بسم الله الرحمن الرحيم

King Fahd University of Petroleum & Minerals

DEPARTMENT OF CIVIL ENGINEERING

Semester 132

CE 203 STRUCTURAL MECHANICS I

Major Exam I

Saturday, April 5, 2014 7:00-9:00 P.M.

KEY SOLUTION

Note to Students

Even though the course is not "standard grading", ***being around the average does not indicate C performance, since there is a minimum amount of course comprehension needed to pass the course satisfactorily*****, irrespective of the exam average and the performance of other students.**
Therefore, students who did poorly in this exam should do double effort in the remaining of the semester to avoid disappointing grade.

After reviewing the key solution and still having a concern about your mark, you may consult with the faculty members who prepared, solved, and graded each problem.

The deadline for review is Thursday April 17, 2014.

Problem	Solved & Graded by
1	Dr. Mohammad Al-Osta
2	Dr. Abdulrahman Khathlan
3	Dr. Abdulrahman Khathlan
4	Dr. Shamshad Ahmad

Notes:

1. **A sheet that includes selected Basic Formulae and definitions is provided with this examination.**
2. **Write clearly and show all calculations, FBDs, and units.**

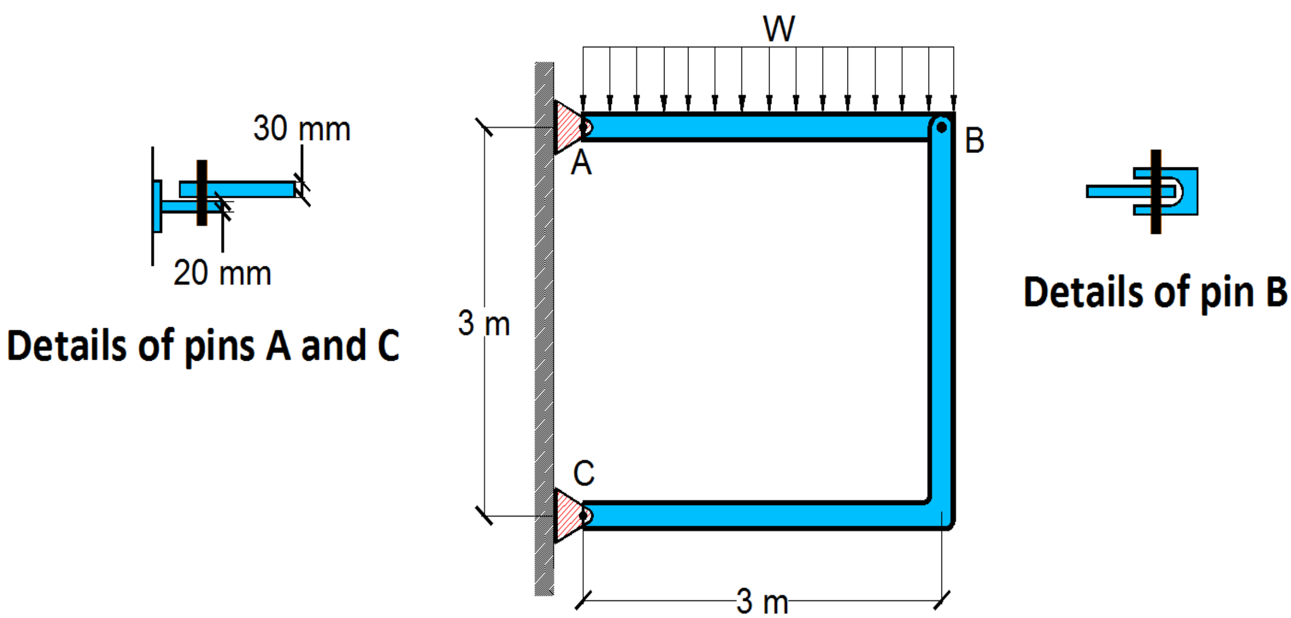
CE 203

For the frame (shown in figure below) determine the following:

(a) The intensity ***W*** of the maximum distributed load that can be applied to member **AB**, if:

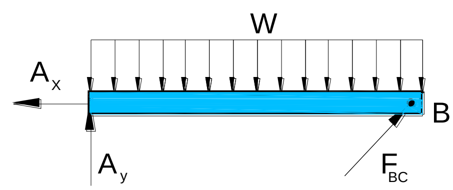
- **the failure shear stress for the pins at A and C is (τ_{fail}) = 200 MPa, a factor of safety of F.S. = 1.5 and the diameter of the pins at A and C is 22 mm; and**
- **the failure bearing stress for the assembly at A and C is (σ_b)$_{fail}$ = 400 MPa and a factor of safety of F.S. = 1.8.**

(b) Use the distributed load ***W*** in **part (a)** to find the smallest diameter of the **pin** at **B** if allowable shear stress **(τ_{allow}) = 80 MPa.**



Solution:

(a) The intensity ***W*** of the maximum distributed load that can be applied to member **AB**



F.B.D (Member AB)

The support reactions at A and C.

Member AB

$$\circlearrowright + \sum M_A = 0$$

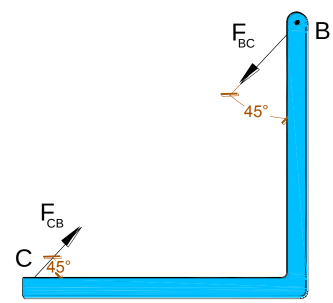
$$F_{BC} \times 3.0 \times \sin 45 - 3W \times 1.5 = 0\,; \quad F_{BC} = 2.121\ W$$

$$+\uparrow \sum Fy = 0$$

$$-3W + F_{BC} \times \sin 45 + Ay = 0\,; \quad Ay = 1.5W \ \uparrow$$

$$+\rightarrow \sum Fx = 0$$

$$F_{BC} \times \cos 45 - Ax = 0\,; \quad Ax = 1.5W \ \leftarrow$$



F.B.D (Member BC)

Member BC

$$+\sum F = 0$$

$$-F_{BC} + F_{CB} = 0\,; \quad F_{CB} = 2.121W$$

Res. forces:

$$F_A = \sqrt{A_y^2 + A_x^2} = \sqrt{(1.5W)^2 + (1.5W)^2} = 2.121W$$

Find W from Shear:

Force @ v pin A = Force @ pin C = 2.121W

$$\tau_{all} = \frac{\tau_{fail}}{F.S.} = \frac{200}{1.5} = 133.333\ MPa$$

$$(\sigma_b)_{all} = \frac{(\sigma_b)_{fail}}{F.S.} = \frac{400}{1.8} = 222.222\ MPa$$

At Pins single shear:

$$A = \frac{\pi d^2}{4} = \frac{\pi 22^2}{4} = 380.133 \text{ mm}^2$$

$$\tau = \frac{V}{A} \quad \Longrightarrow \quad 133.33 = \frac{2.121W*1000}{380.133} \quad \Longrightarrow W = 23.896 \ \frac{kN}{m} \qquad (1)$$

Find W from bearing:

Force @ pin A = Force @ pin C = 2.121W

$$(\sigma_b)_{all} = \frac{(\sigma_b)_{fail}}{F.S.} = \frac{400}{1.8} = 222.222 \text{ MPa}$$

$$A_{min} = \text{td} = 20(22) = 440 \text{ mm}^2$$

$$\sigma = \frac{V}{A} \quad \Longrightarrow \quad 222.2222 = \frac{2.121W*1000}{440} \quad \Longrightarrow W = 46.1 \ \frac{kN}{m} \qquad (2)$$

From Eqs. (1) and (2) Take $W = 23.896 \ \frac{kN}{m}$

(b) Use the distributed load ***W*** in **part (a)** to find the smallest diameter of the **pin** at **B** if allowable shear stress **(τ_{allow}) = 80 MPa.**

Force @ pin B = 2.121W

Double shear :

V= 2.121W/2 = 2.121*23.896/2= 25.342 kN

$$\tau = \frac{V}{A} \quad \Longrightarrow \quad 80 = \frac{25.342*1000}{\frac{\pi d^2}{4}} \quad \Longrightarrow d = 20.08 \, mm$$

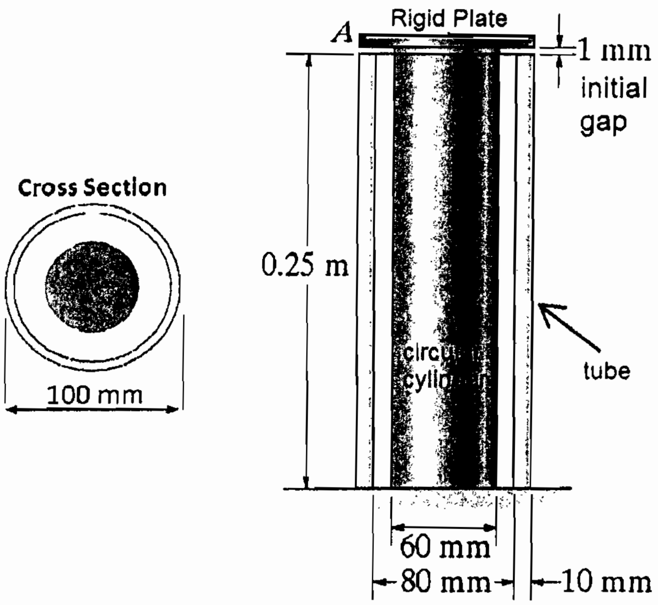
Problem 2: (30 points)

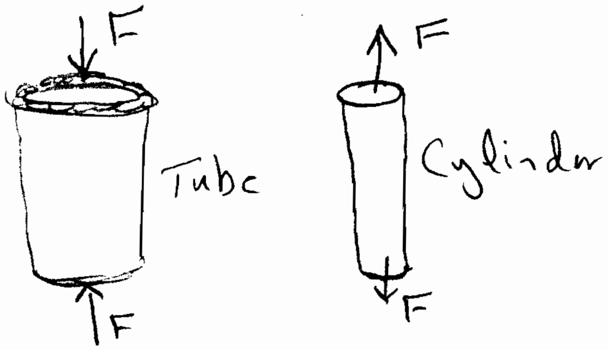
A circular rod sits inside a circular tube as shown in the figure. Both rods are made of the same material and both are fixed to the floor. The temperature of the **tube only** is increased by (ΔT).

Determine the value of (ΔT) needed to produce a normal stress in the tube equal to 10 MPa.

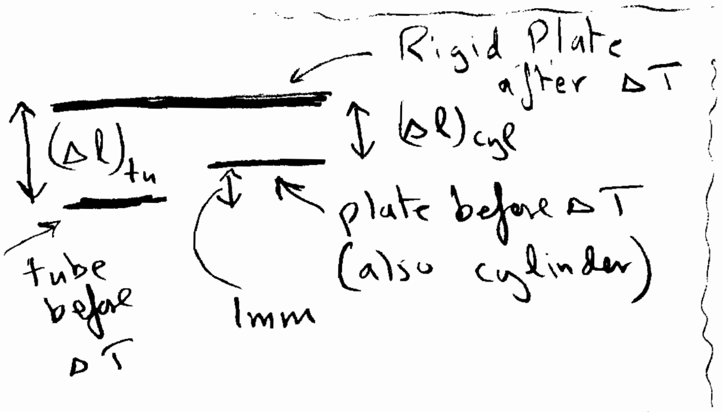
E = 10 GPa , α = 40 X 10^{-6} /^{0}C

Because there is stress in the tube, then definitely, the gap has closed and the tube began pulling the cylinder due to ΔT.





From the F.B.D. & $\Sigma F_y = 0$
F is the same in both rods, but opposite direction



Compatibility Eqn

$$(\Delta l)_{tube} = (\Delta l)_{cyl} + 1 \text{ mm}$$

$$(\alpha l \Delta T) - \frac{(F)(250)}{(10{,}000)A_{tu}} = \frac{(F)(251)}{(10{,}000)A_{cy}} + 1$$

$$A_{tube} = \pi(50^2 - 40^2) = 900\pi \text{ mm}^2$$

$$A_{cy} = \pi(30)^2 = 900\pi \text{ mm}^2$$

using $\sigma_{tub} = 10$ MPa

$$F = (\sigma)(A_{tu}) = (10)(900\pi) = 28274 \text{ N}$$

$$(40 \times 10^{-6})(250)\Delta T - .25 = .251 + 1$$

$$.01\ \Delta T = 1.501$$

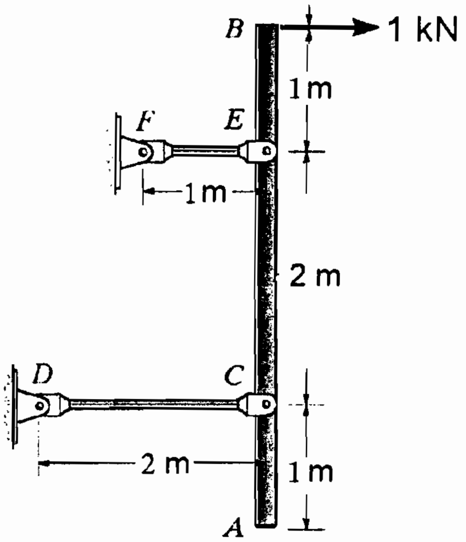
$$\boxed{\Delta T = +150.1\ ^{\circ}C}$$

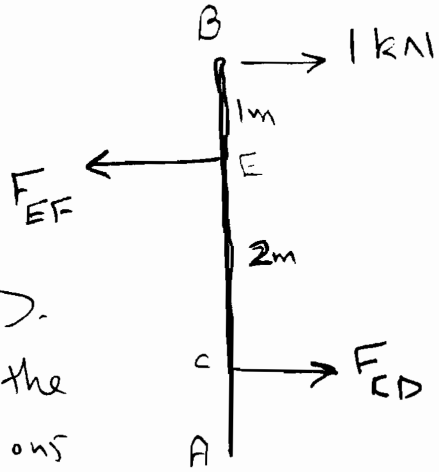
Problem 3: (20 points)

Rigid beam AB is supported using two rods CD and EF as shown.

Determine the magnitude and direction of the horizontal displacement of point A.

For the rods : **E =100 GPa , and Area = 100 mm²**





F.B.D.
guess the reactions

$+\circlearrowleft \Sigma M_c = 0 \qquad 2F_{CD} - (1)(1) = 0$

$\xrightarrow{+} \Sigma F_x = 0 \qquad 1 + F_{CD} - F_{EF} = 0$

$F_{CD} = +.5\text{ kN}$, $F_{EF} = +1.5\text{ kN}$ } + means that the assumed direction is correct

EF: F_{EF} ← ▭ → F_{EF}

$N = F_{EF} = +1.5\text{ kN}$

CD: F_{CD} → ▭ ← F_{CD}

$N = -F_{CD} = -.5\text{ kN}$

$$(\Delta l)_{EF} = \frac{Nl}{EA} = \frac{(1500)(1000)}{(100{,}000)(100)}$$

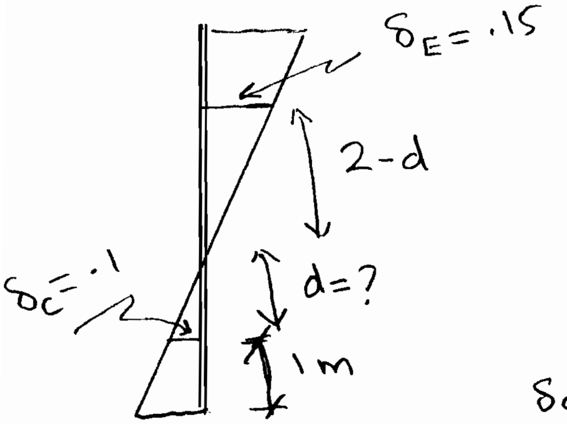
$(\Delta l)_{EF} = +0.15\text{ mm}$

$\delta_E = 0.15\text{ mm} \rightarrow$

$$(\Delta l)_{CD} = \frac{(-500)(2000)}{(100{,}000)(100)}$$

$(\Delta l)_{CD} = -0.1\text{ mm}$

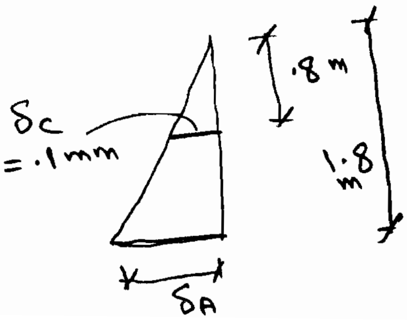
$\delta_c = 0.1\text{ mm} \leftarrow$



Using similarity of Triangles

$$\frac{d}{2-d} = \frac{0.1}{0.15}$$, solve for d

$d = 0.8\text{ m}$



$$\frac{\delta_A}{\delta_c} = \frac{1.8}{.8}$$

$\delta_A = 0.225\text{ mm} \leftarrow$

Ans

Problem 4: (25 points)

A solid block is subjected to a compressive force acting along *y*-axis, as shown below. The deformations in the *x* and *y*-directions were measured as $\delta_x = +0.014$ mm and $\delta_y = -0.048$ mm, respectively.

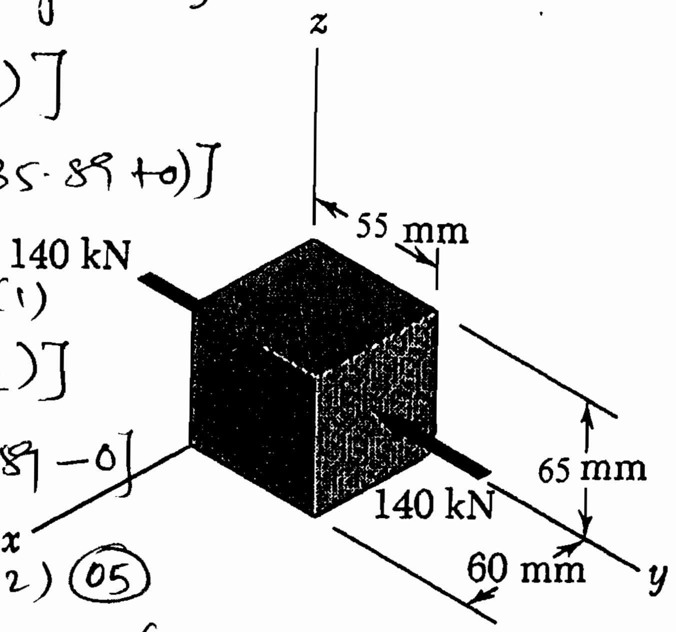
$\sigma_x = 0, \quad \sigma_y = \frac{-140\times10^3}{60\times65} = -35.89$ MPa

Determine:

a) the deformation in the *z*-direction (δ_z) $\quad \sigma_z = 0$

b) the force to be applied along *z*-axis to keep the deformation in the *z*-direction, δ_z as zero.

$\epsilon_x = \frac{0.014}{60} = 2.33\times10^{-4}, \quad \epsilon_y = \frac{-0.048}{55} = -8.727\times10^{-4}$



$\epsilon_x = \frac{1}{E}[\sigma_x - \nu(\sigma_y + \sigma_z)]$

$\Rightarrow 2.33\times10^{-4} = \frac{1}{E}[0 - \nu(-35.89 + 0)]$

$\Rightarrow \nu = 6.501\times10^{-6} E \quad \cdots (1)$

$\epsilon_y = \frac{1}{E}[\sigma_y - \nu(\sigma_x + \sigma_z)]$

$\Rightarrow -8.727\times10^{-4} = \frac{1}{E}[-35.89 - 0]$

$\Rightarrow E = 41125$ MPa $\quad \cdots (2)$ (05)

From Eq. (1), $\nu = 6.501\times10^{-6} \times 41125 = 0.267$ (05)

(a) $\epsilon_z = \frac{1}{E}[\sigma_z - \nu(\sigma_x + \sigma_y)] = \frac{1}{41125}[0 - 0.267(0 - 35.89)]$

$\Rightarrow \epsilon_z = 2.33\times10^{-4} = \frac{\delta_z}{65}$

$\Rightarrow \delta_z = +0.0151$ mm Ans (05)

(b) $\delta_z = 0, \therefore \epsilon_z = 0 = \frac{1}{E}[\sigma_z - \nu(\sigma_x + \sigma_y)]$

$\Rightarrow \sigma_z - 0.267(0 - 35.89) = 0$

$\Rightarrow \sigma_z = -9.582$ MPa $= 9.582$ MPa (C) (06)

$\therefore P_z = A_z \times \sigma_z = 55\times60\times9.582$

$= 31622$ N $= 31.622$ kN (C) (04)

Ans