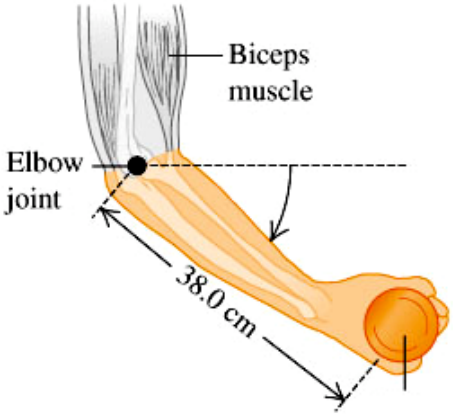
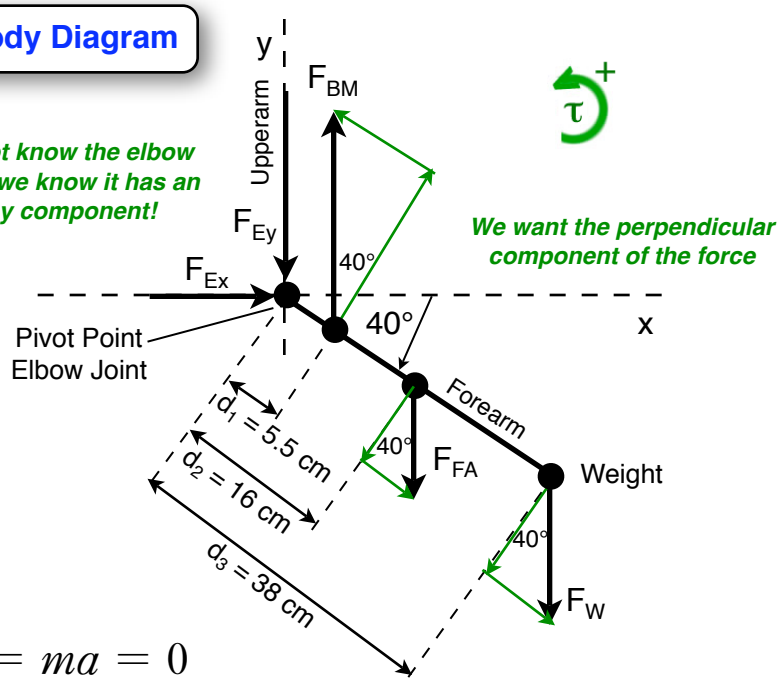
Physics 180A Chapter 10 Problem 52

A 72.0 kg weight lifter is doing arm raises using a 7.50 kg weight in her hand. Her arm pivots around the elbow joint, starting 40.0° below the horizontal. Biometric measurements have shown that both forearms and the hands together account for 6.00 % of a person's weight. Since the upper arm is held vertically, the biceps muscle always acts vertically and is attached to the bones of the forearm 5.50 cm from the elbow joint. The center of mass of this person's forearm-hand combination is 16.0 cm from the elbow joint, along the bones of the forearm, and the weight is held 38.0 cm from the elbow joint. What force does the biceps muscle exert on the forearm? Find the magnitude and direction of the force that the elbow joint exerts on the forearm.



FreeBody Diagram



We do not know the elbow force but we know it has an x and y component!

We want the perpendicular component of the force

Sum of Forces *Static Equilibrium*

$$\Sigma F_x = F_{Ex} = ma = 0 \quad = ?$$

$$\Sigma F_y = -F_{Ey} + F_{BM} - F_{FA} - F_W = ma = 0$$

$$\tau = F_\perp d$$

Sum of Torques *Static Equilibrium*

$$\Sigma\tau = F_{BM}\, d_1 \cos\theta - F_{FA}\, d_2 \cos\theta - F_W\, d_3 \cos\theta = I\alpha = 0$$

No torques on Elbow forces since they are acting on the pivot point.

---

a. What force does the biceps muscle exert on the forearm?

Sum of Torques

$$F_{BM}\, d_1 \cos\theta - F_{FA}\, d_2 \cos\theta - F_W\, d_3 \cos\theta = 0$$

$$F_{BM}\, d_1 \cos\theta = F_{FA}\, d_2 \cos\theta + F_W\, d_3 \cos\theta$$

The cosine of the angle cancels in all terms.

$$F_{BM} = \frac{F_{FA}\, d_2 + F_W\, d_3}{d_1}$$

$$F_{BM} = \frac{0.5\,(0.06)\,72kg\,(0.16m) + 7.5kg\,(9.8m/s^2)\,0.38m}{0.055m}$$

$$F_{BM} = 570N \text{ upwards} \quad !!!$$

To keep the forearm stationary your Bicep Muscle needs to provide a lot of force since it is applied so close to the pivot point.

b. Find the magnitude and direction of the force that the elbow joint exerts on the forearm.

Sum of Forces

$$-F_{E_y} + F_{BM} - F_{FA} - F_W = 0$$

$$F_{E_y} = F_{BM} - F_{FA} - F_W$$

$$F_{E_y} = 570N - 2.16kg\,(9.8m/s^2) - 7.50kg\,(9.8m/s^2)$$

$$F_{E_x} = 0 \quad \textit{no force in the x-direction}$$

$$F_{E_y} = 475\ N \text{ downwards}$$

This amount of force is necessary to keep the forearm stationary.