First Exam, Strength of Materials, Fall-2013

21/25

University of Jordan / Faculty of Engineering & Technology
Mechanical Engineering Department
Fall Semester 2012/2013

First Exam — **Date: Mar. 12th, 2013**
Strength of Materials — **Time: 75 Minutes**

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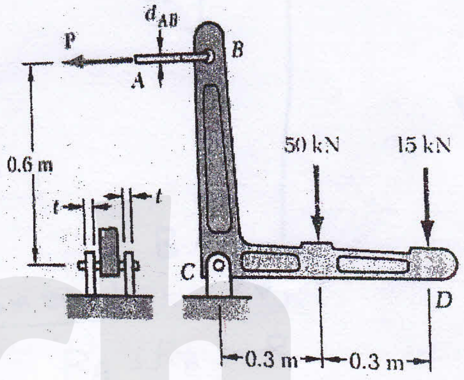
Question (1)……[7 points]

Two forces are applied to the bracket *BCD* as shown. (*a*) Knowing that the control rod *AB* is to be made of a steel having an ultimate normal stress of 600 MPa, determine the diameter of the rod for which the factor of safety with respect to failure will be 3.3. (*b*) The pin at *C* is to be made of a steel having an ultimate shearing stress of 350 MPa. Determine the diameter of the pin *C* for which the factor of safety with respect to shear will also be 3.3.

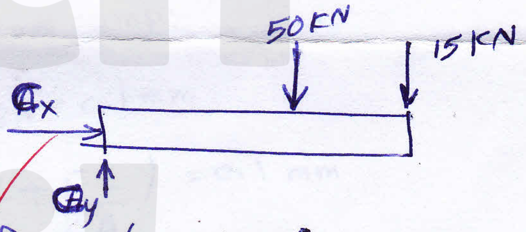


$+\circlearrowleft \Sigma M_C = 0$

$-15(0.6) - 50(0.3) + P(0.6) = 0$

$P(0.6) = 105$

$\boxed{P = 175\ kN}$



$\Sigma F_y = 0$

$C_y = 65\ KN$

$F.S = \dfrac{\sigma_{ult}}{\sigma_{allow}} \Rightarrow \sigma_{allow} = \dfrac{\sigma_{ult}}{F.S} = \dfrac{600 \times 10^6\ Pa}{3.3} = 181.81\ MPa$

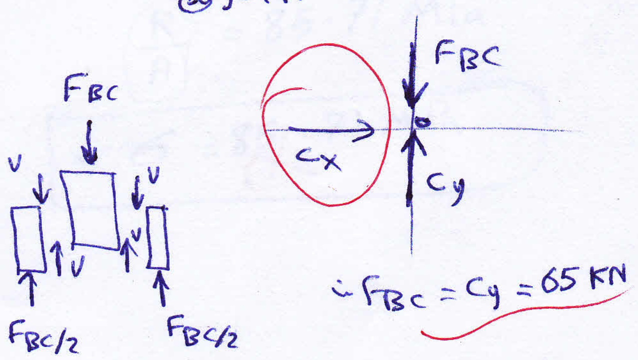
$181.81 \times 10^6 = \dfrac{175 \times 10^3\ N}{\frac{\pi}{4}(d)^2} \Rightarrow 142.8 \times 10^6\ d^2 = 175 \times 10^3$

$\boxed{d = 0.035\ m}$

(b) $\dfrac{3.3}{\cancel{F.S}} = \dfrac{350 \times 10^6\ Pa}{\tau}$

$\tau = \dfrac{350 \times 10^6}{3.3} = 106.06\ MPa$

@ joint C



$\therefore F_{BC} = C_y = 65\ KN$

$\tau = \dfrac{V}{\frac{\pi}{4}(d^2)}$

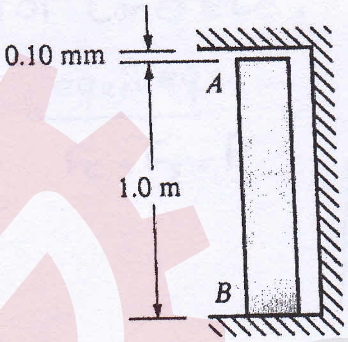
$106.06 \times 10^6 = \dfrac{F_{BC}/2}{\frac{\pi}{4}(d^2)}$

$d^2(83.3 \times 10^6) = 32.5 \times 10^3$

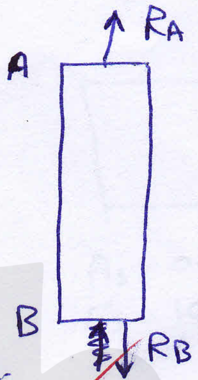
$\boxed{d = 0.0196\ m}$

Question (2)……[6 points]

A copper bar AB of length 1.0 m is placed in position at room temperature with a gap of 0.10 mm between end A and a rigid wall (see figure). Calculate the axial compressive stress σ in the bar if the temperature rises 40 °C. (For copper, use $\alpha = 17 \times 10^{-6}/°C$ and $E = 110$ GPa.)



⇒ F.B.D



from equil:-

$R_A = R_B = R$

from comp:-

$\delta_{BA} = 0.1$ mm

$\left(\alpha(\Delta T)L + \frac{FL}{EA}\right) = 0.1$ mm

$17\times10^{-6}(40)(1) + \frac{R(1)}{110\times10^{9}A} = 0.1$ mm

$6.8\times10^{-4} + \frac{R}{A}9.1\times10^{-12} = 0.1\times10^{-3}$ m

$\frac{R}{A}(9.1\times10^{-12}) = 7.8\times10^{-4}$

$\frac{R}{A} = 85.71$ MPa

$\therefore \sigma = 85.71$ MPa

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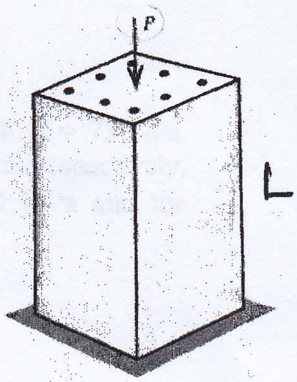
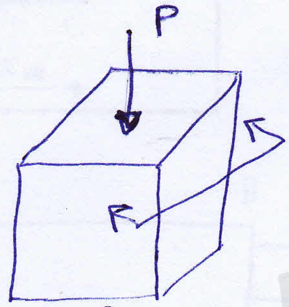
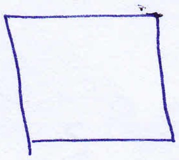
Question (3)……[6 points]

A square column of reinforced concrete is compressed by an axial force P (see figure). What fraction of the load will be carried by the concrete if the total cross-sectional area of the steel bars is one-tenth of the cross-sectional area of the concrete and the modulus of elasticity of the steel is ten times that of the concrete?



- E_s and A_s for Steel.
- E_c and A_c for Concrete.





$A_s = 0.1 A_c$

$E_s = 10 E_c$

~~$\sigma = \frac{P}{A}$~~

comp. eq:

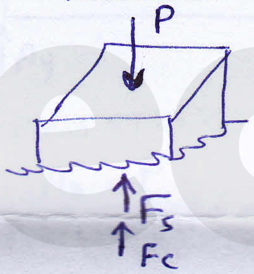
$\delta_c = \delta_s$

$\frac{F_c L}{E_c A_c} = \frac{F_s L}{E_s A_s}$

$\frac{F_s}{F_c} = \frac{E_s A_s}{E_c A_c}$

equil eq:

$F_c + F_s = P$



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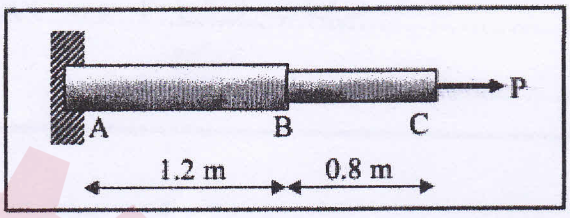
$\frac{F_s}{F_c} = \frac{(10 E_c)(0.1 A_c)}{E_c A_c} \Rightarrow \boxed{\frac{F_s}{F_c} = 1} \Rightarrow F_s = F_c$

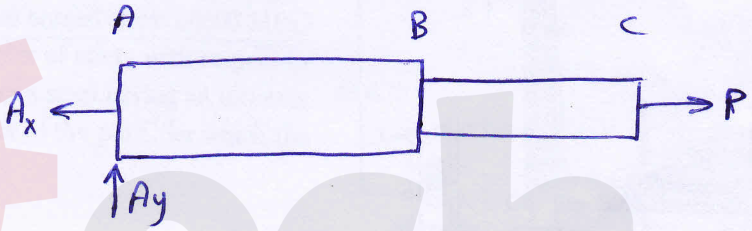
$2F_c = P$

$\boxed{F_c = P/2}$

Question (4)……[6 points]

Both portions of the shown rod ABC are made of aluminum for which E = 73 GPa. Knowing that the diameters of portions AB and BC are 30 and 20 mm, respectively, determine the largest axial force **P** that can be applied if σ_{all} = 160 MPa and the corresponding deflection at point **C** is not to exceed 2 mm.





from equil :-

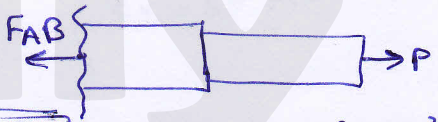
$A_x = P$

from comp :-

$\delta_{AC} = 2mm$ ---- ①

$\delta_{AC} = \delta_{AB} + \delta_{BC}$ ----

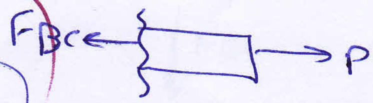
$\delta_{AB} = \frac{FL}{EA}$



$\delta_{AB} = \frac{P(1.2)}{E\ 3.93\times10^{-4}}$

$A_{AB} = \frac{\pi}{4}(0.03^2)$ ~~= 3.93×10⁻⁴ m²~~ 7.069×10⁻⁴ m²

$\delta_{BC} = \frac{FL}{EA} = \frac{P(0.8)}{E(3.14\times10^{-4})}$



$A_{BC} = \frac{\pi}{4}(0.02)^2 = 3.14\times10^{-4}\ m^2$

Sub in ①

$\frac{P(1.2)}{E(3.93\times10^{-4})} + \frac{P(0.8)}{E(3.14\times10^{-4})} = 0.002\ m$

$P\left(\frac{1.2\ m}{E(3.93\times10^{-4})} + \frac{0.8\ m}{E(3.14\times10^{-4})}\right) = 0.002$

5.816×10^{-8} ~~7.673×10~~ $P = 0.002\ m$

~~P = 26.06 KN~~

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$P(5.816\times10^{-8}) = 0.002\ m$

P = 34.4 KN

7.069×10^{-4}