PHYS 221

Electromagnetism (1)
2nd semester 1446

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Problems 6

Chapter 30 Problems

4,16,17,31,35,63

4. Calculate the magnitude of the magnetic field at a point 100 cm from a long, thin conductor carrying a current of 1.00 A.

$$B = \frac{\mu_0 I}{2\pi r} = \frac{\left(4\pi \times 10^{-7}\right)(1.00\ \text{A})}{2\pi(1.00\ \text{m})} = \boxed{2.00 \times 10^{-7}\ \text{T}}$$

16. Two long, parallel conductors, separated by 10.0 cm, carry currents in the same direction. The first wire carries current $I_1 = 5.00$ A and the second carries $I_2 = 8.00$ A. (a) What is the magnitude of the magnetic field created by I_1 at the location of I_2? (b) What is the force per unit length exerted by I_1 on I_2? (c) What is the magnitude of the magnetic field created by I_2 at the location of I_1? (d) What is the force per length exerted by I_2 on I_1?

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

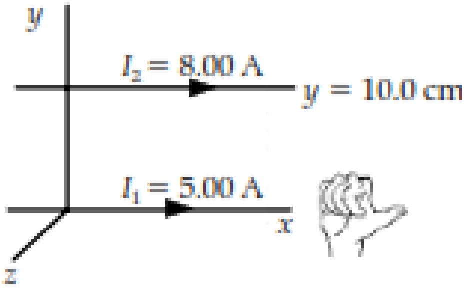


FIG. P30.16(a)

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

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

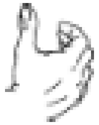
(b) $$\mathbf{F}_B = I_2 \boldsymbol{\ell} \times \mathbf{B} = (8.00\ \text{A})\left[(1.00\ \text{m})\hat{\mathbf{i}} \times (1.00 \times 10^{-5}\ \text{T})\hat{\mathbf{k}}\right] = (8.00 \times 10^{-5}\ \text{N})(-\hat{\mathbf{j}})$$

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

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

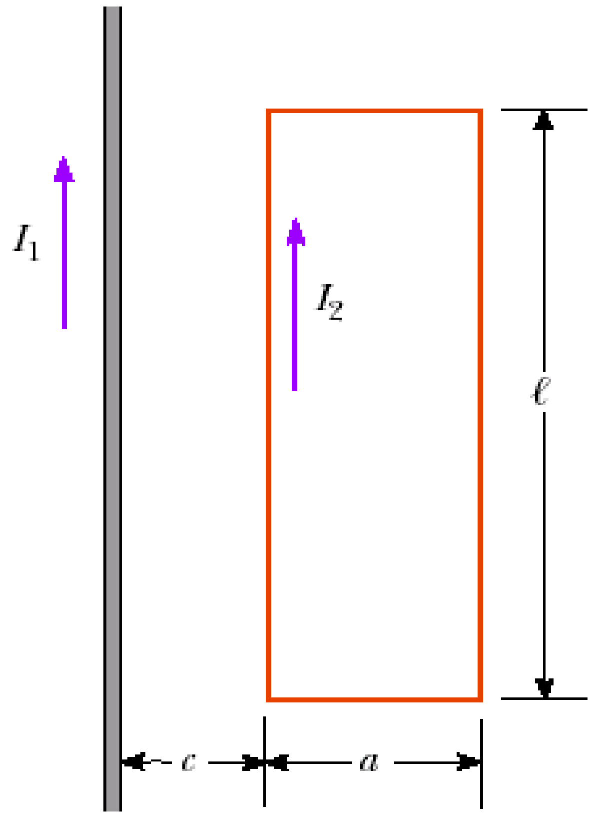
$$\mathbf{B} = \boxed{1.60 \times 10^{-5}\ \text{T into the page}}$$

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



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

17. In Figure P30.17, the current in the long, straight wire is $I_1 = 5.00$ A and the wire lies in the plane of the rectangular loop, which carries the current $I_2 = 10.0$ A. The dimensions are $c = 0.100$ m, $a = 0.150$ m, and $\ell = 0.450$ m. Find the magnitude and direction of the net force exerted on the loop by the magnetic field created by the wire.



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

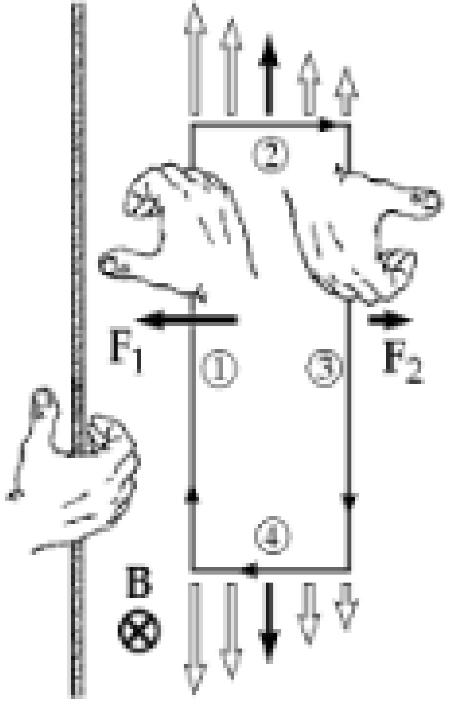
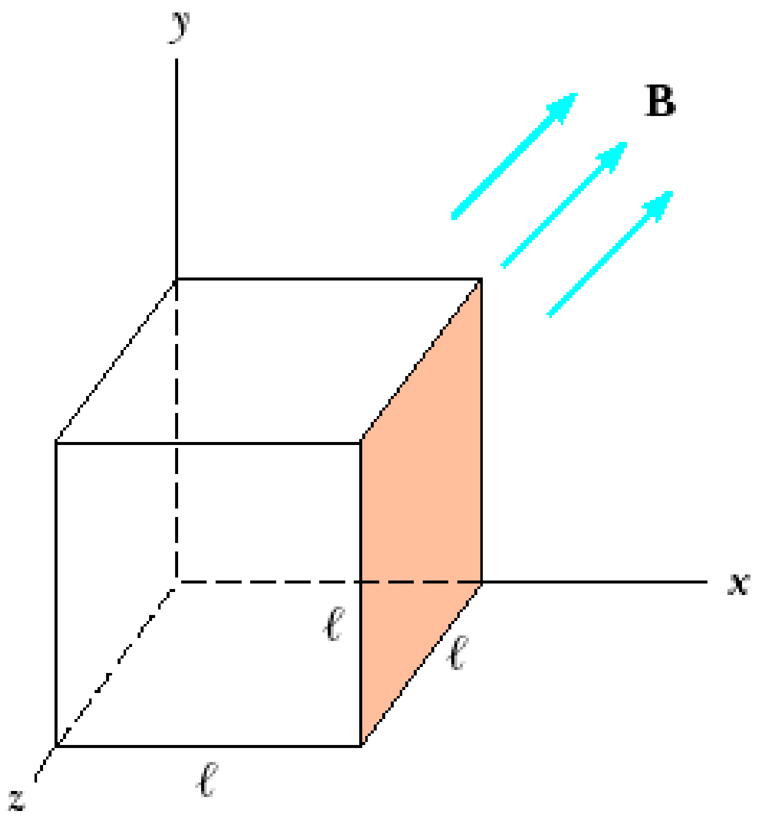


FIG. P30.17

31. What current is required in the windings of a long solenoid that has 1 000 turns uniformly distributed over a length of 0.400 m, to produce at the center of the solenoid a magnetic field of magnitude 1.00 × 10–4 T?

$$B = \mu_0 \frac{N}{\ell} I \text{ so } I = \frac{B}{\mu_0 n} = \frac{\left(1.00 \times 10^{-4}\ \text{T}\right) 0.400\ \text{m}}{\left(4\pi \times 10^{-7}\ \text{T} \cdot \text{m/A}\right) 1\,000} = \boxed{31.8\ \text{mA}}$$

35. A cube of edge length ℓ = 2.50 cm is positioned as shown in Figure P30.35. A uniform magnetic field given by B = (5 + 4 + 3)T exists throughout the region. (a) Calculate the flux through the shaded face. (b) What is the total flux through the six faces?

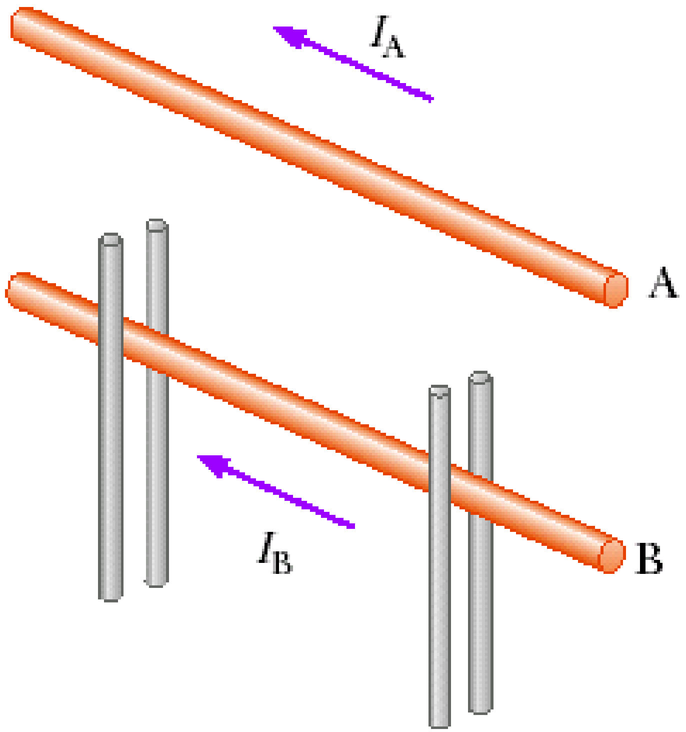


(a) $\Phi_B = \int \mathbf{B} \cdot d\mathbf{A} = \mathbf{B} \cdot \mathbf{A} = \left(5\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + 3\hat{\mathbf{k}}\right) \text{T} \cdot \left(2.50 \times 10^{-2} \text{ m}\right)^2 \hat{\mathbf{i}}$

$\Phi_B = 3.12 \times 10^{-3} \text{ T} \cdot \text{m}^2 = 3.12 \times 10^{-3} \text{ Wb} = \boxed{3.12 \text{ mWb}}$

(b) $\left(\Phi_B\right)_{\text{total}} = \oint \mathbf{B} \cdot d\mathbf{A} = \boxed{0}$ for *any* closed surface (Gauss's law for magnetism)

63. Two long, parallel conductors carry currents in the same direction as shown in Figure P30.63. Conductor A carries a current of 150 A and is held firmly in position. Conductor B carries a current IB and is allowed to slide freely up and down (parallel to A) between a set of nonconducting guides. If the mass per unit length of conductor B is 0.100 g/cm, what value of current IB will result in equilibrium when the distance between the two conductors is 2.50 cm?



At equilibrium, $\frac{F_B}{\ell} = \frac{\mu_0 I_A I_B}{2\pi a} = \frac{mg}{\ell}$ or $I_B = \frac{2\pi a (m/\ell) g}{\mu_0 I_A}$

$$I_B = \frac{2\pi(0.025\,0\text{ m})(0.010\,0\text{ kg/m})(9.80\text{ m/s}^2)}{(4\pi \times 10^{-7}\text{ T}\cdot\text{m/A})(150\text{ A})} = \boxed{81.7\text{ A}}$$