12. A certain simple earthquake detector consists of a little box firmly anchored to the Earth. Suspended inside the box is a massive magnet that is surrounded by stationary coils of wire fastened to the box. Explain how this device works, applying two important principles of physics—one studied in Chapter 2, and the other in this chapter.

13. How do the direction of the magnetic force and its effects differ between the motor effect and the generator effect, as shown in Figure 25.7?

14. When you turn the shaft of an electric motor by hand, what occurs in the interior coils of wire?

15. Your friend says that, if you crank the shaft of a dc motor manually, the motor becomes a dc generator. Do you agree or disagree?

16. Does the voltage output increase when a generator is made to spin faster? Defend your answer.

17. An electric saw running at normal speed draws a relatively small current. But, if a piece of wood being sawed jams and the motor shaft is prevented from turning, the current dramatically increases and the motor overheats. Why?

18. If you place a metal ring in a region in which a magnetic field is rapidly alternating, the ring may become hot to your touch. Why?

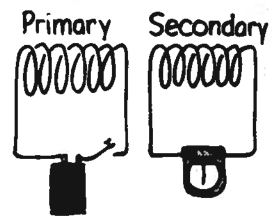
19. A magician places an aluminum ring on a table. Underneath is a hidden electromagnet. When the magician says "abracadabra" (and pushes a switch that starts current flowing through the coil under the table), the ring jumps into the air. Explain his "trick."

20. In the chapter-opening photograph, Jean Curtis asks her class why the copper ring levitates about the iron core of the electromagnet. What is the explanation, and does it involve ac or dc?

21. How could a lightbulb near, but not touching, an electromagnet be lit? Is ac or dc required? Defend your answer.

22. A length of wire is bent into a closed loop and a magnet is plunged into it, inducing a voltage and, consequently, a current in the wire. A second length of wire, twice as long, is bent into two loops of wire, and a magnet is similarly plunged into it. Twice the voltage is induced, but the current is the same as that produced in the single loop. Why?

23. Two separate but similar coils of wire are mounted close to each other, as shown below. The first coil is connected to a battery and has a direct current flowing through it. The second coil is connected to a galvanometer. 1. How does the galvanometer respond when the switch in the first circuit is closed? 2. After being closed how does the meter respond when the current is steady? 3. When the switch is opened?



24. Why will more voltage be induced with the apparatus shown above if an iron core is inserted in the coils?

25. Why will a transformer not work if you are using dc?

26. How does the current in the secondary of a transformer compare with the current in the primary when the secondary voltage is twice the primary voltage?

27. In what sense can a transformer be considered to be an electrical lever? What does it multiply? What does it *not* multiply?

28. What is the principal difference between a step-up transformer and a step-down transformer?

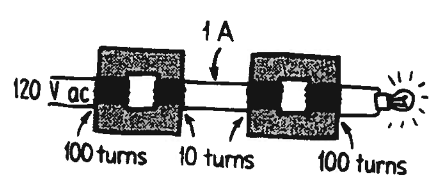
29. Why can a hum usually be heard when a transformer is operating?

30. Why doesn't a transformer work with direct current? Why is ac required?

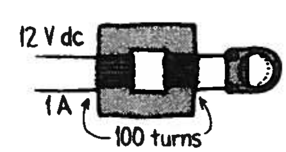
31. Why is it important that the core of a transformer pass through both coils?

32. Are the primary and secondary coils in a transformer physically linked, or is there space between the two? Explain.

33. In the circuit shown, how many volts are impressed across the lightbulb and how many amps flow through it?



34. In the circuit shown, how many volts are impressed across the meter and how many amps flow through it?



35. How would you answer the previous question if the input were 12 V ac?

36. Can an efficient transformer step up energy? Defend your answer.

37. Your friend says that, according to Ohm's law, high voltage produces high current. Then your friend asks, "So how can power be transmitted at high voltage and *low* current in a power line?" What is your illuminating response?

38. If a bar magnet is thrown into a coil of high-resistance wire, it will slow down. Why?

39. Your physics instructor drops a magnet through a long vertical copper pipe and it moves slowly compared with the drop of a nonmagnetized object. Provide an explanation.

40. This exercise is similar to the previous one. Why will a bar magnet fall slower and reach terminal velocity in a vertical copper or aluminum tube but not in a cardboard tube?

41. Although copper and aluminum are not magnetic, why is a sheet of either metal more difficult to pass between the pole pieces of a magnet than a sheet of cardboard?

42. A metal bar, pivoted at one end, oscillates freely in the absence of a magnetic field. But, when it oscillates between the poles of a magnet, its oscillations are quickly damped. Why? (Such magnetic damping is used in a number of practical devices.)

43. The metal wing of an airplane acts like a "wire" flying through the Earth's magnetic field. A voltage is induced between the wing tips, and a current flows along the wing, but only for a short time. Why does the current stop even though the airplane continues flying through the Earth's magnetic field?

44. What is wrong with this scheme? To generate electricity without fuel, arrange a motor to operate a generator that will produce electricity that is stepped up with transformers so that the generator can operate the motor and simultaneously furnish electricity for other uses.

45. With no magnets in the vicinity, why will current flow in a large coil of wire waved around in the air?

46. We know that the source of a sound wave is a vibrating object. What is the source of an electromagnetic wave?

47. What does an incident radio wave do to the electrons in a receiving antenna?

48. How do you suppose the frequency of an electromagnetic wave compares with the frequency of the electrons it sets into oscillation in a receiving antenna?

49. A friend says that changing electric and magnetic fields generate one another, and that this gives rise to visible light when the frequency of change matches the frequencies of light. Do you agree? Explain.

50. Would electromagnetic waves exist if changing magnetic fields could produce electric fields, but changing electric fields could not, in turn, produce magnetic fields? Explain.

Problems

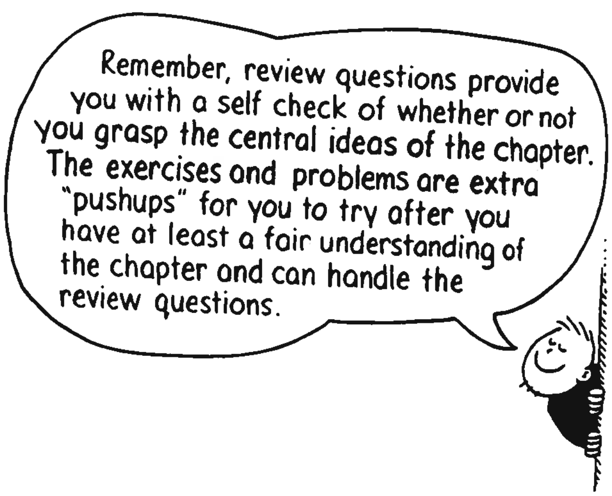
1. The primary coil of a step-up transformer draws 100 W. Find the power provided by the secondary coil.

2. An ideal transformer has 50 turns in its primary and 250 turns in its secondary. 12 V ac is connected to the primary. Find: (a) volts ac available at the secondary; (b) current in a 10-ohm device connected to the secondary; and (c) power supplied to the primary.

3. A model electric train requires 6 V to operate. If the primary coil of its transformer has 240 windings, how many windings should the secondary have, if the primary is connected to a 120-V household circuit?

4. Neon signs require about 12,000 V for their operation. What should be the ratio of the number of loops in the secondary to the number of loops in the primary for a neon-sign transformer that operates from 120-V lines?

5. 100 kW (10^5 W) of power is delivered to the other side of a city by a pair of power lines between which the voltage is 12,000 V. (a) What current flows in the lines? (b) Each of the two lines has a resistance of 10 ohms. What is the voltage change *along* each line? (Think carefully. This voltage change is along each line, not between the lines.) (c) What power is expended as heat in both lines together (distinct from power delivered to customers)? Do you see why it is so important to step voltages up with transformers for long-distance transmission?



Projects

1. Compare the size of the Moon on the horizon with its size higher in the sky. One way to do this is to hold at arm's length various objects that will just barely block out the Moon. Experiment until you find something just right, perhaps a thick pencil or a pen. You'll find that the object will be less than a centimeter, depending on the length of your arms. Is the Moon really bigger when it is near the horizon?
2. Which eye do you use more? To test which you favor, hold a finger up at arm's length. With both eyes open, look past it at a distant object. Now close your right eye. If your finger appears to jump to the right, then you use your right eye more. Check with friends who are both left-handed and right-handed. Is there a correlation between dominant eye and dominant hand?

Exercises

1. A friend says, in a profound tone, that light is the only thing we can see. Is your friend correct?
2. Your friend goes on to say that light is produced by the connection between electricity and magnetism. Is your friend correct?
3. What is the fundamental source of electromagnetic radiation?
4. Which have the longest wavelengths—light waves, X-rays, or radio waves?
5. Which has the shorter wavelengths, ultraviolet or infrared? Which has the higher frequencies?
6. How is it possible to take photographs in complete darkness?
7. What is it, exactly, that waves in a light wave?
8. We hear people talk of "ultraviolet light" and "infrared light." Why are these terms misleading? Why are we less likely to hear people talk of "radio light" and "X-ray light"?
9. Knowing that interplanetary space consists of a vacuum, what is your evidence that electromagnetic waves can travel through a vacuum?
10. What is the principal difference between a gamma ray and an infrared ray?
11. What is the speed of X-rays in a vacuum?
12. Which travels faster through a vacuum—an infrared ray or a gamma ray?
13. Your friend says that microwaves and ultraviolet light have different wavelengths but travel through space at the same speed. Do you agree or disagree?
14. Your friend says that any radio wave travels appreciably faster than any sound wave. Do you agree or disagree, and why?
15. Your friend says that outer space, instead of being empty, is chock full of electromagnetic waves. Do you agree or disagree?
16. Are the wavelengths of radio and television signals longer or shorter than waves detectable by the human eye?
17. Suppose a light wave and a sound wave have the same frequency. Which has the longer wavelength?
18. Which requires a physical medium in which to travel—light, sound, or both? Explain.
19. Do radio waves travel at the speed of sound, or at the speed of light, or somewhere in between?
20. When astronomers observe a supernova explosion in a distant galaxy, they see a sudden, simultaneous rise in visible light and other forms of electromagnetic radiation. Is this evidence to support the idea that the speed of light is independent of frequency? Explain.
21. What are the similarities and differences between radio waves and light?
22. A helium-neon laser emits light of wavelength 633 nanometers (nm). Light from an argon laser has a wavelength of 515 nm. Which laser emits the higher-frequency light?
23. Why would you expect the speed of light to be slightly less in the atmosphere than in a vacuum?
24. If you fire a bullet through a tree, it will slow down inside the tree and emerge at a speed that is less than the speed at which it entered. Does light, then, similarly slow down when it passes through glass and also emerge at a lower speed? Defend your answer.
25. Pretend that a person can walk only at a certain pace—no faster, no slower. If you time her uninterrupted walk across a room of known length, you can calculate her walking speed. If, however, she stops momentarily along the way to greet others in the room, the extra time spent in her brief interactions gives an *average* speed across the room that is less than her walking speed. How is this

similar to light passing through glass? In what way does it differ?

26. Is glass transparent or opaque to light of frequencies that match its own natural frequencies? Explain.

27. Short wavelengths of visible light interact more frequently with the atoms in glass than do longer wavelengths. Does this interaction time tend to speed up or to slow down the average speed of short-wavelength light in glass?

28. What determines whether a material is transparent or opaque?

29. You can get a sunburn on a cloudy day, but you can't get a sunburn even on a sunny day if you are behind glass. Explain.

30. Suppose that sunlight falls both on a pair of reading glasses and on a pair of dark sunglasses. Which pair of glasses would you expect to become warmer? Defend your answer.

31. Why does a high-flying airplane cast little or no shadow on the ground below, while a low-flying airplane casts a sharp shadow?

32. Only some of the people on the daytime side of the Earth can witness a solar eclipse when it occurs, whereas all the people on the nighttime side of the Earth can witness a lunar eclipse when it occurs. Why is this so?

33. Lunar eclipses are always eclipses of a full Moon. That is, the Moon is always seen full just before and after the Earth's shadow passes over it. Why is this? Why can we never have a lunar eclipse when the Moon is in its crescent or half-moon phase?

34. Do planets cast shadows? What is your evidence?

35. In 2004, the planet Venus passed between the Earth and the Sun. What kind of eclipse, if any, occurred?

36. What astronomical event would be seen by observers on the Moon at the time the Earth experiences a lunar eclipse? At the time the Earth experiences a solar eclipse?

37. Light from a location on which you concentrate your attention falls on your fovea, which contains only cones. If you wish to observe a weak source of light, like a faint star, why should you not look *directly* at the source?

38. Why do objects illuminated by moonlight lack color?

39. Why do we not see color at the periphery of our vision?

40. From your experimentation with Figure 26.15, is your blind spot located noseward from your fovea or to the outside of it?

41. Why should you be skeptical when your sweetheart holds you and looks at you with constricted pupils and says, "I love you"?

42. Can we infer that a person with large pupils is generally happier than a person with small pupils? If not, why not?

43. The intensity of light decreases as the inverse square of the distance from the source. Does this mean that light energy is lost? Explain.

44. Light from a camera flash weakens with distance in accord with the inverse-square law. Comment on an airline passenger who takes a flash photo of a city at nighttime from a high-flying plane.

45. Ships determine the ocean depth by bouncing sonar waves from the ocean bottom and measuring the round-trip time. How do some airplanes similarly determine their distance to the ground below?

46. The planet Jupiter is more than five times as far from the Sun as the planet Earth. How does the brightness of the Sun appear at this greater distance?

47. When you look at the night sky, some stars are brighter than others. Can you correctly say that the brightest stars emit more light? Defend your answer.

48. When you look at a distant galaxy through a telescope, how is it that you're looking backward in time?

49. When we look at the Sun, we are seeing it as it was 8 minutes ago. So we can only see the Sun "in the past." When you look at the back of your own hand, do you see it "now" or in "the past"?

50. "20/20 vision" is an arbitrary measure of vision—meaning that you can read what an average person can read at a distance of 20 feet in daylight. What is this distance in meters?

Problems

1. In about 1675, the Danish astronomer Olaus Roemer, measuring the times when one of Jupiter's moons appeared from behind Jupiter in its successive trips around that planet, and noticing the delays in these appearances as the Earth got farther from Jupiter, concluded that light took an extra 22 min to travel 300,000,000 km across the diameter of the Earth's orbit around the Sun. What approximate value for the speed of light did Roemer deduce? How much does it differ from our modern value? (Roemer's measurement, although not accurate by modern standards, was the first demonstration that light travels at a finite, not an infinite, speed.)

2. In one of Michelson's experiments, a beam from a revolving mirror traveled 15 km to a stationary mirror. How long a time interval elapsed before the beam returned to the revolving mirror?