Sp '20 Exam 2F

1. (30 pts) An empty 28 μF capacitor is connected to a 12 Volt battery and allowed to reach its maximum charge. The capacitor is then disconnected from the battery, and a slab of dielectric material (K = 2.3) is inserted between the plates.

a) What is the new potential difference across the plates of the capacitor?
b) What is the charge on the positive plate of the capacitor after the slab is inserted?
c) If this empty 28 μF capacitor is connected to the 12 Volt battery and in series with a 4.0 Ohm resistor, how long does it take after the circuit is completed for the capacitor to reach 88% of its maximum possible charge?

a) If C disconnected from battery, Q = constant but V can change since $\vec{E}$ is weakened by K.

$\Delta V_{new} \propto E_{new}$ so $\Delta V_{new} = \frac{\Delta V_{orig}}{K} = \frac{12}{2.3} = \boxed{5.2\ V}$

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b) $Q_{orig} = C\Delta V = (28\times10^{-6})(12)$

$= 3.36\times10^{-4}\ C$

same after K inserted, so $\boxed{Q_{new} = 3.4\times10^{-4}\ C}$

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c) $Q(t) = Q_{max}(1 - e^{-t/RC})$

$0.88 = 1 - e^{-t/RC}$

$0.12 = e^{-t/RC}$

$-2.12 = -\frac{t}{(4)(28\times10^{-6})}$

$\boxed{t = 2.4\times10^{-4}\ s}$

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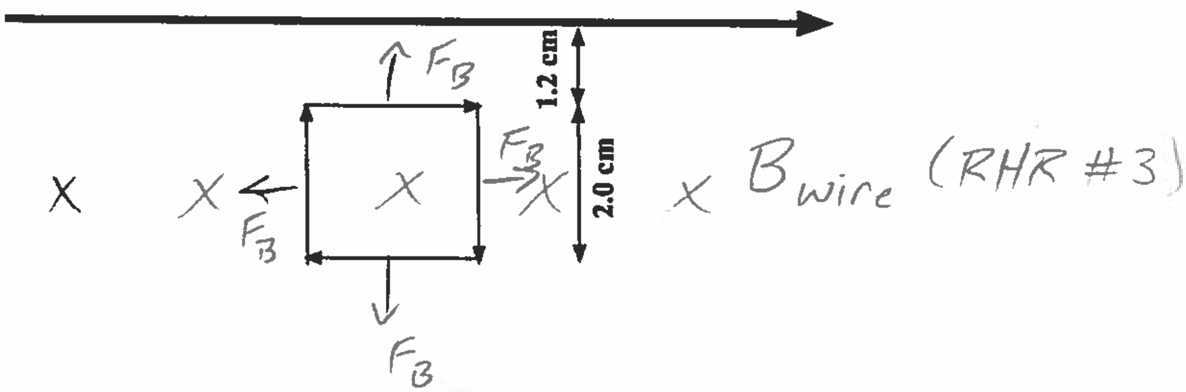
2. (35 pts) A long straight wire carries a current of 8.5 Amps. A square wire loop with a clockwise current of 6.2 Amps is placed in the vicinity of the long straight wire as shown below.

a) What is the magnitude and direction of the net magnetic force on the wire loop due to the straight wire?

b) What is the magnitude of the net torque on the wire loop due to the straight wire?



$|F_B|$ on left + right wire are equal + opposite, so they cancel out.

$$B_{TOP} = \frac{\mu_0 (8.5)}{2\pi(.012)} = 142\ \mu T$$

$$F_{TOP} = \ell I B \sin 90 = (.02)(6.2)(142\times10^{-6}) = 1.76\times10^{-5}$$

$$B_{BOT} = \frac{\mu_0 (8.5)}{2\pi(.032)} = 53\ \mu T$$

$$F_{BOT} = (.02)(6.2)(53\times10^{-6}) = 6.59\times10^{-6}$$

$F_{TOT} = +1.76\times10^{-5}$ (up) $- 6.59\times10^{-6}$ (down) $=$ 1.1×10^{-5} N, ↑

b) Since B_{ext} parallel to $\vec{B}_{loop}$, $\vec{\tau} = 0$

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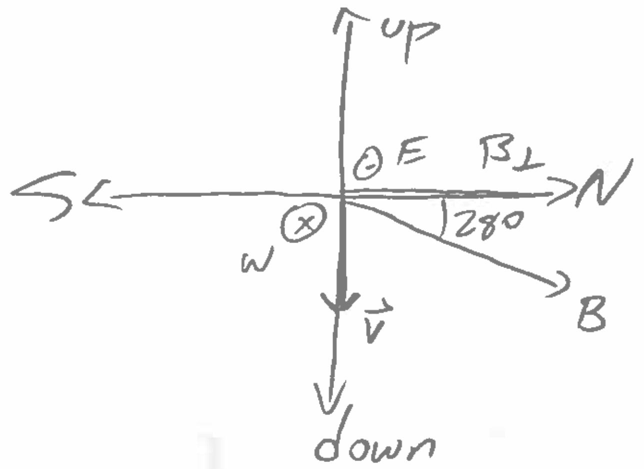
3. (35 pts) A 95-cm long, thin conducting rod is oriented East-West and is falling vertically downward with a speed of 37 m/s through a magnetic field with magnitude 45 μT pointing in a direction 28° vertically below due North.

a) What is the magnitude of the induced EMF in the rod?
b) Which end of the rod is positive, East or West?
c) Assume 0.33 Amps of current flows through the rod in the same direction that positive charges are forced, what is the magnitude and direction of the magnetic force on the rod?



$B_\perp = 45 \cos 28°$

$= 39.7\ \mu T$

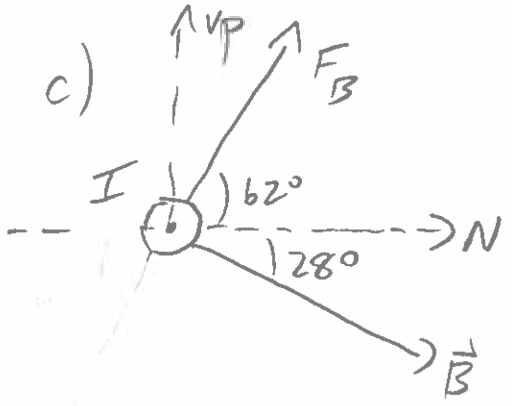
a) $\mathcal{E}_{ind} = B_\perp l v$

$= (39.7 \times 10^{-6})(.95)(37)$

$= 1.4 \times 10^{-3}$ Volts

b) F_B points ⊙ due to RHR #1, so East

c)



$\vec{F}_B = l I B \sin 90$

$= (.95)(.33)(45 \times 10^{-6})(1)$

$= 1.4 \times 10^{-5}$ N

62° above North