Chapter 23 Solutions – Problems 1, 3, 6, 7, 9, 13, 17, 19, 23, 25, 27, 30

1. The angle of importance is between a vector perpendicular to the plane of the board (called the normal to the plane of the board) and a vector parallel to the magnetic field, as shown in Fig. 23.5 of the text. As you can see from the picture, the perpendicular component of **B** is *B*cos(theta). This is exactly the angle given in the problem. a) When theta is 0^o, the flux is its maximum value BA = (0.150 T)(0.06 m^2) = 0.009 Wb. b) When theta is 90^o , there is no flux because the field "sees" the board edgewise. c) When theta is 40^o, the flux is less than its maximum value by the factor cos(40^o). Flux = (0.009 Wb)cos(40^o) = 0.0069 Wb.

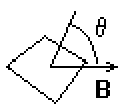
3. Notice that the angle 67^o given in the problem is with respect to the surface of the tabletop and is called the dip angle. The angle that corresponds to the theta of problem 1 is not 67^o, but rather its complement, 23^o. Therefore

   flux = (3.14 x 0.2^2) (0.58 x 10^{-4} T)cos(23^o) = 6.7 x 10^{-6} Wb.

6. The picture shows the setup for the question. The field is along the *x* axis, and the orientation of the loop is defined by the line perpendicular to the plane of the loop (the normal). The angle between this normal and the magnetic field vector is theta. Notice that when the angle theta is 0^o the flux is its maximum value of *BA*. As theta increases from 0^o, the flux is reduced until it reaches zero at theta = 90^o.

   a. For an angle shift of 0^o to 60^o:
      flux change is (0.020 T)(0.0040 m^2)(cos 60^o – cos 0^o) = – 4 x 10^{-5} Wb.

   b. For an angle shift of 30^o to 40^o:
      flux change is (0.020 T)(0.0040 m^2)(cos 40^o – cos 30^o) = – 8.0 x 10^{-6} Wb.

7. This question is an application of Faraday's Law, E_{ind} = – N(change in flux)/(time interval). The negative sign has to do with the direction of the induced voltage and as a result the direction of the induced current. **I recommend that you forget about the negatve sign in Faraday's law and just use Lenz's law to determine the direction of the induced current!** This means to regard the Faraday law to find the magnitude of the induced voltage.

   a. Assuming N = 1 and a 0.5 s time interval in case a) of the previous problem, the magnitude of the induced emf is
      E_{ind} = (4 x 10^{-5} Wb)/(0.5 s) = 8 x 10^{-5} V.
   b. For the case b) in the previous problem, the magnitude of the induced emf is
      E_{ind} = (8 x 10^{-6} Wb)/(0.5 s) = 1.6 x 10^{-5} V.

9. Imagine a bar of iron on which are wound 2 coils. One coil is called the primary, and the other is called the secondary. A change in current through the primary causes the magnetic flux through the bar to change. This changing flux also passes through the secondary and induces a voltage in the secondary. (Remember that the area of a loop is (pi)r^2. Therefore,
   Magnitude of E_{ind} = (500 loops) (0.62 T)(pi)(0.0040 m)^2/(0.03 s) = 0.52 V

13. Flux can change either because 1) the area through which the field passes changes, 2) the field itself changes, or 3) both the area and the field change. In this problem, the magnetic field stays constant, but the area changes. From the sketch, observe that in a time interval delta *t*,
    the change in area = (0.045 m)(v)(delta t).
    a. Therefore, substituting numbers into Faraday's law, with v = 0.20 m/s,
    $$\frac{\Delta\phi}{\Delta t} = B\frac{\Delta A}{\Delta t} = (0.25)\frac{(0.045)(0.20)\Delta t}{\Delta t} = 2.25\times 10^{-3}\ \text{V}$$
    .
    b. The numerical answer to a) is the emf. Since the downward pointing flux is decreasing in magnitude, the induced emf and current will act to try to retard this shrinking flux. The induced current (by Lenz's law) creates a downward pointing magnetic field through the loop and this implies a clockwise current.
    c. If R = 0.020 ohms, then current = V/R = (0.00225 V) /(0.020 ohms) = 0.11 V.

17. The turn ratio in an ideal transformer is equal to the ratio of the voltages. The turn ratio must therefore be (120 V)/(9.0 V). A backwards connection would step up the voltage instead of stepping it down. The stepped up voltage would be (120/9) x 120 V, or 1600 V.

19. a. This is a step-up transformer since there are more turns on the secondary than on the primary.
    b. Since the ratio of secondary to primary turns is 20 to 1, the output voltage is 20 times larger than the input voltage. Thus, an input of 120 V results in an output of V_{out} = 20 x 120 V = 2400 V.

23. When the motor runs, it produces ¼ hp. Using the conversion factor 1 hp = 746 J, we know that the power used by the motor is (1/4)(746) = 186.5 watts. There is also a small power loss in the resistance of the motor, but neglecting it will give a close approximation the total

power. Since power = IV, the current is

I = (186.5 W)(110 V) = 1.7 A.

Now, to get the back emf, we use the loop equation, substituting the approximate current. The circuit loop contains the 110 volt source, the small resistance and the motor. The small resistance produces a voltage drop of IR = (1.7 A)(0.59) = 0.85 V, and the motor has a back emf that must account for the rest of the total drop. The loop equation is then 110 – IR – emf = 0, giving an emf = 109.15 V.

Correcting for the power loss in the resistance is not all that hard. The power output of the motor plus the power lost in the resistance is the total power supplied by the source. Thus

186.5 W + $I^2R = IV$.

The resulting equation is

$186.5 + 0.5\,I^2 = 110\,I$,

leading to the result I = 1.72 A and a back emf of 109.14 V, almost the same as before.

25. This problem is a simple application of the expression

$V = Bvd$.V = (0.25 T)(15 m/s)(0.70 m) = 2.8 V.

27. Again we use the expression $V = Bvd$.

V = (0.46 x 10^{-4} T)(150 m/s)(20 m) = 0.14 V.

To figure out which wing is positive and which is negative, use the right-hand rule for + or the left-hand rule for –. You should find that electrons will be forced to the right. Therefore, the right-hand wing will be negative.

30. This is a more complex problem than you are expected to have on a test, but see if you can follow the explanation. The first step is to see that the perpendicular component of the B field is Bcos(theta).

   a. Knowing this, the emf in the rod is [Bcos(theta)]vd.
   b. From the emf just found, the current is

      I = emf/R = ($Bvd\cos 30^{\circ}$)/R.
   c. Remember that electrons, not protons move in a conductor. Using the left-hand rule, applied to electrons on the rod, notice that electrons will be forced to the right (looking down the slope). Therefore the current, by definition goes to the left to produce a clockwise current.
   d. There is a force on the rod because it carries a current and is moving through the field. Its strength is

$$F = IdB_{\perp} = \frac{Bvd}{R}\cos(30^{\circ})dB\cos(30^{\circ})$$
$$= \frac{B^2d^2v}{R}\cos^2(30^{\circ}) = \frac{3B^2d^2v}{4R}$$