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23MET101- ENGINEERING MECHANICS

UNIT I - BASICS & STATICS OF PARTICLES

Equilibrium of a particle

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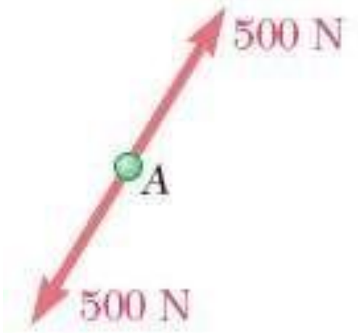
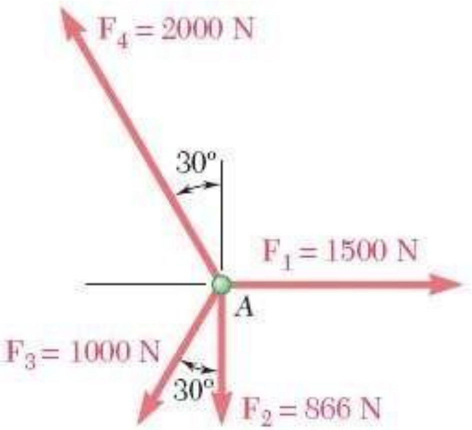
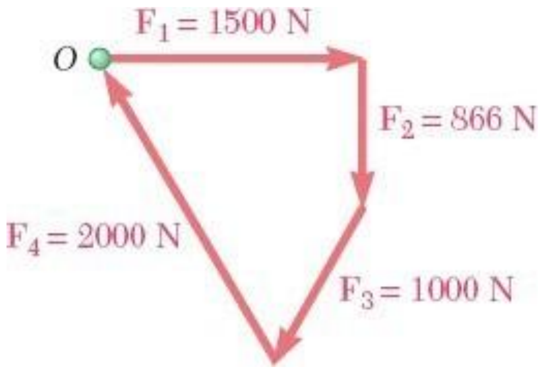
Equilibrium of a Particle

- When the resultant of all forces acting on a particle is zero, the particle is in *equilibrium*.
- *Newton's First Law*: If the resultant force on a particle is zero, the particle will remain at rest or will continue at constant speed in a straight line.







- Particle acted upon by two forces:
  - equal magnitude
  - same line of action
  - opposite sense

- Particle acted upon by three or more forces:
  - graphical solution yields a closed polygon
  - algebraic solution

$$R = \sum F = 0$$

$$\sum F_x = 0 \qquad \sum F_y = 0$$

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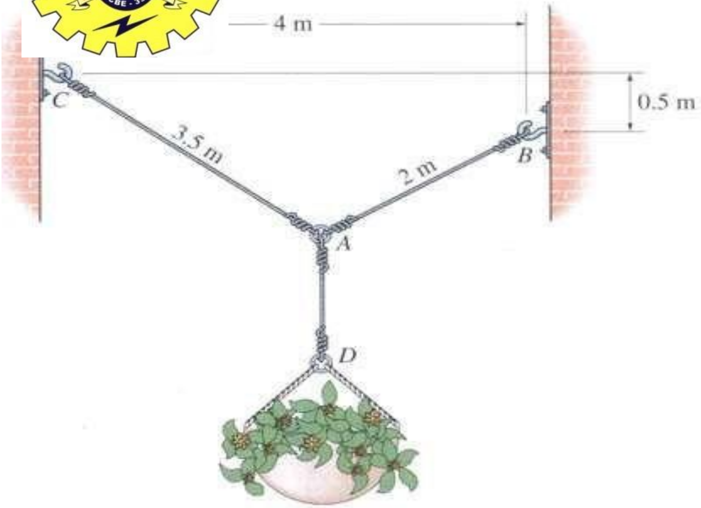
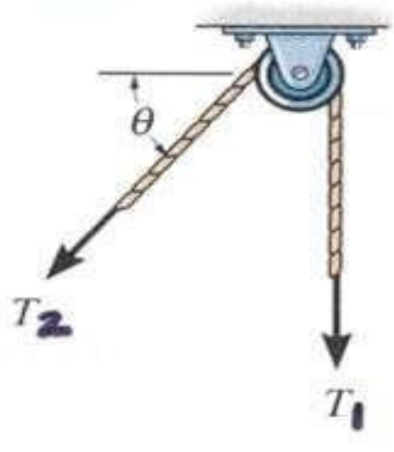
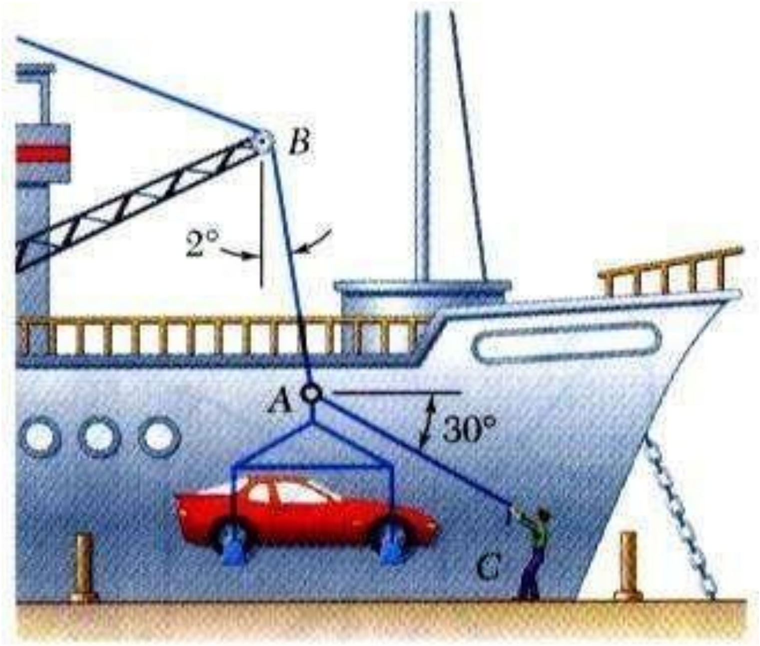
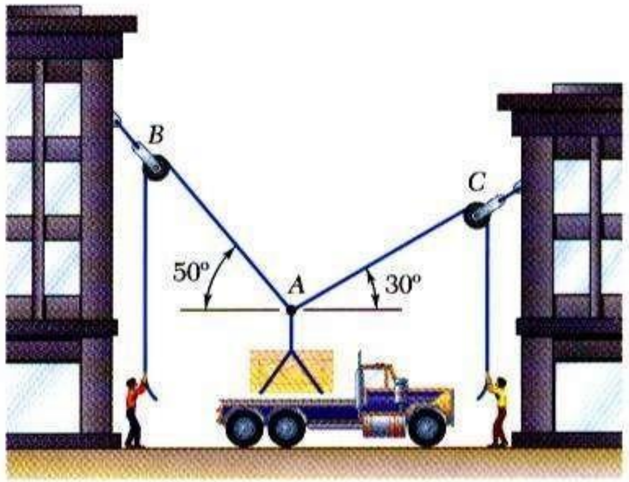
Examples for Equilibrium





CablesABandAC carries the spool of weight

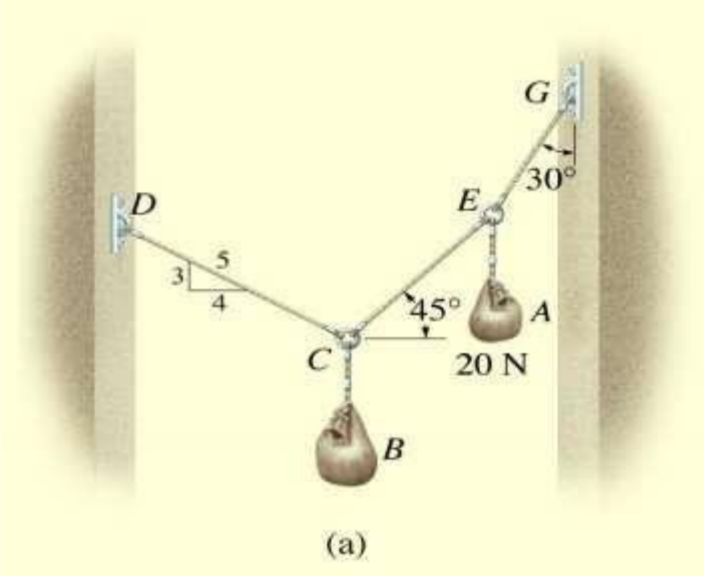




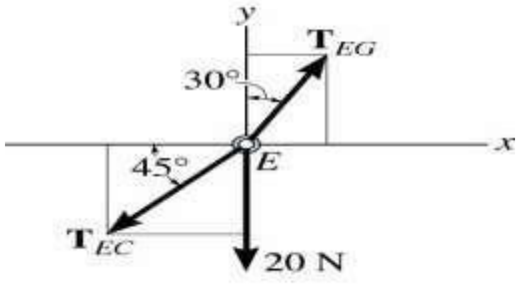
Problem 4

Given: Sack A weighs 20 N. and geometry is as shown.

Find: Forces in the cables and weight of sack B.



1. Apply Equilibrium condition at Point E and solve for the unknowns (T_{EG} & T_{EC}).
2. Repeat this process at C.



(b)

Note that the assumed directions for the forces in the two cables EG and EC are tensile in nature.

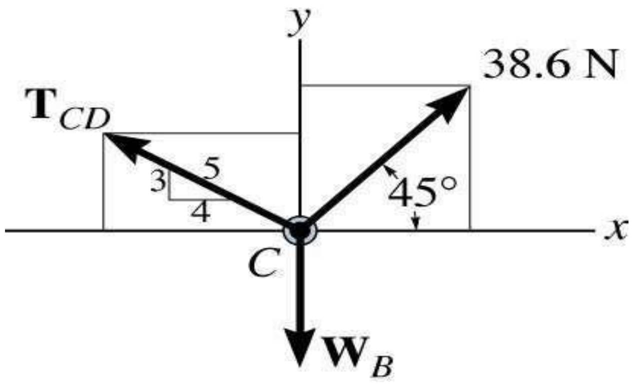
$+\rightarrow \quad \sum F_x = T_{EG} \sin 30^o - T_{EC} \cos 45^o = 0$

$+\uparrow \quad \sum F_y = T_{EG} \cos 30^o - T_{EC} \sin 45^o - 20\,N = 0$

Solving these two simultaneous equations for the two unknowns, we get

$T_{EC} = 38.6\,N$

$T_{EG} = 54.6\,N$



(c)

Now move on to the point C and consider equilibrium at C

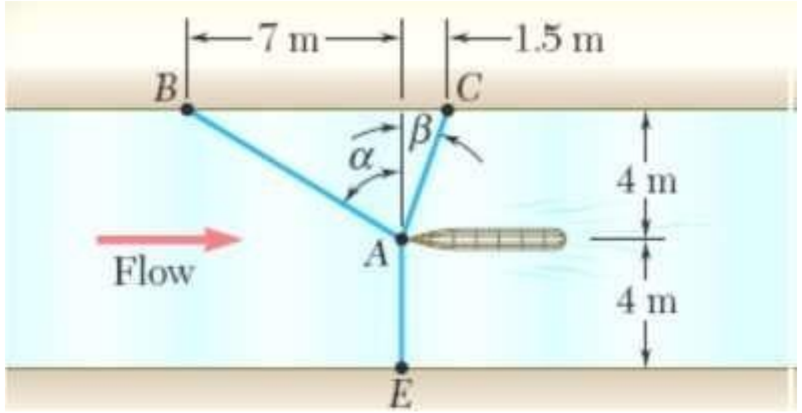
Apply Equilibrium Condition

$+\rightarrow \Sigma F_x = 38.64\cos 45° - (4/5)T_{CD} = 0$

$+\uparrow \Sigma F_y = (3/5)T_{CD} + 38.64\sin 45° - W_B = 0$

Solving the first equation and then the second we get $T_{CD} = 34.2$ N and $W_B = 47.8$ N.

Problem 5

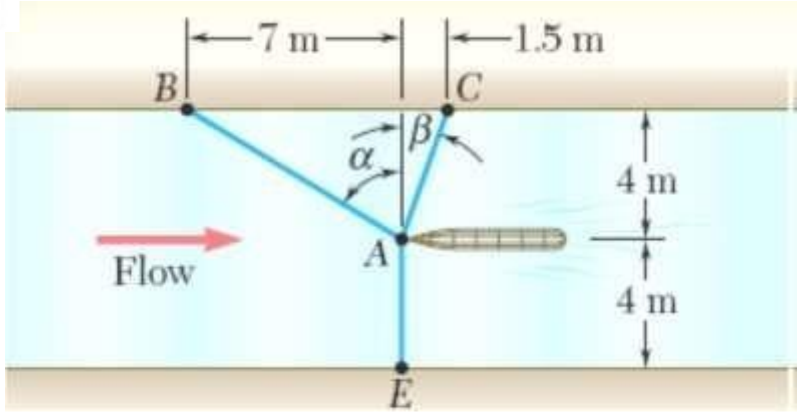


It is desired to determine the drag force at a given speed on a prototype sailboat hull. A model is placed in a test channel and three cables are used to align its bow on the channel centerline. For a given speed, the tension is 200-N in cable *AB* and 300-N in cable *AE*.

Determine the drag force exerted on the hull and the tension in cable *AC*.

SOLUTION:

- Choosing the hull as the free body, draw a free-body diagram.
- Express the condition for equilibrium for the hull by writing that the sum of all forces must be zero.
- Resolve the vector equilibrium equation into two component equations. Solve for the two unknown cable tensions.

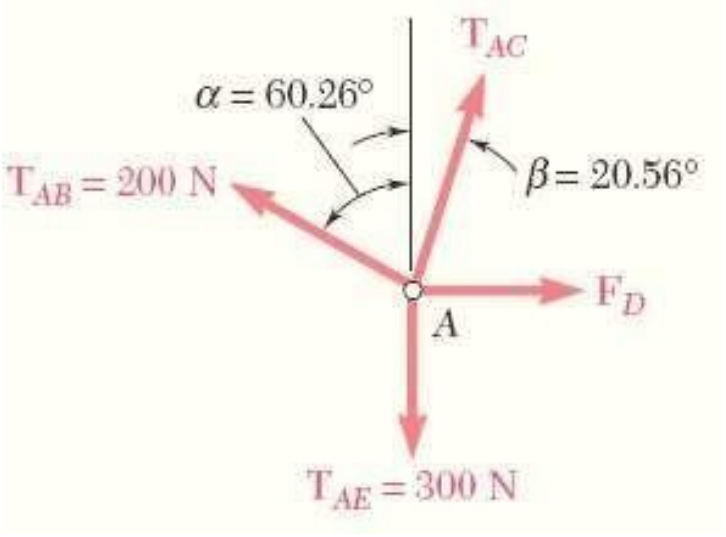


SOLUTION:

- Choosing the hull as the free body, draw a free-body diagram.

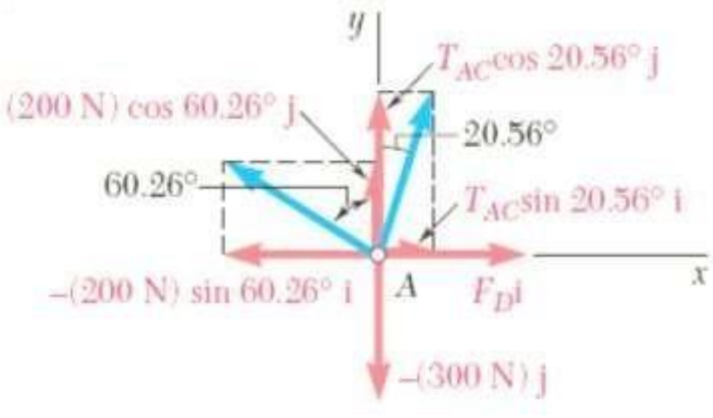
$$\tan\alpha = \frac{7\,\text{m}}{4\,\text{m}} = 1.75 \qquad \tan\beta = \frac{1.5\,\text{m}}{4\,\text{m}} = 0.375$$

$$\alpha = 60.25^\circ \qquad \beta = 20.56^\circ$$



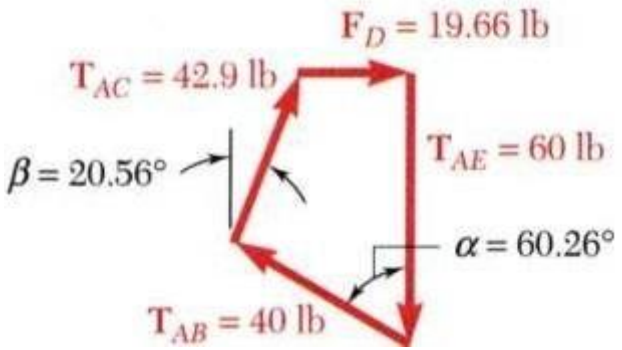
- Express the condition for equilibrium for the hull by writing that the sum of all forces must be zero.

$$R = T_{AB} + T_{AC} + T_{AE} + F_D = 0$$



- Resolve the vector equilibrium equation into two component equations. Solve for the two unknown cable tensions.

$$\vec{T}_{AB} = -(200\,\text{N})\sin 60.26°\,\vec{i} + (200\,\text{N})\cos 60.26°\,\vec{j}$$
$$= -(173.66\,\text{N})\vec{i} + (99.21\,\text{N})\vec{j}$$
$$\vec{T}_{AC} = T_{AC}\sin 20.56°\,\vec{i} + T_{AC}\cos 20.56°\,\vec{j}$$
$$= 0.3512\,T_{AC}\,\vec{i} + 0.9363\,T_{AC}\,\vec{j}$$
$$\vec{T} = -(300\,\text{N})\vec{i}$$
$$\vec{F}_D = F_D\,\vec{i}$$



$$\vec{R} = 0$$
$$= (-173.66 + 0.3512\,T_{AC} + F_D)\vec{i}$$
$$+ (99.21 + 0.9363\,T_{AC} - 300)\vec{j}$$

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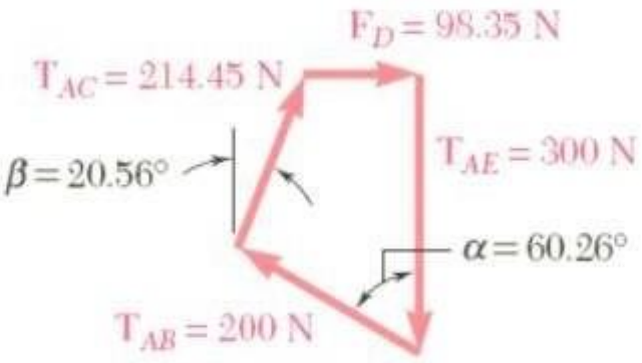


$$R = 0$$

$$= \left(-173.66 + 0.3512\,T_{AC} + F_D\right)\vec{i} + \left(99.21 + 0.9363\,T_{AC} - 300\right)\vec{j}$$

This equation is satisfied only if each component of the resultant is equal to zero

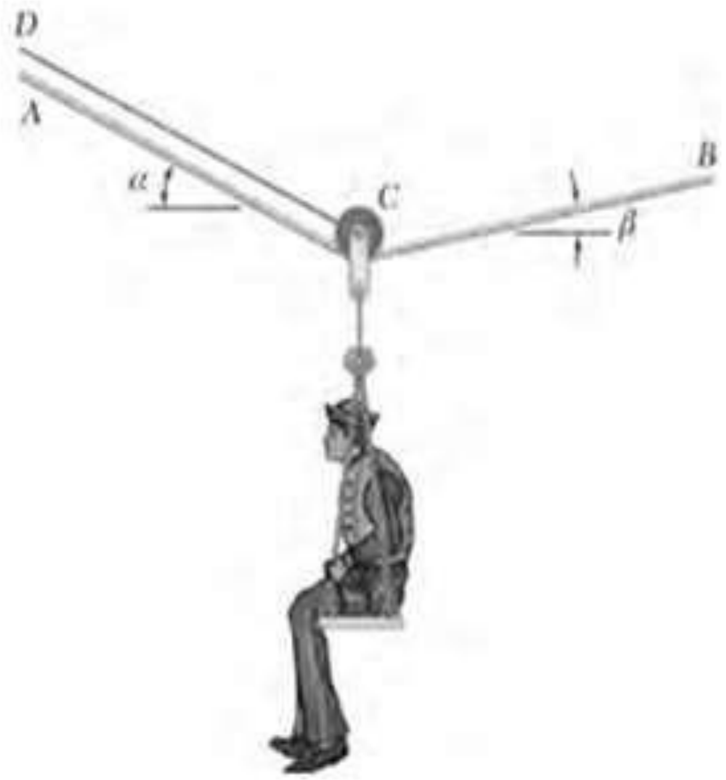
$$\left(\sum F_x = 0\right) \quad 0 = -173.66 + 0.3512 T_{AC} + F_D$$

$$\left(\sum F_y = 0\right) \quad 0 = 99.21 + 0.9363 T_{AC} - 300$$

$$T_{AC} = +214.45\text{N}$$

$$F_D = +98.35\text{ N}$$

Problem 6



A sailor is being rescued using a boatswain's chair that is suspended from a pulley that can roll freely on the support cable ACB and is pulled at a constant speed by cable CD. Knowing that a = 25^{o} and b = 15^{o} and that the tension in cable CD is 80 N, determine (a) the combined weight of the boatswain's chair and the sailor, (b) in tension in the support cable ACB.

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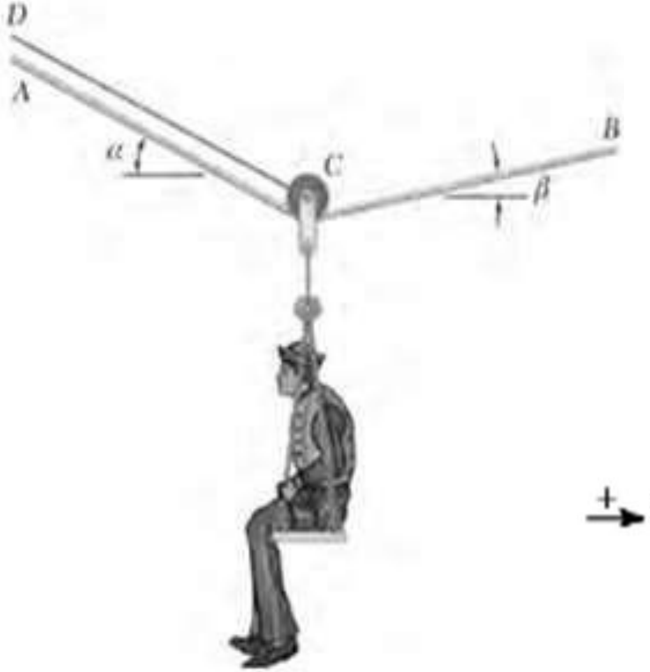

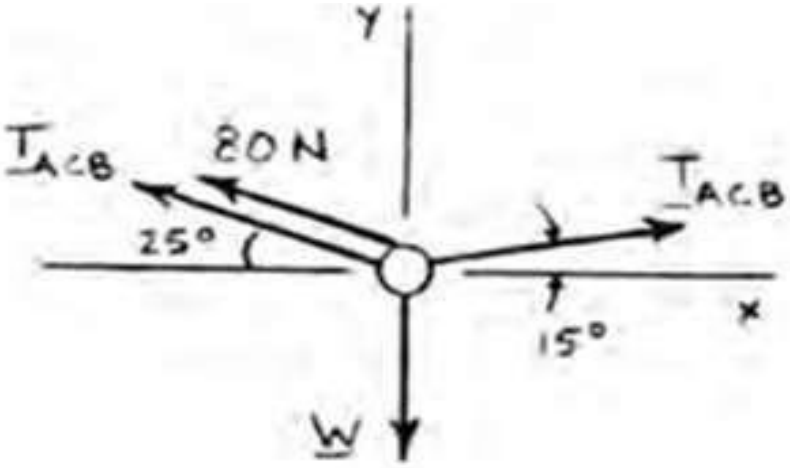

$\xrightarrow{+} \Sigma F_x = 0$: $T_{ACB} \cos 15 - T_{ACB} \cos 25 - 80 \cos 25 = 0$

$T_{ACB} = 1216.15$ N

$+\uparrow \Sigma F_y = 0$: $121615 \sin 15 + 121615 \sin 25 + 80 \sin 25 - W = 0$

$W = 86254$ N

(a) $W = 863$ N

(b) $T_{ACB} = 1216$ N

References

1. Ferdinand P Beer& E.Russel Johnston "VECTOR MECHANICS FOR ENGINEERS STATICS & Dynamics", (Ninth Edition) Tata McGraw Hill Education Private Limited, New Delhi.

2. Engineering Mechanics – Statics & Dynamics by S.Nagan, M.S.Palanichamy, Tata McGraw-Hil (2010).