Physics 24 Exam 1
February 18, 2014

| Exam Total |
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| **/ 200** |

Printed Name: _____

Rec. Sec. Letter: _____

Five multiple choice questions, 8 points each. Choose the **best** or **most nearly correct** answer.

_____ 1. The total electric flux passing through a Gaussian surface is found to be positive. Which of the following statements must be true?
[A] The total charge outside the surface is positive.
[B] The total charge inside the surface is positive.
[C] The total charge outside the surface is negative.
[D] The total charge inside the surface is negative.

_____ 2. The figure shows an electric dipole with its dipole moment oriented perpendicular to a uniform electric field. For this orientation the magnitude of the torque on the dipole is _____ and the potential energy of the dipole is _____.
[A] 0, minimum　　　　　　　　[B] 0, maximum
[C] minimum, 0　　　　　　　　[D] maximum, 0.
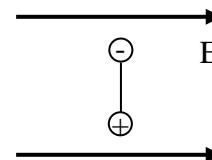
_____ 3. A proton is released from rest in a uniform electric field. The proton then moves under the influence of the electric field. Which of the following is true for the proton?
[A] The proton's potential energy increases and it moves toward higher electric potential.
[B] The proton's potential energy decreases and it moves toward higher electric potential.
[C] The proton's potential energy increases and it moves toward lower electric potential.
[D] The proton's potential energy decreases and it moves toward lower electric potential.

_____ 4. A parallel plate capacitor with capacitance C_0 is connected to a battery of potential V_0 and acquires a charge Q_0. With the battery still connected, the separation between the plates is **decreased** by a factor of 2. What are the new charge on the plates and potential difference between them after this change is made?
[A] $2Q_0$, V_0　　　　[B] $Q_0/2$, V_0　　　　[C] Q_0, $2V_0$　　　　[D] Q_0, $V_0/2$

_____ 5. The Hoverdog® in the picture is negatively charged, and the rings positively charged. If the Hoverdog® is released from rest, it will
[A] Oscillate back and forth between the rings.
[B] Launch to the right at a high speed.
[C] Lick the nearest human's face.
[D] Ask Dr. Parris, he's the Hoverdog® expert.

Note: no Hoverdogs® were harmed in the preparation of this exam.

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6. (40 points total) A positive charge Q is uniformly distributed over one half of a semi-circle of radius a. Negative charge of twice that magnitude is uniformly distributed over the bottom half of the semi-circle, as shown in the figure.

(a) (5 points) Draw on the figure at right the individual electric fields due to the positive and the negatively charged halves of the semi-circle.

(b) (20 points) Calculate the electric field at the origin due to the positively charged half of the semicircle, using the coordinate system indicated. Express your answer **in unit vector notation**, in terms of the parameters Q, a, and Coulomb's constant k.

$q_1 = +Q$

a O

y

x

$q_2 = -2Q$
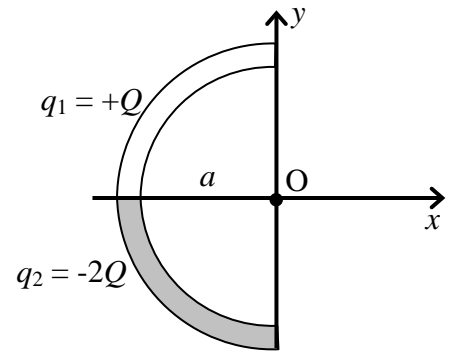
(c) (15 points) Find the total electric field at the origin, due to the entire semi-circle of charge. Feel free to state and use any appropriate symmetry arguments to simplify your calculation. Express your answer **in unit vector notation**, in terms of the parameters Q, a, and Coulomb's constant k.

7. (40 points total) A metal spherical shell of inner radius a and outer radius b holds a net positive charge of $+2Q$. Inside this spherical shell, held fixed at the center, is a negative point charge $-Q$.

(a) (10 points) Starting from a statement of Gauss's Law, find the magnitude of the electric field for $r<a$.
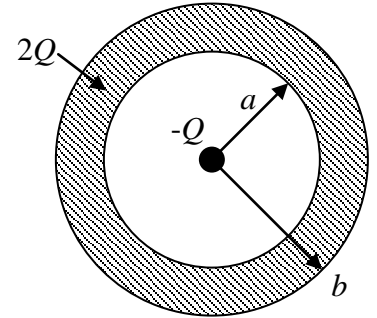
(b) (5 points) What is the magnitude of the electric field for $a<r<b$?

(c) (10 points) Starting from a statement of Gauss's Law, find the magnitude of the electric field for $r>b$.

(d) (10 points) Find the **surface charge densities** σ_a and σ_b on the inner and outer surfaces of the conductor.

(e) (5 points) What are the directions of $\vec{E}$ for $r<a$ and $r>b$? You can show the directions in a diagram or describe the directions in words.

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8. (40 points total) You are building a Coulomb gun, that is, a device that uses the Coulomb force to fire a bullet. Initially, two identical charged spheres of radius R and mass m are held in place inside an insulating frictionless barrel of length L (where L is defined in the figure). They are separated by a thin insulating barrier and carry identical positive charges. When the trigger of the gun is pulled, the right sphere is released from rest.
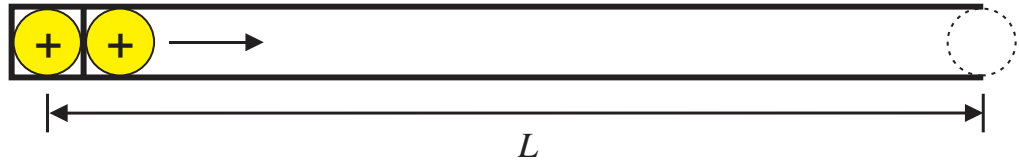

(a) (20 points) Calculate the value Q of the spheres' charges such that the bullet (the right sphere) has a speed v when its center reaches the end of the barrel. You can treat the charges as point charges at the centers of their respective spheres.

(b) (10 points) Find the work done by the Coulomb force during the acceleration of the bullet inside the barrel.

(c) (10 points) Determine the magnitude of the force required to hold the bullet in place before the trigger is pulled.

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9. (40 points total) In the capacitor circuit shown, $V_b - V_a = +30$ volts. Use starting equations for all calculations.

(a) (15 points) Calculate the total (equivalent) capacitance of this configuration of capacitors.
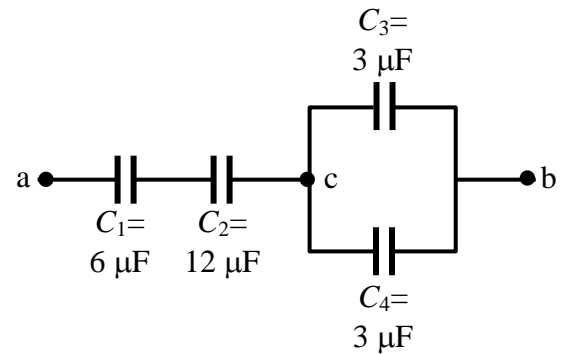
(b) (15 points) Calculate the charge stored in each of the 3 microfarad capacitors (C_3 and C_4).

(c) (10 points) Calculate the magnitude of the potential difference between points a and c. Which point is at a higher potential, a or c?

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