Physics 2145 Spring 2019 Test 2 (4 pages)

Name: ___Solution___ **March 22, 2019** **Total Score:** ___120___ **/120_**

e = 1.602 x 10^{-19} C $\quad I = \frac{\Delta q}{\Delta t} \quad I = \frac{V}{R} \quad R = \rho\frac{L}{A} \quad P = IV = \frac{V^2}{R} = I^2R$

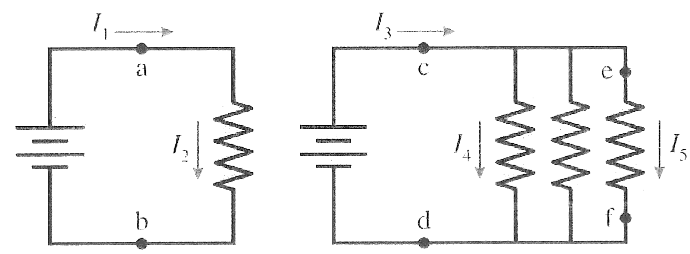
series: $R_{eq} = \sum_i R_i \quad$ parallel: $\frac{1}{R_{eq}} = \sum_i \frac{1}{R_i} \quad C = \frac{Q}{V}$

Discharging $\quad Q = Q_0 e^{-\frac{t}{RC}} \quad I = I_0 e^{-\frac{t}{RC}} \quad V_C = V_{C0} e^{-\frac{t}{RC}}$

Charging $\quad Q = Q_f\left(1 - e^{-\frac{t}{RC}}\right) \quad I = I_0 e^{-\frac{t}{RC}} \quad V_C = V_{Cf}\left(1 - e^{-\frac{t}{RC}}\right)$

D 1.(5) A wire has resistance R. What will be its resistance if it is stretched to twice its original length without changing the volume of the wire? $L \to 2L \quad A \to \frac{1}{2}A \quad R \to 4R$

A) ½ R B) R C) 2R D) 4R



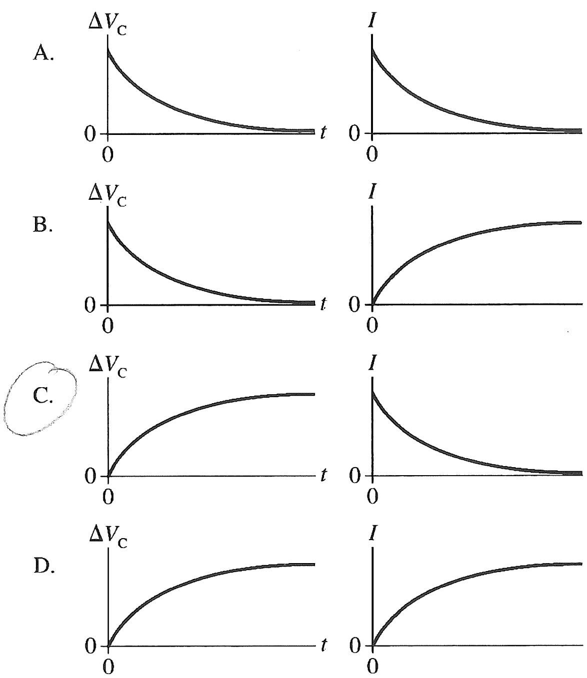
B 2. (5) In the two circuits on the right, the batteries are identical and all resistors are identical. Which of the statements is **FALSE**?

A) $I_1=I_2$ ✓ (B) $I_1=I_3$)
C) $I_1=I_4$ D) $I_1=⅓ I_3$

D 3. (5) If the voltage across a resistor is doubled, which of the following is true? The power dissipated by the resistor________, and the resistance___________.

A) doubles, doubles.
B) quadruples, doubles.
C) doubles, remains unchanged.
(D)) quadruples, remains unchanged

$V \to 2V$
$I \to 2I$
$P \to 4P$



C 4. (5) A capacitor is charged through a resistor. Which of the graphs at the right represent best the capacitor voltage and the current?

20 /20 points for this page

5) (20) A potassium ion channel in a cell membrane is filled with intracellular fluid. The potassium ions have charge e. If the channel is open for 2ms, 1.5×10^4 ions flow through the channel. The potential difference across the channel is 70mV.

a)(5) Calculate the current through the channel.

$$I = \frac{\Delta Q}{\Delta t} = \frac{N \cdot e}{\Delta t} = \frac{1{,}5\times10^{4} \cdot 1{,}6\times10^{-19}\,C}{2\times10^{-3}\,s} = 1{,}2\times10^{-12}\,A = 1{,}2\,pA$$

b)(5) Calculate the resistance of the ion channel.

$$R = \frac{V}{I} = \frac{70\times10^{-3}\,V}{1{,}2\times10^{-12}\,A} = 5{,}8\times10^{10}\,\Omega$$

c) (5) The channel has the shape of a cylinder with a diameter of 0.30nm and a length of 5.0nm. Calculate the resistivity of the intracellular fluid.

$$R = \rho \frac{L}{A} \qquad \rho = \frac{RA}{L} = 5{,}8\times10^{10}\,\Omega \cdot \frac{\frac{\pi}{4}(0.3\times10^{-9}\,m)^2}{5\times10^{-9}\,m}$$

$$\rho = 0{,}82\,\Omega m$$

c)(5) Calculate the power dissipated in the channel.

$$P = IV = 1{,}2\times10^{-12}\,A \cdot 70\times10^{-3}\,V = 8.4\times10^{-14}\,W$$

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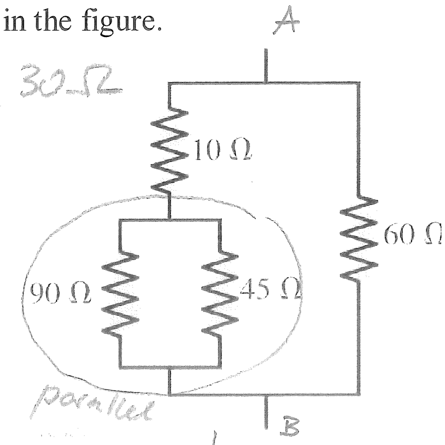
6. a) (20 points) Find the equivalent resistance of the resistor circuit shown in the figure.

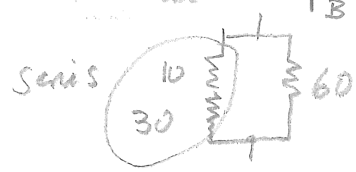


$$\frac{1}{R_{90+45}} = \frac{1}{90\,\Omega} + \frac{1}{45\,\Omega} = \frac{2+1}{90\,\Omega} = \frac{3}{90\,\Omega} \qquad R_{90+45} = 30\,\Omega$$

$$R_{10+30} = 10\,\Omega + 30\,\Omega = 40\,\Omega$$

$$\frac{1}{R_{eq}} = \frac{1}{40\,\Omega} + \frac{1}{60\,\Omega} = \frac{3+2}{120\,\Omega} = \frac{5}{120\,\Omega} = \frac{1}{24\,\Omega}$$

$$R_{eq} = 24\,\Omega$$



b) (20) A battery provides a potential difference of 48V between points A and B. Calculate the total current through the network, the potential drop across each of the resistors, and the current through each resistor. Put the answers in the table below.

$$I_{tot} = \frac{V}{R_{eq}} = \frac{48V}{24\,\Omega} = 2A$$

$60\,\Omega$: $V = 48V$ $\quad I = \frac{V}{R} = \frac{48V}{60\,\Omega} = 0.8A$

Leaves 1.2A for other branch ⇒ $10\,\Omega$: 1.2A $\quad V = IR = 12V$

→ leaves 36V for parallel 90+45: $I_{90} = \frac{36V}{90\,\Omega} = 0.4A$, $I_{45} = \frac{36V}{45\,\Omega} = 0.8A$ } 1.2A ✓

Total current:

10Ω	V= 12V	I= 1.2A
45 Ω	V= 36 V	I= 0.8A
90 Ω	V= 36 V	I= 0.4A
60 Ω	V= 48 V	I= 0.8 A

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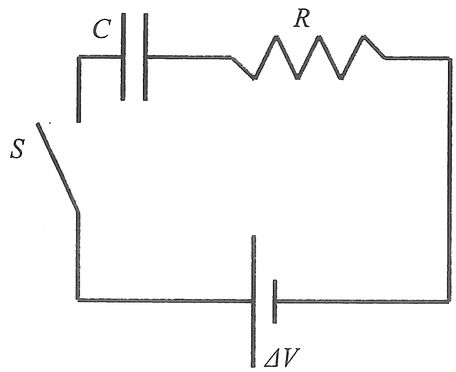
Charging

7) (40) A 4.0 μF capacitor is initially uncharged. It is connected in series with a switch, a 20 kΩ resistor, and an emf of 20 volts.



a)(5) Calculate the time constant of the circuit.

$$\tau = RC = 20\times10^{3}\,\Omega \cdot 4\times10^{-6}\,F = 80\times10^{-3}\,s$$

b)(5) Calculate the current through the resistor immediately after the switch is closed.

$$I = \frac{\Delta V}{R} = \frac{20\,V}{20\times10^{3}\,\Omega} = 10^{-3}\,A$$

c)(5) Determine the charge on the capacitor a very long time ($t \to \infty$) after the switch is closed.

$$C = \frac{Q}{\Delta V} \qquad Q_\infty = C\cdot\Delta V = 4\times10^{-6}\,F\cdot 20V = 80\times10^{-6}\,C = 80\,\mu C$$

d) (10) Calculate the charge on the capacitor 20 ms after the switch is closed.

$$Q = Q_f\left(1 - e^{-t/RC}\right)$$

$$Q = 80\,\mu C\left(1 - e^{-\frac{20\,ms}{80\,ms}}\right) = 17.7\,\mu C$$

e) (15) Calculate the time after which the current has decreased to one fourth its maximum value.

$$I = I_0 e^{-t/RC}$$

$$\frac{1}{4} I_0 = I_0 e^{-t/RC}$$

$$\frac{1}{4} = e^{-t/RC}$$

$$\ln \tfrac{1}{4} = -t/RC$$

$$t = -RC \ln \tfrac{1}{4}$$

$$t = RC \ln 4$$

$$t = 80\,ms \cdot \ln 4$$

$$t = 111\,ms$$

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