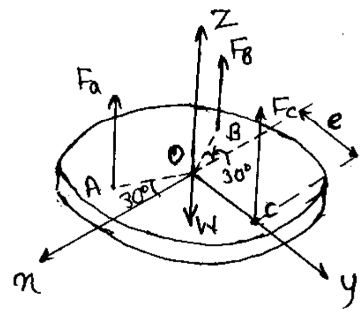
Solutions to Chapter 2. HW Problems

Solution of problem 2.3

Let $\delta_a, \delta_b, \delta_c$ be the deflections of springs a, b, c respectively.



OA = OB = 1 m.

Geometric compatibility:

$$\delta_a = \delta_b = \delta_c. \quad \text{— (i)}$$

∴ Force deformation relations ~~deformation force~~ :

$$F_a = k_a \delta_a \quad \text{— ii)}$$

$$F_b = k_b \delta_b \quad \text{— iii)}$$

$$F_c = k_c \delta_c \quad \text{— iv)}$$

Where $k_a = k_b = 14$ kN/m. ; $k_c = 16$ kN/m.

Equilibrium of disk:

For disk to be hang level

$$\Sigma M_{ox} = 0 \Rightarrow e \times F_c - F_a \times \sin 30 - F_b \times \sin 30 = 0. \quad \text{— v)}$$

$$\Sigma F_z = 0 \Rightarrow F_a + F_b + F_c = W$$

$$= 1.1 \times 10^3 \quad \text{— vi)}$$

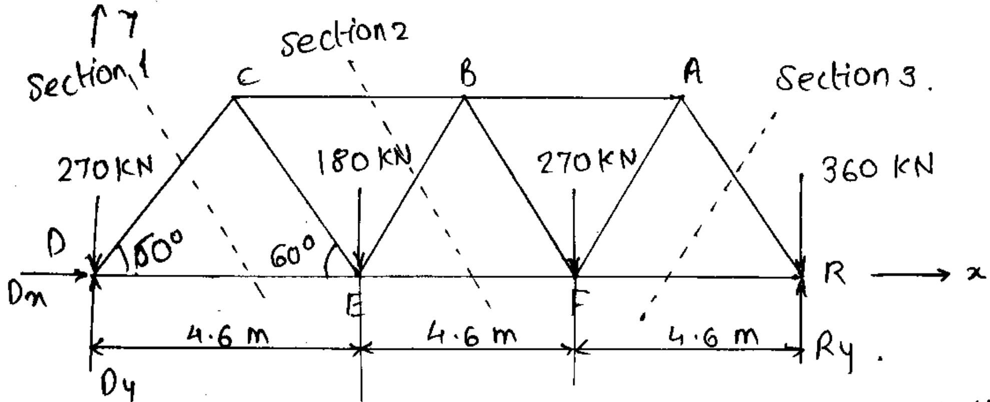
Solving above eqns

$F_a = F_b = 0.35$ KN

$F_c = 0.4$ KN.

$e = 0.875$ m.

Solution to problem 2.7



A railroad bridge : Loads are due to stationary train.

element material : steel with area = 3250 mm^2.

To Find: Horizontal displacement of R.

Note that Horizontal displacement of $R \cong \delta_{DE} + \delta_{EF} + \delta_{FR}$.

To find reactions:

$\Sigma F_x = 0. \Rightarrow D_x = 0.$

$+\circlearrowright \Sigma M_D = 0 \Rightarrow 180 \times DE + 270 \times DF + 360 \times DR - R_y \times DR = 0.$

$$\therefore R_y = \frac{180 \times 4.6 + 270 \times 9.2 + 360 \times 13.8}{13.8}$$

$$= 600 \text{ kN}.$$

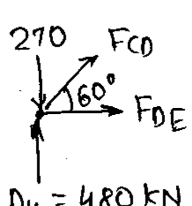
$+\uparrow \Sigma F_y = 0 \Rightarrow D_y + R_y - 270 - 180 - 270 - 360 = 0.$

$\therefore D_y = +480$ kN.

$\therefore D_y$ is in up~~down~~ward direction.

Estimation of forces in members DE, EF, FR.

Section 1:



$+\uparrow \Sigma F_y = 0 \Rightarrow F_{CD} \sin 60 - 270 + 480 = 0.$

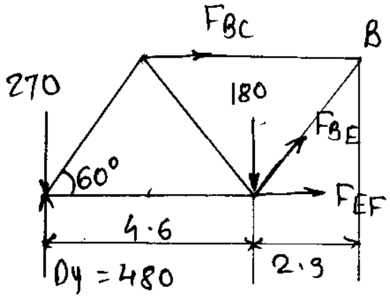
$\therefore F_{CD} = -242.49$ kN.

$\Sigma F_x = 0 \Rightarrow F_{DE} = -F_{CD} \cos 60$

$= 242.49 \cos 60 = 121.24$ kN.

(problem 2.7 (contd)

Section 2:

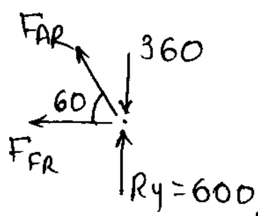


$+\circlearrowleft \Sigma M_B = 0 \Rightarrow$

$-F_{EF} \times 4.6 \sin 60 - 270 \times 6.9 - 180 \times 2.3 + 480 \times 6$

$\Rightarrow F_{EF} = \cancel{225.17}\ 259.8$ KN.

Section 3:



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

$F_{AR} \sin 60 - 360 + 600 = 0.$

$\therefore F_{AR} = -277.13$ KN.

$\xrightarrow{+} \Sigma F_x = 0 \Rightarrow$

$-F_{AR} \cos 60 - F_{FR} = 0.$

$\therefore F_{FR} = 138.6$ KN.

Horizontal displacement of R:

$\delta = \delta_{DE} + \delta_{EF} + \delta_{FR}$

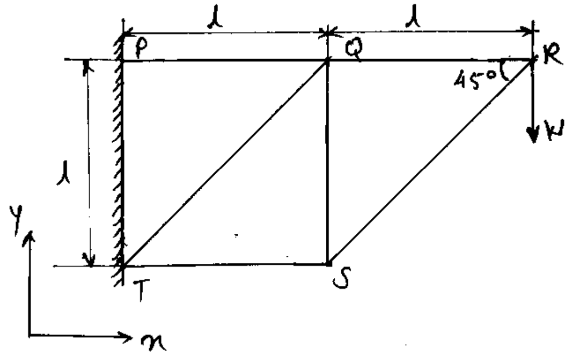
$= \dfrac{L}{AE}(F_{DE} + F_{EF} + F_{FR})$

$= \dfrac{4.6}{3250 \times 10^{-6} \times 200 \times 10^9}(121.3 + \cancel{249.8}\ \cancel{225.17}\ 259.8 + 138.6) \times 10^3.$

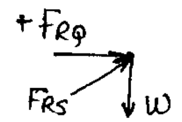
$= \cancel{3.49}\ 3.68 \times 10^{-3}$ m

$= \cancel{3.49}\ 3.68$ mm.

Solution to problem 2.10



At Point R



$\overset{+}{\rightarrow} \Sigma F_x = 0$

$\therefore \; +F_{RQ} + F_{RS}\cos 45 = 0 \qquad$ – i)

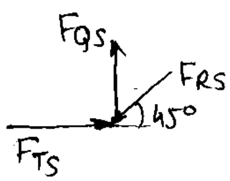
$+\uparrow \Sigma F_y = 0 \Rightarrow F_{RS}\sin 45 - W = 0. \qquad$ – ii)

C : Compression
T : Tension

equations i) & ii) gives.

$F_{RS} = \sqrt{2}\,W \;(C) \qquad F_{RQ} = -W\,(C)$
$\qquad\qquad\qquad\qquad\qquad\quad = W\,(T)$

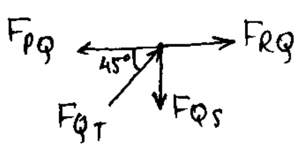
For Point S:



$\overset{+}{\rightarrow} \Sigma F_x = 0 \Rightarrow F_{TS} - F_{RS}\cos 45 = 0 \Rightarrow F_{TS} = W$

$+\uparrow \Sigma F_y = 0 \Rightarrow F_{QS} - F_{RS}\sin 45 = 0 \Rightarrow F_{QS} = W\;(T).$

For point Q:



$+\uparrow \Sigma F_y = 0 \Rightarrow F_{QT}\sin 45 - F_{QS} = 0$

$F_{QT} = \sqrt{2}\,W\,(C).$

$\overset{+}{\rightarrow} \Sigma F_x = 0 \quad -F_{PQ} + F_{RQ} + F_{QT}\cos 45 = 0.$

$\therefore \; F_{PQ} = 2W\;(T).$

ii) To Find vertical deflection of joint R:

deflection in PQ

$$\delta_{pq} = \frac{F_{PQ}\,l}{AE} = \frac{2Wl}{AE} \quad \text{elongation.}$$

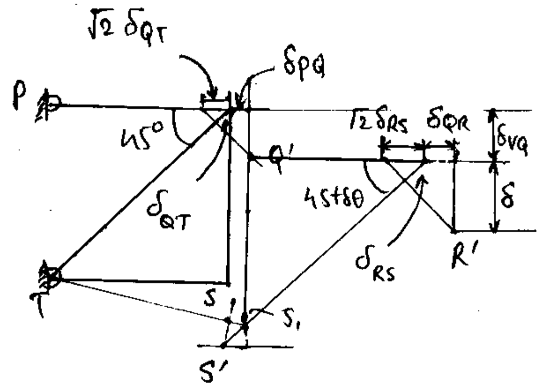
Problem 2.10 (contd.)

$$\delta_{QT} = \frac{F_{QT} \times \sqrt{2}\, l}{AE} = \frac{\sqrt{2}\, W \times \sqrt{2}\, l}{AE} = \frac{2Wl}{AE} \quad \text{(compression)}.$$

$$\cancel{\delta_{QS} = \frac{F_{QS}\, l}{AE} = \frac{Wl}{AE} \text{ (elongation).}}$$

$$\delta_{QR} = \frac{F_{QR}\, l}{AE} = \frac{Wl}{AE} \quad \text{(elongation)}.$$

$$\delta_{RS} = \frac{F_{RS}\, \sqrt{2}\, l}{AE} = \frac{2Wl}{AE} \quad \text{(compression)}.$$



Final configuration: $P\,T\,Q'S'R'$.

Verticle ~~displ~~ deflection of joint.

$$\delta_{VQ} = \delta_{PQ} + \sqrt{2}\,\delta_{TQ}.$$

Verticle deflection of R :

note that effect of changed position of s will be to change angle from 45° to $(45+\delta\theta)^\circ$. As deflections are small we neglect change in angle $\delta\theta$.

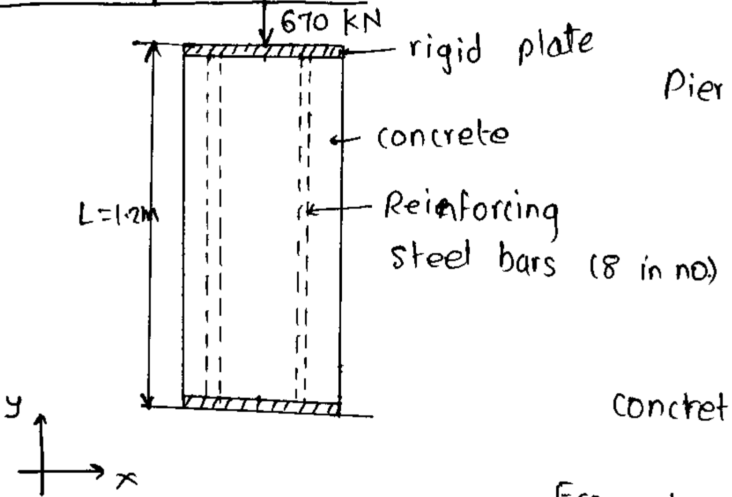
$$\therefore \delta_{VR} = \delta_{VQ} + \delta.$$

$$= \delta_{PQ} + \sqrt{2}\,\delta_{TQ} + (\delta_{QR} + \sqrt{2}\,\delta_{RS}).$$

$$= \frac{2Wl}{AE} + \sqrt{2} \times \frac{2Wl}{AE} + \frac{Wl}{AE} + \sqrt{2} \times \frac{2Wl}{AE}.$$

$$= (3+4\sqrt{2})\frac{Wl}{AE}.$$

Solution to problem 2.11.



Pier crosssection : 0.3×0.3

$\Rightarrow A = 9 \times 10^{-2}\, m^2$.

cross section: 25×25

$A_s = 6.25 \times 10^{-4}\, m^2$

concrete area $A_c = A - A_s \times 8$

$= 8.5 \times 10^{-2}$,

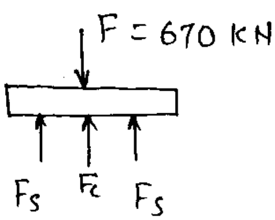
$E_{concrete} \equiv E_c = 17$ GPa.

$E_{steel} \equiv E_s = 200$ GPa.

To Find: i) Stresses in steel and concrete.

ii) Deflection.

Equilibrium of rigid plate:



$+\uparrow \sum F_y = 0 \Rightarrow 8 \times F_s + F_c - F = 0.$ — i)

Force deformation relationship:

$$\left.\begin{aligned} \delta_s &= \frac{F_s L}{A_s E_s} \\ \delta_c &= \frac{F_c L}{A_c E_c} \end{aligned}\right\} \quad \text{— ii)}$$

Compatibility :

$\delta_s = \delta_c = \delta$ - say — iii)

From equations i), ii) and iii)

$$8 \times \frac{A_s E_s \delta}{L} + \frac{A_c E_c \delta}{L} = F.$$

(Problem ~~2·1~~ 2·11 contd.)

$$\therefore \quad \delta = \frac{F \cdot L}{8 A_S E_S + A_C E_C}$$

$$= \frac{670 \times 10^3 \times 1.2}{8 \times 6.25 \times 10^{-4} \times 2 \times 10^{11} + 8.5 \times 10^{-2} \times 1.7 \times 10^{10}}$$

$$= 3.29 \times 10^{-4} \text{ m.}$$

Stress in concrete $= \sigma_c = E_c \dfrac{\delta}{L}$.

$$= 1.7 \times 10^{10} \times \frac{3.29 \times 10^{-4}}{1.2}$$

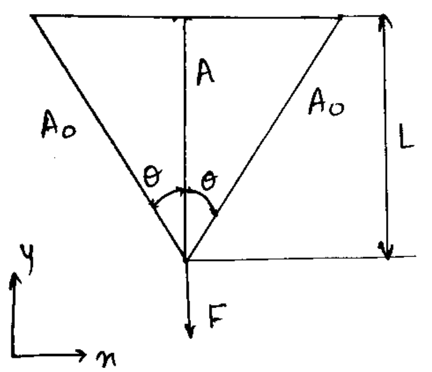
$$= 4.66 \times 10^6 \text{ N/m}^2.$$

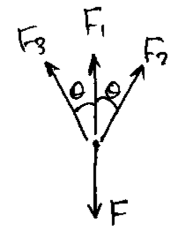
Stress in steel bar $= \sigma_S = E_S \dfrac{\delta}{L}$.

$$= 2 \times 10^{11} \times \frac{3.29 \times 10^{-4}}{1.2}$$

$$= 54.833 \times 10^6 \text{ N/m}^2.$$

Solution to problem 2.12





$\overset{+}{\rightarrow} \Sigma F_x = 0 \Rightarrow$

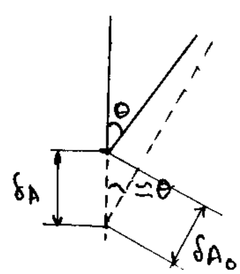
$$-F_3 \sin\theta + F_2 \sin\theta = 0. \Rightarrow F_3 = F_2$$

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

$$-F + F_1 + F_2 \cos\theta + F_3 \cos\theta = 0.$$

$$\therefore \; F_1 + 2F_2 \cos\theta = F. \quad \text{——— (i)}$$

Geometric Compatibility :



For small deflection θ will remain approxim constant.

$$\delta A_o = \delta_A \cos\theta .$$

$$\frac{F_2 (L/\cos\theta)}{A_o E} = \frac{F_1 L \cos\theta}{E A} \quad \text{——— (ii)}$$

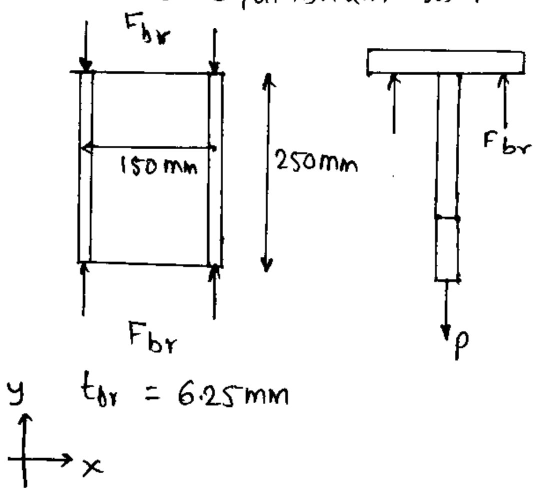
$$\text{(i) \& (ii)} \Rightarrow F_2 = \frac{F}{\left(\frac{A}{A_o \cos^2\theta} + 2\cos\theta\right)} .$$

$$F_1 = \frac{F}{\left(1 + 2\frac{A_o}{A}\cos^3\theta\right)} .$$

Solution to problem 2.14

i) When $\delta < 0.08\,mm$.

The equilibrium is :



$\Sigma F_y = 0 \Rightarrow$

$F_{br} = P$ — i)

Force deformation relation:

$$\delta_{br} = \frac{F_{br} L_{br}}{A_{br} E_{br}} \qquad \text{— 2)}$$

Compatibility :

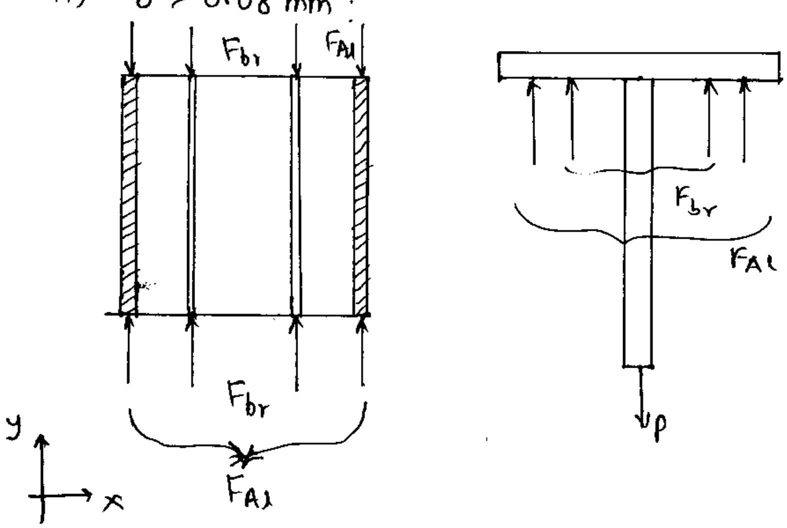
$$\delta = \delta_{br} \qquad \text{— 3)}$$

equations 1), 2), 3) gives relation for P-δ curve as

$$P = F_{br} = \frac{A_{br} E_{br}}{L_{br}} \times \delta_{br} = \frac{A_{br} E_{br}}{L_{br}} \times \delta .$$

$$\therefore P = K_{br}\,\delta$$

ii) $\delta > 0.08\,mm$:



$$\Sigma F_y = 0 \Rightarrow F_{br} + F_{Al} = P \qquad \text{— (4)}$$

(Problem 2.14 contd)

Force deformation :

$$\delta_{br} = \frac{F_{br} L_{br}}{A_{br} E_{br}} \quad , \quad \delta_{Al} = \frac{F_{Al} L_{Al}}{A_{Al} E_{Al}} \quad — \quad (5)$$

Compatibility condition :

$$\delta_{br} = \delta_{Al} + 8\times10^{-5} = \delta \quad \longrightarrow \quad (6)$$

P-δ curve's relation: From equation 4) 5) 6)

$$P = F_{br} + F_{Al}$$

$$= \frac{A_{br} E_{br}}{L_{br}} \delta_{br} + \frac{A_{Al} E_{Al}}{L_{Al}} \delta_{Al}$$

$$= k_{br}\,\delta + k_{Al}\,(\delta - 8\times10^{-5})$$

$$P = (k_{br} + k_{Al})\,\delta - k_{Al}\times 8\times10^{-5}$$

Numerical values:

$$k_{br} = \frac{A_{br} E_{br}}{L_{br}} = \frac{\pi d_{br} t_{br} E_{br}}{L} = \frac{\pi \times 150\times10^{-3} \times 6.25\times10^{-3} \times 10^{11}}{250\times10^{-3}}$$

$$= 11.78\times10^{8}\ N/m.$$

$$k_{Al} = \frac{A_{Al} E_{Al}}{L_{Al}} = \frac{\pi d_{Al} t_{Al} E_{Al}}{L} = \frac{\pi \times 250\times10^{-3} \times 6.25\times10^{-3} \times 0.7\times 10^{11}}{250\times10^{-3}}$$

$$= 13.75\times10^{8}\ N/m.$$

$$\therefore P = (k_{br} + k_{Al})\,\delta - k_{Al}\times 8\times10^{-5}$$

$$= 25.53\times10^{8}\,\delta - 109.96\times10^{3}$$

P at $\delta = 0.08\times2 \Rightarrow$
$= 0.16$ mm

$$P = (25.53\times10^{8}\times 0.16 - 109.96\times10^{5})\times10^{-3}$$

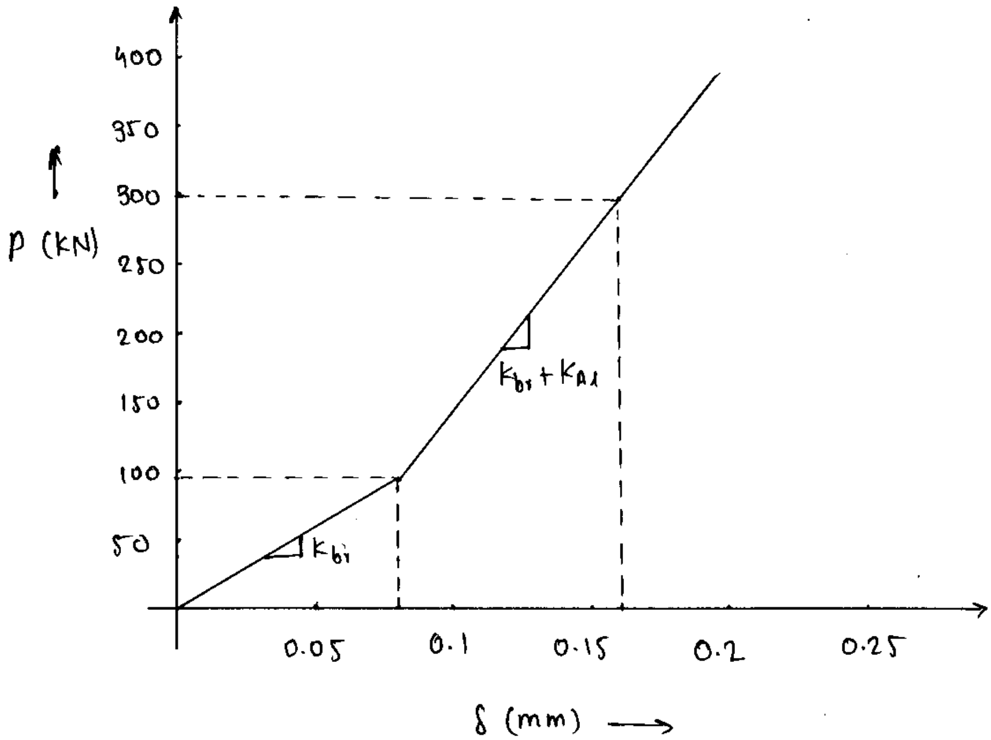
$$= 298.52\ kN.$$

(Problem 2.14 contd.)

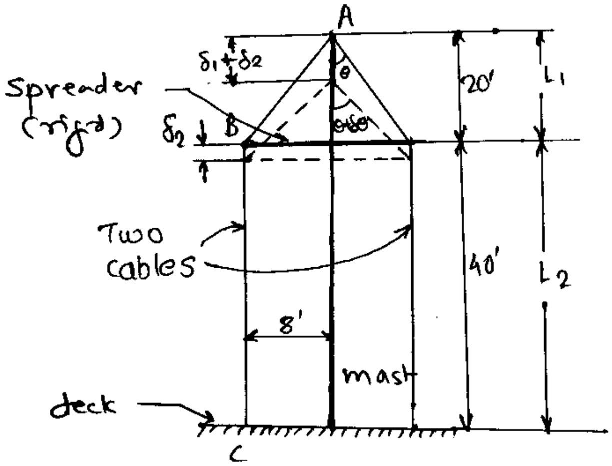
P at $\delta = 0.08$ mm $\Rightarrow$ $P = 11.78 \times 10^8 \times 8 \times 10^{-5}$

$= 94.25 \times 10^3$ N.

P-δ plot.



Solution to problem 2.16



Idealisation:

i) Rigid spreader rigidly attached to m

ii) Cables pass over spreader ends withou friction.

iii) deck is rigid.

iv) Length of turnbuckles are negligib

Geometry of deformation:

Let $L_3 = AB + BC$.

δ_1 = shortening of upper portion of mast.

δ_2 = Shortening of lower portion of mast.

δ_3 = Shortening of cables.

undeformed state : $L_3 = \sqrt{L_1^2+8} + L_2$ — i)

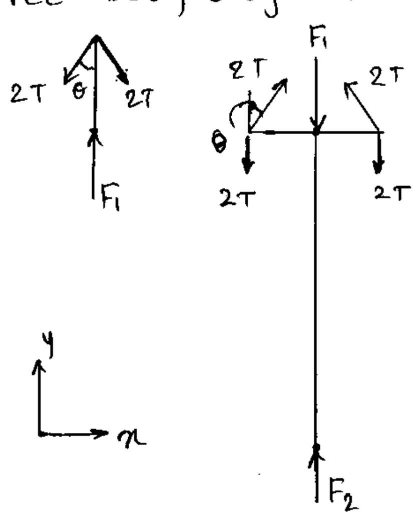
Deformed states : $L_3 - \delta_3 = \sqrt{(L_1-\delta_1)^2+8} + L_2 - \delta_2$ — ii)

Let $\delta_3 = \delta_3' - \delta_3''$

where δ_3' = decrease in length of cables due to tightening of turnbuckle.

δ_3'' = increase in length of cables due to tension.

Free body diagram:



Equilibrium:

It is assumed that the ropes run over frictionless guides and are weightless, the tension in each rope is uniform, = T say. Since deflections are expected to be small, the changes in various angles to be small and, we

(Problem 2.16 contd.)

assume them to be zero. in the equilibrium equation.

Equilibrium of upper mast :

$+\uparrow \Sigma F_y = 0 \Rightarrow F_1 - 2T\cos\theta - 2T\cos\theta = 0.$

$F_1 = 4T\cos\theta.$ — iii)

Lower mast : $+\uparrow \Sigma F_y = 0 \Rightarrow$

$4T\cos\theta - 4T - F_1 + F_2 = 0$ — iv).

From equations iii) and iv)

$T = F_2/4 \;;\quad F_1 = F_2\cos\theta.$

Expanding equation ii) using $(1+\epsilon)^n \simeq 1+n\epsilon$ for $\epsilon << 1$

$$\sqrt{L_1^2+8^2} - \frac{\delta_1 L_1}{\sqrt{L_1^2+8^2}} + L_2 - \delta_2 = L_3 - \delta_3.$$

using i) we can write above equation as

$$-\frac{\delta_1 L_1}{\sqrt{L_1^2+8^2}} = \delta_2 - \delta_3 \Rightarrow -0.93\delta_1 = \delta_2 - \delta_3 \text{ — v).}$$

For δ_3' : δ_3' = decrease in length due to turnbuckle

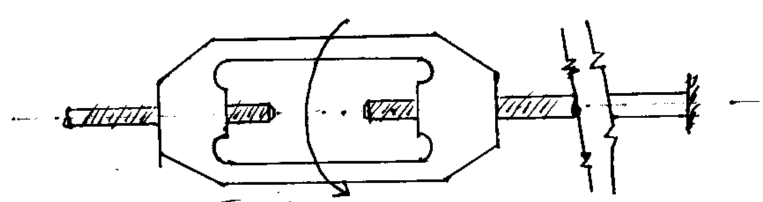
= 2 × no. of turns × pitch.

note that factor 2 is appearing because the two wires are simultaneously pulled through turnbuckle. (see the figure) ~~also see footnote~~.

$\therefore \delta_3' = 2 \times 15 \times \frac{1}{20} \times \frac{1}{12} = 0.125$ ft.

$\delta_3'' = \frac{T}{k}$. $\quad k$ = spring constant of rope (length L_3).

$= \frac{k'}{L_3}$



Turnbuckle.

(Probem 2.16 contd.)

k' = spring constant of 1 ft rope.

$= 140{,}000 \ lb/in$

$= 12 \times 140000 \ lb/ft. \times 1.ft.$

$= 12 \times 140\,000 \ lb.$

$$\therefore \delta_3'' = \frac{T L_3}{k'}$$

from eq^n i) $l_3 = \sqrt{20^2+8^2} + 40$

$= 61.54'$

$$\therefore \delta_3'' = \frac{F_2 \times 61.54}{4 \times 12 \times 140000} = 9.158 \times 10^{-6} F_2 \ ft.$$

$$\therefore \delta_3 = 0.125 - 9.158 \times 10^{-6} F_2$$

$$\delta_1 = \frac{F_1 L_1}{AE_1} = \frac{F_2 \cos\theta \times 20}{20 \times 1.6 \times 10^6}$$

now $\theta = \tan^{-1} \frac{8}{20} = 21.8^\circ$.

$$\therefore \delta_1 = 5.8 \times 10^{-7} F_2 \ ft.$$

$$\delta_2 = \frac{F_2 l_2}{A E_2} = \frac{F_2 \times 40}{20 \times 1.6 \times 10^6} = 12.5 \times 10^{-7} F_2 \ ft.$$

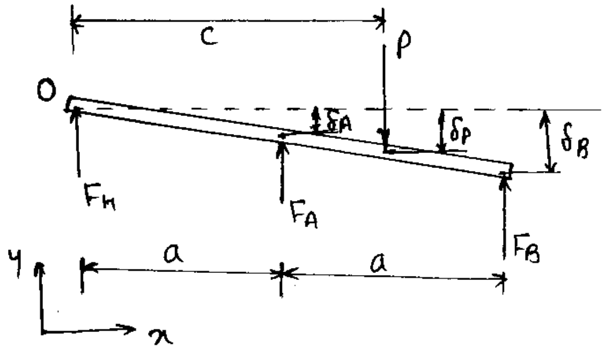
Substituting values of $\delta_1, \delta_2, \delta_3$ into equation v)

$$-0.93 \times 5.8 \times 10^{-7} F_2 = 12.5 \times 10^{-7} F_2 - 0.125 + 9.158 \times 10^{-6} F_2$$

$$\therefore F_2 = 11418.2 \ lb.$$

Solution to problem 2.19 :

To find: Location of load P :



Idealization:

i) No friction at pivot.

ii) Beam is weightless.

iii) Springs don't deflect sidwards.

From geometry of Deflection for rigid beam.

$$\delta_A = \frac{1}{2}\delta_B \quad , \quad \delta_P = \frac{c}{2a}\delta_B .$$

Force deformation relationship:

$$F_A = k\delta_A = \frac{k}{2}\delta_B .$$

$$F_b = k\delta_B .$$

Equilibrium : $\circlearrowleft \Sigma M_O = 0 \Rightarrow$

$$P \times c - F_A \cdot a - F_b \cdot 2a = 0$$

$$\Rightarrow P = \frac{5}{2} k\delta_B \frac{a}{c} .$$

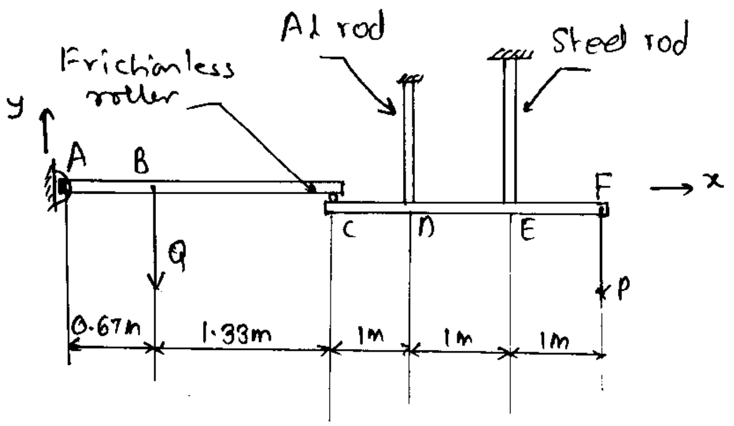
$$\therefore \frac{P}{\delta_P} = \frac{5/2\, k\,\delta_B\, a/c}{\frac{c}{2a}\delta_B} = 5\frac{a^2}{c^2}k .$$

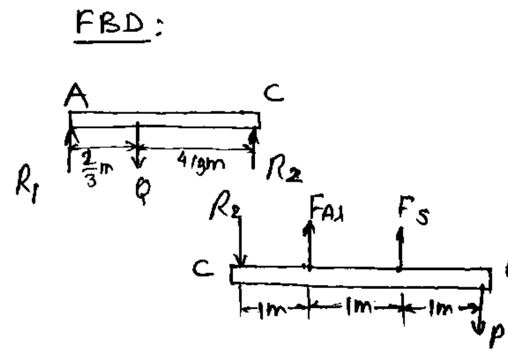
We need to have $\frac{P}{\delta_P} = \frac{20}{9}k$.

$$\therefore 5\frac{a^2}{c^2}k = \frac{20}{9}k$$

$$\therefore c = 1.5a .$$

Solution to problem 2.25.





Al rod: $A_{Al} = 625\ mm^2$; $l_{Al} = 0.67$ mm.

Steel rod : $A_S = 1250\ mm^2$; $l_S = 1$ m.

Equilibrium gives: $+\circlearrowleft \Sigma M_A = 0. \Rightarrow$.
(Rod AC)

$$-\frac{2}{3}Q + 2R_2 = 0 \quad \Rightarrow R_2 = \frac{Q}{3} \qquad \text{— 1)}$$

Rod CF

$$+\uparrow \Sigma F_y = 0 \quad \Rightarrow \quad F_{Al} + F_S - R_2 - P = 0. \qquad \text{— 2)}$$

$$+\circlearrowleft \Sigma M_C = 0 \quad \Rightarrow \quad F_{Al} + 2F_S - 3P = 0. \qquad \text{— 3).}$$

From equations 1), 2), 3) we have:

$$F_{Al} + F_S = P + Q/3 \qquad \text{— 4)}$$

$$F_{Al} + 2F_S = 3P \qquad \text{— 5).}$$

Force deformation relationship:

$$\delta_{Al} = \frac{F_{Al}\, l_{Al}}{A_{Al} E_{Al}} \quad ; \quad \delta_{st} = \frac{F_S\, l_S}{A_S E_S} \qquad \text{— 6).}$$

Compatibility: $\delta_{Al} = \delta_{st}$.

$$\therefore \frac{F_{Al}\, l_{Al}}{E_{Al} A_{Al}} = \frac{F_S\, l_S}{A_S E_S}.$$

(Problem 2.25 contd.)

$$\therefore F_{Al} = \frac{\lambda_s}{\lambda_{Al}} \cdot \frac{E_{Al} A_{Al}}{E_s A_s} F_s = \frac{1}{0.67} \times \frac{0.7 \times 10^{11} \times 625 \times 10^{-6}}{2 \times 10^{11} \times 1250 \times 10^{-6}} \times F_s .$$

$$\therefore F_{Al} \simeq \overset{0.25}{\cancel{0.5223}} F_s . \quad \text{— 7)}.$$

From equation 5) and 7)

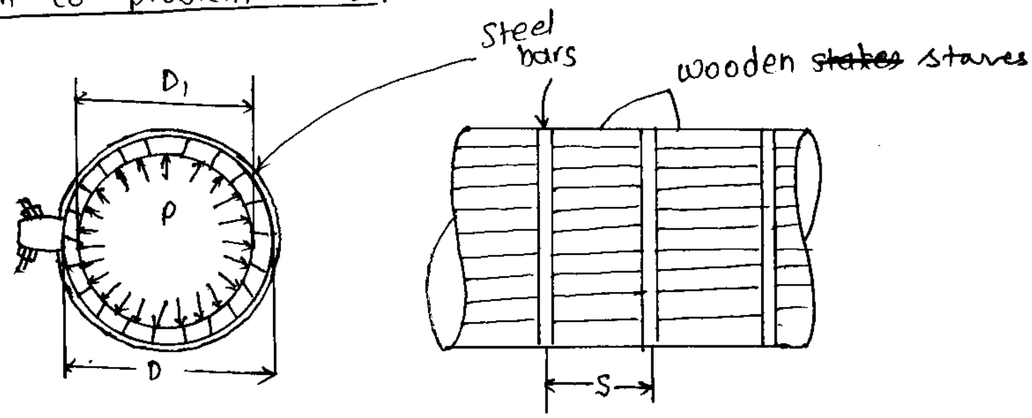
$$F_S = \frac{3}{2.25} P . \quad \text{— 8)}$$

From equatn 8) and 4).

$$0.25 \times \frac{3}{2.25} P + \frac{3}{2.25} P = P + Q/3 .$$

$$\therefore Q = \cancel{0.812\ Q} .\ 2P$$

Solution to problem 2.26.



- Wooden staves held togather by circumferetial steel bar.

$P = 100$ psi ; steel bar diameter $= d = 1$ in.

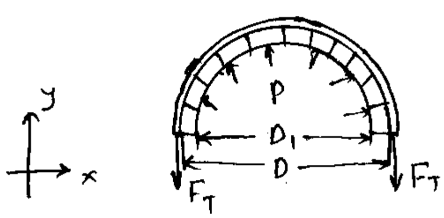
$\Delta D \leq 0.03''$ to avoid leakage

$D = 40 + 2 * 2.5 = 40 + 5 = 45''$.

$D_1 = 40''$.

To find S; spacing between steel bars.

F.B.D. of half water pipe of length S.



S is perpendicular to paper.

Equilibrium:

$\Sigma F_y = 0 \Rightarrow$

$2F_T = PD_1S$

$\therefore F_T = \dfrac{PD_1S}{2}$ — 1)

Force deformation relationship:

original length of bar $= \dfrac{\pi D}{2}$.

change in length due to pressure $= \dfrac{\pi \Delta D}{2}$.

$\therefore \delta = \dfrac{Fl}{AE} \Rightarrow \dfrac{\pi \Delta D}{2} = \dfrac{F_T \frac{\pi D}{2}}{\frac{\pi d^2}{4} E} \Rightarrow \Delta D = \dfrac{4 F_T D}{\pi d^2 E}$ — 2)

(problem 2.26 contd.)

From equations 1) and 2).

$$\Delta D = \frac{4D}{\pi d^2 E} \left(\frac{P D_1 S}{2} \right).$$

$$\therefore \Delta D = \frac{2 P D D_1 S}{\pi d^2 E}.$$

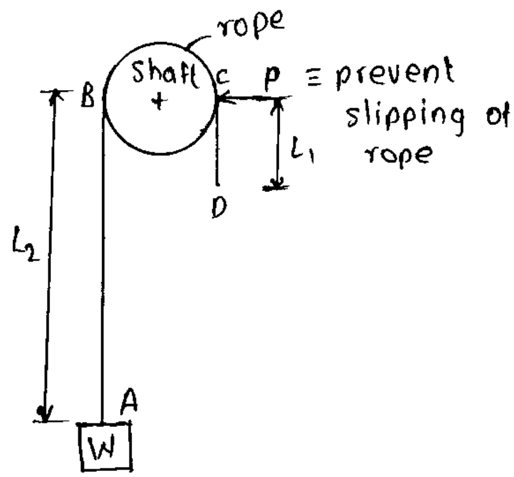
From the condition $\Delta D \leq 0.03''$, considering limiting case

$$0.03 = \frac{2 P D D_1 S}{\pi d^2 E}$$

$$\Rightarrow \quad S = \frac{0.03 \times \pi \times 1^2 \times 30 \times 10^6}{2 \times 100 \times 45 \times 40}$$

$$= 7.85''$$

Solution to problem 2.27



Given:

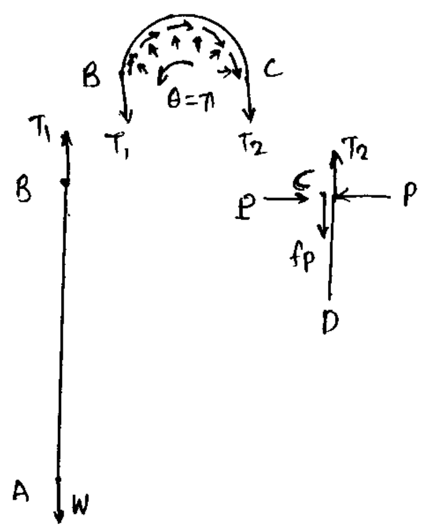
Shaft diameter $= d$
rope c/s area $= A$
modulus of elasticity $= E$
length (shorter side) $= L_1$
length (longer side) $= L_2$

Not requi

friction coefficient $= f$.

To Find P:

F.B.D. of rope:



Equilibrium of rope BC

$$T_1 = T_2 e^{f\pi} \quad \text{— 1)}$$

Equilibrium of rope AB

$$T_1 = W \quad \text{— 2)}$$

Equilibrium of rope CD

$$T_2 = fP \quad \text{— 3)}.$$

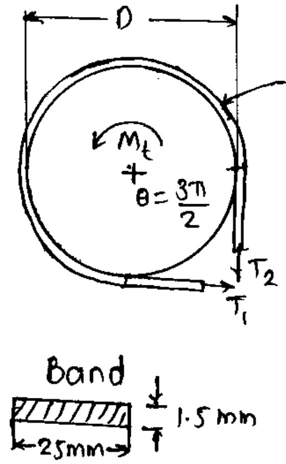
Determination of P:

Substituting equation 2), 3) into 1):

$$W = fPe^{f\pi}.$$

$$\therefore P = \frac{W}{f} e^{-f\pi}.$$

Solution to problem 2.28.



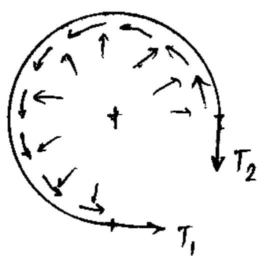
Given:

1) Wheel diameter $D = 300$ mn
2) Torque $M_t = 225$ N.m.
3) friction co-efficient $= f = 0.$

To find:

1) T_1 and T_2 to prevent rotati of wheel.

F.B.D. of steel band:



Equilibrium $\Rightarrow$

$$T_2 = T_1 e^{f(3\pi/2)} \quad \text{— 1)}$$

Equilibrium of pully :

$$M_t = (T_2 - T_1)\, r \quad \text{— 2)}$$

Solving 1) and 2) we get:

$$M_t = T_1 \left(e^{f\left(\frac{3\pi}{2}\right)} - 1 \right) r$$

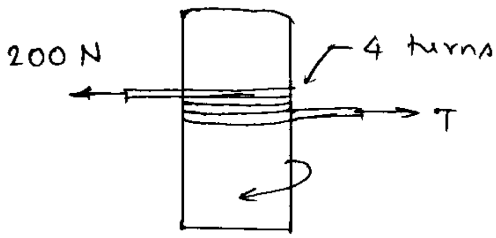
$$\therefore T_1 = \frac{M_t}{(e^{f(3\pi/2)} - 1)\, r} = \frac{225}{(e^{0.4 \times 3\pi/2} - 1) \times 0.15}$$

$$\therefore T_1 = 268.5 \text{ N}$$

$$T_2 = T_1 e^{f\, 3\pi/2} = 268.5 \times e^{0.4 \times 3\pi/2}$$

$$= 1768.53 \text{ N.}$$

Solution to problem 2.29.



coefficient of friction = 0.3.

To find T.

$$\frac{T}{200} = e^{f\theta}$$

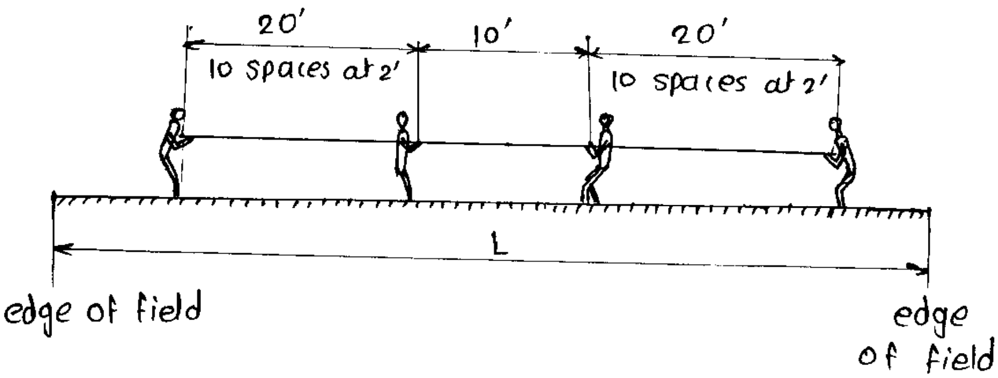
$$= e^{0.3 \times 4 \times 2\pi}$$

$$\therefore T = 200 \times e^{0.3 \times 4 \times 2\pi}$$

$$= 376.3 \times 10^3 \text{ N}$$

$$= 376.3 \text{ KN.}$$

Solution to problem 2.34



Given: 22 students

rope dia = 1/2" (not needed) ; rope length(L) = 50'

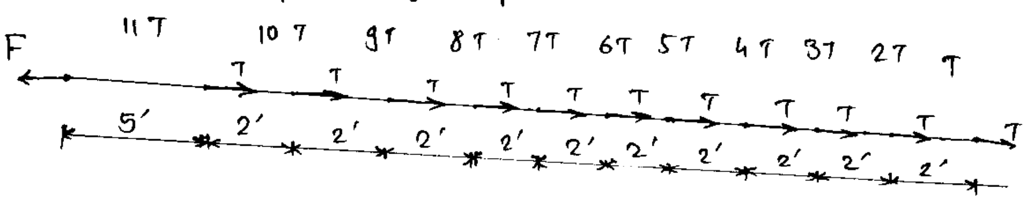
clearance between rope end and field end = 4' each.

Tension applied by each student = 100 lb.

spring constant of rope = 29,400 lb/in. for every feet.

To find: L.

F.B.D. of ~~rope~~ half rope



Change in half rope length:

$$= \frac{T\times 2}{k} + \frac{2T\times 2}{k} + \frac{3T\times 2}{k} + \frac{4T\times 2}{k} + \frac{5T\times 2}{k} + \frac{6T\times 2}{k} + \frac{7T\times 2}{k} + \frac{8T\times 2}{k} + \frac{9T\times 2}{k} + \frac{10T\times 2}{k} + \frac{11T\times 5}{k}.$$

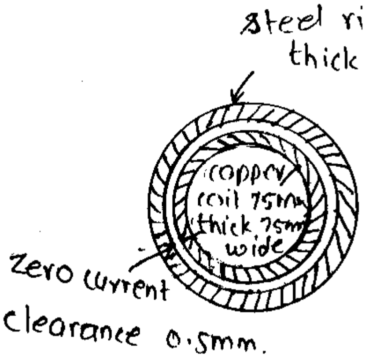
$$= \frac{165\,T}{k}. = \frac{165\times 100}{29400} = \frac{165}{294}\,"$$

Required field length:

$$= 2\times 4' + 50' + 2\left(\frac{165}{294}\right)\frac{1}{12}$$

$$= 58.09'$$

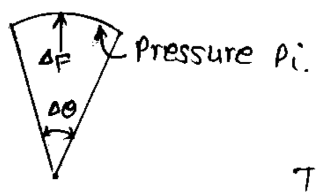
Solution to problem 2.38



Let

δ_{RC} = increase in radius of copper coil.

δ_{RS} = increase in radius of steel ring.

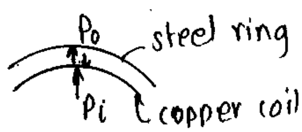


Radial force ΔF on the element of coil $= 70 \times 10^3 \times r\,\Delta\theta$

This is equivalent to pressure,

$$p_i = \frac{\Delta F}{\text{~~thickness~~ width in longitudinal dir}^n \times r\,\Delta\theta}$$

$$= \frac{\Delta F}{\text{width} \times r\,\Delta\theta} = \frac{70 \times 10^3 \times r\,\Delta\theta}{75 \times 10^{-3} \times r\,\Delta\theta}$$



$$= 0.933 \times 10^6 \text{ N/m}^2$$

$$= 0.933 \text{ MPa}.$$

Let P_o be the pressure between coil and ring:

$$\therefore \delta_{RC} = \frac{(P_i - P_o)\,r^2}{t_c E_c} = \frac{(P_i - P_o) \cdot 2.4^2}{75 \times 10^{-3} \times 117 \times 10^3}.$$

$$\delta_{RS} = \frac{P_o\, r^2}{t_s E_s} = \frac{P_o \times 2.4^2}{25 \times 10^{-3} \times 200 \times 10^3}.$$

Geometric compatibility :

$$\delta_{RC} = \delta_{RS} + 0.5 \times 10^{-3} \Rightarrow \frac{(P_i - P_o) \times 2.4^2}{75 \times 10^{-3} \times 117 \times 10^3} = \frac{P_o \times 2.4^2}{25 \times 10^{-3} \times 200 \times 10^3} + 0.5$$

Substituting value of p_i we get $P_o = 0.0622$ MPa.

$\therefore$ Tangential force:

$$F_T = (p_i - p_o)\, r\, b$$

$$\therefore F_T = (0.933 - 0.0622) \times 2.4 \times 10^3 \times 75 = 156.74 \text{ KN}.$$