# Physics 104 : Discussion 5b

**26.** A copper wire is 8.00 m long, and has a cross-sectional area of 1.00 x $10^{-4}$ $m^2$. This wire forms a 1-turn loop in the shape of a square and is then connected to a battery that applies a potential difference of 0.100 V. If the loop is placed in a uniform magnetic field of magnitude 0.400 T, what is the maximum torque that can act on it? The resistivity of copper is 1.70 x $10^{-8}$ Ω·m.

**19.26** The resistance of the loop is

$$R = \frac{\rho L}{A} = \frac{\left(1.70\times10^{-8}\ \Omega\cdot\text{m}\right)\left(8.00\ \text{m}\right)}{1.00\times10^{-4}\ \text{m}^2} = 1.36\times10^{-3}\ \Omega,$$

and the current in the loop is $I = \dfrac{\Delta V}{R} = \dfrac{0.100\ \text{V}}{1.36\times10^{-3}\ \Omega} = 73.5\ \text{A}$

The magnetic field exerts torque $\tau = NBIA\sin\theta$ on the loop, and this is a maximum when $\sin\theta = 1$. Thus,

$$\tau_{max} = NBIA = (1)(0.400\ \text{T})(73.5\ \text{A})(2.00\ \text{m})^2 = \boxed{118\ \text{N}\cdot\text{m}}$$

**32.** A mass spectrometer is used to examine the isotopes of uranium. Ions in the beam emerge from the velocity selector at a speed of 3.00 X $10^5$ m/s and enter a uniform magnetic field of 0.600 T directed perpendicularly to the velocity of the ions. What is the distance between the impact points formed on the photographic plate by singly charged ions of $^{235}$U and $^{238}$U?

**19.32** Since the centripetal acceleration is furnished by the magnetic force acting on the ions, $qvB = \dfrac{mv^2}{r}$ or the radius of the path is $r = \dfrac{mv}{qB}$. Thus, the distance between the impact points (i.e., the difference in the diameters of the paths followed by the $U_{238}$ and the $U_{235}$ isotopes) is

$$\Delta d = 2\left(r_{238} - r_{235}\right) = \frac{2v}{qB}\left(m_{238} - m_{235}\right)$$

$$= \frac{2\left(3.00\times10^5\ \text{m/s}\right)}{\left(1.60\times10^{-19}\ \text{C}\right)\left(0.600\ \text{T}\right)}\left[\left(238\ \text{u} - 235\ \text{u}\right)\left(1.66\times10^{-27}\ \frac{\text{kg}}{\text{u}}\right)\right]$$

or $\Delta d = 3.11\times10^{-2}\ \text{m} = \boxed{3.11\ \text{cm}}$

**38.** The two wires shown in Figure P19.38 carry currents of 5.00 A in opposite directions and are separated by 10.0 cm. Find the direction and magnitude of the net magnetic field (a) at a point midway between the wires, (b) at point $P_1$ (10.0 cm to the right of the wire on the right), and (c) at point $P_2$ (20.0 cm to the left of the wire on the left).

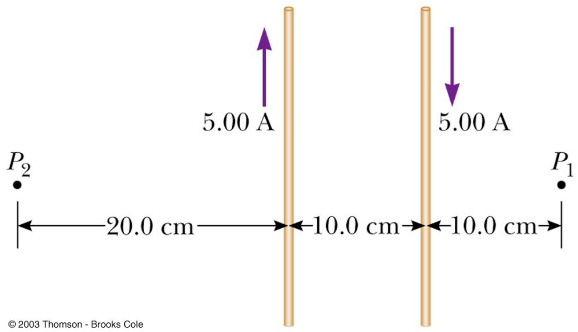


**Figure P19.38**

**19.38** Assume that the wire on the right is wire 1 and that on the left is wire 2. Also, choose the positive direction for the magnetic field to be out of the page and negative into the page.

(a) At the point half way between the two wires,

$$B_{net} = -B_1 - B_2 = -\left[\frac{\mu_0 I_1}{2\pi r_1} + \frac{\mu_0 I_2}{2\pi r_2}\right] = -\frac{\mu_0}{2\pi r}\left(I_1 + I_2\right)$$

$$= -\frac{\left(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}\right)}{2\pi\left(5.00 \times 10^{-2}\ \mathrm{m}\right)}(10.0\ \mathrm{A}) = -4.00 \times 10^{-5}\ \mathrm{T}$$

or $B_{net} = \boxed{40.0\ \mu\mathrm{T}\ \text{into the page}}$

(b) At point $P_1$, $B_{net} = +B_1 - B_2 = \dfrac{\mu_0}{2\pi}\left[\dfrac{I_1}{r_1} - \dfrac{I_2}{r_2}\right]$

$$B_{net} = \frac{\left(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}\right)}{2\pi}\left[\frac{5.00\ \mathrm{A}}{0.100\ \mathrm{m}} - \frac{5.00\ \mathrm{A}}{0.200\ \mathrm{m}}\right] = \boxed{5.00\ \mu\mathrm{T}\ \text{out of page}}$$

(c) At point $P_2$, $B_{net} = -B_1 + B_2 = \dfrac{\mu_0}{2\pi}\left[-\dfrac{I_1}{r_1} + \dfrac{I_2}{r_2}\right]$

$$B_{net} = \frac{\left(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}\right)}{2\pi}\left[-\frac{5.00\ \mathrm{A}}{0.300\ \mathrm{m}} + \frac{5.00\ \mathrm{A}}{0.200\ \mathrm{m}}\right]$$

$$= \boxed{1.67\ \mu\mathrm{T}\ \text{out of page}}$$

**48.** It is desired to construct a solenoid that has a resistance of 5.00 Ω (at 20°C) and that produces a magnetic field at its center of 4.00 x $10^{-2}$ T when it carries a current of 4.00 A. The solenoid is to be constructed from copper wire having a diameter of 0.500 mm. If the radius of the solenoid is to be 1.00 cm, determine (a) the number of turns of wire needed and (b) the length the solenoid should have.

**19.48** (a) From $R = \rho L/A$, the required length of wire to be used is

$$L = \frac{R \cdot A}{\rho} = \frac{(5.00\ \Omega)\left[\pi\left(0.500\times 10^{-3}\ \text{m}\right)^2/4\right]}{1.70\times 10^{-8}\ \Omega\cdot\text{m}} = 57.7\ \text{m}$$

The total number of turns on the solenoid (i.e., the number of times this length of wire will go around a 1.00 cm radius cylinder) is

$$N = \frac{L}{2\pi r} = \frac{57.7\ \text{m}}{2\pi\left(1.00\times 10^{-2}\ \text{m}\right)} = \boxed{919}$$

(b) From $B = \mu_0 n I$, the number of turns per unit length on the solenoid is

$$n = \frac{B}{\mu_0 I} = \frac{4.00\times 10^{-2}\ \text{T}}{\left(4\pi\times 10^{-7}\ \text{T}\cdot\text{m/A}\right)(4.00\ \text{A})} = 7.96\times 10^{3}\ \text{turns/m}$$

Thus, the required length of the solenoid is

$$\frac{N}{n} = \frac{919\ \text{turns}}{7.96\times 10^{3}\ \text{turns/m}} = 0.115\ \text{m} = \boxed{11.5\ \text{cm}}$$