Department of Physics
University of California, Berkeley

Mid-term Examination 2
Physics 7B, Sections 2 and 3

6:30 pm - 8:30 pm, November 8, 2005

Name:_____

SID No:_____

Discussion Section:_____

Name of TA:_____

Answer all 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. State the formula you plan to use, if it is not derived in this examination, for carrying out any numerical calculation. 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}
Mass of electron, m_e	9.11×10^{-31} kg
Charge of electron, q_e	-1.602×10^{-19} C
Mass of proton, m_p	1.67×10^{-27} kg
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 BTU	1055 J
1 hp	746 W

1. Two identical small spheres are suspended from a point at the ceiling with silk threads of length L. Each sphere of mass m has charge q.

(a) [15 points] Assume the angle between the threads is small, determine the separation between the spheres after they reach equilibrium.

(b) [5 points] If the spheres are conducting, explain what happens to them after one is discharged.

2. N electrons are uniformly spread onto the surface of a thin ring of radius R.

(a) [14 points] Determine the electric field due to the charged ring at a point P, a distance y from the plane of the ring along its central axis.

(b) [6 points] A proton, initially at rest at point P, is constrained to move along the central axis of the ring. Determine the angular frequency of the motion.

3. We need to build a capacitor made up of four concentric conducting cylinders with radii R_a, R_b, R_c, and R_d such that $R_a > R_b > R_c > R_d$. Each cylinder has a length L. The cylinders b and c are connected by metal strips in the radial direction. The outermost cylinder has charge q whereas the innermost one has -q.

(a) [5 points] Apply the Gauss's law to determine the electric field everywhere.

(b) [5 points] Determine the electric potential everywhere.

(c) [5 points] Determine the capacitance of this capacitor.

(d) [5 points] If the space between the cylinders c and d is now filled with oil with dielectric constant K, what is the change in energy stored in this capacitor?

4. A custom-designed resistor is made of a truncated cone such that the diameter of one end is 2a, and the other end is 2b. The length of the resistor along the axis is L. The taper is small so that the current is assumed to flow through the ends uniformly.

(a) [10 points] If the electrical conductivity of the material is σ, what is the resistance of this resistor?

(b) [10 points] Two of these custom-made resistors, with resistance R_1 and R_2, may be connected either in series or parallel across a battery with emf ϵ. The internal resistance of the battery can be ignored. We want the power loss of the parallel combination to be five times that of the series combination. If R_1 is 100 Ω, what is R_2?

5. As shown in Figure 1, the body of an electric eel can be modelled as a circuit made of 140 rows of batteries. There are 5000 batteries in each row. Each battery has an emf ϵ of 0.15 V and an internal resistance r of 0.25 Ω. The resistance of the sea water, R_W, is 800 Ω.

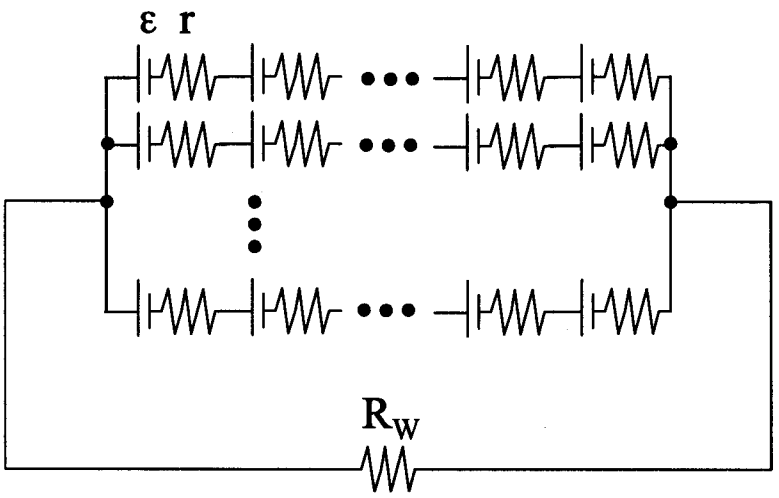

Figure 1:

(a) [15 points] Calculate the current through R_W.

(b) [5 points] Determine the current through each row of batteries, and hence explain why the electric eel won't kill itself.

End of Examination