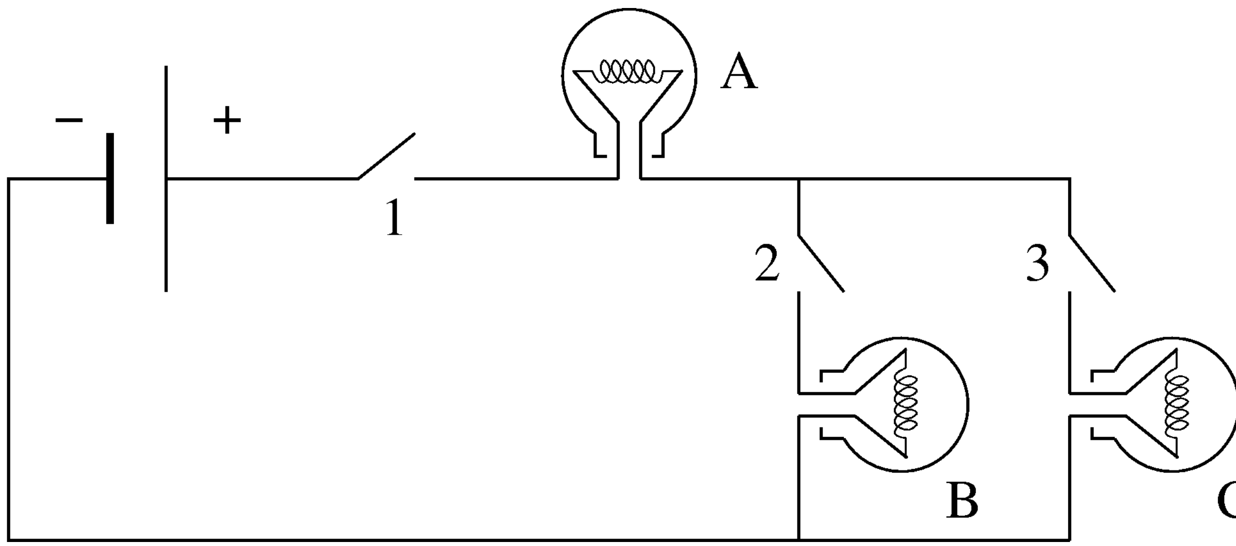
Problem 1 (35 points)

The circuit below consists of a battery (with negligible internal resistance), three incandescent light bulbs *(A, B & C)* each with exactly the same resistance, and three switches *(1, 2, & 3)*. In what follows, you may assume that, regardless of how much current flows through a given light bulb, its resistance remains unchanged. Assume that when current flows through a light bulb it glows. The higher the current, the brighter the light will be.



In each situation *(a,b,c)* as described below, we want to know which light bulbs are glowing (and which are not), and how bright they are (relative to each other). *Always briefly discuss your reasoning.*

a. (6) Switch #1 is closed; the others are open.

b. (6) Switches #1 and #2 are closed; #3 is open.

c. (6) All three switches are closed.

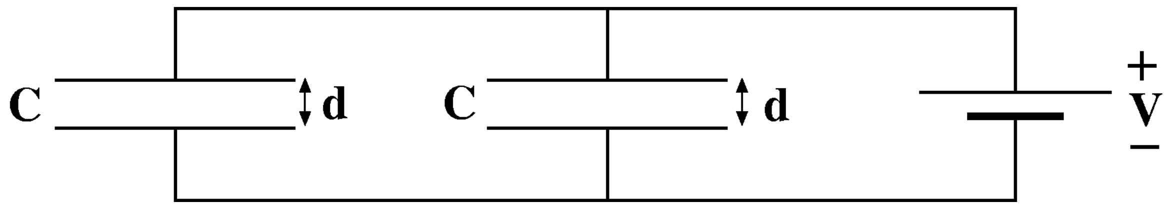
d. (7) Now compare the situations *a, b,* and *c*. Which bulb is the brightest of all, and which is the the faintest of all (the bulbs that are off do not count)?

We now replace bulb *A* by a wire of negligible resistance. We still have the three switches and the two light bulbs *B & C*.

e. (10) Answer the questions *b* through *d* again. In your answers refer clearly and unambiguously which part *(b, c* or *d)* you are addressing.

Problem 2 (30 points)

Two identical ideal plate capacitors in air, each with capacitance C, are connected to a battery of voltage V as shown schematically below. The plates are separated by a distance d. Express all your answers in terms of C, V, and d and also κ (in the case of questions c and d).



a. (5) What is the total charge residing on **each** plate (4 answers please)?

b. (5) What is the electric field (direction and magnitude) between the plates of each capacitor?

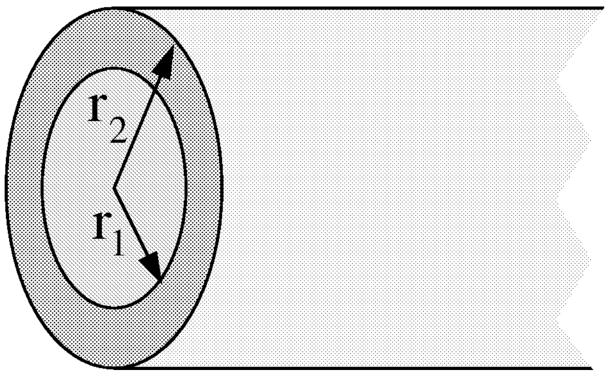
Without changing anything else (**the battery remains connected**), we fill the entire air gap of the capacitor on the left with a dielectric ($\kappa = 3$).

c. (10) What now is the total charge residing on **each** plate (4 answers please)?

d. (10) What now is the electric field (direction and magnitude) between the plates of each capacitor?

Problem 3 (35 points)

A long well-conducting cylindrical pipe has length L, an inner radius r_1 and outer radius r_2 (see figure). $L \gg r_2$, thus you may ignore "end-effects."



We release an amount of charge $+q$ on the *inside* of the cylinder by briefly touching the inner wall with a charged object.

a. (7) How will this charge $+q$ distribute itself? Make sure you discuss how much of the charge will be (i) on the inner surface with radius r_1, (ii) in the region $r_1 < r < r_2$, and (iii) on the outer surface with radius r_2. **Give your reasons**.

b. (9) What is the E-field (direction and magnitude) in the regions: (i) $r < r_1$, (ii) $r_1 < r < r_2$, and (iii) $r > r_2$? Show how you arrived at your answers.

c. (9) What is the potential difference between the axis of the cylinder and the outer surface? Show how you arrived at your answer.

We now (after the release of charge $+q$ on the inside) place a dielectric core (κ=3) in the hollow part of the cylinder. This core has radius r_1.

d. (10) With this core in place, what now are your answers to question *b*? Give your reasons.