Structural Mechanics I

Second Semester 2004-2005 (Term 042)

by

Dr. Radwam Al-Juruf

C. E. Department

K.F.U.P.M.

King Fahd University of Petroleum & Minerals
CIVIL ENGINEERING DEPARTMENT

STRUCTURAL MECHANICS I: CE 203

Second Semester 2004-2005 (Term 042)

Text: Mechanics of Materials (6th ed.) by R.C. Hibbeler (2004)
Instructor: Dr. Radwan Al-Juruf **Office:** 16-136 Tel: 2559

COURSE OUTLINE & SCHEDULE

Lect.	Date		Subject	Section
1	February	12	Mechanics & Definitions of Stress in Deformable Bodies	1.1, 1.2
2		14	Normal Stress	1.3 (partial)
3		16	Average Normal Stress	1.4
4		19	Shear Stress	1.5
5		21	Factor of Safety; Bearing Stress; Structural *Design*	1.6, 1.7; handouts
6		23	Definition of Strain, Stress-Strain Diagrams	2.1,2.2,3.1,3.2
7		26	Hooke's Law; Material Behavior; Poisson's Ratio	3.3, 3.4, 3.6
8		28	Deformation of Axially Loaded Members	4.2, 4.3
9	March	02	Statically Indeterminate Problems; Design Applications	4.4, 4.5
10		05	Thermal Stresses and Thermal Strain	4.6
11		07	Thermal Stress (continued)	4.6
12		09	Stress Concentrations	4.7; Handouts
13		12	Stress Components Under General Loading	1.3 (partial)
14		14	Generalized Hooke's Law	10.6
-	**March**	**15**	**First Major Examination [Tuesday Evening].**	**1.2-4.6**
15		16	Wednesday class is ~~excused~~	
16		19	Torsion of Circular Shafts	5.1, 5.2
17		21	Transmission Shafts and Gears	5.3
18		23	Transmission Shafts and Gears (Continued)	5.3; 5.4
19		26	Angle of Twist	5.4
20		28	Statically Indeterminate Shafts	5.5
21		30	Torsion of Solid Non-Circular Sections	5.6
22	April	02	Twisting of Thin-Walled Closed Sections	5.7
23		04	.... (continued); *Design* Applications	5.7; 11.4
24		06	Shear & Bending Moment Diagrams–Method of Summations	6.1, 6.2
-	**April 9-15, 2005**		**Mid-term Break**	-
25		16	Shear & Bending Moment Diagrams–Method of Summations	6.2
26		18	Shear & Bending Moment Diagrams–Method of Summations	6.2
27		20	Bending Stresses in Straight Beams	6.3
28		23	The Flexure Formula	6.4
29		25	" " (continued)	6.4
30		27	Shear in Straight Beams, Shear Formula	7.1, 7.2

Lect.	Date		Subject	Section
31	April	30	Shear Stress in Beams	7.3
32	May	02	Shear Flow in Beams; Design of Beams & Applications	7.4; 11.1; 11.2
-	May	03	**Second Major Exam [Tuesday Evening].**	**4.7; 10.6 & 5.1-6.4**
33		04	Wednesday class is excused	-
34		07	Thin-Walled Pressure Vessels & Compound Stresses	8.1; 8.2
35		09	Compound Normal Stress	8.2
36		11	Compound Shear Stress	8.2
37		14	Compound Normal/Shear Stress	8.2
38		16	Transformation of Plane Stress	9.1, 9.2
39		18	Principal Normal Stresses & Maximum Shear Stresses	9.3
40		21	Mohr's Circle	9.4
41		23	Mohr's Circle (continued); Design Applications	9.4; 9.5 - 9.7
42		25	Beam Deflection; Moment – Curvature Equation	12.1, 12.2
43		28	Beam Deflections by Singularity Functions	12.3; 12.6
44		30	Singularity Functions Method (cont'd)	12.6 (cont'd)
45	June	01	Analysis of Statically Indeterminate Beams	12.6 (cont'd)

Grade Distribution:

Attendance		= 4%
Quizzes		= 6%
Homework		= 10%
First Exam	[Tuesday, March 15, 2005; Time: 7:00 p.m.]	= 20%
Second Exam	[Tuesday, May 03, 2005; Time: 7:00 p.m.]	= 25%
Final Exam	[Material coverage & schedule are yet to be determined]	= 35%

Remarks:

1. Homework assignments/*solutions* are distributed and *collected* every Monday. It is expected that each student will exert enough effort to prepare his assignments and submit the solutions with a cover-page (provided by the instructor). Ruled papers must be used.
2. Applications from Chapter 11 (Design Concepts and Applications to Beams and Shafts) are inserted at appropriate times/topics through home-works, tests, and examinations. Additional handouts are provided during the course.
3. The University regulations regarding excessive absences will be strictly adhered to in this course. 9 unexcused absences → DN grade in the course.
4. No late homework will be accepted.

HW # 1

Solve the following problems in the textbook:

1-34

1-38

1-42

1-45

1-53

1-61

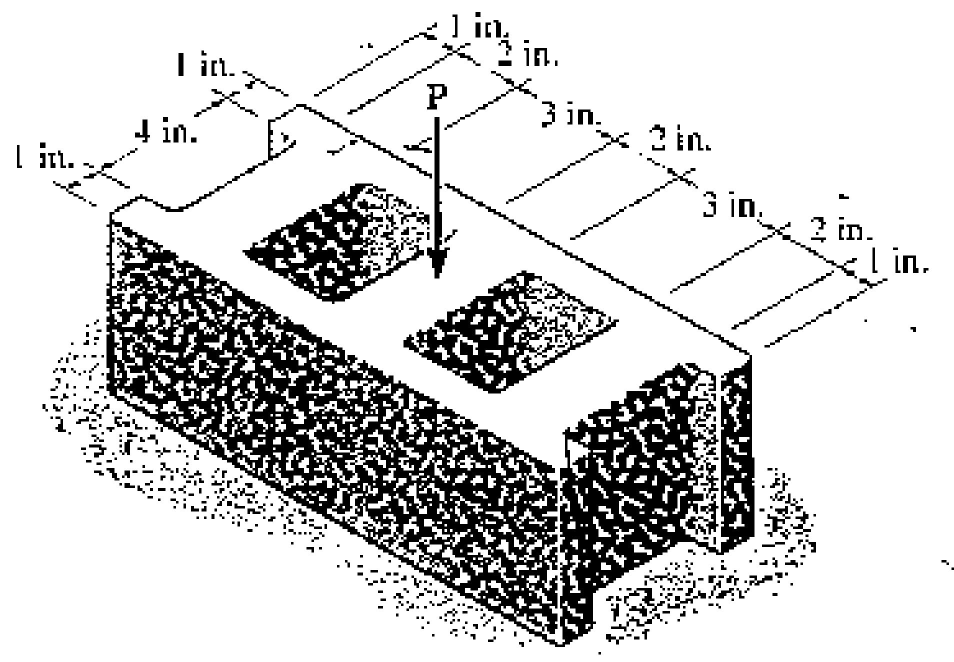
1-69

SOLUTIONS OF HOMEWORK #1.

INSTRUCTOR:- DR. RADWAN S. AL-JUROF.

PROBLEM #① (1-34):-

1–34. The cinder block has the dimensions shown. If the material fails when the average normal stress reaches 120 psi, determine the largest centrally applied vertical load **P** it can support.



Probs. 1–34/1–35

Solution:-

given:-

$\sigma_{fails} = 120 psi$

Required:-

$P = ?$

since we know.

the stress at fail $= \sigma_{fail} = P/A$.

Area of Cinder Block $= A_c$

$\Rightarrow A_c = 6 \times 14 - 2 \times 3 \times 4 - 2 \times 4 \times 1$

$\Rightarrow A_c = 52 \, in^2$.

$\therefore P = \sigma_{fail} \times A_c$

$= 120 \times 52$

$\Rightarrow P = 6240 \, lb$

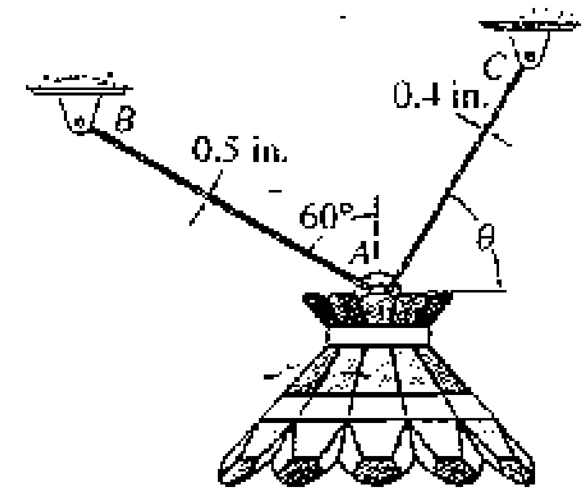
$\Rightarrow P = 6.24 \, kip$.

$\therefore$ The largest applied vertical load

$P = 6.24 \, kip$.

PROBLEM # 2 (1-38) :-

1–38. The 50-lb lamp is supported by two steel rods connected by a ring at A. Determine the angle of orientation θ of AC such that the average normal stress in rod AC is twice the average normal stress in rod AB. What is the magnitude of this stress in each rod? The diameter of each rod is given in the figure.



Probs. 1–36/1–37/1–38

Required :-

$\theta = ?$

$\sigma_{AB} = ?$

$\sigma_{AC} = ?$

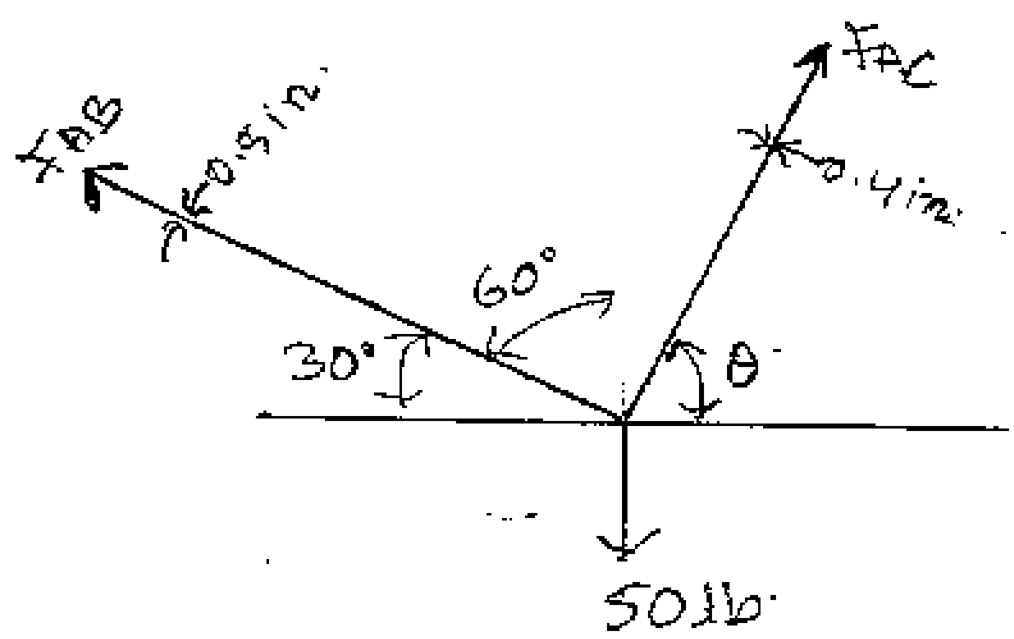
given :-

$\sigma_{AC} = 2\sigma_{AB}$

$\Rightarrow \dfrac{F_{AC}}{A_{AC}} = 2 \times \dfrac{F_{AB}}{A_{AB}}$

$A_{AC} = \dfrac{\pi}{4}(0.4)^2 = 0.1257\ in^2$

$A_{AB} = \dfrac{\pi}{4}(0.5)^2 = 0.1963\ in^2$



Applying Equilibrium condition.

$\xrightarrow{+} \Sigma F_x = 0$

$F_{AB} \cos 30 = F_{AC} \cos\theta$

$(\sigma_{AB} \cdot A_{AB}) \cos 30 = (\sigma_{AC} \cdot A_{AC}) \cos\theta$

$\Rightarrow (\sigma_{AB} \times A_{AB}) \cos 30 = (2 \times \sigma_{AB} \times A_{AC}) \cos\theta$

$\Rightarrow \dfrac{A_{AB}}{2 A_{AC}} = \dfrac{\cos\theta}{\cos 30}$

$\Rightarrow \dfrac{0.1963}{2 \times 0.1257} = \dfrac{\cos\theta}{\cos 30}$

$\Rightarrow \cos\theta = 0.78 \times \cos 30 = 0.676$

$\Rightarrow \theta = 47.45°$

$\therefore \theta = 47.45°$

P.T.O

Now finding stresses.

$\because$ $F_{AB} \cos 30 = F_{AC} \cos\theta$

$\Rightarrow F_{AB} \cos 30 = F_{AC} \cos 47.45$

$\Rightarrow F_{AB} = 0.781 F_{AC}$ — (1)

& $+\uparrow \Sigma F_y = 0$

$F_{AB} \sin 30^\circ + F_{AC} \sin 47.45 - 50 = 0$ — (2)

Solving (1) + (2)

$0.781 F_{AC} \sin 30 + F_{AC} \sin 47.45 - 50 = 0$

$\Rightarrow F_{AC} = 44.36\ lb$

& $F_{AB} = 34.65\ lb$

$\therefore \sigma_{AC} = \dfrac{F_{AC}}{A_{AC}} = \dfrac{44.36}{0.1257} = 353\ psi$

& $\sigma_{AB} = \dfrac{F_{AB}}{A_{AB}} = \dfrac{34.65}{0.1963} = 176.6\ psi$

$\therefore \sigma_{AC} = 353\ psi$

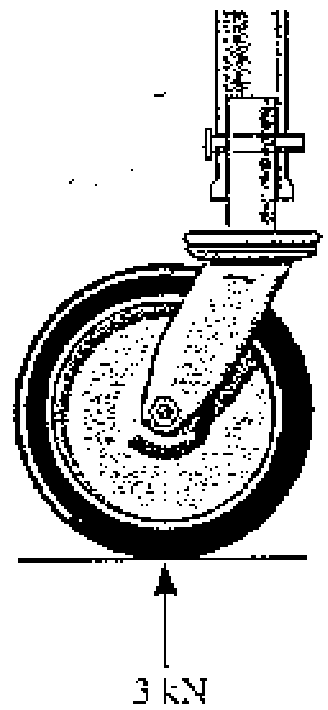
$\sigma_{AB} = 176.6\ psi$

PROBLEM #(3) (1-42)

given:-
dia of pin = 4 mm.
Normal force = P = 3 KN.

Required:-
$\tau_{avg} = ?$

1–42. The supporting wheel on a scaffold is held in place on the leg using a 4-mm-diameter pin as shown. If the wheel is subjected to a normal force of 3 kN, determine the average shear stress developed in the pin. Neglect friction between the inner scaffold puller leg and the tube used on the wheel.



Prob. 1–42

Area of Pin is

$A_p = \frac{\pi}{4}(4)^2$

$\Rightarrow A_p = 12.57 \text{ mm}^2$

$V = P/2 = 3/2 = 1.5 \text{ KN}$

& $\tau_{avg} = \frac{V}{A_p}$

$\Rightarrow \tau_{avg} = \frac{1.5 \times 10^3}{12.57}$

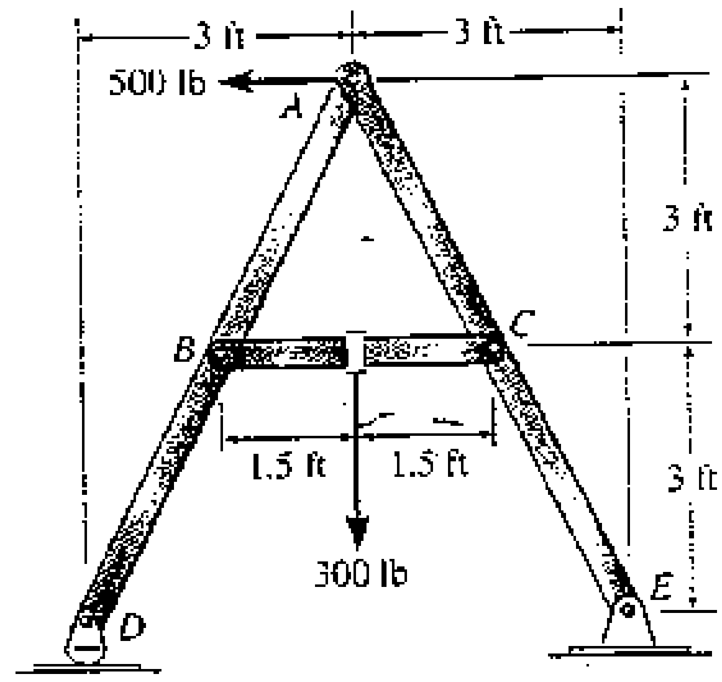
$\Rightarrow \tau_{avg} = 119.37 \text{ KPa}.$

$\therefore \tau_{avg} = \underline{119.37 \text{ KPa}}.$

PROBLEM # ④ (1-45).

1–45. The pins on the frame at D and E each have a diameter of 0.25 in. If these pins are subjected to *double shear*, determine the average shear stress in each pin.

1–46. Solve Prob. 1–45 assuming that pins D and E are subjected to *single shear*.



Probs. 1–43/1–44/1–45/1–46

Solution:-

given:-

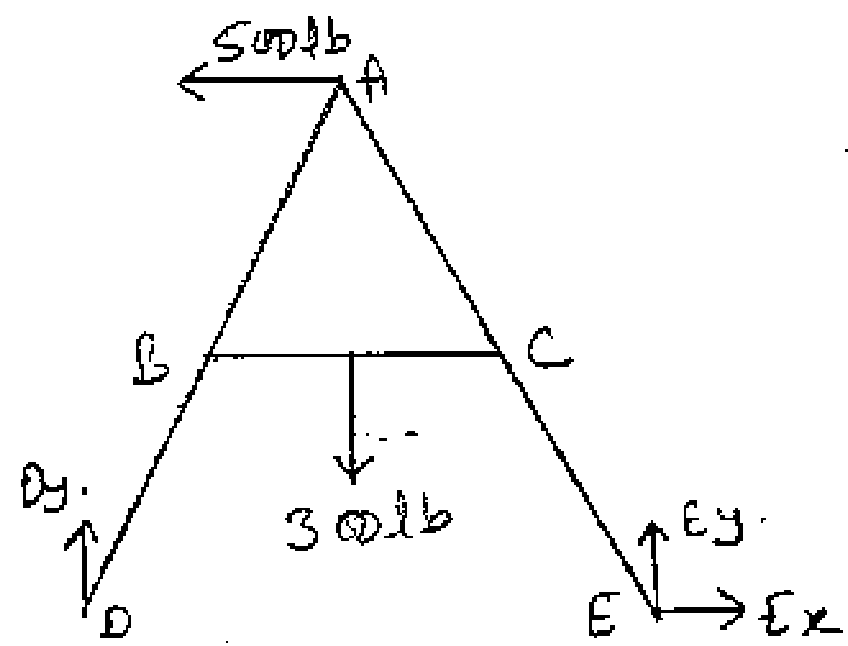
dia of pins at E & F is 0.25 in.

Required:-

$(\tau_D)_{avg} = ?$

$(\tau_E)_{avg} = ?$

Applying Equilibrium conditions.



$\circlearrowleft + \Sigma M_D = 0$

$-300 \times 3 + 500 \times 6 + E_y \times 6 = 0$

$\Rightarrow E_y = -350\,lb.$

$+\uparrow \Sigma F_y = 0$

$D_y + E_y = 300$

$D_y = 300 + 350$

$\Rightarrow D_y = 650\,lb.$

$\xrightarrow{+} \Sigma F_x = 0$

$E_x - 500 = 0$

$\Rightarrow E_x = 500\,lb.$

$\therefore R_E = \sqrt{E_x^2 + E_y^2} = \sqrt{(500)^2 + (-350)^2} = 610.33\,lb.$

Shear at pin E = $V_E = \frac{R_E}{2} = 305.164\,lb.$

Shear at pin D = $V_D = \frac{D_y}{2} = 325\,lb.$

P.T.O

$$\therefore (\tau_D)_{avg} = \frac{V_D}{A_D} = \frac{325}{\frac{\pi}{4}(0.25)^2} = 6620 \text{ psi}$$

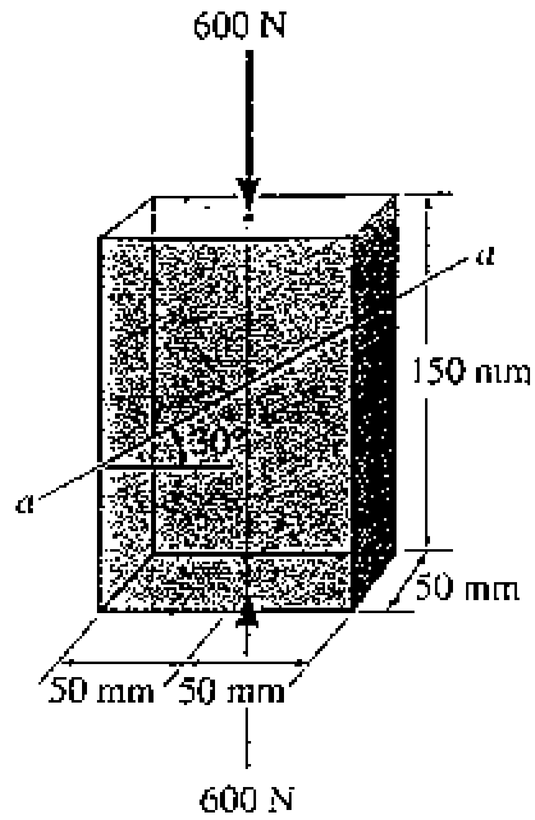
$$\Rightarrow (\tau_D)_{avg} = 6.62 \text{ ksi.}$$

$$\& \ (\tau_E)_{avg} = \frac{V_E}{A_E} = \frac{305.164}{\frac{\pi}{4}(0.25)^2} = 6220 \text{ psi}$$

$$\Rightarrow (\tau_E)_{avg} = 6.22 \text{ ksi.}$$

PROBLEM # 5 (1-53):-

1–53. The plastic block is subjected to an axial compressive force of 600 N. Assuming that the caps at the top and bottom distribute the load uniformly throughout the block, determine the average normal and average shear stress acting along section a–a.



Prob. 1–53

Solution:-

Required:-

$\sigma_{avg} = ?$

$\tau_{avg} = ?$

From fig. 1

calculating width 'w' along a-a.

$\therefore w = \dfrac{100}{\cos 30} = 115.5\,mm$

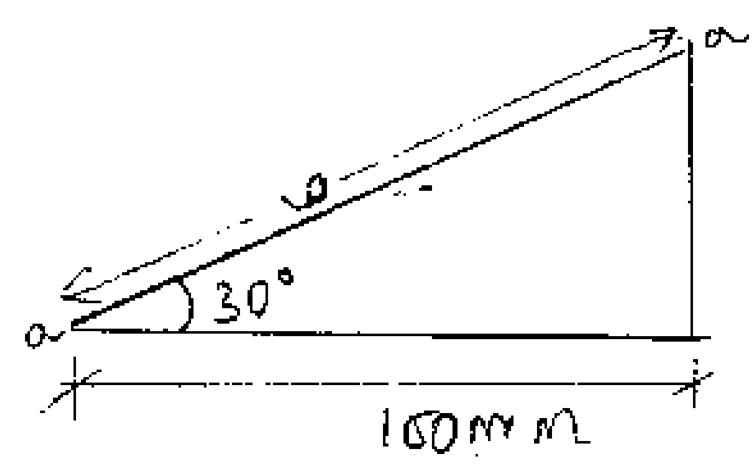


fig. 1

$\therefore$ Area of section a-a.

$A = 115.5 \times 50 = 5773\,mm^2$

Calculating components of force.

from fig. 2

$N = 600 \cos 30° = 519.6\,N$

$V = 600 \sin 30° = 300\,N$

$\therefore \sigma_{avg} = \dfrac{N}{A} = \dfrac{519.6}{5773} = 90\,kPa$

$\Rightarrow \sigma_{avg} = 90\,kPa$

$\tau_{avg} = \dfrac{V}{A} = \dfrac{300}{5773} = 52\,kPa.$

$\Rightarrow \tau_{avg} = 52\,kPa.$

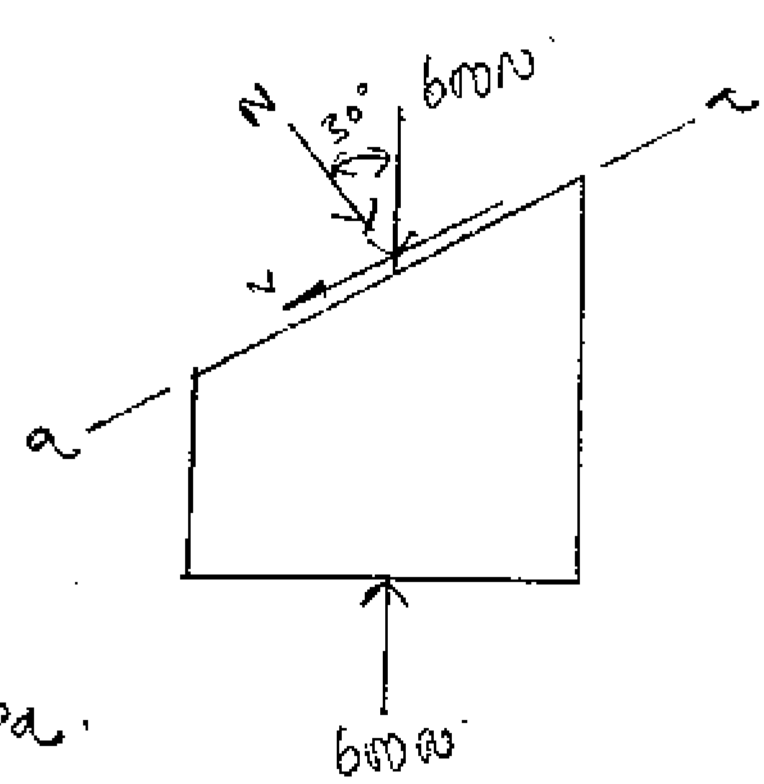
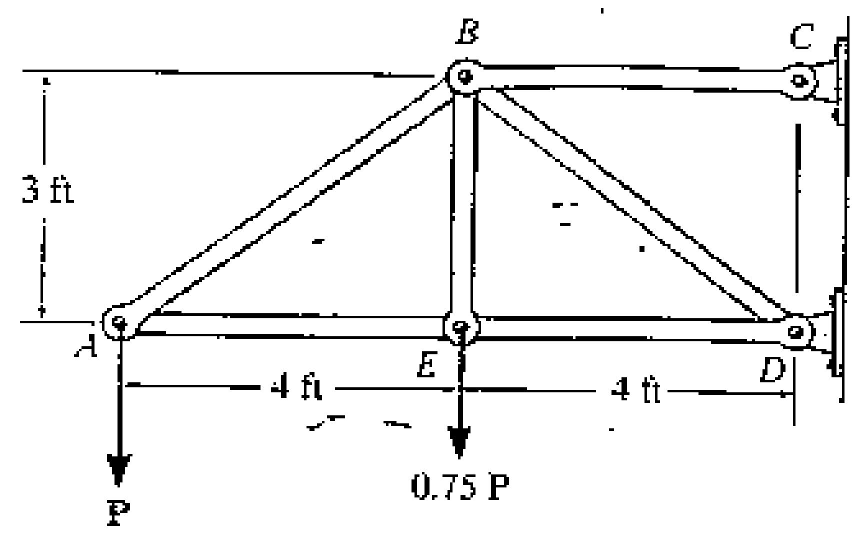


fig. 2

PROBLEM #(6)(1-61):-

1-61. The bars of the truss each have a cross-sectional area of 1.25 in². If the maximum average normal stress in any bar is not to exceed 20 ksi, determine the maximum magnitude P of the loads that can be applied to the truss.



Probs. 1–60/1–61

Solution:-

Given:-

$A_{bar} = 1.25\ in^2$

$\sigma_{avg} = 20\ ksi$

Required:-

$P = ?$

Applying Equilibrium Equations:-

$\circlearrowleft + \sum M_D = 0$

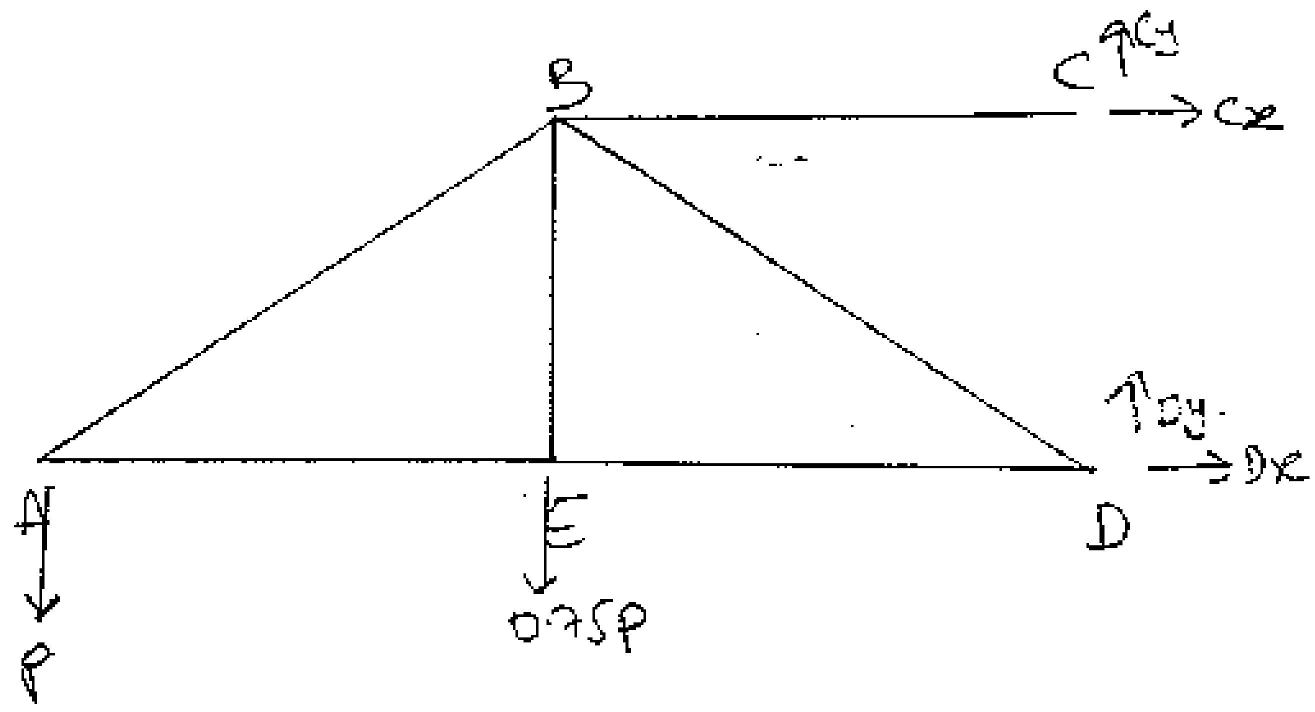
$8 \times P + 4 \times 0.75P - C_x \times 3 = 0$

$\Rightarrow 11P - 3C_x = 0$ —(1)

& $\circlearrowleft + \sum M_C = 0$

$8 \times P + 4 \times 0.75P + D_x \times 3 = 0$

$\Rightarrow 11P + 3D_x = 0$ —(2)



FBD

$\because C_x = F_{BC} = \sigma_{BC} \times A_{BC} = 20 \times 1.25 = 25\ kip$

Sub in (1)

$11P - 3 \times 25 = 0$

$\therefore P = 6.82\ kip$

$+\ D_x = F_{ED} + F_{BD} \cos 45° = \sigma_{ED} \times A_{ED} + \sigma_{BD} \times A_{BD} \times \cos 45°$

$\Rightarrow D_x = 20 \times 1.25 + 20 \times 1.25 \times \cos 45° = 42.68\ kip$

Sub in (2)

$11P + 3 \times 42.68 = 0$

$\Rightarrow P = 11.64\ kip$

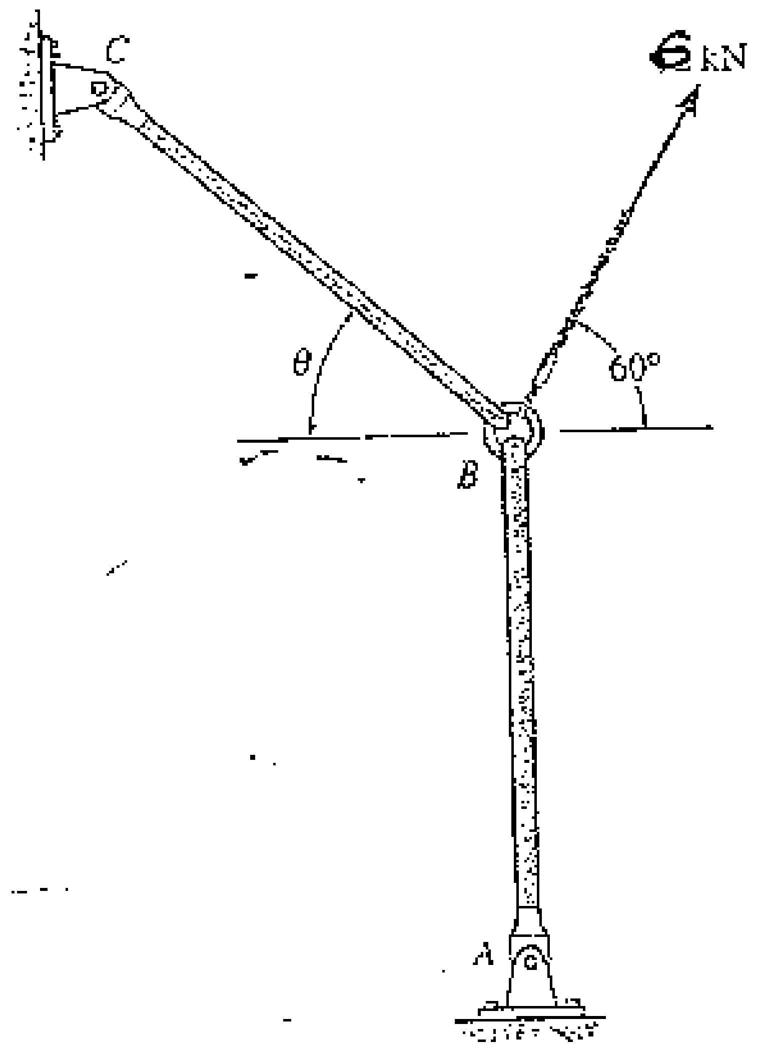
$\therefore P_{max} = 6.82\ kip$ //

(9)

PROBLEM (4) (1-68)

*1–68. Rods AB and BC have diameters of 25 mm and 18 mm, respectively. If a load of 6 kN is applied to the ring at B, determine the average normal stress in each rod if $\theta = 60°$.

1–69. Rods AB and BC each have a diameter of 4 mm. If a load of 6 kN is applied to the ring at B, determine the smallest angle θ of rod BC so that the average normal stress in each rod is equivalent.



Probs. 1–68/1–69

Solution

Given:-

$\theta = 60°$

$A_{AB} = \frac{\pi}{4} \times 25^2$

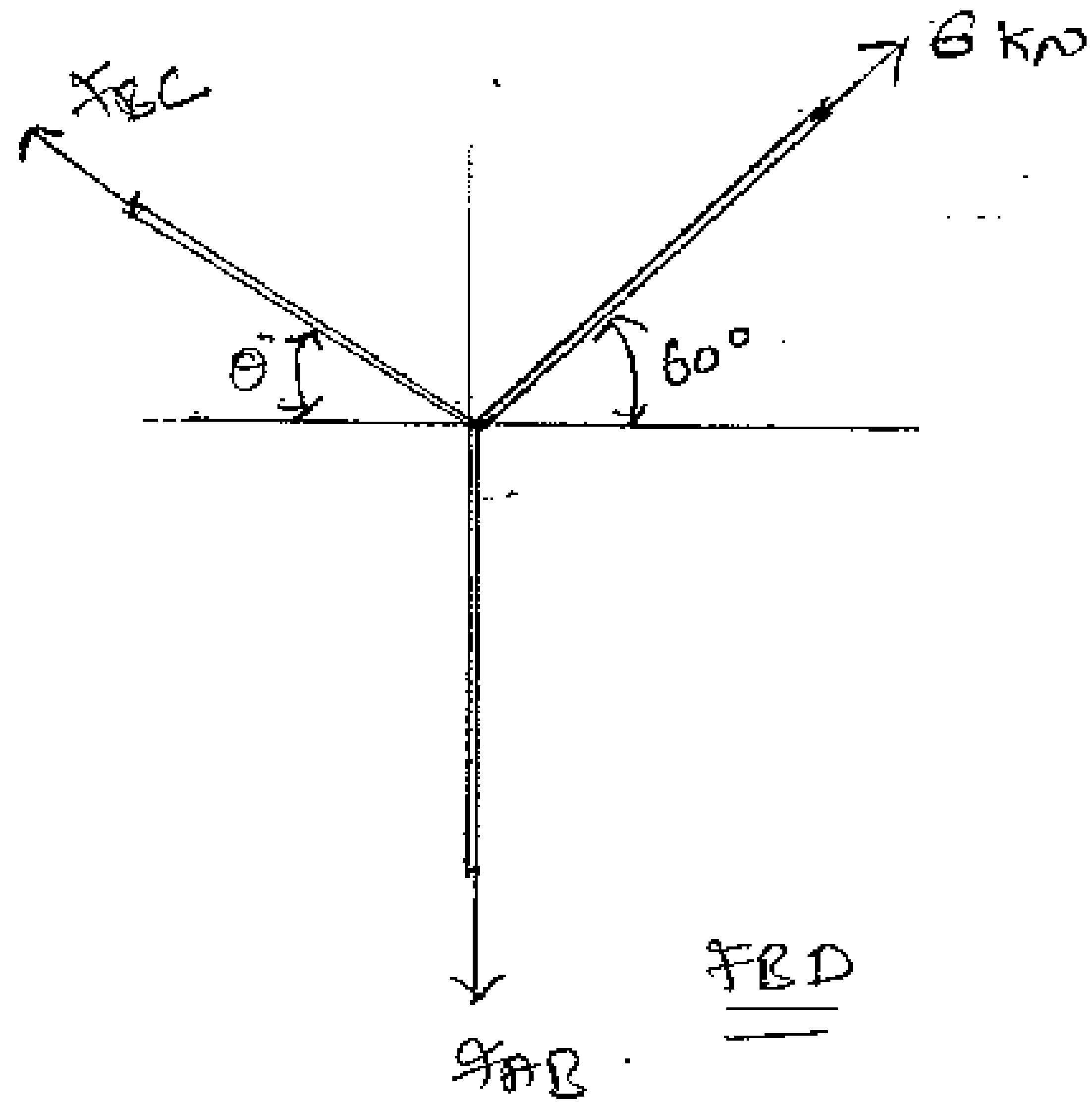
$= 490.874\ mm^2$

$A_{BC} = \frac{\pi}{4} \times 18^2$

$= 254.47\ mm^2$

$\sigma_{AB} = \sigma_{BC}$

$\Rightarrow \frac{F_{AB}}{A_{AB}} = \frac{F_{BC}}{A_{BC}} \rightarrow (1)$



FBD

Equations Of Equilibrium

$\overset{+}{\rightarrow} \Sigma F_x = 0$

$6\cos 60° = F_{BC}\cos\theta$

$\therefore F_{BC} = \frac{3}{\cos\theta}$

$+\uparrow \Sigma F_y = 0$

$F_{BC}\sin\theta° + 6\sin 60° - F_{AB} = 0$

$\Rightarrow 3\frac{\sin\theta}{\cos\theta} + 5.196 - F_{AB} = 0$

$\Rightarrow F_{AB} = 3\tan\theta + 5.196$

sub in (1)

$\therefore \frac{3\tan\theta + 5.196}{490.874} = \frac{3/\cos\theta}{254.47}$

$\Rightarrow 3\sin\theta + 5.196\cos\theta = 5.79$

by solving above we get

$\theta = 45.1°$

HW#2

Solve the following problems in the text:

1 – 107

1 – 111

2 – 3

2 – 13

3 – 7

3 – 13

3 – 39

HW # 3

Solve the following problems in the text :

4-3

4-21

4-31

4-39

4-55

4-74

4-85

HW #4

Solve the following problems in the text:

4-77

4-80

4-85

4-87

4-95

4-100

4-101