Q30.2 No magnetic field is created by a stationary charge, as the rate of flow is zero. A moving charge creates a magnetic field.

Q30.3 The magnetic field created by wire 1 at the position of wire 2 is into the paper. Hence, the magnetic force on wire 2 is in direction down × into the paper = to the right, away from wire 1. Now wire 2 creates a magnetic field into the page at the location of wire 1, so wire 1 feels force up ×into the paper = left, away from wire 2.

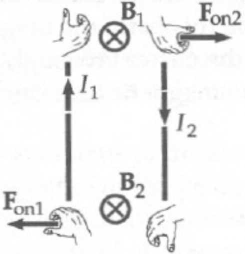

FIG. Q30.3

Q30.18 Atoms that do not have a permanent magnetic dipole moment have electrons with spin and orbital magnetic moments that add to zero as vectors. Atoms with a permanent dipole moment have electrons with orbital and spin magnetic moments that show some net alignment.

Q30.26 The medium for any magnetic recording should be a hard ferromagnetic substance, so that thermal vibrations and stray magnetic fields will not rapidly erase the information.

Section 30.1 The Biot-Savart Law

P30.1 $B = \dfrac{\mu_0 I}{2R} = \dfrac{\mu_0 q(v/2\pi R)}{2R} = \boxed{12.5\ \text{T}}$

P30.2 $B = \dfrac{\mu_0 I}{2\pi R} = \dfrac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(1.00 \times 10^{4}\ \text{A})}{2\pi(100\ \text{m})} = 2.00 \times 10^{-5}\ \text{T} = \boxed{20.0\ \mu\text{T}}$

P30.3 (a) $$B = \frac{4\mu_0 I}{4\pi a}\left(\cos\frac{\pi}{4} - \cos\frac{3\pi}{4}\right) \text{ where } a = \frac{\ell}{2}$$

is the distance from any side to the center.

$$B = \frac{4.00 \times 10^{-6}}{0.200}\left(\frac{\sqrt{2}}{2} + \frac{\sqrt{2}}{2}\right) = 2\sqrt{2} \times 10^{-5}\ \text{T} = \boxed{28.3\ \mu\text{T into the paper}}$$

FIG. P30.3

(b) For a single circular turn with $4\ell = 2\pi R$,

$$B = \frac{\mu_0 I}{2R} = \frac{\mu_0 \pi I}{4\ell} = \frac{(4\pi^2 \times 10^{-7})(10.0)}{4(0.400)} = \boxed{24.7\ \mu\text{T into the paper}}$$

P30.6 We can think of the total magnetic field as the superposition of the field due to the long straight wire (having magnitude $\frac{\mu_0 I}{2\pi R}$ and directed into the page) and the field due to the circular loop (having magnitude $\frac{\mu_0 I}{2R}$ and directed into the page). The resultant magnetic field is:

$$\boxed{\mathbf{B} = \left(1+\frac{1}{\pi}\right)\frac{\mu_0 I}{2R} \text{ (directed into the page)}}.$$

P30.16 Let both wires carry current in the x direction, the first at $y = 0$ and the second at $y = 10.0$ cm.

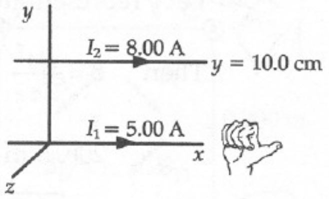

FIG. P30.16(a)

(a) $$\mathbf{B} = \frac{\mu_0 I}{2\pi r}\hat{\mathbf{k}} = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(5.00\ \text{A})}{2\pi(0.100\ \text{m})}\hat{\mathbf{k}}$$

$$\mathbf{B} = \boxed{1.00 \times 10^{-5}\ \text{T out of the page}}$$

(b) $$\mathbf{F}_B = I_2 \boldsymbol{\ell} \times \mathbf{B} = (8.00\ \text{A})\left[(1.00\ \text{m})\hat{\mathbf{i}} \times \left(1.00 \times 10^{-5}\ \text{T}\right)\hat{\mathbf{k}}\right] = \left(8.00 \times 10^{-5}\ \text{N}\right)\left(-\hat{\mathbf{j}}\right)$$

$$\boxed{\mathbf{F}_B = 8.00 \times 10^{-5}\ \text{N toward the first wire}}$$

(c) $$\mathbf{B} = \frac{\mu_0 I}{2\pi r}\left(-\hat{\mathbf{k}}\right) = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(8.00\ \text{A})}{2\pi(0.100\ \text{m})}\left(-\hat{\mathbf{k}}\right) = \left(1.60 \times 10^{-5}\ \text{T}\right)\left(-\hat{\mathbf{k}}\right)$$

$$\mathbf{B} = \boxed{1.60 \times 10^{-5}\ \text{T into the page}}$$

(d) $$\mathbf{F}_B = I_1 \boldsymbol{\ell} \times \mathbf{B} = (5.00\ \text{A})\left[(1.00\ \text{m})\hat{\mathbf{i}} \times \left(1.60 \times 10^{-5}\ \text{T}\right)\left(-\hat{\mathbf{k}}\right)\right] = \left(8.00 \times 10^{-5}\ \text{N}\right)\left(+\hat{\mathbf{j}}\right)$$

$$\mathbf{F}_B = \boxed{8.00 \times 10^{-5}\ \text{N towards the second wire}}$$

P30.17 By symmetry, we note that the magnetic forces on the top and bottom segments of the rectangle cancel. The net force on the vertical segments of the rectangle is (using Equation 30.11)

$$\mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2 = \frac{\mu_0 I_1 I_2 \ell}{2\pi}\left(\frac{1}{c+a} - \frac{1}{c}\right)\hat{\mathbf{i}} = \frac{\mu_0 I_1 I_2 \ell}{2\pi}\left(\frac{-a}{c(c+a)}\right)\hat{\mathbf{i}}$$

$$\mathbf{F} = \frac{\left(4\pi \times 10^{-7}\ \mathrm{N/A^2}\right)(5.00\ \mathrm{A})(10.0\ \mathrm{A})(0.450\ \mathrm{m})}{2\pi}\left(\frac{-0.150\ \mathrm{m}}{(0.100\ \mathrm{m})(0.250\ \mathrm{m})}\right)\hat{\mathbf{i}}$$

$$\mathbf{F} = \left(-2.70 \times 10^{-5}\,\hat{\mathbf{i}}\right)\ \mathrm{N}$$

or $\mathbf{F} = \boxed{2.70 \times 10^{-5}\ \mathrm{N\ toward\ the\ left}}$.

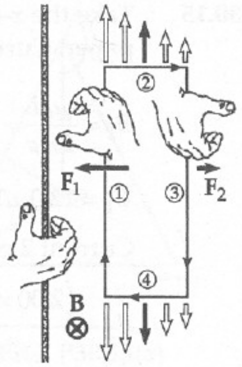

FIG. P30.17

P30.23 From Ampere's law, the magnetic field at point a is given by $B_a = \frac{\mu_0 I_a}{2\pi r_a}$, where I_a is the net current through the area of the circle of radius r_a. In this case, $I_a = 1.00$ A out of the page (the current in the inner conductor), so

$$B_a = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(1.00\ \text{A})}{2\pi(1.00 \times 10^{-3}\ \text{m})} = \boxed{200\ \mu\text{T toward top of page}}.$$

Similarly at point b: $B_b = \frac{\mu_0 I_b}{2\pi r_b}$, where I_b is the net current through the area of the circle having radius r_b.

Taking out of the page as positive, $I_b = 1.00\ \text{A} - 3.00\ \text{A} = -2.00\ \text{A}$, or $I_b = 2.00$ A into the page. Therefore,

$$B_b = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(2.00\ \text{A})}{2\pi(3.00 \times 10^{-3}\ \text{m})} = \boxed{133\ \mu\text{T toward bottom of page}}.$$