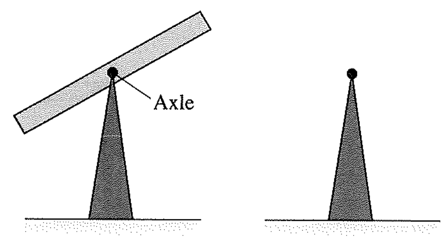
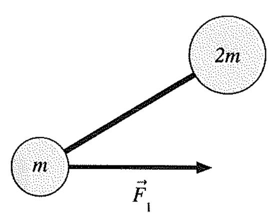
# 8 Equilibrium and Elasticity

## 8.1 Torque and Static Equilibrium

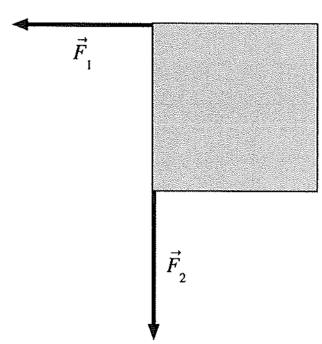
1. A uniform rod pivots about a frictionless, horizontal axle through its center. It is placed on a stand, held motionless in the position shown, and then gently released. On the right side of the figure, draw the final, equilibrium position of the rod. Explain your reasoning.




2. A dumbbell consists of masses $m$ and $2m$ connected by a massless, rigid rod. Force $\vec{F}_1$ acts on mass $m$ as shown. Draw and label the vector of a force $\vec{F}_2$ acting on mass $2m$ that will cause the dumbbell to have pure translational motion without any rotation. Make sure the length of your vector shows the magnitude of $\vec{F}_2$ relative to $\vec{F}_1$.



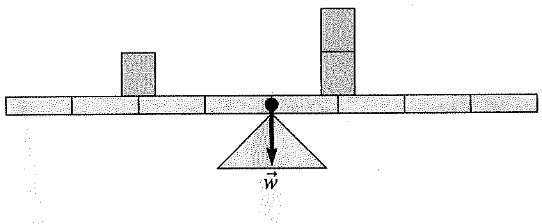

3. Forces $\vec{F}_1$ and $\vec{F}_2$ have the same magnitude. They are applied to the corners of a square plate as shown. Draw and label a *single* force vector $\vec{F}_3$ applied to the appropriate point on the plate that will cause the plate to be in total static equilibrium. Make sure the length of your vector shows the magnitude of $\vec{F}_3$ relative to $\vec{F}_1$ and $\vec{F}_2$.



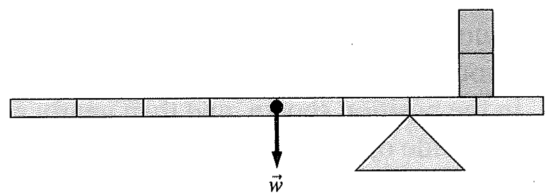
**Exercises 4–7:** Each of the following shows a uniform beam of weight $w$ and several blocks, each of which also has weight $w$. The gravitational force acting downward on the center of gravity of the beam is already shown. For each:

- Draw and label force vectors at each point where a force acts on the beam. You should have both upward and downward vectors. The length of each vector should indicate its magnitude relative to the vector showing the weight of the beam.
- Explain why the beam is or is not in equilibrium.

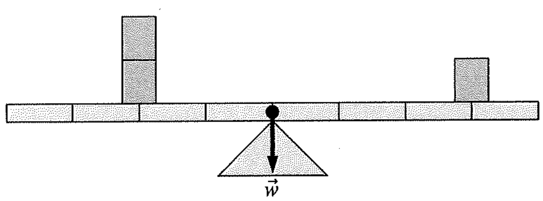
4.



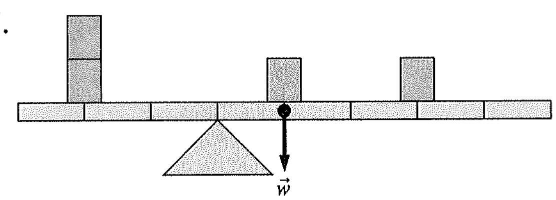

5.




6.



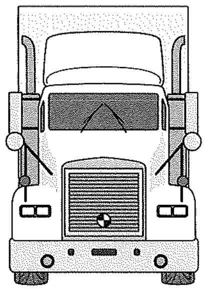

7.



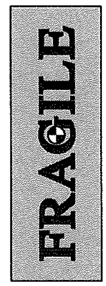
## 8.2 Stability and Balance

8. The center of gravity is marked on each of the objects below.
   - Show and label with a $t$ the object's track width or base of support.
   - Show and label with an $h$ the height of the object's center of gravity.
   - Use a ruler to measure the track width and the height of the center of gravity, and then calculate the critical angle.

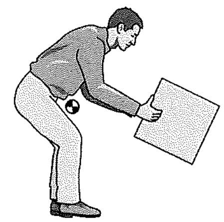
a.



b.

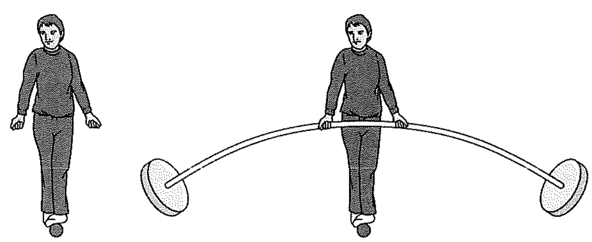



c.



| a. | b. | c. |
|---|---|---|
| $t =$ | $t =$ | $t =$ |
| $h =$ | $h =$ | $h =$ |
| $\theta_c =$ | $\theta_c =$ | $\theta_c =$ |

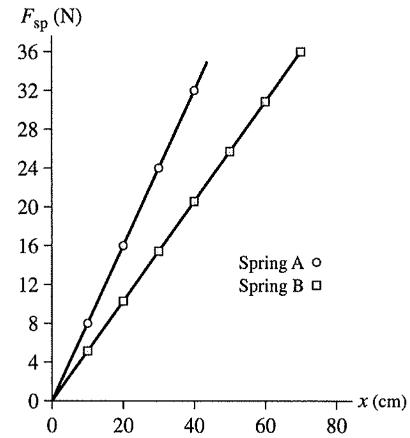
9. Tightrope walkers often carry a long pole that is weighted at the end. The pole serves two purposes: to change the critical angle for balance, and to increase the walker's moment of inertia.
   a. Use the diagrams below to describe how the critical angle is changed by the tightrope walker's use of the pole.



   b. Why would increasing the tightrope walker's moment of inertia also help to make him less likely to fall?

## 8.3 Springs and Hooke's Law

10. The graph below shows the stretching of two different springs, A and B, when different forces were applied.

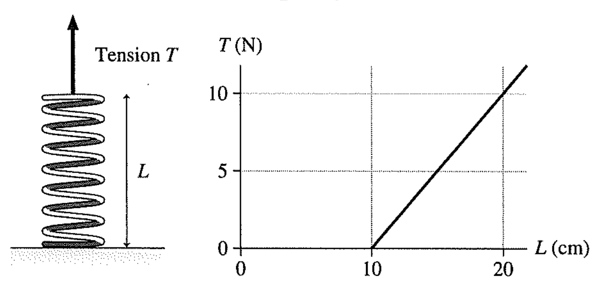



a. Which spring is stiffer? That is, which spring requires a larger pull to get the same amount of stretch? Explain how you can tell by looking at the graph.

b. Determine the spring constant for each spring.

$k_A$ = ______ $k_B$ = ______

11. A spring is attached to the floor and pulled straight up by a string. The spring's tension is measured. The graph shows the tension in the spring as a function of the spring's length *L*.




a. Does this spring obey Hooke's Law? Explain why or why not.

b. If it does, what is the spring constant?

12. A spring has an unstretched length of 10 cm. It exerts a restoring force $F$ when stretched to a length of 11 cm.

    a. For what length of the spring is its restoring force $3F$? ______________

    b. At what compressed length is the restoring force $2F$? ______________

13. The left end of a spring is attached to a wall. When Bob pulls on the right end with a 200 N force, he stretches the spring by 20 cm. The same spring is then used for a tug-of-war between Bob and Carlos. Each pulls on his end of the spring with a 200 N force.

    a. How far does Bob's end of the spring move? Explain.

    b. How far does Carlos's end of the spring move? Explain.

14. A weight hung from a spring stretches the spring by 4.0 cm. If the same weight is hung from a second spring having half the spring constant as the first, by how much will the second spring stretch? Explain.

## 8.4 Stretching and Compressing Materials

15. A force stretches a wire by 1 mm.
    a. A second wire of the same material has the same cross section and twice the length. How far will it be stretched by the same force? Explain.

    b. A third wire of the same material has the same length and twice the diameter as the first. How far will it be stretched by the same force? Explain.

16. A 2000 N force stretches a wire by 1 mm.
    a. A second wire of the same material is twice as long and has twice the diameter. How much force is needed to stretch it by 1 mm? Explain.

    b. A third wire is twice as long as the first and has the same diameter. How far is it stretched by a 4000 N force?

17. A wire is stretched right to the breaking point by a 5000 N force. A longer wire made of the same material has the same diameter. Is the force that will stretch it right to the breaking point larger than, smaller than, or equal to 5000 N? Explain.

## You Write the Problem!

**Exercises 18–19:** You are given the equation that is used to solve a problem. For each of these:

a. Write a *realistic* physics problem for which this is the correct equation. Look at worked examples and end-of-chapter problems in the textbook to see what realistic physics problems are like. Be sure that the problem you write, and the answer you ask for, is consistent with the information given in the equation.
b. Draw a free-body diagram or force diagram for your problem.
c. Finish the solution of the problem.

18. $n + T - 80\text{ N} = 0$
$(0.60\text{ m})\,T - (0.50\text{ m})(80\text{ N}) = 0$

19. $k(0.050\text{ m}) - (0.15)(0.12\text{ kg})(9.8\text{ m/s}^2) = (0.12\text{ kg})(0.65\text{ m/s}^2)$