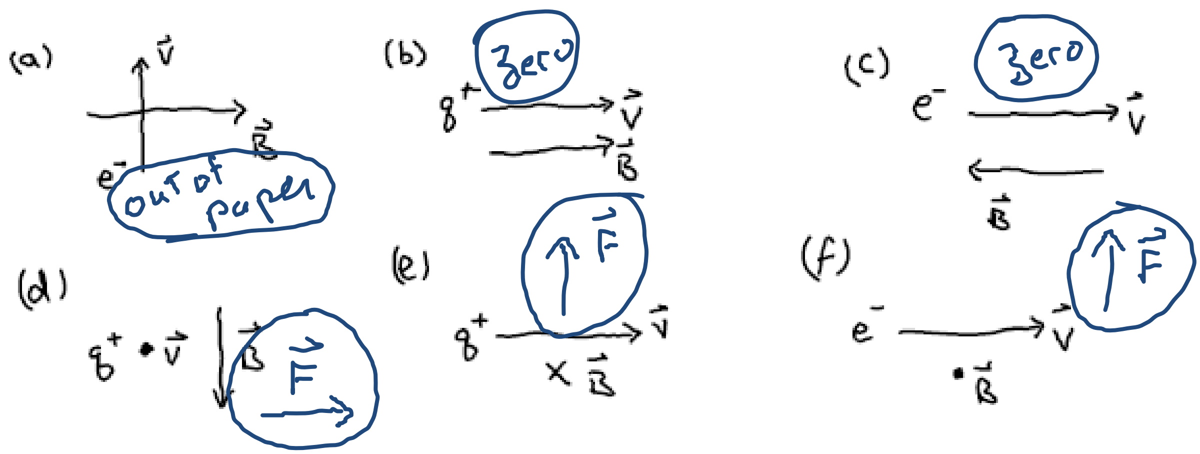
P114 University of Rochester NAME SLM-Solnkey
S. Manly Spring 2015

Exam 2 (March 24, 2015)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work unless otherwise indicated.

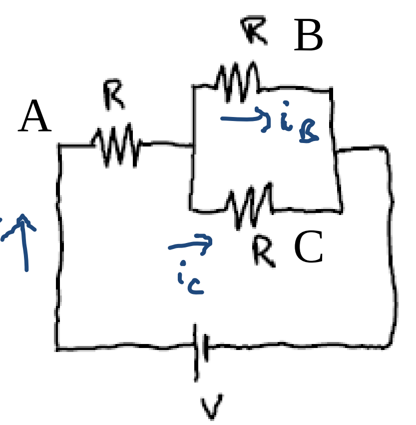
Problem 1 (18 pts, 3 points per part):

Shown below are six sketches showing a moving charge and a magnetic field. The charges are clearly specified as positive or negative. The velocity vector for each charge is shown. The magnetic field vector is also shown. Specify for each part the direction of the force vector on the charged particle due to the magnetic field. You can indicate the direction of the force with a vector labeled "F" or text (such as "into paper", "out of paper", "to the right", etc.) If there is no force, write "zero" by the sketch. If you are confused about which hand is your right hand, please feel free to ask Prof. Manly.



Problem 2 (15 pts, show work):

Three identical resistors are connected to a 12 V battery as shown in the sketch. Each resistor has a resistance of 3 Ohms. The specific resistors are specified by the letters A, B, C.



a) Determine the current through the resistor at position A.

$R_{TOT} = R + R' = R + R/2 = 3R/2$

$\frac{1}{R'} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R}$

$V = I R_{TOT}$

$I = \frac{V}{R_{TOT}}$

$I = \frac{12}{3/2}(3) = \frac{8}{3}$ Amps

b) Determine the potential drop across the resistor at position B.

$\frac{8}{3}$ Amps at point A

by symmetry $\frac{1}{2} I = \frac{4}{3}$ Amps will go through Each of the other two resistors

$V_B = i_B R_B = \frac{4}{3} 3 = 4$ volts

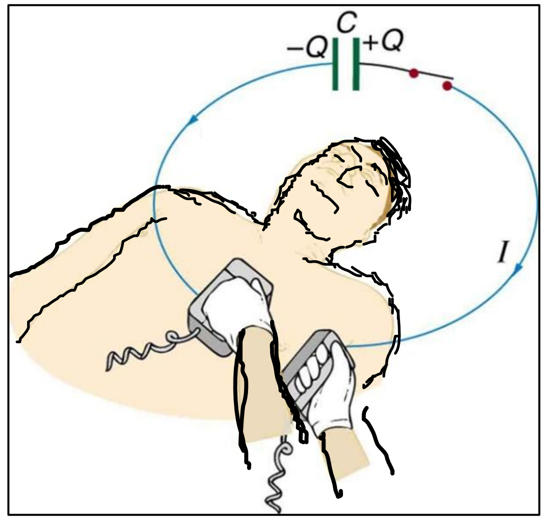
c) What is the total power output of the battery?

$P_{TOT} = P_A + P_B + P_C = (8)\frac{8}{3} + (2) 4 \frac{4}{3} = \frac{64}{3} + \frac{32}{3} = \frac{96}{3} = 32$ Watts

use $P = VI$

Problem 3 (16 pts, show work, 4 pts per part):

A heart defibrillator sends a 6 A current through the chest of a patient by applying a 10,000 V potential as shown in the figure.



a) What is the resistance of the path from one paddle to the other?

$V = iR$

$10000 = 6R$

$R = 1666.7\ \Omega$

b) Given the resistance you calculate in part (a), if the capacitor in the defibrillator has a capacitance of 8 μF, how much time does it take the charge on the capacitor in the defibrillator to drop to 1/e of its initial value?

$q = q_0 e^{-t/RC}$

q falls to $\frac{1}{e}$ of q_0 in $t = RC$

$t = (1666.7)(8\times10^{-6}) = 0.01$ seconds

c) How much energy is stored in the capacitor before it is discharged?

$E = \frac{1}{2}CV^2 = \frac{1}{2}(8\times10^{-6})(10000)^2 = 400$ Joules

d) For the defibrillator to work, it is important that the current through the chest reach a specified value (in this case 6 A). A conducting gel is used on the paddles to reduce the resistance of the path the current takes through the chest. Briefly discuss why it is important to use this gel, i.e. what might you expect to happen if the gel were not present and why. (Discuss this in terms of the concepts and language you've studied in this class.)

If gel is not present the resistive path is higher at the paddle - skin interface. Where the resistance is high, there is resistive heating and skin may burn. If the resistance is high, V will have to be higher to get the same current ($V = IR$) and this will lead to an even higher probability of burning the skin because of the higher power ($P = VI$).

1)	/18
2)	/15
3)	/16
4)	/15
5)	/18
6)	/18
tot	/100

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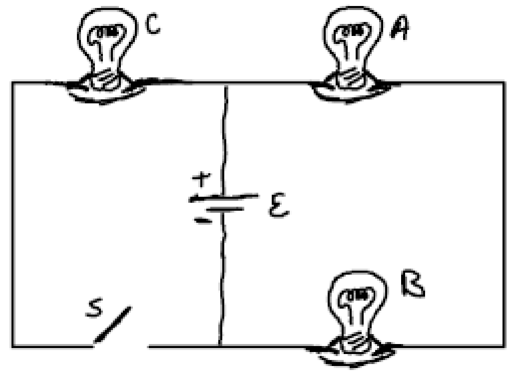
Problem 4 (15 pts, 3 pts per part):



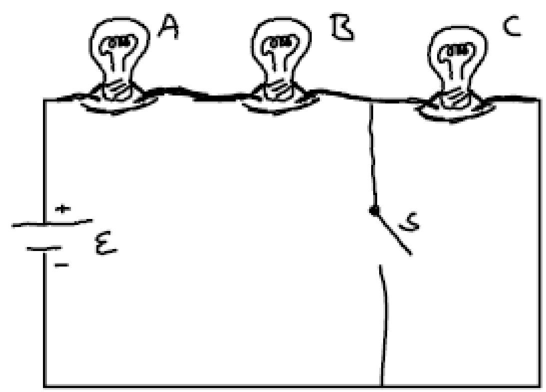
Consider the circuit to the right that contains three identical light bulbs: A, B, and C. Assume the EMF ε is an ideal battery with no internal resistance. Initially the switch S is off as shown in the sketch. When that is the case, bulb C is off and bulbs A and B are on and have the same brightness.

a) What happens to the brightness of each of the bulbs when the switch S is closed?

C Turns on, A and B brightness is unchanged

b) When the switch S is closed, rank the relative ordering of the brightness of the bulbs (for example: state clearly something like A=B=C or A>B>C or whatever).

C > A = B



Consider the circuit to the right that contains three identical light bulbs: A, B, and C. Assume the EMF ε is an ideal battery with no internal resistance. Initially the switch S is off as shown in the sketch. When that is the case, all three bulbs are on and shine with equal brightness.

c) What happens to the brightness of each of the bulbs when the switch S is closed?

A and B get brighter
C turns off

d) When the switch S is closed, rank the relative ordering of the brightness of the bulbs (for example: state clearly something like A=B=C or A>B>C or whatever).

A = B > C

Bottom (second)

Referring to the ~~top (first)~~ circuit, now assume the EMF ε is a battery with a small internal resistance. Initially the switch S is off as shown in the sketch. When that is the case, all three bulbs are on and shine with equal brightness.

e) What happens to the brightness of each of the bulbs when the switch S is closed?

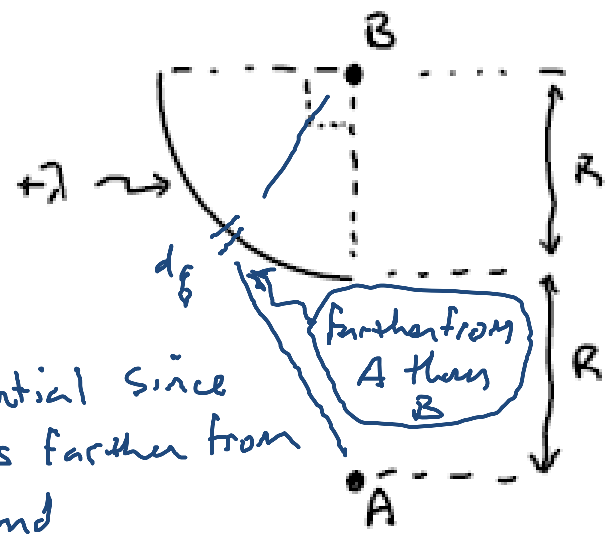
A + B get Brighter
C turns off

Problem 5 (18 pts):

Referring to the sketch, a positive charge Q is spread uniformly over an arc formed into one-quarter of a circle with radius R. Point B is at the center of curvature of the arc. Point A lies a distance R away from the one end of the arc as shown in the sketch. The potential is defined to be zero very far (an infinite distance) from the arc.

(6 pts) In terms of Q and R, what is the absolute potential at point B?

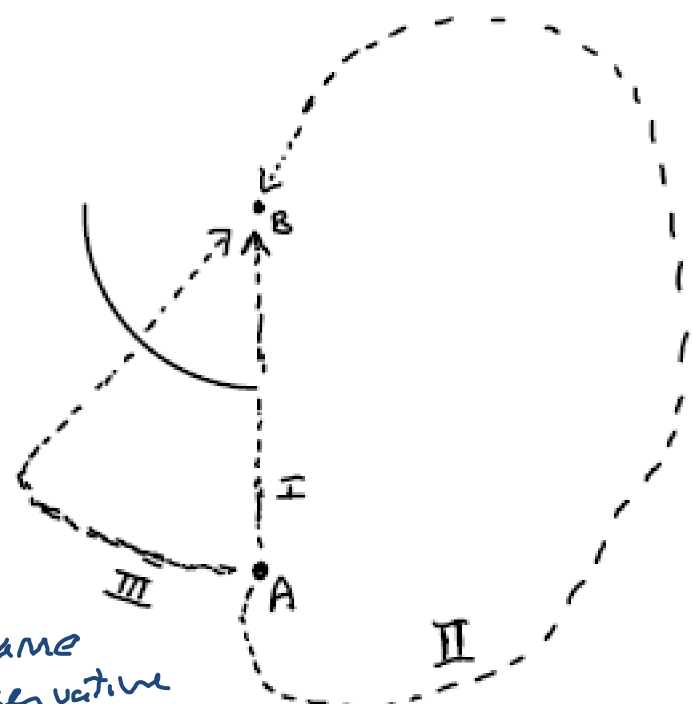
$$V_B = \frac{kQ}{R}$$



(6 pts) Is point A at a higher/lower/the same potential as point B? Why?

Point A is at a lower potential since the bulk of the charge is farther from Point A than point B and each dq contributes $dv = k\,dq/r$

(6 pts) Referring to the same configuration of charge and points in space as above, Jed Clampett considers moving a test charge q from point A to point B along one of three different paths, I, II, and III (as shown to the right). He asks your advice about which path he should take. Fundamentally, he's lazy and wants to do this with the least work possible. Which path should Jed use for moving the charge? Why?



Jed can use any of the three paths. It will require the same work to move charge along each of the 3 paths since the endpoints are the same and electrostatics is a conservative force

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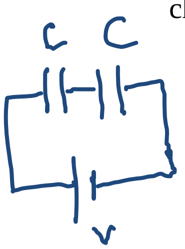
Problem 6 (18 pts, show work):
Two identical parallel plate capacitors with C=2.0 μF are connected in series across the terminals of a 9 V battery.

a) (4 pts) After waiting for a long time so that the capacitors are fully charged, how much charge resides on each capacitor?



$\frac{1}{C_{TOT}} = \frac{1}{C} + \frac{1}{C}$ $\quad C_{TOT} = \frac{C}{2}$

$Q = C_{TOT} V$

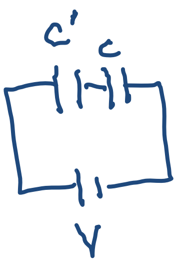
Q on each capacitor $= C_{TOT} V$

$= \frac{2\times10^{-6}}{2}(9) = 9\ \mu C$

b) (4 pts) What is the potential difference across each capacitor?

By symmetry the potential Drop across each capacitor is $\frac{1}{2}V = 4.5\ V$

c) (5 pts) Think of the two capacitors you considered in parts (a) and (b) as parallel plates with empty space between the plates. Now in one of these capacitors that empty space is filled with a dielectric slab with K=2.5. What is the charge on each capacitor now?



$C' = KC = (2.5)(2\times10^{-6}) = 5\times10^{-6}$ Farads

$\frac{1}{C_{TOT}} = \frac{1}{C'} + \frac{1}{C} = \frac{1}{2\times10^{-6}} + \frac{1}{5\times10^{-6}}$ $\quad C_{TOT} = 1.43\ \mu F$

$Q = C_{TOT} V = (1.43\times10^{-6})9 = 12.9\ \mu C$

d) (5 pts) After the dielectric is inserted in part (c), what is the potential difference across each capacitor?

for capacitor with dielectric

$\frac{Q}{C} = V = \frac{12.9\times10^{-6}}{5\times10^{-6}} = 2.58$ volts

for other capacitor

$\frac{Q}{C} = V = \frac{12.9\times10^{-6}}{2\times10^{-6}} \approx 6.45$ volts

these two sum to ~9 volts as they should.