Physics 122, sections 502-4 and 8101 **Assignment 6**
Laura Lising **Due March 20, start of class**

Reference: Cutnell & Johnson, 19.4-19.7 (electric potential, capacitance), 16.1-16.3, 16.5 (beginning waves and sound).

1) In class we decided that since capacitance of a parallel plate capacitor increases with area (A) and decreases with distance (d) between them, a formula for it could be of the form C=(constant)A/d. The constant is called ε_0, and is about 9×10^{-12} Farads/meter. So $C=\varepsilon_0 A/d$.

a) Estimate the capacitance of two pie plates held at a distance of 1 cm from each other.

b) What would be the effect of the capacitance of putting Styrofoam plates between the pie plates? (I heard some of you guys making the argument that the fact that the Styrofoam cup in the Leyden jar problem had something to do with the ease with which it held charge.

c) The dielectric constant for insulators is a constant that takes into account how well an insulator can be polarized. The constant gets bigger if the insulator has bigger dipoles (ex, more separation between the charges in the dipoles.) This constant is a unitless number that is 1 for an insulator that really doesn't polarize, and gets larger for more polarizable insulators. You could modify the equation for a capacitor to take into account the dielectric constant of whatever material separates the two conductors of a parallel-plate capacitor. Considering what you said in part b, would you multiply or divide the right side of the equation above by the dielectric constant? Why?

d) Think back to the membrane in previous problems. We said the thickness of the membrane was 8 nm and the capacitance was 10^{-4} μF. On what size area of the membrane is charge collecting? Does this make sense to you? Why or why not? (The dielectric constant of membranes is on the order of 10. How does that change your answer. Does your result make more or less or the same amount of sense to you now?)

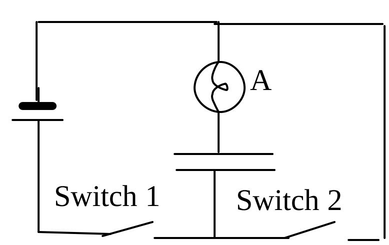
2) The AA batteries in a walkman might last about 20 hours when playing tapes, and the player says (in very tiny print!) that it uses a maximum of 0.15 Amps of current.

a) Estimate the potential energy stored in an average 1.5 Volt AA battery.

b) How high off the ground must a AA battery be so that its gravitational potential energy equals its stored electrical potential energy?

c) Estimate the energy costs from your average 1.5 volt AA battery compared to energy from wall socket. In other words, how much does it cost for say, 1000 Joules of energy from batteries versus from the wall. Wall socket energy costs about 10 cents a kilowatt hour.

3) The circuit at right contains a battery, a bulb, a switch, and a capacitor. The capacitor is initially uncharged.

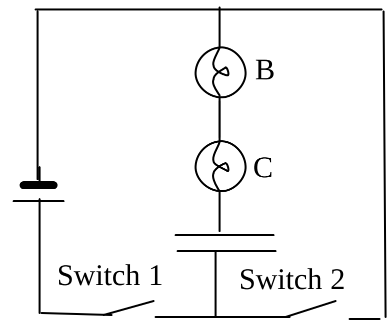


a) describe the behavior of the bulb in the two situations below.

i) Switch 1 is closed. Describe the behavior of the bulb from just after the switch is closed until a long time later. Explain.

ii) Switch 1 is now opened and switch 2 is closed. Describe the behavior of the bulb from just after the switch is closed until a long time later. Explain your reasoning.

b) a second identical bulb is now added to the circuit as shown. The capacitor is discharged.



i) Switch 1 is closed and 2 left open. Describe the behavior of bulbs B and C from just after the switch is closed until a long time later. Explain. How does the brightness of bulb C compare tot he brightness of bulb A in question i of part a? A long time after the switch 1 is closed, is the potential difference across the capacitor greater than, less than, or equal to the potential difference across the battery?

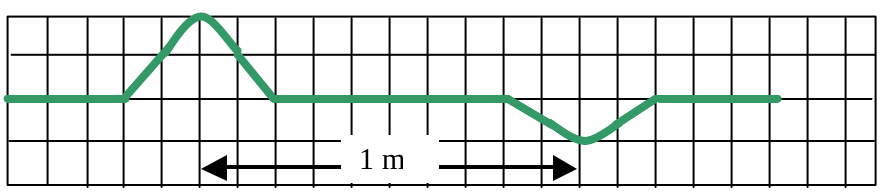
ii) Now switch 1 is opened and 2 is closed. Describe the behavior of bulbs B and C from just after the switch is closed until a long time later. Explain. How does the initial brightness of bulb C compare to the initial brightness of bulb A in question ii of part a? A long time after the switch is closed, is the potential difference across the capacitor greater than, less than, or equal to the potential difference across the battery?

4) In class we decided that a capacitor discharges more slowly if it has a large capacitance (easily keeps it's charge) or if it is discharging through a large resistance. This gave us a time constant $\tau = 1/RC$.

a) If it takes about a millisecond to discharge the membrane, what is the resistance of the ion channels through which the sodium ions travel?

b) A defribillator requires a pretty big current to be delivered for a very short time to a the heart of a victim of cardiac arrest. . The defribillator is a large capacitor that is charged up and the disconnected from the power supply when it's ready. It is then connected to the patients chest with the kind of electrolytic gel that you measured in lab. Explain why a capacitor is used rather than a direct connection to a power supply and why it is important to use low-resistance gel.

5) This figure shows two wave pulses of different amplitudes at time t=0. The pulses are moving toward each other, each traveling at a speed of 10 m/s. At t = 0 seconds, they are 1 meter apart.



a) Sketch the shape of the string at time t = 0.05 seconds.

b) Sketch the shape of the string at t = 0.1 seconds.

c) Think of the point on the string exactly halfway between the pulses. Describe its motion —try to be precise — from t = 0 until after the wave pulses have passed each other.

6) Suppose you were to place a candle in front of a loudspeaker, and crank the volume up good and high. (Of course, make a prediction first, if you decide to try it.)

a) What would you expect to see the candle flame do? Would it bend away from the speaker? Toward it? Neither?

b) What other answer might someone give to part a, and how would they argue for it? (If you can't think of any, you might need to talk to other people!)

c) Can you respond to the reasoning in part b? Why doesn't it work? (When *would* it work, and how is this situation different?)