Homework 9

Chapter 23

Problem 2. An $N = 25$ turn circular coil of wire has diameter $d = 1.00$ m. It is placed with it's axis along the direction of the Earth's magnetic field of $B = 50.0\ \mu$T, and then in $t = 0.200$ s it is flipped 180°. An average emf of what magnitude is generated in the coil?

The flux before the flip is

$$\Phi_{Bi} = AB = N\pi r^2 B \ , \tag{1}$$

and the flux after the flip is

$$\Phi_{Bf} = -AB = -N\pi r^2 B \ . \tag{2}$$

From Ampere's law

$$\varepsilon = -\frac{d\Phi_B}{dt} = 2N\pi r^2 B/dt = 9.82 \text{ mV} \ . \tag{3}$$

Problem 6. A coil of $N = 15$ turns and radius $R = 10.0$ cm surrounds a long solenoid of radius $r = 2.00$ cm and $n = 1.00 \cdot 10^3$ turns/m (Fig. P23.6). The current in the solenoid changes as $I = (5.00 \text{ A}) \sin(120t)$. Find the induced emf in the 15 turn coil as a function of time.

Because the solenoid is long, we can pretend it is infinite, so all the magnetic field is contained inside the solenoid, and there is no magnetic field outside (see page 751).
The field inside the solenoid is given by

$$B = \mu_0 n I \ , \tag{4}$$

so the flux through the large coil is

$$\Phi_B = \int B dA = N\pi r^2 B = N\pi r^2 \mu_0 n I \ . \tag{5}$$

The induced emf is then

$$\varepsilon = -\frac{d\Phi_B}{dt} = -\pi\mu_0 n N r^2 \frac{dI}{dt} = -\pi\mu_0 n N r^2 (5.00 \text{ A} \cdot 120 \text{ Hz}) \cos(120t) = -14.2 \cos(t \cdot 120 \text{ rad/s}) \text{ mV} \ , \tag{6}$$

where we are assuming that the units on 120 are rad/s, otherwise we'd have to convert them to rad/s to make the units work out on the coefficient.

Problem 12. Consider the arrangement shown in Figure P23.12. Assume that $R = 6.00\Omega$, $l = 1.20$ m, and a uniform $B = 2.50$ T magnetic field is directed into the page. At what speed should the bar be moved to produce a current of 0.500 A in the resistor.

This problem is almost identical to the recitation Problem 13. Copying the induced current formula:

$$I = \frac{\varepsilon}{R} = \frac{-lvB}{R} \ , \tag{7}$$

where the $-$ sign indicates the current is counterclockwise (out of the page), so current flows upward through the bar.
We can solve this equation for v, yielding

$$v = \frac{IR}{lB} = 1.00 \text{ m/s} \ . \tag{8}$$