38.1: Introduction to Torque

Torque is the rotational counterpart of force. Suppose a body rotates about an axis and a force F is applied some distance r from the axis (Fig. 38.1.1). The distance from the rotation axis to the point at which the force is applied is called the moment arm. If the force is applied perpendicular to the moment arm (Fig. 38.1.1(a)), then torque τ is defined as

$$\tau = Fr. \tag{38.1.1}$$

Torque in SI units is measured in units of newton-meters (Nm); in CGS units it is measured in dyne-centimeters (dyn cm); and in British engineering units, it is measured in foot-pounds (ft lbf).

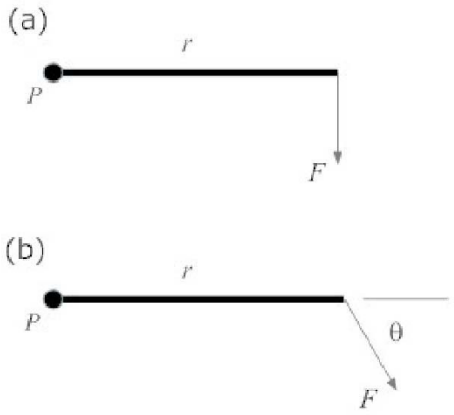

Figure 38.1.1: Torque on a rod that pivots about point P. (a) Force F applied normal to the rod; (b) force F applied obliquely.

More generally, suppose the force is applied at some angle θ to the moment arm (Fig. 38.1.1(b)). Then only the component of the force F perpendicular to the moment arm contributes to the torque:

$$\tau = Fr\sin\theta \tag{38.1.2}$$

Torque is actually a vector quantity. Its magnitude is as described above; its direction is perpendicular to the plane containing the force and the moment arm. Let $\mathbf{r}$ be a vector pointing from the rotation axis to the point at which the force is applied. Then the torque vector $\boldsymbol{\tau}$ is defined as

$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F} \tag{38.1.3}$$

The direction of $\boldsymbol{\tau}$ is given by a right-hand rule: if you curl the fingers of your right hand from $\mathbf{r}$ into $\mathbf{F}$, then the thumb of your right hand points in the direction of $\boldsymbol{\tau}$.