NOTRE DAME UNIVERSITY

Faculty of Engineering

60/100

CEN 203 MECHANICS OF MATERIALS

NAME

Test # 1

Set D

Time : 75 minutes

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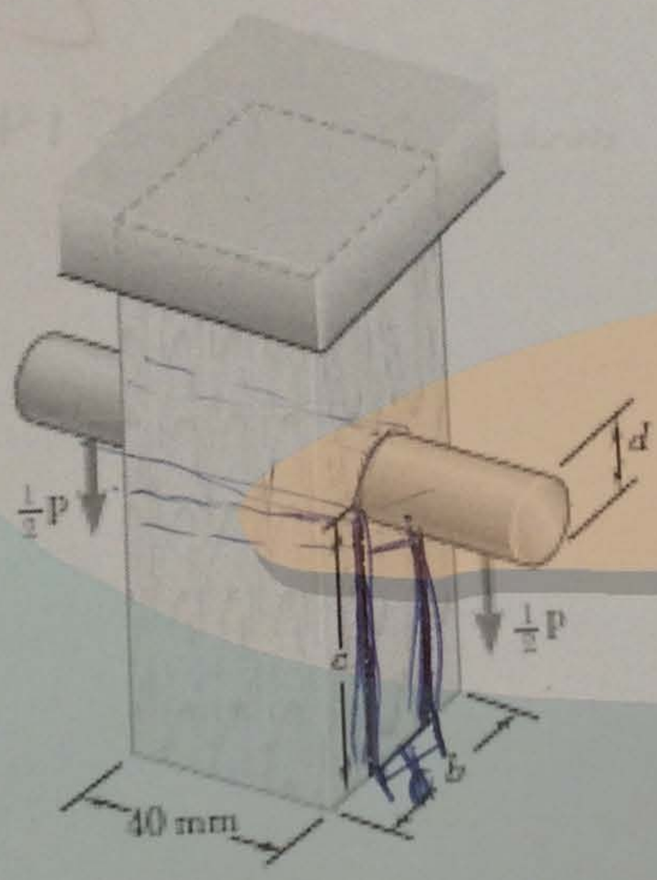
Problem B 20 points

A load **P** is supported as shown by a steel pin that has been inserted in a short wooden member hanging from the ceiling.

The ultimate strength of the wood used is 60 MPa in tension and 7.5 MPa in shear.
The ultimate strength of the steel is 145 MPa in shear.

Knowing that $b = 40$ mm, $c = 55$ mm, and $d = 12$ mm,

Determine the load **P** if an overall factor of safety of 3.2 is desired.



$\tau_w = 7.5$ MPa

$\sigma_w = 60$ MPa

$\tau_{st} = 145$ MPa

$b = 40$ mm

$c = 55$ mm

$d = 12$ mm

$F.S = \frac{\text{ultimate}}{\text{all}} = 3.2$

wood

$\tau_{all} = 2.34$ MPa

$\sigma_{all} = \cancel{45.31}$ MPa
18.75

steel

$\tau_{st\,all} = 45.31$ MPa

$\tau_w = \frac{P}{A} = \frac{P}{2(\frac{\pi}{4}d^2)}$

$2.34 = \frac{P}{2(\frac{\pi}{4}d^2)}$

$P = \cancel{264.5}$ N

$P = 529.0$ N

$\sigma_{all} = \frac{P}{A}$

$18.75 = \frac{P}{(\frac{\pi}{4}d^2)(40)}$

$P = 84780$ N

(-2) 2

$$\tau_w = \frac{P}{2(c \times b)}$$ double shear

$$2.34 = \frac{P}{2(40 \times 55)}$$

$$P = 10296\ N$$

$$\tau_{st} = \frac{1}{2(\frac{\pi}{4} d^2)}$$

$$P = 10243.68\ N$$

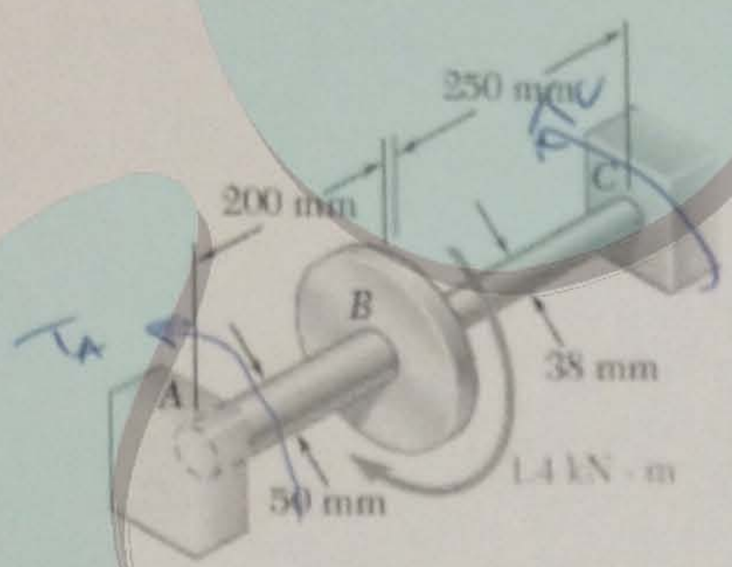
choosing The Lowest one $\Rightarrow P =$

14/30

Problem D 30 points

Two solid shafts AB & BC are made of steel ($G = 77.2$ GPa) and are connected to a coupling disk B and to fixed supports at A and C.
For the loading shown, determine:

(a) the reaction at supports A & C
(b) the maximum shearing stress in shaft AB
(c) the maximum shearing stress in shaft BC



$G = 77.26$ Pa

ϕ Phi
δ Delta
σ SIGMA

a) $T_A + T_C = 1.4 \times 10^3$ ✓

$\phi_{B/A} = \phi_{B/C}$

$$\frac{T_A(200)}{(\pi/4(50)^4)(77.2\times10^3)} = \frac{T_C(250)}{(\pi/4(38)^4)(77.2\times10^3)}$$ ✓ ✗ −4

$0.1019\,T_A = 0.2205\,T_C$ −2

$T_A = 2.164\,T_C$

$T_C = 442.4$ N ✓ $T_A = 957.57$ N −2

b) $\tau = \frac{T_{AB}\,c}{J} = \frac{(957.57)(50\times10^{-3})}{\frac{\pi}{2}(50\times10^{-3})^4} = 4.878\times10^6$ Pa

−2

c) $\tau = \frac{Tc\left(38\times10^{-3}\right)}{\frac{\pi}{2}\left(38\times10^{-3}\right)^4} = 5.14\times10^{6}\ Pa$

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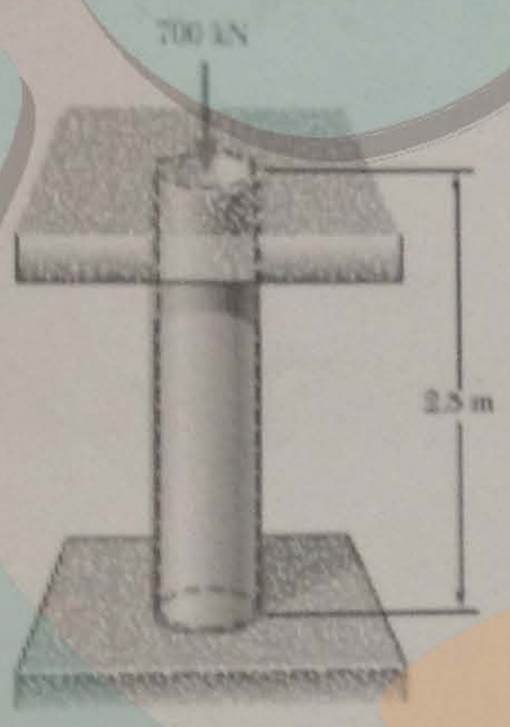
Problem C 15 points

A 2.5-m length of a steel pipe of 300-mm outer diameter and 15-mm wall thickness is used as a column to carry a 700-kN centric axial load.

Knowing that $E = 200$ GPa and $\nu = 0.30$. Determine:

(*a*) the change in length of the pipe
(*b*) the change in its outer diameter
(*c*) the change in its wall thickness



$d_2 = 300$ mm
$d_1 = 285$ mm

$L = 2.5$ m

$P = 700$ kN

$E = 200 \times 10^3$ MPa

$\nu = 0.3$

a) $\delta = \frac{PL}{AE} = \frac{(700 \times 10^3)(2.5 \times 10^3)}{\frac{\pi}{4}(300^2 - 285^2)(200 \times 10^3)} = 1.27$ mm

(-1)

b) $\nu = \frac{-\varepsilon_{lat}}{\varepsilon_{long}}$

$0.3 = \frac{-\varepsilon_{lat}}{\frac{L' - L}{L}}$

$0.3 = \frac{-\varepsilon_{lat}}{\frac{-1.27 \times 10^{-3}}{2.5 \times 10^3}}$

$\varepsilon_{lat} = 1.524 \times 10^{-7}$

$\frac{d_2' - d_2}{d_2} = 1.524 \times 10^{-7} \Rightarrow d_2' - d_2 = 4.572 \times 10^{-8}$ m

DD =

$$\frac{d_1' - d_1}{d_1} = 1.524 \times 10^{-7}$$

Dinner = 270 not 285

change in inner diameter = 4.33×10^{-8}

change in wall thickness = change in outer dia − change in inner dia

$4.572 \times 10^{-8} - 4.33 \times 10^{-8}$

change in wall Thickness = 2.4×10^{-9}

17/35

Problem A 35 points

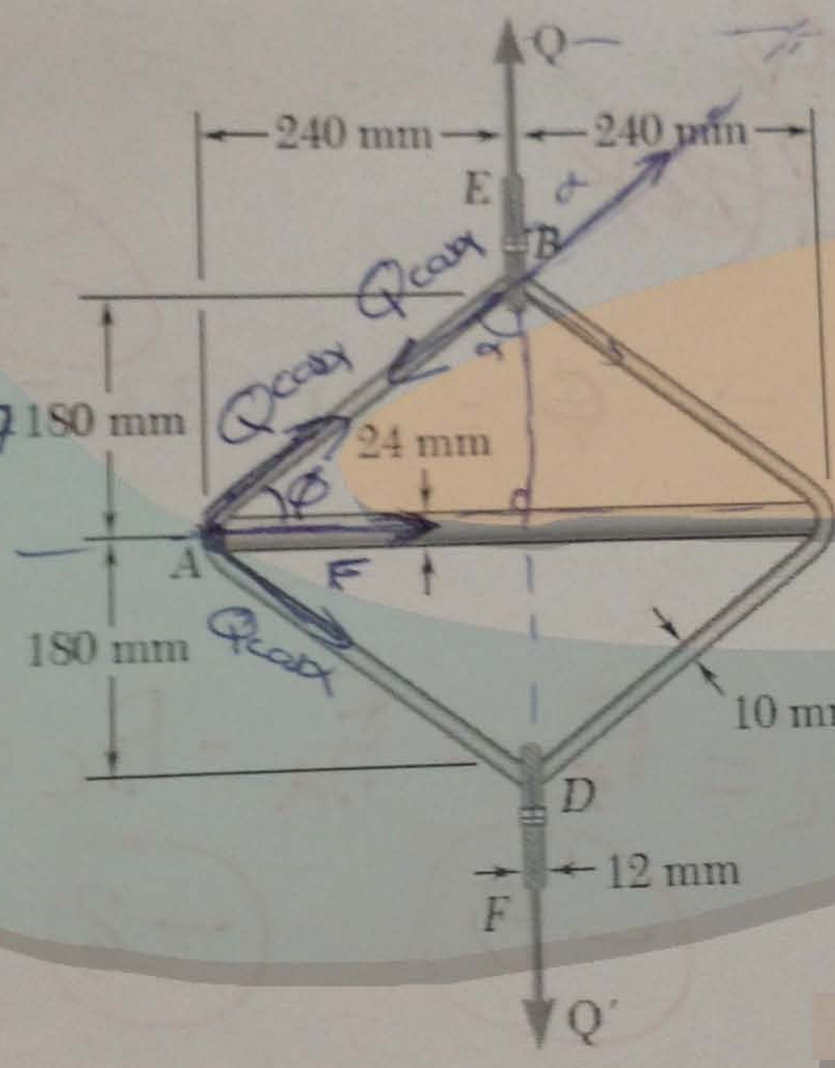
A steel loop *ABCD* of length 1.2 m and of 10-mm diameter is placed as shown around a 24-mm-diameter aluminum rod *AC*.

Cables *BE* and *DF*, each of 12-mm diameter, are used to apply the load **Q**.

The ultimate strength of the steel used for the loop and the cables is 480 MPa and that the ultimate strength of the aluminum used for the rod is 260 MPa.

Determine the largest load **Q** that can be applied if an overall factor of safety of 3 is desired.

Hint: Take advantage of symmetry and of the particular geometry.



Q = Q'

steel { l_{ABCD} = 1.2 m, d = 10 mm, τ_{us} = 480 MPa } ⇒ τ = 160 MPa

ϕ = 36.87

dl { d = 24mm, τ_{ud} = 260 MPa } τ_{all} = 86.66 MPa

cable BE/DF { d = 12mm, τ_{uc} = 480 MPa } ⇒ τ_{all} = 160 MPa

F.S = 3 ⇒ $\tau_c = \tau_b$ = 160 MPa

⇒ τ_{all} = 86.66

• for the cable ⇒ $\tau_c = \frac{P}{A}$

$160 = \frac{P}{\frac{\pi}{4}(12)^2}$ ⇒ P = 18086.4 N

for the steel:

$$\tan\alpha = \frac{240}{180} \Rightarrow \alpha = 53.13^\circ$$

$$160 = \frac{Q\cos\alpha}{\frac{\pi}{4}(10)^2}$$

$$Q = 20933.28\ N$$

5/6 Q (-1) (-1)

for The ael :

$$F_{ae} = 2\,\Phi\cos\alpha \times \cos\phi$$

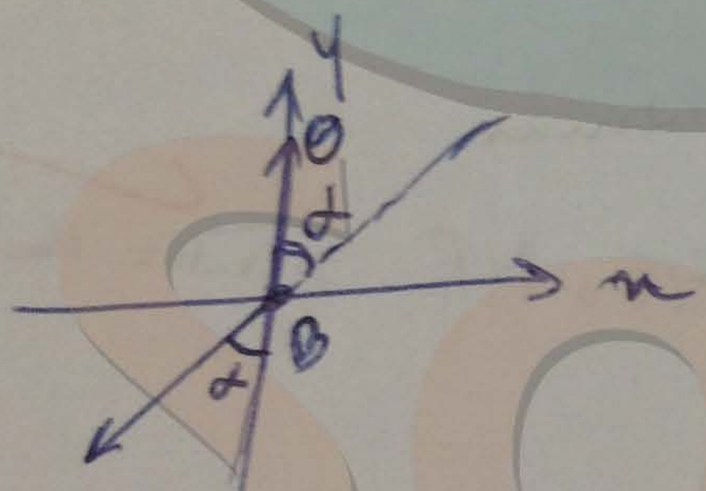
$$0.96\,\Phi$$

$$\sigma = \frac{0.96\,\Phi}{\frac{\pi}{4}(24)^2} = \frac{Q}{\frac{\pi}{4}(12)^2}$$

$$86.66 = \frac{0.96\,\Phi}{904.32} \Rightarrow \Phi = 81633.72\ N$$

$$F_{BC} = F_{BA} = F_{DA} = F_{DC} = \frac{5}{6}Q$$

(-5) (-2) (-2)



$$F_{AC} = -\frac{4}{3}Q$$

(-2)

Correct value (-5)

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