1) (5pts) Which of these statements is consistent with Ohm’s Law? (V= voltage difference, I= current)
   a) The electric field inside a conductor is exactly zero.
   b) The derivative dV/dI is a constant.
   c) The derivative dV/dI is proportional to I.
   d) V and I are independent of each other.

2) (5pts) A capacitor is being charged by a **constant** current. Which of the following figures represents the potential difference across the capacitor as a function of time?

   ![Graph Options]

3) (5pts) A cylindrical wire is stretched in a way that it still remains a cylinder. The resistance of the stretched wire is measured end to end along its length. Compared to the original resistance of the wire the stretched wire will have:
   a) the same resistance
   b) larger resistance
   c) smaller resistance
   d) none of the above

4) (5pts) A battery, a resistor and a capacitor are connected in series. If we want to shorten the time it takes for the capacitor to reach the battery’s voltage we could:
   a) add another resistor in series with the one already in the circuit.
   b) increase the capacitance.
   c) increase the resistance.
   d) decrease both the resistance and capacitance.

5) (5pts) The electric field (E), current density (J) and resistivity (ρ) are related through the following equation: \( \overline{E} = \rho \overline{J} \)

   Which of the following statements is true:
   a) For a conductor ρ is very large while for an insulator ρ is very small.
   b) For a conductor ρ is very small while for an insulator ρ is very large.
   c) Conductors and insulators have about the same resistivity.
   d) For conductors resistivity has a negative value, while for insulators it has positive value.
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6) Two capacitors are charged up as shown in the figure. \( C_1 = 1 \mu F \), \( Q_1 = 10^{-4} \, \text{C} \), \( C_2 = 3 \mu F \), \( Q_2 = 3 \times 10^{-4} \, \text{C} \)

Note that the polarity of the charge on \( C_2 \) is opposite of \( C_1 \).

a) (6 pts) With the switches open what is the voltage drop across \( C_1 \) (= \( V_a - V_b \))? 

\[
V = \frac{Q}{C} = \frac{10^{-4} \, \text{coul.}}{10^{-6} \, \text{F}} = 100 \, \text{V}
\]

b) (9 pts) Suppose both switches are closed. Now what is \( V_a - V_b \)?

\[
Q_{\text{total}} = Q_1 + Q_2 = [10^{-4} \, \text{coul.} + (-3 \times 10^{-4} \, \text{coul.})] = -2 \times 10^{-4} \, \text{coul.} \text{ (this is now the total charge on the upper plates)}
\]

\[
Q_{\text{total}} = Q_1 + Q_2 = C_1 V_1 + C_2 V_2 = V(C_1 + C_2) \text{ (voltage across both caps the same since they are in parallel now)}
\]

\[
V = \frac{Q_{\text{total}}}{C_1 + C_2} = \frac{-2 \times 10^{-4} \, \text{coul}}{4 \times 10^{-6} \, \text{F}} = -50 \, \text{V} \Rightarrow V_a - V_b = -50 \, \text{V}
\]

7) (5 pts) A battery is used to charge a parallel plate capacitor. The battery is removed and the plates are moved closer to each other. Which of the following statements is true?

a) the surface charge density is increased.

b) the energy stored in the capacitor is increased.

c) the capacitance is increased.

d) the charge on each plate is decreased.

8) (5 pts) Two capacitors are in parallel with each other. Which of the following statements is true?

a) The capacitors will always have the same amount of charge on them.

b) The capacitors will always have the same voltage difference across them.

c) The capacitors will always store the same amount of energy.

d) The capacitors will always have the same current through them.
9a) (3pts) Use the “junction rule” for currents to write an equation that relates the currents at point c) in the circuit.

\[ I_7 + I_6 - I_2 - I_5 = 0 \]

9b) (4pts) Use the “loop rule” to write an equation for the potential changes in terms of current(s), resistance(s), and EMF(s) as we travel from a) to b) to d) to f) to e) to c) to h) to g) to a).

\[ V_1 - I_1R_1 + I_3R_3 + I_4R_4 - V_3 + I_5R_5 - V_6 + I_6R_6 = 0 \]

9c) (5 pts) The voltage at a is \( V_a = 2V \), and \( V_1 = 10V \), \( R_1 = 5\Omega \), \( I_1 = 0.4A \). What is the voltage at point b, \( V_b \)?

\[ V_b = V_a + 10V - (5\Omega)(0.4A) = 10V \]

10) Three light bulbs, represented by resistors, are in the following circuit. Each bulb has a resistance of 100\( \Omega \).

10a) (3pts) What is the equivalent resistance of light bulbs 2 and 3 ?

\[ \frac{1}{R} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{100\Omega} + \frac{1}{100\Omega} \Rightarrow R = 50\Omega \]

10b) (6pts) How much power is dissipated in bulb 1 ?

Current in bulb 1: \( I_1 = (100V/150\Omega) \), voltage across bulb 1: \( V_1 = R_1(100V/150\Omega) = (100\Omega)(100V/150\Omega) \) power in bulb 1: \( P = I_1V_1 = 44.4W \)

10c) (4 pts) If bulb 2 is unscrewed and taken out of the circuit will light bulb 1 increase or decrease in brightness?

You MUST explain your answer (numerical results are not required, but correct physics is.). No explanation=zero points.

Decrease. When bulb 2 is taken out of the circuit the total current in the circuit decreases (since the circuit resistance increases) and therefore the voltage drop across bulb 1 decreases too. So, we now have less power dissipated in bulb 1 and therefore its brightness decreases.
11) In the circuit on the right the capacitor is initially uncharged and no current is flowing through \( R \). The switch is then moved to position a.

11a) (5pts) Use the loop rule to write (DO NOT SOLVE) an equation for the charge on the capacitor as a function of time.

going around the loop we have: \( E-IR-q/C=0 \)
\( E-Rdq/dt-q/C=0 \)

11b) (5pts) Suppose the charge on the capacitor as a function of time is: \( q(t) = CV(1-e^{-t/RC}) \)
What is the current in the resistor as a function of time (in terms of \( V,C,R \))?
The current is the derivative of \( q(t) \) with respect to \( t \).

\[
I = \frac{dq}{dt} = CV \frac{d}{dt}(1-e^{-t/RC}) = CV \frac{d}{dt}(1-e^{-t/RC}) = CV \frac{e^{-t/RC}}{RC} = \frac{V}{R} e^{-t/RC}
\]

12) In each of the following the magnitude of the magnetic field (\( B \)) is 1.5 Tesla and the speed (\( |v| \)) of the particle is 40 m/s.

12a) (5pts) For Fig. (ii) what is the direction of the magnetic force if the moving charge is negative?

12b) (5 pts) For which figure is the magnitude of the magnetic force smallest?

12c) (5pts) Suppose the moving charge in Fig. (iii) is an electron. What is the magnitude of the magnetic force that acts on it?

\[
F=(1.6\times10^{-19}C)(1.5T)(40m/s)\sin40=6.2\times10^{-18}N
\]