Assignment VI, HONS 158 (Honors Physics II)
Spring 2016
Due 2/24/16 at start of class

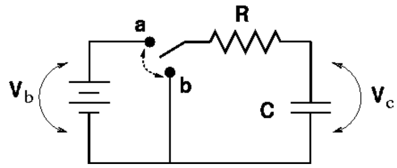
As always, please put your answers on separate paper.

1. Below is a picture of an RC circuit. Let the capacitor be initially uncharged and assume the switch is toggled to the "a" position at time $t = 0$.

   a) Find an expression for the voltage drop over the *resistor* as a function of time.

   b) Use your answer to part (a) to determine the time at which the voltage drop over the resistor is exactly one half of the voltage supplied by the battery (V_b). Leave your answer in terms of R and C.

   c) If $R = 3.3$ kΩ, $V_b = 1$ kV, and $C = 20$ μF – how much charge is on the positive plate of the capacitor after 10 milliseconds?



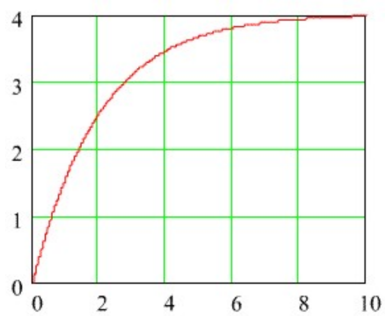
2. Above is the same picture of the RC circuit. Assume that the switch has been aligned so that the switch is connected to point "a" for a very long time – so long that no more current runs in the circuit because an equilibrium has been reached. Now, at time $t = t_\circ$, the switch is moved to position "b".

   a) Write an expression for $|I(t)|$ for this circuit, assuming $t > t_\circ$. (Leave your answer in terms of V_b, R, C, $t_\circ$, and t).

   b) If $R = 4.7$ kΩ, $V_b = 500$ V, and $C = 50$ μF, how much total charge moves through the resistor between $t = t_\circ$ and $t = t_\circ + 3\tau$? (Hint...your answer to part (a) might be helpful here). (Don't worry about the sign of the charge).

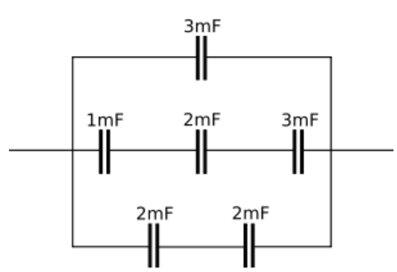
3. Again look at the same picture of the RC circuit on the previous page for reference. Below is a picture of $V_C(t)$ (in volts) as a function of t (in seconds) after switching the switch to position "a". (You may assume that the capacitor was initially uncharged). Based on the plot below and the circuit above, answer the following:

    a) What is the voltage of the battery?
    b) If the resistor has a resistance of 3300 Ω, what is the Capacitance of the capacitor?
    c) If the resistor has a resistance of 3300 Ω, how much resides on the surface of the capacitor at $t = 3$ seconds?
    d) If the resistor has a resistance of 3300 Ω, how much energy is stored in the capacitor after $t = 10$ seconds?
    e) Let's say the capacitor is charged as implied in parts (a)-(d) above and then removed from the circuit (while still retaining its charge). The capacitor is then put in a very simple circuit, in series with a lightbulb of resistance 7 Ω. (This is actually reasonable for a small light bulb like the ones we used in lab when first learning about circuits). Technically, current runs through this new circuit forever, but at some point it doesn't appear like the bulb is lit any longer. The brightness of the bulb is related to the instantaneous power being dissipated by the bulb. If the bulb does not appear to be lit up when its instantaneous power drops below 0.1 W, how long can the capacitor keep the bulb lit?



4. Please see figure of a portion of a circuit below.

    a) What is the total capacitance of the circuit below?
    b) How much energy would be stored in this capacitor network if it was connected directly to a 15 V battery?



5. A particle with a charge of 32 μC experiences a force of 7.3×10^{-5} N when it moves at right angles to a magnetic field with a speed of 18 m/s. What force does this particle experience when it moves at a speed of 3.7 m/s at an angle of 62° relative to the magnetic field?

6. A 5.70 μC particle moves through a region of space where an electric field of magnitude 1320 N/C points in the $\hat{\imath}$ direction and a magnetic field of 0.79 T points in the $\hat{k}$ direction. If the net force acting on the particle is 3.79×10^{-3} N in the $\hat{\imath}$ direction, find the magnitude and direction of the particle's velocity. (Assume that the particle's velocity is in the $x - y$ plane).

7. A proton with kinetic energy K moves perpendicular to a magnetic field of magnitude $B_\circ$. What is the radius of its circular path? (Leave your answer in terms of K, $B_\circ$, and fundamental constants only). (Note – you can't leave a v in your answer! However, the charge and mass on a proton are considered fundamental constants).

8. The Earth's magnetic field varies a little bit over its surface, but it is generally between about 0.2 Gauss and 0.6 Gauss. Let's use a value of 0.4 Gauss as a typical value. A transmission line is designed to transport, say, 10 kA of current. For simplicity, we will assume this is DC current.

   a) How far away would you have to be from the center of this transmission line so that the strength of the magnetic field generated by the transmission line is equal to the Earth's magnetic field?

   b) How close would you have to be to this transmission line to experience the same magnetic field associated with an MRI scan (about 1.5 Tesla)?

9. The strength of the magnetic field in the center of a current loop is equal to $B = \frac{\mu_\circ I}{2r}$ (as we may have already mentioned in class). For the sake of this problem, let's treat a Hydrogen atom as a single, stationary proton with an electron orbiting it in a circular orbit. (We'll find out later this semester that this is a bit nuts....but for now we'll stick with this picture).

   a) Assume that your electron (with a mass of 9.11×10^{-31} kg and a charge of 1.602×10^{-19} C) is in uniform circular motion with the associated centripetal force being supplied by the Coulomb attraction between the proton and the electron. We will assume that the electron is in a stable circular motion a distance 5.3×10^{-11} meters from the (stationary) proton. What, then, must be the speed of the electron? (You'll have to think back to last semester).

   b) If we think of it, we now can write the associated "current" for an electron orbiting a proton; this would be the total charge that moves divided by the time it takes to complete a full circuit. You have all the information to find this, so identify the "current" for a single electron orbiting a proton.

   c) This "current" would induce a magnetic field at the center of the atom. What is the magnitude of this magnetic field?