Appendix A

FE Exam Review Problems

A-1.1: A plane truss has downward applied load P at joint 2 and another load P applied leftward at joint 5. The force in member 3–5 is:

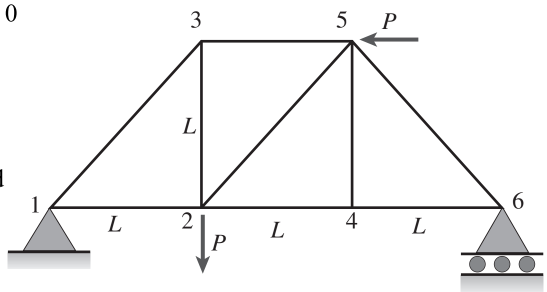
(A) 0
(B) $-P/2$
(C) $-P$
(D) $+1.5\,P$

Solution

$\Sigma M_1 = 0$

$V_6(3L) + PL - PL = 0$

so $\quad V_6 = 0$



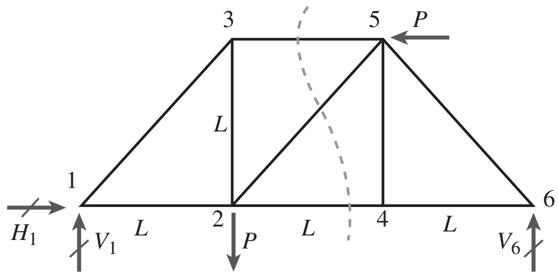
<u>Method of sections</u>

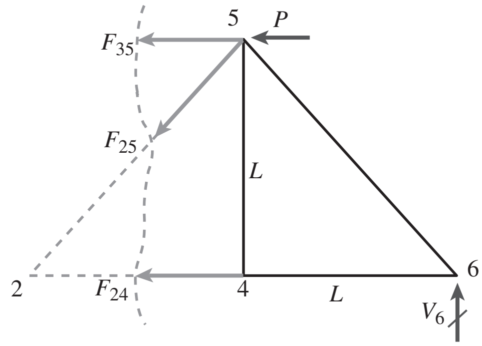
Cut through members 3-5, 2-5 and 2-4; use right hand FBD

$\Sigma M_2 = 0$

$F_{35}L + PL = 0$

$F_{35} = -P$

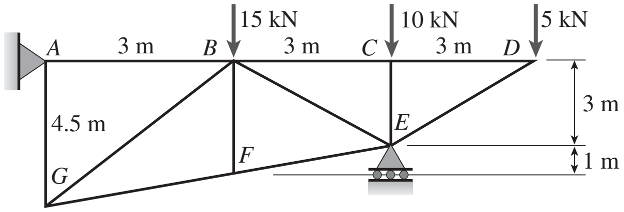




A-1.2: The force in member *FE* of the plane truss below is approximately:

(A) −1.5 kN
(B) −2.2 kN
(C) 3.9 kN
(D) 4.7 kN

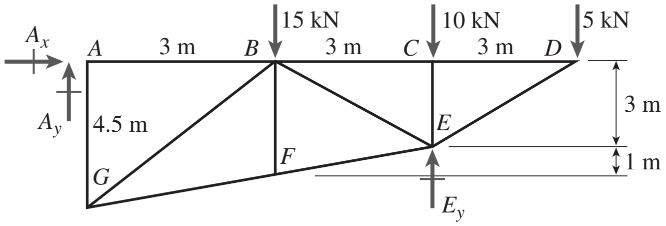
Solution



Statics

$$\Sigma M_A = 0 \qquad E_y(6\ \text{m}) - 15\ \text{kN}(3\ \text{m}) - 10\ \text{kN}(6\ \text{m}) - 5\ \text{kN}(9\ \text{m}) = 0$$

$$E_y = 25\ \text{kN}$$



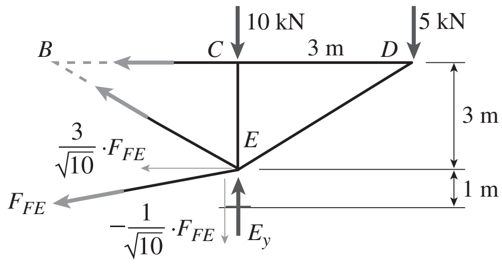
Method of sections: cut through BC, BE and FE; use right-hand FBD; sum moments about B

$$\frac{-3}{\sqrt{10}} F_{FE}(3\ \text{m}) - \frac{1}{\sqrt{10}} F_{FE}(3\ \text{m}) - 10\ \text{kN}(3\ \text{m}) - 5\ \text{kN}\ (6\ \text{m}) + E_y(3\ \text{m}) = 0$$

Solving

$$F_{FE} = \frac{5}{4}\sqrt{10}\ \text{kN}$$

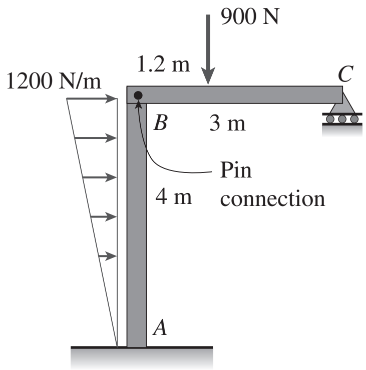
$$F_{FE} = 3.95\ \text{kN}$$

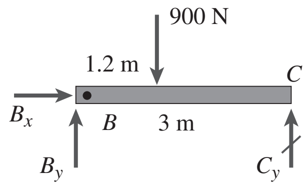


A-1.3: The moment reaction at *A* in the plane frame below is approximately:

(A) $+1400\ \text{N}\cdot\text{m}$
(B) $-2280\ \text{N}\cdot\text{m}$
(C) $-3600\ \text{N}\cdot\text{m}$
(D) $+6400\ \text{N}\cdot\text{m}$

Solution





<u>Statics</u>: use FBD of member BC to find reaction C_y

$$\Sigma M_B = 0 \qquad C_y(3\text{ m}) - 900\text{ N}(1.2\text{ m}) = 0$$

$$C_y = \frac{900\text{N}(1.2\text{ m})}{3\text{ m}} = 360\text{ N}$$

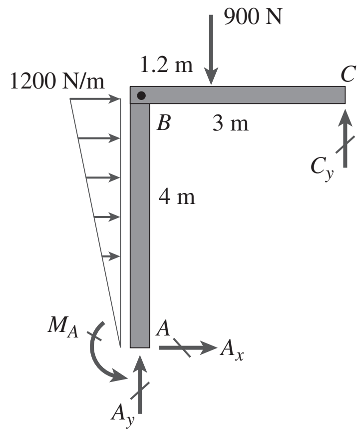
<u>Sum moments about A for entire structure</u>

$$\Sigma M_A = 0$$

$$M_A + C_y(3\text{ m}) - 900\text{ N}(1.2\text{ m}) - \frac{1}{2}\left(1200\,\frac{\text{N}}{\text{m}}\right)4\text{ m}\left(\frac{2}{3}\,4\text{ m}\right) = 0$$

Solving for M_A

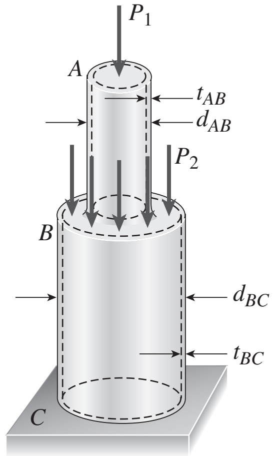
$$M_A = 6400\ \text{N}\cdot\text{m}$$



A-1.4: A hollow circular post *ABC* (see figure) supports a load $P_1 = 16$ kN acting at the top. A second load P_2 is uniformly distributed around the cap plate at *B*. The diameters and thicknesses of the upper and lower parts of the post are $d_{AB} = 30$ mm, $t_{AB} = 12$ mm, $d_{BC} = 60$ mm, and $t_{BC} = 9$ mm, respectively. The lower part of the post must have the same compressive stress as the upper part. The required magnitude of the load P_2 is approximately:

(A) 18 kN
(B) 22 kN
(C) 28 kN
(D) 46 kN

Solution



$P_1 = 16$ kN $\quad d_{AB} = 30$ mm $\quad t_{AB} = 12$ mm

$d_{BC} = 60$ mm $\quad t_{BC} = 9$ mm

$$A_{AB} = \frac{\pi}{4}[d_{AB}^2 - (d_{AB} - 2t_{AB})^2] = 679 \text{ mm}^2$$

$$A_{BC} = \frac{\pi}{4}[d_{BC}^2 - (d_{BC} - 2t_{BC})^2] = 1442 \text{ mm}^2$$

Stress in *AB*: $\quad \sigma_{AB} = \dfrac{P_1}{A_{AB}} = 23.6$ MPa

Stress in *BC*: $\quad \sigma_{BC} = \dfrac{P_1 + P_2}{A_{BC}}$ $\quad <$ must equal σ_{AB}

Solve for P_2 $\quad P_2 = \sigma_{AB} A_{BC} - P_1 = 18.00$ kN

Check: $\quad \sigma_{BC} = \dfrac{P_1 + P_2}{A_{BC}} = 23.6$ MPa $\quad <$ same as in *AB*

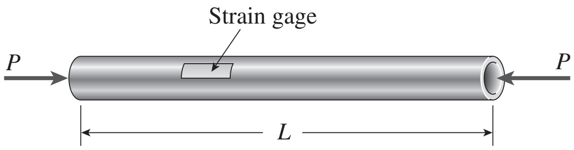
A-1.5: A circular aluminum tube of length $L = 650$ mm is loaded in compression by forces *P*. The outside and inside diameters are 80 mm and 68 mm, respectively. A strain gage on the outside of the bar records a normal strain in the longitudinal direction of 400×10^{-6}. The shortening of the bar is approximately:

(A) 0.12 mm
(B) 0.26 mm
(C) 0.36 mm
(D) 0.52 mm

Solution

$\varepsilon = 400\,(10^{-6}) \qquad L = 650$ mm

$\delta = \varepsilon L = 0.260$ mm



A-1.6: A steel plate weighing 27 kN is hoisted by a cable sling that has a clevis at each end. The pins through the clevises are 22 mm in diameter. Each half of the cable is at an angle of 35° to the vertical. The average shear stress in each pin is approximately:

(A) 22 MPa
(B) 28 MPa
(C) 40 MPa
(D) 48 MPa

Solution

$W = 27\text{ kN} \qquad d_p = 22\text{ mm} \qquad \theta = 35°$

Cross sectional area of each pin:

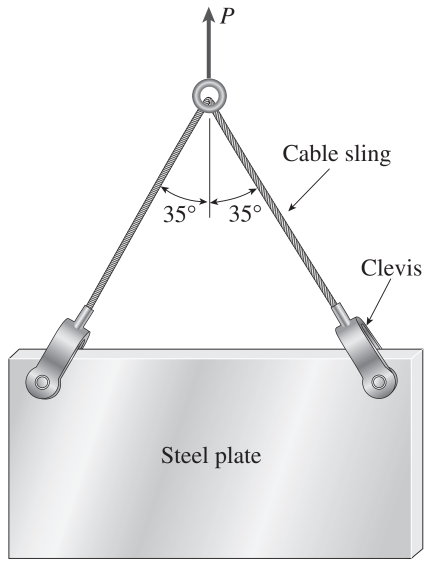
$$A_p = \frac{\pi}{4} d_p^2 = 380\text{ mm}^2$$

Tensile force in cable:

$$T = \frac{\left(\frac{W}{2}\right)}{\cos(\theta)} = 16.48\text{ kN}$$

Shear stress in each clevis pin (double shear):

$$\tau = \frac{T}{2A_P} = 21.7\text{ MPa}$$



A-1.7: A steel wire hangs from a high-altitude balloon. The steel has unit weight 77kN/m^3 and yield stress of 280 MPa. The required factor of safety against yield is 2.0. The maximum permissible length of the wire is approximately:

(A) 1800 m
(B) 2200 m
(C) 2600 m
(D) 3000 m

Solution

$$\gamma = 77 \frac{kN}{m^3} \qquad \sigma_Y = 280 \text{ MPa} \qquad FS_Y = 2$$

Allowable stress: $\sigma_{allow} = \dfrac{\sigma_Y}{FS_Y} = 140.0 \text{ MPa}$

Weight of wire of length L: $W = \gamma A L$

Max. axial stress in wire of length L: $\sigma_{max} = \dfrac{W}{A} \qquad \sigma_{max} = \gamma L$

Max. length of wire: $L_{max} = \dfrac{\sigma_{allow}}{\gamma} = 1818 \text{ m}$ ⇦

A-1.8: An aluminum bar ($E = 72$ GPa, $\nu = 0.33$) of diameter 50 mm cannot exceed a diameter of 50.1 mm when compressed by axial force P. The maximum acceptable compressive load P is approximately:

(A) 190 kN
(B) 200 kN
(C) 470 kN
(D) 860 kN

Solution

$$E = 72 \text{ GPa} \qquad d_{init} = 50 \text{ mm} \qquad d_{final} = 50.1 \text{ mm} \qquad \nu = 0.33$$

Lateral strain: $\varepsilon_L = \dfrac{d_{final} - d_{init}}{d_{init}} \qquad \varepsilon_L = 0.002$

Axial strain: $\varepsilon_a = \dfrac{-\varepsilon_L}{\nu} = -0.006$

Axial stress: $\sigma = E\varepsilon_a = -436.4 \text{ MPa}$ < below yield stress of 480 MPa so Hooke's Law applies

Max. acceptable compressive load:

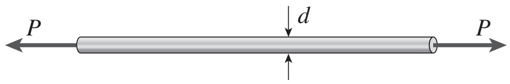
$$P_{max} = \sigma\left(\frac{\pi}{4} {d_{init}}^2\right) = 857 \text{ kN}$$ ⇦

A-1.9: An aluminum bar ($E = 70$ GPa, $\nu = 0.33$) of diameter 20 mm is stretched by axial forces P, causing its diameter to decrease by 0.022 mm. The load P is approximately:

(A) 73 kN
(B) 100 kN
(C) 140 kN
(D) 339 kN

Solution

$E = 70$ GPa $\quad d_{init} = 20$ mm $\quad \Delta d = -0.022$ mm $\quad \nu = 0.33$



Lateral strain: $\varepsilon_L = \dfrac{\Delta d}{d_{init}}$

$\varepsilon_L = -0.001$

Axial strain: $\varepsilon_a = \dfrac{-\varepsilon_L}{\nu} = 3.333 \times 10^{-3}$

Axial stress: $\sigma = E\varepsilon_a = 233.3$ MPa $\quad$ < below yield stress of 270 MPa so Hooke's Law applies

Max. acceptable load:

$$P_{max} = \sigma\left(\frac{\pi}{4}{d_{init}}^2\right) = 73.3 \text{ kN}$$

A-1.10: A polyethylene bar ($E = 1.4$ GPa, $\nu = 0.4$) of diameter 80 mm is inserted in a steel tube of inside diameter 80.2 mm and then compressed by axial force P. The gap between steel tube and polyethylene bar will close when compressive load P is approximately:

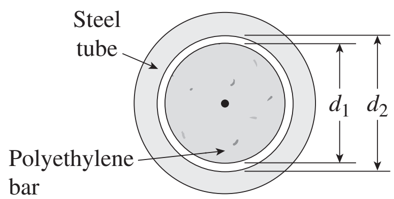
(A) 18 kN
(B) 25 kN
(C) 44 kN
(D) 60 kN

Solution

$E = 1.4$ GPa $\quad d_1 = 80$ mm $\quad \Delta d_1 = 0.2$ mm $\quad \nu = 0.4$

Lateral strain: $\varepsilon_L = \dfrac{\Delta d_1}{d_1}$

$\varepsilon_L = 0.003$



Axial strain: $\varepsilon_a = \dfrac{-\varepsilon_L}{\nu} = -6.250 \times 10^{-3}$

Axial stress: $\sigma = E\varepsilon_a = -8.8$ MPa $\quad$ < well below ultimate stress of 28 MPa so Hooke's Law applies

Max. acceptable compressive load:

$$P_{max} = \sigma\left(\frac{\pi}{4}{d_1}^2\right) = 44.0 \text{ kN}$$

A-1.11: A pipe ($E = 110$ GPa) carries a load $P_1 = 120$ kN at A and a uniformly distributed load $P_2 = 100$ kN on the cap plate at B. Initial pipe diameters and thicknesses are: $d_{AB} = 38$ mm, $t_{AB} = 12$ mm, $d_{BC} = 70$ mm, $t_{BC} = 10$ mm. Under loads P_1 and P_2, wall thickness t_{BC} increases by 0.0036 mm. Poisson's ratio v for the pipe material is approximately:

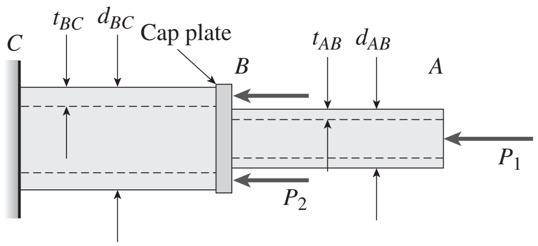
(A) 0.27
(B) 0.30
(C) 0.31
(D) 0.34

Solution

$E = 110$ GPa $\quad d_{AB} = 38$ mm $\quad t_{AB} = 12$ mm $\quad d_{BC} = 70$ mm

$t_{BC} = 10$ mm $\quad P_1 = 120$ kN $\quad P_2 = 100$ kN

$$A_{BC} = \frac{\pi}{4}[d_{BC}{}^2 - (d_{BC} - 2t_{BC})^2] = 1885 \text{ mm}^2$$



Axial strain of BC: $\quad \varepsilon_{BC} = \dfrac{-(P_1 + P_2)}{EA_{BC}} = -1.061 \times 10^{-3}$

Axial stress in BC: $\quad \sigma_{BC} = E\varepsilon_{BC} = -116.7$ MPa

(well below yield stress of 550 MPa so Hooke's Law applies)

Lateral strain of BC: $\quad \Delta t_{BC} = 0.0036$ mm

$$\varepsilon_L = \frac{\Delta t_{BC}}{t_{BC}} = 3.600 \times 10^{-4}$$

Poisson's ratio: $\quad v = \dfrac{-\varepsilon_L}{\varepsilon_{BC}} = 0.34$ ⇦ $<$ confirms value for **brass** given in properties table