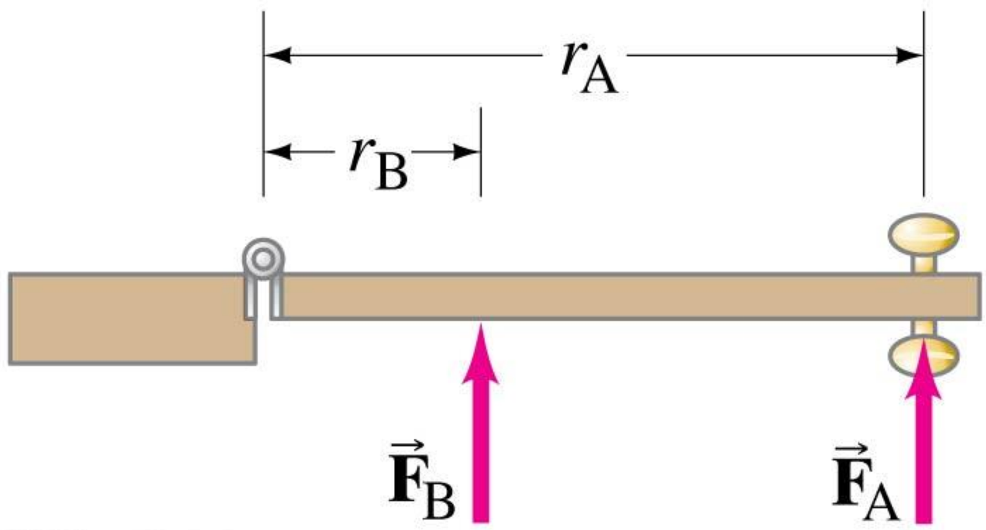
Chapter 8
Rotational Motion
(Only the Torque)

8-4 Torque

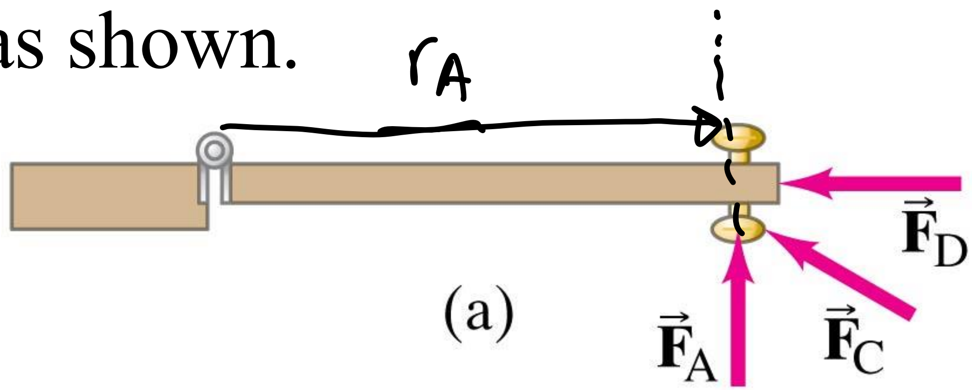
To make an object start rotating, a force is needed; the position and direction of the force matter as well.

The perpendicular distance from the axis of rotation to the line along which the force acts is called the lever arm.



8-4 Torque

Here, the lever arm for F_A is the distance from the knob to the hinge; the lever arm for F_D is zero; and the lever arm for F_C is as shown.



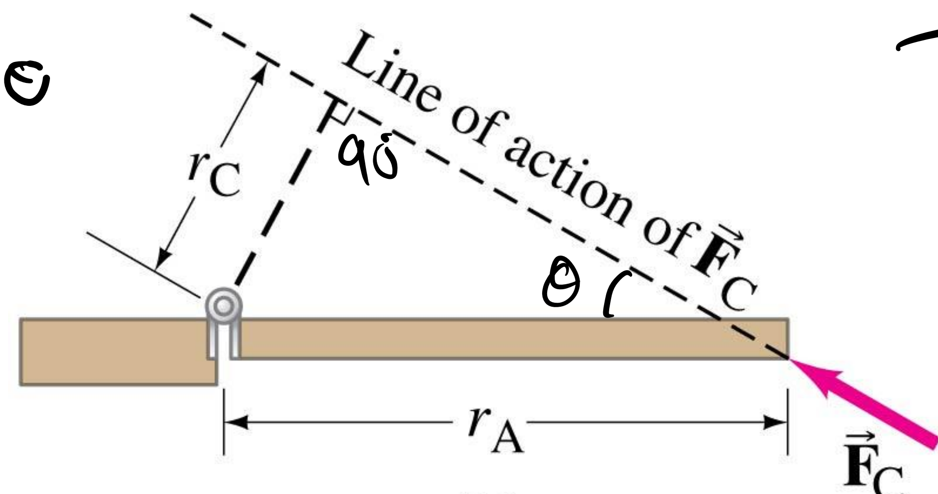
(a)

$\sin\theta = \frac{r_c}{r_A}$

$r_c = r_A \sin\theta$

$\tau = F \times$ lever arm

$= F\, r_A \sin\theta$



(b)

8-4 Torque

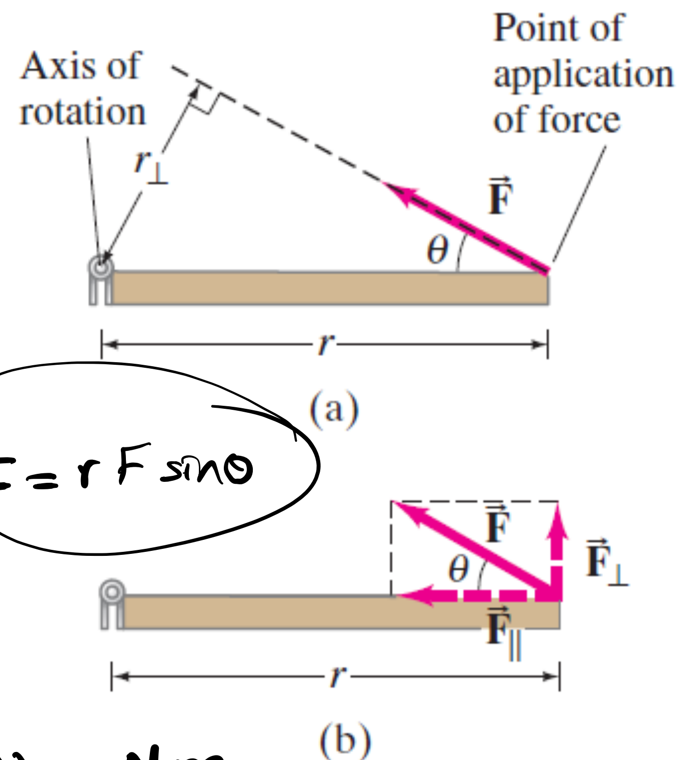
Tourque is a vector quantity

magnitude

$\tau = r F \sin\theta$

+

direction

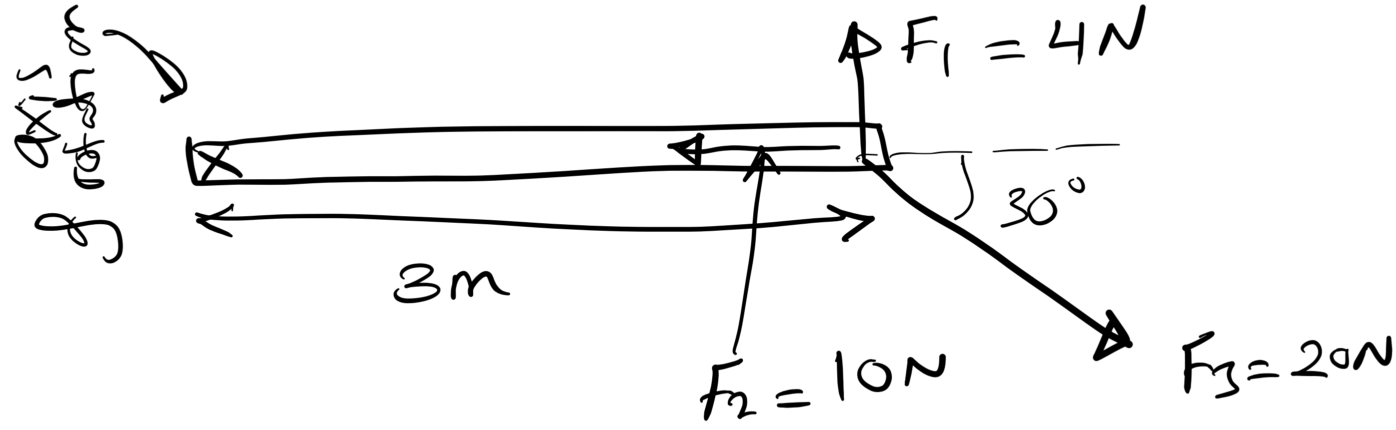


$\tau = r F \sin\theta$

unit N.m

if rotation will be clockwise $\Longrightarrow$ $-$

" " " " counterclockwise $\Longrightarrow$ $+$



Calculate the tourque of each force.

$$\tau_1 = r F_1 \sin\theta$$
$$= (3)(4)\sin 90^\circ = 12 \text{ N.m}$$
$$\vec{\tau}_1 = +12 \text{ Nm}$$

$$\tau_2 = r F_2 \sin\theta$$
$$= (3)(10)\sin(0) = 0$$

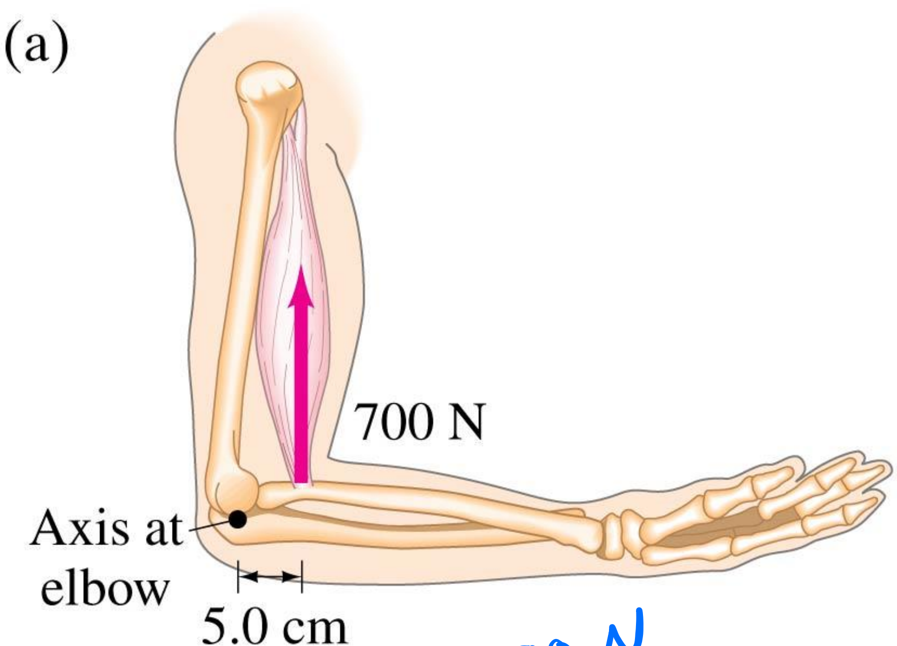
$$\tau_3 = r F_3 \sin\theta$$
$$= (3)(20)\sin 30^\circ = \underline{30 \text{ N.m}}$$
$$\underline{\vec{\tau}_3 = -30 \text{ N m}}$$

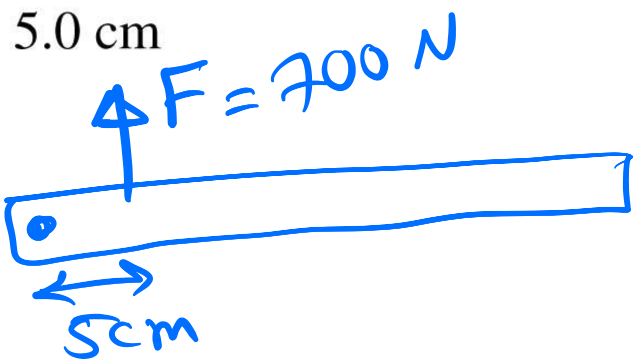
clockwise rotation

$$\vec{\tau}_{net} = 12 + 0 - 30$$
$$= -18 \text{ N.m}$$

The biceps muscle exerts a vertical force on the lower arm. Calculate in each case the torque about the axis of rotation through the elbow joint, assuming the muscle is attached 5.0 cm from the elbow as shown.

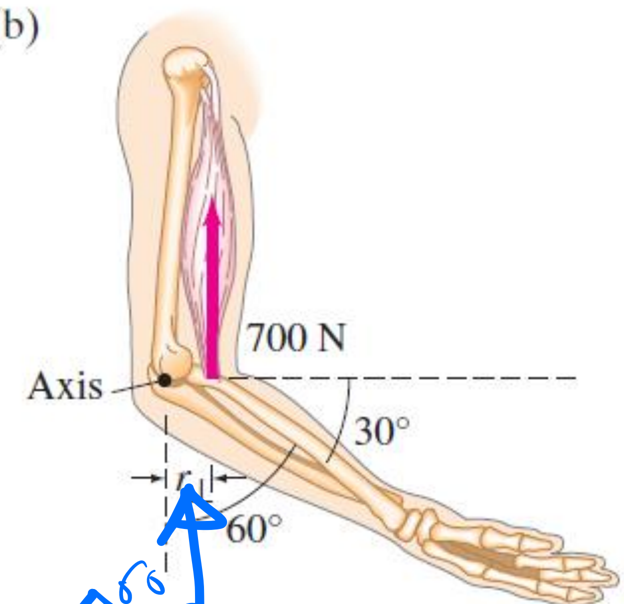
(a)

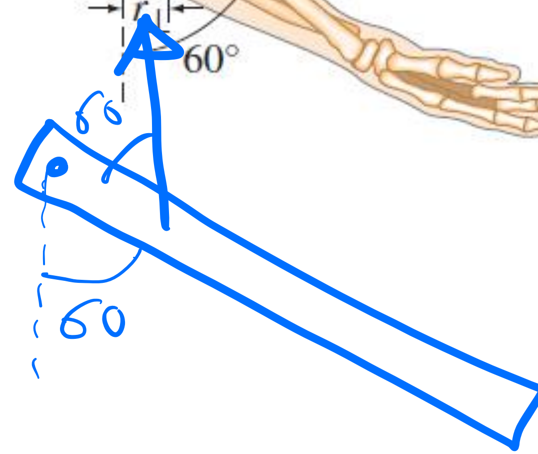




$\tau = 700 \times 0.05 \times \sin 90°$
$= 35$ N.m

(b)





$\tau = 700 \times 0.05 \times \sin 60$
$= 30$ N.m

25. (II) Calculate the net torque about the axle of the wheel shown in Fig. 8–42. Assume that a friction torque of 0.60 m · N opposes the motion.

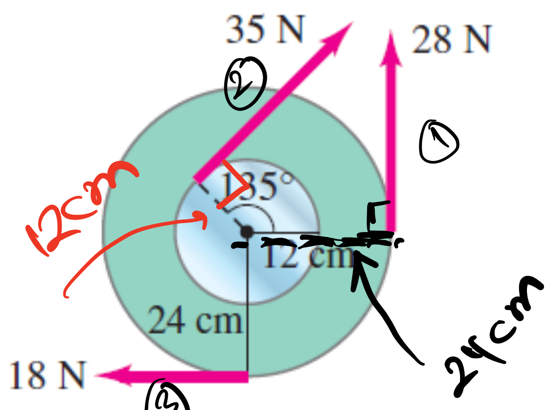


FIGURE 8–42 Problem 25.

$$\tau_1 = r F \sin\theta$$
$$= 0.24 \times 28 \times \sin 90^\circ$$
$$= 6.72 \text{ N.m}$$
$$\vec{\tau}_1 = +6.72 \text{ N.m}$$

$$\tau_2 = r F \sin\theta$$
$$= (0.12)(35)\sin 90$$
$$= 4.2 \text{ N.m}$$
$$\vec{\tau} = -4.2 \text{ N.m}$$

$$\tau_3 = r F \sin\theta$$
$$= (0.24)(18)\sin 90$$
$$= 4.3 \text{ N.m}$$
$$\vec{\tau}_3 = -4.3 \text{ N.m}$$

$$\vec{\tau}_{net} = 6.72 - 4.2 - 4.3$$
$$= -1.78 \text{ N.m}$$

27. (II) Two blocks, each of mass m, are attached to the ends of a massless rod which pivots as shown in Fig. 8–43. Initially the rod is held in the horizontal position and then released. Calculate the magnitude and direction of the net torque on this system when it is first released.

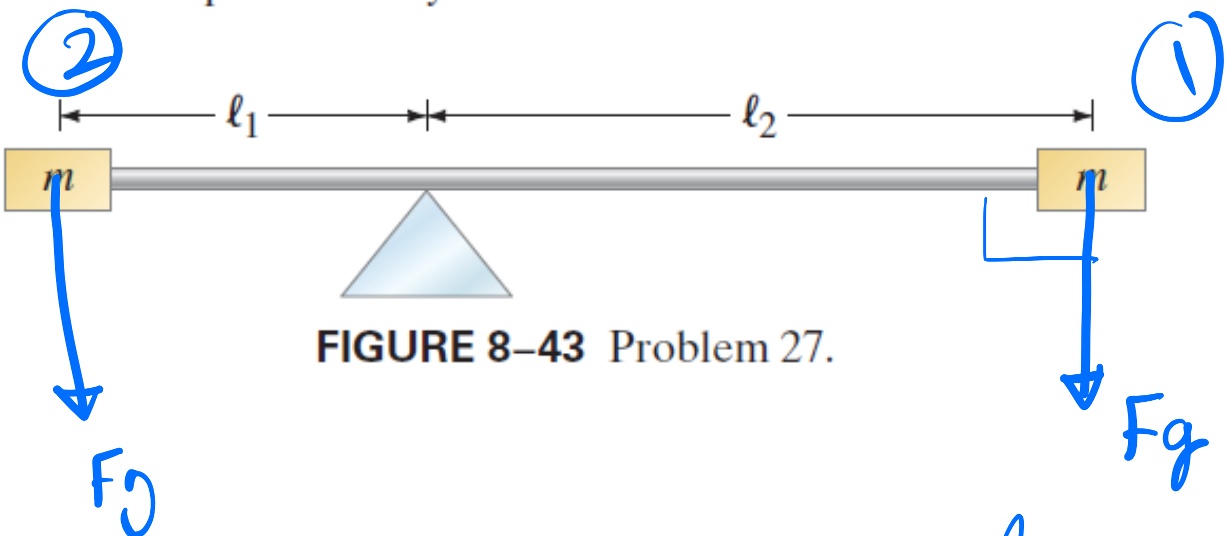


FIGURE 8–43 Problem 27.

$$\tau_1 = mg\ell_2 \sin 90^\circ = mg\ell_2$$

$$\vec{\tau}_1 = -mg\ell_2$$

$$\tau_2 = mg\ell_1 \sin 90^\circ = mg\ell_1$$

$$\vec{\tau}_2 = +mg\ell_1$$

$$\vec{\tau}_{net} = mg\ell_1 - mg\ell_2$$