PHYSICS 4C: QUIZ 6 SOLUTIONS

Problem 1

Magnetic field outside the solenoid is 0 and inside

$$B = \mu_0 n I_s, \tag{1}$$

where I_s is the current through the solenoid. The flux through the coil is

$$\Phi_B = B\pi r_s^2 N = \pi\mu_0 n I_s r_s^2 N. \tag{2}$$

The EMF in the coil is

$$\varepsilon = -\frac{d\Phi_B}{dt} = -\pi\mu_0 n \dot{I}_s r_s^2 N = -0.11\text{V}. \tag{3}$$

The magnitude of the current is

$$I = \frac{\varepsilon}{R} = 0.74\text{A} \tag{4}$$

and the power dissipated is

$$P = I^2 R = 0.081\text{W}. \tag{5}$$

Problem 2

The current is clockwise because right-hand rule shows that clockwise current creates magnetic field into the page, which would compensate for the increasing magnetic flux. The change of the magnetic flux through the loop is

$$\dot{\Phi}_B = B\dot{A} = Bhv. \tag{6}$$

Since the current on the top and bottom sides of the loop is equal and opposite, the force is only result of current in the right segment of the loop.

$$\vec{F} = I\vec{h} \times \vec{B} \tag{7}$$

$\vec{B}$ and $\vec{h}$ are orthogonal, so

$$I = \frac{F}{hB} = 0.28\text{A} \tag{8}$$

which means the power dissipated is

$$P = I^2 R = 0.062\text{W}. \tag{9}$$

The EMF is

$$\varepsilon = IR = 0.22\text{V} = -\dot{\Phi}_B = -Bhv. \tag{10}$$

Solving for the magnitude of velocity,

$$v = \frac{\varepsilon}{Bh} = 0.62\text{m/s}. \tag{11}$$

Problem 3

$$I = \frac{dQ}{dt} = \frac{\varepsilon}{R} = -\frac{1}{R}\frac{d\Phi_B}{dt} \tag{12}$$

$$dQ = -\frac{d\Phi_B}{R} \tag{13}$$

$$\Delta Q = -\frac{\Delta\Phi_B}{R} = -\frac{\pi r^2 B}{R}(\cos\theta_f - \cos\theta_i) = 0.014\text{C} \tag{14}$$

Problem 4

The magnetic field of the wire is

$$B = \frac{\mu_0 I_w}{2\pi r} \tag{15}$$

$\vec{B}$ is perpendicular to the plane of the loop and equal at the top and bottom sides of the loop, which have equal and opposite current, so only the left (1) and right (2) sides of the loop will contribute to the force. The magnetic field at the left side B_1 is greater than the magnetic field at the right side B_2, so the left side contributes to the force more. Since the force is attractive, the current in the wire needs to be in the same direction as the current in the left segment of loop, therefore, I_w is up. The force is

$$\vec{F} = I_l\vec{l}_1 \times \vec{B}_1 + I_l\vec{l}_2 \times \vec{B}_2, \tag{16}$$

the magnitude of which in SI units is

$$F = I_l h\frac{\mu_0 I_w}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = 6.4 \times 10^{-6}\left(\frac{1}{.06} - \frac{1}{.06 + w}\right) = 8 \times 10^{-5}, \tag{17}$$

where w is the width of the loop. Rearranging,

$$w = \left(\frac{-8 \times 10^{-5}}{6.4 \times 10^{-6}} + \frac{1}{.06}\right)^{-1} - .06 = 0.18\text{m} \tag{18}$$