STAPLE

Physics 201 Name KEY

Exam 1 – Electrostatics

February 7, 2013

This is a closed book examination but during the exam you may refer to a 3"x5" note card with words of wisdom you have written on it. There is extra scratch paper available. Your explanation is worth ¾ of the points. Explain your answers!

A general reminder about problem solving:

- Show all your work.
- Really; Show All Work!
- Focus
  - Draw a picture of the problem
  - What is the question? What do you want to know?
  - List known and unknown quantities
  - List assumptions
- Physics
  - Determine approach – What physics principles will you use?
  - Pick a coordinate system
  - Simplify picture to a schematic (if needed)
- Plan
  - Divide problem into sub-problems
  - Modify schematic and coordinate system (if needed)
  - Write general equations
- Execute
  - Write equations with variables
  - Do you have sufficient equations to determine your unknowns?
  - Simplify and solve
- Evaluate
  - Check units
  - Why is answer reasonable?
  - Check limiting cases!

1. [4 PTS] A point with charge Q_1 and a sphere with charge Q_2 are located in an empty region of space. The magnitude of the force on the point charge is 12 N when the center of the sphere is 2 meters away. What is the magnitude of force on the sphere when the point charge is moved 1 meter closer so that only 1 meter now separates the center of the sphere and the point charge?
   a) 3 N
   b) 6 N
   c) 12 N
   d) 24 N
   e) 48 N

Force is proportional to $1/r^2$. $\vec{F} = \frac{kq_1q_2}{r^2}\hat{r}$ We are only interested in the magnitude $\frac{F}{F_o} = \frac{r_o^2}{r^2} = \frac{r_o^2}{\left(\frac{r_o}{2}\right)^2} = 4$ so F=4x12N=48N

2. [4 PTS] A hollow metal sphere is placed between two large charged plates. Plate A has a charge of -92 nC and plate B has a charge of +46 nC. The plates are separated by 90 cm and the center of the metal sphere is placed 30 cm from plate A (so the sphere is closer to plate A). The plates and the sphere are in static equilibrium (nothing is moving). The electric field inside the metal sphere
   a) is proportional to $1/r^2$
   b) is positive pointing towards plate A.
   c) is zero.
   d) is positive pointing towards plate B.
   e) can not be determined without the size of the sphere.

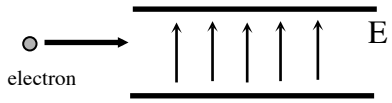
When a conductor (metal) is in static equilibrium the electric field inside is zero – otherwise charges would move till there was no field.

3. [4 PTS] A large neutral metal disk is grounded through a switch. A negatively charged balloon is brought near it (but does not touch it) while the switch is closed. The switch is opened (the disk is no longer grounded) and the balloon is taken away. The disk is now
   a) charged but we cannot know its polarity.
   b) neutral (has no net charge).
   c) negatively charged.
   d) positively charged.
   e) none of these.

The balloon induces the negative charges to move away to ground since they have a path. When the switch is opened the negative charges cannot return. Hence disk is left with a positive charge.

The next two problems involve a cathode-ray tube like those found in old TVs. In a cathode-ray tube an electron traveling in a vacuum at $v=3\times10^6$ m/s enters a region between two deflection plates where there is an upward electric field of magnitude 7.8×10^4 N/C.

4. [4 PTS] Indicate the direction the electron is deflected.
   a) The electron is deflected up.
   b) The electron is deflected down.
   c) The electron is deflected into the page.
   d) The electron is deflected out of the page.
   e) The electron is not deflected.



Force is proportional to charge and electric field. $\vec{F} = q\vec{E}$

5. [4 PTS] Calculate the acceleration of the electron while it is between the deflection plates.
   a) $a = 1.37\times10^{16}$ m/s^2
   b) $a = 2.25\times10^{6}$ m/s^2
   c) $a = 4.44\times10^{-7}$ m/s^2
   d) $a = 7.29\times10^{-17}$ m/s^2
   e) $a = 0$ m/s^2

Force is proportional to charge and electric field. $\vec{F} = q\vec{E}$
Force is proportional to mass and acceleration. $\vec{F} = m\vec{a}$
Hence, $\vec{a} = \frac{q\vec{E}}{m}$

6. [4 PTS] Two rings of radius 1.7 cm are 20 cm apart and concentric with a common horizontal x-axis. What is the magnitude of the electric field midway between the rings if both rings carry a charge of +28 nC?
   a) 0 N/C
   b) 6.30×10^3 N/C
   c) 1.26×10^4 N/C
   d) 2.52×10^4 N/C
   e) 5.04×10^4 N/C

Force is proportional to charge and electric field. $\vec{F} = q\vec{E}$

7. [4 PTS] An alpha particle is a He nucleus and consists of two neutrons and two protons. Two alpha particles are separated by 2.5 nm. What is the dominant force acting on these particles.
   a) The gravitational force.
   b) The strong force.
   c) The electrostatic force.
   d) The weak force.
   e) All the forces are of equal magnitude at this distance.

Electrostatic force is dominant until you are at distances equal to the atomic nucleus 10^{-15} m = 10^{-6} nm.

The next three questions concern a neutral atom and a point charge initially separated by 30 nm.

8. [4 PTS] What is the force between these objects?
   a) The force is repulsive.
   b) There is no force.
   c) The force is attractive.

The point charge induces a dipole that is orientated so there is a net attractive force.

9. [4 PTS] The distance between these objects increases to 60 nm. The magnitude of the force
   a) is greater.
   b) does not change.
   c) is smaller.

If the distance increases the magnitude of the force must decrease.

10. [4 PTS] The distance between these objects increases to 60 nm. The magnitude of the force changes by a factor of
   a) 32
   b) 16
   c) 8
   d) 4
   e) 2
   f) 0

Attractive force is proportional to $1/r^5$.

$$\frac{F}{F_o} = \frac{r_o^5}{r^5} = \frac{r_o^5}{(2r_o)^5} = \frac{1}{32}$$

The next two problems can be done on the back of your exam or on additional paper.

11. [12 PTS] An electron that is initially at rest is between two parallel plates of radius 22 cm. At time t = 0 sec both plates are instantly charged so one has a charge of 35 nC and the other has -35 nC.
   a) What is the velocity of the electron after it has traveled 3 mm?
   b) How long does it take to travel 3 mm? NOTE: Think kinematics.

From kinematics $t = \sqrt{\frac{2\Delta x}{a}} = 1.14\times10^{-9} sec$ and $v = at = 5.24\times10^{6}\frac{m}{s}$

where $a = \frac{qE}{m} = \frac{q}{m}\frac{\sigma}{\epsilon_o} = \frac{q\ 4\pi k}{m}\frac{Q}{\pi R^2} = \frac{q\ 4k\ Q}{mR^2} = 4.58\times10^{15}\frac{m}{s^2}$

12. [12 PT] The electric field 10 cm from the surface of a hollow copper sphere of radius 10 cm is 15 N/C. Graph the electric field as a function of distance from the center of the sphere to a radial distance of 1.0 meter.

$1/4\pi\varepsilon_o = k = 9\ x10^9\ Nm^2/C^2$
mass of electron = $m_e = 9.109x10^{-31}$ kg
mass of proton = $m_p = 1.673x10^{-27}$ kg
charge of electron = $q_e = -1.602x10^{-19}$ C
$V_{sphere} = 4\pi r^3/3$
$A_{sphere} = 4\pi r^2$

$E = 0$ for $r < 0.1m$

$E = \frac{kq}{r^2}$ for $r \geq 0.1m$

where $E(r = 0.2m) = \frac{9\times10^9\ \frac{Nm^2}{C^2}\ q}{(0.2m)^2} = 15\frac{N}{C}$

so $q = 6.6\bar{6}\times10^{-11}C$