Chapter 29

1. (a) The magnitude of the magnetic field due to the current in the wire, at a point a distance r from the wire, is given by

$$B = \frac{\mu_0 i}{2\pi r}.$$

With r = 20 ft = 6.10 m, we have

$$B = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(100\ \text{A})}{2\pi(6.10\ \text{m})} = 3.3\times 10^{-6}\ \text{T} = 3.3\ \mu\text{T}.$$

(b) This is about one-sixth the magnitude of the Earth's field. It will affect the compass reading.

4. The straight segment of the wire produces no magnetic field at C (see the *straight sections* discussion in Sample Problem — "Magnetic field at the center of a circular arc of current"). Also, the fields from the two semicircular loops cancel at C (by symmetry). Therefore, $B_C = 0$.

11. (a) $B_{P_1} = \mu_0 i_1 / 2\pi r_1$ where i_1 = 6.5 A and $r_1 = d_1 + d_2$ = 0.75 cm + 1.5 cm = 2.25 cm, and $B_{P_2} = \mu_0 i_2 / 2\pi r_2$ where $r_2 = d_2$ = 1.5 cm. From $B_{P1} = B_{P2}$ we get

$$i_2 = i_1\left(\frac{r_2}{r_1}\right) = 6.5\ \text{A}\left(\frac{1.5\ \text{cm}}{2.25\ \text{cm}}\right) = 4.3\ \text{A}.$$

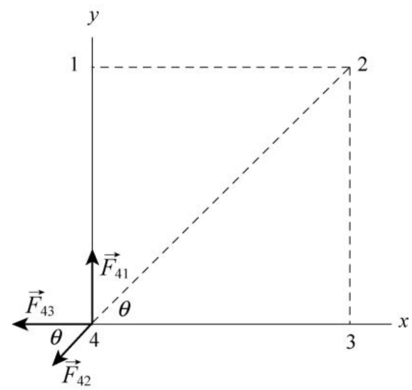
(b) Using the right-hand rule, we see that the current i_2 carried by wire 2 must be out of the page.

12. (a) Since they carry current in the same direction, then (by the right-hand rule) the only region in which their fields might cancel is between them. Thus, if the point at which we are evaluating their field is r away from the wire carrying current i and is $d - r$ away from the wire carrying current 3.00i, then the canceling of their fields leads to

$$\frac{\mu_0 i}{2\pi r} = \frac{\mu_0 (3i)}{2\pi(d-r)} \quad\Rightarrow\quad r = \frac{d}{4} = \frac{16.0\ \text{cm}}{4} = 4.0\ \text{cm}.$$

(b) Doubling the currents does not change the location where the magnetic field is zero.

37. We use Eq. 29-13 and the superposition of forces: $\vec{F}_4 = \vec{F}_{14} + \vec{F}_{24} + \vec{F}_{34}$. With $\theta = 45°$, the situation is as shown on the right.



The components of $\vec{F}_4$ are given by

$$F_{4x} = -F_{43} - F_{42}\cos\theta = -\frac{\mu_0 i^2}{2\pi a} - \frac{\mu_0 i^2 \cos 45°}{2\sqrt{2}\pi a} = -\frac{3\mu_0 i^2}{4\pi a}$$

and

$$F_{4y} = F_{41} - F_{42}\sin\theta = \frac{\mu_0 i^2}{2\pi a} - \frac{\mu_0 i^2 \sin 45°}{2\sqrt{2}\pi a} = \frac{\mu_0 i^2}{4\pi a}.$$

Thus,

$$F_4 = \left(F_{4x}^2 + F_{4y}^2\right)^{1/2} = \left[\left(-\frac{3\mu_0 i^2}{4\pi a}\right)^2 + \left(\frac{\mu_0 i^2}{4\pi a}\right)^2\right]^{1/2} = \frac{\sqrt{10}\mu_0 i^2}{4\pi a} = \frac{\sqrt{10}\left(4\pi\times10^{-7}\ \mathrm{T\cdot m/A}\right)\left(7.50\mathrm{A}\right)^2}{4\pi\left(0.135\mathrm{m}\right)}$$

$$= 1.32\times10^{-4}\ \mathrm{N/m}$$

and $\vec{F}_4$ makes an angle ϕ with the positive x axis, where

$$\phi = \tan^{-1}\left(\frac{F_{4y}}{F_{4x}}\right) = \tan^{-1}\left(-\frac{1}{3}\right) = 162°.$$

In unit-vector notation, we have

$$\vec{F}_1 = (1.32\times10^{-4}\ \mathrm{N/m})[\cos162°\hat{\mathrm{i}} + \sin162°\hat{\mathrm{j}}] = (-1.25\times10^{-4}\ \mathrm{N/m})\hat{\mathrm{i}} + (4.17\times10^{-5}\ \mathrm{N/m})\hat{\mathrm{j}}$$

43. We use Eq. 29-20 $B = \mu_0 ir/2\pi a^2$ for the B-field inside the wire ($r < a$) and Eq. 29-17 $B = \mu_0 i/2\pi r$ for that outside the wire ($r > a$).

(a) At $r = 0$, $B = 0$.

(b) At $r = 0.0100\mathrm{m}$, $B = \dfrac{\mu_0 ir}{2\pi a^2} = \dfrac{(4\pi\times10^{-7}\ \mathrm{T\cdot m/A})(170\mathrm{A})(0.0100\mathrm{m})}{2\pi(0.0200\mathrm{m})^2} = 8.50\times10^{-4}\mathrm{T}.$

(c) At $r = a = 0.0200\mathrm{m}$, $B = \dfrac{\mu_0 ir}{2\pi a^2} = \dfrac{(4\pi\times10^{-7}\ \mathrm{T\cdot m/A})(170\mathrm{A})(0.0200\mathrm{m})}{2\pi(0.0200\mathrm{m})^2} = 1.70\times10^{-3}\mathrm{T}.$

(d) At $r = 0.0400\mathrm{m}$, $B = \dfrac{\mu_0 i}{2\pi r} = \dfrac{(4\pi\times10^{-7}\ \mathrm{T\cdot m/A})(170\mathrm{A})}{2\pi(0.0400\mathrm{m})} = 8.50\times10^{-4}\mathrm{T}.$

50. It is possible (though tedious) to use Eq. 29-26 and evaluate the contributions (with the intent to sum them) of all 1200 loops to the field at, say, the center of the solenoid. This would make use of all the information given in the problem statement, but this is not the method that the student is expected to use here. Instead, Eq. 29-23 for the ideal solenoid (which does not make use of the coil radius) is the preferred method:

$$B = \mu_0 in = \mu_0 i\left(\frac{N}{\ell}\right)$$

where i = 3.60 A, $\ell = 0.950$ m, and N = 1200. This yields B = 0.00571 T.

51. It is possible (though tedious) to use Eq. 29-26 and evaluate the contributions (with the intent to sum them) of all 200 loops to the field at, say, the center of the solenoid. This would make use of all the information given in the problem statement, but this is not the method that the student is expected to use here. Instead, Eq. 29-23 for the ideal solenoid (which does not make use of the coil diameter) is the preferred method:

$$B = \mu_0 in = \mu_0 i\left(\frac{N}{\ell}\right)$$

where i = 0.30 A, $\ell = 0.25$ m, and N = 200. This yields $B = 3.0\times10^{-4}$ T.

54. As the problem states near the end, some idealizations are being made here to keep the calculation straightforward (but are slightly unrealistic). For circular motion (with speed, $v_\perp$, which represents the magnitude of the component of the velocity perpendicular to the magnetic field [the field is shown in Fig. 29-19]), the period is (see Eq. 28-17)

$$T = 2\pi r/v_\perp = 2\pi m/eB.$$

Now, the time to travel the length of the solenoid is $t = L/v_\parallel$ where $v_\parallel$ is the component of the velocity in the direction of the field (along the coil axis) and is equal to $v\cos\theta$ where θ = 30º. Using Eq. 29-23 ($B = \mu_0 in$) with $n = N/L$, we find the number of revolutions made is $t/T = 1.6 \times 10^6$.