well as direction. Like other vectors two forces can be added, or a force can be substituted from another force, or may be a force can be multiplied by scalars as well as another vector. Unlike scalar quantities, two vector can't be added arithmatically, they must be geometrically added. Suppose we have a force 10 kN acting on a particle towards east, and suppose another force of 10 kN is acting towards north. We know that 10 kg mass +10 kg mass = 20 kg mass, but here forces of 10 kN towards east and 10 kN towards north, when added produces a resultant of magnitude =10*sqrt(2)=14.14 kN.

To add two forces acting on a plane we use

(i) Triangle's Law and
(ii) Paralellogram Law.

In case of more than two forces exist, then we use force resolution method to find the resultant.

Q2) What are the different methods of Force Addition? Explain them with proper sketches and geometrical derivation.

click on the question to get the answer

QUESTION: **WHAT IS A RESULTANT OF A FORCE SYSTEM?**

ANSWER: We have already discussed about addition of two forces on a plane by either

(i) Triangle's Law or
(ii) Paralellogram Law.

For more than two vectors we use

(iii) Polygon Law of Force Addition.
(iv) Force Resolution Method.

The resultant of a force system is the Force which produces same effect as the combined forces of the force system would do. So if we replace all the combined forces of the force system would do. So if we replace all components of the force by the resultant force, then there will be no change in effect.

The Resultant of a force system is a vector addition of all the components of the force system. The magnitude as well as direction of a resultant can be measured through analytical method. Almost any system of known forces can be resolved into a single force called a resultant force or simply a Resultant. The resultant is a representative force which has the same effect on the body as the group of forces it replaces. (A couple is an exception to this) It, as one single force, can represent any number of forces and is very useful when resolving multiple groups of forces. One can progressively resolve pairs or small groups of forces into resultants. Then another resultant of the resultants can be found and so on until all of the forces have been combined into one force. This is one way to save time with the tedious "bookkeeping" involved with a large number of individual forces. Resultants can be determined both graphically and algebraically.

The Parallelogram Method and the Triangle Method are used to find the resultant of a force system. It is important to note that for any given system of forces, there is only one resultant.

Q: **WHAT IS A COMPONENT OF A FORCE? WHAT IS FORCE RESOLUTION?**

ANSWER: It is often convenient to decompose a single force into two distinct forces. These forces, when acting together, have the same external effect on a body as the original force. They are known as components. Finding the components of a force can be viewed as the converse of finding a resultant. There are an infinite number of components to any single force. And, the correct choice of the pair to represent a force depends upon the most convenient geometry. For simplicity, the most convenient is often the coordinate axis of a structure.

A force can be represented as a pair of components that correspond with the X and Y axis. These are known as the rectangular components of a force. Rectangular components can be thought of as the two sides of a right angle which are at ninety degrees to each other. The resultant of these components is the hypotenuse of the triangle. The rectangular components for any force can be found with trigonometrical relationships:

component of a force F along X-axis is $\mathbf{F_x = F\cos\theta}$ and
component along Y-axis is $\mathbf{F_y = F\sin\theta}$.

numericals

EXTRA NOTE: When forces are being represented as vectors, it is important to should show a clear distinction between a resultant and its components. The resultant could be shown with color or as a dashed line and the components as solid lines, or vice versa. NEVER represent the resultant in the same graphic way as its components.

The Steps to find a Resultant of a force system: (for con-current forces)

STEP 1:

RESOLVE ALL THE COMPONENT FORCES ALONG X-AXIS AND Y-AXIS.

If a force F acts on an object at an angle θ with the positive X-axis, then its component along X-axis is $\mathbf{F_x = F\cos\theta}$, and that along Y-axis is $\mathbf{F_y = F\sin\theta}$.

STEP 2:

Add all the X-components or Horizontal components and it is denoted by $\mathbf{\Sigma F_x}$. Add all the Y-components and denote it as $\mathbf{\Sigma F_y}$.

STEP 3:

MAGNITUDE OF THE RESULTANT R will be equal to the square root of the sum of square of $\mathbf{\Sigma F_x}$ and $\mathbf{\Sigma F_y}$.

STEP 4:

DIRECTION OF THE RESULTANT (α)

α equals to the tan inverse of ($\mathbf{\Sigma F_x/\Sigma F_y}$).

EQUILIBRANT:

Any concurrent set of forces, not in equilibrium, can be put into a state of equilibrium by a single force. This force is called the Equilibrant. It is equal in magnitude, opposite in sense and co-linear with the resultant. When this force is added to the force system, the sum of all of the forces is equal to zero. A non-concurrent or a parallel force system can actually be in equilibrium with respect to all of the forces, but not be in equilibrium with respect to moments.

[*EXTRA NOTE: Graphic Statics and graphical methods of force resolution were developed before the turn of the century by Karl Culmann. They were the only methods of structural analysis for many years. These methods can help to develop an intuitive understanding of the action of the forces. Today, the Algebraic Method is considered to be more applicable to structural design. Despite this, graphical methods are a very easy way to get a quick answer for a structural design problem and can aid in the determination of structural form.*]

QUESTION: **WHAT IS STATIC EQUILIBRIUM**?
What are the conditions of static equilibrium for
(i) con-current force system
(ii) coplanar non concurrent force system?

Ans: A body is said to be in equilibrium when there is no change in position as well as no rotation exist on the body. So to be in equilibrium process, there must not be any kind of motions ie there must not be any kind of translational motion as well as rotational motion.

We also know that to have a linear translational motion we need a net force acting on the object towards the direction of motion, again to induce an any kind of rotational motion, a net moment must exists acting on the body. Further it can be said that any kind of complex motion can be resolved into a translational motion coupled with a rotating motion.

Therefore a body subjected to a force system would be at rest if and only if the net force as well as the net moment on the body be zero. Therefore the general condition of any system to be in static equilibrium we have to satisfy two conditions

(i) Net force on the body must be zero ie, $\Sigma \mathbf{F_i} = \mathbf{0}$;
(ii) Net moment on the body must be zero ie, $\Sigma \mathbf{M_o} = \mathbf{0}$.

Now we can apply these general conditions to different types of Force System.

So, for **Concurrent force system**, the equilibrium conditions are as follows
(i) $\Sigma \mathbf{F_x} = \mathbf{0}$; (ii) $\Sigma \mathbf{F_y} = \mathbf{0}$
and for coplanar **non concurrent force system**, the equilibrium conditions are as follows
(i) $\Sigma \mathbf{F_x} = \mathbf{0}$; (ii) $\Sigma \mathbf{F_y} = \mathbf{0}$; (iii) $\Sigma \mathbf{M_i} = \mathbf{0}$

MOMENT ON A PLANE:

For a force system the total resultant moment about any arbitrary point due to the individual forces are equal to the moment produced by the resultant about the same point. Now if the system is at equilibrium condition, then the resultant force would be zero. Hence, the moment produced by the resultant about any arbitrary point is zero. In case of coplanar & concurrent force system, as the forces are concurrent i.e. each of the force passes through a common point, hence moments produce by these three forces about the con-current point would be zero. But in case of non concurrent forces the total moments would be zero only when the body is in equilibrium.

What is Momentum of a Mass?

Momentum is a physical quantity. It is associated with motion. In fact any object in motion is said to have a momentum. A mass at a static equilibrium does have a zero value. As it has a direction as well as magnitude, it is a vector quantity. The magnitude of momentum of an object is equal to the mass of the object multiplied by the magnitude of the object's velocity. It is denoted by (P). Hence, **P = mV**
where m = mass of the object and V = velocity of the object. Therefore, the direction of momentum will be the direction of velocity itself.

3) **WHAT ARE DIFFERENT TYPES OF JOINTS? Discuss them in details.**

Answer: The Concepts of Joints. In Engineering terminology any force carrying linear member is called as links. Links can be attached to each other by the fasteners or joints. Hence, we can say to prevent the relative motion between two links completely or partially we use fasteners or joints.

Basically there are three types of joints which we shall discuss and they are named as,
(i) pin/ hinged joints, (ii) roller joints and (iii) fixed joints.

They are classified according to the degrees of freedom of the links they would allow. Like a pin or hinge joint is consisted of two links joined by the insertion of a pin at the pivot hole. A pin joint doesn't allow vertical or horizontal relative velocities between the two links.

For better understanding of the mechanism of pin joint we would like to make a simplest type of pin joints. Suppose we would take two links and make holes at one of the ends of each link. Now if we insert a bolt through the holes of both the links, then what we get is an example of pin/hinge joints.

A pin joint although restricts any kind of horizontal or vertical displacement but they can not restrict rotation about an axis passing through the hole, in clockwise or anti clockwise direction. Hence it provides two reactions one vertical and one horizontal to restrict any kind of movement along that direction.

4) **WHAT IS MOMENT? Differentiate between moment, torque and couple. Also state and prove VARIGNON's theorem of moments.**

Whenever we apply force on a rigid body at a point other than its Center of Mass, the body exhibit a rotational motion about the center of mass other than a translational motion. Where as the translational motion is there due to the application of force on the object, the rotational motion is there due to eccentric application of force at a point away from the center of mass. But if we apply force at the center of the mass, then no rotational tendency has been observed. It is also observed that the longer is the distance between the center of mass and the point of application of force, larger is the magnitude of rotation. The physical quantity that is responsible for motion is termed as Moment. It is denoted by M and M is a vector quantity as it has direction, either clockwise or anti-clockwise. So, if a force F act at a point d distance from the center of mass, then the total moment produced about the center of mass is the vector cross product of the position vector of the force, and the force itself.

$$\mathbf{M=d\ X\ F} \text{ ------ ()}$$

Therefore, same force would produce different magnitudes of revolution rate and as rate of revolution depends upon Moment, it should produce different magnitudes of Moments. The axis about which a force tries to rotate an object, is called center of rotation as well as it is the axis of moment also. To find the moment produced by a force about a point (O) in the plane, we need to multiply the magnitude of the force and the perpendicular distance of the line of action of the force from the point (O).

WHAT IS CENTROID? EXPLAIN IT IN YOUR WORDS.

The word Centroid is used to denote the center of a certain area. But, then one may question, what does it mean when we say a particular point, say G is the centroid of a specific area. We shall explain the concepts using figures to make the point crystal clear!
Suppose in a 3D coordinate system we take a lamina on X-Y plane.

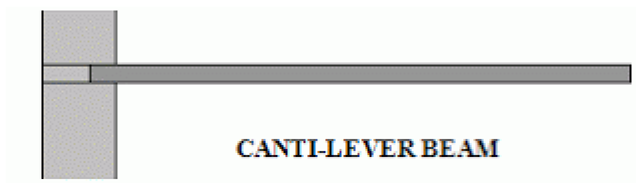
Let the total area A be divided into (**n**) numbers of parts and denote them as $\mathbf{A_1}$, $\mathbf{A_2}$, $\mathbf{A_3}$, ...$\mathbf{A_n}$.
Let's take an elemental area ($\mathbf{A_i}$) is at ($\mathbf{X_i}$) distance from Y axis, and at ($\mathbf{Y_i}$) from X axis.

Hence, the moment of the area $\mathbf{A_i}$ about X-axis is $\mathbf{A_i Y_i}$ and about Y-axis the moment will be $\mathbf{A_i X_i}$. So, the total moment (**M**) of the total area (**A**) will be the total sum of these tiny moments. Now, we shall introduce an abstract idea that if all the area (**A**) is concentrated at a point (**P**) whose coordinates are **(x,y)** so that it produce the same effect on the surroundings here the effects are moments about X-axis and Y-axis.

5) What are beams? Classify them properly. What is support reactions?

BEAM: A beam is a structure generally a horizontal structure on rigid supports and it carries mainly vertical loads. Therefore, beams are a kind of load bearing structures.

Depending upon the types of supports beams can be classified into different categories.



CANTI-LEVER BEAMS:

A beam can be at stable equilibrium with a single fixed support at one end and the other end remains free, which is called as the free end while the other end is known as fixed end. This kind of beam is known as Canti lever beam. The fixed joint at the fixed end produces a horizontal, a vertical reactions and a reaction moment at the fixed end.

SIMPLY SUPPORTED BEAM:

A beam supported as just resting freely on the walls or columns at its both ends is known as simply supported beam. There will be two vertically upward reactions at the ends of a simply supported beam. A simply supported beam can not resist any horizontal load component.

OVER HANGING BEAM:

A beam having its end portion or both the end portions extended in the form of a canti-lever beyond the support or supports is called as over hanging beam.

Above those beams are statically determinate. It means that those beams can be analysed applying the conditions of equilibrium. We can determine the values of the unknown reactions.

There are beams which can not be analysed applying the conditions of equilibrium of coplanar forces. These beams are also known as statically indeterminate structures.

Those types of beams can be classified as,

Fixed beams and Continuous beams.

Fixed Beam: A beam having two fixed joints at the both ends is called fixed beam.

Continuous Beam: The beam which is at rest on more than two supports is called as continuous beam.

6) State coulomb's law of dry friction. Explain the following terms

(i) coefficients of static and dynamic friction

(ii) angle of friction

(iii) angle of repose

(iv) limiting friction

CONCEPTS OF FRICTION ......:

Whenever two bodies are in contact with each other, they exert a force R to each other. The force R is called as Contact Reaction. There exists a natural phenomenon associated with two bodies in contact. It has been seen that when the two bodies are in static condition relative to each other, everything remains as normal phenomenon as there exist two equal and opposite normal reaction will act at the contact surface. But, whenever we try to make a relative motion between those two bodies, an amazing thing occurs, a "phantom force" suddenly pops up between the bodies acting on the contact surface whose sole purpose of creation is to oppose any relative motion between those two objects. Although the exact reasons behind the generation of this force is not known, but there exists two separate models of origin of friction, none of them are confirmed, although both of them are used to explain the most possible reason behind the sudden generation of this opposite force or we may even call it Resistance Force. But, one thing is surely confirmed from the standard model of particle physics and that is between four types of fundamental forces, only electro-magnetic force is responsible for the generation of frictional force.

7) **(i) What is Shear Force and Bending Moment?**

(ii) What do you understand by SFD and BMD?

Ans: Vertical forces that act on a horizontal beam is mainly termed as Shear Force. Where as moments produced by those forces on the beam is
state the working procedure to draw them.

8) What is free body diagram(FBD)? Explain with an example.

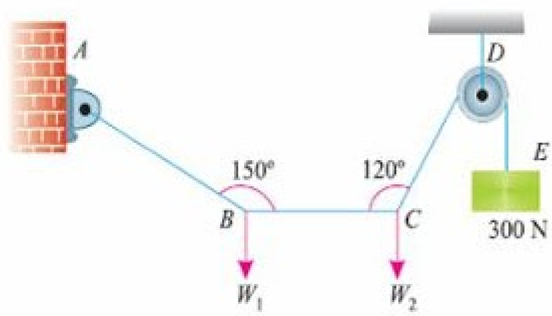
9) What is point of contraflexure?

**10) What is the difference between truss and frames?
Explain different types of truss with proper illustration.**

11) What is simple stress and strain? Compare the stress strain graphs for ductile and brittle materials.

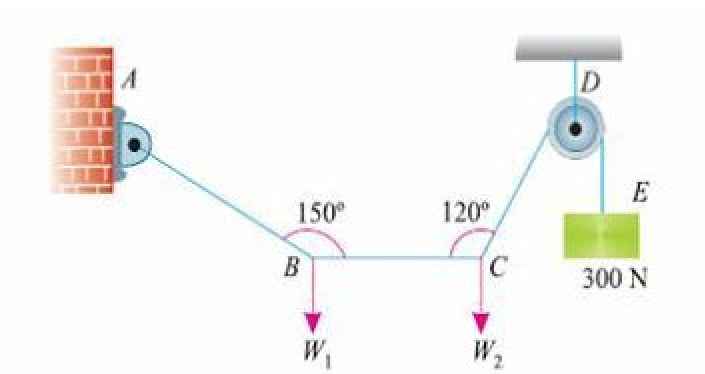
12) What is strain energy and resilience.explain impact loading? Prove that for the same loading, stress induced due to impact loading is twice of the stress induced due to gradually applied load.

SOLUTION OF EME-102; EQUILIBRIUM OF FORCES



A light string ABCDE whose extremity A is fixed, has weights W_1 & W_2 attached to it at B & C. It passes round a small smooth pulley at D carrying a weight of 300 N at the free end E as shown in figure. If in the equilibrium position, BC is horizontal and AB & CD make 150° and 120° with BC, find (i) Tensions in the strings and (ii) magnitudes of W_1 & W_2

Although ABCDE is a single string/rope but still the tensions in the string/rope will be different at different segments like in the segment AB the tensions will be T_1 , but in BC segment it will be different as the weight is attached at a fixed point (point B) on the string, hence it will be T_2 here and in CD it will be T_3 there. As at point D the string is not attached rather passes over a smooth pulley hence the tension in DE and CD will be same ie. T_3 again.

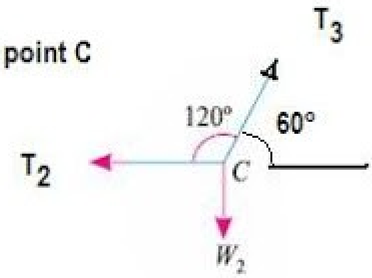


FBD of point E

$\Sigma Fx = 0$

$T_3 = 300$ N

FBD of point C



$\Sigma Fy = 0$

$W_2 = T_3 \text{ Sin } 60°$

$= 300 \times 0.866$

$= 259.80$ N

$\Sigma Fx = 0$

$T_3 \text{ Cos } 60° = T_2$

$T_2 = ½ \times 300$ N

$= 150$ N

$\Sigma Fy = 0$

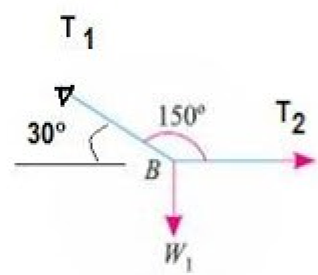
$W_1 = T_1 \text{ Sin } 30°$

$= 86.6$ N

$\Sigma Fx = 0$

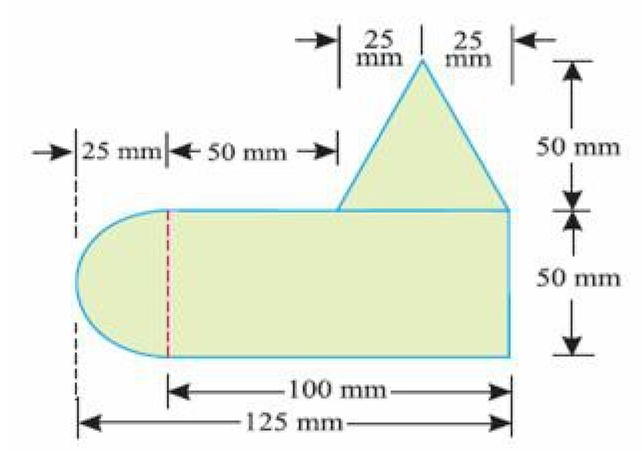
$T_1 \text{ Cos } 30° = T_2$

$T_1 = \dfrac{150 \text{ N}}{0.866} = 173.2$ N



FBD of point B

SOLUTION OF EME-102; CENTROID



HOW TO FIND THE CENTROID OF A COMPOSITE AREA

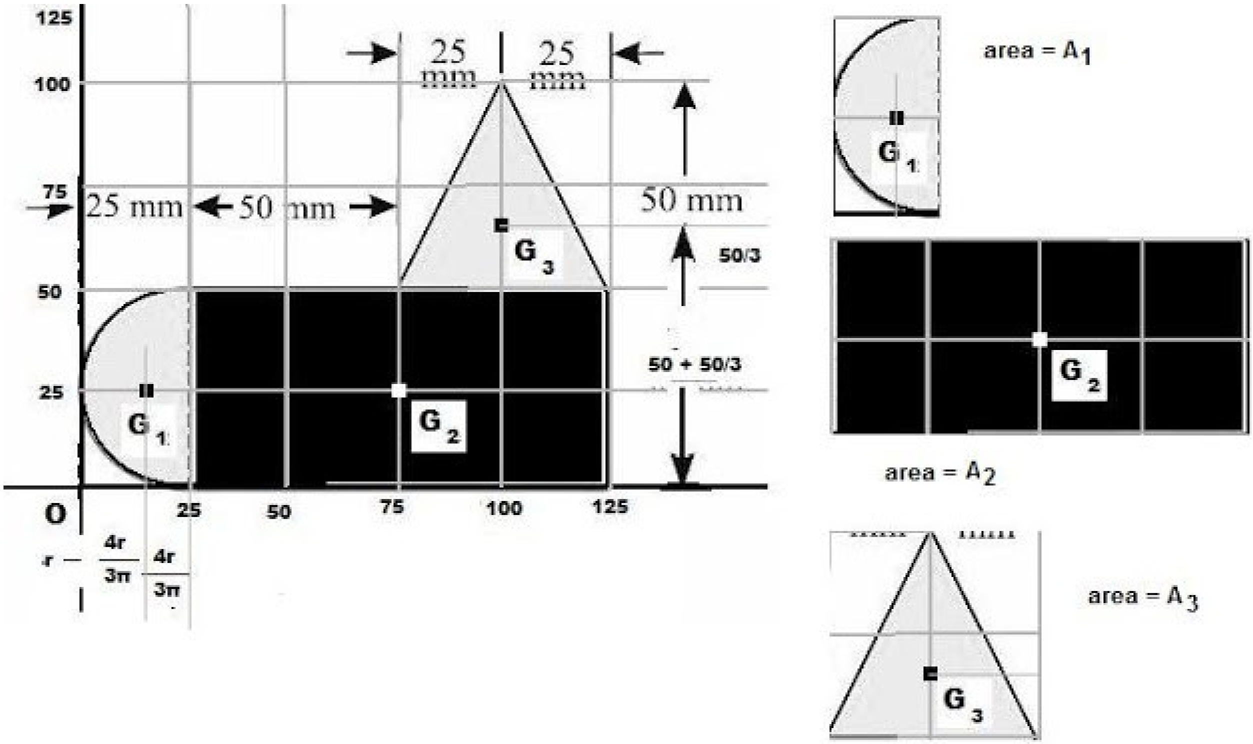
(a composite area consists of several straight or curved lines.)

(i) Draw the figure in a coordinate system. Draw the dimensions too. Every dimensions will be measured with respect to origin of the coordinate system

(ii) Divide the composite area into several parts of basic geometric areas. Lebel them as part-1, part-2, part-3, ...part-n. Let the corresponding areas are A_1, A_2, A_3, ... A_n. Let the centroids are $G_1(X_1,Y_1)$, $G_2(X_2,Y_2)$, $G_3(X_3,Y_3)$, ... $G_n(X_n,Y_n)$.

(iii) Let the centroid of the composite area be G(Xg,Yg). Hence,
$Xg = (A_1X_1 + A_2X_2 + A_3X_3)/(A_1 + A_2 + A_3)$

$Yg = (A_1Y_1 + A_2Y_2 + A_3Y_3)/(A_1 + A_2 + A_3)$



(a) Suppose we have certain area of magnitude (A) in a coordinate system. The centroid of the area will be at its mid-point. A centroid is denoted by G.

In the figure we have a complex geometrical area composed of three basic geometrical areas. A rectangle, a semi circle and a isosceles triangle. Let us denote the centroids as G_1, G_2, G_3 for the given areas in the figure.

We shall have to find the Centroid of the entire area composed of A_1, A_2, A_3.

At first, the composite line is divided into three parts.

Part -1 : The semi-circle : Let the centroid of the area A_1 be $G_1(X_1,Y_1)$

Area, $A_1 = (\pi/2)x(25)^2$ mm² = 981.74 mm²

$X_1 = \{ 25 - (4x25)/(3x\pi)\}$ mm = 14.39 mm

$Y_1 = 25$ mm

Part -2 : The Rectangle : Let the centroid of the A_2 be $G_2(X_2,Y_2)$

Area, $A_2 = 100 \text{ x } 50$ mm² = 5000 mm²

$X_2 = 25 + (100/2) = 75$ mm

$Y_2 = 25$ mm

Part -3 : The Triangle : Let the centroid of the area Area, A_3 be $G_3(X_3,Y_3)$

Area, $A_3 = (1/2) \times 50 \times 50\ mm^2 = 1250\ mm^2$
$X_3 = 25 + 50 + 25 = 100$ mm
$Y_3 = 50 + (50/3) = 66.67$ mm

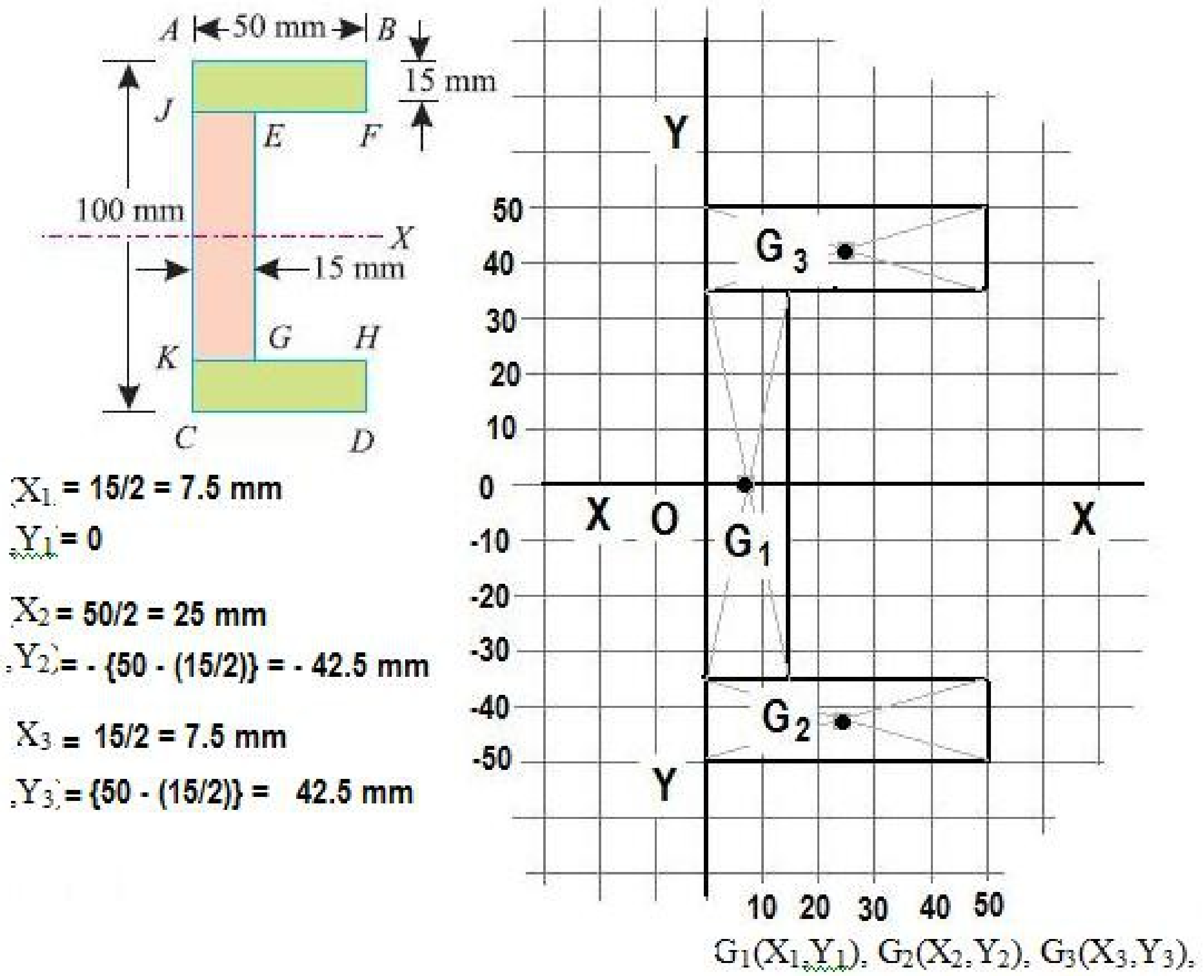
If the centroid of the composite line be G (X_g,Y_g)
$X_g = (\sum A_iX_i)/(\sum A_i)$

$= (A_1X_1 + A_2X_2 + A_3X_3)/(A_1 + A_2 + A_3)$
$= (981.74 \times 14.39 + 5000 \times 75 + 1250 \times 100)/(981.74 + 5000 + 1250)$
$= 71.09$

$Y_g = (\sum A_iY_i)/(\sum A_i)$

$= (A_1Y_1 + A_2Y_2 + A_3Y_3)/(A_1 + A_2 + A_3)$
$= (981.74 \times 25 + 5000 \times 25 + 1250 \times 66.67)/ (981.74 + 5000 + 1250)$
$= 32.20$

SOLUTION OF EME-102; CENTROID 2



HOW TO FIND THE CENTROID OF A COMPOSITE AREA

(a composite area consists of several straight or curved lines.)

(i) Draw the figure in a coordinate system. Draw the dimensions too. Every dimensions will be measured with respect to origin of the coordinate system

(ii) Divide the composite area into several parts of basic geometric areas. Lebel them as part-1, part-2, part-3, ...part-n. Let the corresponding areas are A_1, A_2, A_3, ... A_n. Let the centroids are $G_1(X_1,Y_1)$, $G_2(X_2,Y_2)$, $G_3(X_3,Y_3)$, ... $G_n(X_n,Y_n)$.

(iii) Let the centroid of the composite area be G(Xg,Yg). Hence,

$Xg = (A_1X_1 + A_2X_2 + A_3X_3)/(A_1 + A_2 + A_3)$

$Yg = (A_1Y_1 + A_2Y_2 + A_3Y_3)/(A_1 + A_2 + A_3)$

(a) Suppose we have certain area of magnitude (A) in a coordinate system. The centroid of the area will be at its mid-point. A centroid is denoted by **G.**

In the figure we have a complex geometrical area composed of three basic geometrical areas. Three rectangles. Let us denote the centroids as $\mathbf{G_1, G_2, G_3}$ for the given areas in the figure.

We shall have to find the Centroid of the entire area composed of A_1, A_2, A_3.

At first, the composite line is divided into three parts.

Part -1 : The middle rectangle : Let the centroid of the area A_1 be $G_1(X_1,Y_1)$

Area, $A_1 = (100-15-15)\text{x}15\ mm^2 = 70\text{x}15\ mm^2 = 1050\ mm^2$

$X_1 = 7.5$ mm

$Y_1 = 0$

Part -2 : The lower Rectangle : Let the centroid of the A_2 be $G_2(X_2,Y_2)$

Area, $A_2 = 50 \text{ x } 15\ mm^2 = 750\ mm^2$

$X_2 = 25$ mm

$Y_2 = -42.5$ mm

Part -3 : The upper Rectangle : Let the centroid of the area Area, A_3 be $G_3(X_3,Y_3)$

Area, $A_3 = 50 \text{ x } 15\ mm^2 = 750\ mm^2$

$X_3 = 25$ mm

$Y_3 = 42.5$ mm

If the centroid of the composite line be G (X_g,Y_g)

$X_g = (\sum A_iX_i)/(\sum A_i)$

$= (A_1X_1 + A_2X_2 + A_3X_3)/(A_1 + A_2 + A_3)$

$= (1050 \times 7.5 + 750 \times 25 + 750 \times 25)/(1050 + 750 + 750)$
$= 17.79$ mm

$Y_g = (\sum A_i Y_i)/(\sum A_i)$

$= (A_1Y_1 + A_2Y_2 + A_3Y_3)/(A_1 + A_2 + A_3)$
$= \{1050 \times 0 + 750 \times (-42.5) + 750 \times 42.5\}/(1050 + 750 + 750)$
$= 0$

As the figure is symmetrical about X axis, hence when we take the line of symmetry as our X axis (as we have taken here), we can directly write, $Y_g = 0$

PARALLEL AXIS THEOREM AND IT'S USES IN MOI

Moment Of Inertia of an Area.

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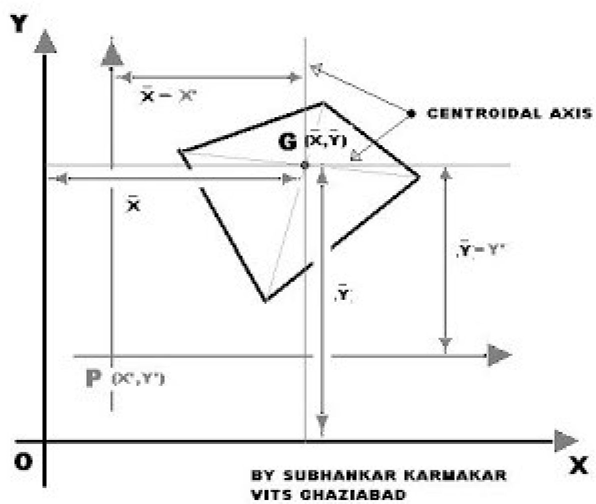
MOI or MOMENTS OF INERTIA is a physical quantity which represents the inertia or resistances shown by the body against the tendency to rotate under the action external forces on the body. It is a rotational axis dependent function as its magnitude depends upon our selection of rotational axis. Although for any axis, we can derive the expression for MOI with the help of calculus, but still it is a cumbersome process.

Now suppose we take a different issue. We know MOI of an area about its centroidal axis is easily be obtained by integral calculus, but can we find a general formula by which we can calculate MOI of an area about any axis if we know its CENTROIDAL MOI.



We shall here find that we can indeed derive an expression by which MOI of any area (A) can be calculated about any Axis, if we know its centroidal MOI and the distance of the axis from it's Centroid G.

If I_{GX} be the centroidal moment of inertia of an area (A) about X axis, then we can calculate MOI of the Area about a parallel axis (here X axis passing through the point P) at a distance $\hat{Y}$-Y'=Y from the centroid if we know the value of I_{GX} and Y, then I_{PX} will be

$I_{PX} = I_{GX} + A.Y^2$ where $Y=\hat{Y}-Y'$

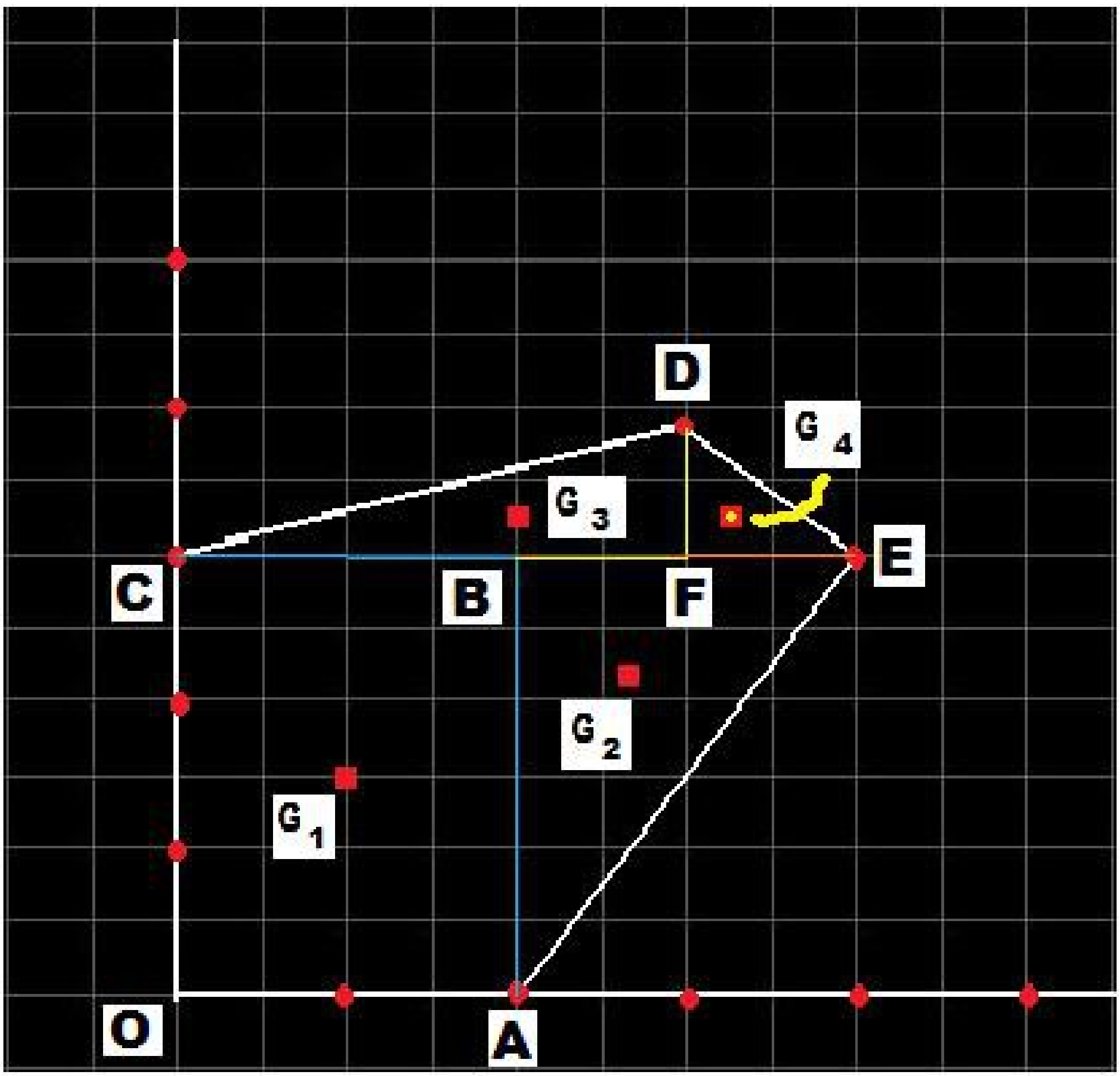
$I_{XX} = I_{OX} = I_{GX} + A.\hat{Y}^2$

Where I_{XX} is the moment of inertia of the area about the co-ordinate axis parallel to X axis and passing through origin O, hence we can say,

$I_{XX} = I_{OX}$

IMPORTANT: The notation of Moment of Inertia

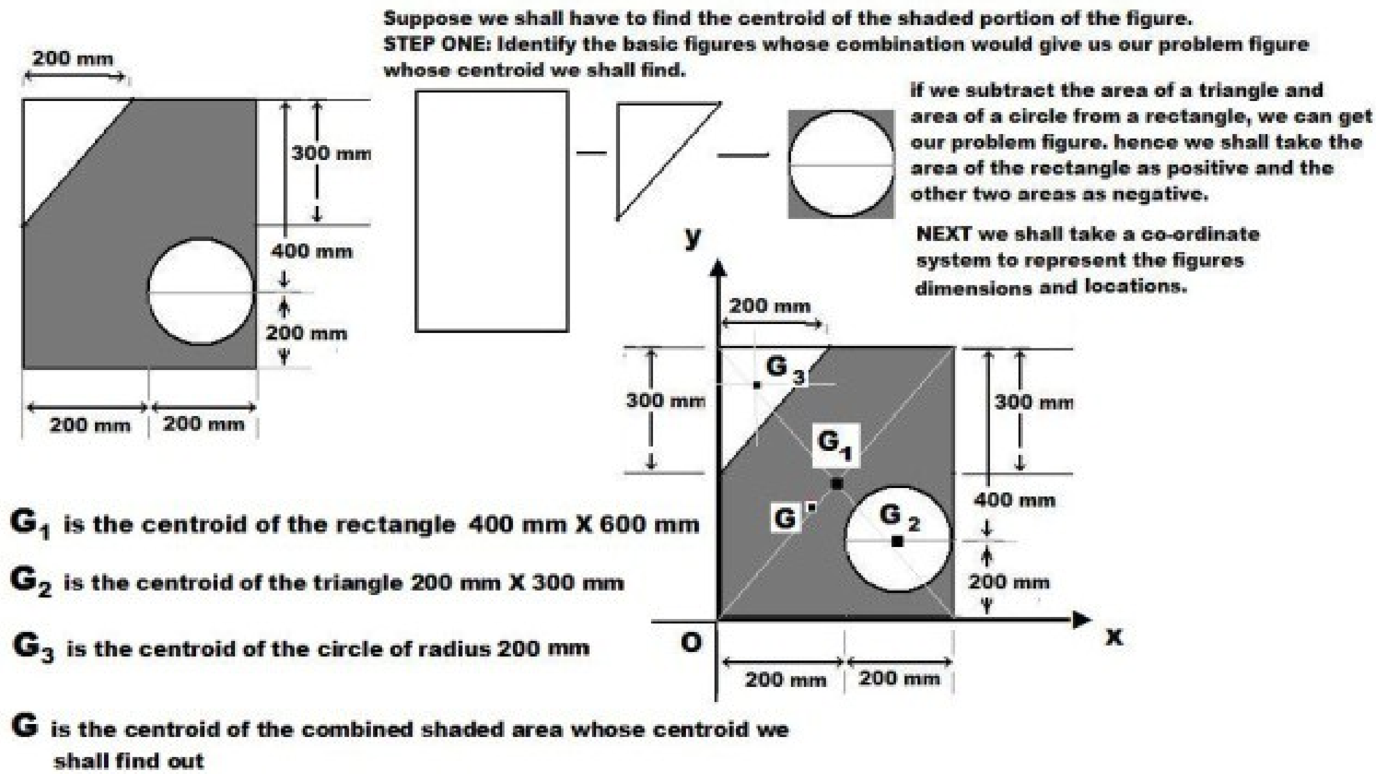
MOI of an area about an axis passing through a point B will be written as I_{BX}

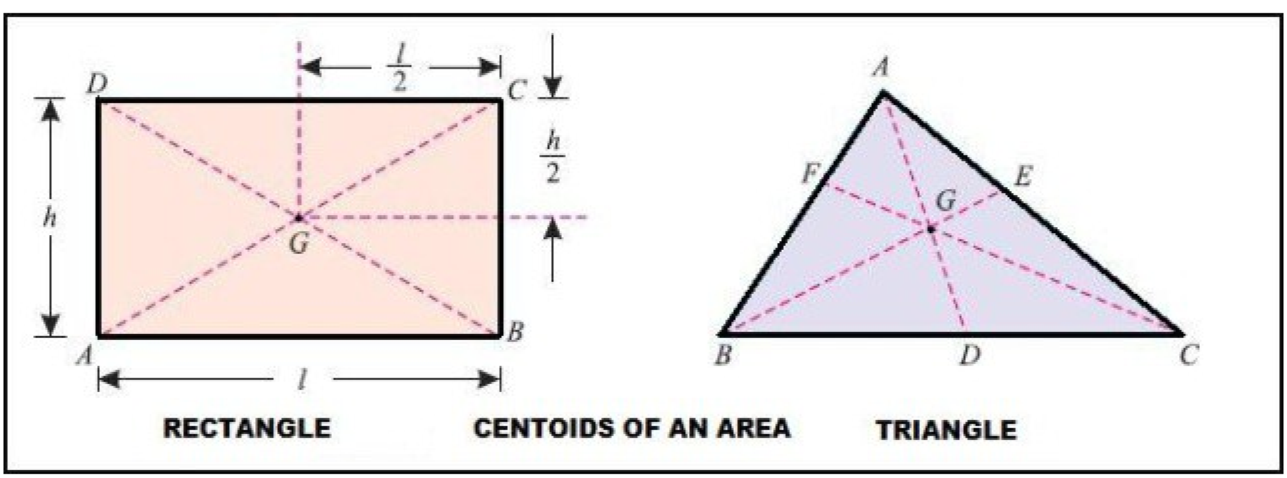


Q: Find the Centroidal Moment of Inertia of the figure given above. Each small division represents 50 mm.

To find out Centroidal MOI

CENTROID OF COMPLEX GEOMETRIC FIGURES:

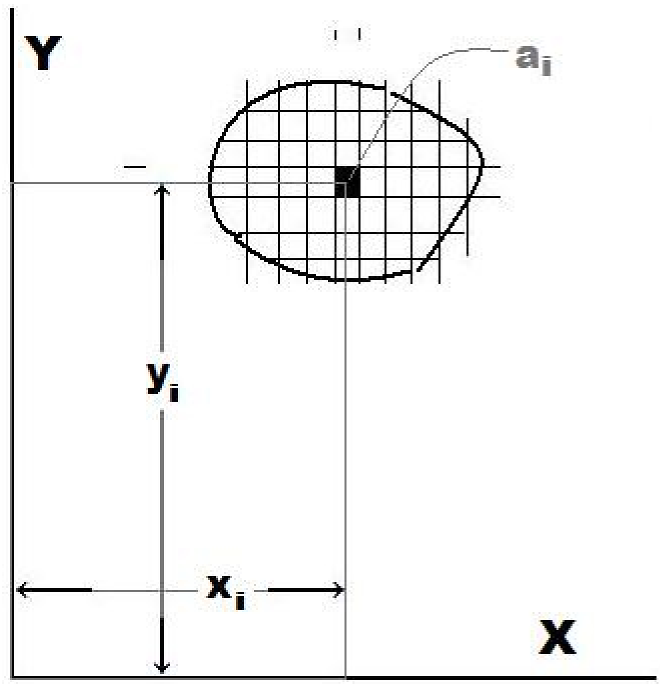




So in this articles, we are going to discuss the concepts of centroid for one dimensional as

well as two dimensional objects.

Let's first discuss about 1D and 2D objects, one by one, an 1D object is a line, practically a metallic rod will be considered as a linear, 1D object. Where as any thin plate of negligible thickness can be considered a 2D body. Suppose we have a thin metallic rectangular plate. If it is considered as a 2D rectangular area of b X h.



The concept of centroid has been developed on the basis of resultant of several areas. We know that an area can be represented as the cross product of two vectors, hence it is also an vector. Suppose we have an area A, in a cartesian 2D coordinate system. We just divide the area into n parts, and represent them as a_1, a_2, a_3, ... a_n.

Let the elemental areas are at a distance x_1, x_2, x_3, ... x_n, from Y axis and y_1, y_2, y_3, ...y_n from X axis.

The total moments produced about Y axis will be equal to the summation of all the individual moments produced by n elemental areas.

Now moment is a vector quantity and we know vectors of same kind can be added together, therefore, all the n moment vectors can be added to get a single value of Resultant Moment.

We also know this resultant moment's position vector. Let the resultant moment passes through a point G. The point through which resultant moment passes through is called Center of the Area or Centroid.

How can we find out the point G, whose coordinates are (X_g,Y_g)?

As moment of an area also obeys VARIGNON'S THEOREM OF MOMENT, then sum of all the moments produced by individual elemental areas will exactly be equal to the moment produced by the total area, i.e. the resultant of all those elemental areas. Now if all the areas are added to have the resultant area which will pass through the centroid G such that it produces a moment of X_gA about Y axis and Y_gA about X axis.

But Varignon's theorem states us that, for a vector system, resultant vector produces the moment about a point, is exactly equal to the sum of all the moments produced by all elemental areas about the same point and in the same plane. Hence, we can write now that,

Sum$(a_1x_1+ a_2x_2+ + +a_nx_n) = AX_g$

we can use summation sign ∑ to represent these equations,

$\sum a_ix_i = (\sum a_i)X_g$

$\Rightarrow X_g = (\sum a_ix_i)/((\sum a_i)$

Sum$(a_1y_1+ a_2y_2+ + +a_ny_n) = AY_g$

$\sum a_iy_i = (\sum a_i)Y_g$

$\Rightarrow Y_g = (\sum a_iy_i)/((\sum a_i)$

Algorithm to find out the Centroid G(X_g, Y_g) of a Complex Geometric Figure.

Step1:

Take a complex 2D figure like an Area or Lamina.

Step2:

Try to identify the basic figures whose algebraic combination produces our problem figure, whose centroid we shall find out.

Step3:

Choose a coordinate system, and make it as our frame of reference. All the distances and coordinate must be define with respect to our frame of reference.

Step4:

Compute the area (a_i), coordinates of their own centroid G_i (x_i, y_i) for each and every elemental areas. While measuring the centroids, all the measurements will be based on according to our chosen Axes.

Step5:

If any particular area has to subtracted to get the complex figure, the area will be negative, where as any area addition will be positive area.

Step6:

If the Centroid of the complex figure be $G(X_g,Y_g)$then,

=> $X_g = (\sum a_i x_i)/((\sum a_i)$

=> $Y_g = (\sum a_i y_i)/((\sum a_i)$

Here G_1 is the centroid of the part one where G_2 is the centroid of the circular area that has to be removed where as G_3 is the centroid of the triangular area that has to be removed also.

If we are asked to find moment of inertia of an area, which is nothing but the "second moment of area" then we shall have to find the centroidal moment of inertia first. Then we shall transfer the Moment of Inertia to another axis ie we shall apply parallel axis theorem to transfer moment of inertia from one axis (here centroidal axis) to another parallel axis.

MOMENTUM : AN IMPORTANT CONCEPT

NEWTON'S LAW OF MECHANICS:

Although we know there are three laws of motion proposed by Issac Newton, but it can be shown that the 2nd law of motion is the fundamental laws of motion, and the other two laws are nothing but special cases of second law.

The second law states that the <u>rate of change of momentum</u> is equal to force, which is another physical quantity and it is a vector.

SO WHAT DOES MOMENTUM MEAN?

MOMENTUM

Tuesday, 16. November, 02:41

Objects in motion are said to have a momentum. This momentum is a vector. It has a size and a direction. The size of the momentum is equal to the mass of the object multiplied by the size of the object's velocity. The direction of the momentum is the same as the direction of the object's velocity.

Momentum is a conserved quantity in physics. This means that if you have several objects in a system, perhaps interacting with each other, but not being influenced by forces from outside of the system, then the total momentum of the system does not change over time. However, the separate momenta of each object within the system may change. One object might change momentum, say losing some momentum, as another object changes momentum in an opposite manner, picking up the momentum that was lost by the first.

IMPORTANCE OF MOMENTUM

Momentum is a corner stone concept in Physics. It is a conserved quantity. That is, within a closed system of interacting objects, the total momentum of that system does not change value. This allows one to calculate and predict the outcomes when objects bounce into one another. Or, by knowing the outcome of a collision, one can reason what was the initial state of the system.

MOMENTUM IS MASS TIMES VELOCITY
When an object is moving, it has a non-zero momentum. If an object is standing still, then its momentum is zero. To calculate the momentum of a moving object multiply the mass of the object times its velocity. The symbol for momentum is a small p.
MOMENTUM IS A VECTOR QUANTITY
Momentum is a vector. That means, of course, that momentum is a quantity that has a magnitude, or size, and a direction. The above problem is a one dimensional problem. That is, the object is moving along a straight line. In situations like this the momentum is usually stated to be positive, i.e., to the right, or negative, i.e., to the left.
MOMENTUM IS NOT VELOCITY
.

Sometimes the concept of momentum is confused with the concept of velocity. Do not do this. Momentum is related to velocity. In fact, they both have the same direction. That is, if an object has a velocity that is aimed toward the right, then its momentum will also be directed to the right. However, momentum is made up of both mass and velocity. One must take the mass and multiply it by the velocity to get the momentum.

MOMENTUM IS DIRECTLY PROPORTIONAL TO VELOCITY
If the mass is kept constant, then the momentum of an object is directly proportional to its velocity. In the example at the left, the mass is kept constant at a value of 2.0 kg. The velocity changes from 0 m/s to 10 m/s while the momentum changes from 0 kg-m/s to 20 kg-m/s. This creates a straight line graph when momentum is plotted as a function of velocity. (The symbol for momentum as a function of velocity would be p(v).) The straight line graph demonstrates the direct proportion between momentum and velocity.

That is, if one were to double the velocity of an object, then the momentum of that object would also double. And, if one were to change the velocity of an object by a factor of 1/4, then the momentum of that object would also change by a factor of 1/4.
MOMENTUM IS DIRECTLY PROPORTIONAL TO MASS

If the velocity is kept constant, then the momentum of an object is directly proportional to its mass. In the example at the left, the velocity is kept constant at a value of 3.0 m/s. The mass changes from 0 kg to 10 kg while the momentum changes from 0 kg-m/s to 30 kg-m/s. This creates a straight line graph when momentum is plotted as a function of mass. (The symbol for momentum as a function of mass would be p(m).) The straight line graph demonstrates the direct proportion between momentum and mass.

That is, if one were to triple the mass of an object, then the momentum of that object would also triple. And, if one were to change the mass of an object by a factor of 1/2, then the momentum of that object would also change by a factor of 1/2.
Posted by Subhankar Karmakar at 10:59 AM
THE CONCEPT OF MOMENT:
Moment of force (or moment) is the tendency of a force to twist or rotate an object. This is an important, basic concept in engineering and physics. A **moment** is valued mathematically as the

product of the **force** and the **moment arm**. The **moment arm** is the **perpendicular distance** from the point of rotation, to the **line of action** of the force. The moment may be thought of as a measure of the tendency of the force to cause rotation about an imaginary axis through a point. (Note: In mechanical and civil engineering, "moment" and "torque" have different meanings, while in physics they are synonyms.)

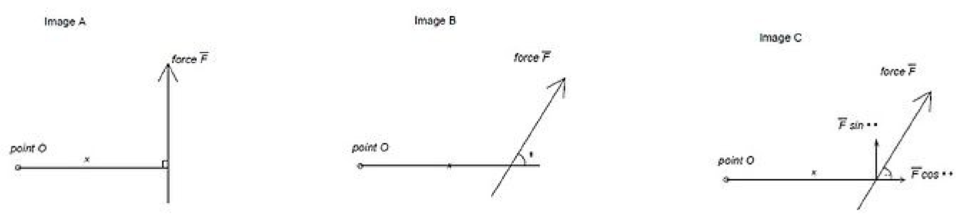
The moment of a force can be calculated about any point and not just the points in which the line of action of the force is perpendicular. Image A shows the components, the force F, and the moment arm, x when they are perpendicular to one another. When the force is not perpendicular to the point of interest, such as Point O in Images B and C, the magnitude of the Moment, **M** of a vector **F** about the point **O** is

$$\mathbf{M_O} = \mathbf{r_{OF}} \times \mathbf{F}$$

where

$\mathbf{r_{OF}}$ is the vector from point O to the position where quantity **F** is applied.

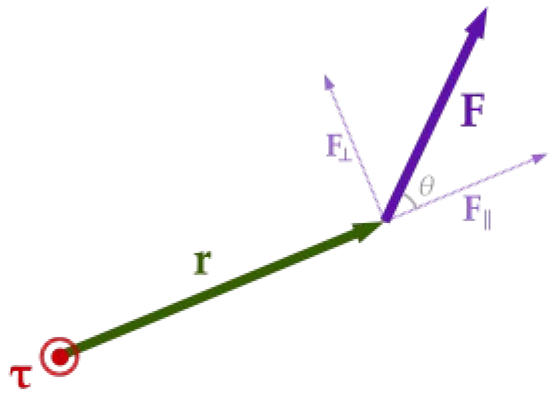
× represents the cross product of the vectors.



[In the figure a moment at Point O, when the components are perpendicular to the Point O. Image B and Image C illustrate the components of a Moment at Point O, when the components are not perpendicular to point O.]

In mechanical engineering (unlike physics), the terms "torque" and "moment" are not interchangeable. "Moment" is the general term for the tendency of one or more applied forces to rotate an object about an axis (the concept which in physics is called torque). "Torque" is a special case of this: If the applied force vectors add to zero (i.e., their "resultant" is zero), then the forces are called a "couple" and their moment is called a "torque".

For example, a rotational force down a shaft, such as a turning screw-driver, forms a couple, so the resulting moment is called a "torque". By contrast, a lateral force on a beam produces a moment (called a bending moment), but since the net force is nonzero, this bending moment is not called a "torque".



A particle is located at position r relative to its axis of rotation. When a force F is applied to the particle, only the perpendicular component $F\perp$ produces a torque. This torque $\tau = r \times F$ has

magnitude $\tau = |r|\ |F\perp| = |r|\,|F|\,\sin\theta$ and is directed outward from the page.

A **Couple** is a system of forces with a resultant (a.k.a. net, or sum) moment but no resultant force.Another term for a couple is a **pure moment**. Its effect is to create rotation without translation, or more generally without any acceleration of the centre of mass.

The resultant moment of a couple is called a **torque**. This is not to be confused with the term torque as it is used in physics, where it is merely a synonym of moment. Instead, torque is a *special case* of moment. Torque has special properties that moment does not have, in particular the property of being independent of reference point.

Simple Couple:

The simplest kind of couple consists of two equal and opposite forces whose lines of action do not coincide. This is called a "simple couple". The forces have a turning effect or moment called a torque about an axis which is normal to the plane of the forces. The SI unit for the torque of the

couple is newton metre.
If the two forces are **F** and **−F**, then the magnitude of the torque is given by the following formula:

$$\tau = F \times d$$

where

τ is the torque
F is the magnitude of one of the forces
d is the perpendicular distance between the forces, sometimes called the *arm* of the couple

The magnitude of the torque is always equal to Fd, with the direction of the torque given by the unit vector $\hat{e}$, which is perpendicular to the plane containing the two forces. When **d** is taken as a vector between the points of action of the forces, then the couple is the cross product of **d** and **F**.

Independence of reference point:

The moment of a force is only defined with respect to a certain point *P* (it is said to be the "moment about *P*"), and in general when *P* is changed, the moment changes. However, the moment (torque) of a*couple* is *independent* of the reference point *P*: Any point will give the same moment.In other words, a torque vector, unlike any other moment vector, is a "free vector". (This fact is called *Varignon's Second Moment Theorem*.)

The proof of this claim is as follows: Suppose there are a set of force vectors $\mathbf{F}_1$, $\mathbf{F}_2$, etc. that form a couple, with position vectors (about some origin *P*) $\mathbf{r}_1$, $\mathbf{r}_2$, etc., respectively. The moment about *P* is

$$M = \mathbf{r}_1 \times \mathbf{F}_1 + \mathbf{r}_2 \times \mathbf{F}_2 + \cdots$$

Now we pick a new reference point *P′* that differs from *P* by the vector **r**. The new moment is

$$M' = (\mathbf{r}_1 + \mathbf{r}) \times \mathbf{F}_1 + (\mathbf{r}_2 + \mathbf{r}) \times \mathbf{F}_2 + \cdots$$

Now the distributive property of the cross product implies

$$M' = \left(\mathbf{r}_1 \times \mathbf{F}_1 + \mathbf{r}_2 \times \mathbf{F}_2 + \cdots\right) + \mathbf{r} \times \left(\mathbf{F}_1 + \mathbf{F}_2 + \cdots\right).$$

However, the definition of a force couple means that

$$\mathbf{F}_1 + \mathbf{F}_2 + \cdots = 0.$$

Therefore,

$$M' = \mathbf{r}_1 \times \mathbf{F}_1 + \mathbf{r}_2 \times \mathbf{F}_2 + \cdots = M$$

This proves that the moment is independent of reference point, which is proof that a couple is a free vector.

Physics of Inertial Forces

Force Effects Caused by Inertia and Accelerating Reference Frames

Inertial forces are not real forces, rather they are often called as "pseudo forces". They produce effects that feel like forces but actually arise from Newton's inertial law in a reference frame that is accelerating.

When a car accelerates forward rapidly, a person inside the car feel pushed back into their seats. When the car turns around a curve, the person feels pulled to the outside of the curve. If the car suddenly comes to a stop, the persons inside the car not wearing seatbelts fly forward, possibly hitting the windshield. The car’s occupants may feel like some force is pushing them around, but in reality there are no forces shoving them in the directions they move inside the car. They feel shoved around the car because the car is accelerating. The occupants, however, follow Newton’s first law, the inertial law, and continue their original motion, as the car accelerates.

Newton’s First Law

Also called the inertial law, Newton’s first law requires that any object with no outside forces acting on it continues to move at a constant velocity. A constant velocity is a constant speed in a straight line because in physics the velocity includes direction. Any change in an object’s velocity (increasing speed, decreasing speed, or changing direction) is called an acceleration and requires an external force to act on the object. This tendency for objects to continue to move at a constant velocity is called inertia.

Inertial Forces

Despite the name, inertial forces are not real forces. Rather they are effects caused by an object’s inertia when the object is in or on something that is accelerating, what physicists call an accelerating reference frame.

For example, consider the occupants of a car rapidly increasing its speed. They feel pushed back into their seats, but not because some force is shoving them in the chest. The only real force acting on them is the back of the car seat accelerating them forward. Because of Newton’s first law, however, these occupants have inertia that tends to keep them at rest. They feel squeezed back into the car seat because the car is accelerating forward while their inertia would tend to keep them at rest.

When the car goes around a curve, it is also accelerating because the direction of the car’s velocity is changing. The occupants’ inertia tends to keep them moving in a straight line. Hence they feel pulled sideways in the car because they experience an inertial force (or effect) caused by the car’s acceleration as it changes direction.

Flying forward into the windshield when a car stops suddenly (Always wear seatbelts!) is a similar inertial effect. The car accelerates to a stop, and the occupants continue moving forward until their seatbelts (or the windshield) exerts a stopping force on the occupants. There is no real force pushing them forward, they just continue their forward motion, as required by Newton's first law, while the car accelerates (slowing) to a stop.

Circular Motion

To move in a circular path, an object must have a centripetal force acting on it. The centripetal force points inward towards the center of the circle. The outward centrifugal effect is the tendency of the object to continue in a straight line motion. Hence, the centrifugal effect is an example of an inertial force and is not a real force acting on an object moving in a circular path.

Inertial forces feel like forces, but they are not real forces. They are effects caused by an object's inertia when it is in or on something that is accelerating.

D'Alembert's principle of inertial forces

D'Alembert showed that one can transform an accelerating rigid body into an equivalent static system by adding the so-called "inertial force" and "inertial torque" or moment. The inertial force must act through the center of mass and the inertial torque can act anywhere. The system can then be analyzed exactly as a static system subjected to this "inertial force and moment" and the external forces. The advantage is that, in the equivalent static system' one can take moments about any point (not just the center of mass). This often leads to simpler calculations because any force (in turn) can be eliminated from the moment equations by choosing the appropriate point about which to apply the moment equation (sum of moments = zero). Even in the course of Fundamentals of Dynamics and Kinematics of machines, this principle helps in analyzing the forces that act on a link of a mechanism when it is in motion. In textbooks of engineering dynamics this is sometimes referred to as d'Alembert's principle.

d'Alembert's principle, alternative form of Newton's second law of motion, stated by the 18th-century French polymath Jean le Rond d'Alembert. In effect, the principle reduces a problem in dynamics to a problem in statics. The second law states that the force F acting on a body is equal to the product of the mass m and acceleration a of the body, or $F = ma$; in d'Alembert's form, the force F plus the negative of the mass m times acceleration a of the body is equal to zero: $F - ma = 0$. In other words, the body is in equilibrium under the action of the real force F and the fictitious force $-ma$. The fictitious force is also called an inertial force and a reversed effective force.

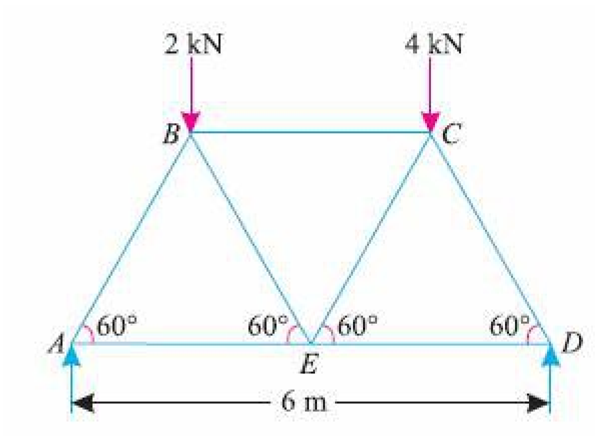
THEORETICAL QUESTIONS ON SIMPLE TRUSSES

SHORT QUESTIONS: TOPIC - TRUSS ANALYSIS

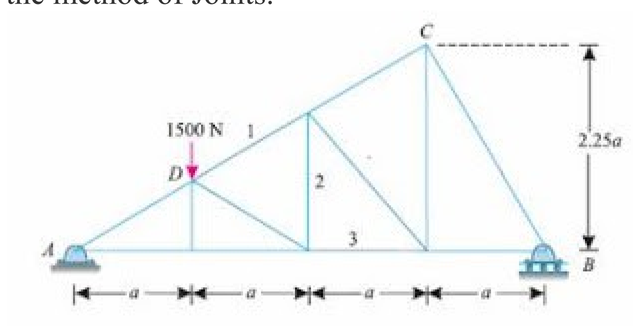
1) What is a truss? Classify them with proper diagrams.
2) State the differences between a perfect truss and an imperfect truss.
3) Distinguish between a deficient truss and a redundant truss.
4) Write the Maxwell's Truss Equation.
5) What are the assumptions made, while finding out the forces in the various members of a truss?

6) What are the differences between a simply supported truss and a cantilever truss? Discuss the method of finding out reactions in both the cases.

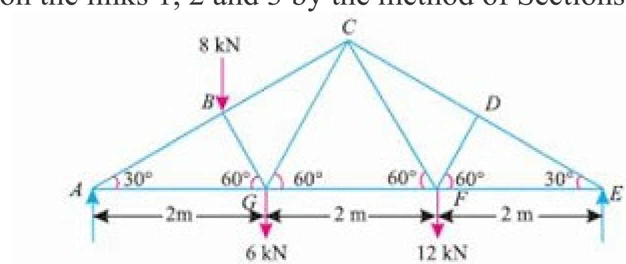
Analyse the following Trusses:



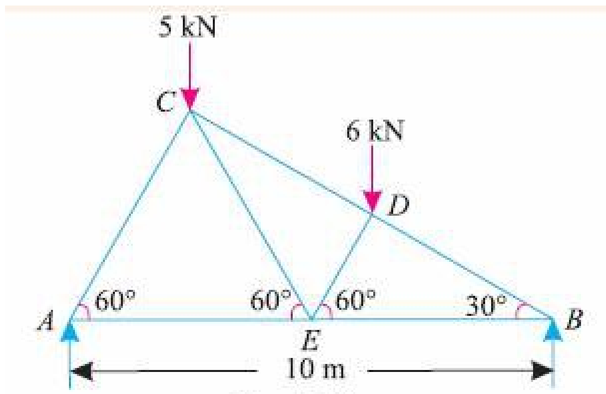
(1) Analyse the Truss by the method of Joints.



(2) Find the internal forces on the links 1, 2 and 3 by the method of Sections.



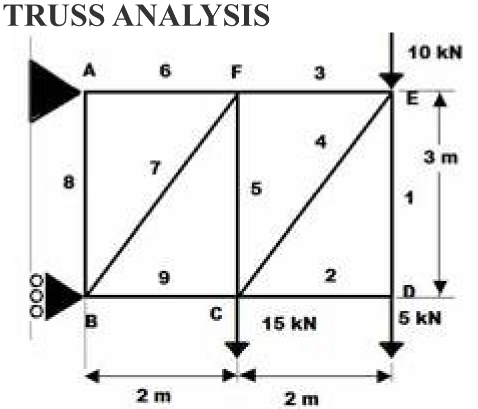
(3) Determine the magnitude and the nature of the forces in the members BC, GC and GF of the given truss.



(4) A truss of span 10 m is loaded as shown in the figure. Find the forces in all the links by any method.

compiled by [Subhankar Karmakar]

SOLUTION OF EME-102; TRUSS ANALYSIS



SOLVE THE TRUSS GIVEN BELLOW WITH THE HELP OF METHODS OF JOINT

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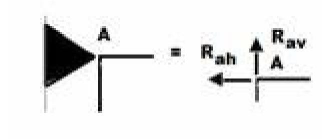
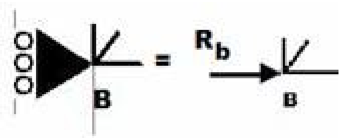
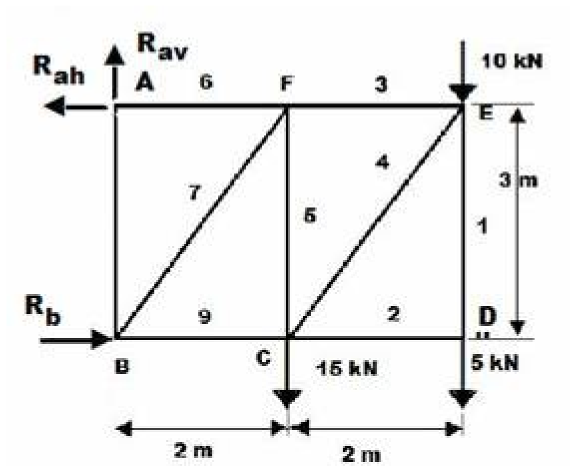
a) REPLACE JOINTS WITH REACTIONS at A and at B







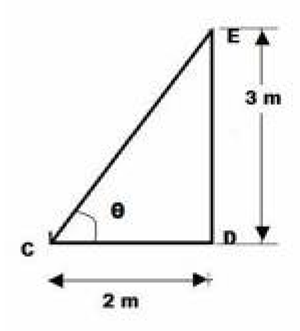
b) Draw FBD of the TRUSS

Applying the conditions of Equilibrium of Coplanar Non-concurrent Force System,

$\sum F_X = 0$; $R_b - R_{ah} = 0$ ------ (i)
(-) ← ● → (+)
$\sum F_Y = 0$; $R_{av} - 10 - 5 - 15 = 0 \Rightarrow R_{av} = 30$ kN ----- (ii)

$\sum M_A = 0$; $10 \times 4 + 5 \times 4 + 15 \times 2 - R_b \times 3 = 0$ ----- (iii)
$R_b = 30$ kN
Hence **$R_{ah} = R_b = 30$ kN**

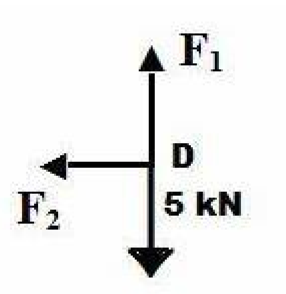
Calculation of Angle θ



The angle $\theta = \tan^{-1}(3/2) = 56.3°$

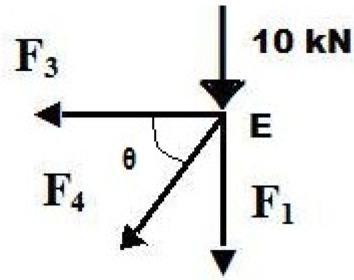
All the unknown forces will be taken as Tensile, if their magnitudes is found negative, then they will be treated as compressive forces.

First we shall choose a joint having only two unknown forces, either we shall choose joint D or joint A
Let us choose joint D first.



We shall consider point D first, as it has only two unknown force. FBD of the point D is drawn.

$\sum \mathbf{F_X = 0;}$ $\quad \mathbf{F_2 = 0}$
$\sum \mathbf{F_Y = 0;}$ $\quad F_1 - 5 = 0$
$\mathbf{F_1 = 5\ kN}$

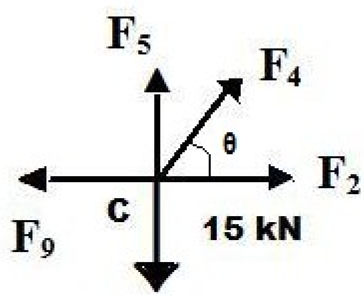


Our next joint will be point E. FBD of the joint E is drawn. As $F_1 = 5$ kN, hence unknown forces are two. F_3 and F_4

$\sum$ **$F_X = 0$;** $\quad -F_3 - F_4 \cos 56.3° = 0$
$\sum$ **$F_Y = 0$;** $\quad -F_1 - 10 - F_4 \sin 56.3° = 0$ [as $F_1 = 5$ kN]

$F_4 = -15/\sin 56.3° = -18.02$ kN

$F_3 = -F_4 \cos 56.3° = 10$ kN



Our next joint is C

F_5 and F_9 are unknown where as $F_4 = -18.02$ kN

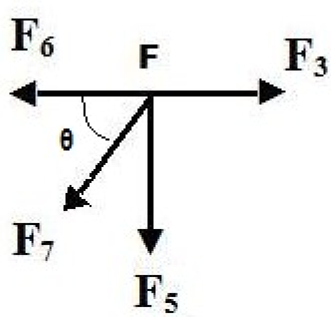
$F_2 = 0$

$\sum$ **$F_X = 0$;** $\quad -F_9 + F_4 \cos 56.3° = 0$

$F_9 = F_4 \cos 56.3° = 10$ kN

$\sum$ **$F_Y = 0$;** $\quad F_5 + F_4 \sin 56.3° - 15 = 0$

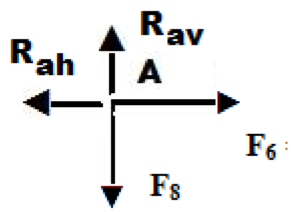
$F_5 = -F_4 \sin 56.3° + 15 = 30$ kN



$F_3 = 10$ kN; $\quad F_5 = 30$ kN

$\sum F_X = 0; \quad F_3 = F_6 + F_7 \cos 56.3°$
$\sum F_Y = 0; \quad - F_5 - F_7 \sin 56.3° = 0$
$F_7 = - F_5 / \sin 56.3° = - 36.05$ kN

$F_6 = F_3 - F_7 \cos 56.3° = 10 + 20 = 30$ kN



$R_{av} = 30$ kN; $R_{ah} = 30$ kN

$\sum F_X = 0; \quad F_6 = R_{ah} = 30$ kN
$\sum F_Y = 0; \quad F_8 = R_{av} = 30$ kN

Sl no	Link	Force	Magnitude	Nature
01	ED	F_1	5 kN	T
02	CD	F2	0	
03	FE	F3	10 kN	T
04	CE	F_4	18.02 kN	C
05	FC	F_5	30 kN	T
06	AF	F_6	30 kN	T
07	BF	F_7	36.05 kN	C
08	AB	F_8	30 kN	T
09	BC	F_9	10 kN	T

Posted by Subhankar Karmakar at 3:56 AM

GROUP-A

Q.1 Answer the following questions as per the

instructions 2x20=20

Choose the correct answer of the following questions:

(i) A truss hinged at one end, supported on rollers at the other, is subjected to horizontals load only. Its reaction at the hinged end will be

(a) Horizontal; (b) Vertical
(c) Both horizontal & vertical
(d) None of the above.

Ans: (c) both horizontal & vertical

(ii) The moment of inertia of a circular section of diameter D about its centroidal axis is given by the expression

(a) π(D)4/16 (b) π(D)4/32
(c) π(D)4/64 (d) π(D)4/4

Ans: (c) π(D)4/64

Fill in the blanks in the following questions:

(iii)The distance of the centroid of an equilateral triangle with each side(a) is ………… from any of the three sides.

Ans a /(2√3)

(iv)Poisson's ratio is defined as the ratio between ……. and ………… .

Ans: Lateral Strain, Longitudinal Strain

(v)If two forces of equal magnitudes P having an angle 2Ө between them, then their resultant force will be equal to ________ .

Ans: 2P CosӨ

Choose correct answer for the following parts:

(vii) Statement 1:

In stress strain graph of a ductile material, yield point starts at the end of the elastic limit.

Statement 2:

At yielding point, the deformation becomes plastic by nature.

(a) Statement 1 is true, Statement 2 is true.
(b) Statement 1 is true, Statement 2 is true and they are unrelated with each other
(c) Statement 1 is true, statement 2 is false.
(d) Statement 1 is false, Statement 2 is false.

Ans: (a) Statement 1 is true, Statement 2 is true.

(viii) Statement 1:

It is easier to pull a body on a rough surface than to push the body on the same surface.

Statement 2:

Frictional force always depends upon the magnitude of the normal force.

(a) Statement 1 is true, Statement 2 is true.
(b) Statement 1 is true, Statement 2 is true and they are unrelated
(c) Statement 1 is true, statement 2 is false.
(d) Statement 1 is false, Statement 2 is false.

Ans: (a) Statement 1 is true, Statement 2 is true.

(ix) In a cantilever bending moment is maximum at

(a) free end (b) fixed end
(c) at the mid span (d) none of these

Choose the correct word/s.

(vi) Two equal and opposite force acting at different points of a rigid body is termed as (Bending Moment/ Torque/ Couple).

Ans: Couple

Ans: (b) fixed end

(x) The relationship between linear velocity and angular velocity of a cycle

(a) exists under all conditions
(b) does not exist under all conditions
(c) exists only when it moves on horizontal plane.
(d) none of these

Ans: (a) exists under all conditions

ENGINEERING. MECHANICS:
Most Common Theoretical Questions
EME - 102; EME - 201

FORCE AND FORCE SYSTEM

Topic: FORCE SYSTEM

1) What is a FORCE SYSTEM? Classify them with examples and diagrams.

Ans: A force system may be defined as a system where more than one force act on the body. It means that whenever multiple forces act on a body, we term the forces as a force system. We can further classify force system into different sub-categories depending upon the nature of forces and the point of application of the forces.

Different types of force system:

(i) COPLANAR FORCES:

If two or more forces rest on a plane, then they are called coplanar forces. There are many ways in which forces can be manipulated. It is often easier to work with a large, complicated system of forces by reducing it an ever decreasing number of smaller problems. This is called the "resolution" of forces or force systems. This is one way to simplify what may otherwise seem to be an impossible system of forces acting on a body. Certain systems of forces are easier to resolve than others. Coplanar force systems have all the forces acting in in one plane. They may be concurrent, parallel, non-concurrent or non-parallel. All of these systems can be resolved by using graphic statics or algebra.

(ii) CONCURRENT FORCES:

A concurrent coplanar force system is a system of two or more forces whose lines of action ALL intersect at a common point. However, all of the individual vectors might not actually be in contact with the common point. These are the most simple force systems to resolve with any one of many graphical or algebraic options. If the line of actions of two or more forces passes through a certain point simultaneously then they are called concurrent forces. concurrent forces may or may not be coplanar.

(iii) LIKE FORCES:

A parallel coplanar force system consists of two or more forces whose lines of action are ALL parallel. This is commonly the situation when simple beams are analyzed under gravity loads. These can be solved graphically, but are combined most easily using algebraic methods. If the lines of action of two or more forces are parallel to each other, they are called parallel forces and if their directions are same, then they are called LIKE FORCES.

(**iv) UNLIKE FORCES**: If the parallel forces are such that their directions are opposite to each other, then they are termed as "UNLIKE FORCE".

(v) NON COPLANAR FORCES:
The last illustration is of a "non-concurrent and non-parallel system". This consists of a number of vectors that do not meet at a single point and none of them are parallel. These systems are essentially a jumble of forces and take considerable care to resolve.

N.B. Almost any system of known forces can be resolved into a single force called a resultant force or simply a Resultant. The resultant is a representative force which has the same effect on the body as the group of forces it replaces. (A couple is an exception to this) It, as one single force, can represent any number of forces and is very useful when resolving multiple groups of forces. One can progressively resolve pairs or small groups of forces into resultants. Then *another resultant of the resultants can be found and so on until all of the forces have been combined into one force. This is one way to save time with the tedious "bookkeeping" involved with a large number of individual forces. Resultants can be determined both graphically and algebraically.The Parallelogram Method and the Triangle Method. It is important to note that for any given system of forces, there is only one resultant.*

It is often convenient to decompose a single force into two distinct forces. These forces, when acting together, have the same external effect on a body as the original force. They are known as components. Finding the components of a force can be viewed as the converse of finding a resultant. There are an infinite number of components to any single force. And, the correct choice of the pair to represent a force depends upon the most convenient geometry. For simplicity, the most convenient is often the coordinate axis of a structure.

A force can be represented as a pair of components that correspond with the X and Y axis. These are known as the rectangular components of a force. Rectangular components can be thought of as the two sides of a right angle which are at ninety degrees to each other. The resultant of these components ...

is the hypotenuse of the triangle. The rectangular components for any force can be found with trigonometrical relationships: $F_x = F\cos\theta$, $Fy = F\sin\theta$. *There are a few geometric relationships that seem to common in general building practice in North America. These relationships relate to roof pitches, stair pitches, and common slopes or relationships between truss members. Some of these are triangles with sides of ratios of 3-4-5, 1-2-sqrt3, 1-1-sqrt2, 5-12-13 or 8-15-17. Committing the first three to memory will simplify the determination of vector magnitudes when resolving more difficult problems.*

When forces are being represented as vectors, it is important to should show a clear distinction between a resultant and its components. The resultant could be shown with color or as a dashed line and the components as solid lines, or vice versa. NEVER represent the resultant in the same graphic way as its components.

Any concurrent set of forces, not in equilibrium, can be put into a state of equilibrium by a single force. This force is called the Equilibrant. It is equal in magnitude, opposite in sense and co-linear with the resultant. When this force is added to the force system, the sum of all of the forces is equal to zero. A non-concurrent or a parallel force system can actually be in equilibrium with respect to all of the forces, but not be in equilibrium with respect to moments.

---

2) What is STATIC EQUILIBRIUM?

What are the conditions of static equilibrium for
(i) concurrent force system
(ii) coplanar non concurrent force system.

Ans: A body is said to be in equilibrium when there is no change in position as well as no rotation exist on the body. So to be in equilibrium process, there must not be any kind of motions ie there must not be any kind of translational motion as well as rotational motion.

We also know that to have a linear translational motion we need a net force acting on the object towards the direction of motion, again to induce an any kind of rotational motion, a net moment must exists acting on the body. Further it can be said that any kind of complex motion can be resolved into a translational motion coupled with a rotating motion.

Therefore a body subjected to a force system would be at rest if and only if the net force as well as the net moment on the body be zero. Therefore the general condition of any system to be in **static equilibrium** we have to satisfy two conditions

(i) Net force on the body must be zero ie, $\Sigma F_i = 0$;
(ii) Net moment on the body must be zero ie, $\Sigma M_i = 0$.

Now we can apply these general conditions to different types of Force System.

For concurrent force system total moment about the concurrent point is always zero as all the forces pass through the point, and we know the moment of a force passing through the point about which we shall take moment is always zero. Hence, the conditions of equilibrium for concurrent forces will be
Net force on the body must be zero ie, $\Sigma F_i = 0$; and we can resolve it along X axis and along Y axis, ie. (i) **$\Sigma F_x = 0$; and** (ii) **$\Sigma F_y = 0$.**

for coplanar non concurrent force system, the equilibrium conditions are
(i) **$\Sigma F_x = 0$; and** (ii) **$\Sigma F_y = 0$.** (iii) **$\Sigma M_i = 0$.**

Moment on a plane:

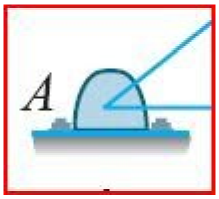
For a force system the total resultant moment about any arbitrary point due to the individual forces are equal to the moment produced by the resultant about the same point. Now if the system is at equilibrium condition, then the resultant force would be zero. Hence, the moment produced by the resultant about any arbitrary point is zero. In case of coplanar & concurrent force system, as the forces are concurrent ie. each of the force passes through a common point. Hence, about that common point total moment of all the forces will be zero.

3) What are different types of joint? discuss them in details.

Answer: The Concepts of Joints. In Engineering terminology any force carrying linear member is called as links. Links can be attached to each other by the fasteners or joints. Hence, we can say to prevent the relative motion between two links completely or partially we use fasteners or joints.

Basically there are three types of joints which we shall discuss and they are named as,
(i) pin/ hinged joints,
(ii) roller joints and
(iii) fixed joints.

PIN JOINTS:



They are classified according to the degrees of freedom of the links they would allow. Like a pin or hinge joint is consisted of two links joined by the insertion of a pin at the pivot hole. A pin joint doesn't allow a vertical or horizontal relative velocities between the two links.

For better understanding of the mechanism of pin joint we would like to make a simplest type of pin joints. Suppose we would take two links and make holes at one of the ends of each link. Now if we insert a bolt through the holes of both the links, then what we get is an example of pin/hinge joints.

A pin joint although restricts any kind of horizontal or vertical displacement but they can not restrict rotation about an axis passing through the hole, in clockwise or anti clockwise direction. Hence it provides two reactions one vertical and one horizontal to restrict any kind of movement along that direction.

ROLLER JOINTS:

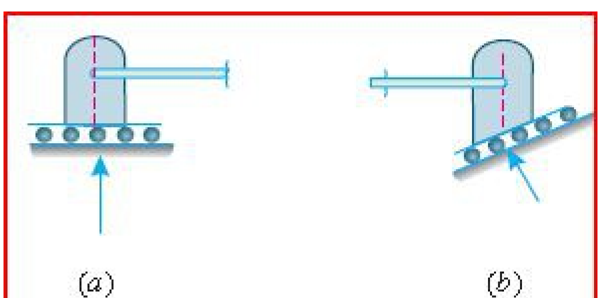


Fig. 12.17. Roller supported end

Posted by Subhankar Karmakar at 12:01 AM

ENGINEERING MECHANICS: GEOMETRICAL ANALYSIS

Assignment No. : 01

1. Solve the following equation for the two roots of x: $x^2 — 16 = 0$

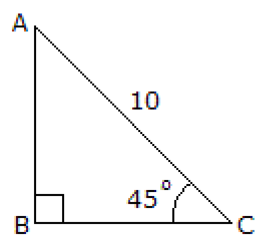
A. $x = 2i, \quad -2i$

B. $x = 4i, \quad -4i$

C. $x = 4, \quad -4$

D. $x = 2, \quad -2$

2.



Using the basic trigonomic functions, determine the length of side AB of the right triangle.

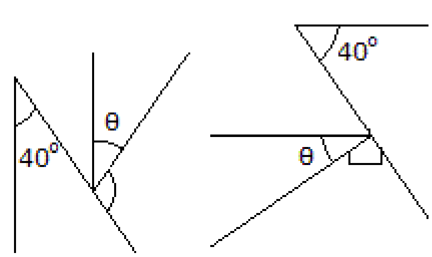
A. $h = 7.07$

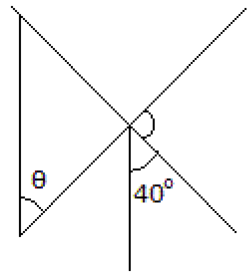
B. $h = 10$

C. $h = 5$

D. $h = 14.14$

3.





Determine the angle θ:

A. $\theta = 30°$

B. $\theta = 40°$

C. $\theta = 60°$

D. $\theta = 50°$

4.

Solve the following equation for x, y, and z:

$x - y + z = -1 \quad -x + y + z = -1 \quad x + 2y - 2z = 5$

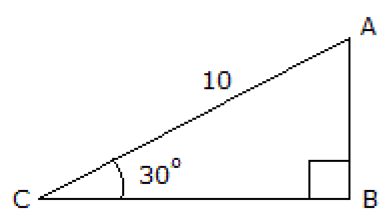
A. $x = 1, \quad y = 1, \quad z = -1$

B. $x = 5/3, \quad y = 7/6, \quad z = -1/2$

C. $x = -2/3, \quad y = -2/3, \quad z = -1$

D. $x = -1, \quad y = 1, \quad z = 1$

5.



Using the basic trigonomic functions, determine the length of side AB of the right triangle.

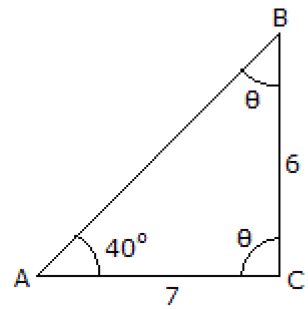
A. $h = 5.77$

B. $h = 11.55$

C. $h = 5$

D. $h = 8.66$

6.



Determine the angles θ and ϕ and the length of side AB of the triangle. Note that there are two possible answers to this question and we have provided only one of them as an answer.

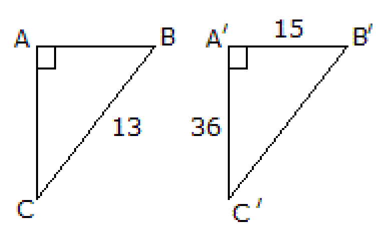
A. $\phi = 46.7°$, $\theta = 93.3°$ d = 9.22

B. $\phi = 50.0°$, $\theta = 90.0°$ d = 9.14

C. $\phi = 40.0°$, $\theta = 100.0°$ d = 9.22

D. $\phi = 48.6°$, $\theta = 91.4°$, d = 9.33

7.



Determine the length of side *AB* if right angle *ABC* is similar to right angle *A'B'C'*:

A. $AB = 5.42$

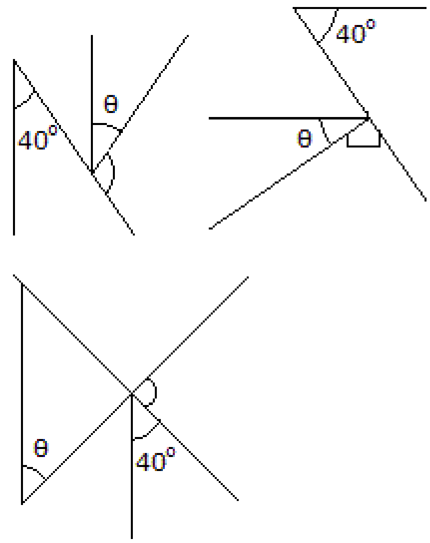
B. $AB = 3$

C. $AB = 5$

D. $AB = 4$

.

8.



Determine the angle θ:

A. $\theta = 30°$

B. $\theta = 40°$

C. $\theta = 60°$

D. $\theta = 50°$

9. Solve the following equation for the two roots of x: $-x^2 + 5x = -6$

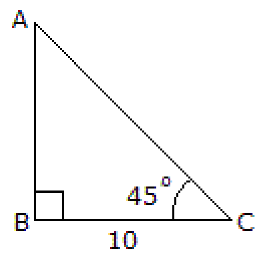
A. $x = 2,\ \ 3$

B. $x = -1,\ \ -5$

C. $x = -1,\ \ 6$

D. $x = -0.742,\ \ 6.74$

10.

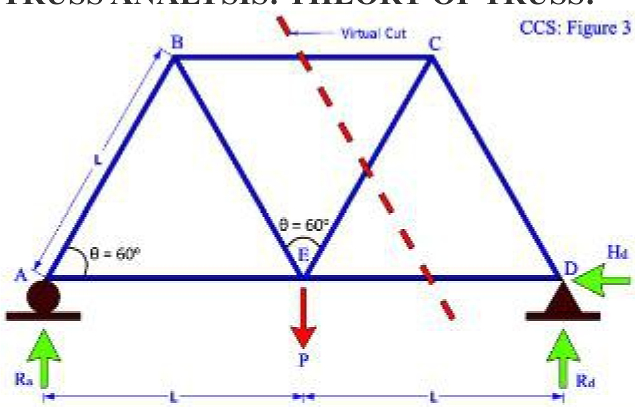


Using the basic trigonomic functions, determine the length of side AB of the right triangle.
A.h = 10
B.h = 7.07
C.h = 14.14
D.h = 5

Posted by [Subhankar Karmakar](#)at [11:16 AM](#)

TRUSS ANALYSIS: THEORY OF TRUSS:

TRUSS ANALYSIS: THEORY OF TRUSS:



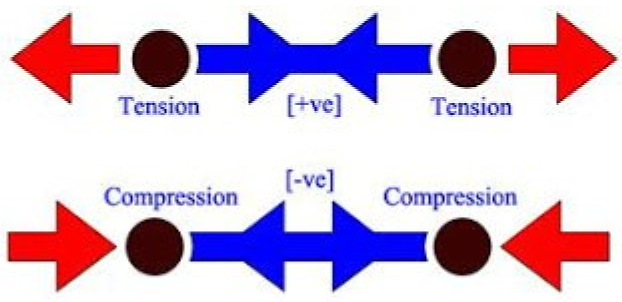
TRUSS :

Truss is a kind of framed structure made of entirely by rigid metallic rods joined by pin. The rods are called as Links or Linkages and the pins are called as joints. Their primary goal is to support the applied loads or we can say they are primarily load bearing structures. We often encounter trusses in our daily life as trusses are used to support roofs of various kinds of industrial sheds. Trusses are used as poles carrying high tension electricity.

LINK/ LINKAGES :

A link is a rigid rod which can bear any external load applied on it. A link can bear two types of forces.

COMPRESSIVE FORCES :



When the external forces applied on the link or rod tries to decrease the length of the rod, then they are called as External Compressive Forces. A truss in equilibrium counters this compressive force by inducing an internal force, equal and opposite the externally applied force. The internal force thus induced balancing the external compressive force is named as Internal Compressive Forces. Generally Compressive Forces are considered as negative in truss analysis.

TENSILE FORCES :

When external loads applied on a link try to increase the length of the link, we call them External Tensile Loads. To neutral the tensile load applied on a link, an equal but opposite internal force is generated named as Internal Tensile forces. Tensile forces are generally considered as positive internal forces.

THE SIMPLEST TRUSS:

A triangular shaped truss made of three linkages and three joints is the simplest type of truss. As it is the simplest geometric shape where there is no change in shape with the application of forces at the joints if the length of rods/ linkages remain unchanged / constant.

MAXWELL'S TRUSS EQUATION:

To distinguish between "statically determinate structure" and "statically indeterminate structure" Maxwell formulated an equation involving the number of linkages (**m**) and number of joints (**j**).

The trusses which satisfies the equation,
$\mathbf{m = 2j - 3}$
are statically determinate structures and named as "**Perfect Trusses**".

If $\mathbf{m > 2j - 3}$, then the number of linkages are more than required, hence, called as "**Redundant Trusses**".

Where as if $\mathbf{m < 2j - 3}$ for any truss, then the number of linkages are less than that of a perfect truss. These kinds of trusses are called as "**Deficient Trusses**".

ASSUMPTIONS CONSIDERED WHILE ANALYZING TRUSSES :

While analyzing trusses, to simplify the analysis we often consider certain assumptions. The purpose of these assumptions are the simplification of a complex problems. The assumptions are

(i) The links are perfectly rigid bodies, ie there occurs no change in the dimensions of the links.

(ii) The pin joints are perfectly smooth, ie there is no friction in the each and every joints.

(iii) The mass and weights of the links are so small compare to the magnitudes of the applied forces, that for truss analysis we shall neglect them. It means the links are massless as well as weightless.

(iv) The cross-sections and material of the links are uniform by nature.

(v) The external loads are only applied on a joint in the truss, whenever we shall place any external load, we must place it one of the joints in the truss.

(vi) Stress in each member is constant along its length.

The objective of analyzing the trusses is to determine the reactions and member forces. The methods used for carrying out the truss analysis with the equations of equilibrium and by considering only parts of the structure through analyzing its free body diagram to solve the unknowns.

Method of Joints

The first to analyze a truss by assuming all members are in tension reaction. A tension member is when a member experiences pull forces at both ends of the bar and usually denoted as positive (+ve) sign. When a member experiencing a push force at both ends, then the bar was said to be in compression mode and designated as negative (-ve) sign.
In the joints method, a virtual cut is made around a joint and the cut portion is isolated as a Free Body Diagram (FBD). Using the equilibrium equations of $\sum F_x = 0$ and $\sum F_y = 0$, the unknown member forces could be solve. It is assumed that all members are joined together in the form of an ideal pin, and that all forces are in tension (+ve) of reactions.
An imaginary section may be completely passed around a joint in the truss. The joint has become a free body in equilibrium under the forces applied to it. The equations $\sum H = 0$ and $\sum V = 0$ may be applied to the joint to determine the unknown forces in members meeting there. It is evident that no more than two unknowns can be determined at a joint with these two equations.

Figure 1: A simple truss model supported by pinned and roller support at its end. Each triangle has the same length, L and it is equilateral where degree of angle, θ is 60° on every angle. The

support reactions, R_a and R_c can be determine by taking a point of moment either at point A or point C, whereas $H_a = 0$ (no other horizontal force).
Here are some simple guidelines for this method of truss analysis:

1. Firstly draw the Free Body Diagram (FBD),
2. Solve the reactions of the given structure,
3. Select a joint with a minimum number of unknown (not more than 2) and analyze it with $\sum F_x = 0$ and $\sum F_y = 0$,
4. Proceed to the rest of the joints and again concentrating on joints that have very minimal of unknowns,
5. Check member forces at unused joints with $\sum F_x = 0$ and $\sum F_y = 0$,
6. Tabulate the member forces whether it is in tension (+ve) or compression (-ve) reaction.

Figure 2: The figure showing 3 selected joints, at B, C, and E. The forces in each member can be determine from any joint or point. The best way to start by selecting the easiest joint like joint C where the reaction R_c is already obtained and with only 2 unknown, forces of F_{CB} and F_{CD}. Both can be evaluate with $\sum F_x = 0$ and $\sum F_y = 0$ rules. At joint E, there are 3 unknown, forces of F_{EA}, F_{EB} and F_{ED}, which may lead to more complex solution compare to 2 unknown values. For checking purposes, joint B is selected to shown that the equation of $\sum F_x$ is equal to $\sum F_y$ which leads to *zero* value, $\sum F_x = \sum F_y = 0$. Each value of the member's condition should be indicate clearly as whether it is in tension (+ve) or in compression (-ve) state.

* (*Trigonometric Functions*:
Taking an angle between member x and z…

- ⑤ $\cos\theta = x / z$
- ⑤ $\sin\theta = y / z$
- ⑤ $\tan\theta = y / x$)

Method of Sections

The section method is an effective method when the forces in all members of a truss are being able to determine. Often we need to know the force in just one member with greatest force in it, and the method of section will yield the force in that particular member without the labor of working out the rest of the forces within the truss analysis.
If only a few member forces of a truss are needed, the quickest way to find these forces is by the method of sections. In this method, an imaginary cutting line called a section is drawn through a stable and determinate truss. Thus, a section subdivides the truss into two separate parts. Since the entire truss is in equilibrium, any part of it must also be in equilibrium. Either of the two parts of the truss can be considered and the three equations of equilibrium $\sum F_x = 0$, $\sum F_y = 0$, and $\sum M = 0$ can be applied to solve for member forces.

Figure 3: Using the same model of simple truss, the details would be the same as previous figure

with 2 different supports profile. Unlike the joint method, here we only interested in finding the value of forces for member BC, EC, and ED.
Few simple guidelines of section truss analysis:

1. Pass a section through a maximum of 3 members of the truss, 1 of which is the desired member where it is dividing the truss into 2 completely separate parts,
2. At 1 part of the truss, take moments about the point (at a joint) where the 2 members intersect and solve for the member force, using $\sum M = 0$,
3. Solve the other 2 unknowns by using the equilibrium equation for forces, using $\sum F_x = 0$ and $\sum F_y = 0$.

Note: The 3 forces cannot be concurrent, or else it cannot be solve.

Figure 4: A virtual cut is introduce through the only required members which is along member BC, EC, and ED. Firstly, the support reactions of R_a and R_d should be determine. Again a good judgment is require to solve this problem where the easiest part would be consider either on the left hand side or the right hand side. Taking moment at joint E (virtual pint) on clockwise for the whole RHS part would be much easier compare to joint C (the LHS part). Then, either joint D or C can be consider as point of moment, or else using the joint method to find the member forces for F_{CB}, F_{CE}, and F_{DE}. Note: Each value of the member's condition should be indicate clearly as whether it is in tension (+ve) or in compression (-ve) state.
Posted by Subhankar Karmakar at 1:25 AM

SECOND SESSIONAL TEST (odd SEMESTER 2009-10) B.Tech…first Semester Sub Name: Engineering Mechanics

SECOND SESSIONAL TEST (odd SEMESTER 2009-10)
B.Tech…first Semester

Sub Name: Engineering Mechanics — Max. Marks: 30
Sub Code: EME-201 — Max. Time: 2: 00 Hr

Group A

Q.1 Choose the correct answer of the following questions 1x6=6

(i) If two forces of equal magnitudes have a resultant force of the same magnitude then the angle between them is
(a) 0^0 (b) 90^0 (c) 120^0 (d) 135^0
Ans: (c)

Explanation: $P^2 = P^2 + P^2 + 2P.P.\cos\theta$
XFER $P^2 = P^2(1+2\cos\theta)$
XFER $\cos\theta = -\frac{1}{2}$
XFER $\theta = 120°$

(ii) If a ladder is kept at rest on a vertical wall making an angle θ with horizontal. If co-efficient of the friction in all the surfaces be μ, then the tangent of the angle θ will be equal to

(a) $(1-\mu^2)/2\mu$ (b) $(1-\mu)^2/2\mu$

(c) $(1-\mu)/2\mu$ (d) none of the above

Explanation: (a) $(1-\mu^2)/2\mu$

(iv) Varignon's theorem is related with _____________ .

Answer: moment

(v) If two forces of equal magnitudes P having an angle (90°- θ) between them, then their resultant force will be equal to ________.

Answer: $\sqrt{2}P\,(1+\sin\theta)$

(vi) A fixed joint produces

(a) 1 (b) 2 (c) 3 (d) 4 reactions

Answer: (c) 3

(vii) The equilibrium conditions of concurrent force system is_________.

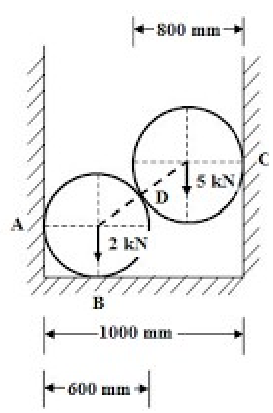
Answer: $\sum F_x = 0$; $\sum F_y = 0$.

Group B 8x3=24

Attempt any three questions

Q.2. State and explain Varignon's theorem of moment. Three forces of magnitudes 3 KN, 4 KN and 2KN act along the three side of an equilateral triangle ΔABC in order. Find the position, direction and magnitude of the resultant force. 4+4

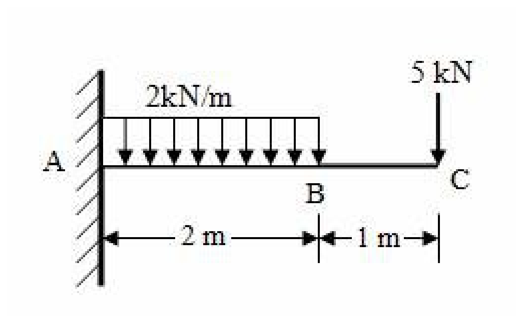
Answer: resultant force: √3 KN



Q.3 (a) Two cylindrical rollers are kept at equilibrium inside a jar or channel as shown in the figure. The channel width is 1000 mm, where as the rollers have diameters 600 mm and 800 mm respectively. The weights are 2 kN and 5 kN respectively. Find all the reactions at contacts.

4+4

(b) What is pure bending? If a stone is thrown with a velocity 400 m/s then find the maximum height that the stone can reach.



Q:4) a) Classify different types of joints in beam with proper explanations.

(b) Find the reactions at the support for the beam as shown in the figure. 4+4

uesday, August 7, 2012

BEAMS, JOINTS AND SUPPORTS

BEAMS & CLASSIFICATION OF BEAMS

BEAM: A beam is a structure generally a horizontal structure on rigid supports and it carries mainly vertical loads. Therefore, beams are a kind of load bearing structures. The horizontal beam is fastened to supports by different types of joints.

Depending upon the types of supports beams can be classified into different categories.

STATICALLY DETERMINATE STRUCTURES:

(i) CANTI-LEVER BEAMS:

A beam can be at stable equilibrium with a single fixed support at one end and the other end remains free, which is called as the free end while the other end is known as fixed end. This kind of beam is known as Canti lever beam. The fixed joint at the fixed end produces a horizontal, a vertical reactions and a reaction moment at the fixed end. It is the most common type of beam we use to see around. As a canti lever beam is supported at one side only, hence, the support must bear moment as well as vertical load. Hence, only fixed joint has to be applied to a cantilever beam.

(ii) SIMPLE SUPPORTED BEAM:

A beam supported as just resting freely on the walls or columns at its both ends is known as simply supported beam. This is the simplest type of beam. The supports at both sides produce two vertical upward reactions. It can not withstand lateral/ horizontal loading on the beam.

There will be two vertically upward reactions at the ends of a simply supported beam. A simply supported beam can not resist any horizontal load component.

(iii) OVER HANGING BEAM:

A beam having its end portion or both the end portions extended in the form of a canti-lever beyond the support or supports is called as over hanging beam. In a over-hanging beam, the beam may extend beyond support in either side or both sides. In a overhanging point of contraflexure has been formed.

OVER-HANGING BEAM

Above those beams are statically determinate. It means that those beams can be analysed applying the conditions of equilibrium. We can determine the values of the unknown reactions.

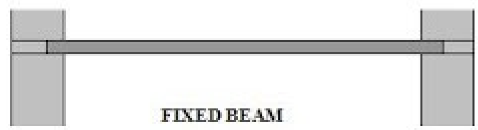
STATICALLY INDETERMINATE STRUCTURES:

There are beams which can not be analysed applying the conditions of equilibrium of coplanar forces. These beams are also known as Statically indeterminate structures.

Those types of beams can be classified as Fixed beams and Continuous beams.

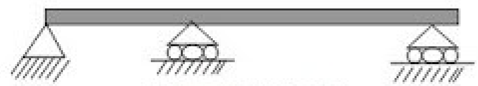
(i) FIXED BEAM:

A beam having two fixed joints at the both ends is called fixed beam. Therefore, it has six unknown reactions and moments. So, this type of beam is statically undeterminate. There will be always two fixed end moments in this type of beam.



(ii) CONTINUOUS BEAM:

The beam which is at rest on more than two supports is called as continuous beam. A beam may have many supports like a beam supporting a over duct system. Here support reaction can not be determined using the equations of equilibrium. Hence, this type of beam is also statically indeterminate. They can be determined by the beam deflection method.



CONTINUOUS BEAM

SUPPORTS AND ITS IMPORTANCE:

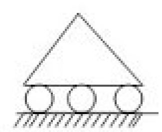
A beam carries load but it transfers the loads via columns or other type of supports. A beam is fastened up with the support by different type of joints. The strength and other properties of a support vastly depend upon the nature of these joints. The supports are classified on the basis of the joint it employs to transfer load from beam to support.

TYPES OF JOINTS:

There are mainly three types of joints. They are roller joint, pin or hinged joint and fixed joint.

(i) ROLLER JOINT:

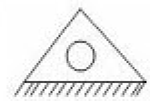
A roller joint is just like a skate board. This joint restricts any vertical movement to the plane upon which the joint rests. If the joint is placed on a horizontal surface, then the reaction given by the joint will be perpendicular to horizontal, hence, it will be vertical. A roller joint only restricts any vertically downward movement. It means the support with roller joint which is known as roller support produces a vertically upward reaction only. As there is no other restrictions like horizontal movement or vertically upward movement, the roller joint produces only one reaction normal to the surface of the joint.



ROLLER JOINT

(ii) HINGED OR PIN JOINT:

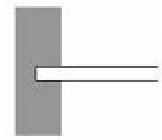
A hinged support restricts any kind of horizontal and vertical directions, but it can not restrict rotation about the pin joint. It indicates that a pin or hinged joint can produce two reactions one in vertical directions and the other is horizontal. Doors and windows are connected to the wall by hinged joint only.



PIN JOINT

(iii) FIXED JOINT:

A fixed joint restricts any type of horizontal and vertical movement as well as any rotation about the center of the joint. Therefore, it must produce two reaction forces, one of them vertical and other one is horizontal. In addition it produces a reaction moment about the center of the joint. That's why a cantilever always needs a fixed joint for its support.



FIXED JOINT

TYPES OF SUPPORTS:

There are four types of supports,

(i) Simple Supports,
(ii) Roller Supports,
(iii) Hinged Supports
(iv) Fixed Supports.

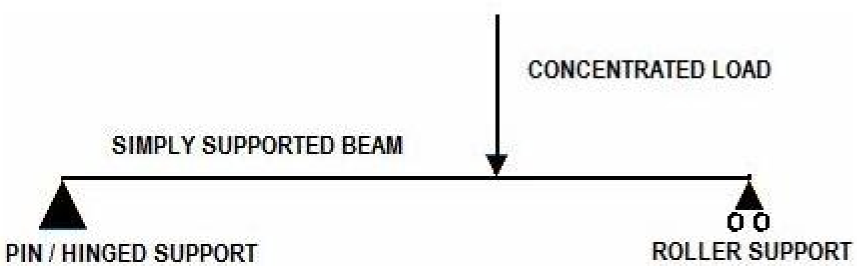
Posted by Subhankar Karmakar at 10:53 AM

LOADING IN A BEAM:

There are four types of loading in a beam

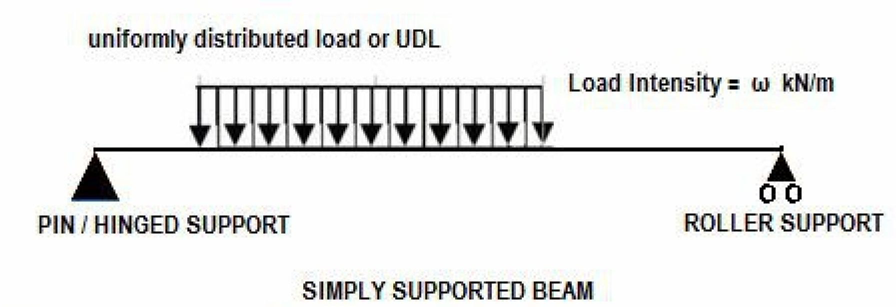
(i) Concentrated load or point load
(ii) Uniformly Distributed Load (UDL)
(iii) Uniformly Varying Load (UVL)
(iv) Pure Moment

(i) Concentrated Load or Point Load

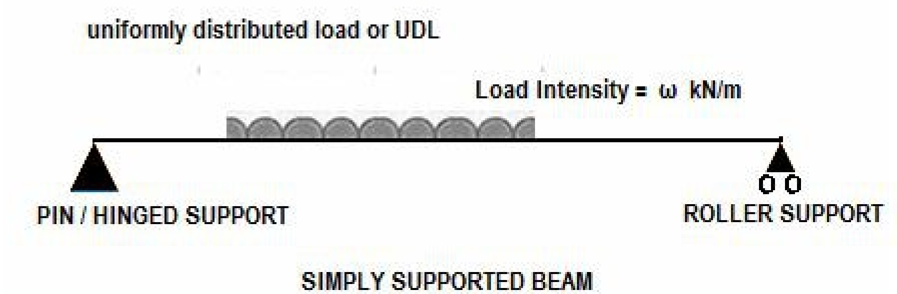


(ii) Uniformly Distributed Load (UDL)

(note made by Subhankar Karmakar)



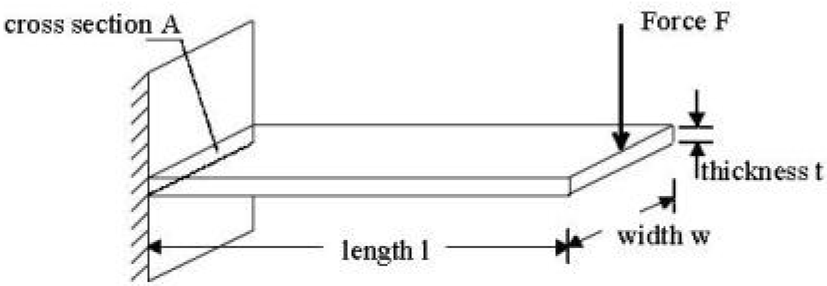
It can be represented also like the figure bellow



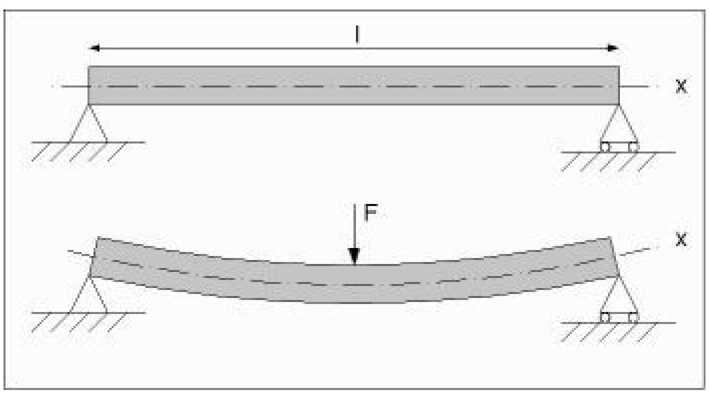
Beam: is a structural member subjected to a system of external forces at right angles to axis.

Types of Beams

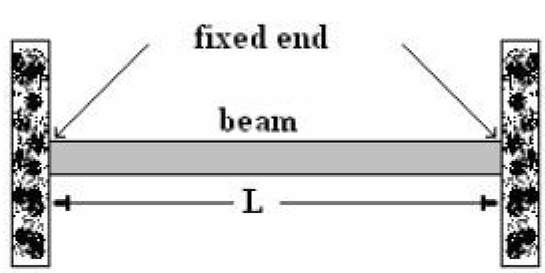
1- Cantilever beam: fixed or built-in at one end while it's other end is free.



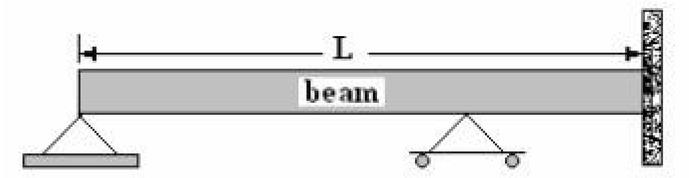
2- Freely or simply supported beam: the ends of a beam are made to freely rest on supports.



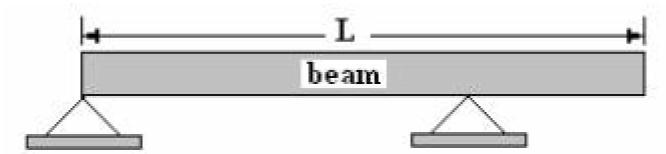
3- Built-in or fixed beam: the beam is fixed at both ends.



4- Continuous beam: a beam which is provided with more than two supports.



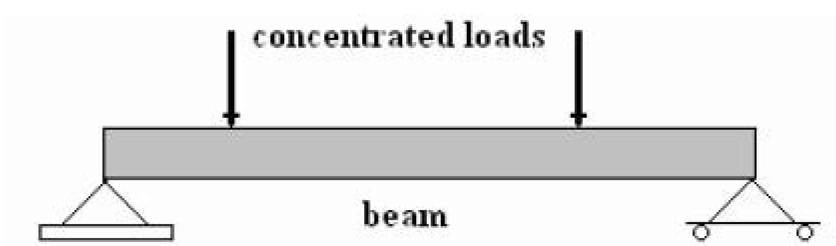
5- Overhanging beam: a beam which has part of the loaded beam extends outside the supports.



Statically Determinate Beams
Cantilever, simply supported, overhanging beams are statically determinate beams as the reactions of these beams at their supports can be determined by the use of equations of static equilibrium and the reactions are independent of the deformation of the beam. There are two unknowns only.

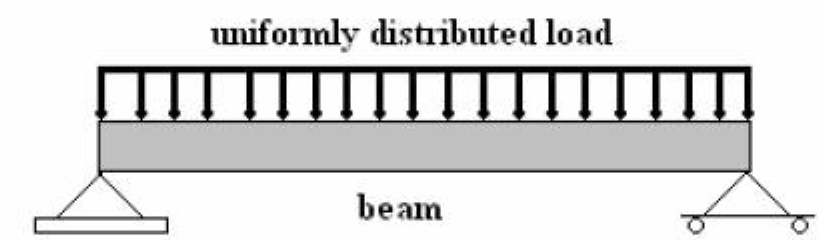
Statically Indeterminate Beams
Fixed and continuous beams are statically indeterminate beams as the reactions at supports cannot be determined by the use of equations of static equilibrium. There are more than two unknown.

Types of Loads
1- Concentrated load assumed to act at a point and immediately introduce an oversimplification since all practical loading system must be applied over a finite area.

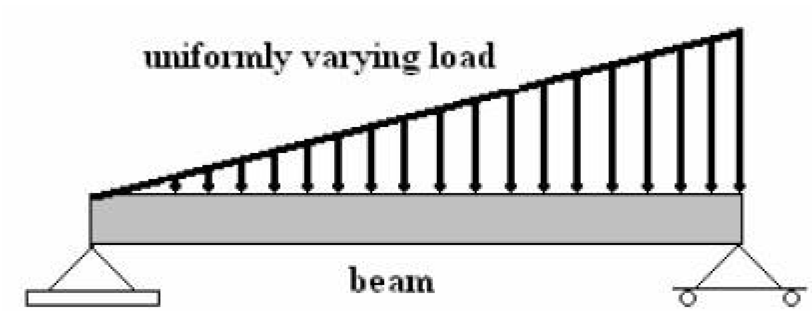


2- Distributed load are assumed to act over part, or all, of the beam and in most cases are assumed to be equally or uniformly distributed.

a- Uniformly distributed load.



a- Uniformly varying load.



Concept of Shear Force and Bending moment in beams:
When the beam is loaded in some arbitrarily manner, the internal forces and moments are developed and the terms shear force and bending moments come into pictures which are helpful to analyze the beams further. Let us define these terms

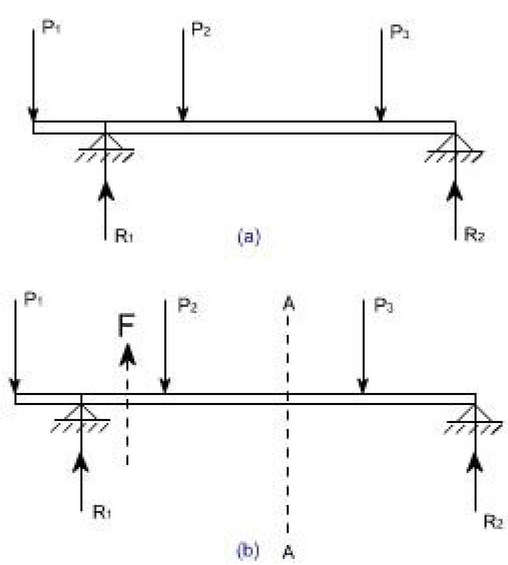


Fig 1

Now let us consider the beam as shown in fig 1(a) which is supporting the loads P1, P2, P3 and is simply supported at two points creating the reactions R1 and R2 respectively. Now let us assume that the beam is to divided into or imagined to be cut into two portions at a section AA. Now let us assume that the resultant of loads and reactions to the left of AA is ?F' vertically upwards, and since the entire beam is to remain in equilibrium, thus the resultant of forces to the right of AA must also be F, acting downwards. This forces ?F' is as a shear force. The shearing force at any x-section of a beam represents the tendency for the portion of the beam to one side of the section to slide or shear laterally relative to the other portion.
Therefore, now we are in a position to define the shear force ?F' to as follows:
At any x-section of a beam, the shear force ?F' is the algebraic sum of all the lateral components of the forces acting on either side of the x-section.

Sign Convention for Shear Force:
The usual sign conventions to be followed for the shear forces have been illustrated in figures 2 and 3.

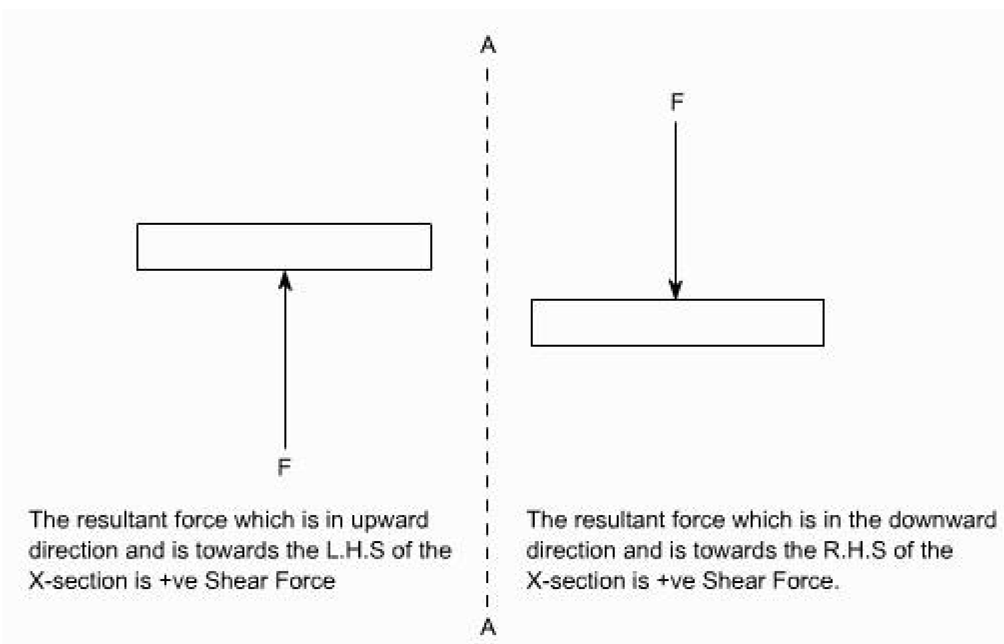


Fig 2: Positive Shear Force

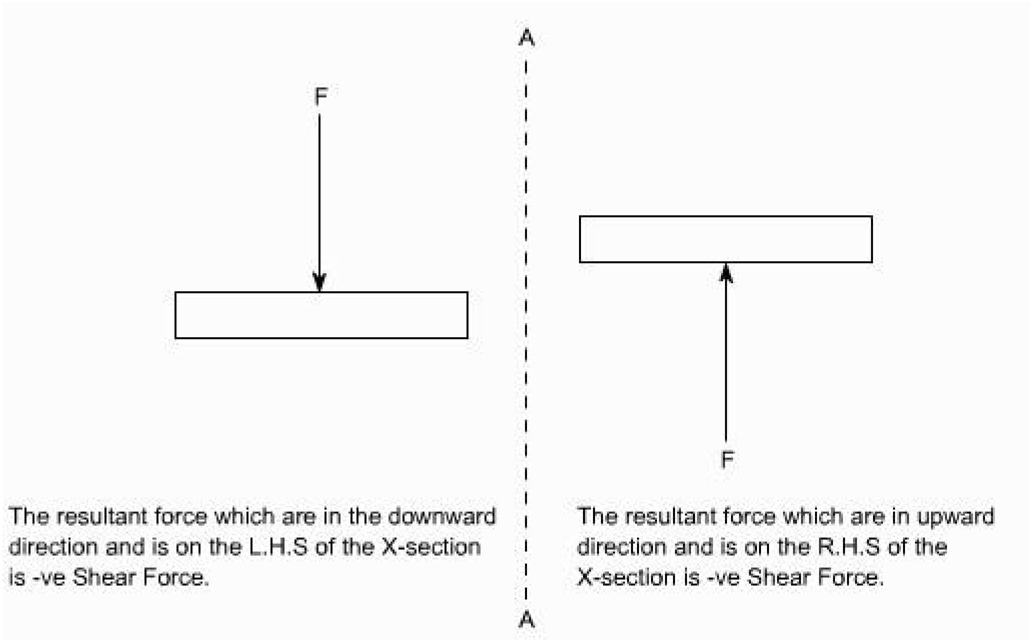


Fig 3: Negative Shear Force

Bending Moment:

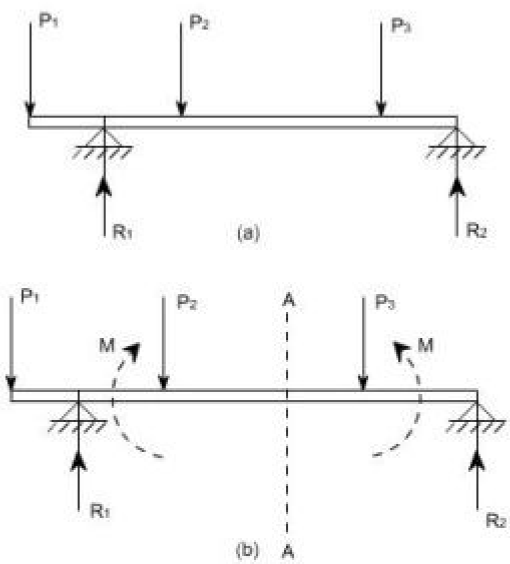


Fig. 4

Let us again consider the beam which is simply supported at the two prints, carrying loads P1, P2 and P3 and having the reactions R1 and R2 at the supports Fig 4. Now, let us imagine that the beam is cut into two potions at the x-section AA. In a similar manner, as done for the case of shear force, if we say that the resultant moment about the section AA of all the loads and reactions to the left of the x-section at AA is M in C.W direction, then moment of forces to the right of x-section AA must be ?M' in C.C.W. Then ?M' is called as the Bending moment and is abbreviated as B.M. Now one can define the bending moment to be simply as the algebraic sum of the moments about an x-section of all the forces acting on either side of the section

Sign Conventions for the Bending Moment:

For the bending moment, following sign conventions may be adopted as indicated in Fig 5 and Fig 6.

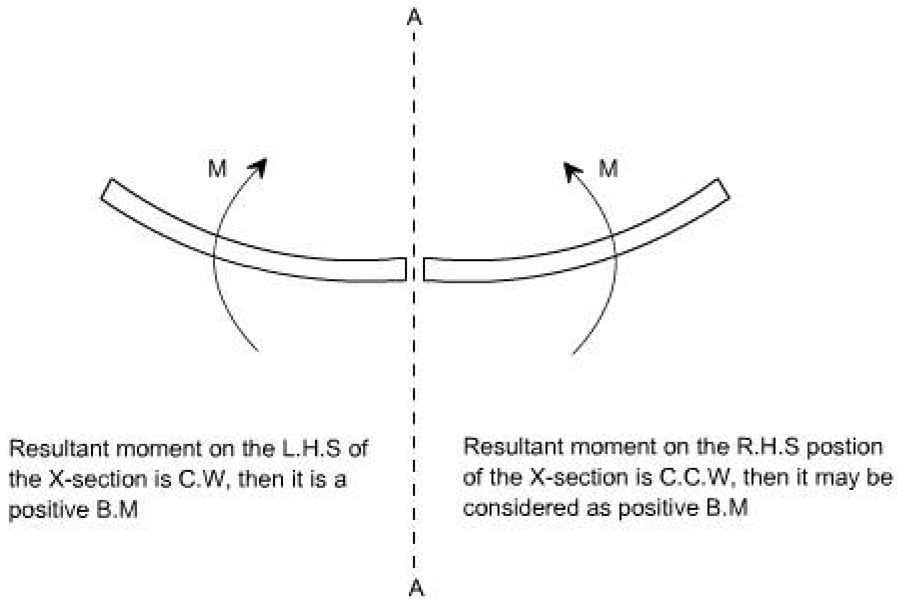


Fig 5: Positive Bending Moment

a- Uniformly varying load.

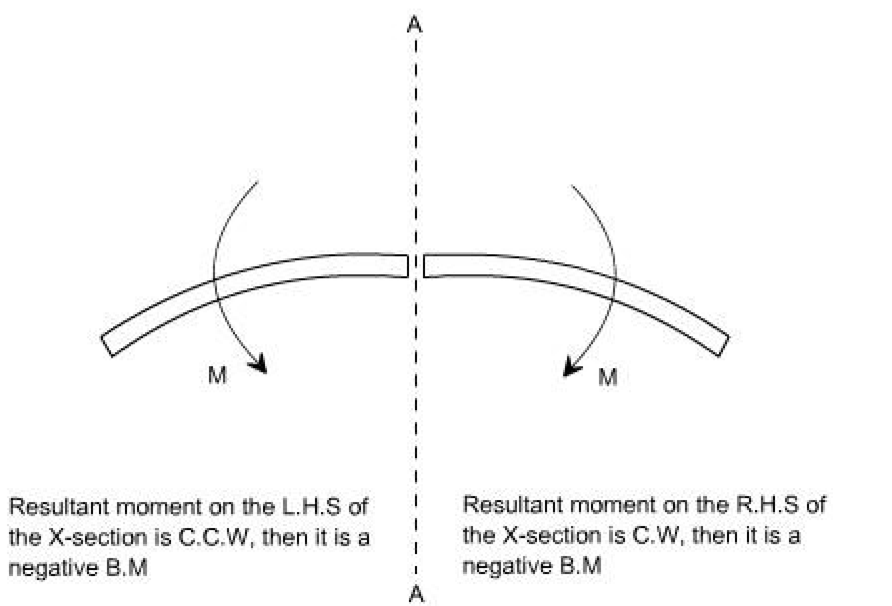


Fig 6: Negative Bending Moment

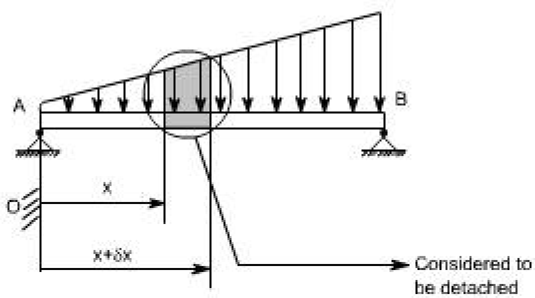
Some times, the terms ?Sagging' and Hogging are generally used for the positive and negative bending moments respectively.

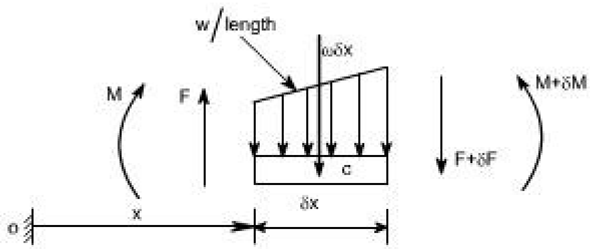
Bending Moment and Shear Force Diagrams:

The diagrams which illustrate the variations in B.M and S.F values along the length of the beam for any fixed loading conditions would be helpful to analyze the beam further.
Thus, a shear force diagram is a graphical plot, which depicts how the internal shear force? F' varies along the length of beam. If x denotes the length of the beam, then F is function x i.e. F(x).
Similarly a bending moment diagram is a graphical plot which depicts how the internal bending moment? M' varies along the length of the beam. Again M is a function x i.e. M(x).

Basic Relationship between the Rate of Loading, Shear Force and Bending Moment:

The construction of the shear force diagram and bending moment diagrams is greatly simplified if the relationship among load, shear force and bending moment is established.
Let us consider a simply supported beam AB carrying a uniformly distributed load w/length. Let us imagine to cut a short slice of length dx cut out from this loaded beam at distance? x' from the origin ?0'.





The forces acting on the free body diagram of the detached portion of this loaded beam are the following
o The shearing force F and F+ dF at the section x and x + dx respectively.
o The bending moment at the sections x and x + dx be M and M + dM respectively.
o Force due to external loading, if ?w' is the mean rate of loading per unit length then the total loading on this slice of length dx is w. dx, which is approximately acting through the centre ?c'. If the loading is assumed to be uniformly distributed then it would pass exactly through the centre ?c'.

This small element must be in equilibrium under the action of these forces and couples.

Now let us take the moments at the point ?c'. Such that

$$M + F.\frac{\delta x}{2} + (F + \delta F).\frac{\delta x}{2} = M + \delta M$$

$$\Rightarrow F.\frac{\delta x}{2} + (F + \delta F).\frac{\delta x}{2} = \delta M$$

$$\Rightarrow F.\frac{\delta x}{2} + F.\frac{\delta x}{2} + \delta F.\frac{\delta x}{2} = \delta M \text{ [Neglecting the product of } \delta F \text{ and } \delta x \text{ being small quantities]}$$

$$\Rightarrow F.\delta x = \delta M$$

$$\Rightarrow F = \frac{\delta M}{\delta x}$$

Under the limits $\delta x \rightarrow 0$

$$\boxed{F = \frac{dM}{dx}} \qquad \ldots\ldots\ldots\ldots \quad (1)$$

Resolving the forces vertically we get

$$w.\delta x + (F + \delta F) = F$$

$$\Rightarrow w = -\frac{\delta F}{\delta x}$$

Under the limits $\delta x \rightarrow 0$

$$\Rightarrow w = -\frac{dF}{dx} \text{ or } -\frac{d}{dx}\left(\frac{dM}{dx}\right)$$

$$\boxed{w = -\frac{dF}{dx} = -\frac{d^2M}{dx^2}} \qquad \ldots\ldots\ldots\ldots (2)$$

Conclusions

From the above relations, the following important conclusions may be drawn

o From Equation (1), the area of the shear force diagram between any two points, from the basic calculus is the bending moment diagram

M = ∫F.dx

o The slope of bending moment diagram is the shear force, thus

F = dM/dx

Thus, if F=0; the slope of the bending moment diagram is zero and the bending moment is therefore constant.

o The maximum or minimum Bending moment occurs where dM/dx=0

The slope of the shear force diagram is equal to the magnitude of the intensity of the distributed loading at any position along the beam. The -ve sign is as a consequence of our particular choice of sign conventions

Q 1. Define stress.

When an external force acts on a body, it undergoes deformation. At the same time the body resists deformation. The magnitude of the resisting force is numerically equal to the applied force. This internal resisting force per unit area is called stress.
Stress = Force/Area

2. Define strain

When a body is subjected to an external force, there is some change of dimension in the body. Numerically the strain is equal to the ratio of change in length to the original length of the body.= P/A unit is N/mm^2

Strain = Change in length/Original length
$e = \delta L/L$

3. State Hooke's law.

It states that when a material is loaded, within its elastic limit, the stress is directly proportional to the strain.

Stress ∝ Strain

$\sigma \propto e$

$\sigma = Ee$
$E = \sigma/e$ unit is N/mm^2

Where,
E - Young's modulus
σ - Stress
e - Strain

4. Define shear stress and shear strain.

The two equal and opposite force act tangentially on any cross sectional plane of the body tending to slide one part of the body over the other part. The stress induced is called shear stress and the corresponding strain is known as shear strain.

5. Define Poisson's ratio.

When a body is stressed, within its elastic limit, the ratio of lateral strain to the longitudinal strain is constant for a given material.

Poisson' ratio (ì or 1/m) = Lateral strain /Longitudinal strain

6. State the relationship between Young's Modulus and Modulus of Rigidity.

E = 2K (1+1/m)

Where,
E - Young's Modulus
K - Bulk Modulus
1/m - Poisson's ratio

7. Define strain energy

Whenever a body is strained, some amount of energy is absorbed in the body. The energy that is absorbed in the body due to straining effect is known as strain energy.

8. What is resilience?

The total strain energy stored in the body is generally known as resilience.

9. State proof resilience

The maximum strain energy that can be stored in a material within elastic limit is known as proof resilience.

10. Define modulus of resilience

It is the proof resilience of the material per unit volume Modulus of resilience = Proof resilience / Volume of the body
11. Give the relationship between Bulk Modulus and Young's Modulus.

E = 3K (1-2/m) Where, E - Young's Modulus K - Bulk Modulus 1/m - Poisson's ratio

12. Define- Rigidity modulus
The shear stress is directly proportional to shear strain. N = Shear stress Shear strain

13. What is compound bar?
A composite bar composed of two or more different materials joined together such that system is elongated or compressed in a single unit.

14. What you mean by thermal stresses?
If the body is allowed to expand or contract freely, with the rise or fall of temperature no stress is developed but if free expansion is prevented the stress developed is called temperature stress or strain.

15. Define- elastic limit
Some external force is acting on the body, the body tends to deformation. If the force is released from the body its regain to the original position. This is called elastic limit

16. Define – Young's modulus
The ratio of stress and strain is constant with in the elastic limit.
E = Stress / Strain

17. Define Bulk-modulus
The ratio of direct stress to volumetric strain.
K = Direct stress / Volumetric strain

18. Define- lateral strain
When a body is subjected to axial load P. The length of the body is increased. The axial deformation of the length of the body is called lateral strain.

19. Define- longitudinal strain
The strain right angle to the direction of the applied load is called lateral strain.

20. What is principle of super position?
The resultant deformation of the body is equal to the algebric sum of the deformation of the individual section. Such principle is called as principle of super position
21. Define point of contra flexure? In which beam it occurs?

Point at which BM changes to zero is point of contra flexure. It occurs in overhanging beam.

22. What is mean by positive or sagging BM?

BM is said to positive if moment on left side of beam is clockwise or right side of the beam is counter clockwise.

23. What is mean by negative or hogging BM?

BM is said to negative if moment on left side of beam is counterclockwise or right side of the beam is clockwise.

24. Define shear force and bending moment?

SF at any cross section is defined as algebraic sum of all the forces acting either side of beam. BM at any cross section is defined as algebraic sum of the moments of all the forces which are placed either side from that point.

25. What is meant by transverse loading of beam?

If load is acting on the beam which is perpendicular to center line of it is called transverse loading of beam.

26. When will bending moment is maximum?

BM will be maximum when shear force change its sign.

27. What is maximum bending moment in a simply supported beam of span 'L' subjected to UDL of 'w' over entire span

Max BM =wL2/8

28. In a simply supported beam how will you locate point of maximum bending moment?

The bending moment is max. when SF is zero. Write SF equation at that point and equating to zero we can find out the distances 'x' from one end .then find maximum bending moment at that point by taking all moment on right or left hand side of beam.

29. What is shear force?

The algebric sum of the vertical forces at any section of the beam to the left or right of the section is called shear force.

30. What is shear force and bending moment diagram?

It shows the variation of the shear force and bending moment along the length of the beam.

31. What are the types of beams?

1. Cantilever beam
2. Simply supported beam
3. Fixed beam
4. Continuous beam

32. What are the types of loads?

1. Concentrated load or point load

2. Uniform distributed load
3. Uniform varying load

33. In which point the bending moment is maximum?

When the shear force change of sign or the shear force is zero

34. Write the assumption in the theory of simple bending?

1. The material of the beam is homogeneous and isotropic.
2. The beam material is stressed within the elastic limit and thus obey hooke's law.
3. The transverse section which was plane before bending remains plains after bending also.
4. Each layer of the beam is free to expand or contract independently about the layer, above or below.
5. The value of E is the same in both compression and tension.

35. Write the theory of simple bending equation?

M/ I = F/Y = E/R
M - Maximum bending moment
I - Moment of inertia
F - Maximum stress induced
Y - Distance from the neutral axis
E - Young's modulus
R - Constant.

36. What types of stresses are caused in a beam subjected to a constant shear force ?

Vertical and horizontal shear stress

37. State the main assumptions while deriving the general formula for shear stresses

The material is homogeneous, isotropic and elastic
The modulus of elasticity in tension and compression are same.
The shear stress is constant along the beam width
The presence of shear stress does not affect the distribution of bending stress.

38. Define: Shear stress distribution

The variation of shear stress along the depth of the beam is called shear stress distribution

39. What is the ratio of maximum shear stress to the average shear stress for the rectangular section?

Qmax is 1.5 times the Qavg.

40. What is the ratio of maximum shear stress to the average shear stress in the case of solid

circular section?

Qmax is 4/3 times the Qavg.

41. What is the maximum value of shear stress for triangular section?

Qmax=Fh2/12I
h- Height
F-load

42. What is the shear stress distribution value of Flange portion of the I-section?

q= f/2I * (D2/4 - y) D-depth y- Distance from neutral axis

43. What is the value of maximum of minimum shear stress in a rectangular cross section?

Qmax=3/2 * F/ (bd)
44. Define Torsion

When a pair of forces of equal magnitude but opposite directions acting on body, it tends to twist the body. It is known as twisting moment or torsional moment or simply as torque.
Torque is equal to the product of the force applied and the distance between the point of application of the force and the axis of the shaft.

45. What are the assumptions made in Torsion equation

• The material of the shaft is homogeneous, perfectly elastic and obeys Hooke's law.
• Twist is uniform along the length of the shaft
• The stress does not exceed the limit of proportionality
• The shaft circular in section remains circular after loading
• Strain and deformations are small.

46. Define polar modulus

It is the ratio between polar moment of inertia and radius of the shaft.
£ = polar moment of inertia/Radius = J/ R

47. Write the polar modulus for solid shaft and circular shaft.

£ = polar moment of inertia/Radius = J/ R J = $\pi D^4/32$

48. Why hollow circular shafts are preferred when compared to solid circular shafts?

• The torque transmitted by the hollow shaft is greater than the solid shaft.
• For same material, length and given torque, the weight of the hollow shaft will be less compared to solid shaft.

49. Write torsional equation

$T/J=C\theta/L=q/R$
T-Torque
J- Polar moment of inertia
C-Modulus of rigidity
L- Length
q- Shear stress
R- Radius

50. Write down the expression for power transmitted by a shaft

$P=2\pi NT/60$
N-speed in rpm
T-torque

51. Write down the expression for torque transmitted by hollow shaft

$T= (\pi/16)*F_s*((D^4-d^4)/d^4$
T-torque
q- Shear stress
D-outer diameter
D- inner diameter

52. Write the polar modulus for solid shaft and circular shaft

It is ratio between polar moment of inertia and radius of shaft

53. Write down the equation for maximum shear stress of a solid circular section in diameter 'D' when subjected to torque 'T' in a solid shaft shaft.

$T=\pi/16 * F_s*D^3$
T-torque
q Shear stress
D diameter

54. Define torsional rigidity

Product of rigidity modulus and polar moment of inertia is called torsional rigidity

55. What is composite shaft?

Some times a shaft is made up of composite section i.e. one type of shaft is sleeved over other types of shaft. At the time of sleeving, the two shaft are joined together, that the composite shaft behaves like a single shaft.

56. What is a spring?

A spring is an elastic member, which deflects, or distorts under the action of load and regains its original shape after the load is removed.

57. State any two functions of springs.

1 . To measure forces in spring balance, meters and engine indicators.
2 . To store energy.

58. What are the various types of springs?

i. Helical springs
ii. Spiral springs
iii. Leaf springs
iv. Disc spring or Belleville springs

59. Classify the helical springs.

1. Close – coiled or tension helical spring.
2. Open –coiled or compression helical spring.

60. What is spring index (C)?

The ratio of mean or pitch diameter to the diameter of wire for the spring is called the spring index.

61. What is solid length?

The length of a spring under the maximum compression is called its solid length. It is the product of total number of coils and the diameter of wire.
$Ls = n_t \times d$
Where, n_t = total number of coils.

62. Define free length.

Free length of the spring is the length of the spring when it is free or unloaded condition. It is equal to the solid length plus the maximum deflection or compression plus clash allowance.
$Lf = \text{solid length} + Y_{max} + 0.15\, Y_{max}$

63. Define spring rate (stiffness).

The spring stiffness or spring constant is defined as the load required per unit deflection of the spring.
K= W/y
Where W -load

Y – deflection

64. Define pitch.

Pitch of the spring is defined as the axial distance between the adjacent coils in uncompressed state. Mathematically
Pitch=free length / n-1

65. Define helical springs.

The helical springs are made up of a wire coiled in the form of a helix and is primarily intended for compressive or tensile load

66. What are the differences between closed coil & open coil helical springs?

The spring wires are coiled very closely, each turn is nearly at right angles to the axis of helix	The wires are coiled such that there is a gap between the two consecutive turns.
Helix angle is less than 10^o	Helix angle is large ($>10^o$)

67. What are the stresses induced in the helical compression spring due to axial load?

1. Direct shear stress
2. Torsional shear stress
3. Effect of curvature

68. What is buckling of springs?

The helical compression spring behaves like a column and buckles at a comparative small load when the length of the spring is more than 4 times the mean coil diameter.

69. What is surge in springs?

The material is subjected to higher stresses, which may cause early fatigue failure. This effect is called as spring surge.

70. Define active turns.

Active turns of the spring are defined as the number of turns, which impart spring action while loaded. As load increases the no of active coils decreases.

71. Define inactive turns.

An inactive turn of the spring is defined as the number of turns which does not contribute to the spring action while loaded. As load increases number of inactive coils increases from 0.5 to 1 turn.

72. What are the different kinds of end connections for compression helical springs?

The different kinds of end connection for compression helical springs are
a. Plain ends
b. Ground ends
c. Squared ends
d. Ground & square ends

73. When will you call a cylinder as thin cylinder?

A cylinder is called as a thin cylinder when the ratio of wall thickness to the diameter of cylinder is less 1/20.

74. In a thin cylinder will the radial stress vary over the thickness of wall?

No, in thin cylinders radial stress developed in its wall is assumed to be constant.
since the wall thickness is very small as compared to the diameter of cylinder.

75. Distinguish between cylindrical shell and spherical shell.

Cylindrical shell	Spherical shell
Circumferential stress is twice the longitudinal stress.	Only hoop stress presents.
It withstands low pressure than spherical shell for the same diameter.	It withstands more pressure than cylindrical shell for the same diameter.

76. What is the effect of riveting a thin cylindrical shell?

Riveting reduces the area offering the resistance. Due to this, the circumferential and longitudinal stresses are more. It reduces the pressure carrying capacity of the shell.

77. What do you understand by the term wire winding of thin cylinder?

In order to increase the tensile strength of a thin cylinder to withstand high internal pressure without excessive increase in wall thickness, they are sometimes pre stressed by winding with a steel wire under tension.

78. What are the types of stresses setup in the thin cylinders?

1. Circumferential stresses (or) hoop stresses
2. Longitudinal stresses

79. Define – hoop stress?

The stress is acting in the circumference of the cylinder wall (or) the stresses induced perpendicular to the axis of cylinder.

80. Define- longitudinal stress?

The stress is acting along the length of the cylinder is called longitudinal stress.

81. A thin cylinder of diameter d is subjected to internal pressure p . Write down the expression for hoop stress and longitudinal stress.

Hoop stress
$\sigma_h = pd/2t$
Longitudinal stress
$\sigma_l = pd/4t$
p- Pressure (gauge)
d- Diameter
t- Thickness

82. State principle plane.

The planes, which have no shear stress, are known as principal planes. These planes carry only normal stresses.

83. Define principle stresses and principle plane.

Principle stress: The magnitude of normal stress, acting on a principal plane is known as principal stresses.
Principle plane: The planes, which have no shear stress, are known as principal planes.

84. What is the radius of Mohr's circle?

Radius of Mohr's circle is equal to the maximum shear stress.

85. What is the use of Mohr's circle?

To find out the normal, resultant stresses and principle stress and their planes.

86. List the methods to find the stresses in oblique plane?

1. Analytical method
2. Graphical method

87. A bar of cross sectional area 600 mm^2 is subjected to a tensile load of 50 KN applied at each end. Determine the normal stress on a plane inclined at 30° to the direction of loading.

$A = 600\ mm^2$
Load, $P = 50KN$
$\theta = 30°$
Stress, σ = Load/Area
= 50*102/600
= $83.33\ N/mm^2$
Normal stress, $\sigma_n = \sigma \cos 2\theta$
= 83.33*cos2*30°
= $62.5\ N/mm^2$

88. In case of equal like principle stresses, what is the diameter of the Mohr's circle?

Answer: Zero

89. Derive an expression for the longitudinal stress in a thin cylinder subjected to a uniform internal fluid pressure.

Force due to fluid pressure = $p \times \pi/4\ xd^2$
Force due to longitudinal stress = $f_2 \times \pi d \times t$
$p \times \pi/4\ xd^2 = f_2 \times \pi d \times t$
$f_2 = 4t$

90.In thin spherical shell, volumetric strain is -------- times the circumferential strain.

Three.

Objective Solving Tricks by GATE Tutor(gate.tutor@gmail.com)

Most of time students complain that they **couldn't complete** their objective paper; they were struck in one or another problem and wasted a lot of time. Some says that their guess went wrong and marks were deducted due to **negative marking**, some could not read paper completely and **missed some easy questions** etc.
I'll like to stress that **objective paper solving is different** from subjective paper. You don't need to study extra for objective questions but practice little bit.
Your guess in solving objective can bring you in difficulty but some **intelligent/educated guess** can add valuable marks to your score. Most of time objective questions have **some hint** in the form of multiple choices for the question.
Following can be used as guidelines for solving objective paper:

General Tips

- Keep the structure of GATE in mind(25 Quest 1 Mark each, 30 Quest. 2 Marks each with 4 common data questions and 4 Linked Questions).
- Plan your time. Allow more time for high point value questions; reserve time at the end to review your work, and for emergencies. I'll suggest following sequence, but you can keep as per your choice: 2 Marks question, Common Data Questions, Linked questions and then single mark

questions.

- Look the whole test over, skimming the quesitons and developing a general plan for your work. If any immediate thoughts come to you, jot them down in the margin
- Start with the section of the test that will yield the most points, but begin working with the easiest questions to gain time for the more difficult ones and to warm up.
- Work quickly, check your timing regularly, and adjust your speed when necessary.
- Avoid reading into the questions. When you find yourself thinking along the lines of "this is too easy; there must be a trick..." mark the question and move on to another. Interpret questions literally.
- Mark key words in every question. To help find the key words, ask yourself WHAT, WHO, WHERE, WHEN, and HOW?

Multiple Choice Specific Tips

- Remember in GATE each question will have four choices for the answer, only one is correct and wrong answer carry 33% negative marks
- Read the question (without reading choices) very carefully.
- Mark important key words and **look for special key words** like not, but, except , or, nor, always, never, and only . Mark these key words. E.g.

Ques The number of leaf nodes in a rooted tree of n(n>0) nodes, with each node having 0 or 3 children is:

Important words to mark in this are, **"n>0"** and **"or"**
The number of leaf nodes in a rooted tree of n(**n>0**) nodes, with each node having 0 **or** 3 children is:
Many times we miss words like "or" and whole question in changed.

- If you can think of answer before reading choices, keep it in mind before reading choices
- Compare with choices and select the best suited answer.
- Most of times **choices are made to confuse**. If there are two or more options that could be the correct answer, compare them to each other to determine the differences between them.
- If there is an encompassing answer choice, for example "**all of the above**", and you are unable to determine that there are at least two correct choices, select the encompassing choice.
- Make **educated/intelligent guesses** - eliminate options any way you can.
- Multiple choices can provide **direct short cut** to get correct answer, especially in numerical problems. For example in the above question

Example
The number of leaf nodes in a rooted tree of n(**n>0**) nodes, with each node having 0 **or** 3 children is:
Choices:
A n/2
B (n-1)/3
C (n-1)/2
D (2n+1)/3

Direct solving the problem can be difficult. Use following short cut.
Imagine few such trees and try to get answer from choices. Lets start with tree with one node, i.e. n = 1. In this case obviously number of leaves should be one(same as root). Putting n=1 in above options only option "D" gives 1. But assure your self with more tries. Next possible value of n = 4 with number of leaves = 3. Putting this is multiple choices only "D" satisfies confirming our solution.

I'll try to include more examples to understand different tricks as and when I get time. But you can always **reach me at** gate.tutor@gmail.com. I'll try to solve your problems. I'll also recommend student to **send their tricks/suggestions** so that they can be included in this page. I'm looking for **contributions from you all** to make this page useful for all student appearing in GATE.

Thanks
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Preparing for GATE can be as easy as preparing for your college examinations. Just take little cautions while studying any topic and do remember that GATE paper focus on your in depth knowledge of subject, your basics, presence of mind during examination etc.

I'll recommend following while preparing for your GATE exams people may differ as this is my personnel opinion :

- Always follow standard books for GATE. Try to cover complete syllabus. If not possible expertise in what ever portion of syllabus you practice.
- Try **preparing notes** after reading every chapter/topic. This may initially take some time but will help you while revising before paper. Click here for expert tips to prepare notes for GATE.
- While reading any chapter/topic do ask your self following questions **"What", "How", and "Why"** and see improvement
- Best way to prepare is to follow cycle **Learn, Test, Analyze, Improve**, Learn, Test, Analyze, Improve ……
  Exam Crazy.com can help you when you test your self for GATE and its **free**.
- Click here to learn effective way to use examcrazy.com test series.
- Do remember that GATE is completely objective question based test. Most of time solving objective questions is tricky. Learn tips to solve GATE objective questions from GATE Tutor.
- In case of doubts **ask some expert or use forums** to discuss questions as provided by examcrazy.com or ask me at gate.tutor@gmail.com
- Don't worry if your percentage in university exams is low as GATE admissions do not consider them. Just maintain minimum percentage required by many colleges including IIT's. Look at GATE Cutoff and eligibility section to know eligibility and cut off of various colleges.

- **Group study** is one of the best ways of preparation. Divide sections/topics between you and your partner and have a brief session on topic from your friend before you actually start topic. This will save your time and efforts and will improve your and your partner's understanding on the topic.
- Normally coaching GATE is not required but if you are not able to concentrate much then this is a good option.