MACHINE DESIGN WINTER TERM - 1999 EXAM -01

NAME:_____ January 28, 1999

- Read the problem carefully.
- Work must be neat and orderly to be graded.
- Return this page with your exam, perform no work on this page. Any work performed on this page will not be graded.

A resultant gear force, F_A, of 600 pounds acts at an angle of 20^0 from the y-axis of an overhanging countershaft as shown in the figure on the next page. The solid, circular machined shaft is to be made of a steel with a BHN of 360 with a yield strength equal to 75% of the ultimate strength. The factor of safety in fatigue is to be 2.50. Fatigue stress concentration factors are 2.0 in bending, 1.75 in axial, and 2.0 in torsional loadings. Notch radii are 0.38 inches.

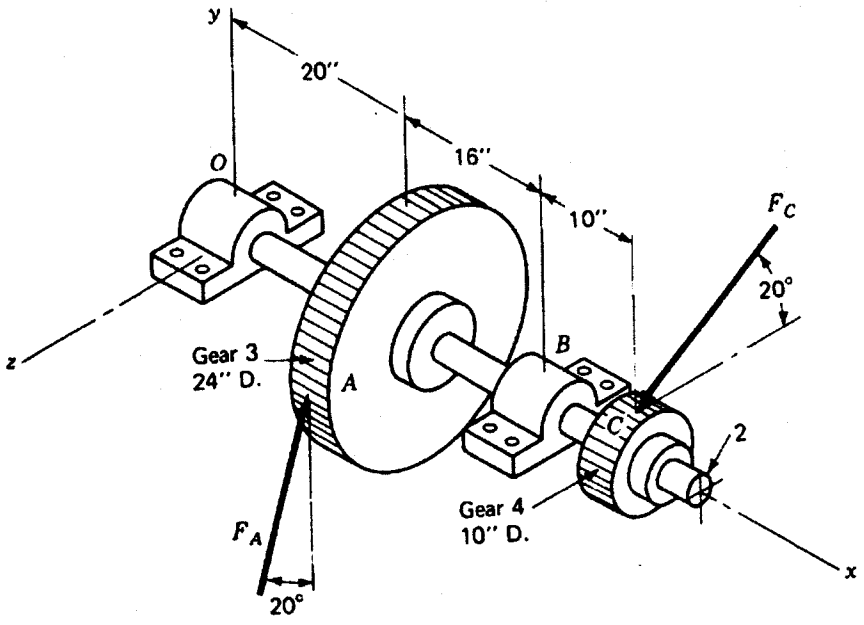
(1) Verify the FBD shown is correct and correct it, if necessary. Show all calculations necessary to justify your decisions.
(2) Construct the shear, moment, axial load, and torsional load diagrams for the shaft.
(3) Using the modified-Goodman line, determine the diameter of the shaft, to the nearest 1/8-inch, at the critical section of the shaft.

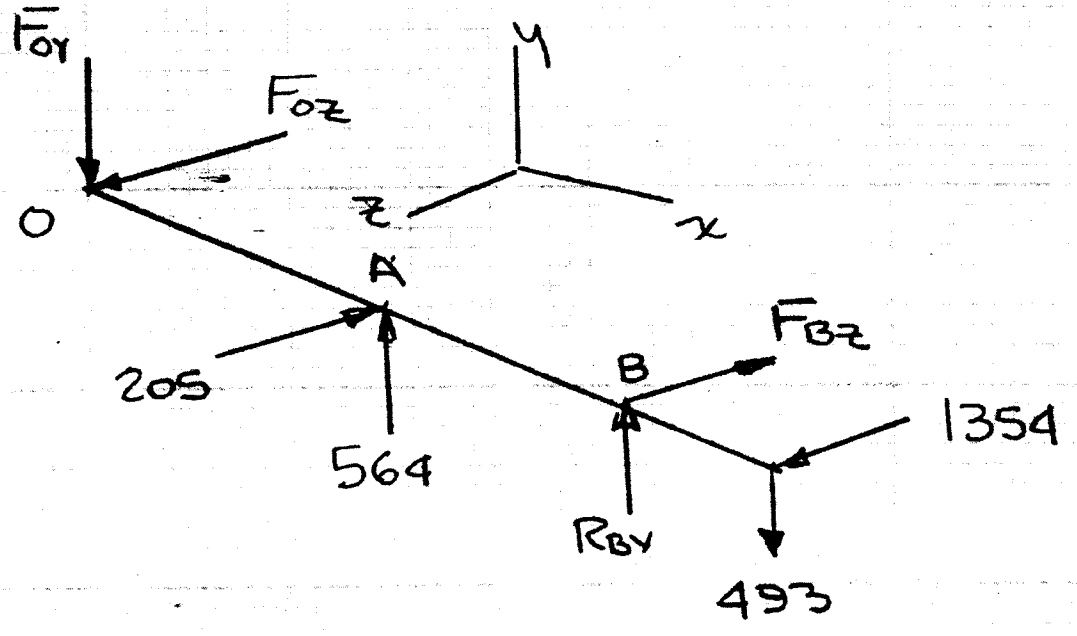
If needed, use the following equations to determine the transmitted (tangential) and radial loads.

$$F_{radial} = F_{transmitted} \tan\varphi$$
$$F_{transmitted} = F\cos\phi$$
$$\phi = 20^0$$

(1) 15 points
(2) 15 points
(3) 20 points

Possible points: 50

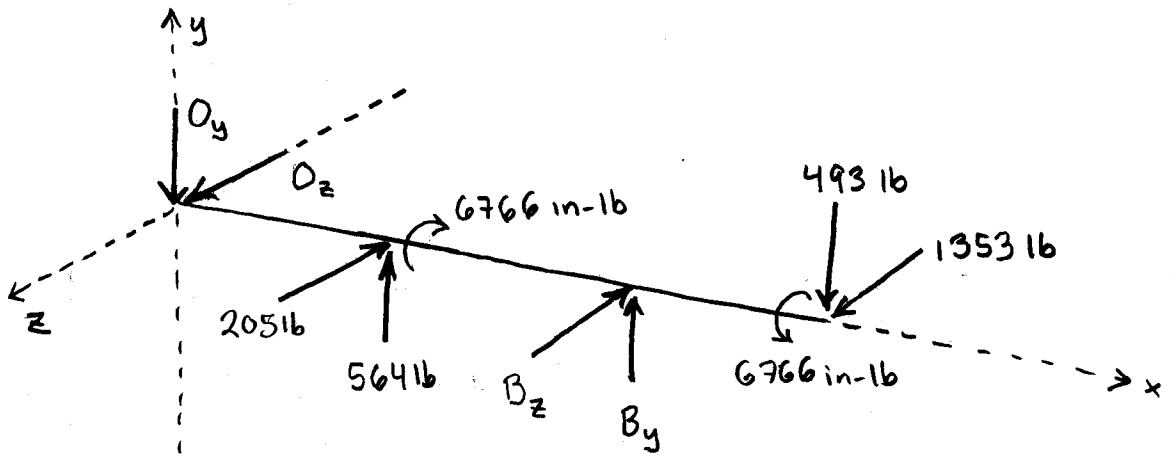

y
20"
16"
10"
O
F_C
20°
z
Gear 3
24" D.
A
B
C
2
Gear 4
10" D.
F_A
20°
x


F_{Oy}
F_{Oz}
y
O
z
x
A
B
F_{Bz}
205
564
1354
R_{By}
493

EXAM #1 10AM

ME 340
1/28/99

FBD:



STATICS:

$\Sigma F_x = 0$; $0 = 0$ (NO AXIAL LOADS)

$\Sigma F_y = 0$; $-O_y + 564\,lb + B_y - 493\,lb = 0$

$\Sigma F_z = 0$; $O_z - 205\,lb - B_z + 1354\,lb = 0$

$\Sigma M_x^o = 0$; $6770\,in\text{-}lb = 6770\,in\text{-}lb$

$\Sigma M_y^o = 0$; $205\,lb(20\,in) + B_z(36\,in) - 1354\,lb(46\,in) = 0$

$$B_z = \frac{-205\,lb(20\,in) + 1353\,lb(46\,in)}{36\,in} = 1615\ lb$$

$\Sigma M_z^o = 0$; $564\,lb(20\,in) + B_y(36\,in) - 493\,lb(46\,in) = 0$

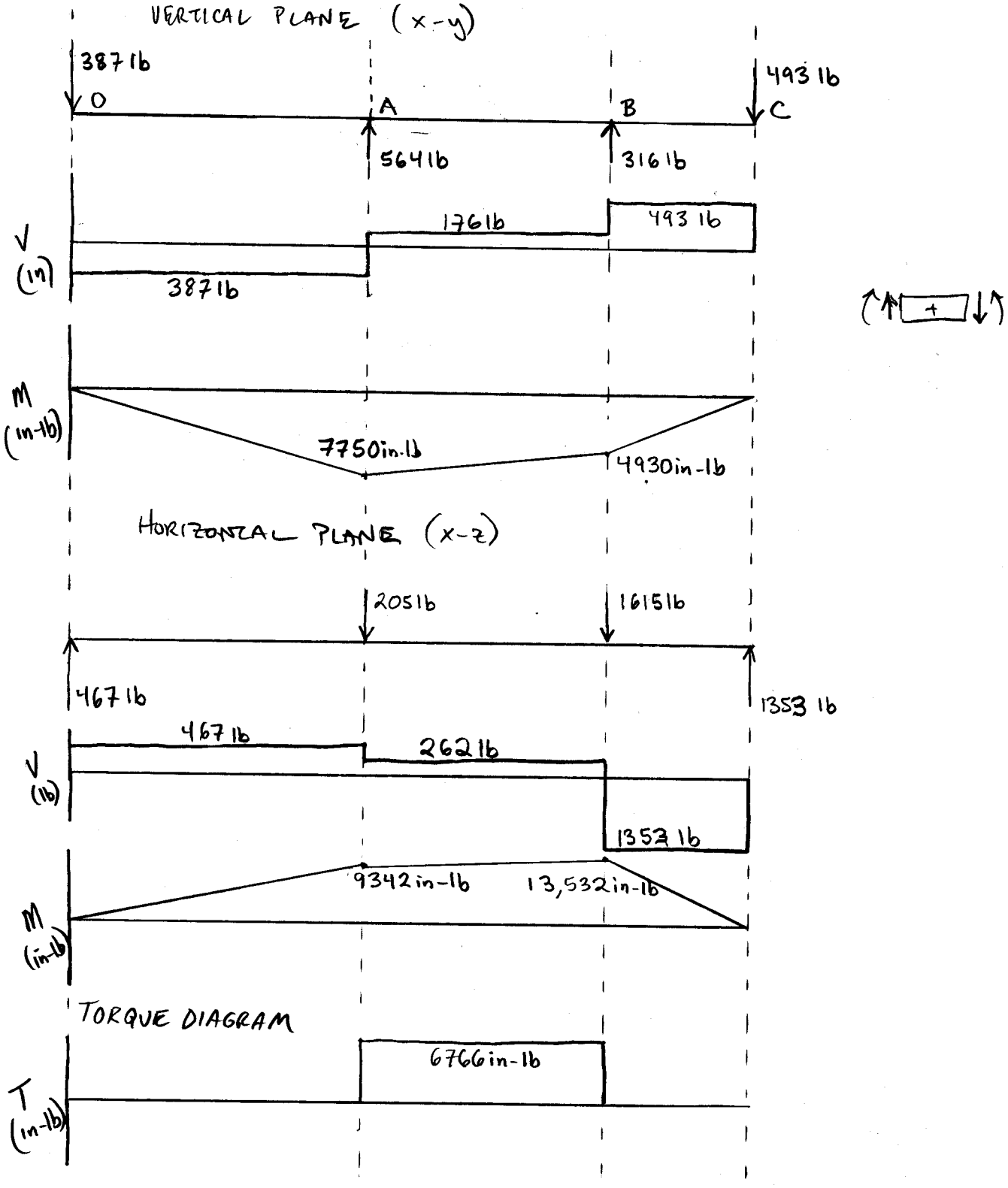
$$B_y = \frac{-564\,lb(20\,in) + 493\,lb(46\,in)}{36\,in} = 316\ lb$$

$O_y = 564\,lb + 316\,lb - 493\,lb = 387\ lb$

$O_z = 205\,lb + 1615\,lb - 1353\,lb = 467\ lb$

EXAM #1 CONTD 10 AM

SHEAR AND MOMENT DIAGRAMS:



NO AXIAL LOADS!

CRITICAL POINT IS AT B (LEFT HAND SIDE)

$$M_{max} = \sqrt{(4930\,in\text{-}lb)^2 + (13{,}532\,in\text{-}lb)^2} = 14{,}402\,in\text{-}lb$$

$$T = 6766\,in\text{-}lb$$

STRESSES:

ALTERNATING (BENDING)

$$\sigma_x = \frac{32M}{\pi d^3} K_f = \frac{32(14{,}402\,in\text{-}lb)}{\pi d^3}(2.0) = \frac{293{,}395}{d^3} = \sigma_a$$

$$\sigma_a' = \frac{293{,}395}{d^3} \quad \text{(VON MISES)}$$

MEAN STRESS (TORSION)

$$\tau_{xy} = \frac{16T}{\pi d^3} K_{ts} = \frac{16(6766\,in\text{-}lb)}{\pi d^3}(2.05) = \frac{70{,}640}{d^3} = \tau_m$$

$$K_{ts} = \frac{K_f - 1}{q} + 1 = \frac{2.0 - 1}{0.95} + 1 = 2.05$$

$$\sigma_m' = \frac{\sqrt{3}\,70{,}640}{d^3} \quad \text{(VON MISES)}$$

ENDURANCE LIMIT:

$$S_e = \frac{1}{2} S_{ut} C_{LOAD} C_{SIZE} C_{SURF} C_{TEMP} C_{RELIAB}$$

$C_{LOAD} = 1$

$C_{SIZE} = 0.869\, d^{-0.097} = 0.869$ (GUESS 1in)

$C_{SURF} = 0.66$

$C_{TEMP} = 1$ ASSUME ROOM TEMPERATURE

$C_{RELIAB} = 1$ ASSUME 50% RELIABILITY

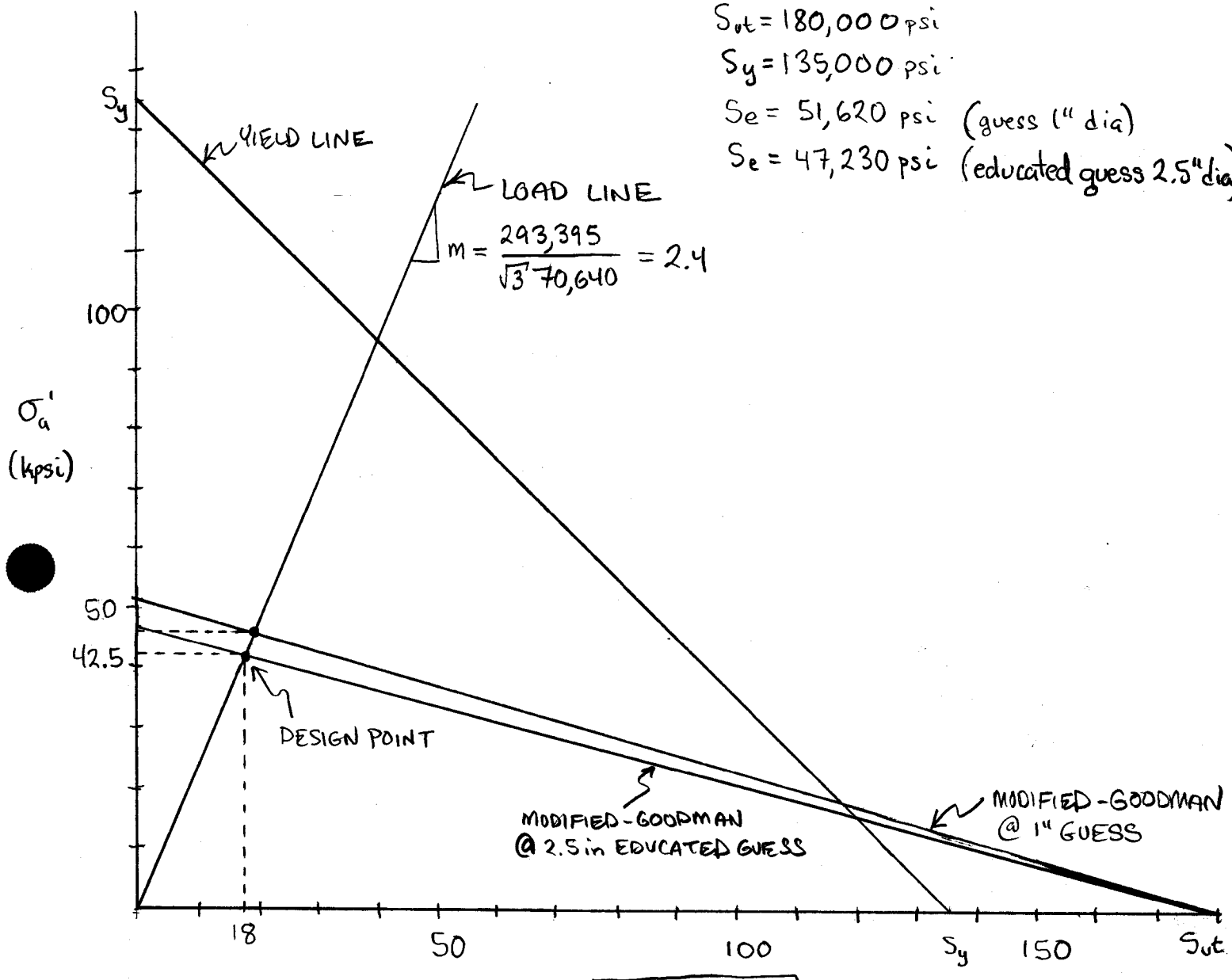
$$S_e = \frac{1}{2}(180{,}000\,psi)\,1(.869)\,.66\,(1)\,1 = 51{,}620\,psi$$

$$\left[S_{ut} = 500(BHN) = 500(360)\right]$$

EXAM #1 CONT'D 10 AM

THE MODIFIED-GOODMAN DIAGRAM

$S_{ut} = 180{,}000$ psi
$S_y = 135{,}000$ psi
$S_e = 51{,}620$ psi (guess 1" dia)
$S_e = 47{,}230$ psi (educated guess 2.5" dia)



$$\sigma'_{a,allow} = \frac{46{,}000\,psi}{2.50} \rightarrow d = \sqrt[3]{\frac{293{,}395\,in\text{-}lb}{18{,}400\,psi}} = 2.51\,in$$

RE-DRAW GOODMAN LINE @ 2.5 in. dia. $\rightarrow S_e = 47{,}230$ psi

NOW $\sigma'_{a,allow} = \frac{42{,}500\,psi}{2.50} \rightarrow d = \sqrt[3]{\frac{293{,}395\,in\text{-}lb}{17{,}000\,psi}} = 2.58\,in$

DOUBLE-CHECK $\sigma'_{m,allow} = \frac{18{,}000\,psi}{2.50} \rightarrow d = \sqrt[3]{\frac{\sqrt{3}\,70{,}640\,in\text{-}lb}{7{,}200\,psi}} = 2.57\,in$

$d = 2\frac{5}{8}"$