Name: Student Number:

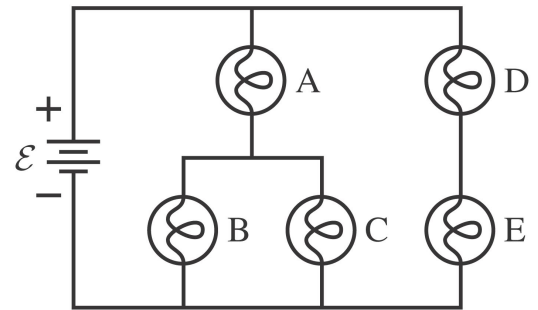# Physics Tutorial - Currents and Circuits

Question 1: Ion Channels

The biochemistry that takes place inside cells depends on various elements that are dissolved in water as ions. The ions enter cells through narrow pores in the cell membrane known as ion channels. Each ion channel, which is formed from a specialized protein molecule, is selective for one kind of ion. Measurements with microelectrodes have shown that a 0.30 nm diameter potassium ion (K^+) channel carries a current of 1.8 pA.

a) How many potassium ions pass through if the ion channel opens for 1.0 ms?

b) What is the current density in the ion channel?

c) The membrane wall is 8 nm thick and the potential across the membrane is 80 mV. What is the conductivity of the ion channel? *Hint: Remember that J = σ E. How do you find E?*

Question 2: The Unbearable Brightness of Being a Light Bulb

The figure to the right shows five identical bulbs connected to an ideal battery. All the bulbs are glowing. Rank in order, from brightest to dimmest, the brightness of bulbs A to E. Explain. (*It may be helpful to remember from class that the power dissipated across two points is P = V^2/R*).
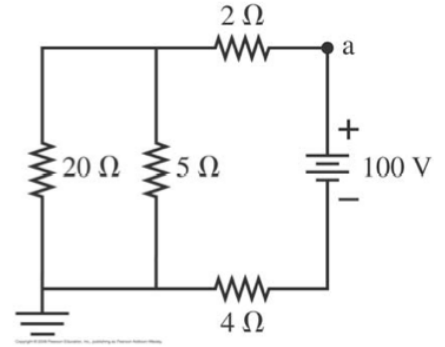
Question 3: Grounded

The three horizontal lines in the bottom left of the circuit is the symbol for ground. Ground sets the potential at that point equal to zero. Find the potential at point a. (*Hint: find the potential that is dropped across each component. Use these drops, or gains, to relate the potential at ground to that at point* a)

Question 4: A resistor?

In the circuit shown a new resistor is added between points A and B. Does the light bulb get brighter, dimmer, or stay the same? Explain.
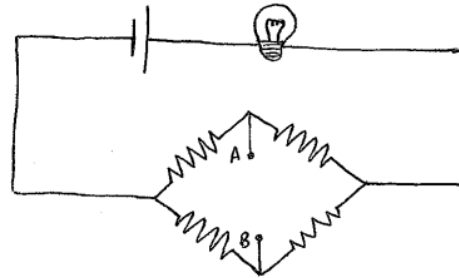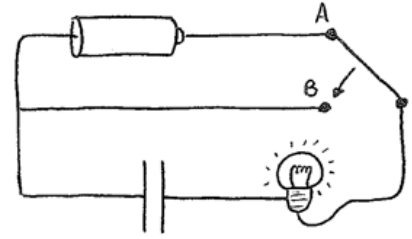
Question 5: The time constant

The circuit shown includes a light bulb with resistance R, a capacitor with capacitance C, and a battery with voltage V. When the switch is flipped from A to B, the process is not instantaneous. Let's estimate the amount of time it takes to discharge the circuit.

a) Looking at the circuit, what are the possible quantities the discharge time could depend on?

b) Can you combine these quantities such that you get something that has units of time?

c) Use Kirchhoff's loop law to get a differential equation describing the RC circuit. Remember, the voltage drop across a capacitor is given by $V = Q/C$ and current can be written in terms of the charge as $I = -dQ/dt$ (i.e., the current is positive as the charge on the capacitor decreases).

d) Find a solution for the equation you found in c).

Question 6: RC Circuits

a) The switch has been closed for a long time, what is the potential across the capacitor?
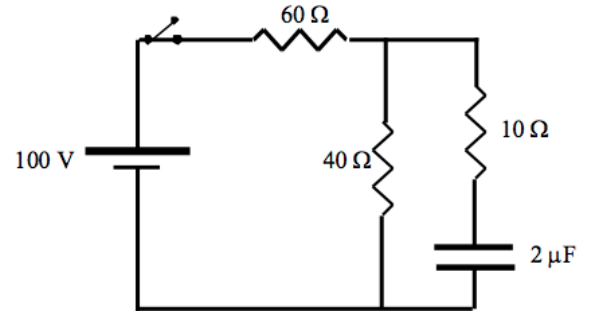
b) When the switch is opened what value of R is used for the time constant?

c) Calculate the charge on the capacitor after two time constants of time have past.

d) Plot the voltage across the capacitor as a function of time.

Extra Practice 1: There and Back Again

The switch in the figure to the right has been in position **a** for a very long time. It is suddenly switched to position **b** for 1.25 ms and then flipped back to **a**.
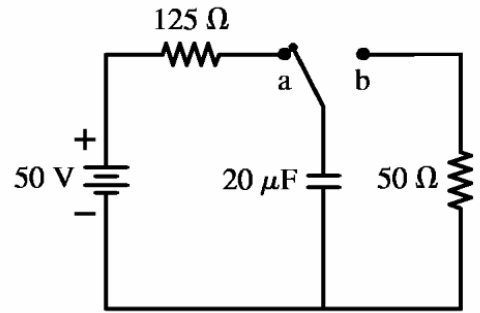
a) Plot the potential across the capacitor as a function of time. What does the plot of the voltage across the resistor look like?

b) Calculate how much energy was dissipated by the resistor (i.e., how much energy is lost by the capacitor?)

Extra Practice 2: Switched.

When the switch is thrown to the left in the figure, the plates of the capacitor C_1 acquire a potential difference 100V and C_2 is initially uncharged. The switch is now thrown to the right. What are the final charges Q_1, Q_2 on the corresponding capacitors?

100 V $C_1 = 15\ \mu F$ $C_2 = 5\ \mu F$
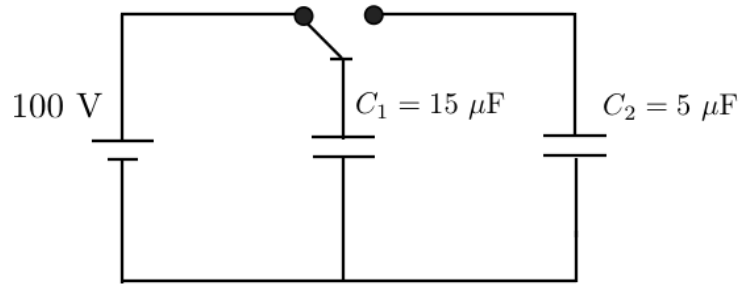
The trick is to realize that the charge is conserved and spread over both capacitors. What is the voltage across each capacitor after the switch is flipped?

Extra Practice 3: Two Loop Circuit

Find the set of equations that describes the current going through each resistor. Define a current in each independent leg of the circuit. The idea is to use Kirchhoff's loop law to get three equations that contain the three unknown current.

(If you want more work, solve for the currents)

300 Ω   100 Ω   200 Ω

19 V   12 V