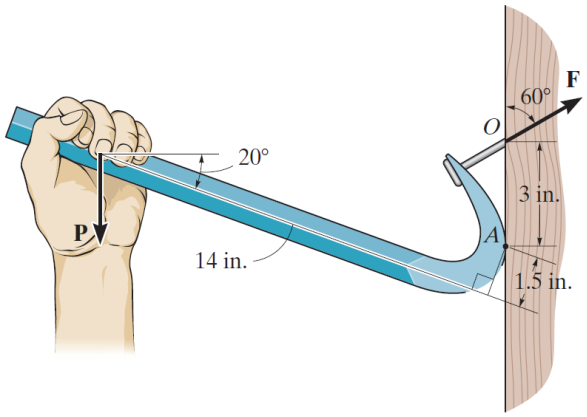
Problem 4-6

The crowbar is subjected to a vertical force of $P = 25$ lb at the grip, whereas it takes a force of $F = 155$ lb at the claw to pull the nail out. Find the moment of each force about point A and determine if **P** is sufficient to pull out the nail. The crowbar contacts the board at point A.

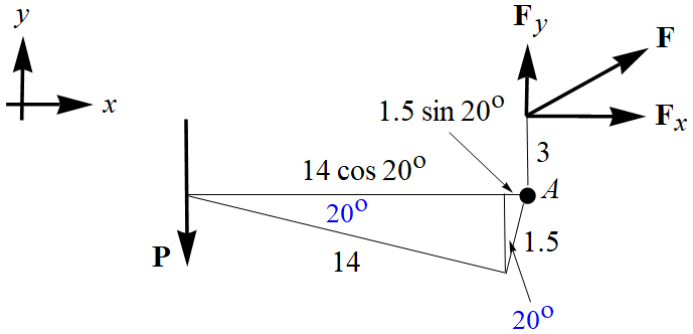


Prob. 4–6

Solution

Method Using Varignon's Theorem

According to Varignon's principle, the moment of each force about point A can be determined by calculating the moment of the force component perpendicular to the moment arm.



In this figure each of the forces is decomposed into components along the x- and y-axes. The components are shown at the point where the force acts at O.

Moment of Force P: $M_P = r_P F_{P\perp} = (14\cos 20° + 1.5\sin 20°)(25)$ in · lb ≈ 342 in · lb ↺

Moment of Force F: $M_F = r_F F_{F\perp} = (3)(155\sin 60°)$ in · lb ≈ 403 in · lb ↻

The arrows shown at the end of the answer indicate the direction the force acts about point A, since the moment is a vector.

$$\mathbf{M}_P \approx (342 \text{ in} \cdot \text{lb})\hat{\mathbf{z}}$$

$$\mathbf{M}_F \approx (-403 \text{ in} \cdot \text{lb})\hat{\mathbf{z}}$$

M_P is not high enough to remove the nail; it must be 403 in · lb or higher.

Method Using Vectors

Treat point A as the origin of an xyz-coordinate system. Then the moment of $\mathbf{P}$ about A is

$$\begin{aligned}\mathbf{r}_P \times \mathbf{P} &= \langle -1.5\sin 20^\circ - 14\cos 20^\circ, -1.5\cos 20^\circ + 14\sin 20^\circ, 0\rangle \times 25\langle 0, -1, 0\rangle \text{ in}\cdot\text{lb} \\ &= \begin{vmatrix} \hat{\mathbf{x}} & \hat{\mathbf{y}} & \hat{\mathbf{z}} \\ -1.5\sin 20^\circ - 14\cos 20^\circ & -1.5\cos 20^\circ + 14\sin 20^\circ & 0 \\ 0 & -25 & 0 \end{vmatrix} \text{ in}\cdot\text{lb} \\ &\approx (342 \text{ in}\cdot\text{lb})\hat{\mathbf{z}},\end{aligned}$$

and the moment of $\mathbf{F}$ about A is

$$\begin{aligned}\mathbf{r}_F \times \mathbf{F} &= \langle 0, 3, 0\rangle \times 155\,\langle \sin 60^\circ, \cos 60^\circ, 0\rangle \text{ in}\cdot\text{lb} \\ &= \begin{vmatrix} \hat{\mathbf{x}} & \hat{\mathbf{y}} & \hat{\mathbf{z}} \\ 0 & 3 & 0 \\ 155\sin 60^\circ & 155\cos 60^\circ & 0 \end{vmatrix} \text{ in}\cdot\text{lb} \\ &\approx (-403 \text{ in}\cdot\text{lb})\hat{\mathbf{z}}.\end{aligned}$$