Chapter 21
Conceptual Questions and Concepts and Calculations

CONCEPTUAL QUESTIONS

ssm Solution is in the Student Solutions Manual.

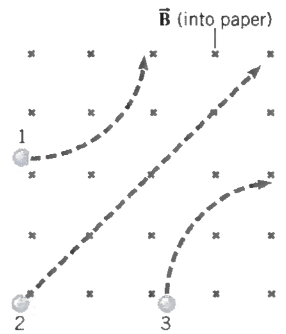
1. Magnetic field lines, like electric field lines, never intersect. Suppose it were possible for two magnetic field lines to intersect at a point in space. Discuss what this would imply about the force(s) that act on a charge moving through such a point, thereby ruling out the possibility of field lines crossing.

2. Suppose you accidentally use your left hand, instead of your right hand, to determine the direction of the magnetic force on a positive charge moving in a magnetic field. Do you get the correct answer? If not, what direction do you get?

3. ssm A charged particle, passing through a certain region of space, has a velocity whose magnitude and direction remain constant. (a) If it is known that the external magnetic field is zero everywhere in this region, can you conclude that the external electric field is also zero? Explain. (b) If it is known that the external electric field is zero everywhere, can you conclude that the external magnetic field is also zero? Explain.

4. Suppose that the positive charge in Figure 21.10*a* were launched from the negative plate toward the positive plate, in a direction opposite to the electric field. A sufficiently strong electric field would prevent the charge from striking the positive plate. Suppose the positive charge in Figure 21.10*b* were launched from the south pole toward the north pole, in a direction opposite to the magnetic field. Would a sufficiently strong magnetic field prevent the charge from reaching the north pole? Account for your answer.

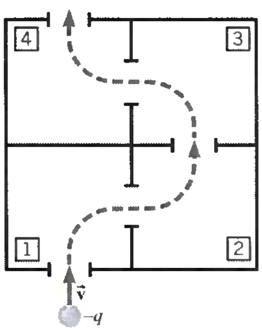
5. Review Conceptual Example 4 and **Concept Simulation 21.1** at **www.wiley.com/college/cutnell** as background for this question. Three particles move through a constant magnetic field and follow the paths shown in the drawing. Determine whether each particle is positively charged, negatively charged, or neutral. Give a reason for each answer.



Question 5

6. Refer to Figure 21.12. Assume that the particle in the picture is a proton. If an electron is projected at point 1 with the same velocity $\vec{v}$, it will not follow the same path as the proton, unless the magnetic field is adjusted. Explain how the magnitude and direction of the field must be changed.

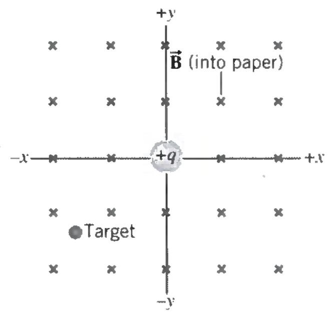
7. The drawing shows a top view of four interconnected chambers. A negative charge is fired into chamber 1. By turning on separate magnetic fields in each chamber, the charge can be made to exit from chamber 4, as shown. (a) Describe how the magnetic field in each chamber should be directed. (b) If the speed of the charge is v when it enters chamber 1, what is the speed of the charge when it exits chamber 4? Why?



8. A positive charge moves along a circular path under the influence of a magnetic field. The magnetic field is perpendicular to the plane of the circle, as in Figure 21.12. If the velocity of the particle is reversed at some point along the path, will the particle retrace its path? If not, draw the new path. Explain.

9. When one end of a bar magnet is placed near a TV screen, the picture becomes distorted. Why?

10. ssm The drawing shows a particle carrying a positive charge $+q$ at the coordinate origin, as well as a target located in the third quadrant. A uniform magnetic field is directed

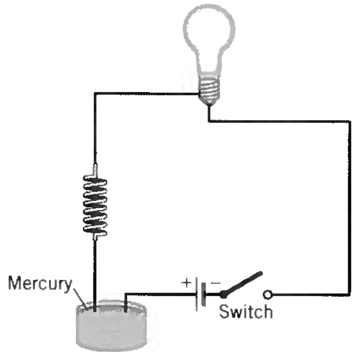


Question 10

perpendicularly into the plane of the paper. The charge can be projected in the plane of the paper only, along the positive or negative x or y axis. Thus, there are four possible directions for the initial velocity of the particle. The particle can be made to hit the target for only two of the four directions. Which two are they? Give your reasoning, and draw the two paths that the particle can follow on its way to the target.

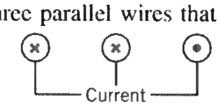
11. Refer to Figure 21.17. (a) What happens to the direction of the magnetic force if the current is reversed? (b) What happens to the direction of the force if *both* the current *and* the magnetic poles are reversed? Explain your answers.

12. The drawing shows a conducting wire wound into a helical shape. The helix acts like a spring and expands back toward its original shape after its coils are squeezed together and released. The bottom end of the wire just barely touches the mercury (a good electrical conductor) in the cup. After the switch is closed, current in the circuit causes the light bulb to glow. Does the bulb glow continually, glow briefly and then go out, or repeatedly turn on and off like a turn signal on a car? Explain.

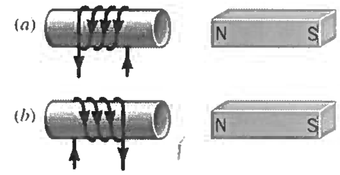


13. In Figure 21.28, assume that the current I_1 is larger than the current I_2. In parts *a* and *b*, decide whether there are places where the total magnetic field is zero. State whether they are located to the left of both wires, between the wires, or to the right of both wires. Give your reasoning.

14. The drawing shows an end-on view of three parallel wires that are perpendicular to the plane of the paper. In two of the wires the current is directed into the paper, while in the remaining wire the current is directed out of the paper. The two outermost wires are held rigidly in place. Which way will the middle wire move? Explain.

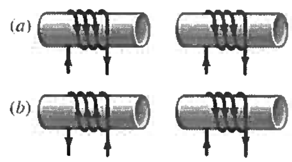


15. For each electromagnet at the left of the drawing, explain whether it will be attracted to or repelled from the permanent magnet at the right.



Question 15

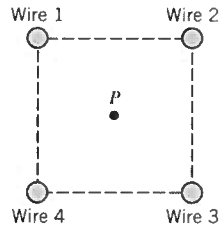
16. For each electromagnet at the left of the drawing, explain whether it will be attracted to or repelled from the adjacent electromagnet at the right.



Question 16

17. Refer to Figure 21.5. If the earth's magnetism is assumed to originate from a large circular loop of current within the earth, how is the plane of this current loop oriented relative to the magnetic axis, and what is the direction of the current around the loop?

18. **ssm** There are four wires viewed end-on in the drawing. They are long, straight, and perpendicular to the plane of the paper. Their cross sections lie at the corners of a square. Currents of the same magnitude are in each of these wires. Choose the direction of the current for each wire, so that when any single current is turned off, the total magnetic field at point P (the center of the square) is directed toward a corner of the square. Account for your answer.



19. Suppose you have two bars, one of which is a permanent magnet and the other of which is not a magnet, but is made from a ferromagnetic material like iron. The two bars look exactly alike. (a) Using a third bar, which is known to be a magnet, how can you determine which of the look-alike bars is the permanent magnet and which is not? (b) Can you determine the identities of the look-alike bars with the aid of a third bar that is not a magnet, but is made from a ferromagnetic material? Give reasons for your answers.

20. In a TV commercial that advertises a soda pop, a strong electromagnet picks up a delivery truck carrying cans of the soft drink. The picture switches to the interior of the truck, where cans are seen to fly upward and stick to the roof just beneath the electromagnet. Are these cans made entirely of aluminum? Justify your answer.

CONCEPTS & CALCULATIONS

Note: Each of these problems consists of Concept Questions followed by a related quantitative Problem. The Concept Questions involve little or no mathematics. They focus on the concepts with which the problems deal. Recognizing the concepts is the essential initial step in any problem-solving technique.

78. GO **Concept Questions** (a) A charge moves along the $+x$ axis and experiences no magnetic force, although there is a magnetic field. What can you conclude about the direction of the magnetic field? (b) A moving charge experiences the maximum possible magnetic force when moving in a magnetic field. What can you conclude about the angle θ that the charge's velocity makes with respect to the magnetic field? Explain your answers.

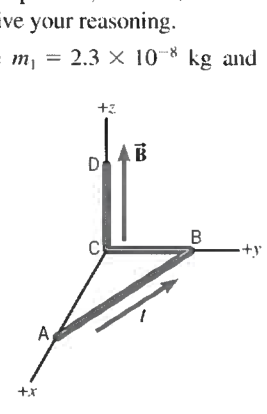
Problem A particle that has an 8.2-μC charge moves with a velocity of magnitude 5.0×10^5 m/s. When the velocity points along the $+x$ axis, the particle experiences no magnetic force, although there is a magnetic field present. The maximum possible magnetic force that the charge could experience has a magnitude of 0.48 N. Find the magnitude and direction of the magnetic field. Note that there are two possible answers for the direction of the field. Make sure that your answers are consistent with your answers to the Concept Questions.

79. GO **Concept Questions** A proton is projected perpendicularly into a magnetic field with a certain velocity and follows a circular path. Then an electron is projected perpendicularly into the same magnetic field with the same velocity. (a) Does the electron follow the exact same circular path that the proton followed? (b) To make the electron follow the exact same circular path as the proton, what, if anything, should be done to the direction and the magnitude of the magnetic field? Account for your answer.

Problem A proton is projected perpendicularly into a magnetic field that has a magnitude of 0.50 T. The field is then adjusted so that an electron will follow the exact same circular path when it is projected perpendicularly into the field with the same velocity that the proton had. What is the magnitude of the field used for the electron? Verify that your answer is consistent with your answers to the Concept Questions.

80. GO **Concept Questions** Particle 1 and particle 2 carry the same charge q, but particle 1 has a smaller mass than particle 2. These two particles accelerate from rest through the same electric potential difference V and enter the same magnetic field, which has a magnitude B. The particles travel perpendicular to the field on circular paths. Upon entering the field region, which particle, if either, has the greater (a) kinetic energy and (b) speed? Give your reasoning.

Problem The masses of the particles are $m_1 = 2.3 \times 10^{-8}$ kg and $m_2 = 5.9 \times 10^{-8}$ kg. The radius of the circular path for particle 1 is $r_1 = 12$ cm. What is the radius of the circular path for particle 2?



81. GO **Concept Question** The drawing shows a wire composed of three segments, AB, BC, and CD. There is a current I in the wire. There is also a magnetic field $\vec{\mathbf{B}}$ that is the same everywhere and points in the direction of the $+z$ axis. Rank the wire segments according to the magnetic force (largest first) that they experience. Justify your ranking.

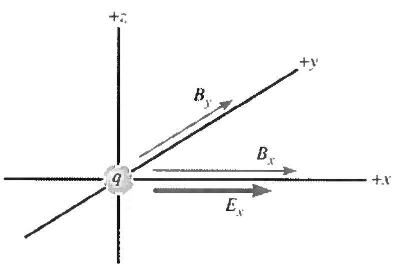
Problem The lengths of the wire segments are $L_{AB} = 1.1$ m, $L_{BC} = 0.55$ m, and $L_{CD} = 0.55$ m. The current is $I = 2.8$ A, and the magnitude of the magnetic field is $B = 0.26$ T. Find the magnitude of the force that acts on each segment. Be sure your answers are consistent with your answer to the Concept Question.

82. GO **Concept Question** You have a wire of length L from which to make the square coil of a dc motor. In a given magnetic field a coil of N turns, each with area A, produces more torque when its total effective area of NA is greater rather than smaller. This follows directly from Equation 21.4. Is more torque obtained by using the length of wire to make a single-turn coil or a two-turn coil, or is the torque the same in each case? Explain.

Problem The length of the wire is $L = 1.00$ m. The current in the coil is $I = 1.7$ A, and the magnetic field of the motor is 0.34 T. Find the maximum torque when the wire is used to make a single-turn square coil and a two-turn square coil. Verify that your answers are consistent with your answer to the Concept Question.

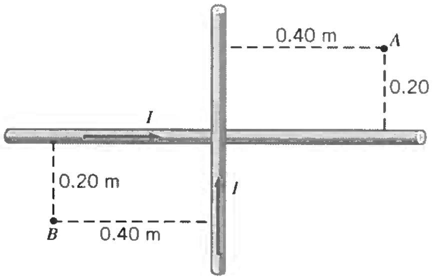
83. GO **Concept Questions** A particle has a charge q and is located at the coordinate origin. An electric field E_x points along the $+x$ axis. A magnetic field also exists, and its components B_x and B_y point along the $+x$ and $+y$ axis, respectively (see the drawing). Which, if any, of the fields (E_x, B_x, B_y) exert a force on the particle if it is (a) stationary and (b) moving along the $+x$ axis? Justify your answers. (c) None of the three fields points along the $+z$ axis. If the particle is moving along this axis, does it experience a force due to any of the fields? Provide a reason for your answer.

Problem The electric and magnetic fields in the drawing are, respectively, $E_x = +245$ N/C, $B_x = +1.80$ T, and $B_y = +1.40$ T, and the charge is $q = +5.60$ μC. Calculate the force (magnitude and direction) exerted on the particle by each of the three fields when it is (a) stationary, (b) moving along the $+x$ axis at a speed of 375 m/s, and (c) moving along the $+z$ axis at a speed of 375 m/s. Be sure your answers are consistent with those in the Concept Questions.

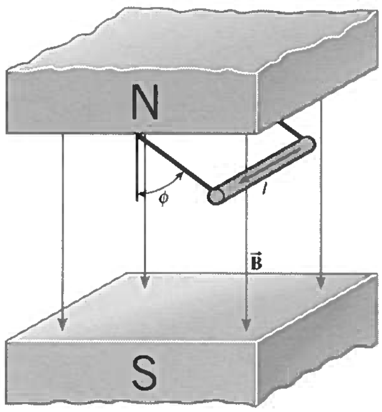


* **84.** GO **Concept Questions** The drawing shows two perpendicular, long, straight wires, both of which lie in the plane of the paper. Each wire carries the same current I. What is the direction of the net magnetic field at (a) point A and (b) point B? (c) Is the magnitude of the net field at point A greater than, less than, or equal to the magnitude of the net field at point B?

Problem The current in each of the wires is $I = 5.6$ A. Find the magnitudes of the net fields at points A and B. Verify that your answers are consistent with your answers to the Concept Questions.



* **85.** GO **Concept Questions** A horizontal wire is hung from the ceiling of a room by two massless strings. A uniform magnetic field is directed from the ceiling to the floor. When a current exists in the wire, the wire swings upward and makes an angle ϕ with respect to the vertical, as the drawing shows. (a) How is the magnitude of the magnetic force related to the magnetic field, the length of the wire, and the current in the wire? (b) What is the direction of the magnetic force? (c) The wire is stationary, so it is in equilibrium. What are the forces that keep it in equilibrium? (d) What must be true about the sum of the forces in the horizontal direction and the sum of the forces in the vertical direction?



Problem The wire has a length of 0.20 m and a mass of 0.080 kg and carries a current of 42 A. The magnitude of the magnetic field is 0.070 T. Find (a) the angle ϕ and (b) the tension in each of the two strings.

Chapter 22
Conceptual Questions and Concepts and Calculations

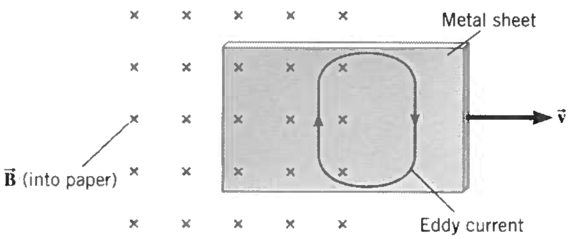
CONCEPTUAL QUESTIONS

ssm Solution is in the Student Solutions Manual.

1. Suppose the coil and the magnet in Figure 22.1*a* were each moving with the same velocity relative to the earth. Would there be an induced current in the coil? Explain.

2. In the discussion concerning Figure 22.5, we saw that a force of 0.086 N from an external agent was required to keep the rod moving at a constant speed. Suppose the light bulb in the figure is unscrewed from its socket. How much force would now be needed to keep the rod moving at a constant speed? Justify your answer.

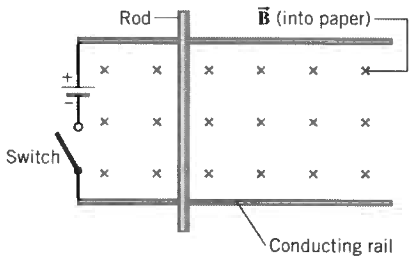
3. Eddy currents are electric currents that can arise in a piece of metal when it moves through a region where the magnetic field is not the same everywhere. The picture shows, for example, a metal sheet moving to the right at a velocity $\vec{v}$ and a magnetic field $\vec{B}$ that is directed perpendicular to the sheet. At the instant represented, the magnetic field only extends over the left half of the sheet. An emf is induced that leads to the eddy current shown. Explain why this current causes the metal sheet to slow down. This action of eddy currents is used in various devices as a brake to damp out unwanted motion.



4. **ssm** A magnetic field is necessary if there is to be a magnetic flux passing through a coil of wire. Yet, just because there is a magnetic field does not mean that a magnetic flux will pass through a coil. Account for this observation.

5. Suppose the magnetic flux through a 1-m^2 flat surface is known to be 2 Wb. From these data, it is possible to determine certain information about the average magnetic field at the surface, but not the magnitude and direction of the total field. What exactly can be ascertained about the field? Explain.

6. A conducting rod is free to slide along a pair of conducting rails, in a region where a uniform and constant (in time) magnetic field is directed into the plane of the paper, as the drawing illustrates. Initially the rod is at rest. Describe the rod's motion after the switch is closed. Be sure to account for the effect of any motional emf that develops.



7. **ssm** Explain how a bolt of lightning can produce a current in the circuit of an electrical appliance, even when the lightning does not directly strike the appliance.

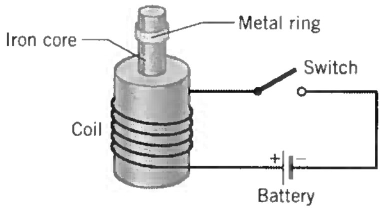
8. Review Conceptual Example 7 before answering this question. A solenoid is connected to an ac source. A copper ring is placed inside the solenoid, with the normal to the ring being parallel to the axis of the solenoid. The copper ring gets hot, yet nothing touches it. Why?

9. A robot is designed to move parallel to a cable hidden under the floor. The cable carries a steady direct current I. A sensor mounted on the robot consists of a coil of wire. The coil is near the floor and parallel to it. As long as the robot moves parallel to the cable, with the coil directly over it, no emf is induced in the coil, since the magnetic flux through the coil does not change. But when the robot deviates from the parallel path, an induced emf appears in the coil. The emf is sent to electronic circuits that bring the robot back to the path. Explain why an emf would be induced in the sensor coil.

10. In a car, the generator-like action of the alternator occurs while the engine is running and keeps the battery fully charged. The headlights would discharge an old and failing battery quickly if it were not for the alternator. Explain why the engine of a parked car runs more quietly with the headlights off than with them on when the battery is in bad shape.

11. In Figure 22.3 a coil of wire is being stretched. (a) Using Lenz's law, verify that the induced current in the coil has the direction shown in the drawing. (b) Deduce the direction of the induced current if the direction of the external magnetic field in the figure were reversed. Explain.

12. (a) When the switch in the circuit in the drawing is closed, a current is established in the coil and the metal ring jumps upward. Explain this behavior. (b) Describe what would happen to the ring if the battery polarity were reversed.



13. The string of an electric guitar vibrates in a standing wave pattern that consists of nodes and antinodes. (Section 17.5 discusses standing waves.) Where should an electromagnetic pickup be located in the standing wave pattern to produce a maximum emf, at a node or an antinode? Why?

14. **ssm** An electric motor in a hair dryer is running at normal speed and, thus, is drawing a relatively small current, as in part (b) of Example 12. What happens to the current drawn by the motor if the shaft is prevented from turning, so the back emf is suddenly reduced to zero? Remembering that the wire in the coil of the motor has some resistance, what happens to the temperature of the coil? Justify your answers.

15. One transformer is a step-up device, while another is step-down. These two units have the same voltage across and the same current in their primary coils. Does either one deliver more power to the circuit attached to the secondary coil? If so, which one? Ignore any heat loss within the transformers and account for your answer.

CONCEPTS & CALCULATIONS

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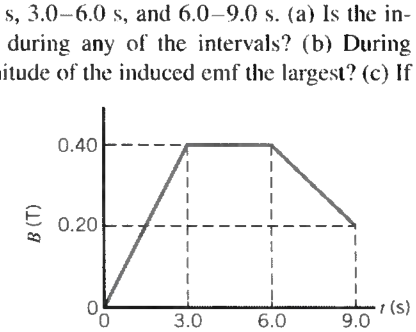
75. **Concept Questions** Two circuits contain an emf produced by a moving metal rod, like that in Figure 22.4*b*. The speed of the rod is the same in each circuit, but the bulb in circuit 1 has one-half the resistance of the bulb in circuit 2. The circuits are otherwise identical. Is (a) the motional emf and (b) the current in circuit 1 greater than, the same as, or less than, that in circuit 2? (c) If the speed of the rod in circuit 1 were doubled, how would the power delivered to the light bulb compare to that in circuit 2? Provide a reason for each of your answers.

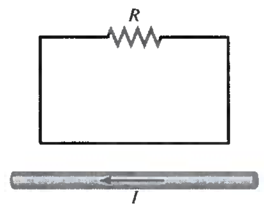
Problem The resistance of the light bulb in circuit 1 is 55 Ω, and that in circuit 2 is 110 Ω. Determine (a) the ratio $\mathcal{E}_1/\mathcal{E}_2$ of the emfs and (b) the ratio I_1/I_2 of the currents. (c) If the speed of the rod in circuit 1 is twice that in circuit 2, what is the ratio P_1/P_2 of the powers? Check to see that your answers are consistent with your answers to the Concept Questions.

76. **Concept Questions** A magnetic field passes through a stationary wire loop, and its magnitude changes in time according to the graph in the drawing. The direction of the field remains constant, however. There are three equal time intervals indicated in the graph: 0–3.0 s, 3.0–6.0 s, and 6.0–9.0 s. (a) Is the induced emf equal to zero during any of the intervals? (b) During which interval is the magnitude of the induced emf the largest? (c) If the direction of the current induced during the first interval is clockwise, what is the direction during the third interval? In all cases, provide a reason for your answer.



Problem The loop consists of 50 turns of wire and has an area of 0.15 m^2. The magnetic field is oriented parallel to the normal to the loop. For purposes of this problem, this means that $\phi = 0°$ in Equation 22.2. (a) For each interval, determine the induced emf. (b) The wire has a resistance of 0.50 Ω. Determine the induced current for the first and third intervals. Make sure your answers are consistent with your answers to the Concept Questions.

77. **Concept Questions** The drawing shows a straight wire carrying a current I. Above the wire is a rectangular loop that contains a resistor R. (a) Does the magnetic field produced by the current I penetrate the loop and generate a magnetic flux? (b) When is there an induced current in the loop, if the current I is constant or if it is decreasing in time? (c) When there is an induced magnetic field produced by the loop, does it always have a direction that is opposite to the direction of the magnetic field produced by the current I? Provide a reason for each answer.



Problem If the current I is decreasing in time, what is the direction of the induced current through the resistor R—left to right or right to left? Give your reasoning.

78. **Concept Questions** A flat coil of wire has an area A, N turns, and a resistance R. It is situated in a magnetic field such that the normal to the coil is parallel to the magnetic field. The coil is then rotated through an angle of 90°, so that the normal becomes perpendicular to the magnetic field. (a) Why is an emf induced in the coil? (b) What determines the amount of induced current in the coil? (c) How is the amount of charge Δq that flows related to the induced current I and the time interval $t - t_0$ during which the coil rotates?

Problem The coil has an area of 1.5×10^{-3} m^2, 50 turns, and a resistance of 140 Ω. During the time when it is rotating, a charge of 8.5×10^{-5} C flows in the coil. What is the magnitude of the magnetic field?

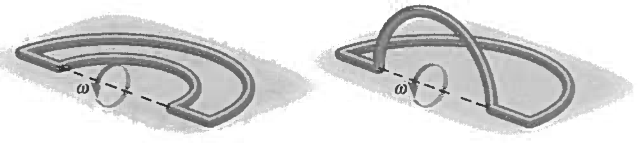
79. **Concept Questions** A constant current I exists in a solenoid whose inductance is L. The current is then reduced to zero in a certain amount of time. (a) If the wire from which the solenoid is made has no resistance, is there a voltage across the solenoid during the time when the current is constant? (b) If the wire from which the solenoid is made has no resistance, is there an emf across the solenoid during the time that the current is being reduced to zero? (c) Does the solenoid store electrical energy when the current is constant? If so, express this energy in terms of the current and the inductance. (d) When the current is reduced from its constant value to zero, what is the rate at which energy is removed from the solenoid? Express your answer in terms of the initial current, the inductance, and the time during which the current goes to zero.

Problem A solenoid has an inductance of $L = 3.1$ H and carries a current of $I = 15$ A. (a) If the current goes from 15 to 0 A in a time of 75 ms, what is the emf induced in the solenoid? (b) How much electrical energy is stored in the solenoid? (c) At what rate must the electrical energy be removed from the solenoid when the current is reduced to zero in 75 ms?

80. GO **Concept Questions** The rechargeable batteries for a laptop computer need a much smaller voltage than what a wall socket provides. Therefore, a transformer is plugged into the wall socket and produces the necessary voltage for charging the batteries. (a) Is the transformer a step-up or a step-down transformer? (b) Is the current that goes through the batteries greater than, equal to, or smaller than the current coming from the wall socket? (c) If the transformer has a negligible resistance, is the electric power delivered to the batteries greater than, equal to, or less than the power coming from the wall socket? In all cases, provide a reason for your answer.

Problem The batteries of a laptop computer are rated at 9.0 V, and a current of 225 mA is used to charge them. The wall socket provides a voltage of 120 V. (a) Determine the turns ratio of the transformer. (b) What is the current coming from the wall socket? (c) Find the average power delivered by the wall socket and the average power sent to the batteries. Be sure your answers are consistent with your answers to the Concept Questions.

* **81.** GO **Concept Questions** The drawing shows a coil of copper wire that consists of two semicircles joined by straight sections of wire. In part *a* the coil is lying flat on a horizontal surface. The dashed line also lies in the plane of the horizontal surface. Starting from the orientation in part *a*, the smaller semicircle rotates at an angular frequency ω about the dashed line, until its plane becomes perpendicular to the horizontal surface, as shown in part *b*. A uniform magnetic field is constant in time and is directed upward, perpendicular to the horizontal surface. The field completely fills the region occupied by the coil in either part of the drawing. (a) In which part of the drawing, if either, does a greater magnetic flux pass through the coil? Account for your answer. (b) As the shape of the coil changes from that in part *a* of the drawing to that in part *b*, does an induced current flow in the coil, and, if so, in which direction does it flow? Give your reasoning. To describe the flow, imagine that you are above the coil looking down at it. (c) How is the period T of the rotational motion related to the angular frequency ω, and in terms of the period, what is the shortest time interval that elapses between parts *a* and *b* of the drawing?



(*a*) (*b*)

Problem The magnitude of the magnetic field is 0.35 T. The resistance of the coil is 0.025 Ω, and the smaller semicircle has a radius of 0.20 m. The angular frequency at which the small semicircle rotates is 1.5 rad/s. Determine the average current (including the proper algebraic sign), if any, induced in the coil as the coil changes shape from that in part *a* of the drawing to that in part *b*.

* **82.** GO **Concept Questions** In a television set the power needed to operate the picture tube comes from the secondary of a transformer. The primary of the transformer is connected to a wall receptacle. (a) How is the power delivered by the receptacle to the primary related to the power delivered by the secondary to the picture tube? Give your answer in the form of an equation, and explain what assumptions are implied when this equation is used. (b) How is the turns ratio of the transformer related to the currents in the primary and the secondary? (c) How is the turns ratio of the transformer related to the voltage across the primary and the voltage across the secondary? (d) Express the turns ratio N_s/N_p of the transformer in terms of the power P used by the picture tube, the voltage V_p across the primary, and the current I_s in the secondary.

Problem The primary of the transformer is connected to a 120-V receptacle. The picture tube of a television set uses 91 W, and there is 5.5 mA of current in the secondary coil of the transformer to which the tube is connected. Find the turns ratio N_s/N_p of the transformer.