Chapter 22 – Problems 1, 3, 5, question 4, 9, 11, 15, 17, 19, 20, 21, 22, 24, 27, 31, 32

1. The force on a wire carrying current I is $F = ILB\sin(\text{theta})$, where theta is the angle of the wire with respect to the magnetic field **B**. Remember that F and B are the magnitudes of the vector force **F** and the vector field **B**. For this problem, the theta is 90 degrees, so that $\sin(90^o) = 1.0$.

   $F = (30\text{ A})(0.50\text{ m})(0.50\text{ T}) = 7.5\text{ N}$.

   To find the direction of this force, use your right hand and point your thumb straight westward along the direction of I. then, keeping your thumb pointing westward, simultaneously point your fingers straight downward in the direction of **B**. Since your palm faces southward, that is the direction of the force.

3. This problem uses the same equation as in problem (1). The units of **B**, however are given in gauss (G) instead of Tesla (T), where 1 T = 10,000 G. In each case, if you point your right-hand thumb along the direction of I and your fingers along **B** (to the right of the page), your palm points "into" the page. The force in each case is

   $F_1 = (15\text{ A})(0.50\text{ m})(0.0250\text{ T})\sin(90^o) = 0.188$ into the page.
   $F_2 = (15\text{ A})(0.50\text{ m})(0.0250\text{ T})\sin(60^o) = 0.162$ into the page.
   $F_1 = (15\text{ A})(0.50\text{ m})(0.0250\text{ T})\sin(0^o) = 0$.

5. This problem again uses the equation $F = ILB\sin(\text{theta})$. Note that according to the definition of theta, $B\sin(\text{theta})$ is often stated as $B_{\text{perpendicular}}$, which is just the component of B that is perpendicular to the direction of current. For this problem, the current is upward from the earth's surface and the component of **B** that is perpendicular to the current is northward. Thus, point your right thumb upward and your fingers northward. Your palm then faces westward in the direction of the force. The magnitude of the force is

   $F = (17\text{ A})(2.0\text{ m})(0.30 \times 10^{-4}\text{ T}) = 1.0 \times 10^{-4}\text{ N}$ (westward)

   Question 4, (not problem 4).

   The field due to the bar magnet is exactly as shown in Figure 22.4 (b) of the book. Now look at the diagram for the question. The direction of the magnetic field all along the wire is downward and inward toward the center. This means that all along the wire there is a force acting inward and upward. Because of the symmetry, the inward component of force all along the wire cancels out, but the upward component adds. Therefore there is a net upward force.

9. The moving proton acts the same as a current, except that the force on the proton has the magnitude $F = qvB\sin(\text{theta})$. The direction of the force is determined by the right-hand rule for currents. Remember, if this were an electron, you would have to use the left-hand rule.

   a. $F_1 = (1.6 \times 10^{-19}\text{ C})(5.0 \times 10^6\text{ m/s})(0.135\text{ T})\sin(90^o) = 1.1 \times 10^{-13}\text{ N}$.
   b. $F_2 = (1.6 \times 10^{-19}\text{ C})(5.0 \times 10^6\text{ m/s})(0.135\text{ T})\sin(50^o) = 0.83 \times 10^{-13}\text{ N}$.
   c. There is no force since the $\sin(0^o)$ is zero.

   In each case, point your fingers along **B** to the right in the plane of the page, with your thumb in the direction of v. Since your palm faces into the page, that is the direction of the force.

11. As shown in your text on page 428, a charged particle moving perpendicular to a field follows a circular path of radius $r = mv/qB$. The mass of the sodium ion is $m = 23 \times 1.66 \times 10^{-27}$ kg and carries a charge of $+e$. If the ion has a speed $v = 3 \times 10^4$ m/s, and is in a circular orbit of 0.20-m radius, then

    $B = (23 \times 1.66 \times 10^{-27}\text{ kg})(3 \times 10^4\text{ m/s})/(1.6 \times 10^{-19}\text{ C})(0.20\text{ m}) = 0.036\text{ T}$.

15. Although starred, this is an easy problem if we use ratios. Recall that for a charged particle moving perpendicular to a magnetic field, the path is circular, with an orbital radius $r = mv/qB$. Since m,v and q are constants, the radius is proportional to the mass. Therefore, $r_2/r_1 = m_2/m_1$, or $r_2 = 9.00(37/35) = 9.51$ cm. Notice that in dealing with ratios, we don't have to change cm to m.

17. Two forces act on the charged particle as it passes through the crossed fields. Consider a charge $+q$ moving with the beam. The force on $+q$ due to the electric field **E** acts downward along the direction of the field. The force on the moving charge due to the magnetic field **B** acts upward according to the right-hand rule. If the two forces exactly balance each other, the charge $+q$ will not be deflected. If the velocity is too small, the force due to the magnetic field is insufficient to balance the force due to the electric field. If the velocity is too great the magnetic force will dominate. Balance is achieved when the two forces are equal. In other words, $qE = qvB$. The charge q cancels and we find the condition for balance to be $v = E/B$.

19. A long straight wire carrying a current I has a **B** field surrounding it, as described on page 430 of your text. The strength of the field is small in general. It is given by the equation

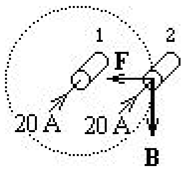
    $B = (\text{mu}_0 I)/(2\text{ pi } r)$

Simple substitution gives the answer I = 60 A.

20. The two wires, are shown endwise, with identical currents of I = 20 A each going in the same direction into the page. Each current creates its own **B** field of concentric clockwise circles around the wire. The field that each wire creates has an effect on the other wire. Part of the field created by wire 1 is shown, that part that passes through the spot where the other wire is located. This field is pointing downward at the position of the second wire. The magnitude of the field of wire 1 at the position of wire 2 is (units are suppressed).

    a. $$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi\times10^{-7})20}{2\pi(0.05)} = 8.0\times10^{-5}\ \text{T}$$

    b. The resulting force acting on the second wire is to the left, according the right-hand rule and has the magnitude
    $F = ILB$, giving F/L = (20 A)(8.0 x 10^{-5} T) = 1.6 x 10^{-3} N.
    If you were to repeat the question by finding the force on wire 1, the answer would be 1.6 x 10^{-3} N to the right. In other words the two wires attract each other.



21. The two wires are shown below, endwise.

    a. Each wire carries a current of 20 A into the page. As in problem 20, each wire has an associated **B**-field consisting of clockwise rings around the wire. Clearly, at a point midway between the two wires, the magnetic fields of wire 1 and wire 2 are identical in magnitude but opposite in direction. Thus the net magnetic field strength is zero.

    b. On the other hand, if the currents are in opposite directions, the two fields add. Assuming the left-hand wire has current into the page, and the right-hand wire has current out of the page, the net **B**-field is downward. The magnitude of the field from each wire at the point midway between them is

$$B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi\times10^{-7})20}{2\pi(0.025)} = 1.6\times10^{-4}\ \text{T}$$

Thus, the net field has a magnitude of twice the field of one wire or 3.2 x 10^{-4} T.

22. For a coil of radius "a," having N loops and carrying a current of 5.0 A, the **B** field at the center of the coil is (suppressing units),

    B = [(N)(mu_0)I]/(2a) = [(200)(4pi x 10^{-7})(5.0)]/[2(0.03)] = 0.021 T.

24. The **B** field along the axis of the solenoid has the magnitude B = (4pi x 10^{-7})nI, where n is the number of turns per meter. As a result, since n = (5000 turns)/(0.40 m) = 12,500, the magnitude of the field along the axis of the solenoid is

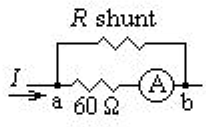
    B = (4pi x 10^{-7} T·m/A)(12500 turns/m)(2.0 A) = 3.14 x 10^{-2} T.

27. Whenever you want the torque on a current loop in an external **B**-field, I suggest you first determine the orientation of the plane of the coil and the direction of the magnetic field created by the coil. Then draw a perpendicular arrow from the center of the plane in the direction of the coil's magnetic field (not the external field). This arrow defines what I call the loop axis. The torque is caused by this "arrow" wanting to line up with the external field. Now let's work the problem.

    A flat current loop is in the magnetic field of the earth. The plane of the loop is vertical and running east-west. This implies that the loop axis points due north or due south, depending on the direction of the loop current. It turns out that the torque has the same magnitude for either direction (but with opposite rotational sense). Let's assume the loop axis points due north, which corresponds to a clockwise current if you looked at the coil while facing north. The external field points northward and downward at an angle of 70^o below a horizontal north-south line. Therefore, the torque is,

    Torque = (area of loop)(current)(number of turns)(external B)sin 70^0
    = (pi)$(0.2\ \text{m})^2$(15 A)(50 turns)(0.65 x 10^{-4} T) = 0.58 x 10^{-2} N·m.

31. An ammeter is used by "breaking" into the wire that carries current. The device must have a very low resistance, however, so as not to affect the current flow. This is accomplished by passing a low resistance shunt in parallel with the meter movement. The configuration of shunt plus meter movement is the ammeter and is shown.



We assume the current coming in has a maximum value of 0.50 A. Of this current, only 0.00100 A is allowed to pass through the meter movement (before damage occurs). This means that almost all of the 0.50 A must flow through the shunt. Now notice that the voltage between points a and b for a current of 0.00100 is V = (0.00100 A) (60 ohms) = 0.060 V. But this must also be the voltage across the shunt. Therefore

R(shunt) = (0.06 V)/(0.499 A) = 0.12 ohms.

32. To make this same meter movement into a voltmeter, we want to be able to hook it across a circuit element without affecting the voltage across the element much. This is accomplished by inserting a large resistance in series with the meter movement. But remember that the current through the meter movement cannot exceed 0.00100 A. This time the 0.00100 A current goes through the added resistance and the 60-ohm internal resistance when the device is hooked across a maximum of 150 volts. Thus,

(R + 60 ohms) = (150 V)/(0.00100 A) = 1.5×10^5 ohms.

$R = 1.5 \times 10^5$ ohms.