Sp '20 Exam 2E

1. (30 pts) A circuit contains a 12-Volt battery, a 6400 Ohm resistor, and a capacitor, initially uncharged. A switch is closed at time t = 0, closing the loop of the circuit. After 0.23 seconds have elapsed, the capacitor is charged to 55% of its maximum capacity.

a) What is the capacitance of the capacitor?
b) What is the charge on the capacitor at this time?
c) What is the voltage drop across (i) the capacitor and (ii) the resistor at this time?

a) $0.55\,Q_{max} = Q_{max}(1 - e^{-t/RC})$

$0.55 = 1 - e^{-t/RC}$

$0.45 = e^{-t/RC}$

$-0.7985 = -\frac{t}{RC}$ ↗

$C = \frac{0.23}{(6400)(.7985)}$

$= \boxed{45\ \mu F}$

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b) $Q = C\mathcal{E}(1 - e^{-t/RC})$

$Q_{max} = (45 \times 10^{-6})(12) = 540\ \mu C$

$RC = (6400)(45 \times 10^{-6}) = 0.288$

$Q = 540(1 - e^{-.23/.288})$

$= 540(0.55)$ $= 297\ \mu C$

or $\boxed{3.0 \times 10^{-4}\ C}$

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c) $\Delta V_C = \frac{Q}{C} = \frac{3.0 \times 10^{-4}}{45 \times 10^{-6}} = \boxed{6.6\ Volts}$ (i)

$\Delta V_R + \Delta V_C = 12$ (loop rule) $\Rightarrow \boxed{\Delta V_R = 5.4\ Volts}$ (ii)

Sp '20 Exam 2E

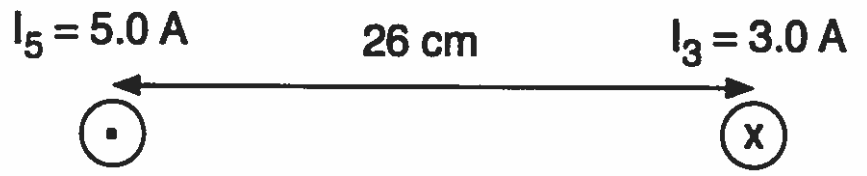
2

1. (35 pts) Two straight wires are oriented perpendicular to the page as shown. Wire $I_5$ passes through the origin, and wire $I_3$ passes through the point x = 26 cm in the xy-plane (the plane of the page).

a) For what value of x (besides infinity) is the total magnetic field due to the two wires equal to zero?

b) An electron is moving toward the left side of the page through the point midway between the two wires. What is the magnitude and direction of the magnetic force on the electron if the velocity is $4.2 \times 10^5$ m/s?

$\vec{B} = 0$ closer to $I_3$ since $I_3$ is smaller, need smaller $r_3$ to compensate for smaller $I_3$




a) $|B_5| = |B_3|$

$$\frac{\mu_0(5)}{2\pi x} = \frac{\mu_0(3)}{2\pi(x-.26)} \Rightarrow \frac{5}{3} = \frac{x}{x-.26} \Rightarrow 5x - 1.3 = 3x$$

$$\rightarrow 2x = 1.3 \Rightarrow \boxed{x = 0.65 \text{ m}}$$

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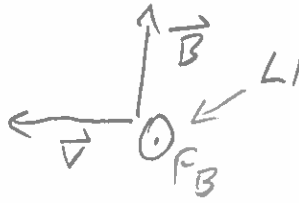
b) $B_5 \uparrow\uparrow B_3$

$I_5$: $\odot$ $\quad$ $I_3$: $\otimes$

$$B_{TOT} = \frac{\mu_0(5)}{2\pi(.13)} + \frac{\mu_0(3)}{2\pi(.13)} = 1.23 \times 10^{-5} \text{ T}$$




LHR says $\vec{F}_B$ points out of page

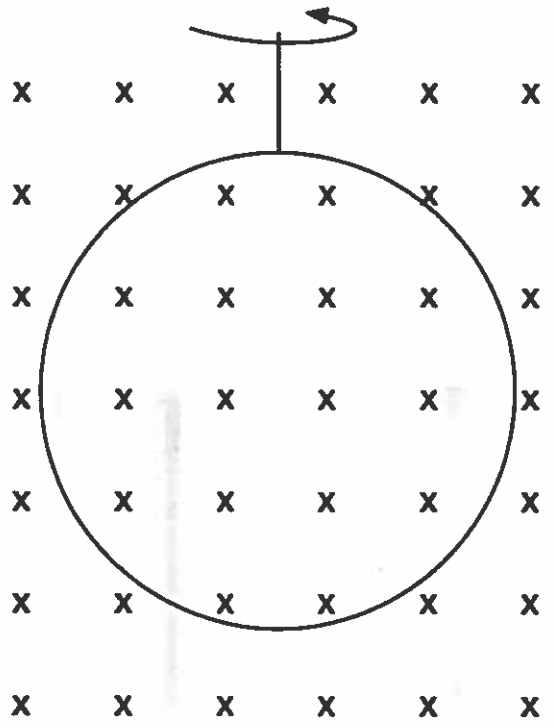
$$F_B = qvB\sin 90^\circ$$

$$= (1.6 \times 10^{-19})(4.2 \times 10^5)(1.23 \times 10^{-5}) = \boxed{8.3 \times 10^{-19} \text{ N}, \odot}$$

Sp '20 Exam 2F,

3. (35 pts) A circular wire with 468 turns, a resistance of 1.33 Ohms, and a radius of 13.5 cm is located within a uniform magnetic field of 78.0 $\mu$T pointing into the page. Initially, the plane of the loop is in the plane of the page as shown.

The loop begins to rotate at a constant speed so that the left side comes out of the page toward you and the right side goes into the page. After 0.250 seconds, the loop has rotated 90.0°. During this time interval, what is the magnitude and direction of the average induced current observed in the loop?



$$\mathcal{E}_{ind} = N \frac{\Delta \Phi_B}{\Delta t}$$

$$= \frac{NBA\,\Delta\cos\theta}{\Delta t}$$

$$= \frac{(468)(78\times10^{-6})\pi(.135)^2(1-0)}{.250}$$

$$= \boxed{8.36\times10^{-3}\ \text{Volts}}$$

$$I_{ind} = \mathcal{E}_{ind}/R = \boxed{6.29\times10^{-3}\ A}$$

$\Phi_B = \otimes$, $\downarrow$ $\Rightarrow$ $B_{ind} = \otimes$ $\Rightarrow$ $\boxed{I_{ind} = \text{clockwis}}$