Phys 202

Recitation 2

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Formulae

The electric potential of a point charge q at a distance r:

$$V = \frac{kq}{r}.$$

If there are more than one charges in space, the electric potential is:

$$V = k(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \cdots).$$

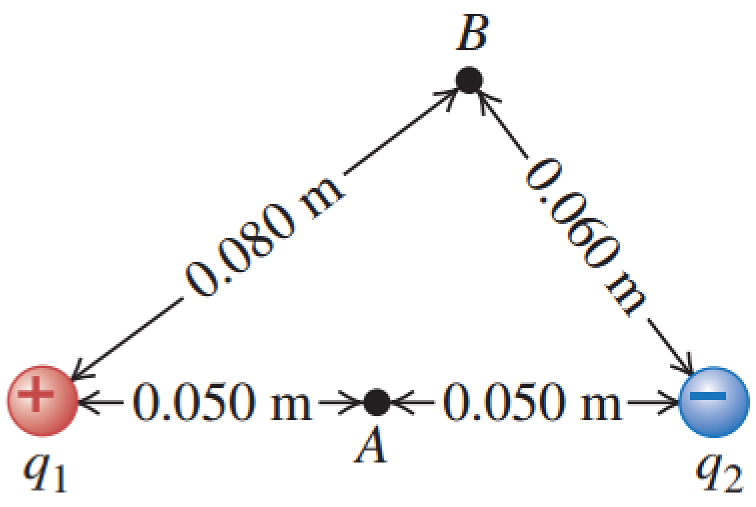
Work done by an electric field on a test charge moving from point a to point b:

$$W_{a\to b} = U_a - U_b = q'(V_a - V_b).$$

$$C = \frac{Q}{V_{ab}}.$$

$$C = \frac{Q}{V_{ab}} = \varepsilon_0 \frac{A}{d}.$$

22. ●● Two point charges $q_1 = +2.40$ nC and $q_2 = -6.50$ nC are 0.100 m apart. Point A is midway between them; point B is 0.080 m from q_1 and 0.060 m from q_2. (See Figure 18.41.) Take the electric potential to be zero at infinity. Find (a) the potential at point A; (b) the potential at point B; (c) the work done by the electric field on a charge of 2.50 nC that travels from point B to point A.



▲ **FIGURE 18.41** Problem 22.

18.22. Set Up: For a single point charge $V = \frac{kq}{r}$. The total potential is the sum of the potentials due to the two point charges. $W_{B\to A} = q(V_B - V_A)$.

Solve: (a) $V_A = \frac{kq_1}{r_{1A}} + \frac{kq_2}{r_{2A}} = \frac{8.99\times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2}{0.050\ \text{m}}(2.40\times 10^{-9}\ \text{C} + [-6.50\times 10^{-9}\ \text{C}]) = -737\ \text{V}$

(b) $V_B = \frac{kq_1}{r_{1B}} + \frac{kq_2}{r_{2B}} = (8.99\times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)\left(\frac{2.40\times 10^{-9}\ \text{C}}{0.080\ \text{m}} + \frac{-6.50\times 10^{-9}\ \text{C}}{0.060\ \text{m}}\right) = -704\ \text{V}$

(c) $W_{B\to A} = q(V_B - V_A) = (2.50\times 10^{-9}\ \text{C})(-704\ \text{V} - (-737\ \text{V})) = 8.2\times 10^{-8}\ \text{J}$

44. ●● A 5.00 pF parallel-plate air-filled capacitor with circular plates is to be used in a circuit in which it will be subjected to potentials of up to 1.00×10^2 V. The electric field between the plates is to be no greater than 1.00×10^4 N/C. As a budding electrical engineer for Live-Wire Electronics, your tasks are to (a) design the capacitor by finding what its physical dimensions and separation must be and (b) find the maximum charge these plates can hold.

18.44. Set Up: $C = \frac{Q}{V_{ab}}$. $V_{ab} = Ed$. $C = \frac{\epsilon_0 A}{d}$.

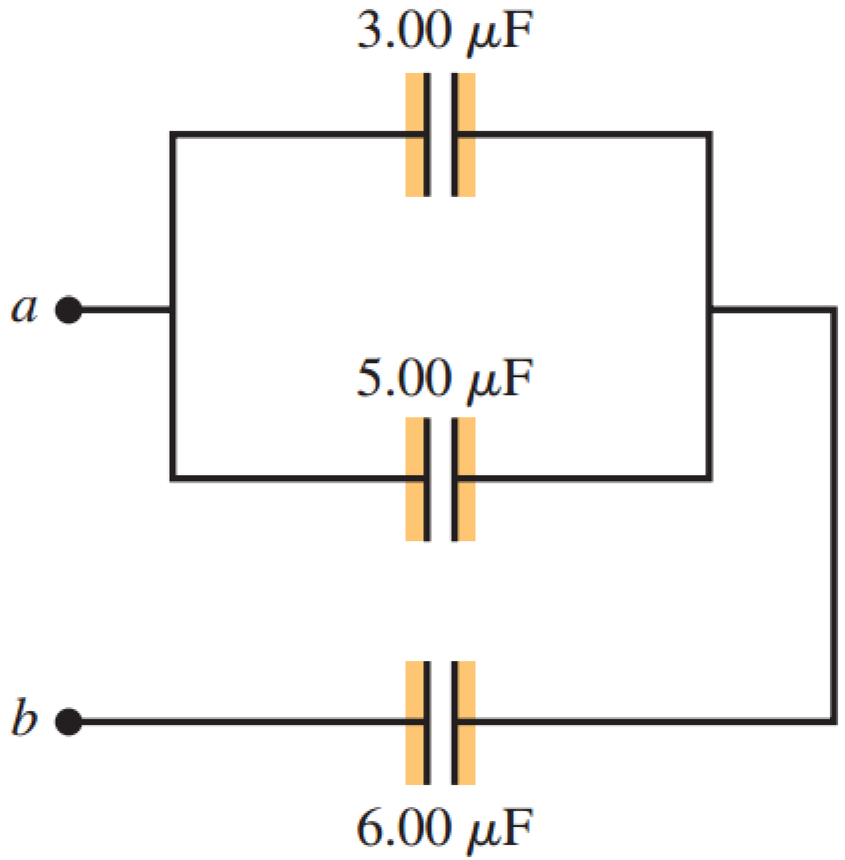
Solve: (a) $d = \frac{V_{ab}}{E} = \frac{1.00 \times 10^2 \text{ V}}{1.00 \times 10^4 \text{ N/C}} = 1.00 \times 10^{-2} \text{ m} = 1.00 \text{ cm}.$

$$A = \frac{Cd}{\epsilon_0} = \frac{(5.00 \times 10^{-12} \text{ F})(1.00 \times 10^{-2} \text{ m})}{8.854 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2)} = 5.65 \times 10^{-3} \text{ m}^2.$$

$A = \pi r^2$ so $r = \sqrt{\frac{A}{\pi}} = 4.24 \times 10^{-2} \text{ m} = 4.24 \text{ cm}.$

(b) $Q = CV_{ab} = (5.00 \times 10^{-12} \text{ F})(1.00 \times 10^2 \text{ V}) = 5.00 \times 10^{-10} \text{ C} = 500 \text{ pC}$

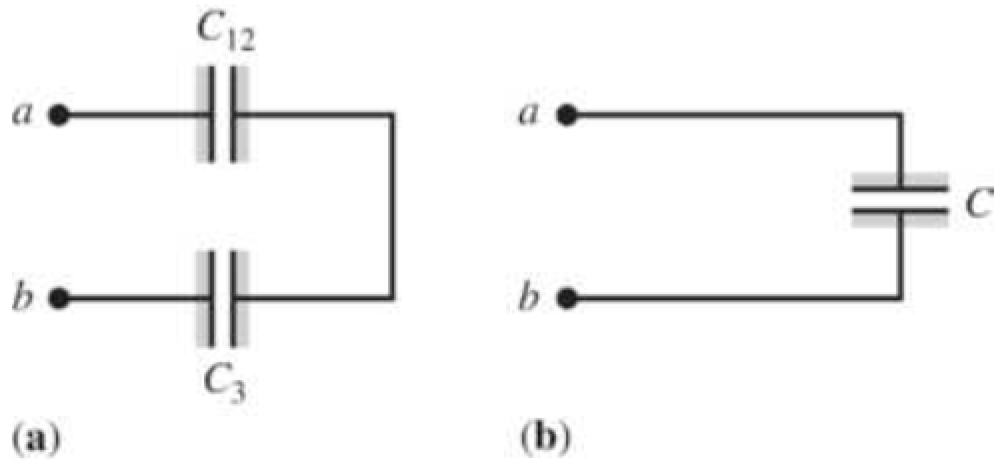
53. ●● In the circuit shown in Figure 18.45, the potential difference across *ab* is +24.0 V. Calculate (a) the charge on each capacitor and (b) the potential difference across each capacitor.



***18.53. Set Up:** $C = \frac{Q}{V}$. For two capacitors in parallel, $C_{eq} = C_1 + C_2$. For two capacitors in series,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \text{ and } C_{eq} = \frac{C_1 C_2}{C_1 + C_2}.$$

For capacitors in parallel, the voltages are the same and the charges add. For capacitors in series, the charges are the same and the voltages add. Let $C_1 = 3.00\ \mu\text{F}$, $C_2 = 5.00\ \mu\text{F}$ and $C_3 = 6.00\ \mu\text{F}$.



Solve: **(a)** The equivalent capacitance for C_1 and C_2 in parallel is $C_{12} = C_1 + C_2 = 8.00\ \mu\text{F}$. This gives the circuit shown in Figure (a) above. In that circuit the equivalent capacitance is

$$C = \frac{C_{12}C_3}{C_{12} + C_3} = \frac{(8.00\ \mu\text{F})(6.00\ \mu\text{F})}{8.00\ \mu\text{F} + 6.00\ \mu\text{F}} = 3.43\ \mu\text{F}.$$

This gives the circuit shown in Figure (b) above. In Figure (b), $Q = CV = (3.43 \times 10^{-6}\ \text{F})(24.0\ \text{V}) = 8.23 \times 10^{-5}\ \text{C}$. In Figure (a) each capacitor therefore has charge $8.23 \times 10^{-5}\ \text{C}$. The potential differences are

$$V_3 = \frac{Q_3}{C_3} = \frac{8.23 \times 10^{-5}\ \text{C}}{6.00 \times 10^{-6}\ \text{F}} = 13.7\ \text{V} \text{ and } V_{12} = \frac{Q_{12}}{C_{12}} = \frac{8.23 \times 10^{-5}\ \text{C}}{8.00 \times 10^{-6}\ \text{F}} = 10.3\ \text{V}.$$

Note that $V_3 + V_{12} = 24.0\ \text{V}$. Then in the original circuit, $V_1 = V_2 = V_{12} = 10.3\ \text{V}$.

$$Q_1 = V_1C_1 = (10.3\ \text{V})(3.00 \times 10^{-6}\ \text{F}) = 3.09 \times 10^{-5}\ \text{C}.$$

$$Q_2 = V_2C_2 = (10.3\ \text{V})(5.00 \times 10^{-6}\ \text{F}) = 5.15 \times 10^{-5}\ \text{C}.$$

$Q_1 = 30.9\ \mu\text{C}$, $Q_2 = 51.5\ \mu\text{C}$ and $Q_3 = 82.3\ \mu\text{C}$. Note that $Q_1 + Q_2 = Q_3$.

(b) $V_1 = 10.3\ \text{V}$, $V_2 = 10.3\ \text{V}$ and $V_3 = 13.7\ \text{V}$

Reflect: Note that $Q_1 + Q_2 = Q_3$, $V_1 = V_2$ and $V_1 + V_3 = 24.0\ \text{V}$