4. (I) A charge $q = 1\ \mu C$ moves with a speed of 10^6 m/s in a uniform field $\mathbf{B} = 500\mathbf{j}$ G. Find the force on it for each of the three directions of the velocity shown in Fig. 29.40. (Use ijk notation.)

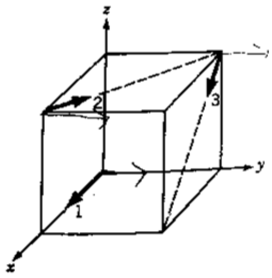


FIGURE 29.40 Exercise 4.

16. (II) A rod of length $\ell = 15$ cm and mass $m = 30$ g lies on a plane inclined at 37° to the horizontal, as shown in Fig. 29.43. A current enters and leaves the rod via light flexible wires which we ignore. For what current (magnitude and direction) will the rod be in equilibrium in a magnetic field $\mathbf{B} = 0.25\mathbf{j}$ T.

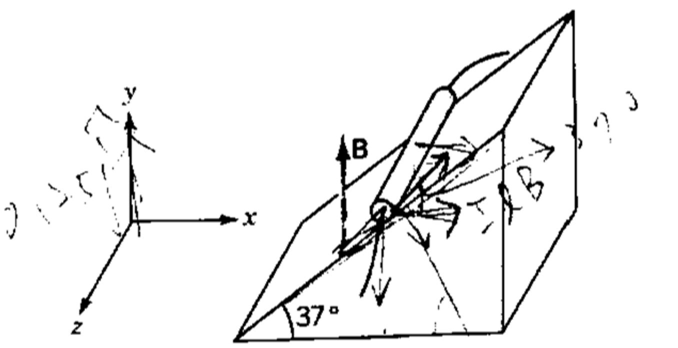


FIGURE 29.43 Exercise 16.

21. (II) A rectangular coil has 16 turns and sides of length a = 20 cm and c = 50 cm. The coil is pivoted about the z axis and its plane is at 30° to a magnetic field $\mathbf{B} = 0.5\mathbf{i}$ T, as shown in Fig. 29.46. (a) Find the force on each side. (b) What is the magnetic moment of the coil? (c) What is the torque on the coil? Take I = 10 A.

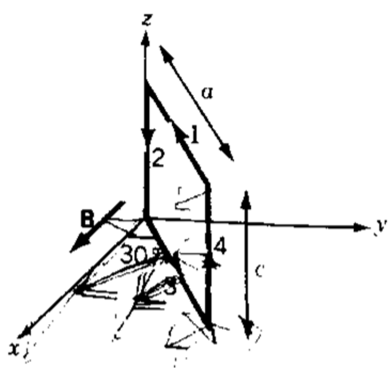


FIGURE 29.46 Exercise 21.

35. (I) A proton moves in a circle of radius 3.2 cm perpendicular to a magnetic field of 0.75 T. Find: (a) the cyclotron frequency; (b) the kinetic energy; (c) the linear momentum.

46. (II) A metallic strip 0.1 cm thick and 1.6 cm wide carries a 15-A current in a field of 0.2 T normal to the width. The Hall potential difference is 6 μV. Find: (a) the drift speed of the carriers; (b) the conduction electron density.

47. (II) A Cu strip of thickness 0.25 cm carrying a current of 10 A is set normal to a magnetic field. The Hall potential difference is 1.2 μV. What is B? Take $n = 8.5 \times 10^{28}$ electrons/m^3.

15. (I) Protons and deuterons ($m_d = 2m_p$, $q = e$) both move in circles with the same radius perpendicular to the lines of a uniform magnetic field. What is the ratio of (a) the linear momenta; and (b) the kinetic energies?

7. (I) A metal rod of mass 10 g and length 8 cm is suspended on two springs, as shown in Fig. 29.53. The springs are extended by 4 cm. When a 20-A current flows through the rod it rises by 1 cm. Determine the magnetic field.

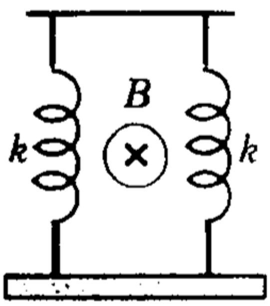


FIGURE 29.53 Problem 7.

6. (I) Three long, straight wires are at the corners of an equilateral triangle with sides of length $L = 6$ cm. They are parallel and carry currents as shown in Fig. 30.26. What is the force per unit length on the top wire?

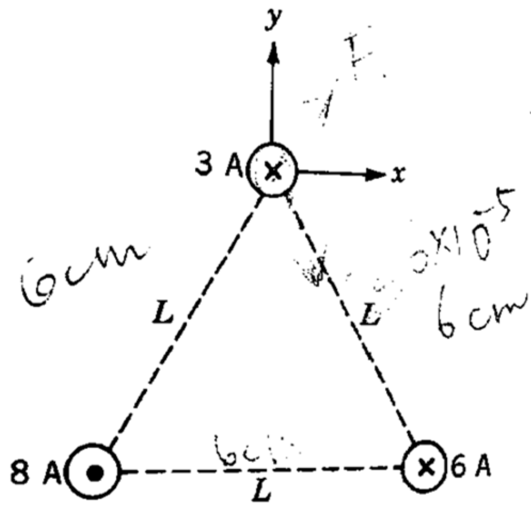


FIGURE 30.26 Exercise 6.

9. (I) A straight infinite current-carrying wire is bent into the form shown in Fig. 30.27. The curve is a semicircle of radius a. What is the field at the point P?

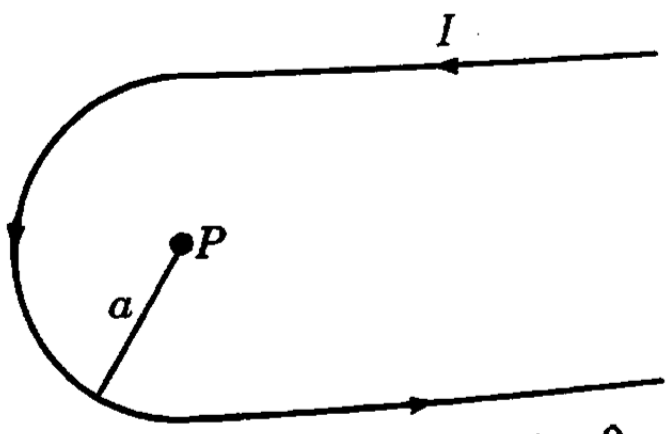


FIGURE 30.27 Exercise 9.

11. (I) A current loop consists of two concentric semicircles joined by radial sections, as shown in Fig. 30.29. What is the field strength at the center of the semicircles?

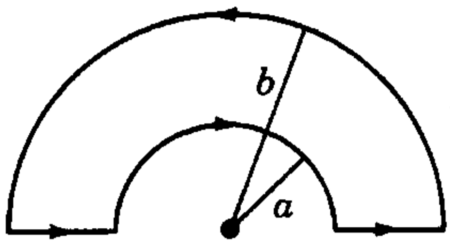


FIGURE 30.29 Exercise 11.

13. (II) A square coil of side ℓ carries a current I. Show that the field strength at its center is

$$B = \frac{2\sqrt{2}\mu_0 I}{\pi \ell}$$

(II) Two infinite straight wires lie parallel to the x and z axes respectively, as in Fig. 30.38. One wire lies along the z axis while the other is located at $y = 10$ cm. Find the resultant magnetic field at the point P, $y = 5$ cm. The directions and values of the currents are indicated.

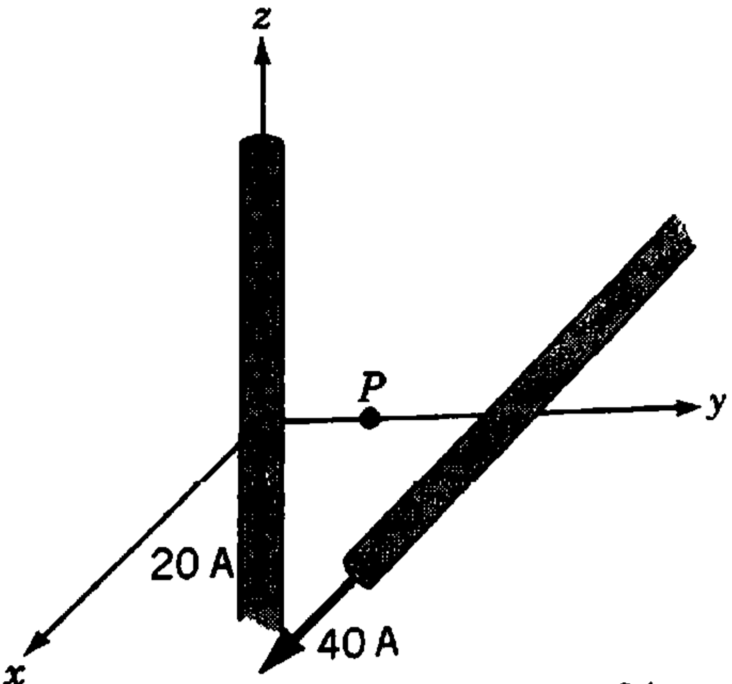
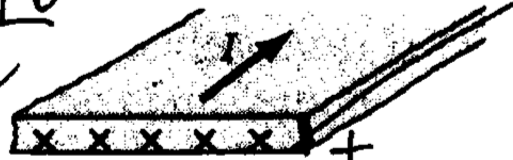


FIGURE 30.38 Exercise 24.

area. Find the magnetic field at all points.

29. (II) An infinite metal plate of thickness t, as in Fig. 30.40, carries a uniform current density J. (a) Use the right-hand rule and symmetry to determine the direction of the field above and below the plate. (b) Determine the magnetic field at a distance a from the plate.

$\frac{\mu_0 J t}{2}$



L.

t.

FIGURE 30.40 Exercise 29.

32. (II) Use the Biot-Savart equation for the field due to an infinite wire to show that Ampère's law is valid for the loop shown in Fig. 30.41. The circular sections are connected by radial lines.

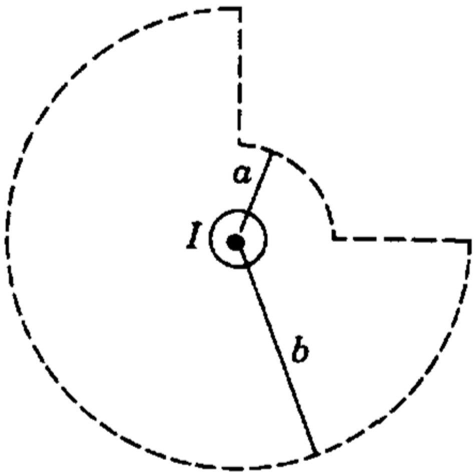


FIGURE 30.41 Exercise 32.

1. (I) A particle of mass m and charge q is in a circular orbit normal to an external field B. Show that the charge creates a magnetic field at the center of its orbit given by

$$\frac{\mu_0}{4\pi}\frac{q^2B}{mR}$$

2. (I) Helmholtz coils are two large circular coils with N tightly wound turns of radius R. The centers of the coils are separated by R, as shown Fig. 30.46. (a) Find the magnetic field along the line joining the centers as a function of x, the distance from the center of one coil. (b) Show that at the midpoint $B = (4/5)^{3/2}\,\mu_0 NI/R$. (c) Show that the field around the midpoint is approximately uniform. (*Hint:* Show that dB/dx and d^2B/dx^2 are both zero at $x = R/2$.)

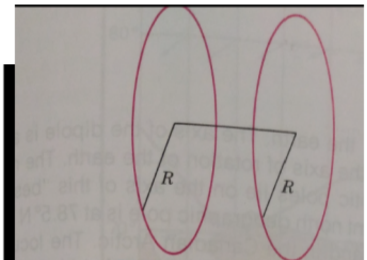


FIGURE 30.46 Problem 2.

4. (II) (a) Show that the magnetic field at a distance y from the center of a wire bent into a square of side ℓ carrying current I, as shown in Fig. 30.47, is

$$B = \frac{\mu_0 I \ell^2}{2\pi(y^2 + \ell^2/4)(y^2 + \ell^2/2)^{1/2}}$$

(b) Show that when $y \gg \ell$, the field is that of a dipole.

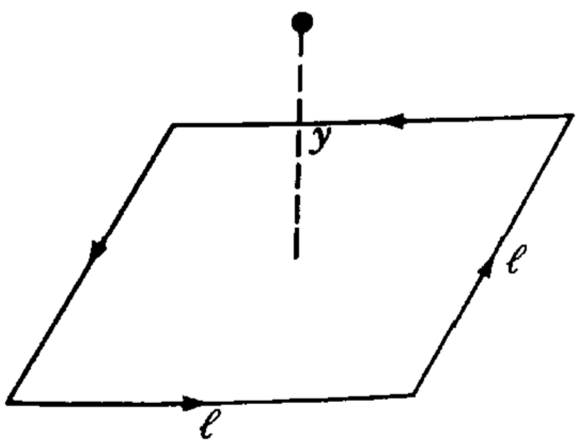
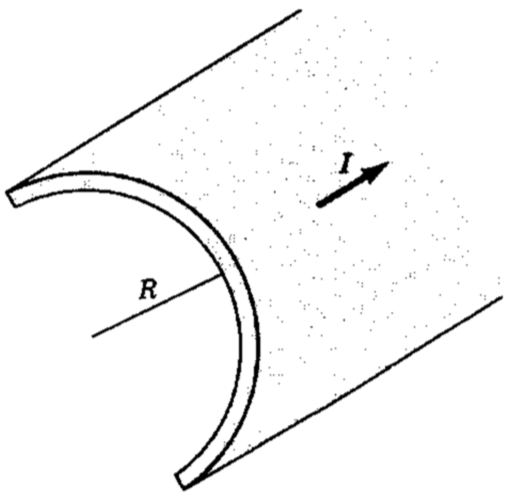


FIGURE 30.47 Problem 4.

10. A current I is uniformly distributed in one-half of a cylindrical tube of radius R, as shown in Fig. 30.51. What is the magnetic field at a point on the axis? Assume the cylinder is infinitely long.



11. (I) A metal rod slides at a constant 30 m/s over frictionless rails separated by 24 cm, as shown in Fig. 31.44. A 0.45-T uniform magnetic field is directed out of the page. Assume the resistance of the rod is 2.7 Ω and that the rails have negligible resistance. Find: (a) the current flowing in the rails; (b) the magnetic force acting on the rod; (c) the mechanical power needed to keep the rod moving at constant velocity; (d) the electrical power dissipated.

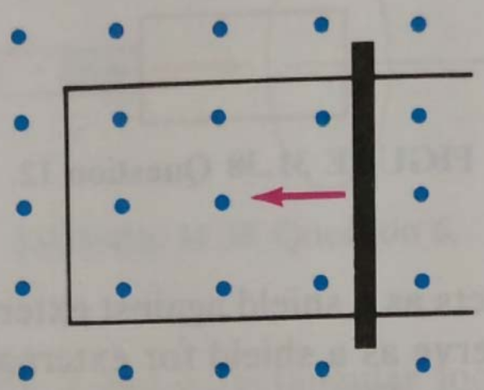


FIGURE 31.44 Exercise 11.

14. (II) A conducting loop is formed with two springs (k = 2 N/m) and a rod of length ℓ = 30 cm and mass m = 20 g, as shown in Fig. 31.45. A uniform magnetic field of 0.4 T is directed perpendicular to the plane of the loop. At t = 0, the rod is released with the springs extended by $\boxed{A = 10\text{ cm.}}$ (a) Write an expression for the induced emf, $\mathscr{E}(t)$. (b) What is the maximum value of the emf, and when does it occur for the first time?

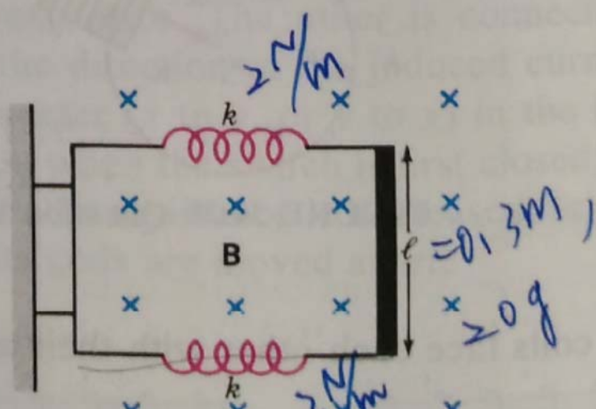


FIGURE 31.45 Exercise 14.

31.6 Induced Electric Fields

23. (II) An electron is at a distance d from the axis of a solenoid, as shown in Fig. 31.47. The uniform magnetic field in the solenoid is changing according to $B = Ct$. Obtain an expression for the electric force on the electron.

27. (I) An airliner with a wingspan of 45 m flies at 300 m/s in a region in which the vertical component of the earth's field is 0.6 G. (a) What is the potential difference between the wingtips?; (b) What would a voltmeter moving with the plane read if its leads were connected to the wingtips?

time for the field to reach zero?

33. (I) An infinite solenoid has 460 turns/m and carries a current given by $I = 3t^2$ A. A square coil of side 1.3 cm is placed inside the solenoid with their axes along the same line. At $t = 0.75$ s the induced emf in the coil is 22 μV. What is the number of turns in the square coil?

2. (I) A long, straight wire carries a constant current $I = 15$ A. A metal rod of length $\ell = 40$ cm moves at constant velocity on rails of negligible resistance that terminate in a resistor $R = 0.05\ \Omega$, as shown in Fig. 31.50. Find the induced current in the resistor given $a = 1$ cm, $d = 5$ cm, and $v = 25$ cm/s.

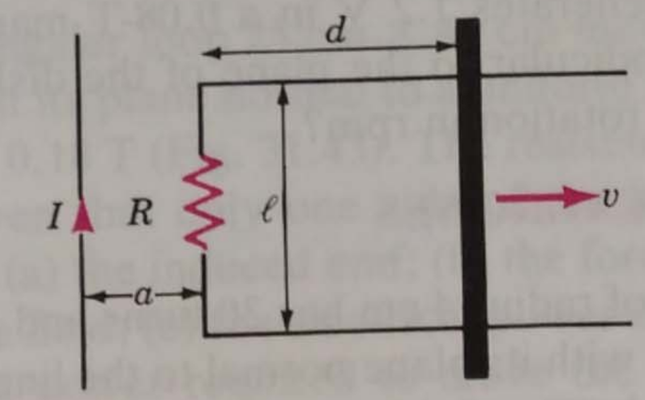


FIGURE 31.50 Problem 2.

4. (I) Find the induced emf in an inductor L when the current varies according to the following functions of time: (a) $I = I_0 \exp(-t/\tau)$; (b) $I = at - bt^2$; (c) $I = I_0 \sin(\omega t)$.

15. (II) Consider two solenoids with the following specifications: $L_1 = 20$ mH, $N_1 = 80$ turns; $L_2 = 30$ mH, $N_2 = 120$ turns, and $M = 7$ mH. At a certain instant the current in coil 1 is 2.4 A and is increasing at 4 A/s, the current in coil 2 is 4.5 A and increasing at 1.8 A/s. Find the magnitude of: (a) Φ_{11}; (b) Φ_{12}; (c) Φ_{21}; (d) $\mathscr{E}_{11}$; (e) $\mathscr{E}_{12}$; (f) $\mathscr{E}_{21}$.

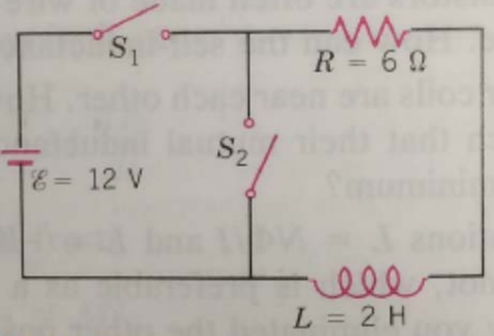


FIGURE 32.26 Exercises 17, 18, 19, 29, and 30

19. (I) In Fig. 32.26, S_2 is open and S_1 is closed at $t = 0$. (a) What is the initial rate of change of the current? (b) At what time does this rate drop to 50% of the initial value? (c) How long would it take for the current to reach its final value if the initial rate of change were maintained?

33. (I) A solenoid with 300 turns has a length of 20 cm and a radius of 1.8 cm. For what current will the energy density within the solenoid be 8 mJ/m^3?

36. (I) The current in an inductor $L = 160$ mH varies according to $I = 2.5 \sin(150\, t)$ A. Find: (a) the induced emf $\mathscr{E}$ at 1.2 ms; (b) the instantaneous power supplied to the inductor at $t = 1.2$ ms.

5. (I) A long, straight wire and a rectangular loop lie in the same plane, as shown in Fig. 32.28. What is their mutual inductance?

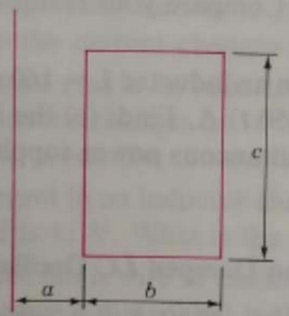


FIGURE 32.28 Problem 5

11. (I) The magnetic field in a plane electromagnetic wave is given by

$$B_y = 2 \times 10^{-7} \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\ \mathrm{T}$$

(a) What is the wavelength and frequency of the wave? (b) Write an expression for the electric field vector.

17. (II) At a distance of 6 m from a monochromatic (single wavelength) point source, the amplitude of the electric field is 10 V/m. Find: (a) the amplitude of the magnetic field; (b) the average power output of the source.

8. (II) Radiation is incident at an angle θ to a flat surface, as shown in Fig. 34.18. Show that the radiation pressure is $u_{av} \cos^2 \theta$. Assume all the radiation is absorbed.

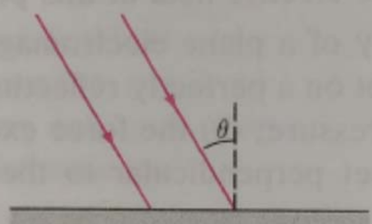


FIGURE 34.18 Problem 8.

10. (II) A *radiometer* consists of two disks of radius 1.2 cm connected by a light rod of length 10 cm that is suspended at its midpoint by a fine thread; see Fig. 34.19. One disk is perfectly absorbing whereas the other is perfectly reflect-

ing. The torque required to rotate the thread is given by Hooke's law, $\tau = \kappa\theta$, where the constant $\kappa = 10^{-11}$ N·m/deg. What is the equilibrium deflection when the sun's radiation (1 kW/m^2) is incident normally on the disks?

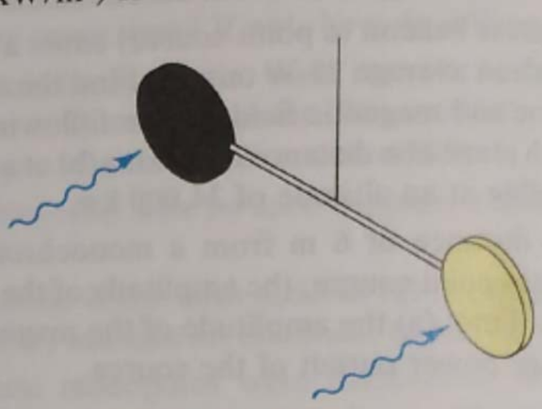


FIGURE 34.19 Problem 10.