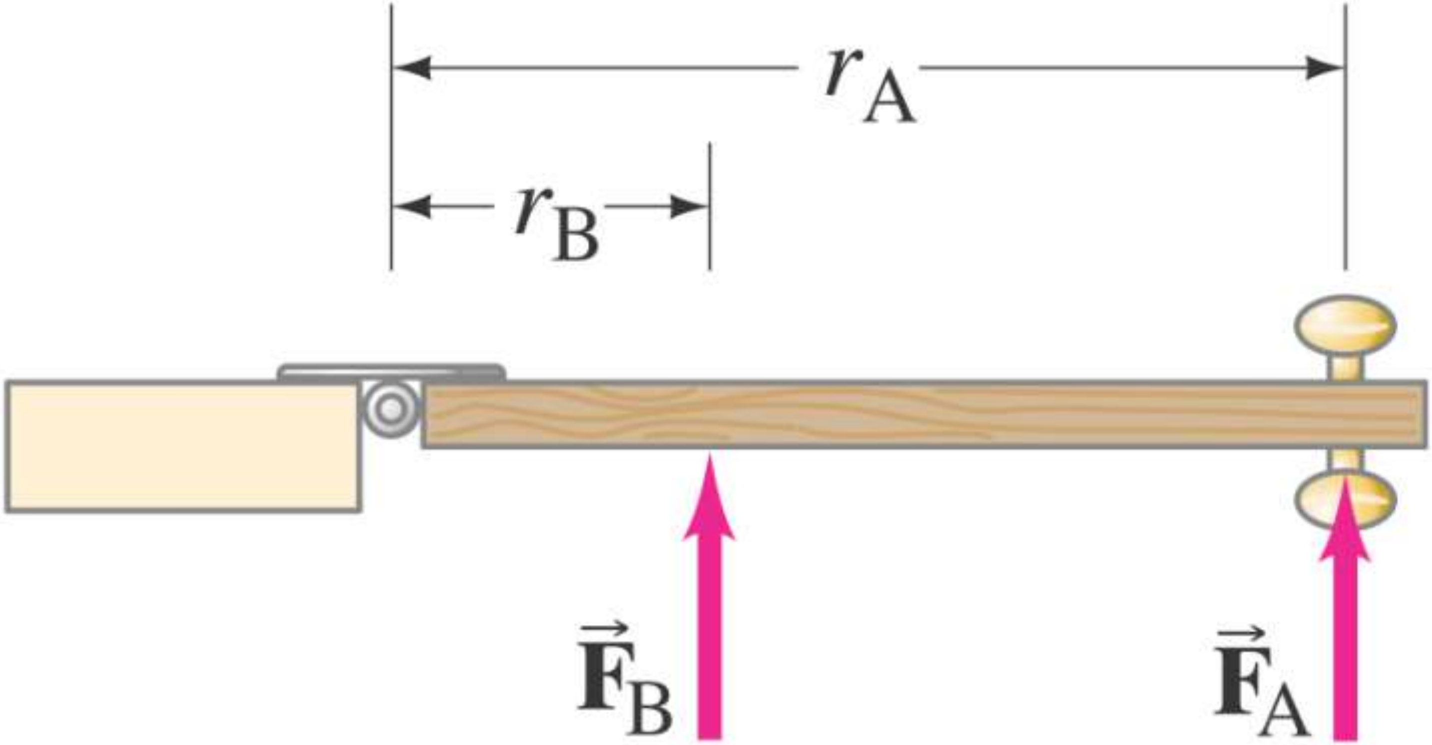
Chapter 8

Rotational Motion

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**.



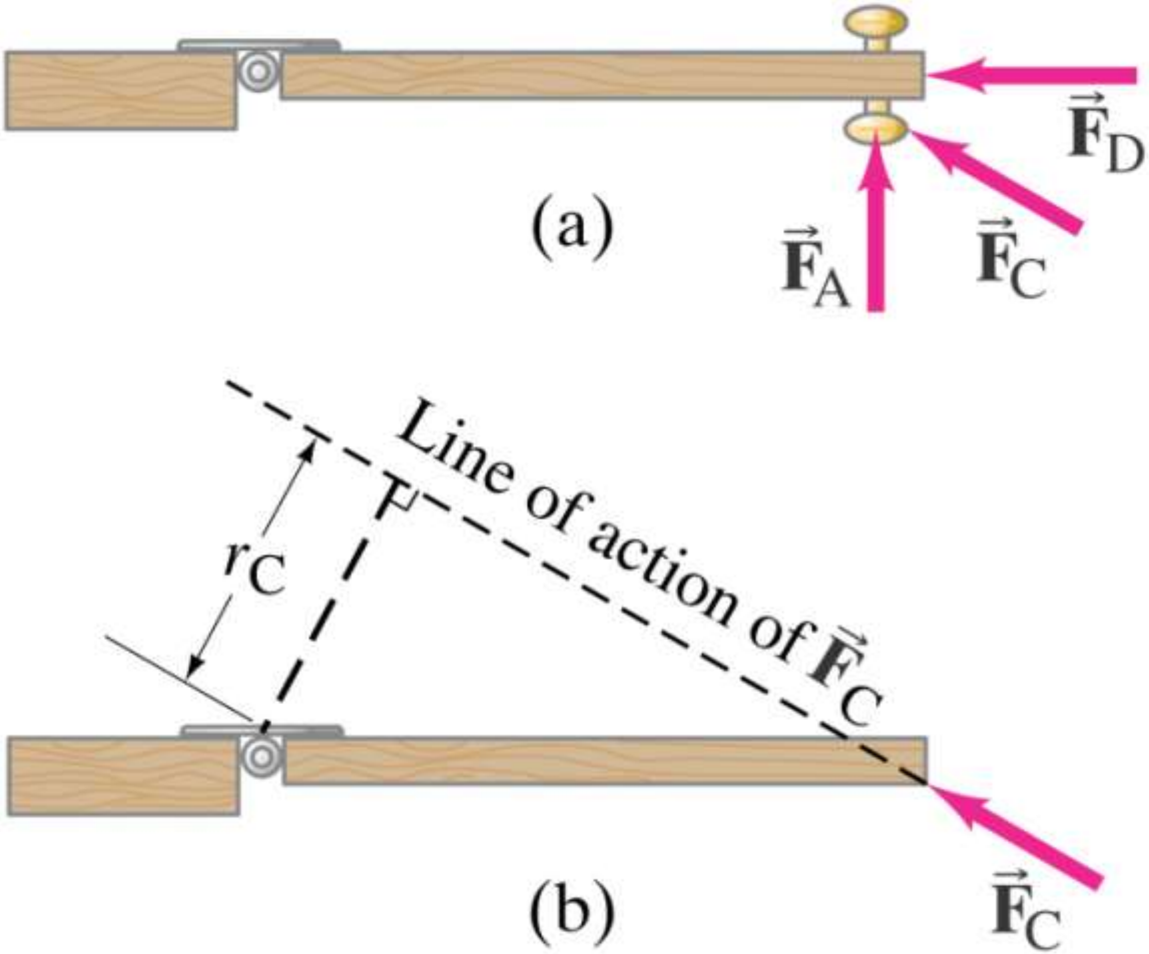
8-4 Torque

(a) (b)

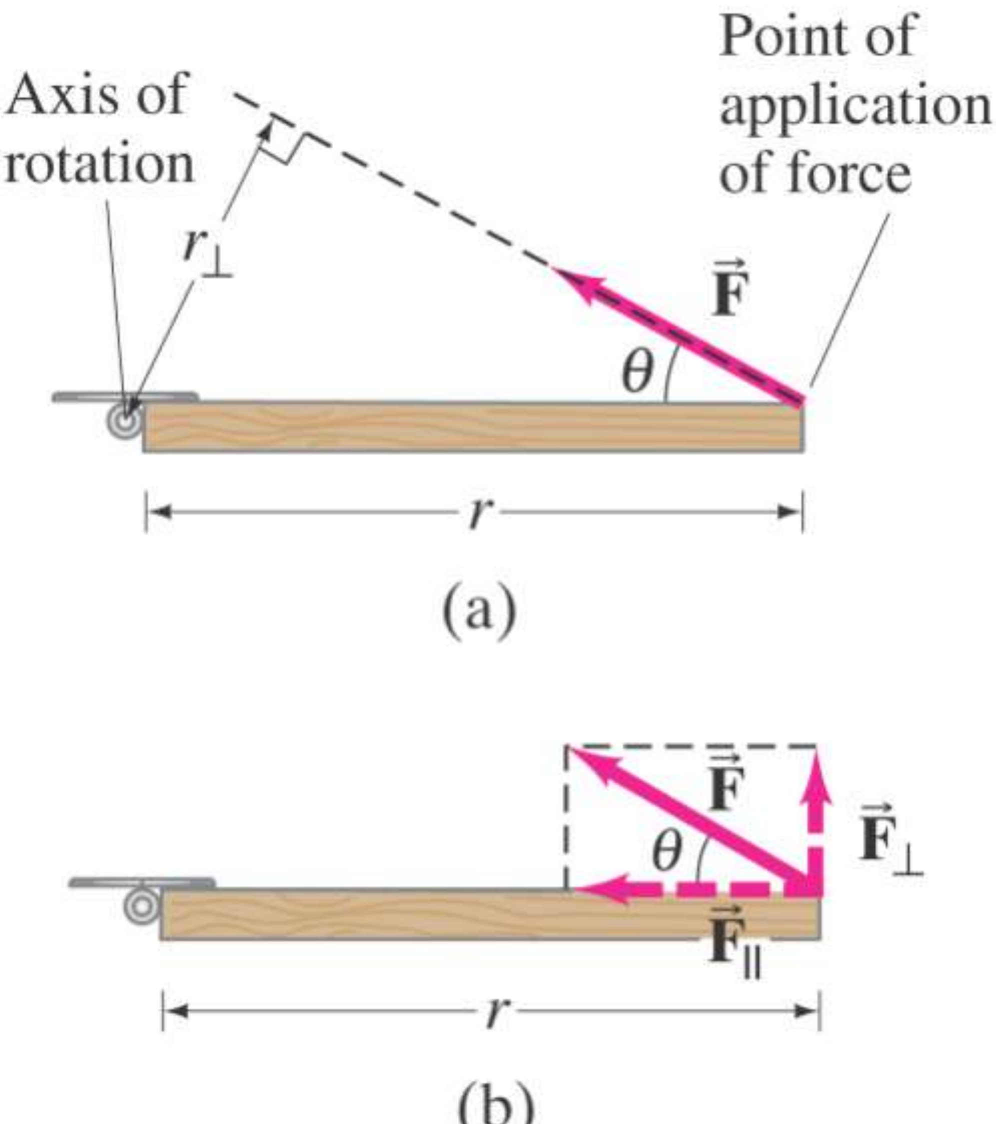
A **longer** lever arm is very helpful in rotating objects.

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.



8-4 Torque



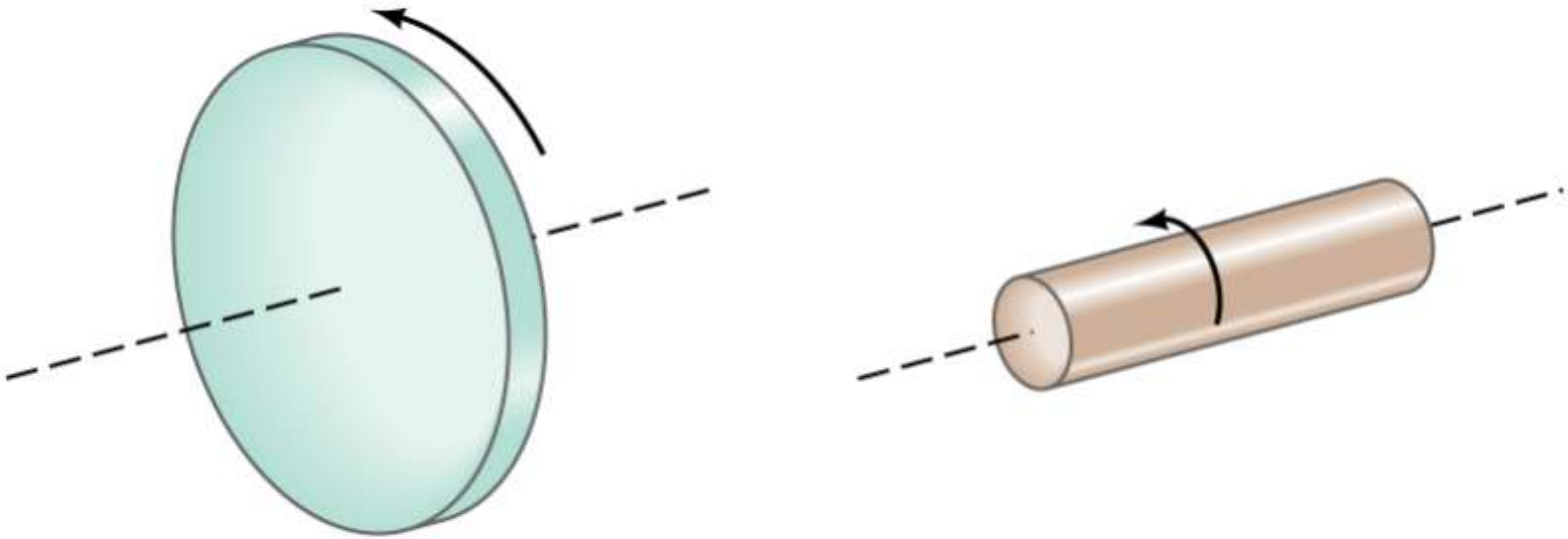
The **torque** is defined as:

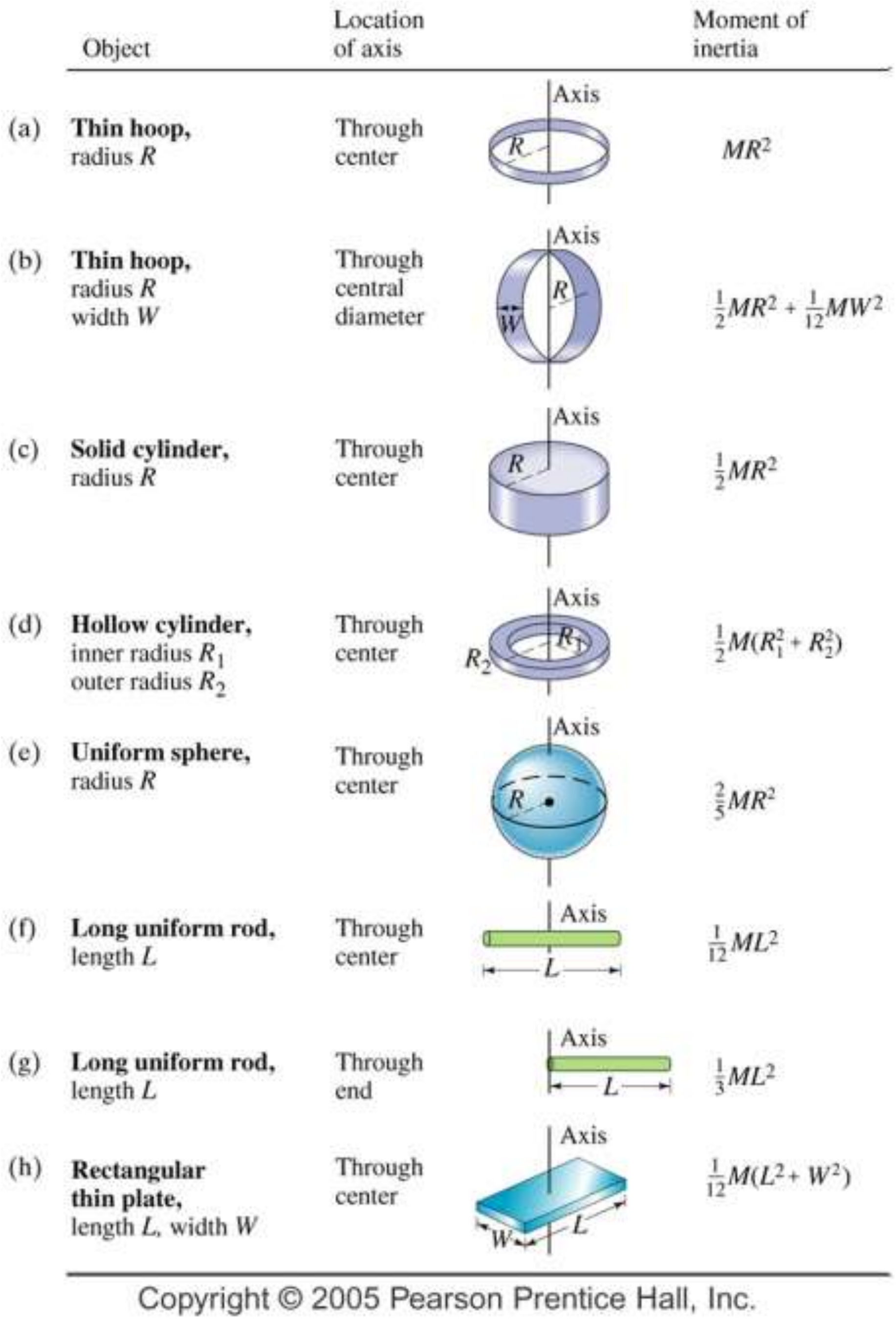
$$\tau = r_\perp F \qquad \text{(8-10a)}$$

8-5 Rotational Dynamics; Torque and Rotational Inertia

The quantity $I = \Sigma m r^2$ is called the **rotational inertia** of an object.

The **distribution** of mass matters here – these two objects have the same mass, but the one on the left has a greater **rotational inertia**, as so much of its mass is far from the axis of rotation.





	Object	Location of axis	Moment of inertia
(a)	**Thin hoop,** radius R	Through center	MR^2
(b)	**Thin hoop,** radius R width W	Through central diameter	$\frac{1}{2}MR^2 + \frac{1}{12}MW^2$
(c)	**Solid cylinder,** radius R	Through center	$\frac{1}{2}MR^2$
(d)	**Hollow cylinder,** inner radius R_1 outer radius R_2	Through center	$\frac{1}{2}M(R_1^2 + R_2^2)$
(e)	**Uniform sphere,** radius R	Through center	$\frac{2}{5}MR^2$
(f)	**Long uniform rod,** length L	Through center	$\frac{1}{12}ML^2$
(g)	**Long uniform rod,** length L	Through end	$\frac{1}{3}ML^2$
(h)	**Rectangular thin plate,** length L, width W	Through center	$\frac{1}{12}M(L^2 + W^2)$

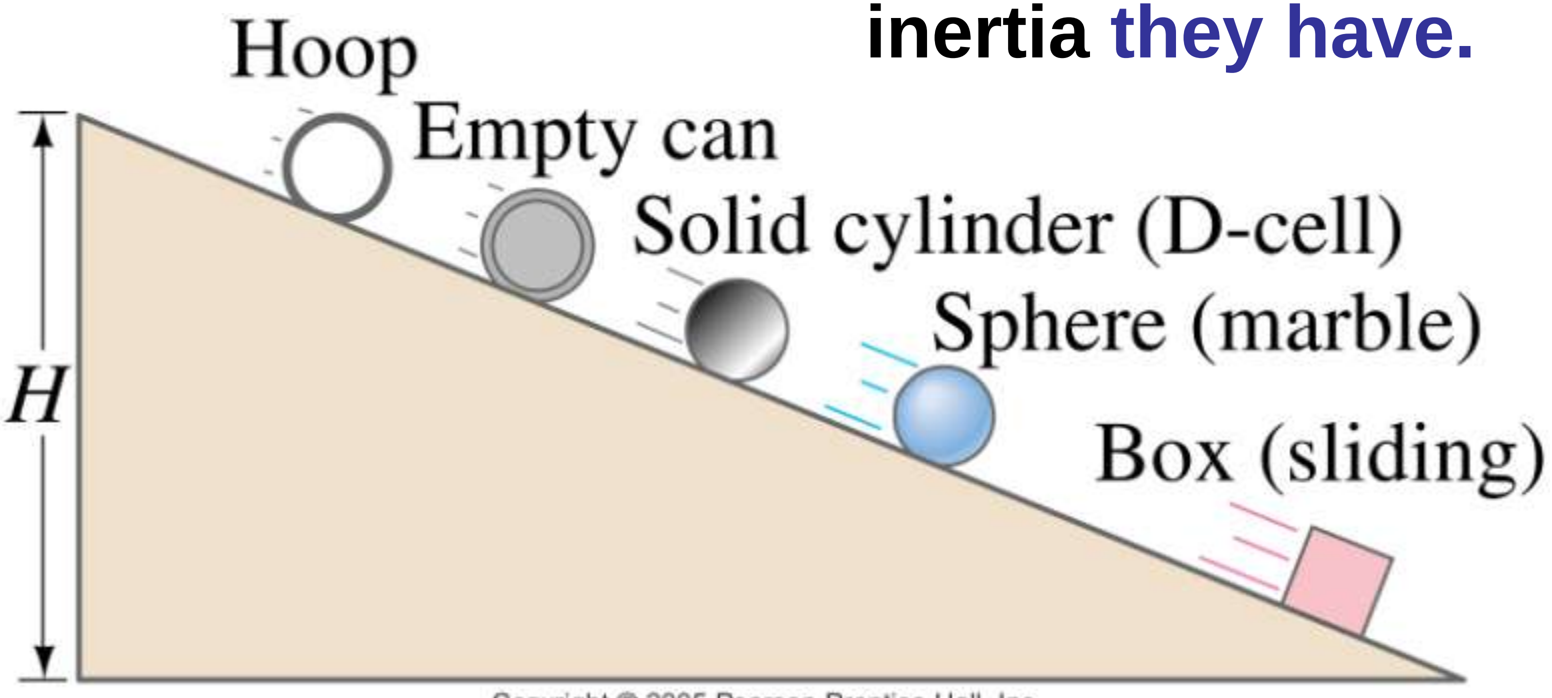
8-5 Rotational Dynamics; Torque and Rotational Inertia

The **rotational inertia** of an object depends not only on its **mass distribution** but also the location of the **axis** of rotation – compare (f) and (g), for example.

8-7 Rotational Kinetic Energy

When using **conservation** of energy, both **rotational** and **translational** kinetic energy must be taken into account.

All these objects have the same **potential** energy at the top, but the time it takes them to get down the incline depends on how much **rotational inertia** they have.



8-5 Rotational Dynamics; Torque and Rotational Inertia

Time for a Gizmo!

8-5 Rotational Dynamics; Torque and Rotational Inertia

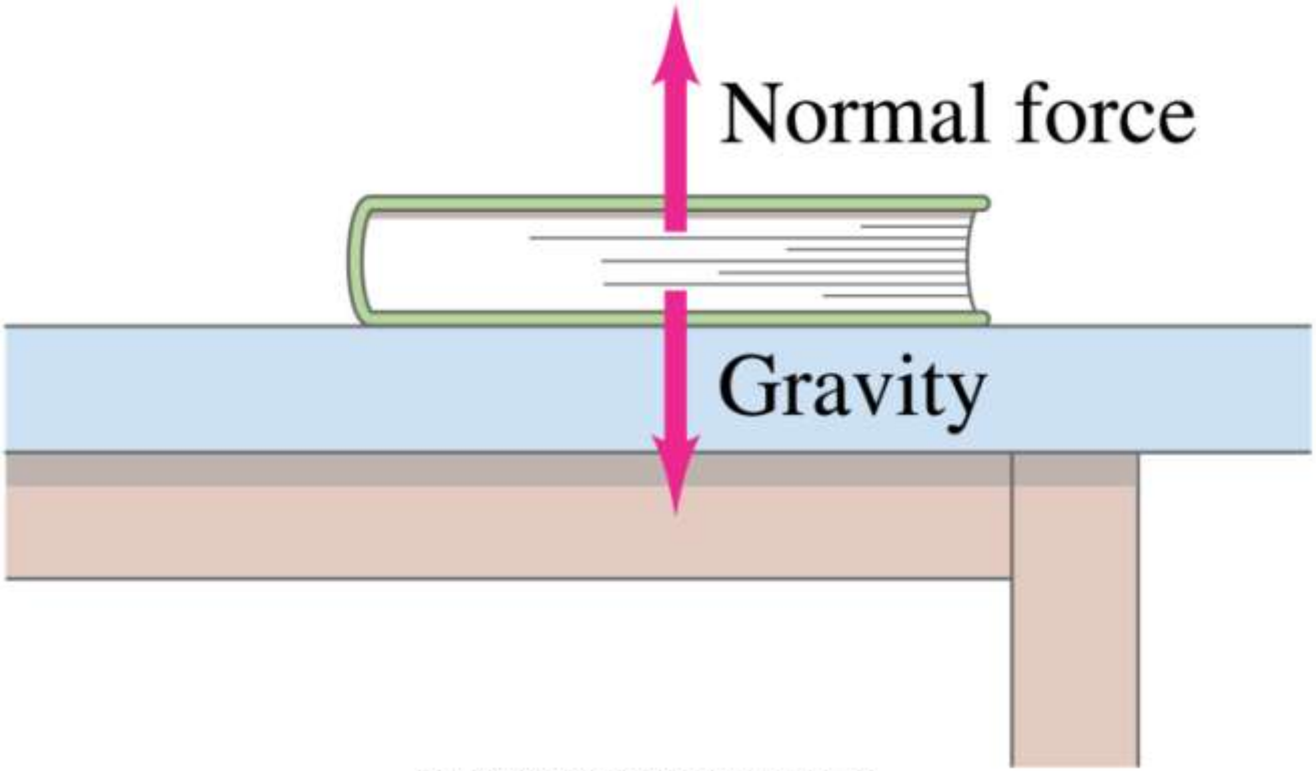
Time for a Gizmo!

Chapter 9

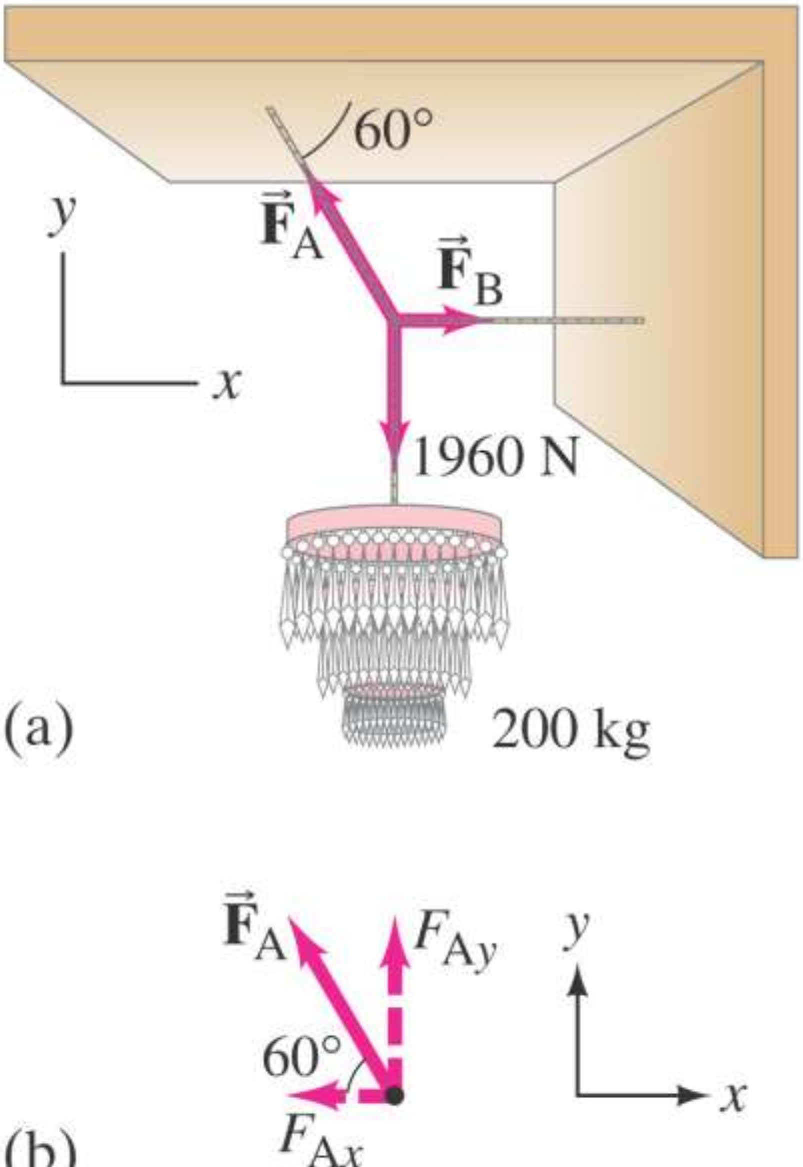
Static Equilibrium; Elasticity and Fracture

9-1 The Conditions for Equilibrium

An object with forces acting on it, but that is not moving, is said to be in **equilibrium**.



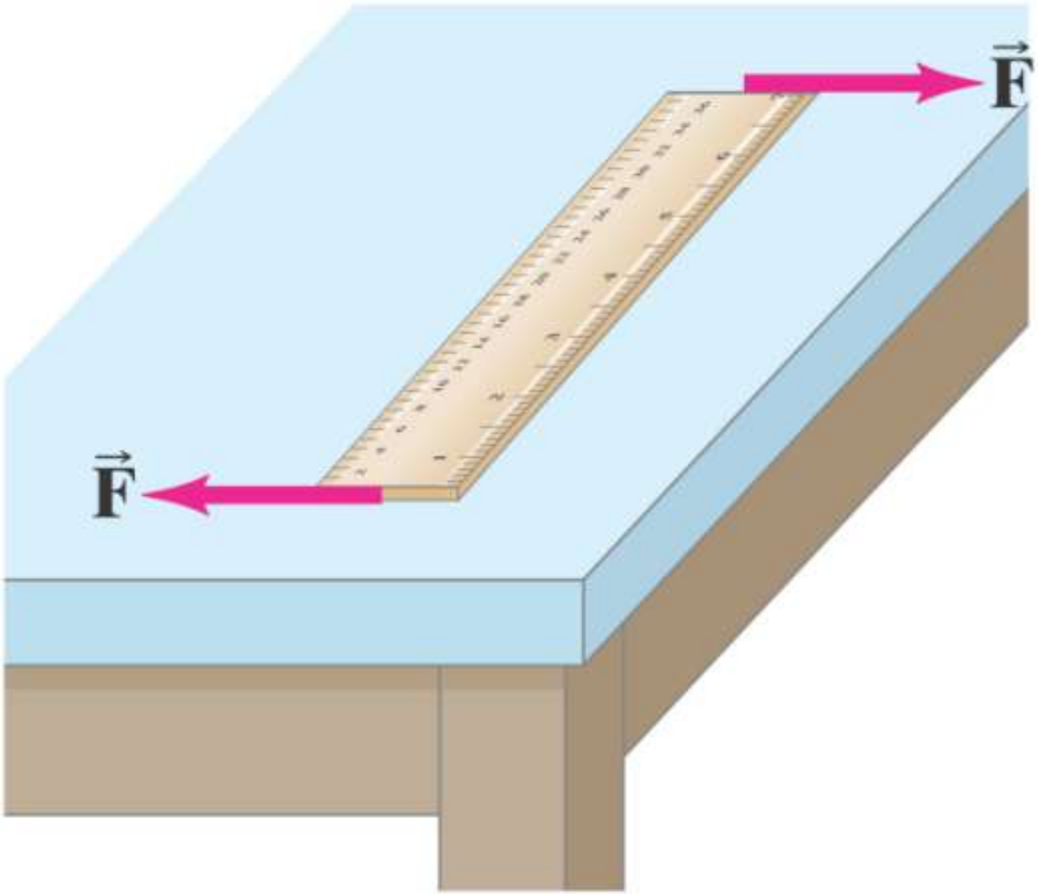
9-1 The Conditions for Equilibrium



The **first** condition for equilibrium is that the **forces** along each coordinate axis add to **zero**.

9-1 The Conditions for Equilibrium

The **second** condition of equilibrium is that there be no **torque** around any axis; the choice of axis is **arbitrary**.



9-2 Solving Statics Problems

1. Choose one **object** at a time, and make a **free-body diagram** showing all the forces on it and where they act.

2. Choose a **coordinate** system and resolve forces into **components**.

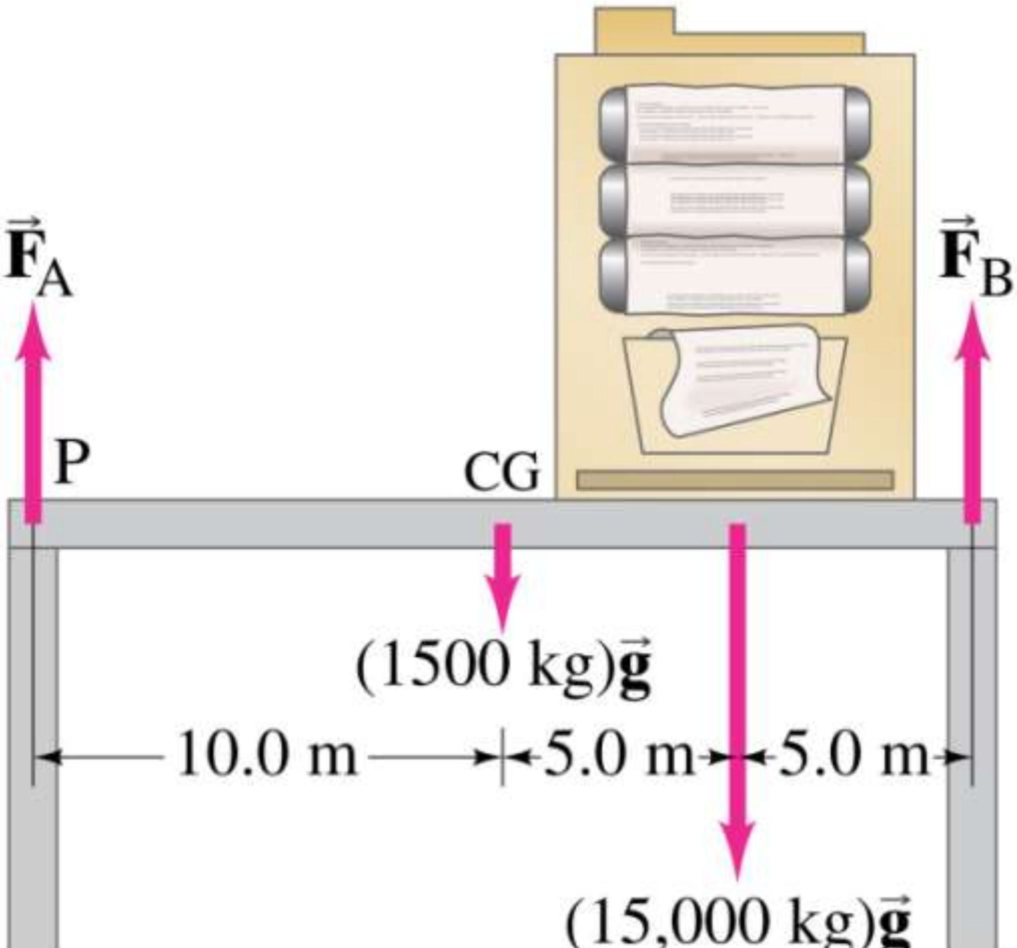
3. Write **equilibrium** equations for the forces.

4. Choose any axis perpendicular to the plane of the forces and write the **torque** equilibrium equation. A clever choice here can simplify the problem enormously.

5. **Solve**.

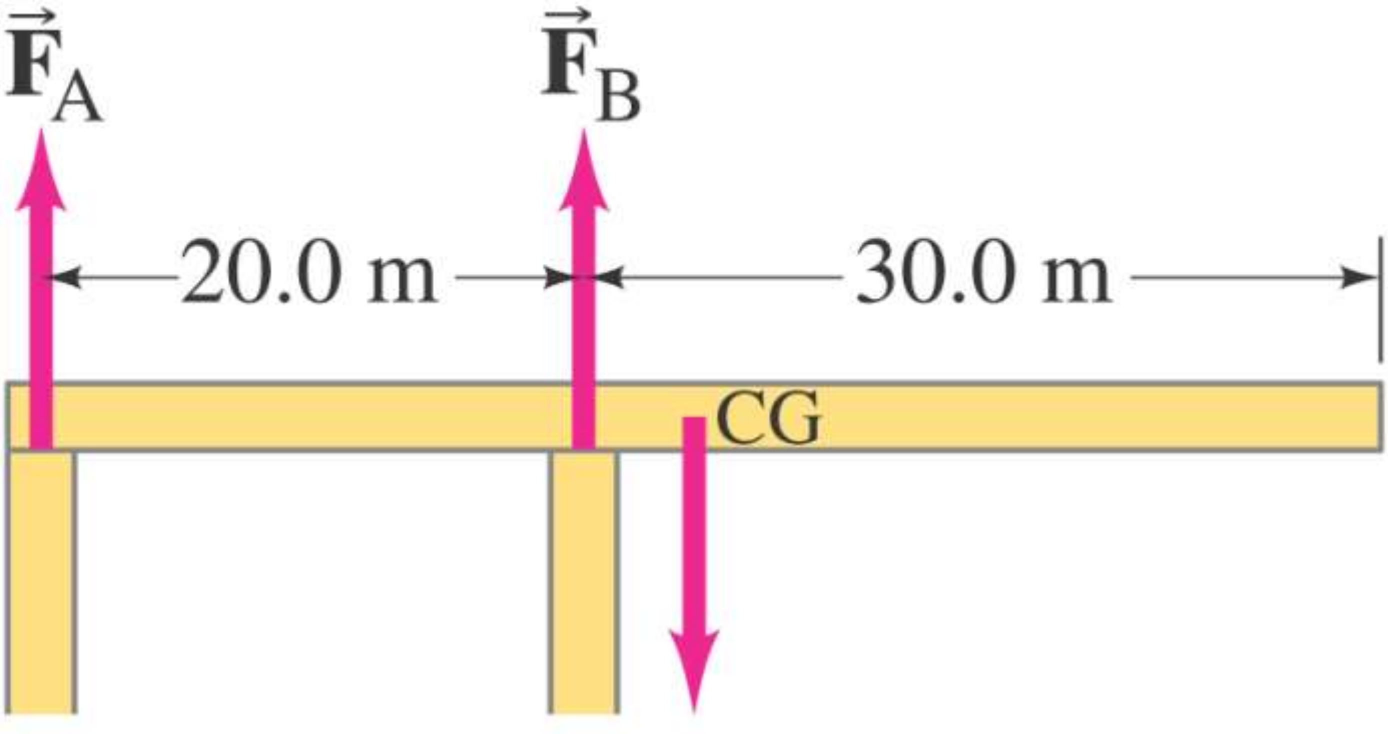
9-2 Solving Statics Problems

The previous technique may not fully solve all statics problems, but it is a good starting point.



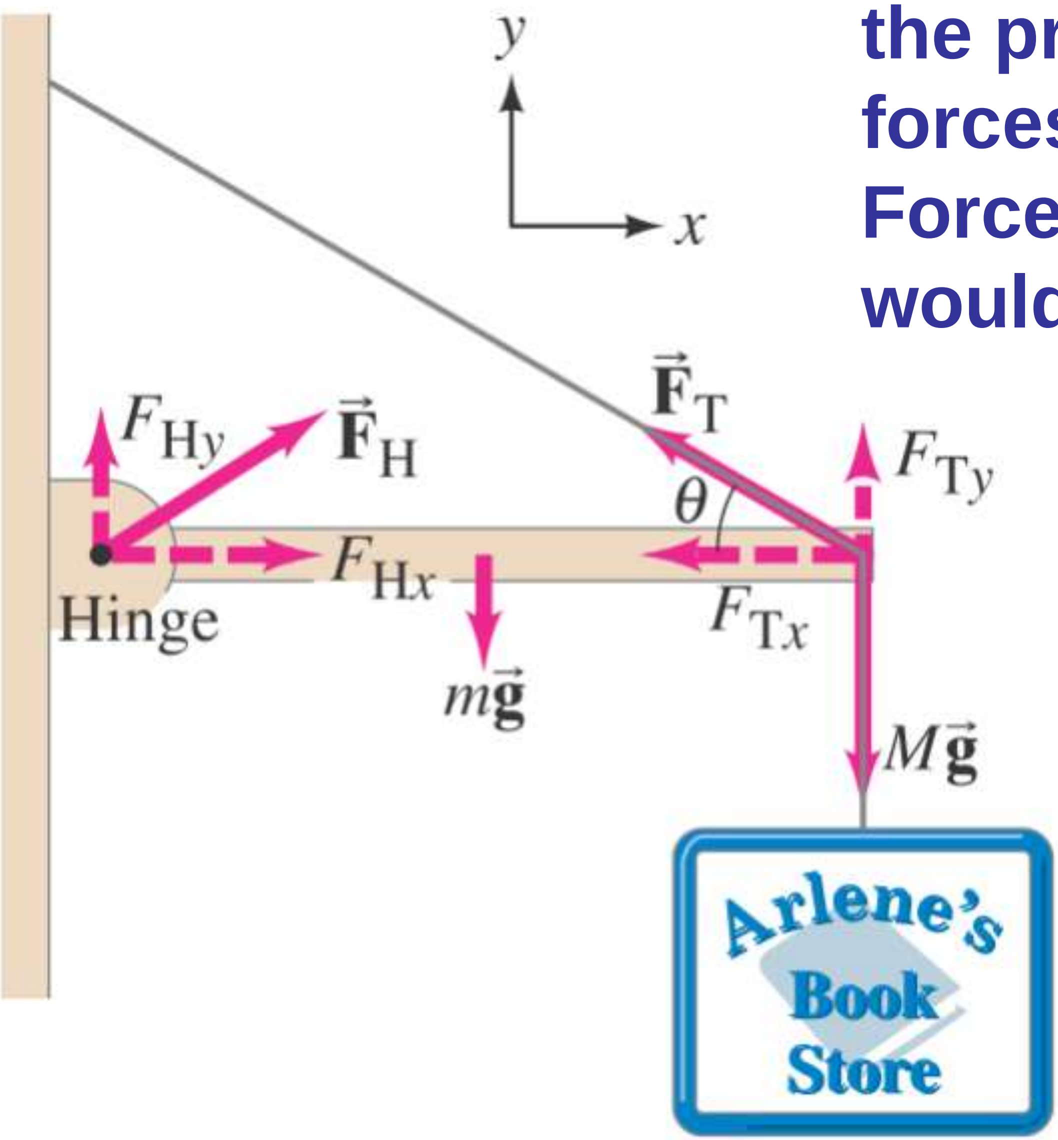
9-2 Solving Statics Problems

If a force in your solution comes out negative (as F_A will here), it just means that it's in the opposite direction from the one you chose. This is trivial to fix, so don't worry about getting all the signs of the forces right before you start solving.



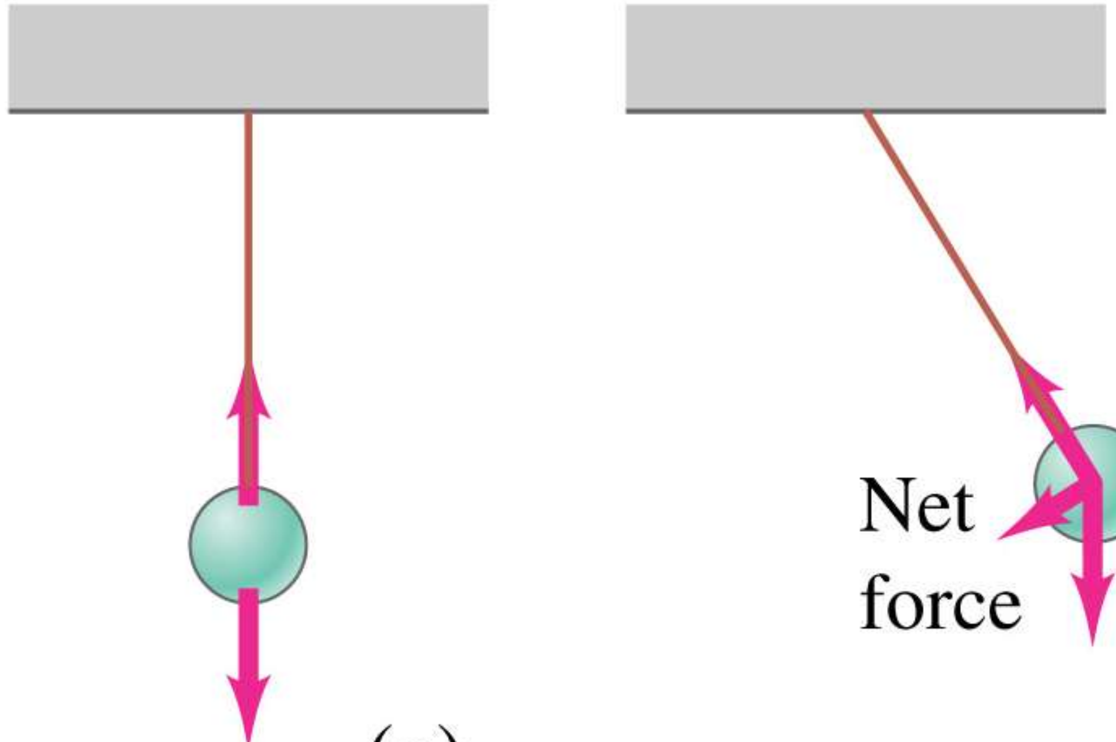
9-2 Solving Statics Problems

If there is a **cable** or **cord** in the problem, it can support forces only **along** its length. Forces perpendicular to that would cause it to bend.



9-4 Stability and Balance

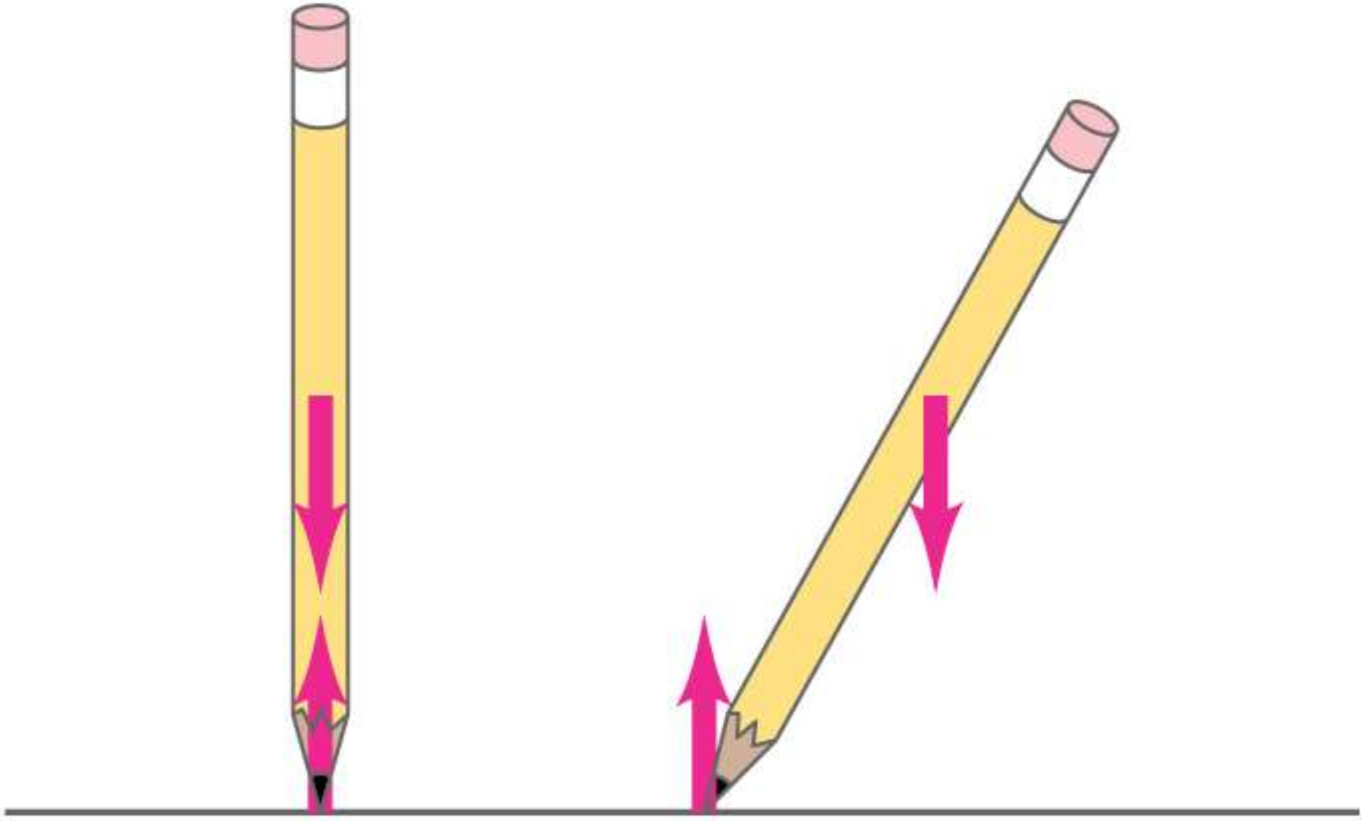
If the forces on an object are such that they tend to return it to its equilibrium position, it is said to be in stable equilibrium.



(a)

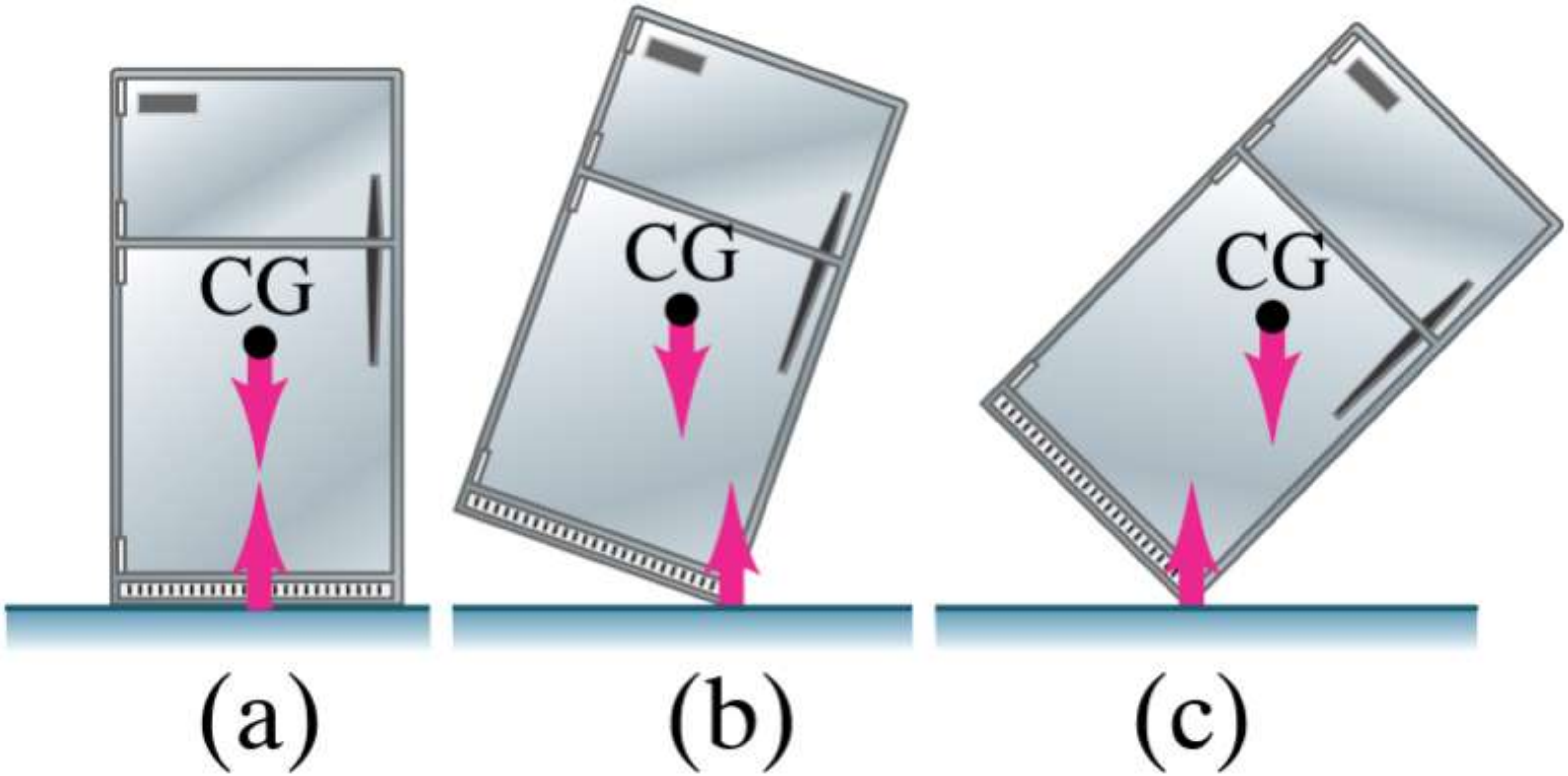
9-4 Stability and Balance

If, however, the forces tend to move it **away** from its equilibrium point, it is said to be in **unstable** equilibrium.



9-4 Stability and Balance

An object in **stable** equilibrium may become **unstable** if it is **tipped** so that its center of gravity is **outside** the pivot point. Of course, it will be stable again once it lands!



9-4 Stability and Balance

People carrying heavy loads automatically **adjust** their posture so their **center of mass** is over their **feet**. This can lead to injury if the contortion is too great.