Example 1

1) In the Bohr model of the hydrogen atom, an electron in the lowest energy state follows a circular path at a distance of $5.29 \times 10^{-11}$ m from the proton.

a) What is the speed of the electron?

b) What is the effective current associated with this orbiting electron?

\[ F = ma \]
\[ F = m \frac{v^2}{r} \]
\[ k \frac{8.1 \times 10^{-19}}{r^2} = m \frac{v^2}{r} \]
\[ v = \sqrt{\frac{k \frac{8.1 \times 10^{-19}}{m r}}{\left(9 \times 10^9 \frac{N \cdot m^2}{e^2}\right) \left(1.6 \times 10^{-19} e\right)^2}} \frac{m/s}{\left(9.11 \times 10^{-31} kg\right) \left(5.27 \times 10^{-11} m\right)} \]
\[ v = 2.19 \times 10^6 \text{ m/s} \]

b) \[ i = \frac{\partial Q}{\partial t} \]
\[ i = \frac{9 v}{2 \pi r} \]
\[ i = \frac{\left(1.6 \times 10^{-19} e\right) \left(2.19 \times 10^6 \text{ m/s}\right)}{2 \pi \left(5.27 \times 10^{-11} m\right)} \]
\[ i = 1.05 \times 10^{-3} \text{ A} \rightarrow 1.05 \text{ mA} \]
\[ F = k \frac{q_1 q_2}{r^2} \]
\[ E = k \frac{q}{r^2} \]
\[ V = k \frac{q}{r} \]
\[ \kappa = \frac{1}{4\pi \varepsilon_0} = 9 \times 10^9 \, N \frac{m^2}{C^2} \]
\[ \Delta U = \Delta V q \]
\[ W = \Delta U \]
\[ \Delta U + \Delta KE = 0 \]
\[ KE = \frac{1}{2} m v^2 \]
\[ F = q E \]

Stuff that may help!

\[ e = 1.6 \times 10^{-19} \, C \]
\[ m_e = 9.11 \times 10^{-31} \, kg \]
\[ \mu = 10^{-6} \]
\[ n = 10^{-9} \]

\[ C = \frac{\kappa \varepsilon_0 A}{d} \]

\[ \varepsilon_0 = 8.85 \times 10^{-12} \, \frac{C^2}{N \cdot m} \]

\[ q = CV \]

\[ E = \frac{1}{2} CV^2 \]

\[ V = iR \]
\[ P = i^2 R \]
\[ P = iV \]

\[ \frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \text{or} \quad R_{tot} = R_1 + R_2 + R_3 \]

\[ \frac{1}{C_{tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \quad \text{or} \quad C_{tot} = C_1 + C_2 + C_3 \]

\[ F = ma \]
Question 1

Wednesday, March 11, 2015 7:09 AM

Show all work in the spaces provided.

1) In the figure above each capacitance $C_1$ is 6.9 $\mu$F and each capacitance $C_2$ is 4.6 $\mu$F.
   a) Compute the equivalent capacitance of the circuit between points a and b. (5 pts)

\[
\frac{1}{C_{III}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_1}
\]

\[
\frac{1}{C_{III}} = \frac{3}{6.9 \mu F}
\]

\[
C_{III} = 2.3 \mu F
\]

\[
C_y = C_2 + C_{III}
\]

\[
C_y = 4.6 \mu F + 2.3 \mu F
\]

\[
C_y = 6.9 \mu F = C_1
\]

\[
\frac{1}{C_5} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_1}
\]

\[
C_5 = 2.3 \mu F
\]

\[
C_6 = C_2 + C_5
\]

\[
C_6 = 4.6 \mu F + 2.3 \mu F
\]

\[
C_6 = 6.9 \mu F = C_1
\]
\[
\frac{1}{C_{\text{total}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}
\]

\[C_{\text{total}} = 2.3 \, \text{mF}\]
b) Compute the charge on each of the three capacitors nearest a and b when the voltage between a and b is 420V. (5 pts)

\[ V_2 = V_5 = V_6 \]

\[ V_2 = 140V \]

\[ q_2 = V_2 C_2 = (140V)(4.6\mu F) \]

\[ q_2 = 644\mu C \]

\[ q_6 = 966\mu C \]

\[ q_{+\infty} = (420V)(2.3\mu F) \]

\[ q_{+\infty} = 966\mu C \]

\[ q_6 = C_6 V_6 \]

\[ V_6 = \frac{q_6}{C_6} \]

\[ V_6 = \frac{966\mu C}{6.9\mu F} \]

\[ V_6 = 140V \]
2) A nervous Physicist worries that two metal shelves of his wood frame bookcase might obtain a high voltage if charged by static electricity, perhaps produced by friction.

a) What is the capacitance of the empty shelves if they have area 0.100 m\(^2\) and are 0.200 m apart? (5 pts)

\[
C = \frac{k \varepsilon_0 A}{d} = \left( 1 \right) \left( 8.85 \times 10^{-12} \frac{C^2}{N \cdot m} \right) \left( 0.1 \text{ m}^2 \right) \frac{0.2 \text{ m}}{2 \text{ m}}
\]

\[
C = 4.43 \times 10^{-12} \text{ F} = 4.43 \text{ pF}
\]

b) What is the voltage between them if the opposite charges of magnitude 2.00 nC are placed on them? (5 pts)

\[
V = \frac{q}{C} = \frac{2 \times 10^{-9} \text{ C}}{4.43 \times 10^{-12} \text{ F}}
\]

\[
V = 451.47 \text{ V}
\]
3) Two point charges $q_1 = +2.4 \text{ nC}$ and $q_2 = -6.50 \text{ nC}$ are 0.100 m apart. Point A is midway between them; point B is 0.80 m from $q_1$ and 0.060 m from $q_2$. (see figure above.)

a) What is the electrical potential at point A due to the charges $q_1$ and $q_2$? (3 pts)

$$V_A = k \frac{q_1}{r_{1A}} + k \frac{q_2}{r_{2A}} = (9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \left[ \frac{2.4 \times 10^{-9} \text{ C}}{0.05 \text{ m}} - \frac{6.5 \times 10^{-9} \text{ C}}{0.05 \text{ m}} \right]$$

$$V_A = -738 \text{ V}$$

b) What is the electrical potential at point B due to the charges $q_1$ and $q_2$? (3 pts)

$$V_B = k \frac{q_1}{r_{1B}} + k \frac{q_2}{r_{2B}} = (9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \left[ \frac{2.4 \times 10^{-9} \text{ C}}{0.08 \text{ m}} - \frac{6.5 \times 10^{-9} \text{ C}}{0.06 \text{ m}} \right]$$

$$V_B = -705 \text{ V}$$

c) What is the work done by the electric field on a charge of 2.50 nC that travels from point B to Point A? (4 pts.)

$$W = q \Delta V$$

$$W = q_3 \left[ V_f - V_i \right] = q_3 \left[ V_A - V_B \right]$$

$$W = (2.5 \times 10^{-9} \text{ C}) \left[ -738 \text{ V} - (-705 \text{ V}) \right]$$

$$W = -8.25 \times 10^{-8} \text{ J}$$
4) Just as you touch a metal door knob, a spark of electricity (electrons) jumps from your hand to the knob. The electrical potential of the knob is greater than that of your hand. The work done by the electric force on the electrons is $1.5 \times 10^{-7} J$. How many electrons jump from your hand to the knob? (10 pts)

\[ \Delta V = 3 \times 10^4 V \]

\[ q = \frac{W}{\Delta V} \]

\[ q = \frac{1.5 \times 10^{-7}}{-3 \times 10^4 V} \]

\[ q = 5 \times 10^{-12} C \]

\[ \# \text{ electrons} = \frac{5 \times 10^{-12} C}{-1.6 \times 10^{-19} C/e} = 3.125 \times 10^7 \text{ electrons} \]