

# Chapter 11: Equilibrium

## Translational Equilibrium

Earlier in the course, we said an object is in equilibrium if the net force on it is zero:

$$\begin{array}{ccc} \vec{F}_{net} = \vec{0} & \Leftrightarrow & \vec{a} = \vec{0} \\ \Updownarrow & & \Updownarrow \\ \left. \begin{array}{l} \sum F_x = 0 \\ \sum F_y = 0 \\ \sum F_z = 0 \end{array} \right\} & \Leftrightarrow & \left\{ \begin{array}{l} a_x = 0 \\ a_y = 0 \\ a_z = 0 \end{array} \right. \end{array} \quad (1)$$

But this is really only *one kind* of equilibrium, called **translational equilibrium**. An object is in translational equilibrium if it's not accelerating *translationally*.

## Rotational Equilibrium

There is another kind of equilibrium, called rotational equilibrium. An object is in **rotational equilibrium** if it's not accelerating rotationally (*angularly*). This means:

$$\alpha = 0 \quad (2)$$

From  $\tau_{net} = I\alpha$ , this implies:

$$\tau_{net} = 0 \quad (3)$$

## Choice of Axis

Remember that how much torque a given force produces depends on the axis (or point) you're measuring the torque with respect to. Yet, in (3), I didn't say anything about this choice of axis. In order for an object to be in rotational equilibrium, the net torque on it must be zero for **any choice of axis**.

Because the choice of axis is arbitrary, we might as well choose it so as to make the expression for  $\tau_{net}$  as simple as possible. Often, this is accomplished by following the “rule of thumb” (general guide) below.

### Rule of Thumb for Choosing the Axis of Rotation

- Choose the axis of rotation to be where the greatest number of unknown forces act. Then none of these forces will appear in the expression for  $\tau_{net}$ .

## True Equilibrium (Translational + Rotational)

True equilibrium (translational *and* rotational) is accomplished when the object is not accelerating translationally *or* rotationally. Thus the conditions that are required for an object to be in equilibrium are:

$$\vec{F}_{net} = \vec{0} \quad (4)$$

$$\tau_{net} = 0 \quad (\text{all axes}) \quad (5)$$