ond) system of units is still very much in use in the United y is declining as we aim toward a conversion to metric units. ›t, pound, and second, the fps system uses slugs, foot-pounds, d in Appendix A.1.

auditory sensation in the ear or the disturbance in a medium ›und is carried by waves in a solid, liquid, or gas. Unwanted) as noise.
:an be described by expressing its distance, speed, and accel- A graphical representation of the motion consists of a plot ration as a function of time. Two other basic quantities, force eleration through Newton's second law of motion: $F = ma$. area, and is especially important in describing the behavior of or gas.
n of an object expresses its kinetic energy (energy of motion) energy) as functions of time. Power is the rate at which energy hich work is done. The preferred system of units is the mks ers, kilograms, and seconds as its basic units, but also includes s, joules, watts, and so forth.

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ork:

newton A unit of force.
ng a **potential energy** Stored energy; the capacity to do work by virtue of position.
it to **power** The rate of doing work; equal to work or energy divided by time.
›n or **pressure** Force divided by area.
speed The rate at which distance is covered; equal to dis-
› one tance divided by time.
stroboscope A light that flashes at a regular rate, making
rk by possible a photographic record of motion.
:y (or **watt** A unit of power; equal to one joule per second.
work The net force on an object times the distance through
ıal to which the object moves.
Δ The Greek letter *delta*, denoting change in some quantity.

REVIEW QUESTIONS

1. What are two different meanings of the word *sound*?
2. What is the science of sound generally called?
3. What is the difference between a longitudinal and a transverse wave? Give an example of each.
4. What are four different processes that can produce sound? Give an example of each.
5. What is the difference between *speed* and *velocity*?
6. The slope of a graph of position versus time is equal to what quantity?
7. What three quantities are related by Newton's second law of motion?
8. Describe the motion of an object when no net force is applied.
9. Arrange the following in order from largest to smallest: 0.004 m, 0.4 mm, 4×10^{-5} km, 4×10^{-5} μm.
10. What is the difference between *pressure* and *force*?
11. Compare the pressure on the top and the bottom sides of a thin plate immersed in water.
12. What is the pressure of the atmosphere on our bodies?
13. What is a waveform of a sound?
14. What unit is used to express energy? work?
15. What is *kinetic energy*? *potential energy*?
16. Give a formula for the potential energy of a displaced guitar string and explain each symbol.
17. What is the difference between *power* and *energy*?
18. When you pay your electricity bill, are you paying for power used or for energy used?

QUESTIONS FOR THOUGHT AND DISCUSSION

1. At the same time a rifle is fired in an exactly horizontal position over level ground, a bullet is dropped from the same height. Both bullets strike the ground at the same time. Can you explain why?
2. What are some advantages of using the metric (SI) system of units rather than the English system?
3. In the sixteenth century, Galileo is said to have dropped objects of various weights from the Leaning Tower of Pisa. Since all objects in *free fall* accelerate at 9.8 m/s^2, one would expect them to reach the ground at the same time. Careful observation, however, indicates that an iron ball will strike the ground sooner than a baseball of the same diameter. Can you explain why? Would the same be true on the moon? (The Apollo astronauts actually photographed a free-fall experiment on the moon using a hammer and a feather.)
4. Think of an object comparable in size to each of the following: **(a)** 10^7 m; **(b)** 10^3 m; **(c)** 1 m; **(d)** 10^{-3} m; **(e)** 10^{10} m.
5. Does shifting to a lower gear increase the power of an automobile? Explain.
6. Draw a diagram, similar to Fig. 1.10, showing how pressure acts on a floating object.

EXERCISES

1. Letting your classroom serve as the "origin" ($x = 0$, $y = 0$), express the approximate coordinates (x, y) of your place of residence. Let x = the distance east and y = the distance north, as on a map. Use any convenient unit of distance.
2. The speed of a bicycle increases from 5 mi/h to 10 mi/h in the same time that a car increases its speed from 50 mi/h to 55 mi/h. Compare their accelerations.
3. The density of water is 1.00 g/cm^3 and that of ice is 0.92 g/cm^3. What are the corresponding densities in SI units (kg/m^3)?
4. If the speed limit is posted as 55 mi/h, express this in km/h and in m/s (1 mi = 1.61 km).
5. A car accelerates from rest to 50 mi/h in 12 s. Calculate its average acceleration in m/s^2. Compare this to the acceleration of an object in free fall (1 mi/h = 0.447 m/s).
6. An object weighing 1 lb (English units) has a mass of 0.455 kg. Express its weight in newtons and thereby express a conversion factor for pounds to newtons.
7. Express your own mass in kilograms and your weight in newtons.
8. Calculate average speed in each of the following cases:

(a) An object moves a distance of 25 m in 3 s.

(b) A train travels 2 km, the first at an average speed of 50 km/h and the second at an average speed of 100 km/h. (*Note:* The average speed is not 75 km/h.)

(c) A runner runs 1 km in 3 min and a second kilometer in 4 min.

(d) An object dropped from a height of 75 m strikes the ground in 4 s.

9. Estimate the total force on the surface of your body due to the pressure of the atmosphere.

10. Calculate the kinetic energy of a 1500-kg automobile with a speed of 30 m/s. If it accelerates to this speed in 20 s, what average power has been developed?

11. An electric motor, rated at $\frac{1}{2}$ horsepower, requires 450 W of electrical power. Calculate its efficiency (power out divided by power in). What happens to the rest of the power?

12. Calculate the potential energy of:

(a) A 3-kg block of iron held 2 m above the ground;

(b) A spring with a spring constant $K = 10^3$ N/m stretched 10 cm from its equilibrium length;

(c) A 1-L bottle ($V = 1000\ \text{cm}^3$) with a pressure 10^4 N/m^2 above atmospheric pressure ($P = 10^5$ N/m^2).

EXPERIMENTS FOR HOME, LABORATORY, AND CLASSROOM DEMONSTRATION

Home and Classroom Demonstration

1. *Longitudinal waves on a coiled spring (Slinky)* For best results, suspend a Slinky from a long horizontal stick or rod by attaching several strings (about a meter in length). However, a giant Slinky will work satisfactorily on a smooth polished floor in spite of a small amount of friction. Jerk one end of the Slinky in the direction to increase its length and observe the pulse wave that propagates. Produce a small pulse and a large pulse in rapid succession. Does the distance between the two pulses change as they travel down the spring? What does this indicate about the relationship between amplitude (pulse size) and wave speed? Generate a series of waves by smoothly increasing and decreasing its length.

Repeat the experiment with transverse rather than longitudinal pulses and waves.

2. *Siren disk* Blow air through a siren disk. If none is available, you can construct one by drilling regularly spaced holes in a wooden disk attached to a rotator. Note that the pitch of the tone depends upon the speed of rotation of the disk, whereas the loudness is determined by the rate of airflow.

3. *Moving object stroboscopically observed* In a partially or totally dark room, observe a white ball in stroboscopic light. (If none is available, a hand stroboscope can be constructed by cutting slots around the circumference of a disc mounted on a dowel rod with a finger hole for rotating it). Roll the ball on a table or other horizontal surface and compare what you see to Fig. 1.3(a). Roll the ball down an incline and compare what you see to Fig. 1.3(b).

Observe a mass oscillating on the end of a spring, and see if you can make it appear to stand still by adjusting the rate of

4. *Moving-object video capture* Make a video recording of a moving object. Use a VCR with a single-frame player or a "frame grabber" to transfer single frames to a computer. Measure the distance the object has moved between successive frames.

5. *Falling object stroboscopically observed* Observe a falling object in stroboscopic light (or with video capture) and compare what you see to Fig. 1.8(a). Toss a ball upward at an angle and compare what you see to Fig. 1.8(b).

6. *U-tube manometer* Attach a length of rubber tubing to a U-shaped glass tube filled with colored water placed in front of a meter stick. The difference in heights of the water in the two sides of the U-tube represents the pressure in cm of water (a unit commonly used by organ builders). To convert cm of water to newtons/meter^2 or pascals (Pa), multiply by 100. Calibrate your lungs by blowing and sucking to obtain 100 cm of water (10^4 Pa) above and below atmospheric pressure. Which is easier to do?

7. *Deciding if pressure in a container depends upon the amount of water in the container* Place the end of the tubing attached to a manometer at various depths in a cylinder of water and show that the pressure (in cm of water) is equal to the depth of the tube below the surface. Repeat with containers of varying size and shape to show that the pressure depends only of the depth below the surface, regardless of the shape of the container or how much water it holds.

8. *Force on a container wall* Blowing a collapsed varnish can back to shape demonstrates the relationship of force to ... Measure the area of the large side of the can and

cated on the manometer) to obtain the net force on the collapsed side of the can.

9. *Lifting a concrete block by blowing into a beach ball* A concrete block can be lifted by blowing air into a beach ball. A manometer indicates the pressure in the ball during and after inflation. (How much blowing pressure would be required to inflate an air mattress if someone is already lying on in?)

10. *Air pressure on a newspaper* Cover most of a thin board on a table with a sheet of newspaper. Strike the end of the board with the fist and note that the inertia of the air mass inhibits movement of the newspaper.

11. *Sound waveforms* Connect a microphone to a cathode-ray oscilloscope or a PC with a sound-input card and display

Laboratory Experiments

Accelerated Motion (Experiment 1 in *Acoustics Laboratory Experiments*)

Graph Matching (Experiment 1 in *Physics with Computers*)

Picket Fence Free Fall (Experiment 5 in *Physics with Computers*)