NAME & ID ______________________________

PH 102 / LeClair Summer II 2009

Quiz 4: Solutions

$$Q = C\Delta V \qquad \text{Energy} = \frac{1}{2}Q\Delta V = \frac{1}{2}C\left(\Delta V\right)^2 = Q^2/2C$$

$$C = \epsilon_o A/d \quad \text{parallel plate} \qquad \epsilon_o = \frac{1}{4\pi k_e} = 8.85\times10^{-12}\,\mathrm{C^2/N\cdot m^2} \qquad e = 1.60218\times10^{-19}\,\mathrm{C}$$

$$\frac{1}{C_{\text{eq, series}}} = \frac{1}{C_1} + \frac{1}{C_2} \qquad C_{\text{eq, par}} = C_1 + C_2$$

1. A fully charged defibrillator contains $1.20\,\mathrm{kJ}$ of stored electrical energy in a $1.1\times10^{-4}\,\mathrm{F}$ capacitor. Find the voltage needed to store $1.20\,\mathrm{kJ}$ in the unit.

Solution: In this case, we know the energy stored in the capacitor U and its capacitance C and wish to find the voltage ΔV, so we can use $U = \frac{1}{2}C\left(\Delta V\right)^2$. We should note that $1\,\mathrm{J} = 1\,\mathrm{C\cdot V}$ and $1\,\mathrm{F} = 1\,\mathrm{C/V}$ to make the units come out correctly.

$$U = \frac{1}{2}C\left(\Delta V\right)^2$$

$$\frac{2U}{C} = \left(\Delta V\right)^2$$

$$\Delta V = \sqrt{\frac{2U}{C}} = \sqrt{\frac{2\left(1.2\times10^3\,\mathrm{J}\right)}{1.1\times10^{-4}\,\mathrm{F}}} \approx \sqrt{2.18\times10^7\,\frac{\mathrm{C\cdot V}}{\mathrm{C/V}}} = 4671\,\mathrm{V} \approx 4700\,\mathrm{V}$$

2. Five $5\,\mu\mathrm{F}$ capacitors are connected in parallel. What is the equivalent capacitance? How about if all five are connected in series?

Solution: In parallel, we simply add the values of the capacitors:

$$C_{\text{eq, par}} = C_1 + C_2 + C_3 + C_4 + C_5 = 5\,\mu\mathrm{F}\times5 = 25\,\mu\mathrm{F} \tag{1}$$

In series, we have to add the values harmonically,

$$\frac{1}{C_{\text{eq, ser}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} + \frac{1}{C_5} = \frac{5}{5\,\mu\mathrm{F}} = 1\frac{1}{\mu\mathrm{F}} \tag{2}$$

$$C_{\text{eq, ser}} = 1\,\mu\mathrm{F} \tag{3}$$

3. I have two batteries and three capacitors. How should I connect them to store the most electrical energy? Describe in words or as a circuit diagram as you choose.

Solution: The maximum amount of energy stored will be when we can store the most charge at the largest potential difference. Combining capacitors in series makes the resultant combination lower than any individual capacitor, while combining them in parallel adds their individual capacitances together. Thus, to store the most charge we should connect the capacitors in parallel. The maximum voltage will be achieved when we connect the batteries in series, since this will add their potential differences together (presuming we get the polarity right). Thus, our optimum circuit should look like this: