Department of Physics
University of California, Berkeley

Mid-term Examination 2

Physics 7B, Sections 2 and 3

6:00 pm - 8:00 pm, November 4, 2003

Name:_______________________________________

SID No:_______________________________________

Discussion Section:___________________________

Name of TA:__________________________________

Score:____

Problem 1	
Problem 2	
Problem 3	
Problem 4	
Problem 5	
Problem 6	

Answer all six problems. Write clearly and explain your work. Partial credit will be given for incomplete solutions provided your logic is reasonable and clear. Cross out any parts that you don't want to be graded. Enclose your answers with boxes. **Express all numerical answers in SI units**. Answers with no explanation or disconnected comments will not be credited. If you obtain an answer that is questionable, explain why you think it is wrong.

Constants and Conversion factors

Avogadro number, N_A	6.022×10^{23}
Permittivity of vacuum, ϵ_0	8.85×10^{-12} F·m^{-1}
Universal gas constant, R	8.315 J·mol^{-1}·K^{-1} = 1.99 cal·mol^{-1}·K^{-1}
Boltzmann constant, k	1.381×10^{-23} J·K^{-1}
Stefan-Boltzmann constant, σ	5.67×10^{-8} W·m^{-2}·K^{-4}
Acceleration due to gravity, g	9.8 m·s^{-2}
Specific heat of water	1 kcal·kg^{-1}·°C^{-1}
Heat of fusion of water	80 kcal·kg^{-1}
1 atm	1.013×10^5 N·m^{-2}
1 kcal	4.18×10^3 J
1 hp	746 W

Some useful equations

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\begin{aligned}
\textit{Coulomb's law}: \ \mathbf{F} &= \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{\mathbf{r}} \\
\textit{Electric field}: \ d\mathbf{E} &= \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\hat{\mathbf{r}} \\
\textit{Electric dipole}: \ \mathbf{p} &= q\mathbf{d} \\
\textit{Torque on a dipole}: \ \vec{\tau} &= \mathbf{p} \times \mathbf{E} \\
\textit{Potential energy of a dipole}: \ U &= -\mathbf{p} \cdot \mathbf{E} \\
\textit{Gauss's law}: \ \oint \mathbf{E} \cdot d\mathbf{a} &= \frac{q_{encl}}{\epsilon_0} \\
\textit{Potential difference}: \ V_{ab} &= -\int_a^b \mathbf{E} \cdot d\mathbf{l} \\
\textit{Potential}: \ dV &= \frac{1}{4\pi\epsilon_0}\frac{dq}{r} \\
\textit{Potential energy}: \ U_{ab} &= qV_{ab} \\
\textit{Electric field and potential}: \ \mathbf{E} &= -\nabla V \\
\textit{Capacitance}: \ C &= \frac{q}{V_{ab}} \\
\textit{Capacitors in series}: \ \frac{1}{C_{eq}} &= \sum \frac{1}{C_i}
\end{aligned}
$$

$$
\begin{aligned}
Capacitors\ in\ parallel;\ C_{eq} &= \sum C_i \\
Energy\ stored\ in\ a\ capacitor:\ U &= \frac{1}{2}CV^2 \\
Energy\ density:\ u &= \frac{1}{2}\epsilon_0 E^2 \\
Current:\ i &= \frac{dq}{dt} \\
Current\ and\ current\ density:\ di &= \mathbf{j}\cdot d\mathbf{a} \\
Ohm's\ law:\ V &= iR \\
Ohm's\ law:\ \mathbf{j} &= \sigma\mathbf{E} \\
Resistivity\ and\ resistance:\ R &= \rho\frac{l}{A} \\
Electric\ power\ (dc):\ P &= Vi \\
Average\ electric\ power\ (ac):\ \overline{P} &= \frac{1}{2}i_0^2 R \\
rms\ current:\ i_{rms} &= \frac{1}{\sqrt{2}}i_0 \\
Resistors\ in\ series:\ R_{eq} &= \sum R_i \\
Resistors\ in\ parallel:\ \frac{1}{R_{eq}} &= \sum \frac{1}{R_i} \\
Kirchhoff\ current\ rule:\ \sum i &= 0\ \ at\ a\ node \\
Kirchhoff\ potential\ rule:\ \sum \varepsilon &= \sum iR\ \ around\ a\ loop \\
\nabla V &= \frac{\partial V}{\partial x}\hat{\mathbf{x}} + \frac{\partial V}{\partial y}\hat{\mathbf{y}} + \frac{\partial V}{\partial z}\hat{\mathbf{z}} \\
\nabla V &= \frac{\partial V}{\partial r}\hat{\mathbf{r}} + \frac{1}{r}\frac{\partial V}{\partial \phi}\hat{\phi} + \frac{\partial V}{\partial z}\hat{\mathbf{z}} \\
\nabla V &= \frac{\partial V}{\partial r}\hat{\mathbf{r}} + \frac{1}{r}\frac{\partial V}{\partial \theta}\hat{\theta} + \frac{1}{rsin\theta}\frac{\partial V}{\partial \phi}\hat{\phi}
\end{aligned}
$$

1. (a) [5 points] Why are neutral objects attracted to both negatively and positively charged objects? What accounts for the attraction?

(b) [5 points] Some power tools and equipment run poorly when connected to very long extension cords that are plugged into a 120 V AC outlet. Why? What could you do to improve the situation?

(c) [5 points] Figure 1 is a conductor charged with positive charges. The radius of the smaller spherical end is half of that of the larger end. Sketch in the figure the distribution of the positive charges. Explain your reasoning.

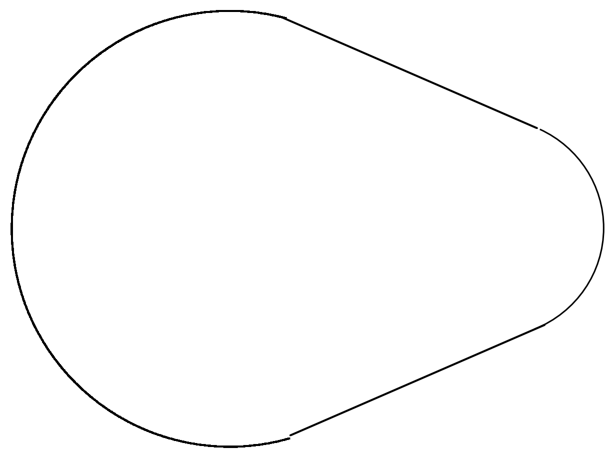

Figure 1: Figure for problem 1(c)

2. [15 points] My remote control contains four AAA batteries. Two batteries are in series (called them a pair), and the two pairs are connected in parallel. Each AAA battery provides 1.5 V EMF and has an internal resistance of 1 Ω. When a button is pressed the battery combination is connected across an LED (light emitting diode) with an equivalent resistance $R_{\text{LED}} = 99\ \Omega$.

(a) [3 points] Draw the equivalent circuit diagram of the full system, label the EMFs, internal resistances, and the LED resistance.

(b) [3 points] Draw the reduced equivalent circuit for a single battery with internal resistance, and the LED resistance. Label the EMF and resistances with their values.

(c) [3 points] Draw the reduced equivalent circuit with a single EMF and one resistance. Again, label the EMF and resistance with their values.

(d) [3 points] Calculate the current through the LED and power dissipated at the LED.

(e) [3 points] What is the current through each battery? How much power does the EMF in each battery provide?

3. [20 points] A parallel-plate capacitor has plates of area A and spacing d between the plates. It is charged with charge Q at the beginning, and is then disconnected from the battery.

(a) [5 points] Apply Gauss's law to determine the electric field $\mathbf{E}$ between the plates. Fringe field is ignored.

(b) [5 points] Starting from the electric field found in part (a), determine the potential difference between the plates.

(c) [1 points] Calculate the capacitance of this parallel-plate capacitor.

(d) [4 points] A dielectric slab of thickness b ($b < d$) is then positioned between the plates.If the dielectric constant of the slab is κ, find the capacitance of the system after the slab is in place as shown in Figure 2

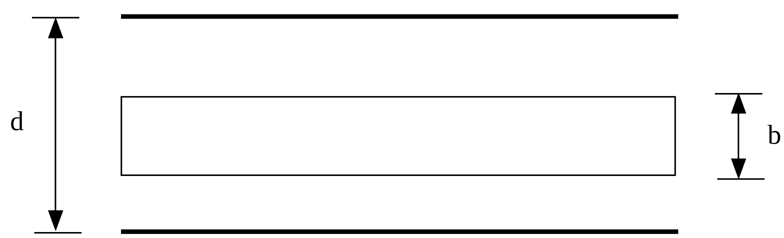

Figure 2: Figure for problem 3

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(e) [5 points] How much work was done by the person who moved the slab from very far away to its final position between the plates?

4. [20 points] Consider an electric dipole in a non-uniform electric field as shown in Figure 3. The dipole is rotated an angle θ from the normal.

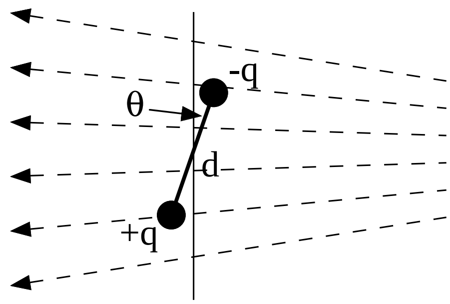

Figure 3: Figure for problem 4

(a) [5 points] Is there a torque on the dipole? Explain your reasoning. If there is a torque, find its direction and magnitude.

(b) [5 points] What is the potential due to the dipole at the center of the dipole, if the potential for the dipole is zero at infinity?

(c) [10 points] Is there a net force on the dipole? Explain your reasoning. If there is a force, determine its direction and magnitude.

5. [15 points] in Figure 4.

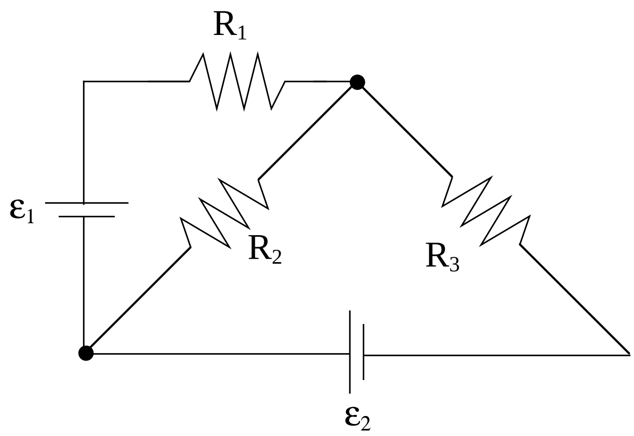

Figure 4: Figure for problem 5

(a) [6 points] Write down a set of independent equations for the currents in the circuit.

(b) [9 points] Determine the current through the resistor R_1 and the potential difference across it.

6. [15 points] The flat circular disk of charge in Figure 5 has a radius of R and a uniform surface charge density σ.

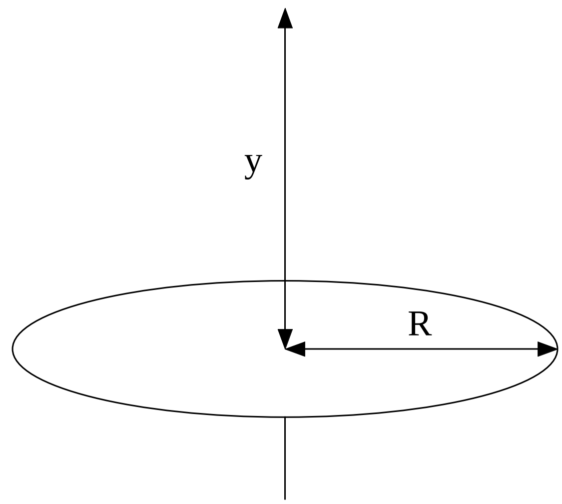

Figure 5: Figure for problem 6

(a) [6 points] Find the potential $V(y)$ at a point that is at a vertical distance y from the center of the disk if $V(0) = 0$.

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(b) [4 points] What is the potential at y equal to infinity?

(b) [5 points] Determine the associated electric field $\mathbf{E}$ using the relation $\mathbf{E} = -\nabla V$.

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End of Examination