ENSC 2143: Strength of Materials

Exam 2

Name: Solution

Section: ______________________

$$\sigma = \frac{P}{A_o}$$

$$\nu = -\frac{\varepsilon_{lateral}}{\varepsilon_{longitudinal}}$$

$$\delta = \int_0^L \frac{P(x)dx}{A(x)E}$$

$$\tau = G\gamma$$

$$\delta = \sum \frac{PL}{AE}$$

$$\tau_{Avg} = \frac{V}{A}$$

$$G = \frac{E}{2(1+\nu)}$$

$$\varepsilon = \frac{\Delta L}{L_o}$$

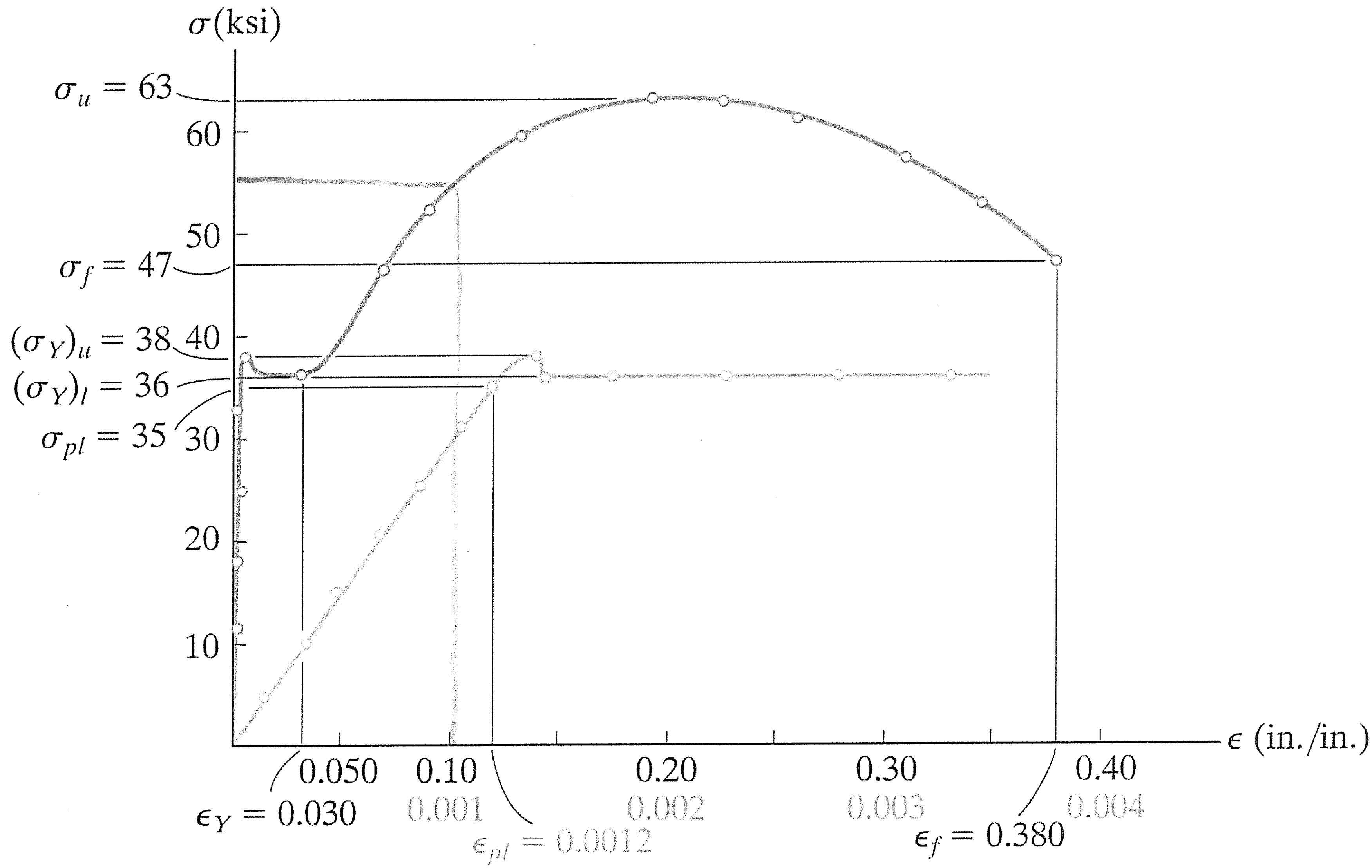
$$\gamma = \frac{\pi}{2} - \theta'$$

$$\sigma = E\varepsilon$$

$$a^2 = b^2 + c^2 - 2bc\cos A$$

$$u_r = \frac{\sigma_{pl}^2}{2E}$$

Aluminum	A-36 Steel
E = 10,600 ksi	E = 29,000 ksi
G = 3,700 ksi	G = 11,000 ksi
σ_y = 60 ksi	σ_y = 36 ksi
σ_u = 68 ksi	σ_u = 63 ksi
α= 12.8 $(10^{-6})/^\circ$F	α= 6.60$(10^{-6})/^\circ$F
τ_y = 25 ksi	τ_y = 21 ksi
τ_u = 42 ksi	



Stress Strain Diagram for A-36 Steel

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This exam will test your knowledge and skills on strength of materials. You have from 5 pm to 8 pm to complete your exam. You may use the supplied equation sheet, a writing utensil, and your calculator. No other external notes or texts are permitted. If you have any questions during the test please raise your hand or approach the instructor or TA and discuss the question quietly.

Problem 1	(25 points)	____________
Problem 2	(25 points)	____________
Problem 3	(25 points)	____________
Problem 4	(25 points)	____________

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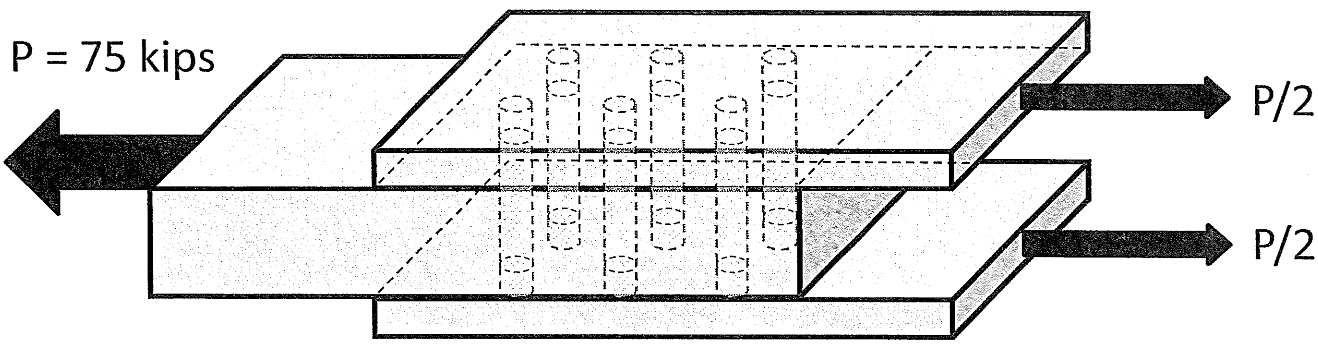
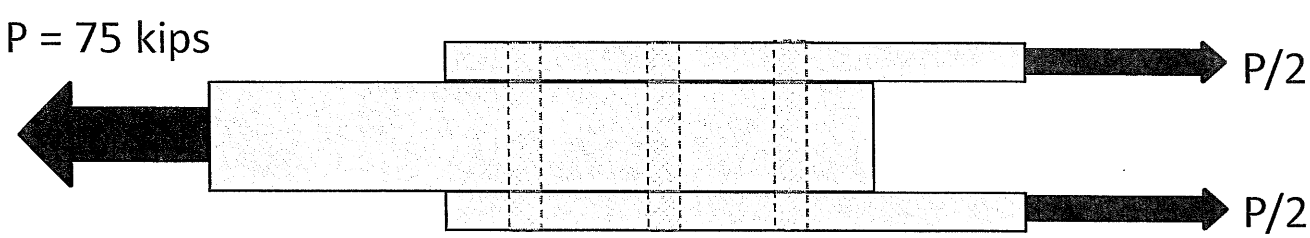
Problem 1

Three rigid plates are connected together with six identical aluminum dowels. Determine the required diameter for the dowels to the closest 1/8" if the allowable shear stress in the dowels is one half of the yield shear strength of Aluminum.





$$\tau_{allowed} = \frac{1}{2}\tau_{yield} = \frac{1}{2}\,25\,\text{ksi} = 12.5\,\text{ksi}$$

$$\tau_{applied} = \frac{V}{A} = \frac{75\,\text{kips}}{12\,A_{bolt}} =$$

12 bolt interfaces

$$\tau_{applied} \le \tau_{allowed}$$

$$\frac{75\,\text{kips}}{12\left(\frac{\pi D^2}{4}\right)} \le 12.5\,\text{ksi}$$

$$D \ge \sqrt{\frac{75\,\text{kips}}{12\,\frac{\pi}{4}\,12.5\,\text{ksi}}} = 0.798\,\text{in}$$

$\frac{6}{8} = 0.75$

$\frac{7}{8} = 0.875\,\text{in}$

$$\boxed{D_{required} = \frac{7}{8}\,\text{in}}$$

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Problem 1 Continued

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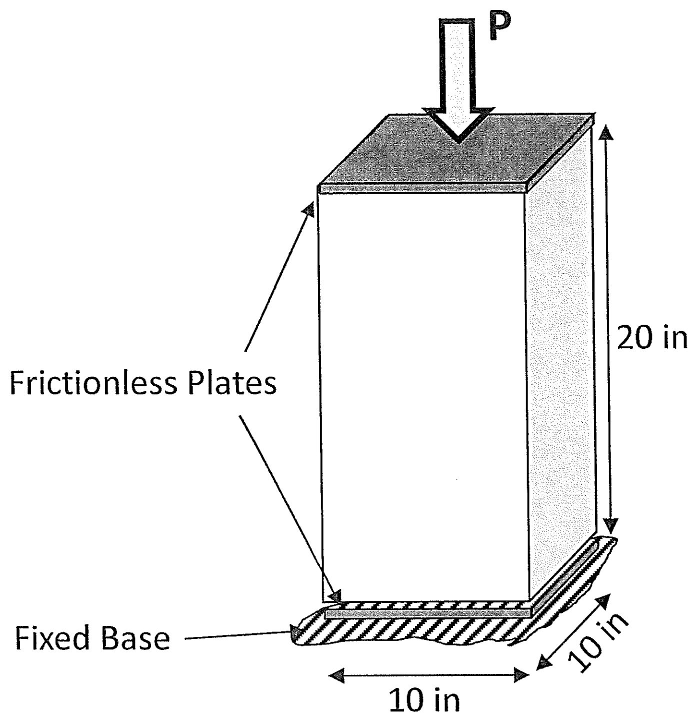
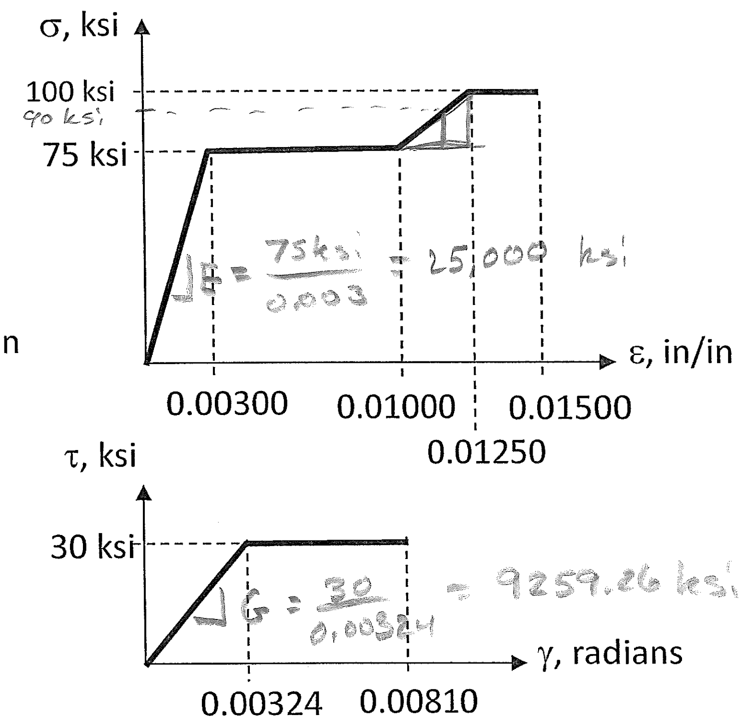
Problem 2

Load is applied to a 10"x10"x20" cube of material. The load is applied through frictionless plates. Material tests were performed and the stress-strain diagrams were developed for normal and shear stress and strains.





Determine

a) The load P that results in yielding.

b) The ultimate load P that can be carried.

c) Vertical displacement at P = 5,000 kips

d) Vertical displacement at P = 9,000 kips

e) The cross sectional dimensions at P = 5,000 kips

a) $P_{yield} = \sigma_{yield}\,\text{Area} = (75\text{ ksi})(100\text{ in}^2) = 7500\text{ kips}$

b) $P_{ultimate} = \sigma_{ult}\,\text{Area} = (100\text{ ksi})(100\text{ in}^2) = 10{,}000\text{ kips}$

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Problem 2 Continued

C) Two ways to solve

If $\sigma < \sigma_{yield}$ it is elastic

$$\sigma = \frac{P}{A} = \frac{5000\,kips}{100\,in^2} = 50\,ksi < 75\,ksi$$

$$\Delta = \frac{PL}{AE} = \frac{(5000\,kips)(20\,in)}{(100\,in^2)(25{,}000\,ksi)} = \boxed{0.04\,in\downarrow}$$

or

$$\Delta = \varepsilon L \qquad \varepsilon = \frac{\sigma}{E} = \frac{50\,ksi}{25{,}000\,ksi} = 0.002$$

$$\Delta = 0.002(20\,in) = \boxed{0.04\,in\downarrow}$$

D) $\sigma = \frac{9000\,kips}{100\,in^2} = 90\,ksi > 75\,ksi \therefore$ yielded

Determine ε @ 90 ksi

$$\varepsilon = 0.01 + \frac{90-75}{100-75}(0.0125 - 0.01)$$

$$\varepsilon = 0.0115$$

$$\Delta = \varepsilon L = (0.0115)(20\,in) = \boxed{0.23\,in\downarrow}$$

E) $G = \frac{E}{2(1+\nu)} \Longrightarrow \nu = \frac{E}{2G} - 1 = \frac{25{,}000}{2(9259.26)} - 1$

$$\nu = 0.35$$

compression

$$\varepsilon_{lateral} = -\nu\,\varepsilon_{long} = -0.35(-0.002) = +0.0007$$

$$D' = D + \Delta D = D + \varepsilon D = 10\,in + 0.0007(10)$$

$$\boxed{D' = 10.007\,in}$$

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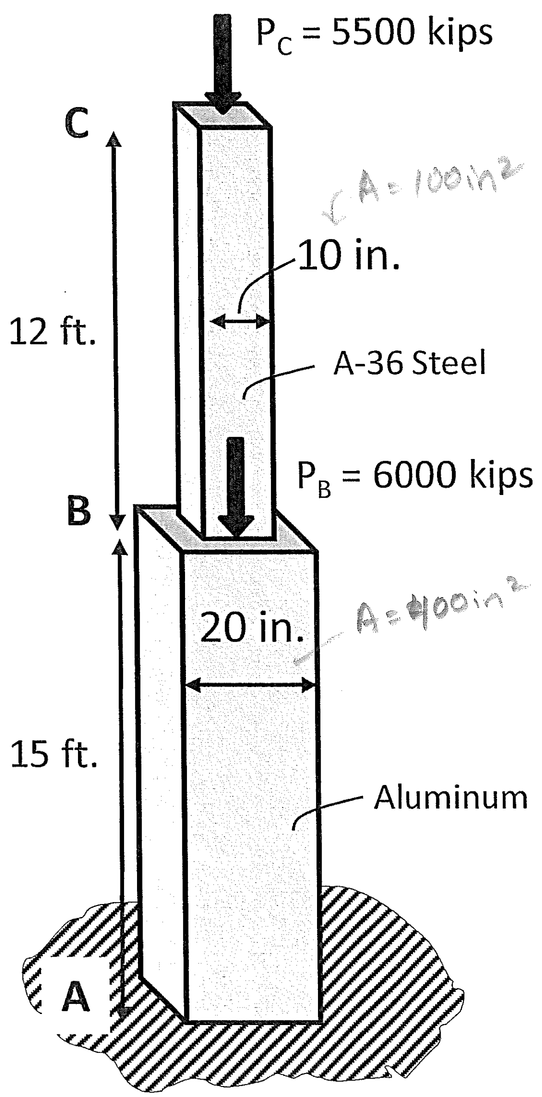
Problem 3

Determine the displacement of point **C** on the axially loaded member. The members are square in cross-section with the dimensions shown. Member AB is made of Aluminum. Member BC is composed of A-36 Steel.



$\Delta_C = \Delta_{C/B} + \Delta_{B/A}$

check if elastic

$\sigma_{steel} = \dfrac{5500 \text{ kips}}{100 \text{ in}^2} = 55 \text{ ksi} > 36 \text{ ksi}$

$\therefore$ yielded

use $\sigma - \varepsilon$ diagram

$55 \text{ ksi} \rightarrow \varepsilon \cong 0.10$

$\Delta_{C/B} = \varepsilon L = 0.10(144 \text{ in}) = 14.4 \text{ in}$

$\sigma_{Aluminum} = \dfrac{11{,}500 \text{ kips}}{400 \text{ in}^2} = 28.75 \text{ ksi} < 60 \text{ ksi}$

$\therefore$ elastic

$\Delta = \dfrac{PL}{AE} = \dfrac{(11{,}500 \text{ kips})(15 \text{ ft})(12 \text{ in/ft})}{(400 \text{ in}^2)(10{,}600 \text{ ksi})}$

$= 0.488 \text{ in}$

$\Delta_C = 14.4 \text{ in} + 0.488 \text{ in}$

$\boxed{\Delta_C = 14.888 \text{ in} \downarrow}$

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Problem 3 Continued

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Problem 4

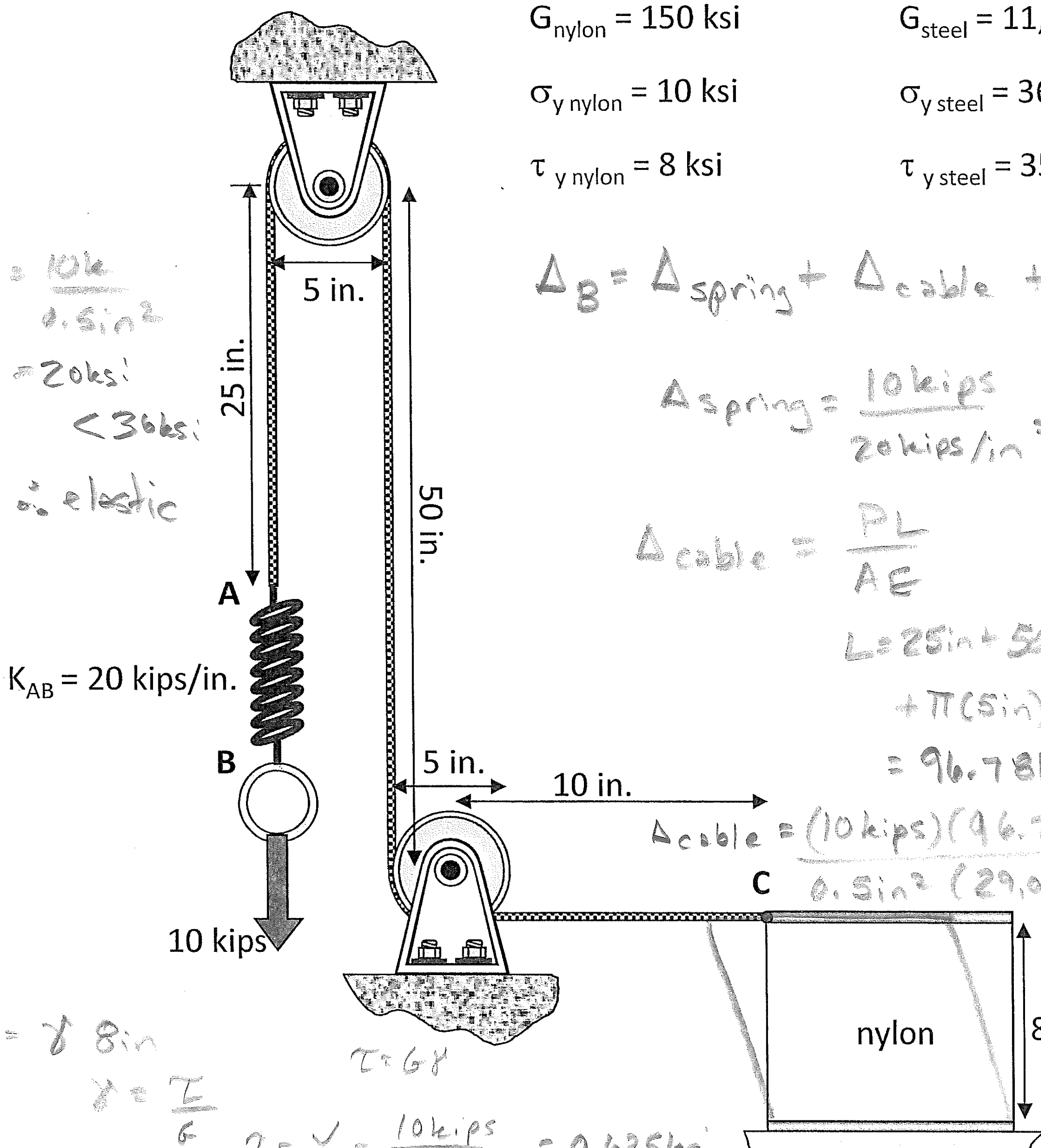
A 10 kip load is applied to a loading ring that is attached to spring AD connected to a a steel cable. The steel cable attaches to a 2”x 8”x 8” nylon block at C. The steel cable has a cross-sectional area = 0.5 in². Determine the vertical displacement of point **B**. Provide your answer out to 3 digits beyond the decimal.

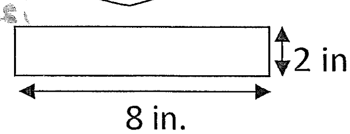
$E_{nylon} = 400$ ksi $\qquad E_{steel} = 29{,}000$ ksi

$G_{nylon} = 150$ ksi $\qquad G_{steel} = 11{,}000$ ksi

$\sigma_{y\ nylon} = 10$ ksi $\qquad \sigma_{y\ steel} = 36$ ksi

$\tau_{y\ nylon} = 8$ ksi $\qquad \tau_{y\ steel} = 35$ ksi





$\sigma_{cable} = \frac{10k}{0.5 in^2} = 20 ksi < 36 ksi$ ∴ elastic

$\Delta_B = \Delta_{spring} + \Delta_{cable} + \Delta_{nylon}$

$\Delta_{spring} = \frac{10 kips}{20 kips/in} = 0.5 in$

$\Delta_{cable} = \frac{PL}{AE}$

$L = 25in + 50in + 10in + \pi(5in)(\frac{3}{4}) = 96.781 in$

$\Delta_{cable} = \frac{(10 kips)(96.781 in)}{0.5 in^2 (29{,}000 ksi)} = 0.066746 in$

$\Delta_{block} = \gamma\, 8in$

$\gamma = \frac{\tau}{G}$ $\qquad \tau = G\gamma$

$\tau = \frac{V}{A} = \frac{10 kips}{(2in)(8in)} = 0.625 ksi < 8 ksi$ ∴ elastic

$\gamma = \frac{0.625 ksi}{150 ksi} = 0.004167$ radians

$\Delta_{Block} = 0.004167(8 in) = 0.03333 in$

$\Delta_B = 0.5 + 0.066746 + 0.03333$

$\Delta_B = 0.600076 = \boxed{0.6001 in}$

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Problem 4 Continued

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Problem 4 Continued