Physics 7B Sp09 Freedman MT2

1. (20 pts total) True – False Questions – Place a T or an F for each question in the table below – 2 pts for each correct answer and a 1 pt reduction for each incorrect answer. Guessing is not necessarily a good idea, but you cannot get less than zero for the entire problem.

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x	

i) A 100-W incandescent light bulb has a higher resistance than a 75-W bulb.

ii) In a region of space with a constant electric potential the electric field must be zero.

iii) For a charged metal conductor shaped like an American football the electric charge density must be higher at the ends than it is on the flattened sides.

iv) It is possible to place an electric dipole consisting of opposite charges separated by a small distance in a constant electric field so it feels no net force and no net torque.

v) In a region of space where the electric field is constant the electric potential must be zero.

vi) A parallel plate capacitor can store more energy for a given stored charge if the dielectric constant of the material between the plates is increased.

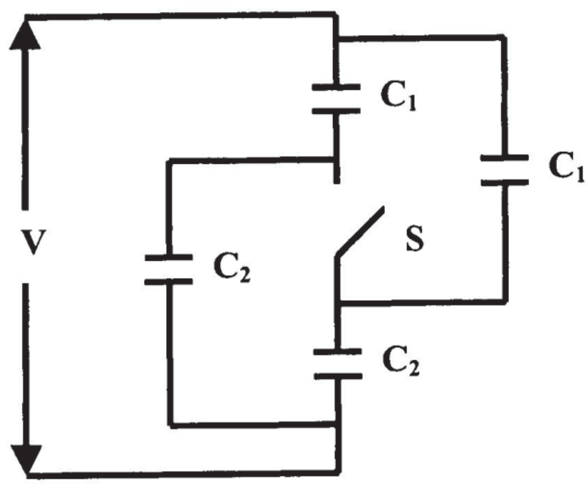
vii) Incandescent light bulbs are more likely to burn out when they are just turned on.

viii) A battery rated for 1 A-hr cannot deliver more than 1 A of electrical current.

ix) A point charge (+Q) sits at the center of a thin hollow conducting sphere of radius R. If the point charge is moved to $R/2$ from the center of the sphere, the electric field outside the sphere will not change.

x) The electric field lines on an equipotential surface must be parallel.

2.(20 pts total) A voltage V is applied to the capacitor network shown in the figure.



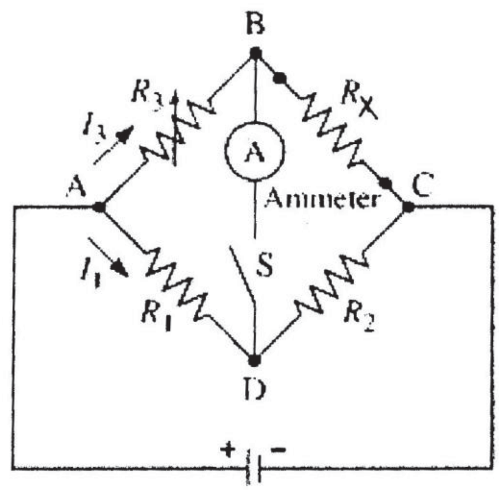
$C_1 = 5\ \mu F$ and $C_2 = 10\ \mu F$

(a)(6 pts) Calculate the equivalent capacitance of the circuit with the switch open.

(b)(6 pts) Calculate the equivalent capacitance of the circuit with the switch closed.

(c)(8 pts) What is the equivalent capacitance if the switch is replaced by a 50 μF capacitor?

3.(20 pts total) A "Wheatstone bridge" is a tool for measuring resistances. An adjustable and calibrated resistor R_3 is adjusted for a particular unknown resistor R_x until the circuit balances and the ammeter (the circled A in the figure) reads zero instantaneous current when the switch S is closed.

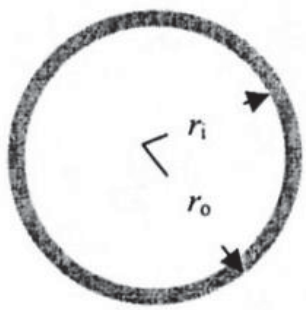


(a)(8 pts) Determine the relationship for R_x in terms of the known resistances R_1, R_2, and R_3 when the bridge is balanced.

(b)(6 pts) The resistance of an unknown length 2.3 mm in diameter Nichrome (Ni, Fe, Cr alloy, resistivity $\rho = 1 \times 10^{-6}\ \Omega\cdot\text{m}$) is measured with a Wheatstone bridge ($R_1 = 45.5\ \Omega$ and $R_2 = 38.3\ \Omega$). At balance $R_3 = 4.72\ \Omega$, how long is the wire?

(c)(6 pts) All real ammeters have some internal resistance. In general, to avoid disturbing the measurement, should the internal resistance be large or small? Explain how the internal resistance of the ammeter effects the measurement. Is there a problem with having R_{int} too large or too small?

4.(20 pts total) Your clever friend has invented a "warm marble" consisting of a spherical shell of a new plastic of inner radius $r_i = 4.00$ mm and outer radius $r_o = 4.01$ mm. The inner and outer surfaces are coated with a thin layer of a good conductor. A small hole and a thin wire provide a way for to provide an electrostatic potential between the inner and outer surface but you can neglect any other effect of the hole and wire. The new plastic is an excellent insulator ($\rho = 10^{12}\ \Omega\cdot\text{m}$) and it has an extremely large dielectric constant ($K = 1000$).



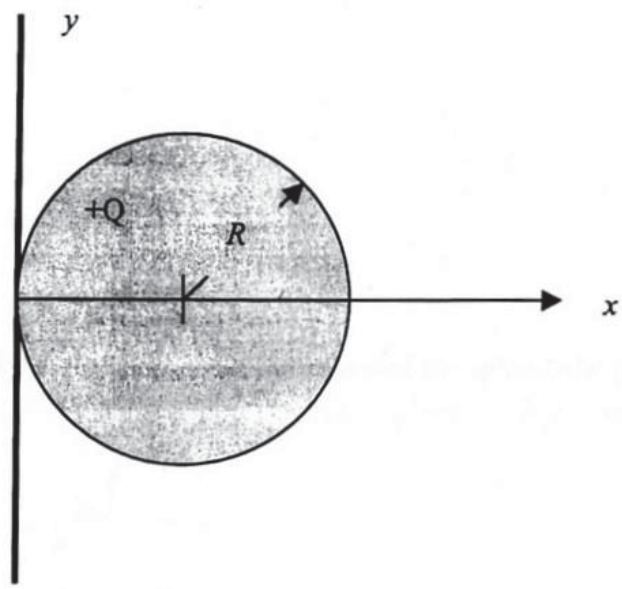
(a)(5 pts) Calculate the capacitance of the warm marble. (Remember. Obtain show both the formula and the numerical value for this type of question.)

(b) (5 pts) Calculate the resistance between the inside and the outside of the warm marble.

(c) (5 pts) How much energy is stored in the marble when a 5000V electric potential is applied between inner and outer surface?

(d)(5 pts) Describe the behavior of the marble when it is disconnected from the power supply. Draw the equivalent circuit and explain how the stored energy decays away in time. Where does the stored energy go?

5.(20 pts total) Consider an insulating sphere of radius R that is next to, and just touching, a very large (nearly infinite) conducting plane with zero net charge. The total charge +Q of the sphere is uniformly distributed within the volume. Take the point at which the sphere touches the conducting plane as the origin of a coordinate system with center of the sphere on the x-axis; the y-axis points up. Remember that the electric field is a vector quantity and you need to specify both its magnitude and direction. (Hint: On problems like this it often helps to replace the conduction plane with a fictitious charge distribution that gives the same electric field distribution as it would be at the surface of the conducting plane. The method is called the "method of image charges".)



(a)(2 pts) Is the charge density constant on the surface of the plane? Is the electrostatic potential constant on the surface of the plane?

(b)(2 pts) Is the charge density constant on the surface of the sphere? Is the electrostatic potential constant on the surface of the sphere?

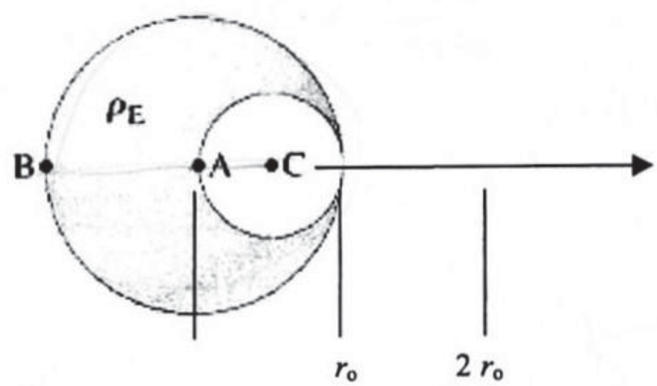
(c)(4 pts) Calculate the electric field at the point $(x, y) = (0, 0)$.

(d)(4 pts) Calculate the electric field at the center of the sphere, the point $(x, y) = (R,0)$.

(e)(4 pts) Calculate the electric field at the point $(x, y) = ((3/2)R,0)$.

(f)(4 pts) Calculate the electric field at the point $(x, y) = (R, R)$.

6.(20 pts total) A sphere of radius r_o carries a volume charge density ρ_E. A spherical cavity of radius $r_o/2$ is scooped out and left empty. There is a small hole at the thinnest point, just large enough to allow an electron to pass through. You may neglect any other consequence of the hole on the electric fields and potentials.



(a)(6 pts) What are the electric fields at A, B and C?

(b)(6 pts) Calculate the electrostatic potential at the points A and B. (Take the potential to be zero at infinity.)

(c)(8 pts) Suppose the constant charge density ρ_E is negative and suppose and electron is initially placed at point A. The electron moves along the x-axis. What is the velocity of the electron when it reaches a point $2r_o$ from point A (see figure).