

- 4. Torque equation.** Let us calculate the torque about an axis through the board at the pivot point, P. Then the lever arms for F_N and for the weight of the board are zero, and they will contribute zero torque (about point P) in our torque equation. Thus the torque equation will involve only the forces \vec{F}_A and \vec{F}_B , which are equal to the weights of the children. The torque exerted by each child will be mg times the appropriate lever arm, which here is the distance of each child from the pivot point. Hence the torque equation is

$$\Sigma\tau = 0$$

$$m_A g(2.5 \text{ m}) - m_B g x + Mg(0 \text{ m}) + F_N(0 \text{ m}) = 0$$

or

$$m_A g(2.5 \text{ m}) - m_B g x = 0,$$

where two terms were dropped because their lever arms were zero.

- 5. Solve.** We solve the torque equation for x and find

$$x = \frac{m_A}{m_B} (2.5 \text{ m}) = \frac{30 \text{ kg}}{25 \text{ kg}} (2.5 \text{ m}) = 3.0 \text{ m}.$$

To balance the seesaw, child B must sit so that her CM is 3.0 m from the pivot point. This makes sense: since she is lighter, she must sit farther from the pivot than the heavier child.

EXERCISE C We did not need to use the force equation to solve Example 9-4 because of our choice of the axis. Use the force equation to find the force exerted by the pivot.

EXAMPLE 9-5 Forces on a beam and supports. A uniform 1500-kg beam, 20.0 m long, supports a 15,000-kg printing press 5.0 m from the right support column (Fig. 9-8). Calculate the force on each of the vertical support columns.

APPROACH We analyze the forces on the beam (the force the beam exerts on each column is equal and opposite to the force exerted by the column on the beam). We label these forces \vec{F}_A and \vec{F}_B in Fig. 9-8. The weight of the beam itself acts at its center of gravity, 10.0 m from either end. We choose a convenient axis for writing the torque equation: the point of application of \vec{F}_A (labeled P), so \vec{F}_A will not enter the equation (its lever arm will be zero) and we will have an equation in only one unknown, F_B .

SOLUTION The torque equation, $\Sigma\tau = 0$, with the counterclockwise direction as positive gives

$$\Sigma\tau = -(10.0 \text{ m})(1500 \text{ kg})g - (15.0 \text{ m})(15,000 \text{ kg})g + (20.0 \text{ m})F_B = 0.$$

Solving for F_B , we find $F_B = (12,000 \text{ kg})g = 118,000 \text{ N}$. To find F_A , we use $\Sigma F_y = 0$, with $+y$ upward:

$$\Sigma F_y = F_A - (1500 \text{ kg})g - (15,000 \text{ kg})g + F_B = 0.$$

Putting in $F_B = (12,000 \text{ kg})g$, we find that $F_A = (4500 \text{ kg})g = 44,100 \text{ N}$.

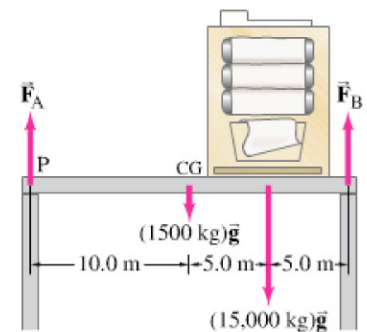


FIGURE 9-8 A 1500-kg beam supports a 15,000-kg machine. Example 9-5.

Figure 9-9 shows a uniform beam that extends beyond its support like a diving board. Such a beam is called a **cantilever**. The forces acting on the beam in Fig. 9-9 are those due to the supports, \vec{F}_A and \vec{F}_B , and the force of gravity which acts at the CG, 5.0 m to the right of the right-hand support. If you follow the procedure of the last Example and calculate F_A and F_B , assuming they point upward as shown in Fig. 9-9, you will find that F_A comes out negative. If the beam has a mass of 1200 kg and a weight $mg = 12,000 \text{ N}$, then $F_B = 15,000 \text{ N}$ and $F_A = -3000 \text{ N}$ (see Problem 10). Whenever an unknown force comes out negative, it merely means that the force actually points in the opposite direction from what you assumed. Thus in Fig. 9-9, \vec{F}_A actually points downward. With a little reflection it should become clear that the left-hand support must indeed pull downward on the beam (by means of bolts, screws, fasteners and/or glue) if the beam is to be in equilibrium; otherwise the sum of the torques about the CG (or about the point where \vec{F}_B acts) could not be zero.

PHYSICS APPLIED Cantilever

PROBLEM SOLVING If a force comes out negative

FIGURE 9-9 A cantilever.

