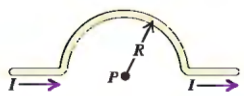
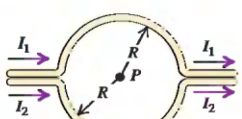
28.30. Calculate the magnitude and direction of the magnetic field at point P due to the current in the semicircular section of wire shown in Fig. 28.46. (*Hint:* Does the current in the long, straight section of the wire produce any field at P?)

Figure 28.46 Exercise 28.30.



28.31. Calculate the magnitude of the magnetic field at point P of Fig. 28.47 in terms of R, I_1, and I_2. What does your expression give when $I_1 = I_2$?

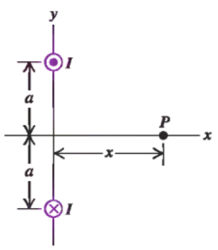
Figure 28.47 Exercise 28.31.



28.32. A closely wound, circular coil with radius 2.40 cm has 800 turns. a) What must the current in the coil be if the

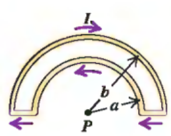
28.60. Figure 28.54 shows an end view of two long, parallel wires perpendicular to the xy-plane, each carrying a current I but in opposite directions. (a) Copy the diagram, and draw vectors to show the $\vec{B}$ field of each wire and the net $\vec{B}$ field at point P. (b) Derive the expression for the magnitude of $\vec{B}$ at any point on the x-axis in terms of the x-coordinate of the point. What is the direction of $\vec{B}$? (c) Graph the magnitude of $\vec{B}$ at points on the x-axis. (d) At what value of x is the magnitude of $\vec{B}$ a maximum? (e) What is the magnitude of $\vec{B}$ when $x \gg a$?

Figure 28.54 Problems 28.60 and 28.61.



28.66. The wire semicircles shown in Fig. 28.58 have radii a and b. Calculate the net magnetic field (magnitude and direction) that the current in the wires produces at point P.

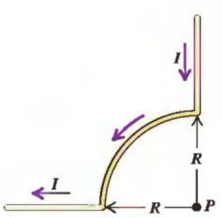
Figure 28.58 Problem 28.66.



28.67. Helmholtz Coils. Fig. 28.59 is a sectional view of two circular coils with radius a, each wound with N turns of

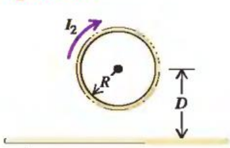
28.68. The wire in Fig. 28.61 carries current I in the direction shown. The wire consists of a very long, straight section, a quarter-circle with radius R, and another long, straight section. What are the magnitude and direction of the net magnetic field at the center of curvature of the quarter-circle section (point P)?

Figure 28.61 Problem 28.69.



28.76. A circular loop has radius R and carries current I_2 in a clockwise direction (Fig. 28.63). The center of the loop is a distance D above a long, straight wire. What are the magnitude and direction of the current I_1 in the wire if the magnetic field at the center of the loop is zero?

Figure 28.63 Problem 28.76.



28.77. A long, straight, solid cylinder, oriented with its axis in the z-direction, carries a current whose current density is $\vec{J}$. The current density, although symmetrical about the cylinder axis, is not constant but varies according to the relationship

$$\vec{J} = \frac{2I_0}{\pi a^2}\left[1 - \left(\frac{r}{a}\right)^2\right]\hat{k} \quad \text{for } r \le a$$
$$= 0 \quad \text{for } r \ge a$$

where a is the radius of the cylinder, r is the radial distance from the cylinder axis, and I_0 is a constant having units of amperes. (a) Show that I_0 is the total current passing through the entire cross section of the wire. (b) Using Ampere's law, derive an expression for the magnitude of the magnetic field $\vec{B}$ in the region $r \ge a$. (c) Obtain an expression for the current I contained in a circular cross section of radius $r \le a$ and centered at the cylinder axis. (d) Using Ampere's law, derive an expression for the magnitude of the magnetic field $\vec{B}$ in the region $r \le a$. How do your results in parts (b) and (d) compare for $r = a$?

Section 29.3 Lenz's Law

29.15. A circular loop of wire is in a region of spatially uniform magnetic field, as shown in Fig. 29.31. The magnetic field is directed into the plane of the figure. Determine the direction (clockwise or counterclockwise) of the induced current in the loop when (a) B is increasing; (b) B is decreasing; (c) B is constant with value B_0. Explain your reasoning.

Figure 29.31 Exercise 29.15 and 29.30.

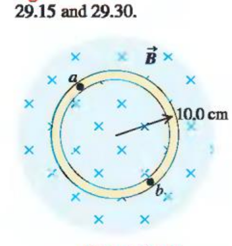
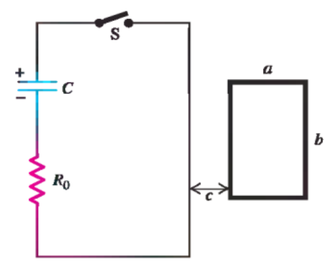


Figure 29.32

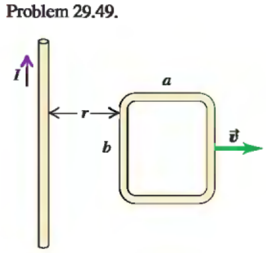
29.45. In the circuit shown in Fig. 29.41 the capacitor has capacitance $C = 20\ \mu F$ and is initially charged to 100 V with the polarity shown. The resistor R_0 has resistance $10\ \Omega$. At time $t = 0$ the switch is closed. The small circuit is not connected in any way to the large one. The wire of the small circuit has a resistance of $1.0\ \Omega/m$ and contains 25 loops. The large circuit is a rectangle 2.0 m by 4.0 m, while the small one has dimensions $a = 10.0$ cm and $b = 20.0$ cm. The distance c is 5.0 cm. (The figure is not drawn to scale.) Both circuits are held stationary. Assume that only the wire nearest the small circuit produces an appreciable magnetic field through it. (a) Find the current in the large circuit 200 μs after S is closed. (b) Find the current in the small circuit 200 μs after S is closed. (*Hint:* See Problem 29.7.) (c) Find the direction of the current in the small circuit. (d) Justify why we can ignore the magnetic field from all the wires of the large circuit except for the wire closest to the small circuit.

Figure 29.41 Problem 29.45.



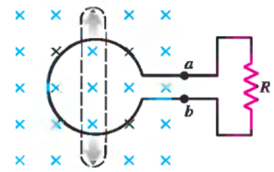
29.48. In Fig. 29.44 the loop is being pulled to the right at constant speed v. A constant current I flows in the long wire, in the direction shown. (a) Calculate the magnitude of the net emf $\mathcal{E}$ induced in the loop. Do this two ways: (i) by using Faraday's law of induction (*Hint:* See Problem 29.7) and (ii) by looking at the emf induced in each segment of the loop due to its motion. (b) Find the direction (clockwise or counterclockwise) of the current induced in the loop. Do this two ways: (i) using Lenz's law and (ii) using the magnetic force on charges in the loop. (c) Check your answer for the emf in part (a) in the following special cases to see whether it is physically reasonable: (i) The loop is stationary; (ii) the loop is very thin, so $a \to 0$; (iii) the loop gets very far from the wire.

Figure 29.44 Problem 29.49.



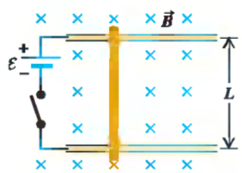
29.53. A flexible circular loop 6.50 cm in diameter lies in a magnetic field with magnitude 0.950 T, directed into the plane of the page as shown in Fig. 29.46. The loop is pulled at the points indicated by the arrows, forming a loop of zero area in 0.250 s. (a) Find the average induced emf in the circuit. (b) What is the direction of the current in R: from a to b or from b to a? Explain your reasoning.

Figure 29.46 Problem 29.53.



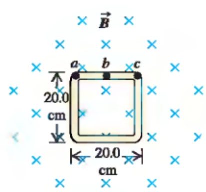
29.56. Terminal Speed. A bar of length $L = 0.8$ m is free to slide without friction on horizontal rails, as shown in Fig. 29.48. There is a uniform magnetic field $B = 1.5$ T directed into the plane of the figure. At one end of the rails there is a battery with emf $\mathcal{E} = 12$ V and a switch. The bar has mass 0.90 kg and resistance 5.0 Ω, and all other resistance in the circuit can be ignored. The switch is closed at time $t = 0$. (a) Sketch the speed of the bar as a function of time. (b) Just after the switch is closed, what is the acceleration of the bar? (c) What is the acceleration of the bar when its speed is 2.0 m/s? (d) What is the terminal speed of the bar?

Figure 29.48 Problem 29.56.



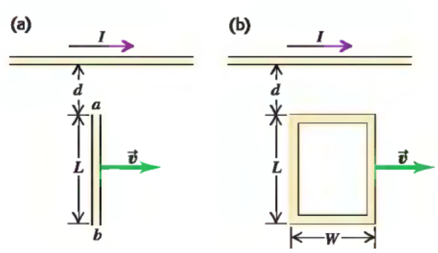
29.75. A square conducting loop, 20.0 cm on a side, is placed in the same magnetic field as shown in Exercise 29.30. (See Fig. 29.55; the center of the square loop is at the center of the magnetic-field region.) (a) Copy Fig. 29.55, and draw vectors to show the directions and relative magnitudes of the induced electric field $\vec{E}$ at points a, b, and c. (b) Prove that the component of $\vec{E}$ along the loop has the same value at every point of the loop and is equal to that of the ring shown in Fig. 29.31 (see Exercise 29.30). (c) What current is induced in the loop if its resistance is 1.90 Ω? (d) What is the potential difference between points a and b?

Figure 29.55 Challenge Problem 29.75.



29.61. The long, straight wire shown in Fig. 29.51a carries constant current I. A metal bar with length L is moving at constant velocity $\vec{v}$, as shown in the figure. Point a is a distance d from the wire. (a) Calculate the emf induced in the bar. (b) Which point, a or b, is at higher potential? (c) If the bar is replaced by a rectangular wire loop of resistance R (Fig. 29.51b), what is the magnitude of the current induced in the loop?

Figure 29.51 Problem 29.61.



29.21. In Fig. 29.37 a conducting rod of length $L = 30.0$ cm moves in a magnetic field $\vec{B}$ of magnitude 0.450 T directed into the plane of the figure. The rod moves with speed $v = 5.00$ m/s in the direction shown. (a) what is the potential difference between the ends of the rod? (b) Which point, a to b, is at higher potential? (c) When the charges in the rod are in equilibrium, what are the magnitude and direction of the electric field within the rod? (d) When the charges in the rod are in equilibrium, which point, a or b, has an excess of positive charge? (e) What is the potential difference across the rod if it moves (i) parallel to ab and (ii) directly out of the page?

Figure 29.37 Exercise 29.21.