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SUBJECT = Advanced Mechanics of Materials

PROGRAMME = M.S (S.E)

INSTRUCTOR = ENGR. FAWAD AHMAD

ANSWER SHEET :

QUESTION NO : 01

Q1: Solution

Moment of section - A is

$M = 14951 \times 0.2$

$= 3068$ Nm

and the torque on the shaft is

$T = 14951 \times 0.15$

$= 2301$ Nm

The normal stress due to M at A is

$$\sigma = \frac{64Md}{2\pi d^4} = \frac{-32M}{\pi d^3}$$

and The max shear stress due to T at A is

$$\tau = \frac{32Td}{2\pi d^4} = \frac{16T}{\pi d^3}$$

The shear stress due to the shear Force F is zero at A.

$$\sigma_{1,3} = \frac{1}{2}\sigma \pm \frac{1}{2}\left(\sigma^2 + 4\tau^2\right)^{1/2},$$

$\sigma_2 = 0$

) Max shear stress Theory

$$\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_3)$$

$$= \frac{1}{2}(\sigma_2 + 4\sigma\tau^2)^{1/2}$$

$$= \frac{1}{2}\left(\frac{32}{\pi d^3}\right)(M^2 + T^2)^{1/2}$$

$$= \frac{16}{\pi d^3}(3068^2 + 2301^2)^{1/2}$$

$$= \frac{19531 \cdot 5}{d^3} \text{ Pa}$$

With FOS $N = 15$ the value of τ_{max} becomes

$$N\,\tau_{max} = \frac{292972 \cdot 5}{d^3} \text{ Pa}$$

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This should not exceed the max shear stress value at yielding in the uniaxial Tension Test

Thus,

$$\frac{1}{d^3}(292972.5) = \frac{\sigma_y}{2} = \frac{207}{2}\times 10^6$$

$$\cancel{d^3}\times\frac{1}{\cancel{d^3}}(29297.5) = 103.5\times 10^6\times d^3$$

$$\frac{29297.5}{103.5\times 10^6} = d^3$$

$$d^3 = 2.83\times 10^{-4}\ m^3$$

or

$$d = 65.65\times 10^{-3}\ m$$

$$d = 6.565\ cm$$

(ii) Octahedral shear stress Theory

$$\tau_{oct} = \frac{1}{3}\left[(\sigma_1-\sigma_2)^2+(\sigma_1-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]^{1/2}$$

with $\sigma_2 = 0$

$$\tau_{oct} = \frac{1}{3}\left[2\sigma_1^2+2\sigma_3^2-2\sigma_1\sigma_3\right]^{1/2}$$

Subsitituting for σ_1 & σ_2 & Simplifying

$$\tau_{oct} = \frac{\sqrt{2}}{3}(\sigma^2+3\tau^2)^{1/2}$$

$$= \frac{\sqrt{2}}{3\pi d^3}\left[(32M)^2+3(16T)^2\right]^{1/2}$$

$$= \frac{16\sqrt{2}}{3\pi d^3}(4M^2+3T^2)^{1/2}$$

$$= \frac{16\sqrt{2}}{3\pi d^3}\left(4(3068)^2+3(2301)^2\right)^{1/2}$$

or

$$= \frac{16\sqrt{2}}{3\pi d^3}\times 7316.7$$

Pa

$$= \frac{\sqrt{2}}{3\pi d^3}\times 117067$$

Equating this ....

$$\frac{\sqrt{2}}{3\pi d^3} \times 15 \times 117067 = \frac{\sqrt{2}}{3} \sigma_y$$

or

$$2 \times 117067 = \pi d^3 \quad \sigma_y = \pi d^3 \times 207 \times 10^6$$

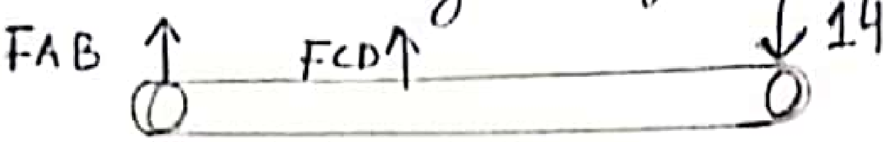
$$\therefore d^3 = 10.56 \times 10^{-4}$$

$$\boxed{d = 10.18\,cm}$$

QUESTION NO : 02

Q2 ANSWER :-

Free body diagram



$\Sigma M_B = 0$

$$0 = -(14\,KN \times 0.6\,m) + FCD \times 0.2\,m$$

$$= \frac{16\,KN \times 0.6}{0.2} = \frac{FCD}{0.\cancel{2}} \times 0.\cancel{2}$$

$FCD = 45\,KN$ Tention

$\Sigma MD = 0$

$$0 = 14\,KN \times 0.4 - FAB \times 0.2$$

$$\frac{FAB \times 0.\cancel{2}}{0.\cancel{2}} = \frac{-14\,KN \times 0.4}{0.2}$$

$FAB = -30\,KN$ Compression

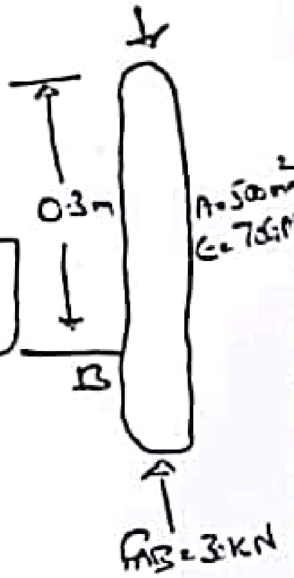
Displacement of B:

(2)

$$\delta_B = \frac{PL}{AE}$$

$$= \frac{(-30\times10^3\,N)(0.3m)}{(500\times10^{-6}m^2)(70\times10^9 Pa)}$$

$$= -257\times10^{-6}m = \boxed{\delta_B = 0.257mm\uparrow}$$

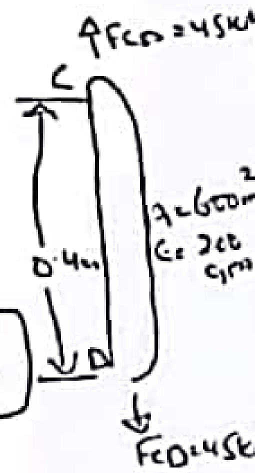


Displacement of D:

$$\delta_D = \frac{PL}{AE}$$

$$= \frac{(45\times10^3 N)(0.4m)}{(600\times10^{-6}m^2)(200\times10^9 Pa)}$$

$$= 150\times10^{-6}m \Rightarrow \boxed{0.150mm\downarrow}$$



Displacement of D

$$\frac{BB'}{DD'} = \frac{BH}{HD} = \frac{0.257}{0.150} = \frac{(200mm)-x}{x}$$

$$\boxed{x = 36.85mm}$$

$$\frac{EE'}{DD'} = \frac{HE}{HD}$$

$$\cancel{\frac{\delta E}{0.300mm} = \frac{(400+73.7)mm}{73.7mm}}$$

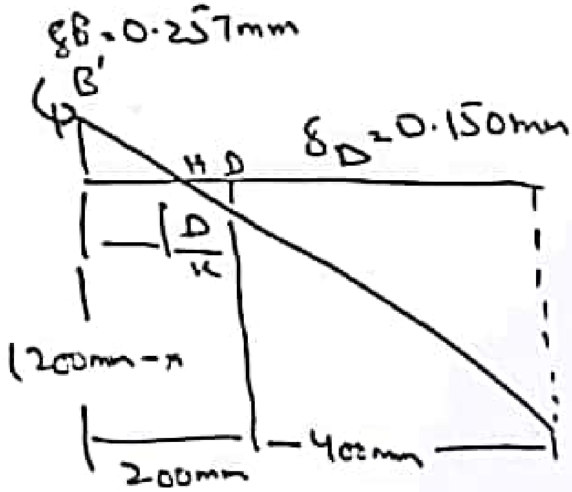
(3)

$$\frac{EE'}{DD'} = \frac{HE}{HD}$$

$$\frac{\delta_E}{0.150\,mm} = \frac{(400 + 36.85)}{36.85}$$

$$\delta_E = \frac{400 + 36.85}{36.85} \times 0.150$$

$$\boxed{\delta_E = 0.964\,mm \downarrow}$$

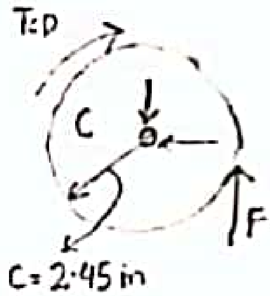


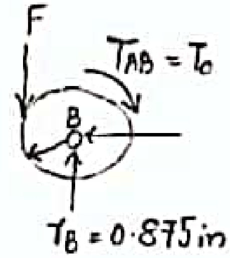
QUESTION NO: 03

Solution :

- Apply a statistics equilibrium analysis on the two shafts to find a relationship b/w T_{CD} and T_0
- Apply a kinematic analysis to relate the angular relation of the gears.
- find the maximum allowable torque on each shaft – choose the smallest.
- find the corresponding angle of twist for each shaft and the net angular rotation of end A.

– • Apply a static equilibrium analysis on the two shafts to find a relationship b/w T_{CD} and T_0



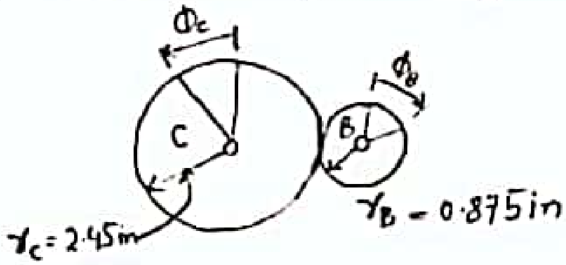


$$\Sigma M_B = 0 = F(0.875 \text{ in}) - T_0$$

$$\Sigma M_C = 0 = F(2.45 \text{ in}) - T_{CD}$$

$$T_{CD} = 2.8\, T_0$$

- Apply a kinematic analysis to relate the angular rotation of the gears.

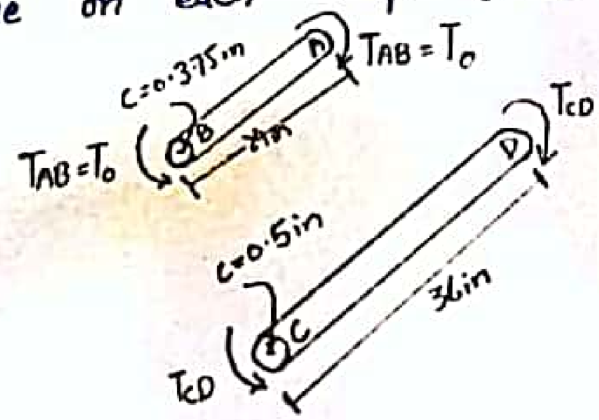


$$r_B \phi_B = r_C \phi_C$$

$$\phi_B = \frac{r_C}{r_B}\phi_C = \frac{2.45 \text{ in.}}{0.875 \text{ in.}}\phi_C$$

$$\phi_B = 2.8\, \phi_C$$

- Find the T_0 for the maximum allowable torque on each shaft chose the smallest



$$\tau_{max} = \frac{T_{AB}c}{J_{AB}} \Rightarrow 10{,}000\ psi = \frac{T_o(0.375\ in.)}{\frac{\pi}{2}(0.375\ in.)^4}$$

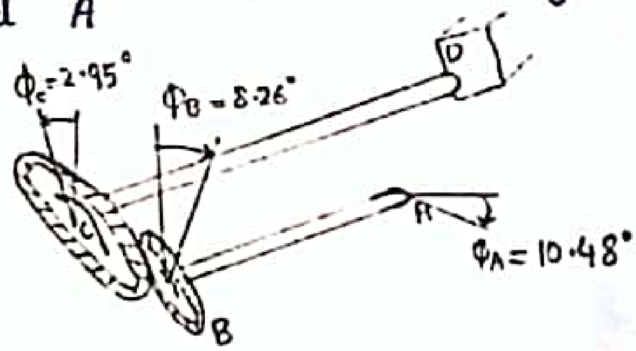
$$= 10{,}000\ psi = \frac{T_o(0.375\ in)}{0.0310\ in^4}$$

$$= 10{,}000\ psi * 0.0310\ in^4 = T_o(0.375\ in)$$

$$= 310\ lb\,in^2 = T_o\ 0.375\ in$$

$$= T_o = \frac{310\ in^2 . lb}{0.375\ in} \Rightarrow \boxed{T_o = 826\ lb.in}$$

— Find the corresponding angle of twist for each shaft and the net angular rotation of end A



$$\phi_{A/B} = \frac{T_{AB}L}{J_{AB}G} = \frac{(826\ lb.in)(24\ in)}{\frac{\pi}{2}(0.375)^4(15\times 10^6\ psi)} = 0.0425\ rad = [$$

$$= 0.00224\ rad = 6^\circ 0' 8.88''$$

$$\phi_{C/D} = \frac{T_{CD}L}{J_{CD}G} = \frac{2.8(826\ lbin)(24in)}{\frac{\pi}{2}(0.5in)^4(15\times 10^6\ psi)}$$

$$= 0.0376\ rad = \boxed{2.15^\circ}$$

$$\phi_B = 2.8\phi_c = 2.8(2.15) = 6.02^\circ$$

$$\phi_A = \phi_B + \phi_{A/B} = \overset{6.02^\circ}{\cancel{8.26}}{}^\circ + 2.43 = \boxed{\phi_A = 8.45^\circ}$$

QUESTION NO: 04

(1)

I D = 14951

So , V = 14 + 3 = 17 kips

⇒ Shear stresses in the flange

$$\tau = \frac{VQ}{It} = \frac{V}{I\cancel{t}}(s\cancel{t})\,h/2 = \frac{Vh}{2I}s$$

$$\tau_B = \frac{Vhb}{2\left(\frac{1}{12}th^2\right)(6b+h)} = \frac{6vb}{th(6b+h)}$$

$$\tau_B = \frac{6\,(17\text{ kips})\,(4\text{in})}{(0.15\text{ in})\,(6\text{in})\,(6\times 4\text{in}+6)}$$

$$\boxed{\tau_B = 16\text{ kips}}$$

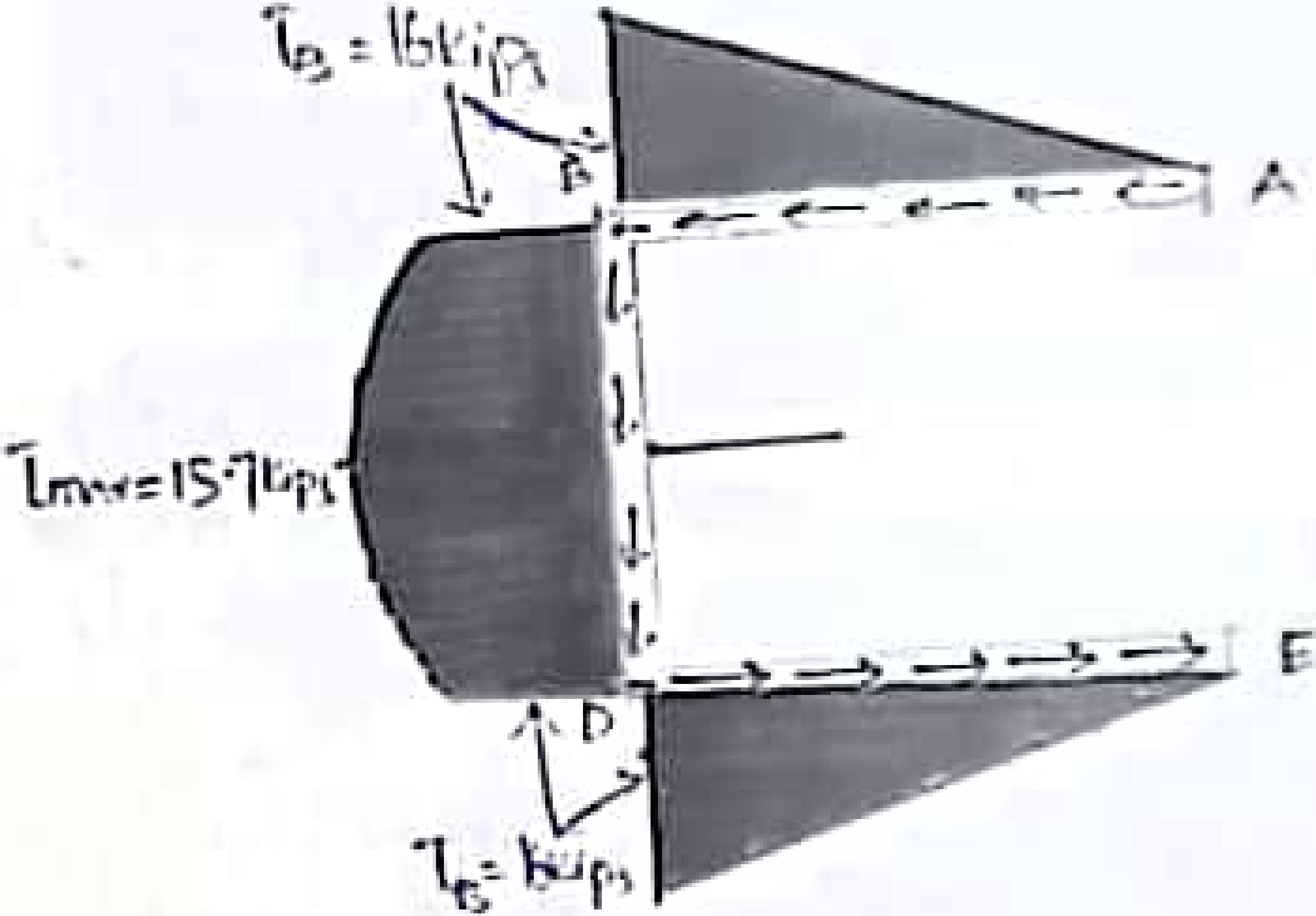
⇒ Shear stress In the Web,

$$\tau_{max} = \frac{VQ}{It} = \frac{V\left(\frac{1}{8}ht\right)(4b+h)}{\frac{1}{12}th^2(6b+h)\,t}$$

$$= \frac{3V(4b+h)}{2th(6b+h)} \quad (2)$$

$$\tau_{max} = \frac{3(17\,\text{Kips})(4 \times 4\,\text{in} + 6\,\text{in})}{2(0.15\,\text{in})(6\,\text{in})(6 \times 6\,\text{in} + 6\,\text{in})}$$

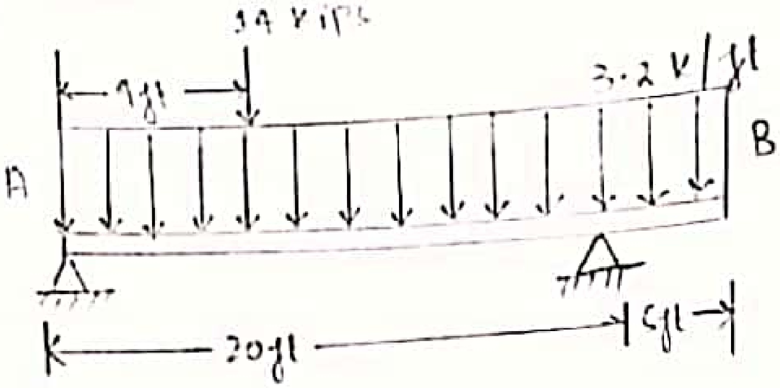
$$\boxed{\tau_{max} = 15.71\ \text{Kips}}$$



τB = 16kips
B
A
τmax = 15.7kips
D
E
τB = kips

QUESTION NO : 05

Q.05 SOLUTION: (1)



Given Data:

$$\delta = 14 + 4 = 18$$

and

$$\tau = 14 + 1 = 15$$

(i) Determine Reaction at A and D.

$$\circlearrowleft^{+} \Sigma M_A = 0$$

$$-14 \times 9 - 80 \times 12.5 + R_D \times 20.0$$

$$\Rightarrow -135 - 1000 + 20R_D = 0$$

$$\Rightarrow -1135 + 20R_D = 0$$

$$\Rightarrow 20R_D = 1135$$

$$\Rightarrow R_D = \frac{1135}{20}$$

$$\Rightarrow \boxed{R_D = 56.75 \text{ kips}} \longrightarrow \text{Eq} (*)$$

Now

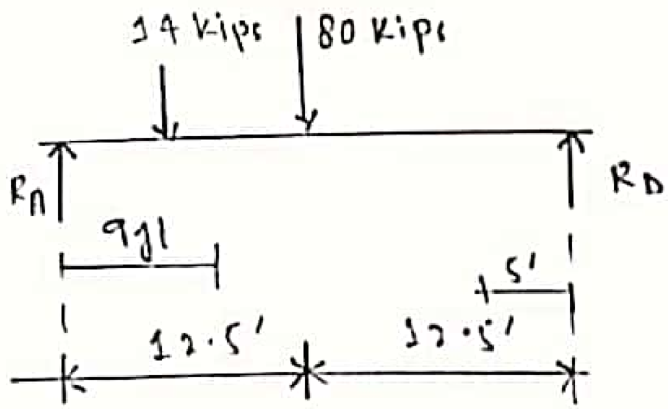
$$+\uparrow \Sigma F_y = 0$$

$$R_A + R_D - 14\text{kips} - 80\text{ kips} = 0$$

$$R_A + R_D - 95\text{ kips} = 0$$

$$\boxed{R_A + R_D = 95\text{ kips}} \longrightarrow \text{Eq} (\#)$$

Put Eq (*) in Eq (#)



$$R_A = 38.25\text{ kips}$$

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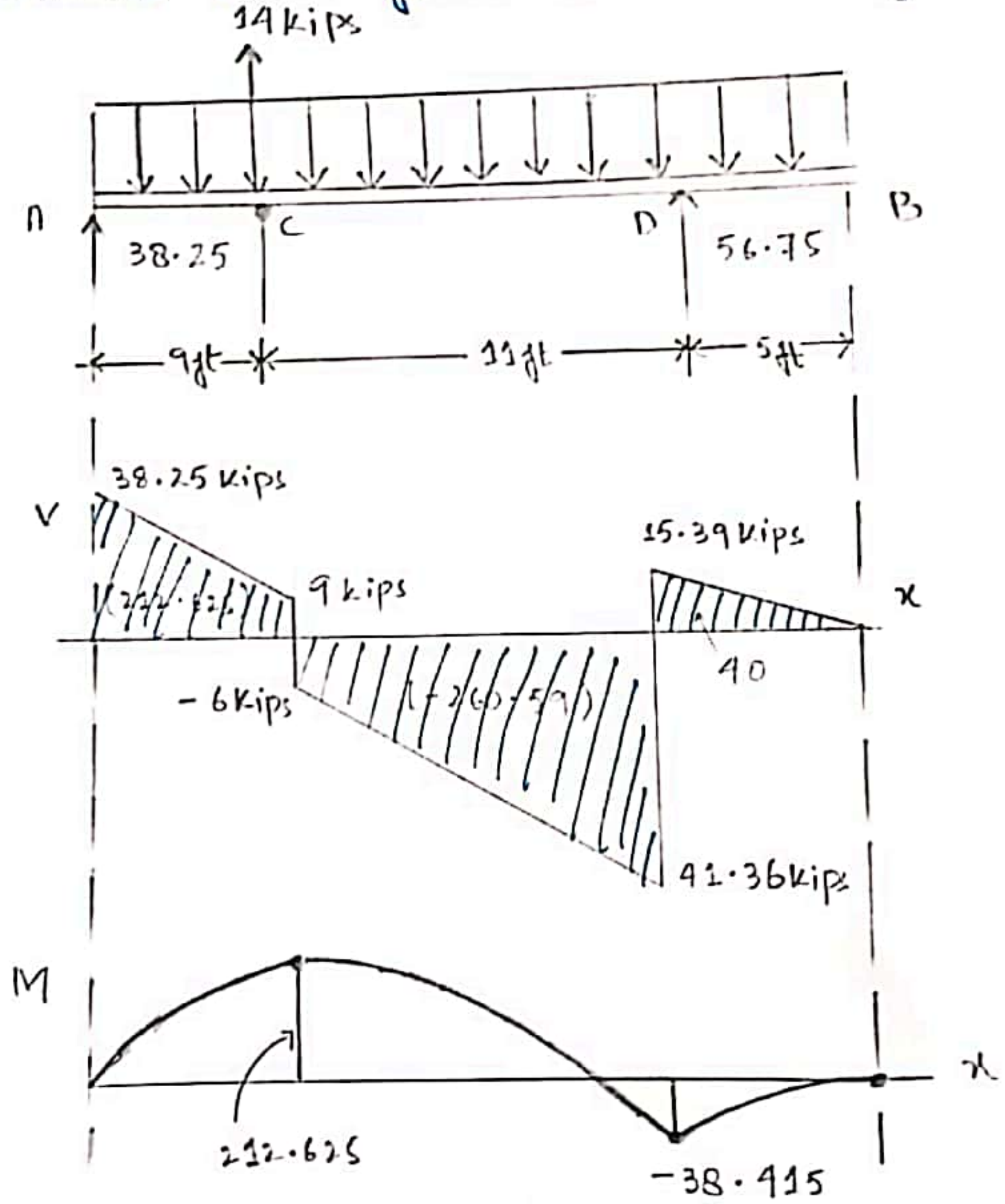
(2)

(ii) To determine shear force and Bending.



$|M| = 239.4$ kip-in with $V = 9$ kips

$|V|_{max} = 41.36$ kips

Calculate required section modulus and select appropriate beam section.

$$S_{min} = \frac{|M|_{max}}{\sigma_{all}} = \frac{24 \text{ kips.in}}{24 \text{ ksi}} = 119.7 \text{ in}^3$$

Select $W_{21} \times 62$ beam section

* Find maximum shearing stress, Assuming uniform shearing stress in web,

$$\tau_{max} = \frac{V_{max}}{A_{web}} = \frac{41.36 \text{ kips}}{8.40 \text{ in}^2} = 5.12 \text{ ksi} < 14.5 \text{ k}$$

* Find maximum normal stress

$$\sigma_a = \frac{M_{max}}{S} = \frac{2873 \text{ 60 kip.in}}{127 \text{ in}^3} = 22.6 \text{ ksi}$$

$$\sigma_b = \sigma_a \frac{y_b}{c} = (22.6 \text{ ksi}) \frac{9.88}{10.5} = 21.3 \text{ ksi}$$

$$\tau_b = \frac{V}{A_{web}} = \frac{12.2 \text{ kips}}{8.40 \text{ in}^2} = 1.45 \text{ ksi}$$

$$\sigma_{max} = \frac{21.3 \text{ ksi}}{2} + \sqrt{\left(\frac{21.3 \text{ ksi}}{2}\right)^2 + (1.45 \text{ ksi})^2}$$

$$\boxed{\sigma_{max} = 21.4 \text{ ksi} < 24 \text{ ksi}}$$