Principles II
Test 3

Show all work!

1) (3 points) Explain why the resistance of most materials increases with temperature.

As the molecules move faster, the electrons will be bounced around more, and will take longer to travel through the material.

2) (3 points) Would you expect the capacitance of a parallel-plate capacitor to increase, decrease, or remain the same, if the distance between the plates was increased? Why?

Decrease — when the plates are pulled apart, the charges feel a weaker attraction to the opposite plate, so the plates can hold less charge for a given voltage.

3) (3 points) An air-filled capacitor has a capacitance of 30 \( \mu \text{F} \). Without changing the space between the plates, an insulating material with a dielectric constant of 2.00 is inserted between the plates. What is the new capacitance of the capacitor?

\[
C = K C_0 = 2 \times 30 = 60 \mu \text{F}
\]

4) (3 points) It is necessary for an extension cord to carry a lot of current. Should the diameter of the wire be wide or narrow? Explain.

Wide — wider wires have less resistance, and can carry more current without overheating.
4) (11 points) For the circuit shown below, determine the equivalent capacitance, and the charge and voltage on each capacitor.

\[ C_5 = \frac{1}{\frac{1}{3} + \frac{1}{6}} = 2 \, \text{nF} \]

\[ C_p = 2 + 4 = 6 \, \text{nF} \]

\[ Q = C \cdot V = (6 \, \text{nF})(12) = 72 \, \text{nC} \]

\[ V_3 = V_{12} = 12 \, \text{V} \]

\[ Q_3 = C_3 \cdot V_3 = (4 \, \text{nF})(12) = 48 \, \text{nC} \]

\[ Q_{12} = C_{12} \cdot V_{12} = (2 \, \text{nF})(12) = 24 \, \text{nC} \]

\[ Q_1 = Q_2 \]

\[ V_1 = \frac{Q_1}{C_1} = \frac{24 \, \text{nC}}{3 \, \text{nF}} = 8 \, \text{V} \]

\[ V_2 = \frac{Q_2}{C_2} = \frac{24 \, \text{nC}}{6 \, \text{nF}} = 4 \, \text{V} \]

5) (7 points) For the circuit shown below, determine the equivalent resistance.

\[ R_{BC} = \frac{1}{\frac{1}{8} + \frac{1}{20}} = \frac{1}{\frac{20 + 1}{20}} = 10 \, \Omega \]

\[ R_{ABC} = 8 + 10 = 18 \, \Omega \]
6) (9 points) For the circuit shown below, determine the current through each of the three resistors.

\[ (1) \quad I_1 = I_2 + I_3 \]
\[ (2) \quad 14 - 4I_1 - 2I_3 = 0 \]
\[ (3) \quad -6I_2 + 10 + 2I_3 = 0 \]
\[ (4) \quad 14 - 4(I_2 + I_3) - 2I_3 = 0 \]
\[ 14 - 4I_2 - 6I_3 = 0 \]
\[ 4I_1 = 12 \]
\[ I_1 = 3A \]

7) (5 points) A 30 \mu F capacitor is charged up completely with a 40 V voltage source. The capacitor is then disconnected from the voltage source, without being discharged, and connected instead to a 20 \mu F capacitor. Determine the voltage and charge on each capacitor after the charge has had time to re-distribute.

- \[ Q_0 = C_1 V = (30 \mu F)(40 V) = 1200 \mu C \]
- \[ C_1 = \frac{Q_1}{V_1} \quad Q_1 = C_1 V_1 = (30)(24) = 720 \mu C \]
- \[ Q_2 = C_2 V_2 = (20)(24) = 480 \mu C \]

\[ Q = Q_1 + Q_2 = 480 + 720 = 1200 \mu C \]

\[ Q_1 + Q_2 = Q_0 = 1200 \mu C \]
\[ C_1 V_{\text{new}} + C_2 V_{\text{new}} = 1200 \mu C \]
\[ (C_1 + C_2) V_{\text{new}} = 1200 \mu C \]
\[ (30 + 20) V_{\text{new}} = 1200 \mu C \]
\[ V_{\text{new}} = 24 V \]

\[ V_1 = V_2 \]

8) A 450 nF capacitor is given a charge of 65.5 nC, and then connected to a 1.25 M\Omega resistor. A) (3 points) What is the maximum current through the resistor?

\[ I_0 = \frac{Q_{\text{max}}}{RC} = \frac{65.5 \text{ nC}}{(1.25 \times 10^6)(450 \times 10^{-9})} = 116 \mu A \]

B) (3 points) What is the time constant for this circuit?

\[ \tau = RC = (1.25 \times 10^6)(450 \times 10^{-9}) = 562.5 \text{ s} \]