Physics 24 Exam 1
September 17, 2013

Printed Name: ____________________________
Rec. Sec. Letter: ______

Exam Total
/ 200

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

1. Two positive charges $Q$ are located a distance $d$ from the origin. One of the charges lies along the positive x-axis, and the other lies along a line making a $30^\circ$ angle with the positive x-axis, as shown in the diagram. What is the y-component of the total electric field at the origin?

   [A] $kQ/2d^2$
   [B] $-2kQ/d^2$
   [C] $-kQ/2d^2$
   [D] $-kQ/d^2$

2. An electron is moving in a uniform electric field, as shown in the diagram. At position (a) the electron speed is $v_0$, and a short time later at position (b) the electron speed is $v_1$. The direction of the force on the electron is ______ and the electron potential energy at (b) is ______ the potential energy at (a).

   [A] $\leftarrow$, greater than
   [B] $\rightarrow$, greater than
   [C] $\leftarrow$, less than
   [D] $\rightarrow$, less than

3. The figure to the right shows a dipole with its moment antiparallel to a uniform electric field. For this orientation 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

4. Gaussian sphere #1 (the solid line) completely encloses isolated point charge $Q$. There are no other charges present. Gaussian sphere #2 (the broken line) also completely encloses point charge $Q$. The diameter of sphere #2 is twice the diameter of sphere #1. If the electric flux through sphere #1 is $\Phi_0$, what is the electric flux through sphere #2?

   [A] $4\Phi_0$
   [B] $\Phi_0/2$
   [C] $2\Phi_0$
   [D] $\Phi_0$

5. Why did the chicken cross the road?

   [A] to minimize its electrical potential energy
   [B] the chicken on the other side had the opposite charge
   [C] a chicken in motion remains in motion
6. (40 points total) A thin horizontal ring of radius $R$ is located in the $xy$ plane with its center at the origin. It is uniformly charged with positive linear charge density (charge per length) $\lambda$.

(a) (5 points) What is the direction of the electric field of the ring at point $P$ located on the $z$-axis a distance $D$ below the origin (circle one)?

Circle one:  Left  Right  Up  Down  Clockwise  Counter-clockwise

(b) (15 points) Calculate the magnitude of the electric field at point $P$.

(c) (5 points) A small ball of negative charge $-Q$ is placed at point $P$. What is the direction of the force exerted by the ring on the ball

Circle one:  Left  Right  Up  Down  Clockwise  Counter-clockwise

(d) (5 points) Calculate the magnitude of the force exerted by the ring on the ball.

(e) (10 points) At what value of the distance $D$ does the force on the ball have its maximum value?

Circle one:  $D = -\infty$  $D = 0$  $0 < D < R$  $D = +\infty$
7. (40 points total) An infinitely long, conducting cylindrical shell of inner radius \( b \) and outer radius \( c \) has a net negative charge per unit length of \( -\lambda \). A solid insulating cylinder of radius \( a \) where \( a < b \) lies along the axis of the shell and carries a uniform positive charge density of \( +\lambda/(\pi a^2) \). A section of the cylindrical conducting shell and the solid insulating cylinder is indicated in the figure below.

(a) (15 points) Using Gauss’s law, find the electric field \( \vec{E} \) for \( 0 < r < a \). Begin with a statement of Gauss’s Law and indicate in the diagram your choice of a Gaussian surface. Express your answer in terms of fundamental constants and some combination of \( a, b, c, r, \) and \( \lambda \).

(b) (10 points) Determine the charge per unit length on the inner and outer surfaces of the conducting cylindrical shell. Show all your steps and justify your answer using Gauss’ law.

\[
\text{charge per unit length at } b = \quad \text{charge per unit length at } c =
\]

(c) (15 points) Find the magnitude of the electric field \( E \) at a radial distance \( r > c \) from the axis of the cylindrical shell. Express your answer in terms of fundamental constants and some combination of \( a, b, c, r \) and \( \lambda \).
8. (40 points total) Two protons \((q = +1.60 \times 10^{-19} \text{ C}, m_p = 1.67 \times 10^{-27} \text{ kg})\) are initially infinitely separated. They are projected toward each other with identical initial speeds. The initial speed of the protons is sufficiently large they will collide. Assume that the radius of a proton is \(r_p = 1.2 \times 10^{-15} \text{ m}\), and that the proton’s charge is spherically symmetric so that the electric field and potential outside the proton are the same as if it were a point charge.

(a) (15 points) What is the potential energy of the two protons at the point where they collide?

(b) (25 points) What is the minimum initial speed the protons must have in order to collide?
9. (40 points total) Capacitor problem. All solutions MUST start with OSE’s.

(a) (10 points) A parallel plate capacitor consists of conducting plates of area \(6 \times 10^{-4} \text{ m}^2\) separated a distance of 2 mm. What is the capacitance of the capacitor?

(b) (10 points) The capacitor plate separation is now changed to 4 mm and a third conducting plate is inserted between the original two plates as shown in the picture. The separation between each of the conducting plates is 2 mm and the areas are still \(6 \times 10^{-4} \text{ m}^2\). What is the capacitance of this newly constructed capacitor?

(c) (10 points) If a battery supplying a potential difference of 20 V is connected to the capacitor as shown in the picture, with the negative terminal connected to the left plate and the positive terminal connected to the middle plate, how much charge is stored?

(d) (10 points) For the capacitor circuit shown, \(C_1 = 2 \mu\text{F}, C_2 = 4 \mu\text{F}, C_3 = 8 \mu\text{F},\) and \(C_4 = 16 \mu\text{F}\.\) Find the equivalent capacitance, \(C_{eq}.\)