Physics 302
Winter Quarter 1992
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FINAL EXAM

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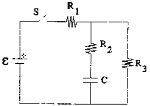
Discussion Section # ______

SHOW ALL WORK!!!!!
REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!
Use the conversion constants and data given on the front page.

Given the circuit shown.



(a) Calculate the charge on the capacitor 1.50 time constants after the switch is closed. (Numerical value.)
(b) Find the current in R_3 at $t = \infty$. (Numerical value.)
(c) Calculate the charge on the capacitor 0.350 s after the switch is opened, after being closed for a long time.
(d) Calculate, in complete detail, the time constant for charging the capacitor. No short cuts from other classes allowed. (Numerical value.)

$\varepsilon = 90.0$ V; $R_1 = 150\ \Omega$; $R_2 = 200\ \Omega$; $R_3 = 300\ \Omega$; $C = 450\ \mu F$

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6 A) $Q(t) = Q_\infty \left(1 - e^{-t/\tau}\right)$ for charging

$Q_\infty = C\,V_{R3} = C \frac{\varepsilon}{R_1 + R_3} \cdot R_3 = 2.7 \times 10^{-2}\,C$

$Q(1.5\tau) = 2.7 \times 10^{-2}\,C\,(1 - e^{-1.5}) = 2.10 \times 10^{-2}\,C$

6 B) at $t \to \infty$ $I_2 = 0$, $I_1 = I_3 = \frac{\varepsilon}{R_1 + R_3} = \frac{90}{150+300} = 0.20A$

6 c) $Q_o = C\,V_{R3} = 2.70 \times 10^{-2}\,C$ as in part A.

After switch is open, $R_{eq} = R_2 + R_3 = 500\,\Omega$, $\tau = R_{eq} C = 0.225s$

$Q(t) = Q_o\, e^{-t/\tau} = 2.7 \times 10^{-2}\, e^{-.350/.225} = 5.70 \times 10^{-3}\,C$

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[Cont.]

D) 1 junction, 2 loops:

① $I_1 = I_2 + I_3$

7 ② $\mathcal{E} - R_1 I_1 - R_2 I_2 - \frac{Q}{C} = 0$ ④ $I_2 = \frac{dQ}{dt}$

③ $\frac{Q}{C} + R_2 I_2 - R_3 I_3 = 0$

Solve for Q & $\frac{dQ}{dt}$:

⑤ $I_3 = \frac{Q}{R_3 C} + \frac{R_2}{R_3} I_2$, from ③

5 ⑥ $\mathcal{E} = (R_1 + R_2) I_2 + \frac{R_1 Q}{R_3 C} + \frac{R_1 R_2}{R_3} I_2 + \frac{Q}{C}$, from ① & ②

⑦ $\mathcal{E} = \frac{(R_1 + R_2) R_3 + R_1 R_2}{R_3} I_2 + \frac{R_1 + R_3}{R_3} \frac{Q}{C}$, rearranging terms

⑧ $\frac{R_3 \mathcal{E}}{(R_1 + R_2) R_3 + R_1 R_2} = \frac{dQ}{dt} + \underbrace{\frac{R_1 + R_3}{(R_1 + R_2) R_3 + R_1 R_2} \cdot \frac{Q}{C}}_{= Q/\tau}$, from ⑦ & ④

So $\tau = \frac{[(R_1 + R_2) R_3 + R_1 R_2]\, C}{R_1 + R_3} = \frac{350 \cdot 300 + 150 \cdot 200}{(150 + 300)} \cdot 450 \times 10^{-6}$ s

$\underline{\tau = 300\ \Omega \times 450\ \mu F = 0.135\ s}$