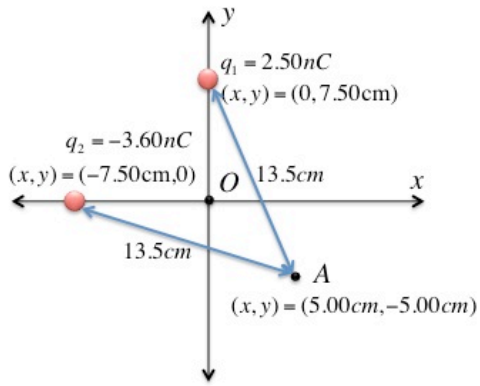
Extra Practice Problem Solutions

Problem 1: Suppose two charged particles are on the xy-plane. Charge $q_1 = 2.50nC$ is at $x = 0\ cm$ and $y = 7.50\ cm$, and charge $q_2 = -3.60nC$ is at $x = -7.50\ cm$ and $y = 0\ cm$ as shown below.

a) Find the electric potential at the origin, V_0.
b) Find the electric potential at point A, V_A, which is located at $x = 5.00\ cm$ and $y = -5.00\ cm$.
c) If a charged particle with $q = 2.40nC$ moves from the origin to point A while q_1 and q_2 are held fixed, calculate the work done by the electric force.



Solution:

a) Charge q_1 and q_2 are both $5.00\ cm$ from the origin. Therefore, $r_1 = r_2 = 5.00\ cm$, and

$$V_0 = \frac{1}{4\pi\epsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right) = 8.99\times10^9 \frac{N\ m^2}{C^2}\left(\frac{2.50\times10^{-9}C}{0.0750\ m} + \frac{-3.60\times10^{-9}C}{0.0750\ m}\right)$$
$$= -132\ V$$

b) Using the Pythagorean theorem, we find that q_1 and q_2 are both $\sqrt{(12.5\ cm)^2 + (5.00\ cm)^2} = 13.5\ cm$ away from point A. Therefore,

$$V_A = \frac{1}{4\pi\epsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right) = 8.99\times10^9 \frac{N\ m^2}{C^2}\left(\frac{2.50\times10^{-9}C}{0.135\ m} + \frac{-3.60\times10^{-9}C}{0.135\ m}\right)$$
$$= -73.3\ V$$

c)

$$U_A - U_0 = q(V_A - V_0) = 2.40\times10^{-9}C(-73.3\ V + 132\ V)$$
$$= 1.41\times10^{-7}\ J$$

Problem 2: A solid spherical conductor with radius 12.0 cm has a net charge −2.50 nC.

a) Determine the magnitude and the direction of the electric field at a point 5.0 cm from the center of the sphere.

b) Determine the magnitude and the direction of the electric field at a point 30.0cm from the center of the sphere.

Solution:

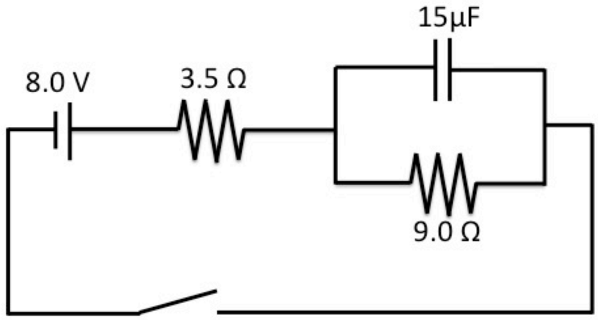
a) In electrostatic, the electric field is zero inside the conductor. So $\vec{E} = 0$ inside.

b) Because of the spherical symmetry, the excess charge on the sphere will distribute uniformly on the surface of the conductor. Therefore, the charge distribution is identical to Example 22.5 in the textbook. So the magnitude is

$$E = \frac{1}{4\pi\epsilon_0}\frac{|q|}{r^2} = 9.0\times10^9 \frac{Nm^2}{C^2}\frac{2.50\times10^{-9}C}{(0.30m)^2} = 250\ \frac{N}{C}$$

and it points radially inward toward the origin because it is negatively charged.

Problem 3: Suppose a 15-μF capacitor is connected to two resistors and one ideal battery as shown below. Before the switch is closed, the capacitor has no charge.



a) What is the current through the 9.0Ω resistor immediately after the switch is closed?
b) What is the current through the 9.0Ω resistor a long time after the switch is closed?
c) What is the charge stored in the capacitor a long time after the switch is closed?

Solution:

a) Immediately after the switch is closed, the capacitor has no charge stored. Therefore, the potential across the capacitor is zero and it behaves as a conducting wire. As a result, all the current will flow through the capacitor and $I = 0$ through the 9.0Ω resistor.
b) After a long time, the capacitor will be fully charged and you cannot send any more current through the capacitor. Therefore, the circuit behaves as if it is broken at the capacitor, and it is equivalent to the two resistors and one battery all in series. The equivalent resistance of the two resistors in series is $R_{eq} = 3.5\Omega + 9.0\Omega = 12.5\Omega$, and the current through the 9.0Ω resistor is $I = \frac{8.0V}{12.5\Omega} = 0.64A$.
c) When the capacitor is fully charged, the potential across the 9.0Ω resistor is $V = (0.64A)(9.0\Omega) = 5.8V$. Because the capacitor and the 9.0Ω resistor are in parallel, the potential across the capacitor must also be $5.8V$. Therefore, $Q = CV = (15\times10^{-6}F)(5.8V) = 8.6\times10^{-5}C$.