



Tutoring problem available (at instructor's discretion) in WileyPLUS and WebAssign



Worked-out solution available in Student Solutions Manual



Number of dots indicates level of problem difficulty



Additional information available in *The Flying Circus of Physics* and at flyingcircusofphysics.com



Worked-out solution is at



Interactive solution is at

<http://www.wiley.com/college/halliday>

sec. 29-2 Calculating the Magnetic Field Due to a Current

•1 A surveyor is using a magnetic compass 6.1 m below a power line in which there is a steady current of 100 A. (a) What is the magnetic field at the site of the compass due to the power line? (b) Will this field interfere seriously with the compass reading? The horizontal component of Earth's magnetic field at the site is $20 \mu\text{T}$.

•2 Figure 29-34a shows an element of length $ds = 1.00 \mu\text{m}$ in a very long straight wire carrying current. The current in that element sets up a differential magnetic field $d\vec{B}$ at points in the surrounding space. Figure 29-34b gives the magnitude dB of the field for points 2.5 cm from the element, as a function of angle θ between the wire and a straight line to the point. The vertical scale is set by $dB_s = 60.0 \text{ pT}$. What is the magnitude of the magnetic field set up by the entire wire at perpendicular distance 2.5 cm from the wire?

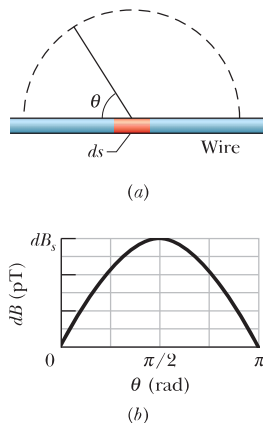


Fig. 29-34 Problem 2.

•3 SSM At a certain location in the Philippines, Earth's magnetic field of $39 \mu\text{T}$ is horizontal and directed due north. Suppose the net field is zero exactly 8.0 cm above a long, straight, horizontal wire that carries a constant current. What are the (a) magnitude and (b) direction of the current?

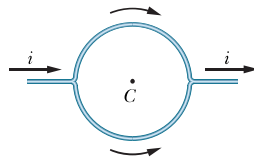


Fig. 29-35 Problem 4.

•4 A straight conductor carrying current $i = 5.0 \text{ A}$ splits into identical semicircular arcs as shown in Fig. 29-35. What is the magnetic field at the center C of the resulting circular loop?

•5 In Fig. 29-36, a current $i = 10 \text{ A}$ is set up in a long hairpin conductor formed by bending a wire into a semicircle of radius $R = 5.0 \text{ mm}$. Point b is midway between the straight sections and so distant from the semicircle that each straight section can be approximated as being an infinite wire. What are the (a) magnitude and (b) direction (into or out of the page) of \vec{B} at a and the (c) magnitude and (d) direction of \vec{B} at b ?

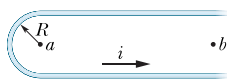


Fig. 29-36 Problem 5.

•6 In Fig. 29-37, point P is at perpendicular distance $R = 2.00 \text{ cm}$ from a very long straight wire carrying a current. The magnetic field \vec{B}

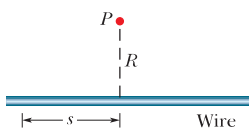


Fig. 29-37 Problem 6.

set up at point P is due to contributions from all the identical current-length elements $i d\vec{s}$ along the wire. What is the distance s to the element making (a) the greatest contribution to field \vec{B} and (b) 10.0% of the greatest contribution?

•7 In Fig. 29-38, two circular arcs have radii $a = 13.5 \text{ cm}$ and $b = 10.7 \text{ cm}$, subtend angle $\theta = 74.0^\circ$, carry current $i = 0.411 \text{ A}$, and share the same center of curvature P . What are the (a) magnitude and (b) direction (into or out of the page) of the net magnetic field at P ?

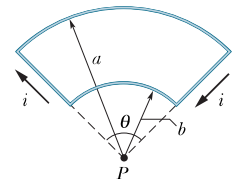


Fig. 29-38 Problem 7.

•8 In Fig. 29-39, two semicircular arcs have radii $R_2 = 7.80 \text{ cm}$ and $R_1 = 3.15 \text{ cm}$, carry current $i = 0.281 \text{ A}$, and share the same center of curvature C . What are the (a) magnitude and (b) direction (into or out of the page) of the net magnetic field at C ?

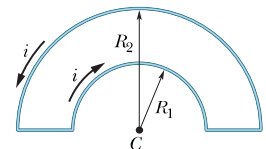


Fig. 29-39 Problem 8.

•9 SSM Two long straight wires are parallel and 8.0 cm apart. They are to carry equal currents such that the magnetic field at a point halfway between them has magnitude $300 \mu\text{T}$. (a) Should the currents be in the same or opposite directions? (b) How much current is needed?

•10 In Fig. 29-40, a wire forms a semicircle of radius $R = 9.26 \text{ cm}$ and two (radial) straight segments each of length $L = 13.1 \text{ cm}$. The wire carries current $i = 34.8 \text{ mA}$. What are the (a) magnitude and (b) direction (into or out of the page) of the net magnetic field at the semicircle's center of curvature C ?

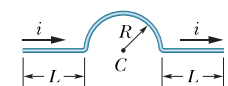


Fig. 29-40 Problem 10.

•11 In Fig. 29-41, two long straight wires are perpendicular to the page and separated by distance $d_1 = 0.75 \text{ cm}$. Wire 1 carries 6.5 A into the page. What are the (a) magnitude and (b) direction (into or out of the page) of the current in wire 2 if the net magnetic field due to the two currents is zero at point P located at distance $d_2 = 1.50 \text{ cm}$ from wire 2?

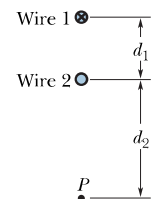


Fig. 29-41 Problem 11.

•12 In Fig. 29-42, two long straight wires at separation $d = 16.0 \text{ cm}$ carry currents $i_1 = 3.61 \text{ mA}$ and $i_2 = 3.00i_1$ out of the page. (a) Where on the x axis is the net magnetic field equal to zero? (b) If the two currents are doubled, is the zero-field point shifted toward wire 1, shifted toward wire 2, or unchanged?

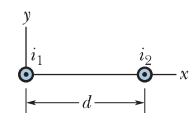


Fig. 29-42 Problem 12.

••13 In Fig. 29-43, point P_1 is at distance $R = 13.1$ cm on the perpendicular bisector of a straight wire of length $L = 18.0$ cm carrying current $i = 58.2$ mA. (Note that the wire is *not* long.) What is the magnitude of the magnetic field at P_1 due to i ?

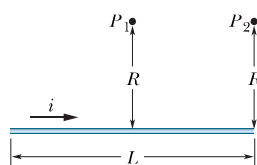


Fig. 29-43 Problems 13 and 17.

••14 Equation 29-4 gives the magnitude B of the magnetic field set up by a current in an *infinitely long* straight wire, at a point P at perpendicular distance R from the wire. Suppose that point P is actually at perpendicular distance R from the midpoint of a wire with a *finite* length L . Using Eq. 29-4 to calculate B then results in a certain percentage error. What value must the ratio L/R exceed if the percentage error is to be less than 1.00%? That is, what L/R gives

$$\frac{(B \text{ from Eq. 29-4}) - (B \text{ actual})}{(B \text{ actual})} (100\%) = 1.00\%$$

••15 Figure 29-44 shows two current segments. The lower segment carries a current of $i_1 = 0.40$ A and includes a semicircular arc with radius 5.0 cm, angle 180° , and center point P . The upper segment carries current $i_2 = 2i_1$ and includes a circular arc with radius 4.0 cm, angle 120° , and the same center point P . What are the (a) magnitude and (b) direction of the net magnetic field \vec{B} at P for the indicated current directions? What are the (c) magnitude and (d) direction of \vec{B} if i_1 is reversed?

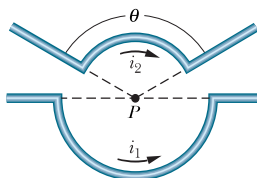


Fig. 29-44 Problem 15.

••16 In Fig. 29-45, two concentric circular loops of wire carrying current in the same direction lie in the same plane. Loop 1 has radius 1.50 cm and carries 4.00 mA. Loop 2 has radius 2.50 cm and carries 6.00 mA. Loop 2 is to be rotated about a diameter while the net magnetic field \vec{B} set up by the two loops at their common center is measured. Through what angle must loop 2 be rotated so that the magnitude of that net field is 100 nT?



Fig. 29-45 Problem 16.

••17 SSM In Fig. 29-43, point P_2 is at perpendicular distance $R = 25.1$ cm from one end of a straight wire of length $L = 13.6$ cm carrying current $i = 0.693$ A. (Note that the wire is *not* long.) What is the magnitude of the magnetic field at P_2 ?

••18 A current is set up in a wire loop consisting of a semicircle of radius 4.00 cm, a smaller concentric semicircle, and two radial straight lengths, all in the same plane. Figure 29-46a shows the arrangement but is not drawn to scale. The magnitude of the magnetic field produced at the center of curvature is $47.25 \mu\text{T}$. The smaller semicircle is then flipped over (rotated) until the loop is again entirely in the same plane (Fig. 29-46b). The magnetic field produced at the (same) center of curvature now has magnitude $15.75 \mu\text{T}$, and its direction is reversed. What is the radius of the smaller semicircle?

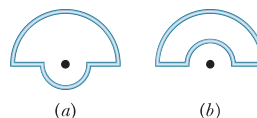


Fig. 29-46 Problem 18.

••19 One long wire lies along an x axis and carries a current of 30 A in the positive x direction. A second long wire is perpendicular to the xy plane, passes through the point $(0, 4.0 \text{ m}, 0)$, and carries a current of 40 A in the positive z direction. What is the magnitude of the resulting magnetic field at the point $(0, 2.0 \text{ m}, 0)$?

••20 In Fig. 29-47, part of a long insulated wire carrying current $i = 5.78$ mA is bent into a circular section of radius $R = 1.89$ cm. In unit-vector notation, what is the magnetic field at the center of curvature C if the circular section (a) lies in the plane of the page as shown and (b) is perpendicular to the plane of the page after being rotated 90° counterclockwise as indicated?

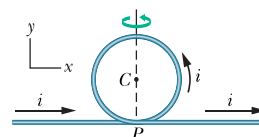


Fig. 29-47 Problem 20.

••21 Figure 29-48 shows two very long straight wires (in cross section) that each carry a current of 4.00 A directly out of the page. Distance $d_1 = 6.00$ m and distance $d_2 = 4.00$ m. What is the magnitude of the net magnetic field at point P , which lies on a perpendicular bisector to the wires?

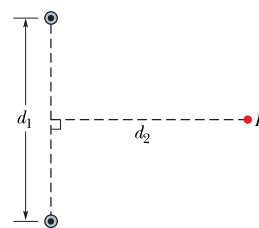


Fig. 29-48 Problem 21.

••22 Figure 29-49a shows, in cross section, two long, parallel wires carrying current and separated by distance L . The ratio i_1/i_2 of their currents is 4.00; the directions of the currents are not indicated. Figure 29-49b shows the y component B_y of their net magnetic field along the x axis to the right of wire 2. The vertical scale is set by $B_{ys} = 4.0$ nT, and the horizontal scale is set by $x_s = 20.0$ cm. (a) At what value of $x > 0$ is B_y maximum? (b) If $i_2 = 3$ mA, what is the value of that maximum? What is the direction (into or out of the page) of (c) i_1 and (d) i_2 ?

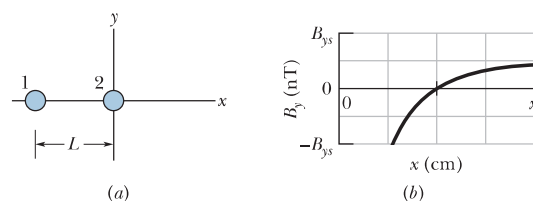


Fig. 29-49 Problem 22.

••23 ILW Figure 29-50 shows a snapshot of a proton moving at velocity $\vec{v} = (-200 \text{ m/s})\hat{j}$ toward a long straight wire with current $i = 350$ mA. At the instant shown, the proton's distance from the wire is $d = 2.89$ cm. In unit-vector notation, what is the magnetic force on the proton due to the current?

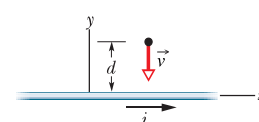


Fig. 29-50 Problem 23.

••24 Figure 29-51 shows, in cross section, four thin wires that are parallel, straight, and very long. They carry identical currents in the directions indicated. Initially all four wires are at distance $d = 15.0$ cm from the origin of the coordinate system, where they cre-

ate a net magnetic field \vec{B} . (a) To what value of x must you move wire 1 along the x axis in order to rotate \vec{B} counter-clockwise by 30° ? (b) With wire 1 in that new position, to what value of x must you move wire 3 along the x axis to rotate \vec{B} by 30° back to its initial orientation?

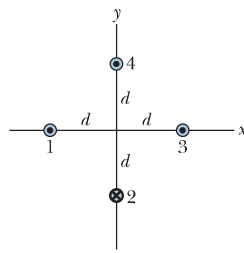


Fig. 29-51
Problem 24.

••25 **SSM** A wire with current $i = 3.00$ A is shown in Fig. 29-52. Two semi-infinite straight sections, both tangent to the same circle, are connected by a circular arc that has a central angle θ and runs along the circumference of the circle. The arc and the two straight sections all lie in the same plane. If $B = 0$ at the circle's center, what is θ ?

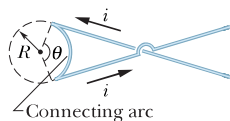


Fig. 29-52
Problem 25.

••26 In Fig. 29-53a, wire 1 consists of a circular arc and two radial lengths; it carries current $i_1 = 0.50$ A in the direction indicated. Wire 2, shown in cross section, is long, straight, and perpendicular to the plane of the figure. Its distance from the center of the arc is equal to the radius R of the arc, and it carries a current i_2 that can be varied. The two currents set up a net magnetic field \vec{B} at the center of the arc. Figure 29-53b gives the square of the field's magnitude B^2 plotted versus the square of the current i_2^2 . The vertical scale is set by $B_s^2 = 10.0 \times 10^{-10} \text{ T}^2$. What angle is subtended by the arc?

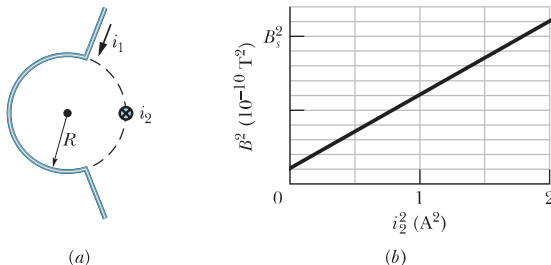


Fig. 29-53 Problem 26.

••27 In Fig. 29-54, two long straight wires (shown in cross section) carry currents $i_1 = 30.0$ mA and $i_2 = 40.0$ mA directly out of the page. They are equal distances from the origin, where they set up a magnetic field \vec{B} . To what value must current i_1 be changed in order to rotate \vec{B} 20.0° clockwise?

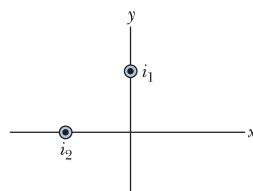


Fig. 29-54 Problem 27.

••28 **SSM** Figure 29-55a shows two wires, each carrying a current. Wire 1 consists of a circular arc of radius R and two radial lengths; it carries current $i_1 = 2.0$ A in the direction indicated. Wire 2 is long and straight; it carries a current i_2 that can be varied; and it is at distance $R/2$ from the center of the arc. The net magnetic field \vec{B} due to the two currents is measured at

the center of curvature of the arc. Figure 29-55b is a plot of the component of \vec{B} in the direction perpendicular to the figure as a function of current i_2 . The horizontal scale is set by $i_{2s} = 1.00$ A. What is the angle subtended by the arc?

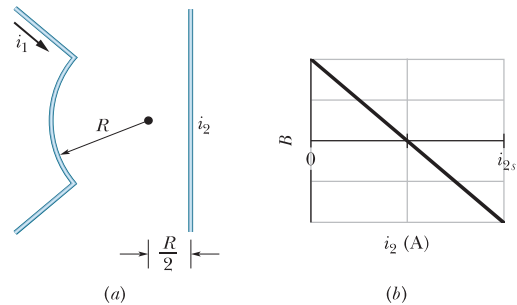


Fig. 29-55 Problem 28.

••29 **SSM** In Fig. 29-56, four long straight wires are perpendicular to the page, and their cross sections form a square of edge length $a = 20$ cm. The currents are out of the page in wires 1 and 4 and into the page in wires 2 and 3, and each wire carries 20 A. In unit-vector notation, what is the net magnetic field at the square's center?

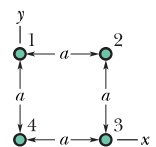


Fig. 29-56
Problems 29,
37, and 40.

••30 Two long straight thin wires with current lie against an equally long plastic cylinder, at radius $R = 20.0$ cm from the cylinder's central axis.

Figure 29-57a shows, in cross section, the cylinder and wire 1 but not wire 2. With wire 2 fixed in place, wire 1 is moved around the cylinder, from angle $\theta_1 = 0^\circ$ to angle $\theta_1 = 180^\circ$, through the first and second quadrants of the xy coordinate system. The net magnetic field

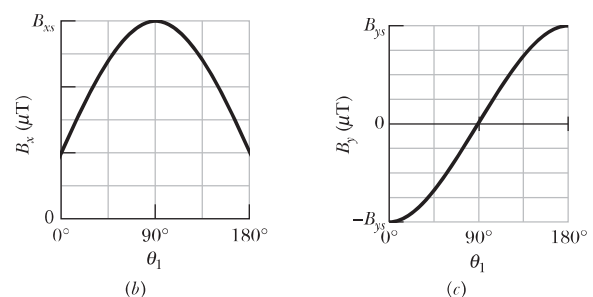
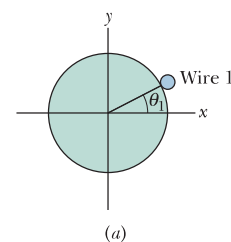


Fig. 29-57 Problem 30.

\vec{B} at the center of the cylinder is measured as a function of θ_1 . Figure 29-57b gives the x component B_x of that field as a function of θ_1 (the vertical scale is set by $B_{xs} = 6.0 \mu\text{T}$), and Fig. 29-57c gives the y component B_y (the vertical scale is set by $B_{ys} = 4.0 \mu\text{T}$). (a) At what angle θ_2 is wire 2 located? What are the (b) size and (c) direction (into or out of the page) of the current in wire 1 and the (d) size and (e) direction of the current in wire 2?

•••31 In Fig. 29-58, length a is 4.7 cm (short) and current i is 13 A. What are the (a) magnitude and (b) direction (into or out of the page) of the magnetic field at point P ?

•••32 The current-carrying wire loop in Fig. 29-59a lies all in one plane and consists of a semicircle of radius 10.0 cm, a smaller semicircle with the same center, and two radial lengths. The smaller semicircle is rotated out of that plane by angle θ , until it is perpendicular to the plane (Fig. 29-59b). Figure 29-59c gives the magnitude of the net magnetic field at the center of curvature versus angle θ . The vertical scale is set by $B_a = 10.0 \mu\text{T}$ and $B_b = 12.0 \mu\text{T}$. What is the radius of the smaller semicircle?

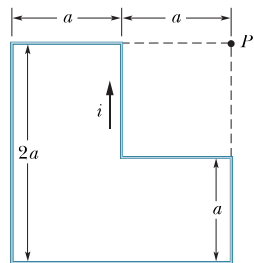


Fig. 29-58 Problem 31.

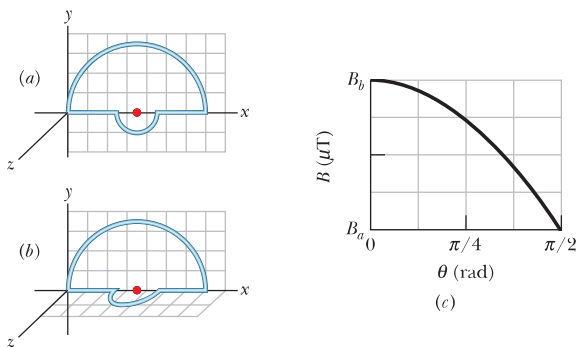


Fig. 29-59 Problem 32.

•••33 **SSM ILW** Figure 29-60 shows a cross section of a long thin ribbon of width $w = 4.91 \text{ cm}$ that is carrying a uniformly distributed total current $i = 4.61 \mu\text{A}$ into the page. In unit-vector notation, what is the magnetic field \vec{B} at a point P in the plane of the ribbon at a distance $d = 2.16 \text{ cm}$ from its edge? (*Hint:* Imagine the ribbon as being constructed from many long, thin, parallel wires.)

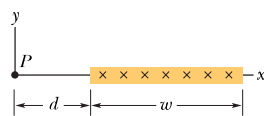


Fig. 29-60 Problem 33.

•••34 Figure 29-61 shows, in cross section, two long straight wires held against a plastic cylinder of radius 20.0 cm. Wire 1 carries current $i_1 = 60.0 \text{ mA}$ out of the page and is fixed in place at the left side of the cylinder. Wire 2 carries current $i_2 = 40.0$

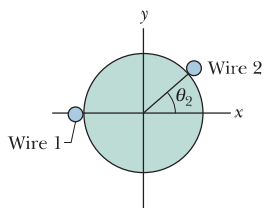


Fig. 29-61 Problem 34.

mA out of the page and can be moved around the cylinder. At what (positive) angle θ_2 should wire 2 be positioned such that, at the origin, the net magnetic field due to the two currents has magnitude 80.0 nT?

sec. 29-3 Force Between Two Parallel Currents

•35 **SSM** Figure 29-62 shows wire 1 in cross section; the wire is long and straight, carries a current of 4.00 mA out of the page, and is at distance $d_1 = 2.40 \text{ cm}$ from a surface. Wire 2, which is parallel to wire 1 and also long, is at horizontal distance $d_2 = 5.00 \text{ cm}$ from wire 1 and carries a current of 6.80 mA into the page. What is the x component of the magnetic force per unit length on wire 2 due to wire 1?

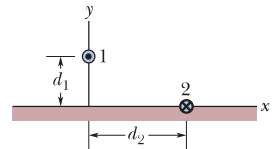


Fig. 29-62 Problem 35.

••36 In Fig. 29-63, five long parallel wires in an xy plane are separated by distance $d = 8.00 \text{ cm}$, have lengths of 10.0 m, and carry identical currents of 3.00 A out of the page. Each wire experiences a magnetic force due to the other wires. In unit-vector notation, what is the net magnetic force on (a) wire 1, (b) wire 2, (c) wire 3, (d) wire 4, and (e) wire 5?

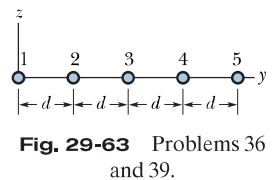


Fig. 29-63 Problems 36 and 39.

••37 **SSM** In Fig. 29-56, four long straight wires are perpendicular to the page, and their cross sections form a square of edge length $a = 13.5 \text{ cm}$. Each wire carries 7.50 A, and the currents are out of the page in wires 1 and 4 and into the page in wires 2 and 3. In unit-vector notation, what is the net magnetic force per meter of wire length on wire 4?

••38 Figure 29-64a shows, in cross section, three current-carrying wires that are long, straight, and parallel to one another. Wires 1 and 2 are fixed in place on an x axis, with separation d . Wire 1 has a current of 0.750 A, but the direction of the current is not given. Wire 3, with a current of 0.250 A out of the page, can be moved along the x axis to the right of wire 2. As wire 3 is moved, the magnitude of the net magnetic force \vec{F}_2 on wire 2 due to the currents in wires 1 and 3 changes. The x component of that force is F_{2x} and the value per unit length of wire 2 is F_{2x}/L_2 . Figure 29-64b gives F_{2x}/L_2 versus the position x of wire 3. The plot has an asymptote $F_{2x}/L_2 = -0.627 \mu\text{N/m}$ as $x \rightarrow \infty$. The horizontal scale is set by $x_s = 12.0 \text{ cm}$. What are the (a) size and (b) direction (into or out of the page) of the current in wire 2?

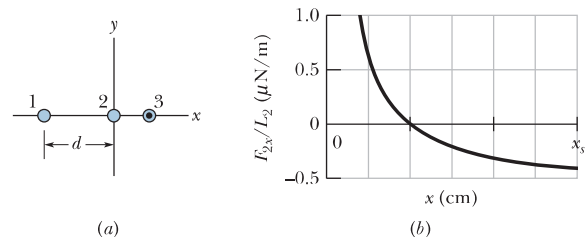


Fig. 29-64 Problem 38.

••39 **SSM** In Fig. 29-63, five long parallel wires in an xy plane are separated by distance $d = 50.0 \text{ cm}$. The currents into the page are

$i_1 = 2.00$ A, $i_3 = 0.250$ A, $i_4 = 4.00$ A, and $i_5 = 2.00$ A; the current out of the page is $i_2 = 4.00$ A. What is the magnitude of the net force *per unit length* acting on wire 3 due to the currents in the other wires?

••40 In Fig. 29-56, four long straight wires are perpendicular to the page, and their cross sections form a square of edge length $a = 8.50$ cm. Each wire carries 15.0 A, and all the currents are out of the page. In unit-vector notation, what is the net magnetic force *per meter of wire length* on wire 1?

••41 ILW In Fig. 29-65, a long straight wire carries a current $i_1 = 30.0$ A and a rectangular loop carries current $i_2 = 20.0$ A. Take $a = 1.00$ cm, $b = 8.00$ cm, and $L = 30.0$ cm. In unit-vector notation, what is the net force on the loop due to i_1 ?

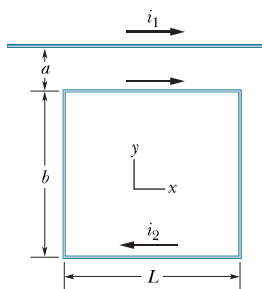


Fig. 29-65 Problem 41.

sec. 29-4 Ampere's Law

•42 In a particular region there is a uniform current density of 15 A/m² in the positive z direction. What is the value of $\oint \vec{B} \cdot d\vec{s}$ when that line integral is calculated along the three straight-line segments from (x, y, z) coordinates $(4d, 0, 0)$ to $(4d, 3d, 0)$ to $(0, 0, 0)$ to $(4d, 0, 0)$, where $d = 20$ cm?

•43 Figure 29-66 shows a cross section across a diameter of a long cylindrical conductor of radius $a = 2.00$ cm carrying uniform current 170 A. What is the magnitude of the current's magnetic field at radial distance (a) 0 , (b) 1.00 cm, (c) 2.00 cm (wire's surface), and (d) 4.00 cm?

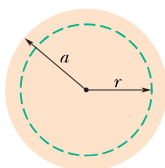


Fig. 29-66 Problem 43.

•44 Figure 29-67 shows two closed paths wrapped around two conducting loops carrying currents $i_1 = 5.0$ A and $i_2 = 3.0$ A. What is the value of the integral $\oint \vec{B} \cdot d\vec{s}$ for (a) path 1 and (b) path 2?

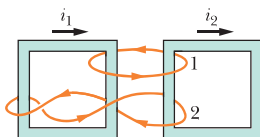


Fig. 29-67 Problem 44.

•45 SSM Each of the eight conductors in Fig. 29-68 carries 2.0 A of current into or out of the page. Two paths are indicated for the line integral $\oint \vec{B} \cdot d\vec{s}$. What is the value of the integral for (a) path 1 and (b) path 2?

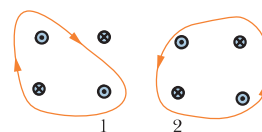


Fig. 29-68 Problem 45.

•46 Eight wires cut the page perpendicularly at the points shown in Fig. 29-69. A wire labeled with the integer k ($k = 1, 2, \dots, 8$) carries the current ki , where $i = 4.50$ mA. For those wires with odd k , the current is out of the page; for those with even k , it is into the page. Evaluate $\oint \vec{B} \cdot d\vec{s}$ along the closed path in the direction shown.

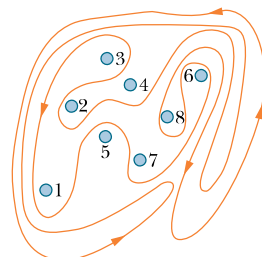


Fig. 29-69 Problem 46.

••47 ILW The current density \vec{J} inside a long, solid, cylindrical wire

of radius $a = 3.1$ mm is in the direction of the central axis, and its magnitude varies linearly with radial distance r from the axis according to $J = J_0 r/a$, where $J_0 = 310$ A/m².

Find the magnitude of the magnetic field at (a) $r = 0$, (b) $r = a/2$, and (c) $r = a$.

••48 In Fig. 29-70, a long circular pipe with outside radius $R = 2.6$ cm carries a (uniformly distributed) current $i = 8.00$ mA into the page. A wire runs parallel to the pipe at a distance of $3.00R$ from center to center. Find the (a) magnitude and (b) direction (into or out of the page) of the current in the wire such that the net magnetic field at point P has the same magnitude as the net magnetic field at the center of the pipe but is in the opposite direction.

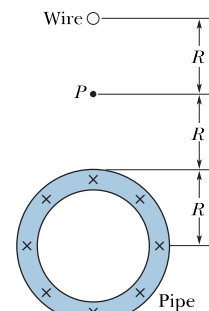


Fig. 29-70 Problem 48.

sec. 29-5 Solenoids and Toroids

•49 A toroid having a square cross section, 5.00 cm on a side, and an inner radius of 15.0 cm has 500 turns and carries a current of 0.800 A. (It is made up of a square solenoid—instead of a round one as in Fig. 29-16—bent into a doughnut shape.) What is the magnetic field inside the toroid at (a) the inner radius and (b) the outer radius?

•50 A solenoid that is 95.0 cm long has a radius of 2.00 cm and a winding of 1200 turns; it carries a current of 3.60 A. Calculate the magnitude of the magnetic field inside the solenoid.

•51 A 200 -turn solenoid having a length of 25 cm and a diameter of 10 cm carries a current of 0.29 A. Calculate the magnitude of the magnetic field \vec{B} inside the solenoid.

•52 A solenoid 1.30 m long and 2.60 cm in diameter carries a current of 18.0 A. The magnetic field inside the solenoid is 23.0 mT. Find the length of the wire forming the solenoid.

••53 A long solenoid has 100 turns/cm and carries current i . An electron moves within the solenoid in a circle of radius 2.30 cm perpendicular to the solenoid axis. The speed of the electron is $0.0460c$ (c = speed of light). Find the current i in the solenoid.

••54 An electron is shot into one end of a solenoid. As it enters the uniform magnetic field within the solenoid, its speed is 800 m/s and its velocity vector makes an angle of 30° with the central axis of the solenoid. The solenoid carries 4.0 A and has 8000 turns along its length. How many revolutions does the electron make along its helical path within the solenoid by the time it emerges from the solenoid's opposite end? (In a real solenoid, where the field is not uniform at the two ends, the number of revolutions would be slightly less than the answer here.)

••55 SSM ILW WWW A long solenoid with 10.0 turns/cm and a radius of 7.00 cm carries a current of 20.0 mA. A current of 6.00 A exists in a straight conductor located along the central axis of the solenoid. (a) At what radial distance from the axis will the direction of the resulting magnetic field be at 45.0° to the axial direction? (b) What is the magnitude of the magnetic field there?

sec. 29-6 A Current-Carrying Coil as a Magnetic Dipole

•56 Figure 29-71 shows an arrangement known as a Helmholtz coil. It consists of two circular coaxial coils, each of 200 turns and radius

$R = 25.0$ cm, separated by a distance $s = R$. The two coils carry equal currents $i = 12.2$ mA in the same direction. Find the magnitude of the net magnetic field at P , midway between the coils.

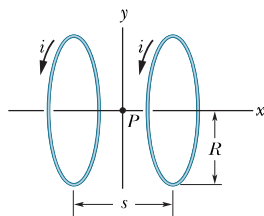


Fig. 29-71 Problems 56 and 90.

•57 SSM A student makes a short electromagnet by winding 300 turns of wire around a wooden cylinder of diameter $d = 5.0$ cm. The coil is connected to a battery producing a current of 4.0 A in the wire. (a) What is the magnitude of the magnetic dipole moment of this device? (b) At what axial distance $z \gg d$ will the magnetic field have the magnitude $5.0 \mu\text{T}$ (approximately one-tenth that of Earth's magnetic field)?

•58 Figure 29-72a shows a length of wire carrying a current i and bent into a circular coil of one turn. In Fig. 29-72b the same length of wire has been bent to give a coil of two turns, each of half the original radius. (a) If B_a and B_b are the magnitudes of the magnetic fields at the centers of the two coils, what is the ratio B_b/B_a ? (b) What is the ratio μ_b/μ_a of the dipole moment magnitudes of the coils?

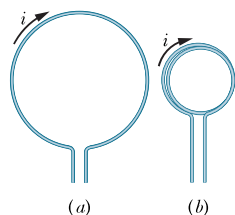


Fig. 29-72 Problem 58.

•59 SSM What is the magnitude of the magnetic dipole moment $\vec{\mu}$ of the solenoid described in Problem 51?

••60 In Fig. 29-73a, two circular loops, with different currents but the same radius of 4.0 cm, are centered on a y axis. They are initially separated by distance $L = 3.0$ cm, with loop 2 positioned at the origin of the axis. The currents in the two loops produce a net magnetic field at the origin, with y component B_y . That component is to be measured as loop 2 is gradually moved in the positive direction of the y axis. Figure 29-73b gives B_y as a function of the position y of loop 2. The curve approaches an asymptote of $B_y = 7.20 \mu\text{T}$ as $y \rightarrow \infty$. The horizontal scale is set by $y_s = 10.0$ cm. What are (a) current i_1 in loop 1 and (b) current i_2 in loop 2?

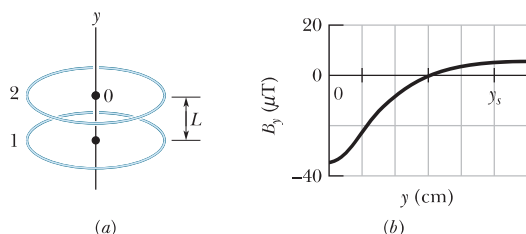


Fig. 29-73 Problem 60.

••61 A circular loop of radius 12 cm carries a current of 15 A. A flat coil of radius 0.82 cm, having 50 turns and a current of 1.3 A, is

concentric with the loop. The plane of the loop is perpendicular to the plane of the coil. Assume the loop's magnetic field is uniform across the coil. What is the magnitude of (a) the magnetic field produced by the loop at its center and (b) the torque on the coil due to the loop?

••62 In Fig. 29-74, current $i = 56.2$ mA is set up in a loop having two radial lengths and two semicircles of radii $a = 5.72$ cm and $b = 9.36$ cm with a common center P . What are the (a) magnitude and (b) direction (into or out of the page) of the magnetic field at P and the (c) magnitude and (d) direction of the loop's magnetic dipole moment?

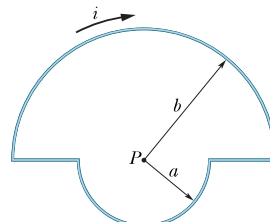


Fig. 29-74 Problem 62.

••63 In Fig. 29-75, a conductor carries 6.0 A along the closed path $abcdefgha$ running along 8 of the 12 edges of a cube of edge length 10 cm. (a) Taking the path to be a combination of three square current loops ($bcbfgb$, $abgha$, and $cdefc$), find the net magnetic moment of the path in unit-vector notation. (b) What is the magnitude of the net magnetic field at the xyz coordinates of $(0, 5.0 \text{ m}, 0)$?

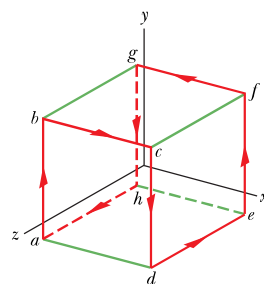


Fig. 29-75 Problem 63.

Additional Problems

64 In Fig. 29-76, a closed loop carries current $i = 200$ mA. The loop consists of two radial straight wires and two concentric circular arcs of radii 2.00 m and 4.00 m. The angle θ is $\pi/4$ rad. What are the (a) magnitude and (b) direction (into or out of the page) of the net magnetic field at the center of curvature P ?

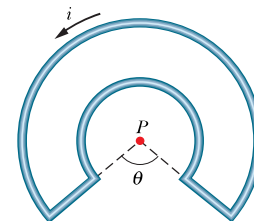


Fig. 29-76 Problem 64.

65 A cylindrical cable of radius 8.00 mm carries a current of 25.0 A, uniformly spread over its cross-sectional area. At what distance from the center of the wire is there a point within the wire where the magnetic field magnitude is 0.100 mT?

66 Two long wires lie in an xy plane, and each carries a current in the positive direction of the x axis. Wire 1 is at $y = 10.0$ cm and carries 6.00 A; wire 2 is at $y = 5.00$ cm and carries 10.0 A. (a) In unit-vector notation, what is the net magnetic field \vec{B} at the origin? (b) At what value of y does $\vec{B} = 0$? (c) If the current in wire 1 is reversed, at what value of y does $\vec{B} = 0$?

67 Two wires, both of length L , are formed into a circle and a square, and each carries current i . Show that the square produces a greater magnetic field at its center than the circle produces at its center.

68 A long straight wire carries a current of 50 A. An electron, traveling at 1.0×10^7 m/s, is 5.0 cm from the wire. What is the magnitude of the magnetic force on the electron if the electron velocity is directed (a) toward the wire, (b) parallel to the wire in the direction of the current, and (c) perpendicular to the two directions defined by (a) and (b)?