Solutions

(1) Power = 150 hp at 1500 rev/min

$d_o \leq 2.5$ inch

$\tau_{all} = 7$ ksi

- Find t_{min} for a hollow shaft
- Compare with solid shaft.

Answer $P = 2\pi f T$

$$\therefore T = \frac{P}{2\pi f} = \frac{150\,hp \times 6600\ in.lb/s / hp}{2\pi \times 1500\ \frac{rev}{min} \times \frac{1\,min}{60\,sec}} \quad 10$$

$$= \frac{150 \times 6600}{2\pi \times 1500} \times 60 \ in.lb = 6303\ in.lb$$

Hollow shaft $\tau_{all} = \frac{Tc_2}{J}$ for hollow shaft

$$\therefore J = \frac{6303\ in.lb \times 2.5/2\ in}{7000\ lb/in^2}$$

$$= 1.125\ in^4 = \frac{\pi}{2}(c_2^4 - c_1^4)$$

$$\therefore c_1^4 = -\frac{2J}{\pi} + c_2^4 = 1.725\ in^4$$

$$c_1 = 1.146\ in$$

$$\therefore t = 0.104\ inch. \quad 15$$

Solid shaft

$$\tau_{all} = \frac{Tc}{\frac{\pi}{2}c^4} = \frac{2T}{\pi c^3}$$

$$\therefore c^3 = \frac{2T}{\pi \tau_{all}} = \frac{2 \times 6303\ in.lb}{\pi \times 7000\ \frac{lb}{in^2}} = 0.5732$$

$$c = 0.8307\ inch \Rightarrow d = 1.661\ inch \quad 15$$

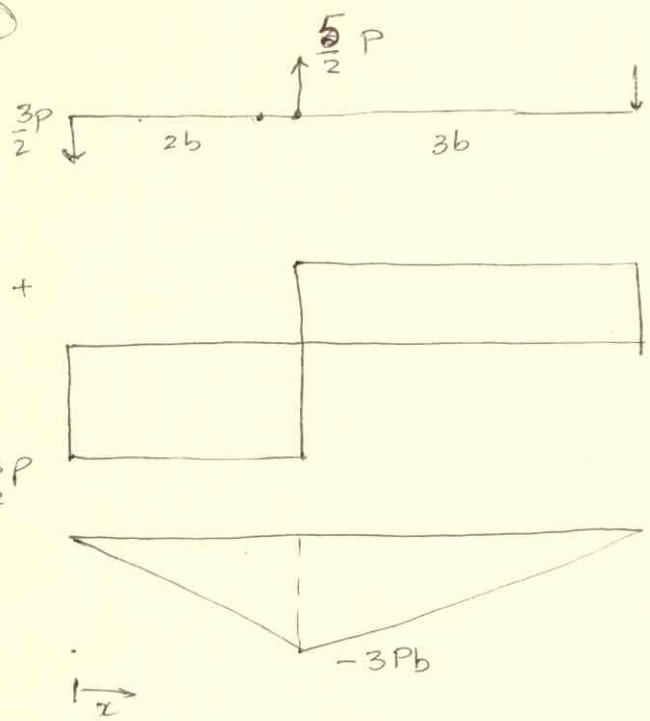
→ Thinner

If the shaft has a length L and density ρ

Mass of solid shaft $= \pi r^2 L \rho = 2.168\,\rho L$

Mass of hollow shaft $= \pi(r_o^2 - r_i^2)\rho L = 0.7828\,\rho L$ → lighter 10

(2)



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(b) For $0 \le x \le 2b$

$$M = -\frac{3}{2}Px$$

$$= -330x$$

for $2b \le x \le 5b$

$$M = -5Pb + Px$$

$$= -13200 + Px$$

(c) The wire is being stretched by a force of $\frac{5}{2}P$ or 550 lb

$$\therefore \delta_B = \frac{P_B L}{AE} = \frac{550\,lb \times 24\,in}{0.01\,in^2 \times 30\times10^6 \frac{lb}{in^2}} = 4.4\times10^{-2}\,in$$

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(d)

For $0 \le x \le 2b$

$$EIy'' = M = -330x$$

$$EIy' = -330\frac{x^2}{2} + C_1$$

$$EIy = -330\frac{x^3}{6} + C_1x + C_2$$

at $x=0$ $y=0$ $\Rightarrow$ $C_2 = 0$

at $x = 2b = 24\,in$, $y = 2.2\times10^{-2}\,in$

$$\therefore 30\times10^6\,psi \times 1\,in^4 \times 2.2\times10^{-2}\,in = -330\times\frac{(24\,in)^3}{6} + C_1 \times 24$$

$$\Rightarrow C_1 = 3195$$

$$\therefore y = -1.835\times10^{-6}x^2 + 9.607\times10^{-4}x$$

Using singularity functions

$$M = -\frac{3}{2}Px + \frac{5}{2}P\langle x-2b\rangle = EIy''$$

$$EIy' = -\frac{3}{4}Px^2 + \frac{5}{4}P\langle x-2b\rangle^2 + C_1$$

$$EIy = -\frac{1}{4}Px^3 + \frac{5}{12}P\langle x-2b\rangle^3 + C_1x + C_2$$

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at $x = 0$ $y = 0 \Rightarrow C_2 = 0$

at $x = 2b$ $y = -2.2\times10^{-2}\ in^2$

$$\therefore EI(-2.2\times10^{-2}\ in^2) = -\frac{1}{4}P(2b)^3 + C_1(2b)$$

$$\therefore C_1 = \frac{-EI(2.2\times10^{-2})}{2b} + \frac{1}{4}P(2b)^2$$

$$= -\frac{30\times10^6\ psi \times 44\times10^{-2}\ in \times 1\ in^4}{2\times12\ in} + \frac{1}{4}\times220\ lb\times(24\ in)^2$$

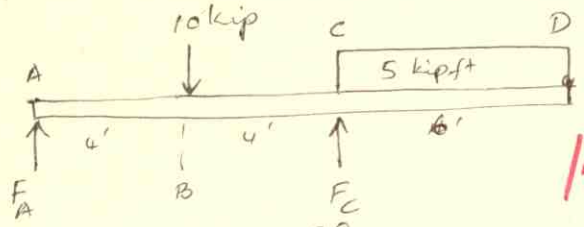
$$= -27500 + 1320 = -26180$$

at $x = 5b$ i.e $x = 60$ inch

$$y = \frac{1}{EI}\left[\left(-\frac{1}{4}\times220\times60^3 + \frac{5}{12}\times220\times36^3\right) - 26180\times60\right]$$

$$= -0.3058\ \text{inch}.$$

(3)



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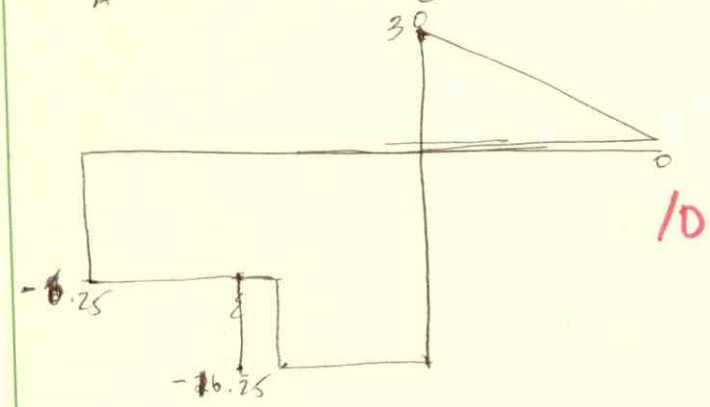
$F_A + F_C = 10 + 30 = 40$ kip

(+) $\sum M_A = 0 = -10\text{kip} \times 4\text{ft} + F_C \times 8\text{ft} - 5 \times 6 \times (8+3)$ kip-ft

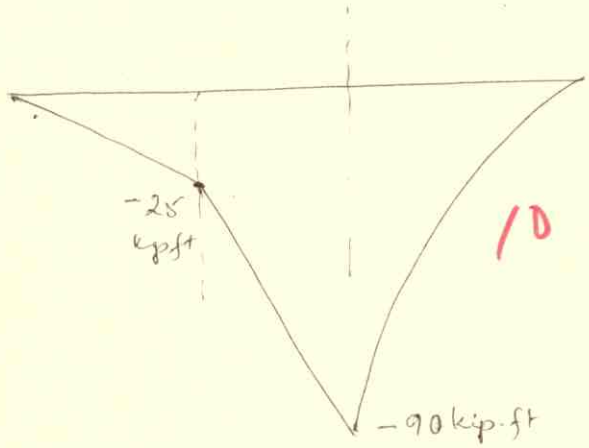
$\therefore F_C = \frac{30 \times 11 + 10 \times 4}{8}$

$= 46.25$ kip

$\therefore F_A = -6.25$ kip.



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$\sigma_{allk} = \frac{M_{max.}}{S} = 24$ ksi

$\therefore S_{min} = \frac{90 \times 12 \text{ kip.in}}{24 \frac{\text{kip}}{\text{in}^2}}$

$= 45 \text{in}^3$ 5

$\tau = \frac{V_{max}}{A}$

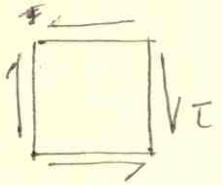
$\therefore A_{min} = \frac{30 \text{ kip}}{14 \text{ ksi}} = 2.14 \text{in}^2$

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Beam	S	dx tw	wt/ft
W 8x 58	52in^3	$8.75 \times 0.51 \text{in}^2$	58 lb
W 10x 45	69.1	$10.10 \times 0.35 \text{in}^2$	45 lb
W 12x 35	45.6	$12.5 \times 0.3 \text{in}^2$	35 lb
W 16x 31	47.2	$15.88 \times 0.275 \text{in}^2 = 4.367 \text{in}^2$	31 lb ← Ok
W 18x 35	57.6	$17.7 \times 0.3 \text{in}^2$	35 lb

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(4)

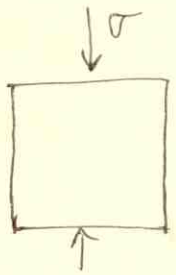


$\tau_{mean} = \tau$ 3

$\sigma_{max} = \tau$ 3 $\quad \theta_{P_1} = -45°$ 3

$\sigma_{min} = -\tau$ 3 $\quad \theta_{P_2} = +45°$ 3

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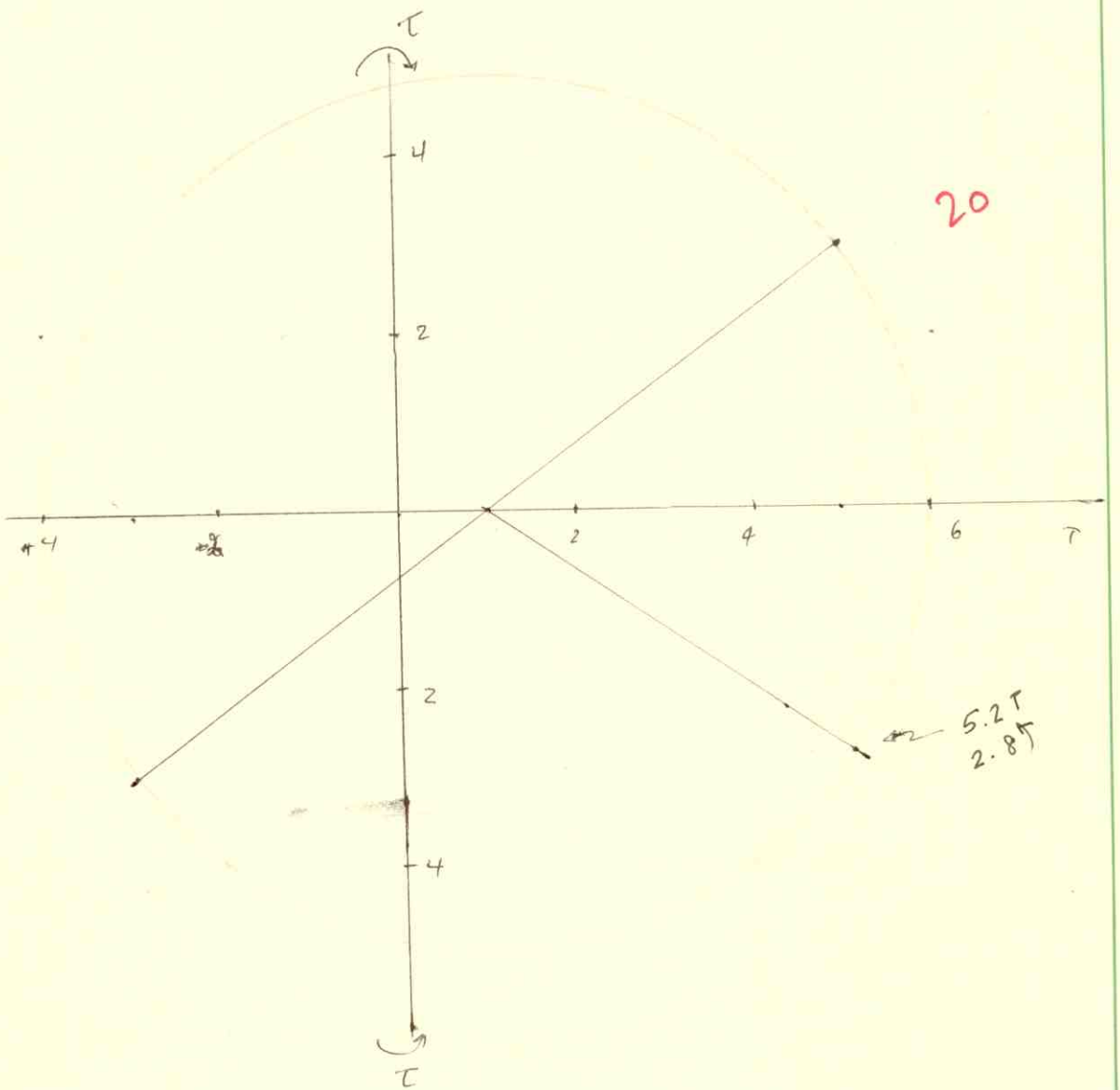
$\sigma_{max} = 0$ 3 $\quad \theta_{P_1} = 0°$ 3

$\sigma_{min} = -\sigma$ 3 $\quad \theta_{P_2} = 90°$ 3

$\tau_{max} = -\frac{\sigma}{2}$ 3

15

C



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(5) $\ell = 0.5 \text{ inch}$

$\Delta\ell = 0.2 \times 10^{-3} \text{ in}$ 10

$\epsilon_{axial} = 4 \times 10^{-4} = \frac{\sigma_{axial}}{E} - \frac{\nu}{E}\sigma_{hoop} = \frac{\sigma_{axial}}{E}(1 - 2\nu)$

1. $\sigma_{axial} = \frac{\epsilon_{axial} \times E}{1 - 2\nu} = \frac{4 \times 10^{-4} \times 29 \times 10^{6} \text{ psi}}{1 - 2 \times 0.3}$ 15

$= 29000 \text{ psi} = \frac{pr}{2t}$

$\therefore \quad p = \frac{29000 \text{ psi} \times 2 \times 0.5 \text{ in}}{30 \text{ in}} = 966.7 \text{ psi}$

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$\tau_{max} = \frac{\sigma_{axial}}{2} = 14500 \text{ psi}$ 10

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22-142 100 SHEETS
22-144 200 SHEETS
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