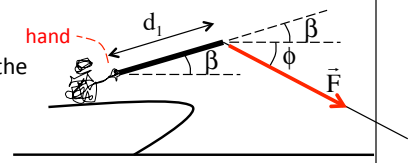
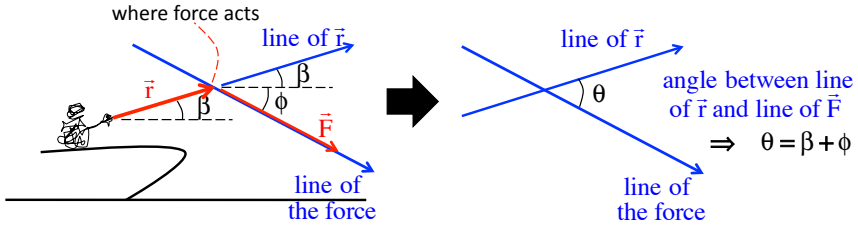
Problem 10.36

The situation is shown in the sketch. What is the torque the fish applies to the man's hands.

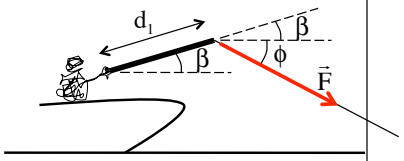


This is a great problem in that it makes you *think* about how the parameters in a torque calculation are defined. For the fun of it, we will do the calculation all three ways.

The definition approach: Eliminating the parts we don't need on the sketch, I've defined "r" in the sketch. (Remember, $\vec{r}$ goes from the *point about which you are taking the torque*—in this case, the hand—to where the force acts.)



With all of this, we can write:

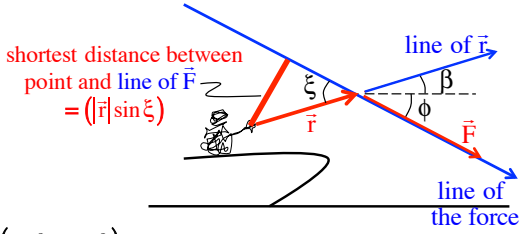


$$\begin{aligned}|\vec{\Gamma}| &= \vec{r}\times\vec{F} \\ &= |\vec{F}||\vec{r}|\sin\theta \\ &= (100.\ \text{N})(2.00\ \text{m})\sin(20^\circ + 37^\circ) \\ &= 168\ \text{N}\cdot\text{m}\end{aligned}$$

The torque is tending to make the man's rotate clockwise, so the torque is negative and equal to $\vec{\Gamma} = -(168\ \text{N}\cdot\text{m})\hat{k}$.

From the perspective of the $r_\perp$ (or *moment arm*) approach: This is the approach used most often (in fact, elementary physics often give their only definition of torque as the product of the *force* and the *moment arm*, where the moment arm is $r_\perp$). This is because there is a very simple question the answer of which will allow you to SEE what $r_\perp$ is in a problem. The question is, "What is the shortest distance between the point about which you are taking the torque and the *line of the force*? (It IS easy to visually identify the shortest distance between a point and a line . . .). Using that in this problem yields:

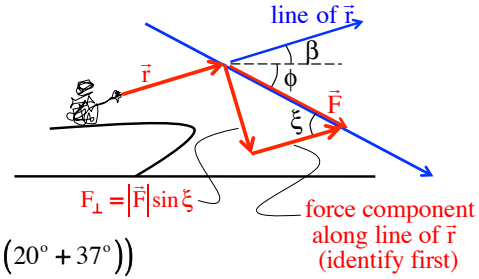
That magnitude is:



$$\begin{aligned}|\vec{\Gamma}| &= \vec{r}\times\vec{F} \\ &= |\vec{F}|r_\perp \\ &= |\vec{F}|(|\vec{r}|\sin\xi) \\ &= (100.\ \text{N})(2.00\ \text{m})\sin(20^\circ + 37^\circ) \\ &= 168\ \text{N}\cdot\text{m}\end{aligned}$$

From the perspective of the $F_\perp$ approach: This is the mirror image of the $r_\perp$ approach, and in most cases it is a little more obscure than is the $r_\perp$ approach. The easiest way to identify $F_\perp$ is to identify the force component that runs *along the line* of $\vec{r}$, then eyeball the force component that must be perpendicular to that line. That perpendicular component is $F_\perp$.

With all of this, we can write:



$$\begin{aligned}|\vec{\Gamma}| &= \vec{r}\times\vec{F} \\ &= |\vec{r}|F_\perp \\ &= |\vec{r}|(|\vec{F}|\sin\xi) \\ &= (2.00\ \text{m})((100.\ \text{N})\sin(20^\circ + 37^\circ)) \\ &= 168\ \text{N}\cdot\text{m}\end{aligned}$$

Bottom line: All of the approaches will work, some easier than others on a given problem. Knowing how to negotiate all of them has the potential to make life a lot nicer.