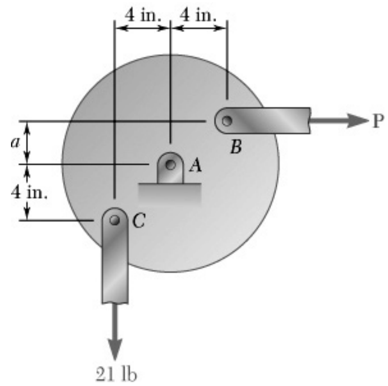
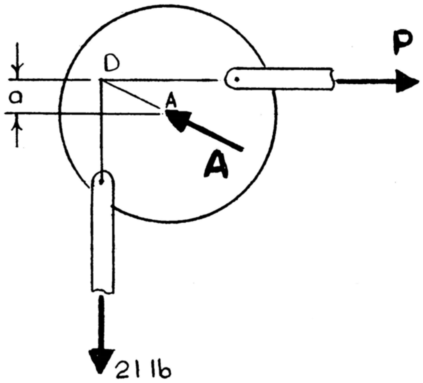
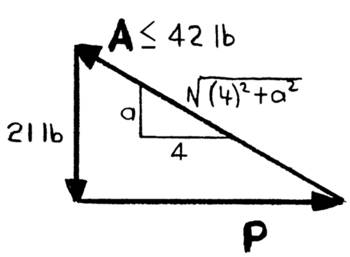
PROBLEM 4.64



Horizontal and vertical links are hinged to a wheel, and forces are applied to the links as shown. Determine the range of values of the distance a for which the magnitude of the reaction at A does not exceed 42 lb.

SOLUTION





Let D be the intersection of the three forces acting on the wheel.

From the force triangle

$$\frac{21\text{ lb}}{a} = \frac{A}{\sqrt{16 + a^2}}$$

or

$$A = 21\sqrt{\frac{16}{a^2} + 1}$$

For

$$A = 42\text{ lb}$$

$$\frac{21\text{ lb}}{a} = \frac{42\text{ lb}}{\sqrt{16 + a^2}}$$

or

$$a^2 = \frac{16 + a^2}{4}$$

or

$$a = \sqrt{\frac{16}{3}} = 2.3094\text{ in.}$$

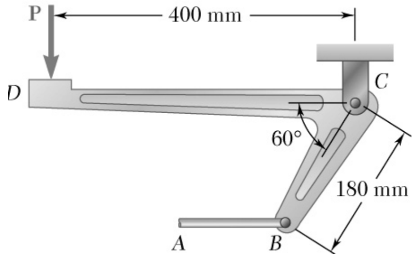
or $a \geq 2.31$ in. ◀

Since

$$A = 21\sqrt{\frac{16}{a^2} + 1}$$

as a increases, A decreases

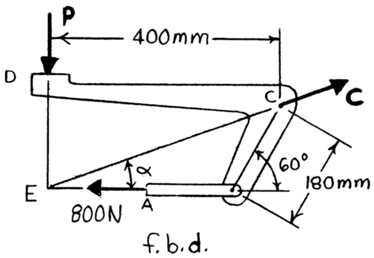
PROBLEM 4.65

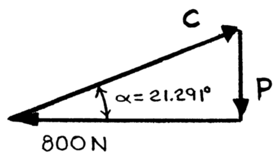


Using the method of Section 4.7, solve Problem 4.21.

P4.21 The required tension in cable *AB* is 800 N. Determine (*a*) the vertical force **P** which must be applied to the pedal, (*b*) the corresponding reaction at *C*.

SOLUTION





Let *E* be the intersection of the three forces acting on the pedal device.

First note

$$\alpha = \tan^{-1}\left[\frac{(180\text{ mm})\sin 60°}{400\text{ mm}}\right] = 21.291°$$

From force triangle

(*a*) $$P = (800\text{ N})\tan 21.291°$$

$$= 311.76\text{ N}$$

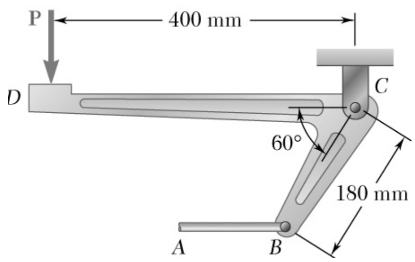
or $\mathbf{P} = 312\text{ N} \downarrow$ ◀

(*b*) $$C = \frac{800\text{ N}}{\cos 21.291°}$$

$$= 858.60\text{ N}$$

or $\mathbf{C} = 859\text{ N} \measuredangle 21.3°$ ◀

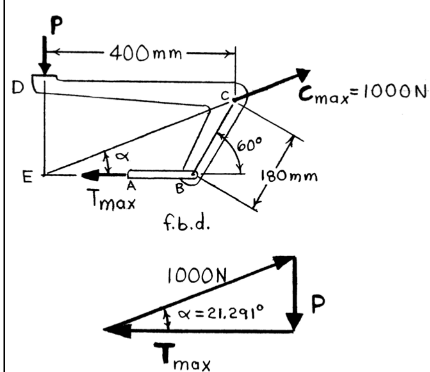
PROBLEM 4.66



Using the method of Section 4.7, solve Problem 4.22.

P4.22 Determine the maximum tension which can be developed in cable *AB* if the maximum allowable value of the reaction at *C* is 1000 N.

SOLUTION



Let *E* be the intersection of the three forces acting on the pedal device.

First note

$$\alpha = \tan^{-1}\left[\frac{(180\text{ mm})\sin 60°}{400\text{ mm}}\right] = 21.291°$$

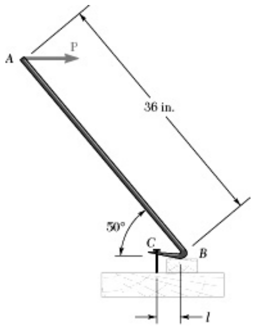
From force triangle

$$T_{\max} = (1000\text{ N})\cos 21.291°$$

$$= 931.75\text{ N}$$

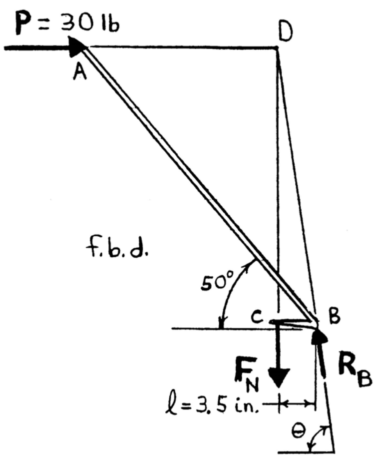
or $T_{\max} = 932$ N ◀

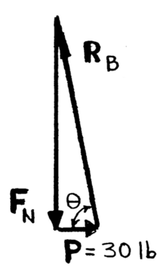
PROBLEM 4.67



To remove a nail, a small block of wood is placed under a crowbar, and a horizontal force **P** is applied as shown. Knowing that $l = 3.5$ in. and $P = 30$ lb, determine the vertical force exerted on the nail and the reaction at B.

SOLUTION





Let D be the intersection of the three forces acting on the crowbar.

First note

$$\theta = \tan^{-1}\left[\frac{(36\text{ in.})\sin 50^\circ}{3.5\text{ in.}}\right] = 82.767^\circ$$

From force triangle

$$F_N = P\tan\theta = (30\text{ lb})\tan 82.767^\circ$$

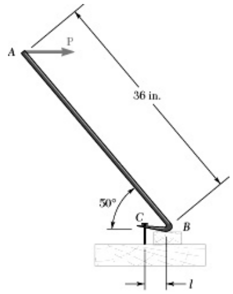
$$= 236.381\text{ lb}$$

$\therefore$ on nail $\mathbf{F}_N = 236\text{ lb}$ ↑ ◀

$$R_B = \frac{P}{\cos\theta} = \frac{30\text{ lb}}{\cos 82.767^\circ} = 238.28\text{ lb}$$

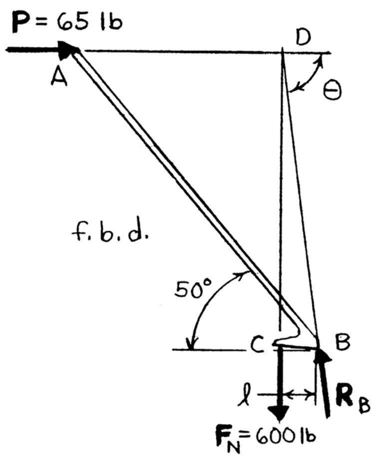
or $\mathbf{R}_B = 238\text{ lb}$ ⦪ 82.8° ◀

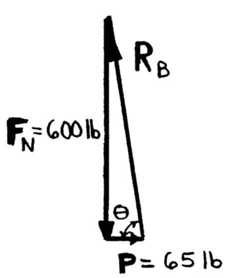
PROBLEM 4.68



To remove a nail, a small block of wood is placed under a crowbar, and a horizontal force **P** is applied as shown. Knowing that the maximum vertical force needed to extract the nail is 600 lb and that the horizontal force **P** is not to exceed 65 lb, determine the largest acceptable value of distance *l*.

SOLUTION





Let *D* be the intersection of the three forces acting on the crowbar.

From force diagram

$$\tan\theta = \frac{F_N}{P} = \frac{600 \text{ lb}}{65 \text{ lb}} = 9.2308$$

$$\therefore \quad \theta = 83.817°$$

From f.b.d.

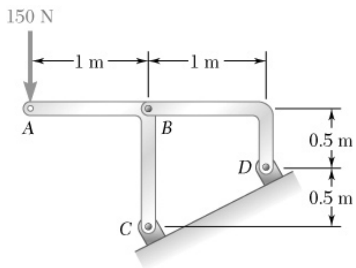
$$\tan\theta = \frac{(36 \text{ in.})\sin 50°}{l}$$

$$\therefore \quad l = \frac{(36 \text{ in.})\sin 50°}{\tan 83.817°} = 2.9876 \text{ in.}$$

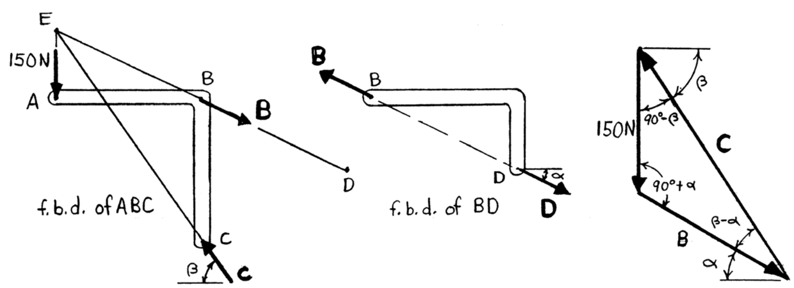
or $l = 2.99$ in. ◀

PROBLEM 4.69

For the frame and loading shown, determine the reactions at *C* and *D*.



SOLUTION



Since member *BD* is acted upon by two forces, **B** and **D**, they must be colinear, have the same magnitude, and be opposite in direction for *BD* to be in equilibrium. The force **B** acting at *B* of member *ABC* will be equal in magnitude but opposite in direction to force **B** acting on member *BD*. Member *ABC* is a three-force body with member forces intersecting at *E*. The f.b.d.'s of members *ABC* and *BD* illustrate the above conditions. The force triangle for member *ABC* is also shown. The angles α and β are found from the member dimensions:

$$\alpha = \tan^{-1}\left(\frac{0.5\text{ m}}{1.0\text{ m}}\right) = 26.565°$$

$$\beta = \tan^{-1}\left(\frac{1.5\text{ m}}{1.0\text{ m}}\right) = 56.310°$$

Applying the law of sines to the force triangle for member *ABC*,

$$\frac{150\text{ N}}{\sin(\beta - \alpha)} = \frac{C}{\sin(90° + \alpha)} = \frac{B}{\sin(90° - \beta)}$$

or

$$\frac{150\text{ N}}{\sin 29.745°} = \frac{C}{\sin 116.565°} = \frac{B}{\sin 33.690°}$$

$$\therefore \quad C = \frac{(150\text{ N})\sin 116.565°}{\sin 29.745°} = 270.42\text{ N}$$

or $\mathbf{C} = 270\text{ N}$ 56.3° ◀

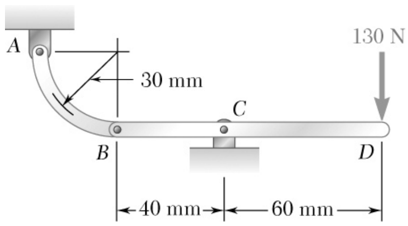
and

$$D = B = \frac{(150\text{ N})\sin 33.690°}{\sin 29.745°} = 167.704\text{ N}$$

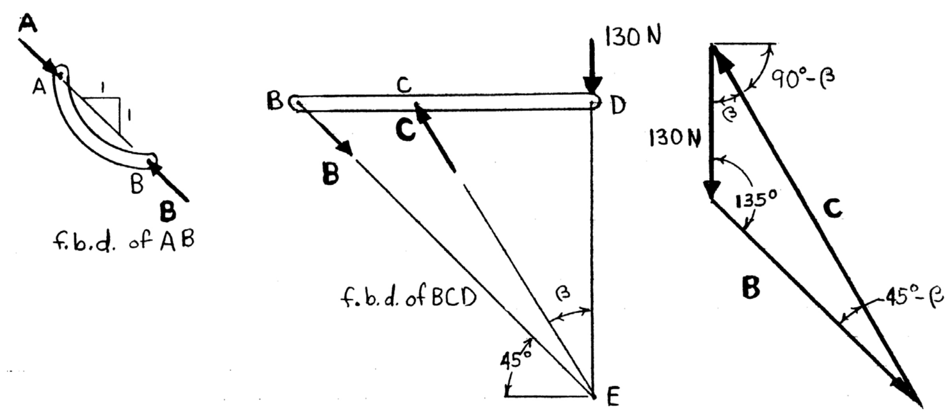
or $\mathbf{D} = 167.7\text{ N}$ 26.6° ◀

PROBLEM 4.70

For the frame and loading shown, determine the reactions at *A* and *C*.



SOLUTION



Since member *AB* is acted upon by two forces, **A** and **B**, they must be colinear, have the same magnitude, and be opposite in direction for *AB* to be in equilibrium. The force **B** acting at *B* of member *BCD* will be equal in magnitude but opposite in direction to force **B** acting on member *AB*. Member *BCD* is a three-force body with member forces intersecting at *E*. The f.b.d.'s of members *AB* and *BCD* illustrate the above conditions. The force triangle for member *BCD* is also shown. The angle β is found from the member dimensions:

$$\beta = \tan^{-1}\left(\frac{60 \text{ m}}{100 \text{ m}}\right) = 30.964°$$

Applying of the law of sines to the force triangle for member *BCD*,

$$\frac{130 \text{ N}}{\sin(45° - \beta)} = \frac{B}{\sin\beta} = \frac{C}{\sin 135°}$$

or

$$\frac{130 \text{ N}}{\sin 14.036°} = \frac{B}{\sin 30.964°} = \frac{C}{\sin 135°}$$

$$\therefore \quad A = B = \frac{(130 \text{ N})\sin 30.964°}{\sin 14.036°} = 275.78 \text{ N}$$

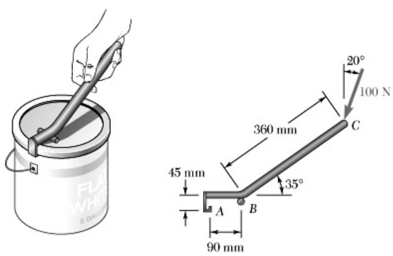
or $\mathbf{A} = 276 \text{ N} \searrow 45.0°$ ◀

and

$$C = \frac{(130 \text{ N})\sin 135°}{\sin 14.036°} = 379.02 \text{ N}$$

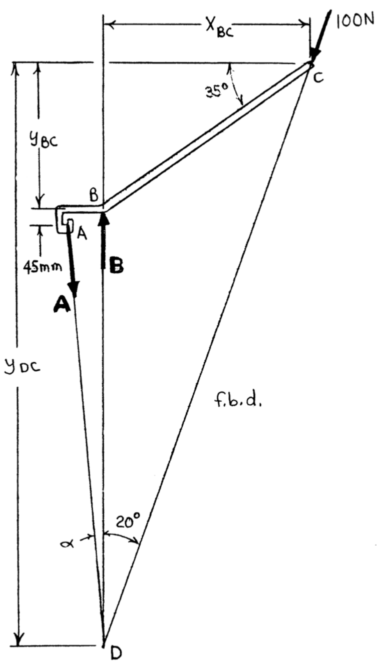
or $\mathbf{C} = 379 \text{ N} \nwarrow 59.0°$ ◀

PROBLEM 4.71



To remove the lid from a 5-gallon pail, the tool shown is used to apply an upward and radially outward force to the bottom inside rim of the lid. Assuming that the rim rests against the tool at *A* and that a 100-N force is applied as indicated to the handle, determine the force acting on the rim.

SOLUTION



The three-force member *ABC* has forces that intersect at *D*, where

$$\alpha = \tan^{-1}\left(\frac{90\text{ mm}}{y_{DC} - y_{BC} - 45\text{ mm}}\right)$$

and

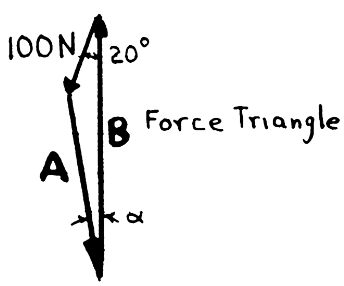
$$y_{DC} = \frac{x_{BC}}{\tan 20°} = \frac{(360\text{ mm})\cos 35°}{\tan 20°}$$

$$= 810.22\text{ mm}$$

$$y_{BC} = (360\text{ mm})\sin 35°$$

$$= 206.49\text{ mm}$$

$$\therefore\ \alpha = \tan^{-1}\left(\frac{90}{558.73}\right) = 9.1506°$$



Based on the force triangle, the law of sines gives

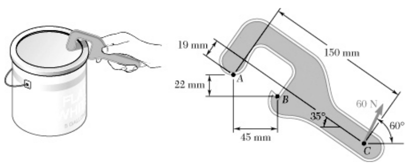
$$\frac{100\text{ N}}{\sin\alpha} = \frac{A}{\sin 20°}$$

$$\therefore\ A = \frac{(100\text{ N})\sin 20°}{\sin 9.1506°} = 215.07\text{ N}$$

or $\qquad \mathbf{A} = 215\text{ N} ⦪ 80.8°$ on tool

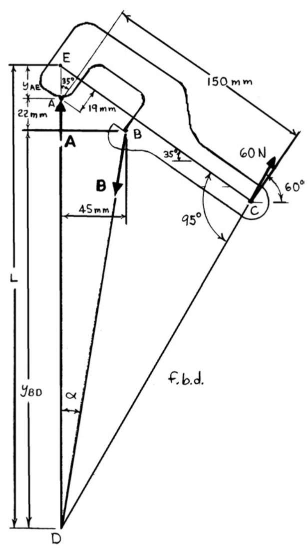
and $\mathbf{A} = 215\text{ N} ⦨ 80.8°$ on rim of can ◀

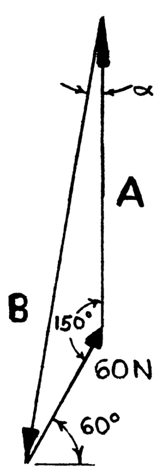
PROBLEM 4.72



To remove the lid from a 5-gallon pail, the tool shown is used to apply an upward and radially outward force to the bottom inside rim of the lid. Assuming that the top and the rim of the lid rest against the tool at A and B, respectively, and that a 60-N force is applied as indicated to the handle, determine the force acting on the rim.

SOLUTION





The three-force member ABC has forces that intersect at point D, where, from the law of sines (ΔCDE)

$$\frac{L}{\sin 95°} = \frac{150 \text{ mm} + (19 \text{ mm})\tan 35°}{\sin 30°}$$

$$\therefore L = 325.37 \text{ mm}$$

Then

$$\alpha = \tan^{-1}\left(\frac{45 \text{ mm}}{y_{BD}}\right)$$

where

$$y_{BD} = L - y_{AE} - 22 \text{ mm}$$

$$= 325.37 \text{ mm} - \frac{19 \text{ mm}}{\cos 35°} - 22 \text{ mm}$$

$$= 280.18 \text{ mm}$$

$$\therefore \alpha = \tan^{-1}\left(\frac{45 \text{ mm}}{280.18 \text{ mm}}\right) = 9.1246°$$

Applying the law of sines to the force triangle,

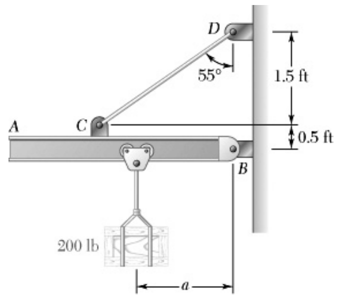
$$\frac{B}{\sin 150°} = \frac{60 \text{ N}}{\sin 9.1246°}$$

$$\therefore B = 189.177 \text{ N}$$

Or, on member $\mathbf{B} = 189.2 \text{ N} \measuredangle 80.9°$

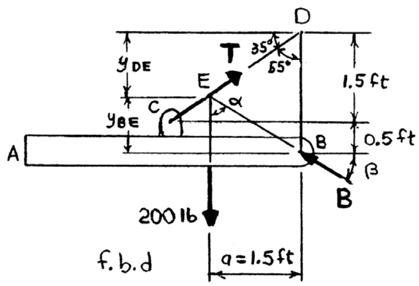
and, on lid $\mathbf{B} = 189.2 \text{ N} \measuredangle 80.9°$ ◀

PROBLEM 4.73



A 200-lb crate is attached to the trolley-beam system shown. Knowing that $a = 1.5$ ft, determine (*a*) the tension in cable *CD*, (*b*) the reaction at *B*.

SOLUTION



From geometry of forces

$$\beta = \tan^{-1}\left(\frac{y_{BE}}{1.5 \text{ ft}}\right)$$

where

$$\begin{aligned} y_{BE} &= 2.0 - y_{DE} \\ &= 2.0 - 1.5\tan 35° \\ &= 0.94969 \text{ ft} \end{aligned}$$

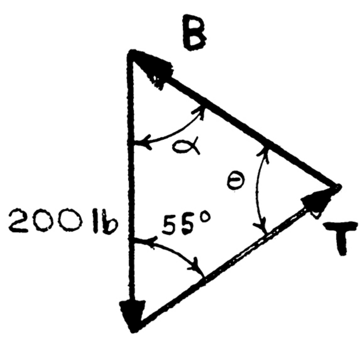
$$\therefore\ \beta = \tan^{-1}\left(\frac{0.94969}{1.5}\right) = 32.339°$$

and

$$\alpha = 90° - \beta = 90° - 32.339° = 57.661°$$

$$\theta = \beta + 35° = 32.339° + 35° = 67.339°$$

Applying the law of sines to the force triangle,



$$\frac{200 \text{ lb}}{\sin\theta} = \frac{T}{\sin\alpha} = \frac{B}{\sin 55°}$$

or

$$\frac{(200 \text{ lb})}{\sin 67.339°} = \frac{T}{\sin 57.661°} = \frac{B}{\sin 55°}$$

(*a*)

$$T = \frac{(200 \text{ lb})(\sin 57.661°)}{\sin 67.339°} = 183.116 \text{ lb}$$

or $T = 183.1$ lb ◀

(*b*)

$$B = \frac{(200 \text{ lb})(\sin 55°)}{\sin 67.339°} = 177.536 \text{ lb}$$

or **B** = 177.5 lb $\searrow$ 32.3° ◀