Exam 1 (February 16, 1999)

Please read the problems carefully and answer them in blue books (one problem per book). Show all your work. Partial credit will be given.

Problem 1 (20 pts):

My sources inside the White House tell me that Monica and Bill are still misleading Congress and the public about what really went on behind closed doors. My source says the current scandal is a cover-up. They were too embarrassed to tell what *really* happened. According to what I can gather, Monica and Bill share a fascination with electrostatics. Their time alone was spent running little experiments. Apparently, they are confused about the results of one experiment. I hope you can explain it.

- **Monica rubbed a plastic cigar case with the skirt of her blue silk dress. This left a positive net charge on the plastic cigar case. (Note: single, fine cigars often come in metal or plastic containers, roughly shaped like the cigar.)**
- **Monica held the plastic case near a metal, conducting cigar case (held in the air by a nonconducting string) but did not touch the case.**
- **While the charged, plastic cigar case was in this position, Bill touched the metal cigar case and removed his hand.**
- **Monica removed the plastic case from the proximity of the metal one.**
- **Then she held the edge of her blue skirt near the metal cigar case (but not touching).**

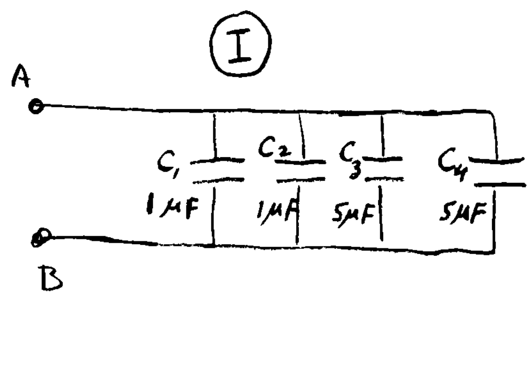
What effect did the blue skirt have on the hanging metal cigar case? Please explain your reasoning.

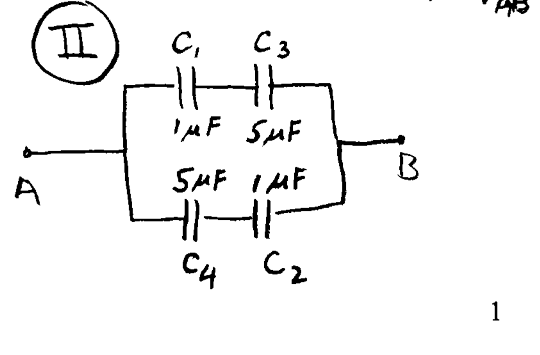
Problem 2 (20 pts):

You are a pencil-necked geek, fresh out of electrical engineering school, ready to change the world! With decent grades and a good word from a friend of a friend, you land a prestigious job as a technical engineer at Bob's High Tech Circuit Design Emporium and Car Wash on the edge of Silicon Valley, south of San Francisco. After working for a week drying cars, you are finally given your first assignment. Bob asks you to design a little circuit destined to make a McDonald's happy meal toy light up when squeezed. He also tells you that "due to a clerical error" the company has a huge surplus of 1 and 5 microfarad capacitors. He leaves you with the kind words of support, "Use them in your design, or else!"

After some work, you decide there are two possible configurations of capacitors (shown below) that you could use in your circuit. Your circuit requires the configuration with the larger stored electrical energy. Which circuit should you choose? Explain your reasoning and show your work. Assume the potential difference across each configuration is V. = 2 VOLTS

$V = V_{AB}$





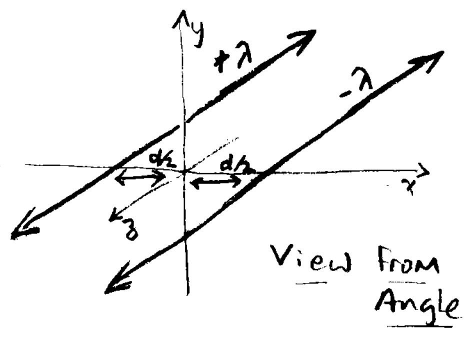
Problem 3 (part a - 7pts, part b - 13 pts):

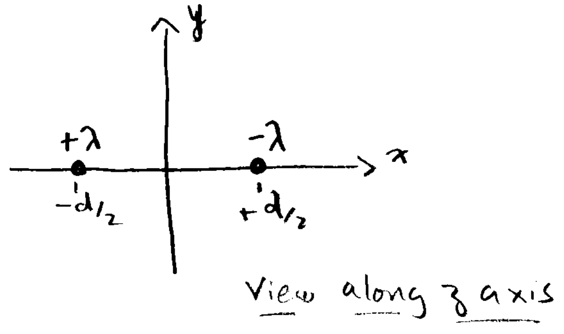
I have a buddy named Chaz. Chaz is an inventor. He's not been "quite right" since the day he was hit in the head by a piece of a smashed guitar at a punk rock concert a few years back. So, he comes up with some pretty wacky ideas. He came in the other day all excited about his new idea to replace clothes-pins, which are used to hang wet clothes on lines to dry. He is proposing to put a large static electric charge on the clothesline and a large static charge of the opposite sign on each item of clothing. He thinks one could then "hang" the items of clothing using the electrostatic attraction between the clothes and the line. I told him this idea would not work for many reasons. Ignoring this, Chaz insisted that we calculate something for him. As I said, Chaz isn't quite right. So, let's humor him.

Chaz is concerned about households with two clotheslines in close proximity. Since both lines would be charged, he is worried that there would be a force between them that could be sufficient to cause one of the lines to break. Now ... finite, slightly curved clotheslines are a bit complicated. However, we can approximate the situation as follows:

Assume two infinite, straight, parallel lines with opposite uniform linear charge densities ($+\lambda$ and $-\lambda$, respectively) are suspended in the air a distance, d, apart. Assume you can ignore the dielectric properties of the air, i.e., treat it as if it is vacuum. Let us assume the line with $+\lambda$ is at $x = -d/2$, $y=0$ and parallel to the z-axis. The line with $-\lambda$ is at $x = +d/2$, $y=0$, and parallel to the z-axis (as well as the other line).

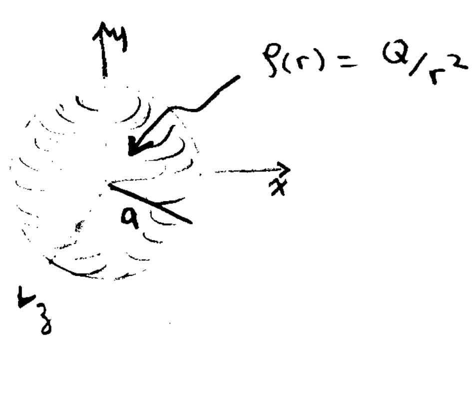
(a) (7 pts) Make a drawing that shows the lines of force of the electric field as well as the equipotential surfaces for this configuration of charge.
(b) (13 pts) Calculate the force per unit length (magnitude and direction) of each line on the other. Assume you are given d and λ. Show your work (Chaz needs all the help he can get!).





Problem 4 (20 pts):

A spherical volume centered at the origin of coordinates with radius a, has a volume charge density $\rho(r)=+Q(1/r^2)$. Calculate the electric field for $r<a$ and for $r>a$.

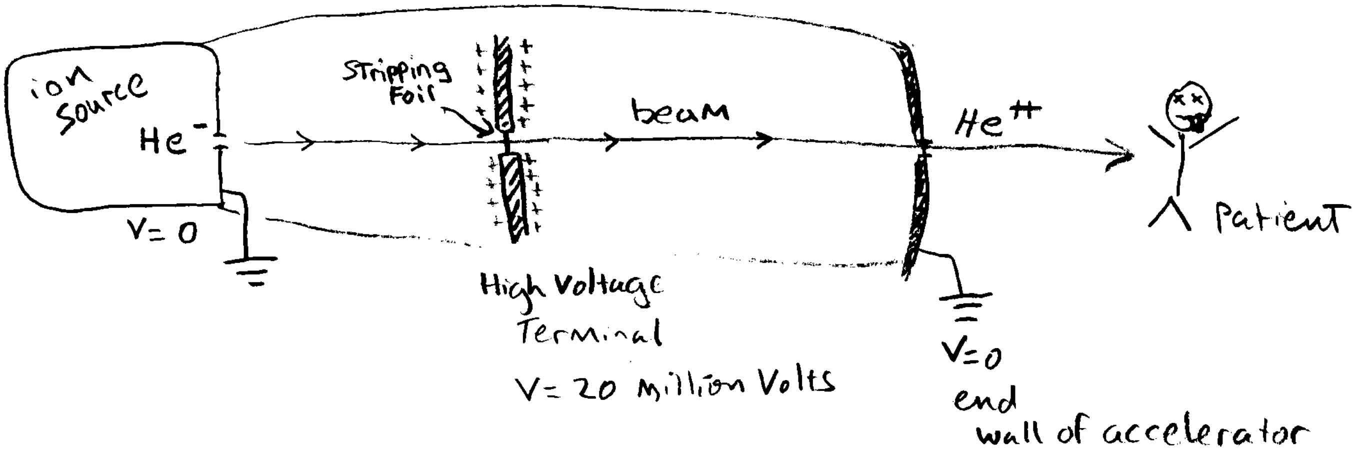


Problem 5 (20 pts):

Tandem van de Graff accelerators are used to accelerate nuclear particles to high energies. Beams of these particles can be used to study nuclear reactions and nuclear structure. Another use for such beams is the treatment of cancerous tumors. It turns out charged particles lose energy as they interact with matter by ionizing the medium they pass through. One of the more fortunate aspects of this energy loss is that most of the energy is dumped right at the end of the particle's path. If one tunes the energy of a particle beam so that the average range of the particle through the body is just sufficient to reach the tumor, most of the energy is released in the tumor, destroying only the tissue you would like to destroy. Cool, huh?!

A tandem van de Graff accelerator consists of a negative ion source at ground (zero potential), a positively charged high voltage terminal, and an electron stripping foil. A negative ion from the source is accelerated toward the positive high voltage terminal. As the ion passes through the thin stripping foil, all the electrons are removed, leaving only the bare positive nucleus. This nucleus is now accelerated (repelled) by the positive high voltage terminal. (See diagram below)

If a He^- ion is accelerated from ground through a potential difference of 20 million volts, stripped of all its electrons to form the He^{++} ion, and then accelerated again from +20 million volts to ground, what is its final kinetic energy?



A rather Poor schematic of
a tandem van de Graff accelerator