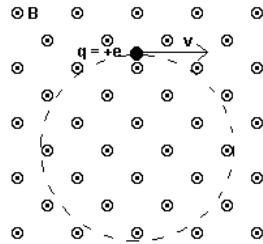


**State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers**  
**Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations**  
**Feel Free to Ask Any Questions**      ☆2a   ☆2b   ☆2c   ☆2e

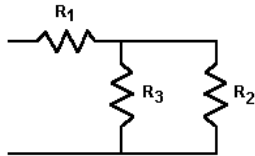
**“There I Was, Officer, Minding My Own Business, When All Of A Sudden...” (50,000 pts.)**

1.) A proton ( $q = +e$ ,  $m_p = 1.67 \times 10^{-27} \text{ kg}$ ) is moving along with velocity  $\vec{v} = 1.38 \times 10^6 \text{ m/s } \hat{i}$ , when a magnetic field,  $B$ , is suddenly turned on in the  $+z$ -direction as shown. The radius of the circular orbit is 2.00 meters. (a) What is the magnitude of the magnetic field  $B$  ?

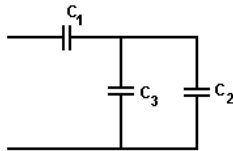


(b) If an electric field vector,  $\vec{E}$ , is turned on after one circle such that the proton's velocity vector  $\vec{v} = 1.38 \times 10^6 \text{ m/s } \hat{i}$  never turns, find the electric field vector,  $\vec{E}$ .

(c) A  $157 \Omega$  resistor is made of three identical resistors ( $R = R_1 = R_2 = R_3$ ) as shown. Find  $R$ .



(d) A  $157 \mu\text{F}$  capacitor is made of three identical capacitors ( $C = C_1 = C_2 = C_3$ ) as shown. Find  $C$ .



(e) At  $t = 3\tau$ , a series RC circuit's current drops to about 5% of its initial value,  $I_0$ . If  $R = 157 \Omega$  and  $C = 157 \mu\text{F}$ , what time is this?

**Yet Another Stupid Star Problem (50,000 points)**

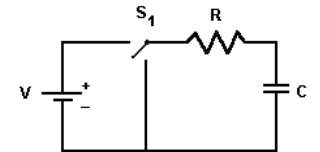
2.) ☆(a) A particular circuit includes a capacitor with  $q(t) = Q_0 \sin(\omega t)$ , where  $\omega = 1.00 \times 10^{-4} \text{ rad/s}$ .<sup>†</sup> Find  $I(t)$ , the current as a function of time.

☆(b) A velocity selector consists of a magnetic  $B$ -field ( $B = 1.60 \text{ T}$ ) and an electric  $E$ -field. If a velocity selector is set for  $v = 1450 \text{ m/s}$  and is  $0.200 \text{ m}$  long, then find the work it takes to keep the charged particle at the selected velocity  $v = 1450 \text{ m/s}$  in a straight line from point  $a$  to point  $b$  by integrating  $W = \int_a^b \vec{F} \cdot d\vec{s}$ . *Hint: You might want to draw a sketch of the velocity selector first.*

☆(c) Serway argues that technically  $V = IR$  is not Ohm's Law, but rather  $\vec{J} = \sigma \vec{E}$ , where  $J$  is the current density,  $\sigma$  is the conductivity (the reciprocal of resistivity,  $\rho$ ) and  $E$  is the electric field that drives the current. Assuming  $E$  is constant, there are three simple equations or definitions that will allow you to replace the variables in  $\vec{J} = \sigma \vec{E}$  and derive  $V = IR$ . *NOTE: This star problem has no calculus, but star points will be awarded for coming up with at least the three equations to replace  $J$ ,  $\sigma$  and  $E$ . Full points for finishing the algebra.*

(d) An air-filled parallel plate capacitor is designed with plates  $50.0 \text{ cm} \times 50.0 \text{ cm}$ , separated by a gap of  $1.00 \text{ mm}$ . Use the two capacitor equations to find the maximum charge  $\pm Q$  that can be placed on the plates before they spark in air.  $E_{\text{max}} = 3 \times 10^6 \text{ V/m}$ .

☆(e) Consider an RC circuit as shown. Flip the switch  $S_1$  to the left and the capacitor charges. Once charged with a charge  $\pm Q_0$ , if the switch  $S_1$  is turned down, then the capacitor discharges. For the discharging capacitor, write a Kirchhoff's Law voltage loop equation. Remember that the definition of current is  $I = dq/dt$ . Show that  $Q(t) = Q_0 e^{-t/RC}$ .



<sup>†</sup>  $\omega$  is an angular frequency – this circuit in a later chapter will turn out to be analogous to the Simple Harmonic Oscillator.