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CH. 6 BENDING 6.1 – 6.2

SECTION 6.1

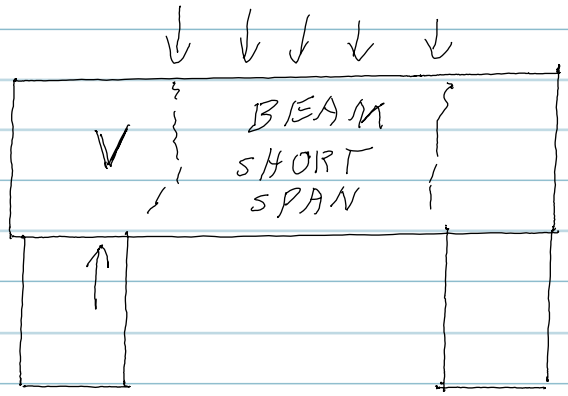
FAILURE OF BEAMS

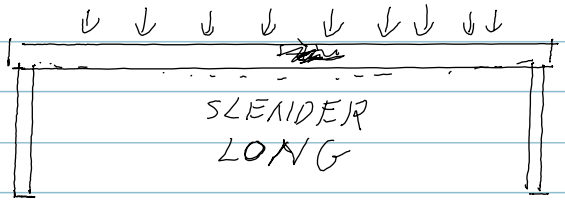
CH 1.2 SEE SMARTNOTES Pg 8-9.

NORMAL – DIRECTION OF LONG AXIS

SHEAR "V" – ACROSS

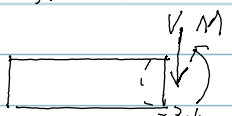
BENDING MOMENT





DRAW / SKETCH BENDING MOMENT DIAGRAMS

$x < \frac{1}{2}L$



$\frac{1}{2}P$

$\Sigma F_y = 0$

$+\frac{1}{2}P - V = 0$

$V = \frac{1}{2}P$

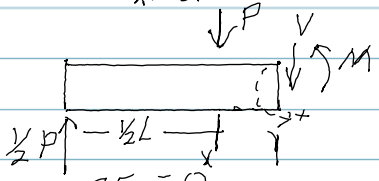
$\Sigma M = \Sigma F \cdot r_\perp = 0$

$-\frac{1}{2}Px + M = 0$

$M = \frac{1}{2}Px$

$y = mx + b$

$x > \frac{1}{2}L$



$\Sigma F_y = 0$

$+\frac{1}{2}P - P - V = 0$

$-\frac{1}{2}P - V = 0$

$V = -\frac{1}{2}P$

$\Sigma M = \Sigma F \cdot r_\perp = 0$

$-\frac{1}{2}Px + P(x - \frac{1}{2}L) + M = 0$

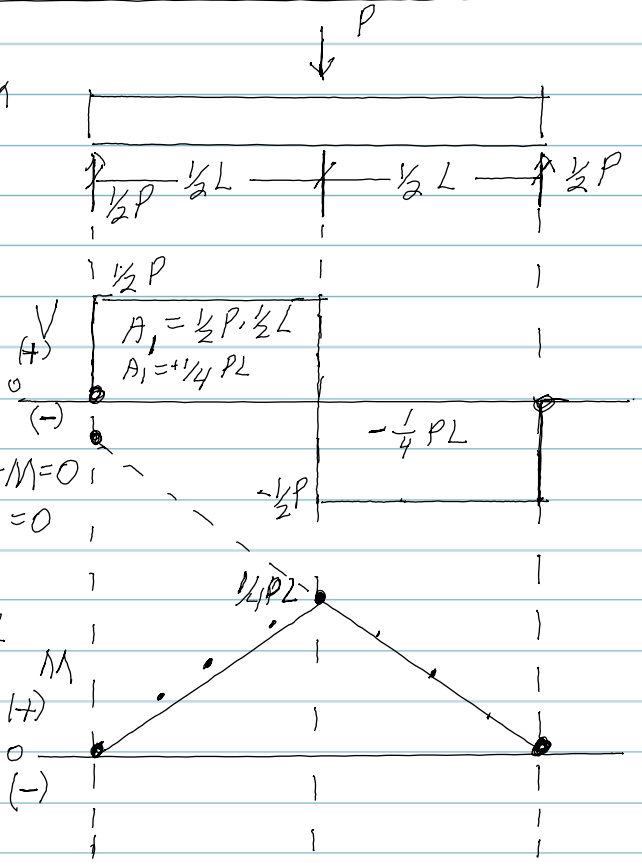
$-\frac{1}{2}Px + Px - \frac{1}{2}PL + M = 0$

$\frac{1}{2}Px - \frac{1}{2}PL + M = 0$

$M = -\frac{1}{2}Px + \frac{1}{2}PL$

$M_{x=\frac{1}{2}L} = -\frac{1}{2}P(\frac{1}{2}L) +$

$M_{\frac{1}{2}L} = +\frac{1}{4}PL$



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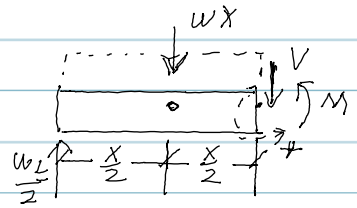
CH. 6.1 – 6.2 BENDING (CONT.)

SECTION 6.2

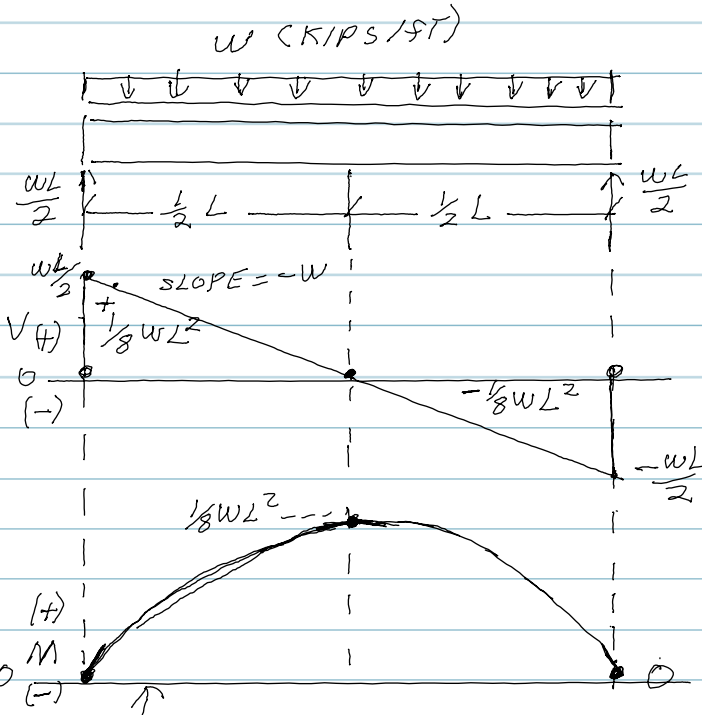
SIMPLE BEAM UNIFORM LOAD



$\Sigma F_y = 0 \Rightarrow +\frac{wL}{2} - wx - V = 0$

$V(x) = -wx + \frac{wL}{2}$

$y = mx + b$



$\Sigma M = 0 \Rightarrow -\frac{wL}{2} \cdot x + (wx)\frac{x}{2} + M = 0$

$M(x) = -\frac{1}{2}wx^2 + \frac{wLx}{2}$

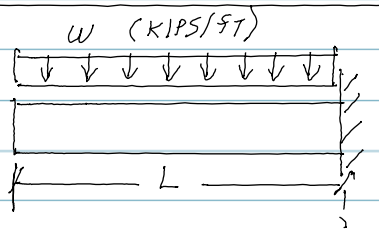
$M(x) = \int_0^x V(x)\,dx = \int_0^x \left(-wx + \frac{wL}{2}\right) dx$

$M(x) = -\frac{1}{2}wx^2 + \frac{wLx}{2}$

KEY POINTS

1) V MAX @ SUPPORTS.
2) M MAX @ CTR $\frac{1}{8}wL^2$

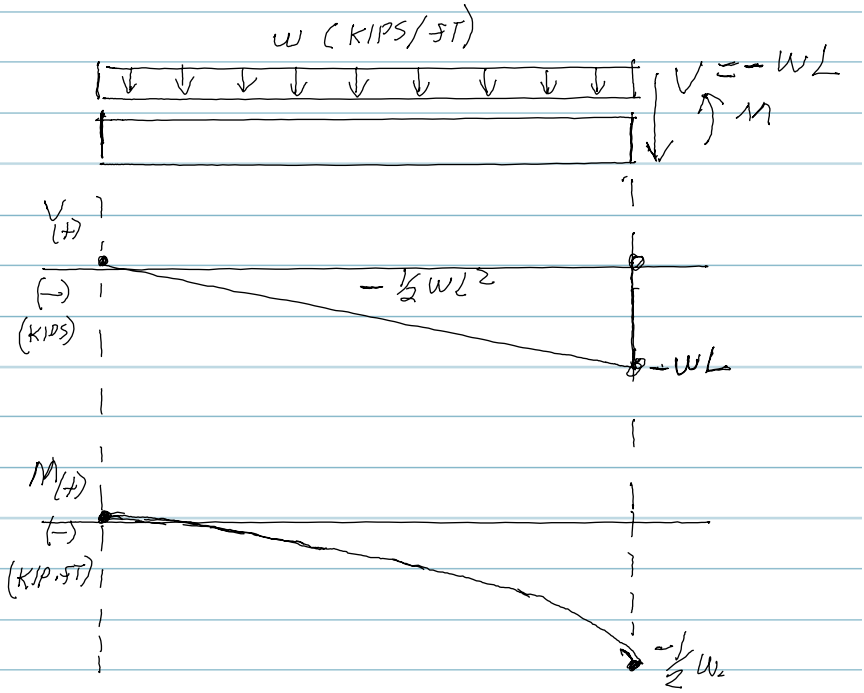
CANTILEVER BEAM



TAKE AWAY

V_{MAX} @ WALL (wL)

M_{MAX} @ WALL ($\frac{1}{2}wL^2$)



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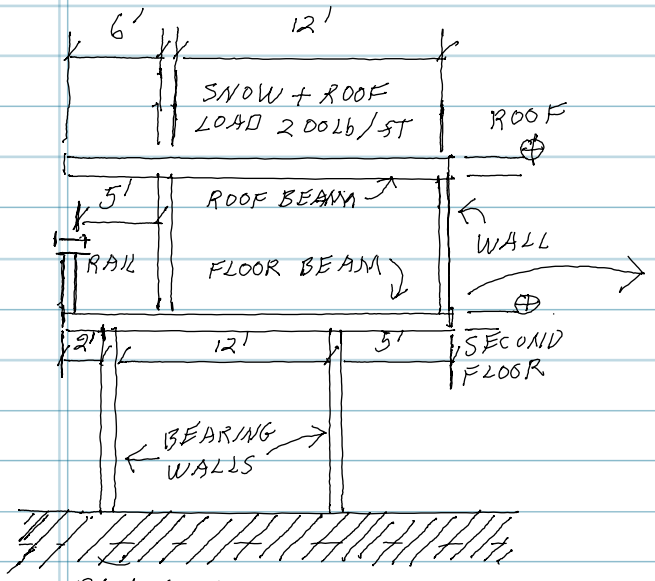
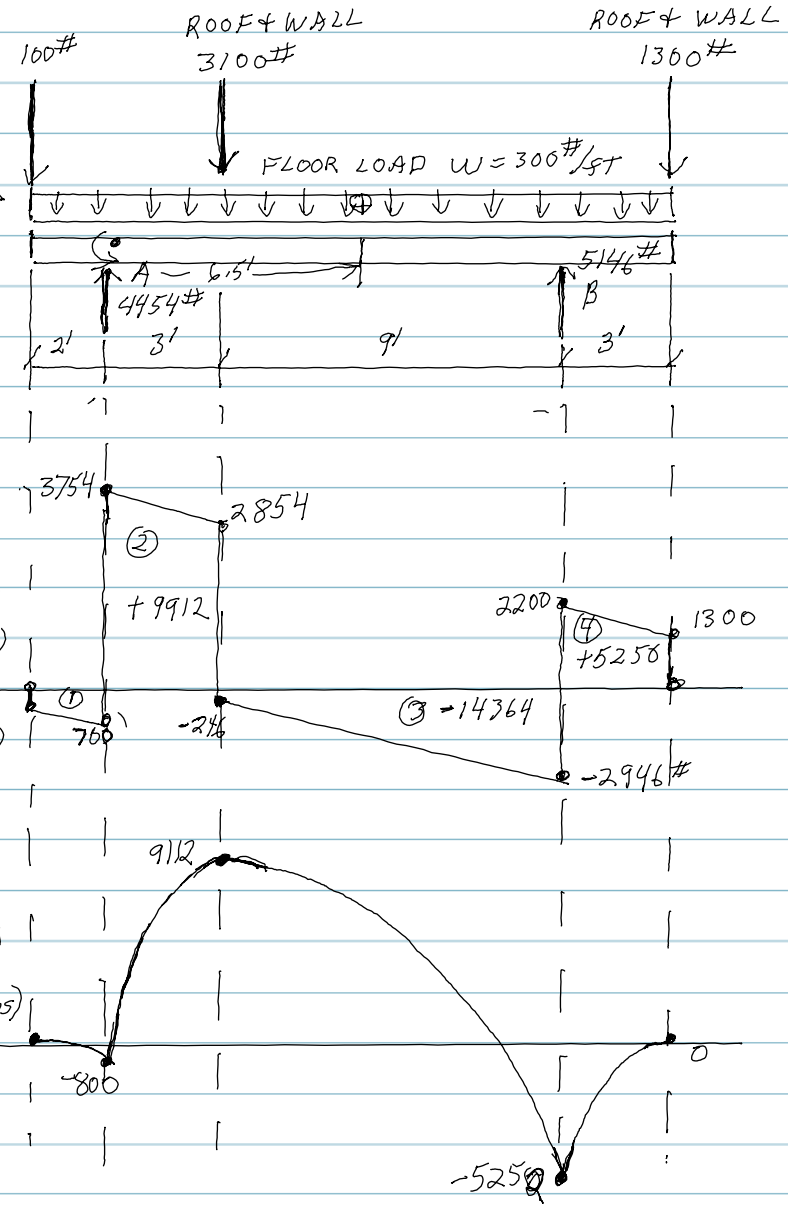
CH. 6.1 – 6.2 BENDING (CONT.)

PRACTICAL EXAMPLE – BEAM DESIGN



BUILDING SECTION



$\Sigma M_A = 0$

$+100(2) - 300(17)6.5 - 3100 + B^{x12} - 1300 = 0$

$-61756 + 12B = 0$

$B = 5146$ LBS

$\Sigma F_y = 0$

$-100 - 3100 - 1300 + A + 5146 - 300(17) = 0$

$A = 4454$ LBS

AREA $= \frac{1}{2}(h_1 + h_2)\,b$

$A_1 = \frac{1}{2}(2')(100+700)$

$A_1 = -800$ FT·LBS

$A_2 = \frac{1}{2}(3754 + 2854)\,3' = 9912$

$A_3 = -\frac{1}{2}(2346 + 2946)\,9' = -14364$

$A_4 = +\frac{1}{2}(2900 + 1300)\,3' = +5250$

KEY POINTS

1) V_{MAX} @ COLUMN "A" 5154 LBS

M_{MAX} @ 3' RIGHT OF "A" 9112 FT·LBS

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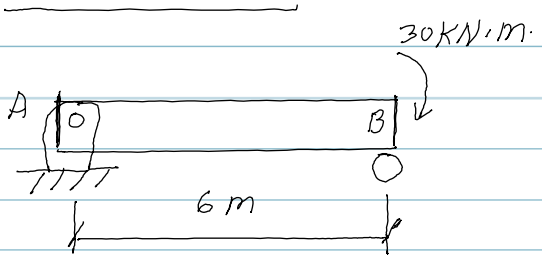
CH 6.1 – 6.2 BENDING (CONT.)

HANDLING APPLIED MOMENTS ON SHEAR & BENDING MOMENT DIAGRAMS

PROB. F6.1



$\Sigma M_B = 0$

$+(A_y)6 - 30 = 0$

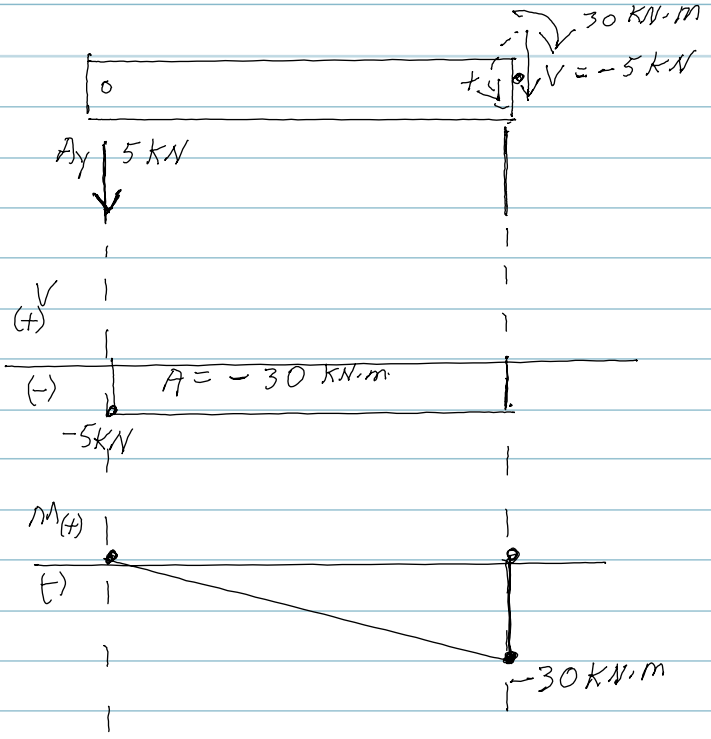
$A_y = \frac{30}{6} = 5KN$

$\Sigma F_y = 0$

$-5KN - V = 0$

$V = -5\,kN$

FBD



RULE ON MOMENTS – APPLIED

↶ CW CAUSES A JUMP POSTIVE,

FBD & SFM DIAGRAM!

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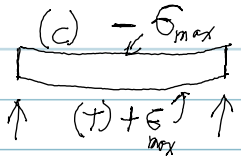
CH. 6.4 THE FLEXURE FORMULA

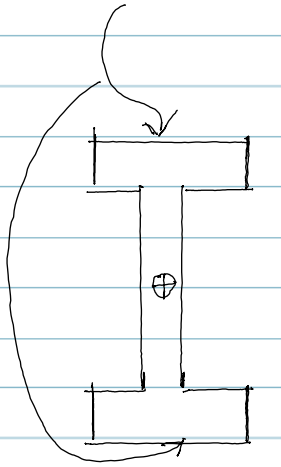
KEY FORMULA

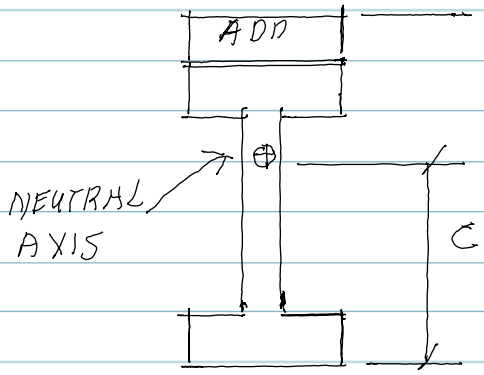
$$\sigma_{max} = \frac{M c}{I}$$

- M: BENDING MOMENT IN BEAM (FT·LBS, N/m)
- c: MAX, ⊥ DISTANCE FROM NEUTRAL AXIS TO BENDING EDGE
- I: MOMENT OF INERTIA OF CROSS SECTION AT CENTROID (ON NEUTRAL AXIS)
- σ_{max}: NORMAL STRESS (MAX).

FLEXURE FORMULA







"M" SHEAR & MOMENT DIAGRAM — SPAN & LOADS — DESIGN PROCESS

σ_{MAX} MATERIAL PROPERTY - ASD

I PROPERTY OF SHAPE - SIZE OF BEAM

PICK ANY TWO ⇒ M, σ_{max} (σ_{allow})

CALCULATE I NECESSARY $I \geq 10\ in^4$ PICK $I = 12.7\ in^4$

$$\tau_{max} = \frac{Tc}{J}$$

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CH. 6.4 FLEXURE FORMULA (CONT.)

EXAMPLE ~~PROB.~~ Pg 294, EX 6.12

GIVEN: STEEL "I" BEAM, UNIFORM LOAD
SIMPLE SUPPORTS, SHAPE SHOWN

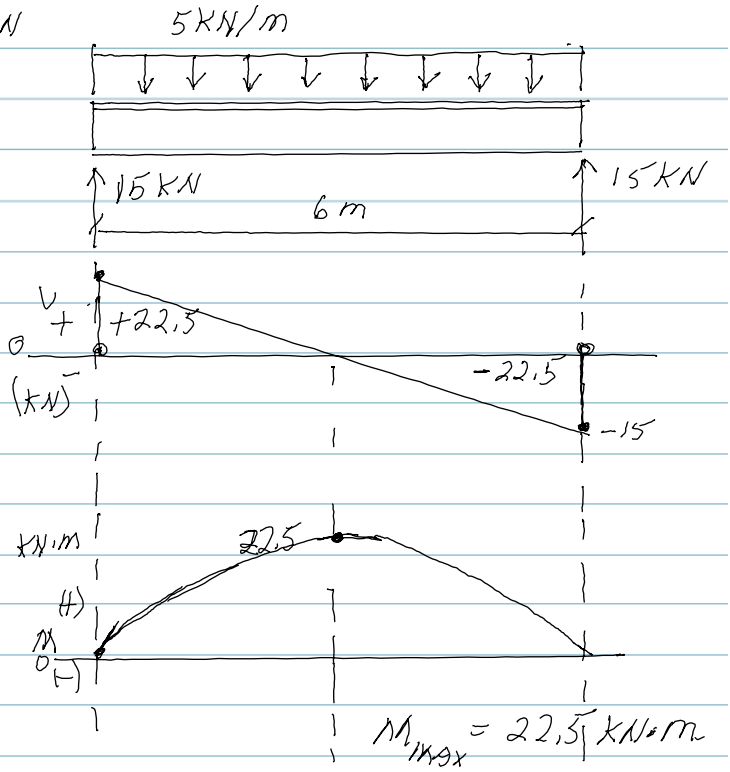
WIDE FLANGE I BEAM
W 460 x 74 (APPENDIX "B" Pg 808
$I = 333 \cdot 10^6 \text{ mm}^4$

FIND: $\sigma_{max} = ?$

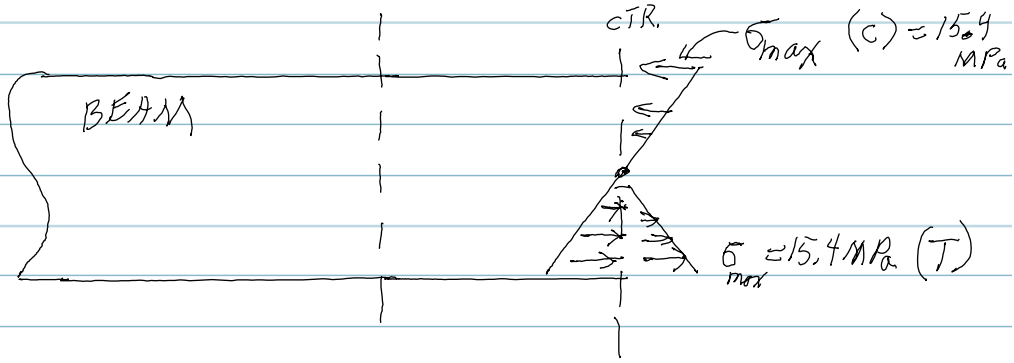
$$\sigma_{max} = \frac{Mc}{I} \qquad M = 22.5 \text{ kN·m}$$

$$\sigma_{max} = \frac{(22.5 \cdot 10^3 \text{ N·m})\left(\frac{.457 \text{ m}}{2}\right)}{333 \cdot 10^{-6} \text{ m}^4}$$

$$\sigma_{max} = 15.4 \text{ MPa}$$



SEE Pg 46 (SN) $M = \frac{1}{8} wL^2$



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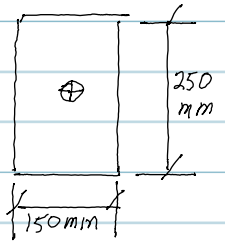
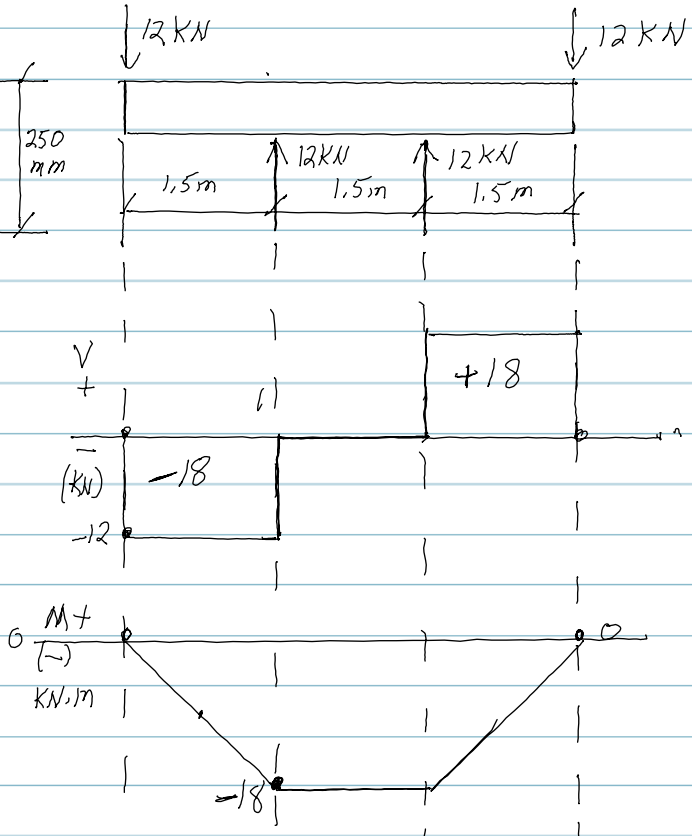
CH 6.4 PROBLEM 6-95

GIVEN:

WOOD BEAM,

FIND: $\sigma_{max} = ?$





SOLUTION:

$$\sigma_{max} = \frac{Mc}{I}$$

$$\sigma_{max} = \frac{(18 \cdot 10^3 N \cdot m)(.125m)}{1.95 \cdot 10^{-4} m^4}$$

$$\sigma_{max} = 1.15 \cdot 10^7 Pa = 11.5 MPa$$

$M_{max} = 18 \; KN \cdot m$

$$c = \frac{.250m}{2} = 0.125 m$$

$$I = \frac{1}{12} b h^3 = \frac{1}{12}(.15m)(.25m)^3$$

$$I = 1.95 \cdot 10^{-4} m^4 =$$

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CH 6.4 FLEXURE FORMULA PROB. 6-73

GIVEN: SOLID STEEL SHAFT
SUPPORT @ "A" & "B" (BEARINGS)
$\sigma_{ALLOW} = 22$ ksi

FIND: $d_{min} = ?$

SOLUTION:

$$\sigma_{max} = \frac{Mc}{I}$$

1) FBD REACTIONS

$\Sigma M_A = 0$

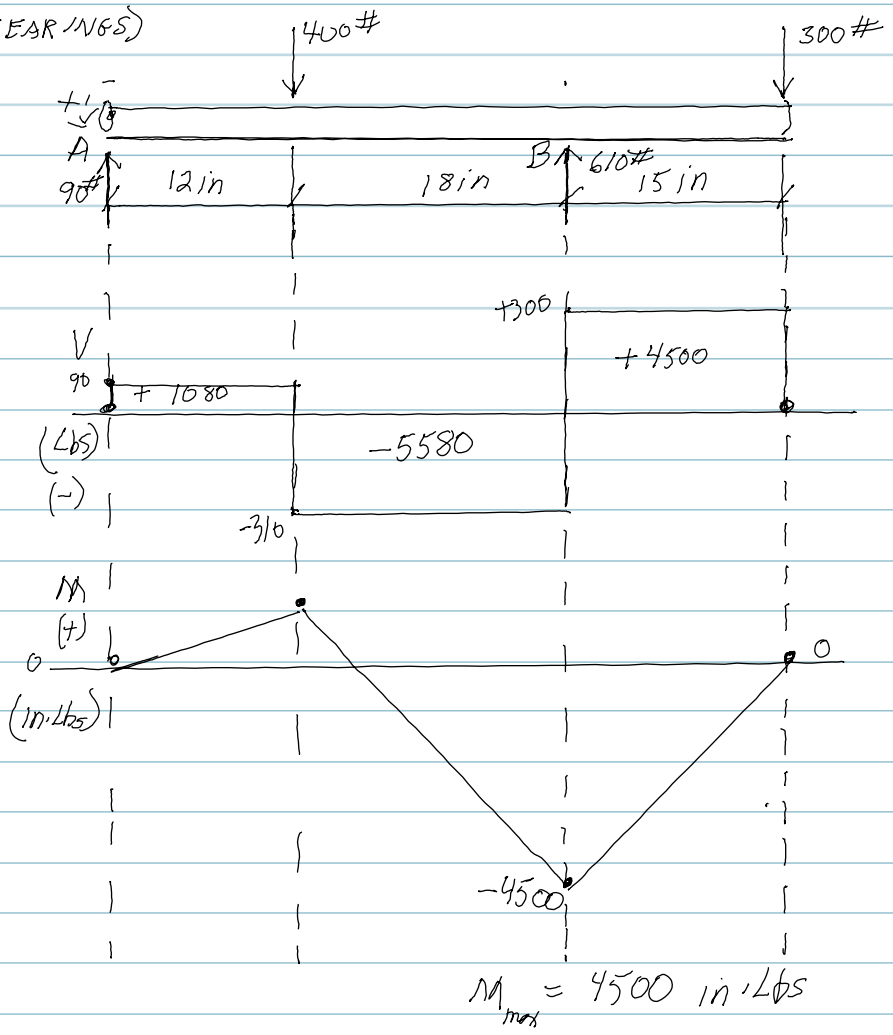
$-400(12) + B(30) - 300(45) = 0$

$B = 610\#$

$\Sigma F_y = 0$

$A - 400 + 610 - 300 = 0$

$A = 90\#$



$M_{max} = 4500$ in·Lbs

2) $\sigma_{max} = \frac{Mc}{\frac{1}{4}\pi r^4} = \frac{M}{\frac{1}{4}\pi r^3}$

$r^3 = \frac{4M}{\pi \sigma_{max}}$

$r^3 = \frac{4(4500 \text{ in·Lbs})}{\pi\left(22000 \frac{\text{Lb}}{\text{in}^2}\right)} = .2604 \text{ in}^3$

$I = \frac{1}{4}\pi r^4$ (INSIDE COVER)

$c = r$

$r = 0.6386$ in

$d_{min} = 1.28$ in

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CH. 6 SHEAR & BENDING MOMENT CONSTRUCTION PUZZLE

CONSTRUCT THE LOADS & SUPPORT FORCES REQUIRED TO MATCH THE SHEAR DIAGRAM GIVEN. NOTE THE FORCES UNITS ARE KIPS. DISTANCE IS IN UNITS OF FEET.