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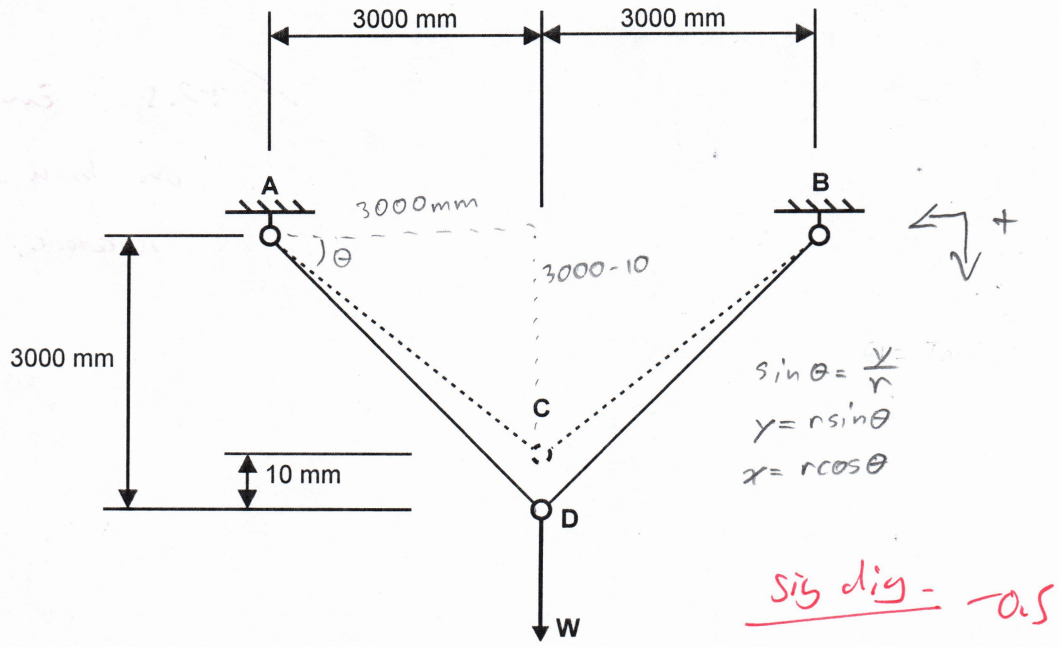
CIV 102F: Quiz #4 1300h-1500h October 3, 2019
Stress, Strain, Energy, Natural Frequency

Cables AD and BD are shown below. They are made out of high-alloy steel and support a weight W at Point D. The weight W causes the lower ring to deflect downwards 10 mm from the undeformed position at C. Both cables have an initial cross-sectional area of 10 mm^2.



Sig dig - -0.5

a) How much longer did the two wires get? What is the stress in these cables? What is the factor of safety against failure?
b) Calculate the value of W in kN which caused the 10 mm displacement. Assume that applying the weight has a negligible influence on the angle of the two wires.
c) Calculate the total strain energy in the two-wire system caused by applying the weight W.
d) How much energy can be absorbed by each wire before they begin to permanently deform?
e) What is the natural frequency of the system?
f) If weight W was increased such that the wires rupture, calculate how far point D would have moved relative to point C. Is it still reasonable to assume that the angle of the two wires is the same still? Calculate the final angle of the cables at points A and B when rupture occurs. *Hint: Use your material properties in your CIV102 notebook to calculate the length of the cables at failure, not Hooke's law.*

a.) $L_o = \sqrt{3000^2 + 2990^2} = 4235.576\text{mm}$ ✓ +2
$L_f = \sqrt{3000^2 \cdot 2} = 4242.641\text{mm}$ $\therefore \boxed{\Delta L = 7.065\text{mm}}$ $\therefore \varepsilon = \frac{\Delta L}{L_o} = 1.668\times10^{-3}$
$E = 200000\text{ MPa}$ $\therefore \sigma = E\varepsilon = 200000\text{ MPa}\cdot(1.668\times10^{-3}) = \boxed{333.6\text{ MPa} = \sigma}$ ✓ +1.
$FOS = \frac{\text{capacity}}{\text{demand}} = \frac{800\text{MPa}}{333.6\text{MPa}} = \boxed{2.398}$ ✓ +1
$\sigma_u = 800\text{MPa}$

b.) $\sigma = \frac{F}{A}$ $\therefore F = \sigma A = 333.6\text{MPa}\cdot 10\text{mm}^2 = 3336\text{N}$ per wire 3.34 kN
$\theta = \tan^{-1}\left(\frac{2990}{3000}\right) = 44.9°$ $\therefore A_y = A\sin\theta = 3336\cdot\sin 44.9° = 2354.79\text{ N}$
Total weight $= 2A_y = 4709.58\text{ N} = \boxed{4.71\text{kN} = W}$ ✓ +1

c.) $\sigma_y = 700\text{ MPa}$, $\sigma_y < \sigma$
$\therefore E = \frac{1}{2}\sigma\varepsilon V$
$= \frac{1}{2}\cdot 333.6\text{MPa}\cdot 1.668\times10^{-3}\cdot\frac{10\text{mm}^2}{10^6}\cdot\frac{4235.576\text{mm}}{10^3} = 11.784\text{J}$ per wire
$\boxed{\text{System} = 23.6\text{J}}$ ✓ +1

d.) $\varepsilon_y = \frac{\sigma_y}{E} = \frac{700\text{MPa}}{200000\text{MPa}} = 3.5\times10^{-3}$
$\therefore E_y = \frac{1}{2}\sigma_y\varepsilon_y\cdot V = \boxed{51.885\text{J}}$ ✓ +1

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e.) $T = 2\pi\sqrt{\frac{m}{k}}$

$\frac{k\Delta L}{A} = E\frac{\Delta L}{L_o}$

$\therefore \quad k = \frac{EA}{L_o}$

$T = 2\pi\sqrt{\frac{4710Ng}{\frac{200000\frac{N}{mm^2}\cdot 10mm^2}{4.235576m}}} = 2\pi\sqrt{\frac{480.1223kg}{459162.121\frac{1}{m}}} = 0.203s$

asks for frequency, not period. ✓ $+0.5$

F.) Not knowing ε_u, D would at least move more than $(L_o \varepsilon_y \sin 44.9°)$mm

✓ $+0.5$ ε_u on back of notebook.