KEY SOLUTION FOR CE203-EXAM 1

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 each problem, who are:

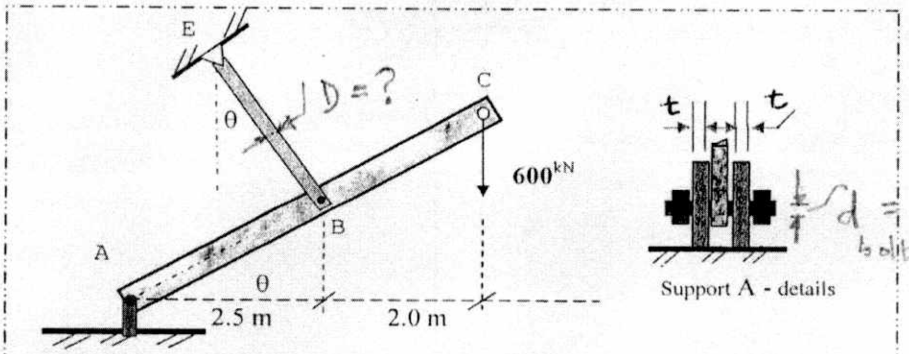
Problem # 1	Dr. S.A. AL-Ghamdi
Problem # 2	Dr. M.M. AL-Zahrani
Problems # 3 & 4	Dr. H.N. AL-Ghamedy
Problem # 5	Dr. Shamshad Ahmad

The deadline for review is Wednesday November 14, 2012.

Problem- The bar ABC is supported by a pin-support at A and a short link BE which has a circular cross-section having a diameter D. For the load shown and with the information listed in the Table:

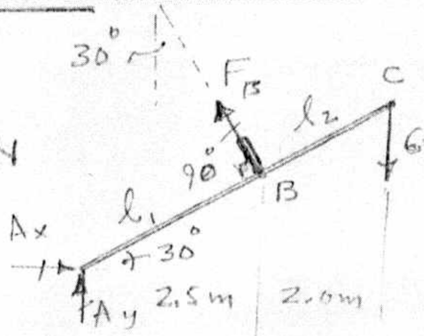
a. Determine the required diameter D of the cross-section of link BE.
b. Determine the shear stress in the bolt at pin-support A which has a diameter of 40 mm.
c. Determine the required plate thickness t at support A.

Given	θ	Safety factor	Material Ultimate Strength (MPa)	
			Normal σ	Bearing σ
Value	30°	1.5	450.	200.



Based on the FBD & Equilibrium Equations:

$l_1 \cos 30^\circ = 2.5 \Rightarrow l_1 = 5/\sqrt{3}$ m



$600.(4.5) - F_B l_1 = 0$

$F_B = 600.(4.5)\sqrt{3}/5 = 935.3$ kN

5) $A_y = 600. - F_B \cos 30^\circ = -210.$ kN

$A_x - F_B \sin 30^\circ = 0 \Rightarrow A_x = 467.7$ kN

$A = \sqrt{A_x^2 + A_y^2} = 512.7$ kN

a) Link BE with circular c/s : $A = \pi D^2/4$

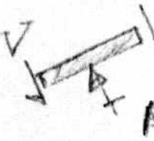
$\sigma_{all} = 450/1.5 = 300$ MPa $\geq \sigma_{max} = N/A$

5) ∴ $A_{req'd} = N/\sigma_{all} = F_B/300\times10^3 = 3.120\times10^{-3}$ m^2

∴ Required $D = \left(\frac{4A_{req'd}}{\pi}\right)^{1/2} = 6.30\times10^{-2}$ m $\simeq 6.3$ cm

b) Shear Stress τ in Bolt at A:

$A - 2V = 0 \Rightarrow V = A/2 = 256.4$ kN

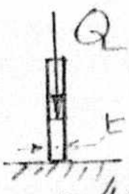


$d_{bolt} = 40.$ mm
Double shear

5) $\tau = V/A_{bolt} = 256.4/[\pi(0.04)^2/4]$

$\cong 204.0$ MPa

c) Required thickness t of vertical stand at Support A:



∵ $Q = V$ then $\sigma_b = Q/A_b = V/t\,d_{bolt} \ngtr \sigma_b^{all}$

5) ∴ Req'd $t = V/(d_{bolt} * \sigma_b^{all}) = \frac{256.4 \text{ kN}}{(0.04\times200./1.5)\times10^3} \simeq 4.81$ cm

Problem 2: (20 points)

The stress-strain diagram for a specimen having a length of 300 mm and a diameter of 25 mm is shown below.

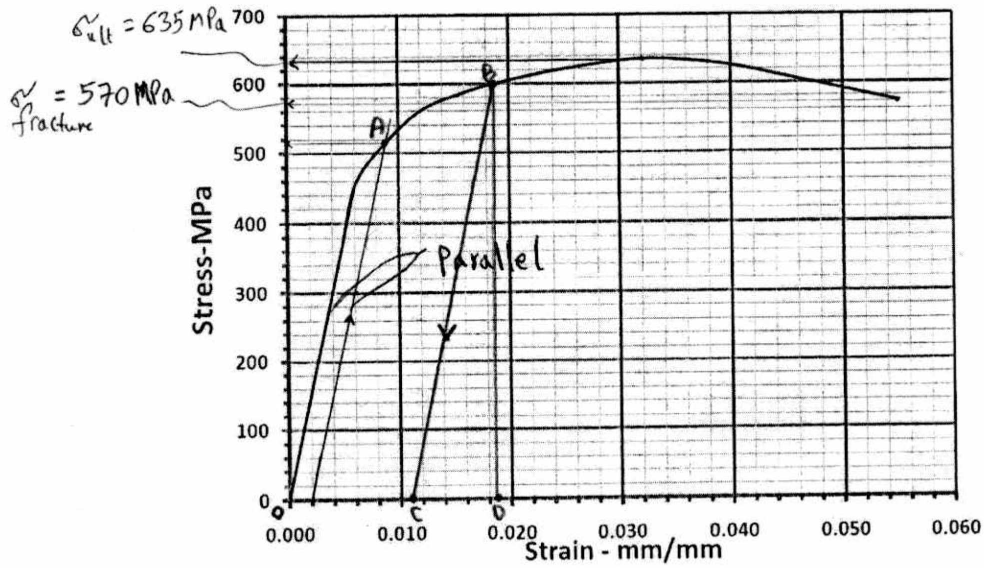
a. Determine the modulus of elasticity, the ultimate stress and the fracture stress.

b. Determine the yield strength using the 0.2% offset method.

c. Determine the new length and diameter when the specimen is stressed to 400 MPa.

d. Determine the final length when the specimen is stressed to 600 MPa and then unloaded.

ν= 0.35



The modulus of elasticity, $E = \dfrac{300\,MPa - 0}{0.004\,\frac{mm}{mm} - 0} = 75 \times 10^9\,Pa$. (3)

The ultimate stress, $\sigma_{ult} = 635\,MPa$. (1)

The fracture stress, $\sigma_{fracture} = 570\,MPa$. (1)

Using 0.2% offset method, the line parallel to the initial straight line of the stress-strain diagram starting from $\epsilon = 0.002\,\frac{mm}{mm}$ as shown in the diagram. The intersection point on the curve represents the yield strengthe which is, $\sigma_{ys} = 515\,MPa$. (3)

When the specimen is stressed to 400 MPa $\Rightarrow \epsilon = 0.005333\,\frac{mm}{mm}$ (2)

Using the modulus of elasticity.

- New length of the specimen $= 300\,mm + (0.005333\,\frac{mm}{mm} \times 300\,mm)$ (2)
$= 301.600\,mm$.

- New diameter of the specimen $= 25\,mm - (0.35 \times 0.005333 \times 25\,mm)$
$= \underline{24.953\,mm}$. (2)

d) when the specimen is stressed to 600 MPa and then unloaded.

①

At 600 MPa $\Rightarrow$ the strain, $\epsilon = 0.0185 \frac{mm}{mm}$

We draw straight line BC from B which is parallel to the straigh portion of the curve (elastic portion).

From the triangle CBD:

②

$$E = \frac{BD}{CD} \Rightarrow CD = \frac{600 \times 10^6 \, Pa}{75 \times 10^9 \, Pa} = 0.008 \frac{mm}{mm}$$

This represents the recovered elastic strain.

②

$\therefore$ The permenant strain $= \epsilon_{perm} = \epsilon_{CD} = 0.0185 - 0.008$

$$= 0.0105 \frac{mm}{mm}.$$

$\therefore$ The final length of the specimen $= L_o + (\epsilon_{perm} * L_o)$

$$= 300\,mm + \left(0.0105 \frac{mm}{mm}\right) \cdot (300\,mm)$$

$$= \underline{303.15\,mm.}$$

①

Problem 3: (20 points)

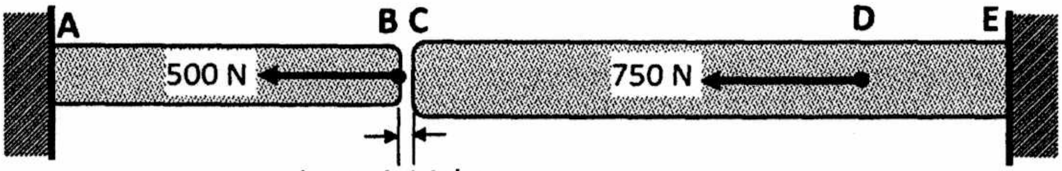
In the figure shown,

a- prove that the problem is ***statically determinate*** after applying the load and temperature;

b- based on the conclusion of pat (a), determine the **stresses in AB, CD, and DE**; *indicate Tension or Compression.*

Note that all dimensions given, including the gap, are before applying the load and temperature.

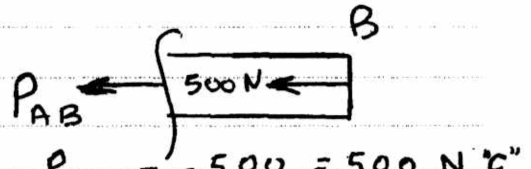
Member \ Properties	L (m)	A (m^2)	E (GPa)	ΔT (°C)	α (/°C)
AB	0.2	$20\,(10)^{-6}$	50	+20	$10\,(10)^{-6}$
CD	0.25	$25\,(10)^{-6}$	100	-10	$20\,(10)^{-6}$
DE	0.1	$25\,(10)^{-6}$	100	-10	$20\,(10)^{-6}$



pts.

a)

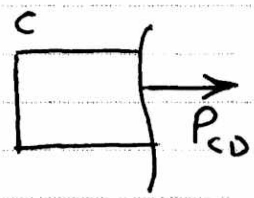
(2) FBD's are drawn [SD: gap "not closed"]



$P_{AB} = -500 = 500$ N "C"

(2) $\delta^P_{AB} = \dfrac{-500(0.2)}{20(10)^{-6}(50)(10)^9}$

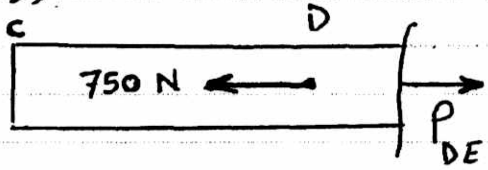
$= -1(10)^{-4}\,m = -0.1$ mm $(\overset{B}{\leftarrow})$



$P_{CD} = 0$

(1) $\delta^T_{AB} = \alpha\,\Delta T L = 10(10)^{-6}(20)(0.2)$

$= 4(10)^{-5}\,m = 0.04$ mm $(\overset{B}{\rightarrow})$



$\Delta_B = -0.1 + 0.04 = -0.06$ mm $(\leftarrow)$

$P_{DE} = 750$N "T"

(1) $\delta^P_{CD} = 0$

(1) $\delta^T_{CD} = 20(10)^{-6}(-10)(0.25) = -5(10)^{-5}\,m = -0.05$ mm $(\overset{C}{\rightarrow})$

(2) $\delta^P_{DE} = \dfrac{750(0.1)}{25(10)^{-6}(100)(10)^9} = 3(10)^{-5}m = 0.03$ mm $(\overset{C}{\leftarrow})$

(1) $\delta^T_{DE} = 20(10)^{-6}(-10)(0.1) = -2(10)^{-5}\,m = -0.02$ mm $(\overset{C}{\rightarrow})$

$\Delta_C = 0.05 - 0.03 + 0.02 = 0.04$ mm $\rightarrow$

(2) $\Delta_{\text{change in gap}} = +0.06 + 0.04 = +0.1$ mm

$\text{gap}_{\text{after } P \,\&\, T} = 1 + 0.1 = 1.1$ mm

(2) $\boxed{\text{The gap does not close} \Rightarrow \text{statically determinate}}$

b)

(2) $\sigma_{AB} = -500/20(10)^{-6} \Rightarrow$ $\boxed{\sigma_{AB} = 25 \text{ MPa "C"}}$

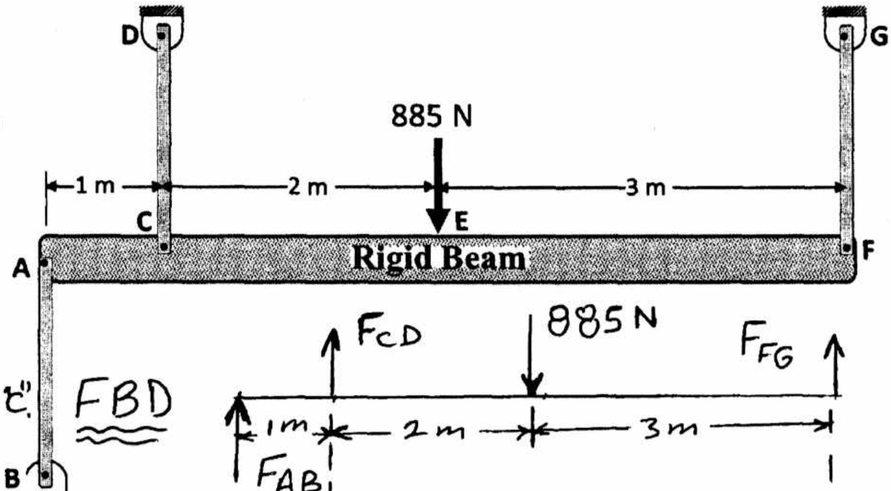
(1) $\boxed{\sigma_{CD} = 0}$

(2) (1) units $\sigma_{DE} = 750/25(10)^{-6} \Rightarrow$ $\boxed{\sigma_{DE} = 30 \text{ MPa "T"}}$

Problem 4: (20 points)

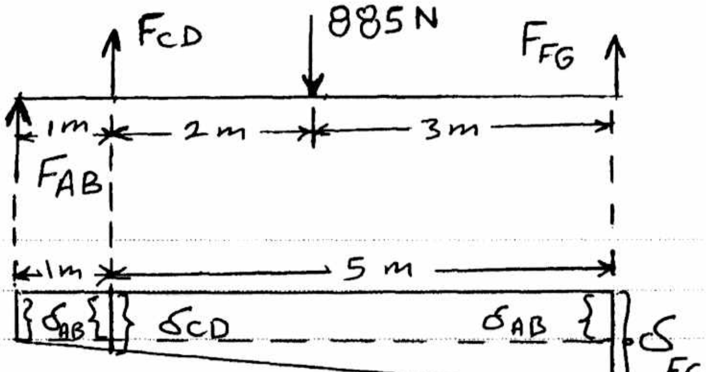
A rigid beam is supported by three links as shown in the figure. Determine the **forces in members (links) AB, CD, and FG**; *indicate Tension or Compression.* **All members have the same length, area, and material (L, A, E).**

Pts.



(2) The FBD is drawn. Note that F_{CD} and F_{FG} are assumed "T", while F_{AB} is assumed "C".

FBD



3 unknowns
2 equil. eqs. (ΣF_y & M)
⇒ stat. indet.

(4) geo. compat. is drawn.

Geom. Compat. or may assume ⇓

(same results)

* Equilibrium:

$+\uparrow \Sigma F_y = 0 \Rightarrow$

(2) $F_{AB} + F_{CD} + F_{FG} - 885 = 0$ ①

$+\circlearrowleft \Sigma M_F = 0 \Rightarrow 885(3) - F_{AB}(6) - F_{CD}(5) = 0$

(3) $\Rightarrow 6F_{AB} + 5F_{CD} - 2655 = 0$ ②

* Geometric Compatibility: Note that AB got shorter ⇒

δ_{AB} is neg. ⇒

(4) $$\frac{\delta_{CD} - (-\delta_{AB})}{1} = \frac{\delta_{FG} - (-\delta_{AB})}{6} \Rightarrow$$

$$6\delta_{CD} + 6\delta_{AB} = \delta_{FG} + \delta_{AB}$$

$$\Rightarrow 6\delta_{CD} + 5\delta_{AB} - \delta_{FG} = 0$$

* Material Behavior : $\delta = PL/EA$ {Note: $\frac{L}{EA}$ is common}

(2) $\Rightarrow 6F_{CD}\left(\frac{L}{EA}\right) - 5F_{AB}\left(\frac{L}{EA}\right) - F_{FG}\left(\frac{L}{EA}\right) = 0 \Rightarrow$ {Note F_{AB} is ⊖ "C"}

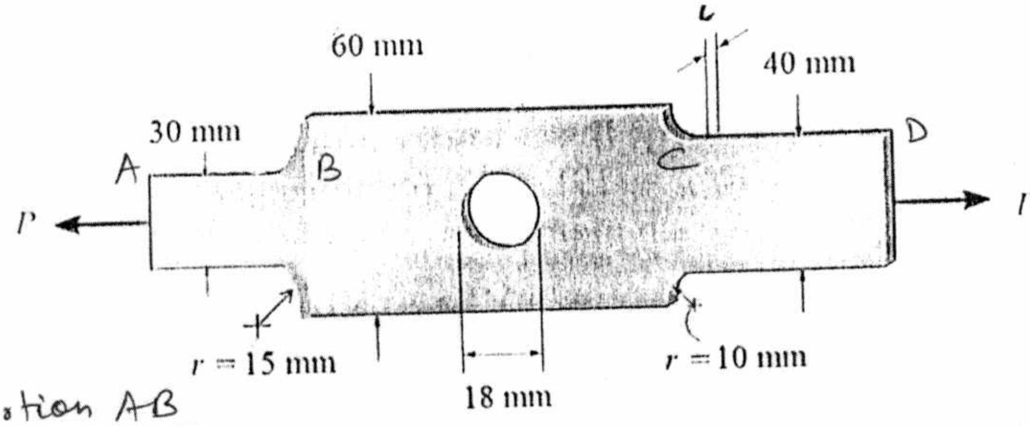
$$6F_{CD} - 5F_{AB} - F_{FG} = 0 \quad ③$$

Solving eqs. ①, ②, and ③ yields

(3) $\boxed{F_{AB} \approx 228\,N \text{ "C"}}$ $\boxed{F_{CD} \approx 257\text{ N "T"}}$ $\boxed{F_{FG} \approx 400\text{ N "T"}}$ ⇐ {All as shown in FBD

Problem 5: (20 points)

The plate shown in the figure has a uniform thickness t and is subjected to a tensile force $P = 10$ kN. Determine the required thickness of the plate if the allowable normal stress is 150 MPa.



Portion AB

$$\frac{r}{h} = \frac{15}{30} = 0.5 \; ; \quad \frac{w}{h} = \frac{60}{30} = 2$$

From graph, $K = 1.4$

$$\sigma_{avg.} = \frac{P}{ht} = \frac{10\times10^3}{30t} = \frac{10^3}{3t}$$

$$\sigma_{max} = K\,\sigma_{avg.} = \sigma_{allow}$$

$$\Rightarrow \quad 1.4 \times \frac{10^3}{3t} = 150 \Rightarrow t = \frac{1.4\times10^3}{3\times150} = 3.11 \text{ mm}$$

Portion BC

$$\frac{2r}{w} = \frac{18}{60} = 0.3 \; ; \text{ from graph, } K = 2.3$$

$$\sigma_{avg.} = \frac{P}{(w-2r)t} = \frac{10\times10^3}{(60-18)t} = \frac{10^4}{42t}$$

$$\sigma_{max} = K\,\sigma_{avg} = \sigma_{allow}$$

$$\Rightarrow \quad \frac{2.3\times10^4}{42t} = 150 \Rightarrow t = \frac{2.3\times10^4}{42\times150} = 3.65 \text{ mm}$$

Portion CD

$$\frac{r}{h} = \frac{10}{40} = 0.25 \; ; \quad \frac{w}{h} = \frac{60}{40} = 1.5$$

From graph, $K = 1.6$

$$\sigma_{avg.} = P/ht = \frac{10\times10^3}{40t} = \frac{10^3}{4t}$$

$$\sigma_{max} = K\,\sigma_{avg.} = \sigma_{allow}$$

$$\Rightarrow \quad 1.6\times\frac{10^3}{4t} = 150 \Rightarrow t = \frac{1.6\times10^3}{4\times150} = 2.66 \text{ mm}.$$

Therefore required thickness $= 3.65$ mm Ans