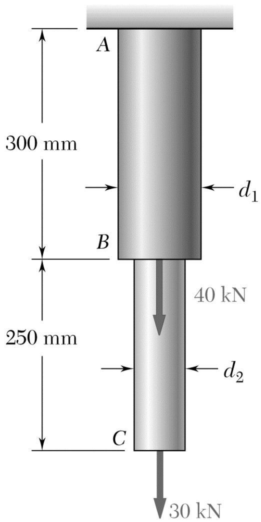



## PROBLEM 1.4

Two solid cylindrical rods *AB* and *BC* are welded together at *B* and loaded as shown. Knowing that $d_1 = 50$ mm and $d_2 = 30$ mm, find the average normal stress at the midsection of (*a*) rod *AB*, (*b*) rod *BC*.

## SOLUTION

(*a*) Rod *AB*

$$P = 40 + 30 = 70 \text{ kN} = 70 \times 10^3 \text{N}$$

$$A = \frac{\pi}{4} d_1^2 = \frac{\pi}{4}(50)^2 = 1.9635 \times 10^3 \text{mm}^2 = 1.9635 \times 10^{-3} \text{m}^2$$

$$\sigma_{AB} = \frac{P}{A} = \frac{70 \times 10^3}{1.9635 \times 10^{-3}} = 35.7 \times 10^6 \text{Pa}$$

$$\sigma_{AB} = 35.7 \text{ MPa} \blacktriangleleft$$

(*b*) Rod *BC*

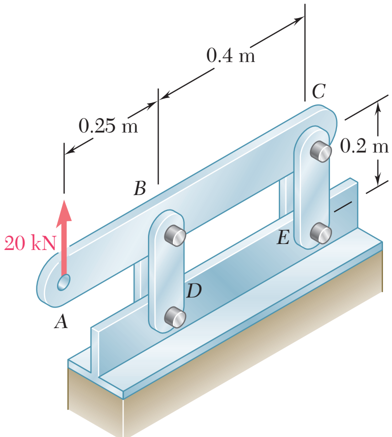
$$P = 30 \text{ kN} = 30 \times 10^3 \text{N}$$

$$A = \frac{\pi}{4} d_2^2 = \frac{\pi}{4}(30)^2 = 706.86 \text{ mm}^2 = 706.86 \times 10^{-6} \text{m}^2$$

$$\sigma_{BC} = \frac{P}{A} = \frac{30 \times 10^3}{706.86 \times 10^{-6}} = 42.4 \times 10^6 \text{Pa}$$

$$\sigma_{BC} = 42.4 \text{ MPa} \blacktriangleleft$$

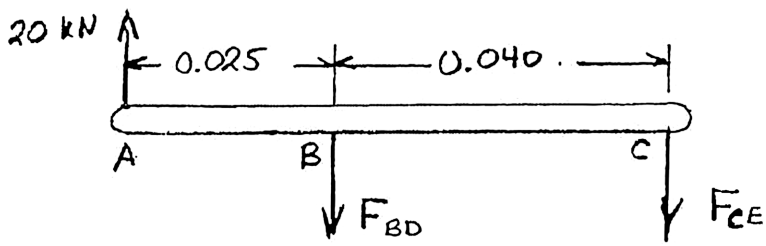
## PROBLEM 1.7




Each of the four vertical links has an $8 \times 36$-mm uniform rectangular cross section and each of the four pins has a 16-mm diameter. Determine the maximum value of the average normal stress in the links connecting (*a*) points *B* and *D*, (*b*) points *C* and *E*.

## SOLUTION

Use bar *ABC* as a free body.




$\Sigma M_C = 0: \quad (0.040) F_{BD} - (0.025 + 0.040)(20 \times 10^3) = 0$

$F_{BD} = 32.5 \times 10^3$ N  Link *BD* is in tension.

$\Sigma M_B = 0: \quad -(0.040) F_{CE} - (0.025)(20 \times 10^3) = 0$

$F_{CE} = -12.5 \times 10^3$ N  Link *CE* is in compression.

Net area of one link for tension $= (0.008)(0.036 - 0.016) = 160 \times 10^{-6}\ \text{m}^2$

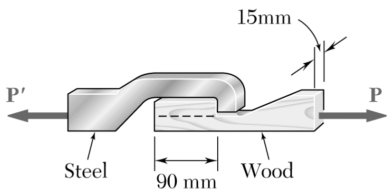
For two parallel links, $A_{\text{net}} = 320 \times 10^{-6}\ \text{m}^2$

(*a*) $\sigma_{BD} = \dfrac{F_{BD}}{A_{\text{net}}} = \dfrac{32.5 \times 10^3}{320 \times 10^{-6}} = 101.563 \times 10^6$  $\sigma_{BD} = 101.6$ MPa ◀

Area for one link in compression $= (0.008)(0.036) = 288 \times 10^{-6}\ \text{m}^2$

For two parallel links, $A = 576 \times 10^{-6}\ \text{m}^2$

(*b*) $\sigma_{CE} = \dfrac{F_{CE}}{A} = \dfrac{-12.5 \times 10^3}{576 \times 10^{-6}} = -21.701 \times 10^{-6}$  $\sigma_{CE} = -21.7$ MPa ◀




## PROBLEM 1.17

When the force **P** reached 8 kN, the wooden specimen shown failed in shear along the surface indicated by the dashed line. Determine the average shearing stress along that surface at the time of failure.

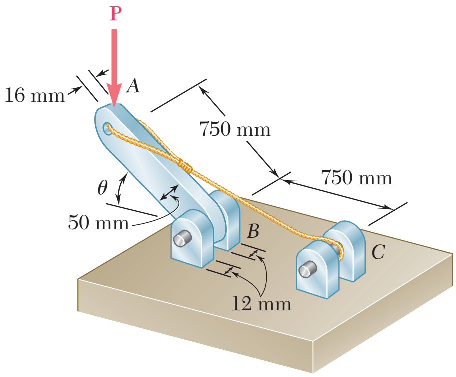
## SOLUTION

Area being sheared: $A = 90 \text{ mm} \times 15 \text{ mm} = 1350 \text{ mm}^2 = 1350 \times 10^{-6} \text{m}^2$

Force: $P = 8 \times 10^3 \text{ N}$

Shearing stress: $\tau = \dfrac{P}{A} - \dfrac{8 \times 10^3}{1350 \times 10^{-6}} = 5.93 \times 10^6 \text{ Pa}$

$\tau = 5.93 \text{ MPa}$ ◀

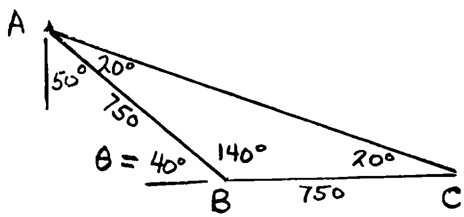



## PROBLEM 1.25

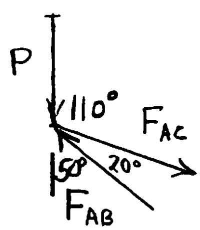
Knowing that $\theta = 40°$ and $P = 9$ kN, determine (*a*) the smallest allowable diameter of the pin at $B$ if the average shearing stress in the pin is not to exceed 120 MPa, (*b*) the corresponding average bearing stress in member $AB$ at $B$, (*c*) the corresponding average bearing stress in each of the support brackets at $B$.

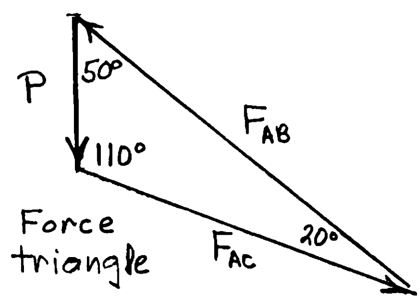
## SOLUTION

Geometry: Triangle $ABC$ is an isoseles triangle with angles shown here.




Use joint A as a free body.




Law of sines applied to force triangle:

$$\frac{P}{\sin 20°} = \frac{F_{AB}}{\sin 110°} = \frac{F_{AC}}{\sin 50°}$$

$$F_{AB} = \frac{P \sin 110°}{\sin 20°}$$

$$= \frac{(9)\sin 110°}{\sin 20°} = 24.727 \text{ kN}$$

## PROBLEM 1.25 *(Continued)*

(*a*) Allowable pin diameter.

$$\tau = \frac{F_{AB}}{2A_P} = \frac{F_{AB}}{2\frac{\pi}{4}d^2} = \frac{2F_{AB}}{\pi d^2} \quad \text{where } F_{AB} = 24.727 \times 10^3 \text{ N}$$

$$d^2 = \frac{2F_{AB}}{\pi\tau} = \frac{(2)(24.727 \times 10^3)}{\pi(120 \times 10^6)} = 131.181 \times 10^{-6} \text{ m}^2$$

$$d = 11.4534 \times 10^{-3} \text{ m} \qquad 11.45 \text{ mm} \blacktriangleleft$$

(*b*) Bearing stress in *AB* at *A*.

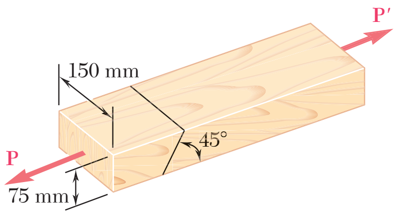
$$A_b = td = (0.016)(11.4534 \times 10^{-3}) = 183.254 \times 10^{-6} \text{ m}^2$$

$$\sigma_b = \frac{F_{AB}}{A_b} = \frac{24.727 \times 10^3}{183.254 \times 10^{-6}} = 134.933 \times 10^6 \text{ Pa} \qquad 134.9 \text{ MPa} \blacktriangleleft$$

(*c*) Bearing stress in support brackets at *B*.

$$A = td = (0.012)(11.4534 \times 10^{-3}) = 137.441 \times 10^{-6} \text{ m}^2$$

$$\sigma_b = \frac{\frac{1}{2}F_{AB}}{A} = \frac{(0.5)(24.727 \times 10^3)}{137.441 \times 10^{-6}} = 89.955 \times 10^6 \text{ Pa} \qquad 90.0 \text{ MPa} \blacktriangleleft$$




## PROBLEM 1.30

Two wooden members of uniform rectangular cross section are joined by the simple glued scarf splice shown. Knowing that the maximum allowable shearing stress in the glued splice is 620 kPa, determine (*a*) the largest load **P** that can be safely applied, (*b*) the corresponding tensile stress in the splice.

## SOLUTION

$$\theta = 90° - 45° = 45°$$

$$A_0 = (150)(75) = 11.25 \times 10^3 \text{mm}^2 = 11.25 \times 10^{-3} \text{m}^2$$

$$\tau = 620 \text{ kPa} = 620 \times 10^3 \text{Pa}$$

$$\tau = \frac{P \sin 2\theta}{2A_0}$$

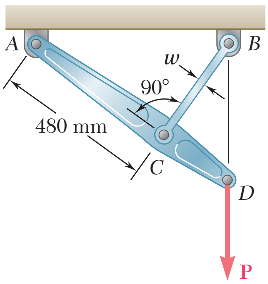
(*a*) $$P = \frac{2A_0\tau}{\sin 2\theta} = \frac{(2)(11.25 \times 10^{-3})(620 \times 10^3)}{\sin 90°}$$

$$= 13.95 \times 10^3 \text{ N} \qquad P = 13.95 \text{ kN} \blacktriangleleft$$

(*b*) $$\sigma = \frac{P \cos^2 \theta}{A_0} = \frac{(13.95 \times 10^3)(\cos 45°)^2}{11.25 \times 10^{-3}}$$

$$= 620 \times 10^3 \text{ Pa} \qquad \sigma = 620 \text{ kPa} \blacktriangleleft$$

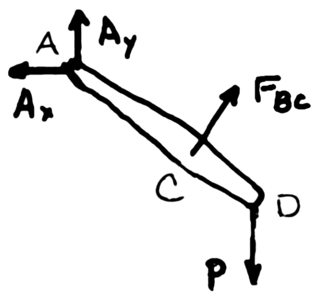
## PROBLEM 1.38




Link *BC* is 6 mm thick, has a width $w = 25$ mm, and is made of a steel with a 480-MPa ultimate strength in tension. What was the safety factor used if the structure shown was designed to support a 16-kN load **P**?

## SOLUTION

Use bar *ACD* as a free body and note that member *BC* is a two-force member.




$$\Sigma M_A = 0:$$

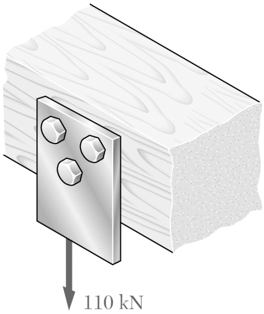
$$(480)F_{BC} - (600)P = 0$$

$$F_{BC} = \frac{600}{480}P = \frac{(600)(16 \times 10^3)}{480} = 20 \times 10^3 \text{ N}$$

Ultimate load for member *BC*: $F_U = \sigma_U A$

$$F_U = (480 \times 10^6)(0.006)(0.025) = 72 \times 10^3 \text{ N}$$

Factor of safety: $\text{F.S.} = \dfrac{F_U}{F_{BC}} = \dfrac{72 \times 10^3}{20 \times 10^3}$ F.S. = 3.60 ◀




## PROBLEM 1.46

Three steel bolts are to be used to attach the steel plate shown to a wooden beam. Knowing that the plate will support a 110-kN load, that the ultimate shearing stress for the steel used is 360 MPa, and that a factor of safety of 3.35 is desired, determine the required diameter of the bolts.

## SOLUTION

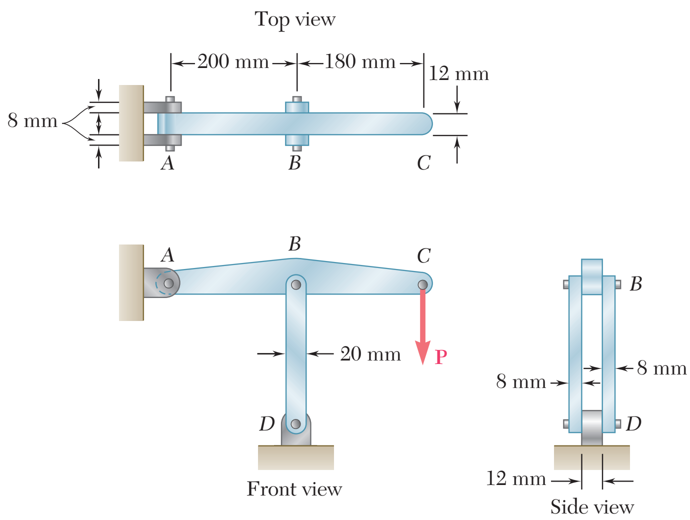
For each bolt, $P = \dfrac{110}{3} = 36.667\text{ kN}$

Required: $P_U = (\text{F.S.})P = (3.35)(36.667) = 122.83\text{ kN}$

$$\tau_U = \frac{P_U}{A} = \frac{P_U}{\frac{\pi}{4}d^2} = \frac{4P_U}{\pi d^2}$$

$$d = \sqrt{\frac{4P_U}{\pi\tau_U}} = \sqrt{\frac{(4)(122.83\times 10^3)}{\pi(360\times 10^6)}} = 20.8\times 10^{-3}\text{m}$$

$d = 20.8\text{ mm}$ ◀

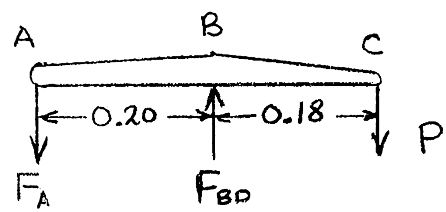



## PROBLEM 1.55

In the structure shown, an 8-mm-diameter pin is used at $A$, and 12-mm-diameter pins are used at $B$ and $D$. Knowing that the ultimate shearing stress is 100 MPa at all connections and that the ultimate normal stress is 250 MPa in each of the two links joining $B$ and $D$, determine the allowable load **P** if an overall factor of safety of 3.0 is desired.

## SOLUTION

Statics: Use $ABC$ as free body.




$$+\circlearrowleft \Sigma M_B = 0: \quad 0.20F_A - 0.18P = 0 \qquad P = \frac{10}{9}F_A$$

$$+\circlearrowleft \Sigma M_A = 0: \quad 0.20F_{BD} - 0.38P = 0 \qquad P = \frac{10}{19}F_{BD}$$

Based on double shear in pin $A$, $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.008)^2 = 50.266 \times 10^{-6}\ \text{m}^2$

$$F_A = \frac{2\tau_U A}{F.S.} = \frac{(2)(100 \times 10^6)(50.266 \times 10^{-6})}{3.0} = 3.351 \times 10^3\ \text{N}$$

$$P = \frac{10}{9}F_A = 3.72 \times 10^3\ \text{N}$$

Based on double shear in pins at $B$ and $D$, $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.012)^2 = 113.10 \times 10^{-6}\ \text{m}^2$

$$F_{BD} = \frac{2\tau_U A}{F.S.} = \frac{(2)(100 \times 10^6)(113.10 \times 10^{-6})}{3.0} = 7.54 \times 10^3\ \text{N}$$

$$P = \frac{10}{19}F_{BD} = 3.97 \times 10^3\ \text{N}$$

Based on compression in links $BD$, for one link, $A = (0.020)(0.008) = 160 \times 10^{-6}\ \text{m}^2$

$$F_{BD} = \frac{2\sigma_U A}{F.S.} = \frac{(2)(250 \times 10^6)(160 \times 10^{-6})}{3.0} = 26.7 \times 10^3\ \text{N}$$

$$P = \frac{10}{19}F_{BD} = 14.04 \times 10^3\ \text{N}$$

Allowable value of $P$ is smallest, $\therefore \quad P = 3.72 \times 10^3$ N

$P = 3.72$ kN ◀