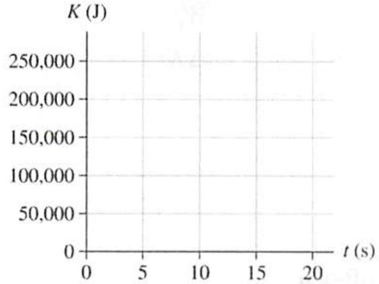
9 Work and Kinetic Energy

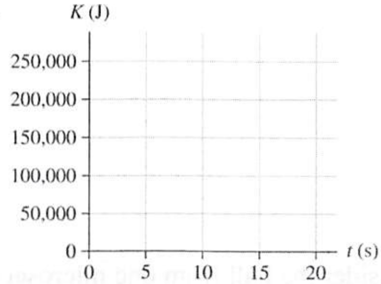
9.1 Energy Overview

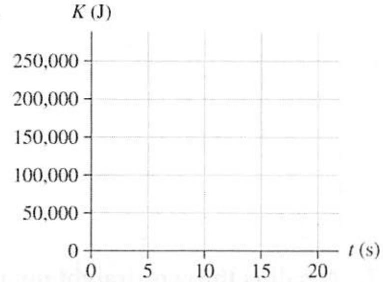
1. Can the following be reasonably modeled with the basic energy model? Answer Yes or No.
   a. A box slides up and down a very smooth ramp. ______
   b. A baseball player slides into second base. ______
   c. A burner heats water to the boiling point. ______
   d. A burner heats a gas. The molecules move faster. ______

9.2 Work and Kinetic Energy for a Single Particle

2. On the axes below, draw graphs of the kinetic energy of
   a. A 1000 kg car that uniformly accelerates from 0 to 20 m/s in 20 s.
   b. A 1000 kg car moving at 20 m/s that brakes to a halt with uniform deceleration in 20 s.
   c. A 1000 kg car that drives once around a 130-m-diameter circle at a speed of 20 m/s.
   Calculate K at several times, plot the points, and draw a smooth curve between them.

a.


b.


c.


Exercises 3–10: For each situation:
- Draw a before-and-after pictorial representation.
- Draw and label the displacement vector $\Delta\vec{r}$.
- Draw a free-body diagram.
- Fill in the table by showing the sign (+, −, or 0) of the quantities listed.

3. An elevator moves up at constant speed.

W_{ten} ______
W_{grav} ______
W_{tot} ______
ΔK ______

4. A descending elevator brakes to a halt.

W_{tens} ______
W_{grav} ______
W_{tot} ______
ΔK ______

5. A box slides up a frictionless slope.

W_{norm} ______
W_{grav} ______
W_{tot} ______
ΔK ______

6. A rope pulls a box to the left across a frictionless floor.

W_{tens} ______
W_{norm} ______
W_{grav} ______
W_{tot} ______
ΔK ______

7. A ball is thrown straight up. Consider the ball from one microsecond after it leaves your hand until the highest point of its trajectory.

W_{hand} ______
W_{grav} ______
W_{tot} ______
ΔK ______

8. A car turns a corner at constant speed.

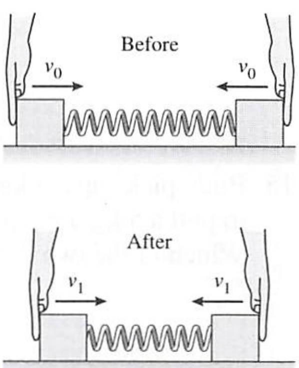
W_{fric} ______
W_{norm} ______
W_{grav} ______
W_{tot} ______
ΔK ______

9. A flat block on a string swings once around a horizontal circle on a frictionless table. The block moves at steady speed.

W_{tens} ______
W_{norm} ______
W_{grav} ______
W_{tot} ______
ΔK ______

10. A 0.2 kg plastic cart and a 20 kg lead cart both roll without friction on a horizontal surface. Equal forces are used to push both carts forward a distance of 1 m, starting from rest. After traveling 1 m, is the kinetic energy of the plastic cart greater than, less than, or equal to the kinetic energy of the lead cart? Explain.

11. Equal forces push together two equal-mass boxes on a frictionless surface. Both boxes have the same initial speed, and later both have the same slower speed. Let the system be the boxes and the spring.



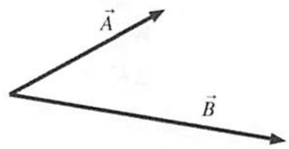
a. Is the work done on the system positive, negative, or zero? Explain.

b. Is ΔE_{sys} positive, negative, or zero? Explain.

9.3 Calculating the Work Done

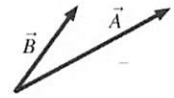
12. For each pair of vectors, is the sign of $\vec{A} \cdot \vec{B}$ positive (+), negative (−), or zero (0)?

a.



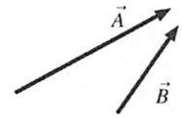
Sign = __________

b.



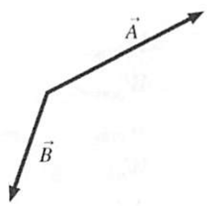
Sign = __________

c.



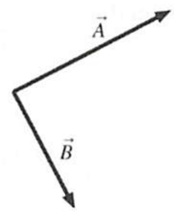
Sign = __________

d.



Sign = __________

e.



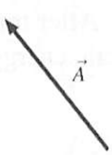
Sign = __________

f.

Sign = __________

13. Each of the diagrams below shows a vector $\vec{A}$. Draw and label a vector $\vec{B}$ that will cause $\vec{A} \cdot \vec{B}$ to have the sign indicated.

a.



$\vec{A} \cdot \vec{B} > 0$

b.

$\vec{A} \cdot \vec{B} < 0$

c.

$\vec{A} \cdot \vec{B} = 0$

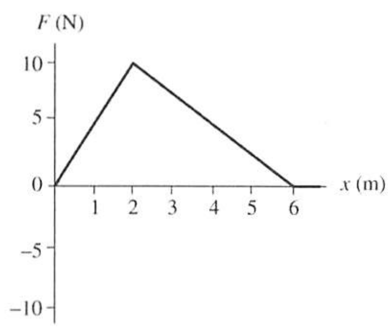
14. If $\vec{A} \cdot \vec{B} = 0$, can you conclude that one of the vectors has zero magnitude. Explain?

15. Rudy picks up a 5 kg box and lifts it straight up, at constant speed, a height of 1 m. Beth uses a rope to pull a 5 kg box up a 15° frictionless slope, at constant speed, until it has reached a height of 1 m. Which of the two does more work? Or do they do equal amounts of work? Explain.

16. A sprinter running the 100-meter dash accelerates down the track. Is the work by the track on the sprinter positive, negative, or zero? Explain.

17. A particle moving along the x-axis experiences the forces shown below. How much work does each force do on the particle? What is each particle's change in kinetic energy?

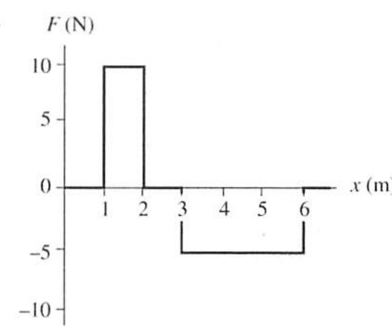
a.



$W =$

$\Delta K =$

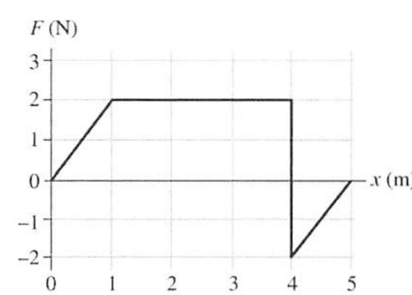
b.



$W =$

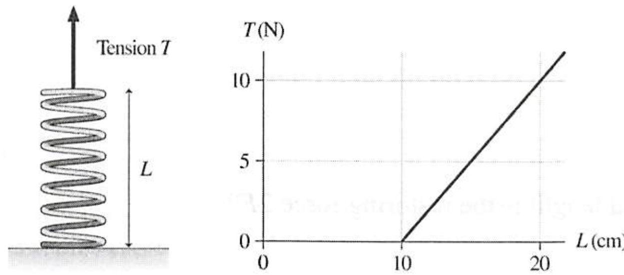
$\Delta K =$

18. A 1 kg particle moving along the x-axis experiences the force shown in the graph. If the particle's speed is 2 m/s at $x = 0$ m, what is its speed when it gets to $x = 5$ m?



9.4 Restoring Forces and the Work Done by a Spring

19. A spring is attached to the floor and pulled straight up by a string. The string's tension is measured. The graph shows the tension in the string 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?

20. Draw a figure analogous to Figure 9.17 in the textbook for a spring that is attached to a wall on the *right* end. Use the figure to show that F and Δs always have opposite signs.

21. 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 $2F$?

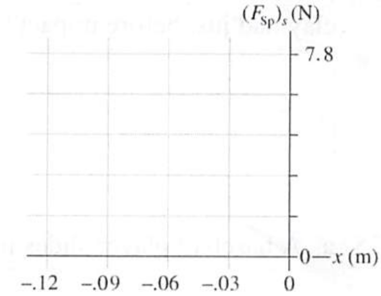
22. The left end of a spring is attached to a wall. When Bob pulls on the right end with a 200 N force, he stretches the spring by 20 cm. The same spring is then used for a tug-of-war between Bob and Carlos. Each pulls on his end of the spring with a 200 N force.

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

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

23. In Example 9.9 in the textbook, a compressed spring with a spring constant of 65 N/m expands from $x_0 = -12$ cm $= -0.12$ m to its equilibrium position at $x_1 = 0$ m.

a. Graph the spring force $(F_{Sp})_s$ from $x_1 = -0.12$ m to $x_1 = 0$ m.



b. Use your graph to determine ΔK, the change in a cube's kinetic energy when launched by a spring that has been compressed by 12 cm.

c. Use your result from part b to find the launch speed of a 100 g cube in the absence of friction. Compare your answer to the value found in the Example 9.9.

9.5 Dissipative Forces and Thermal Energy

24. A ball of clay traveling at 10 m/s slams into a wall and sticks. What happens to the kinetic energy the clay had just before impact?

25. a. A baseball player slides into second base. What happens to the runner's kinetic energy?

b. How should you define the system to analyze this situation with the energy principle?

9.6 Power

26. a. If you push an object 10 m with a 10 N force in the direction of motion, how much work do you do on it?

b. How much power must you provide to push the object in 1 s? In 10 s? In 0.1 s?

27. You push with a force of 400 N and use 200 W of power to push a box across a rough floor at steady speed.

a. How much force is needed to push the box twice as fast? Explain.

b. How much power would you need to push the box twice as fast?