Physics H7B Fall 2014
Dr. Winoto - Midterm 2
Wed, November 5th, 2014

Instruction for the examination:
- In the front of your bluebook, next to your name, please write you SID.
- You may use a calculator without any wireless internet connection and one 8.5”x11” sheet of notes
- Topic covered: Electrostatics, Purcell Ch.1-4
- There are 4 problems (25 points each regardless of difficulty), do them in any order you prefer.
- Total points for the exam = 100 points for a perfect score
- You have exactly 120 minutes to complete the test
- **Show all your work!** Please outline and explain in details all your physical and mathematical reasonings in a clear, rational, step-by-step and logical manner.
- Cross out any parts of your written exam that you would like to discard and not considered as part of your answers.
- Good luck!!

1. (25 points)
An electric charge +q is distributed uniformly on a very thin ring of radius a. The ring is place in the yz-plane with its center at the origin. A charge of -q is placed at the origin, as shown in figure 1.
(a). Find the potential V at the point P=(x, 0, 0).
(b). What is the electric field vector **E** at P?
(c). How does the electric field **E** varies with x for x >> a? In other words, find **E** as a function of x.
(d). How does this field (from part c) compare with the electric field of a dipole? Please explain in careful detail.

2. (25 points)
A charge +Q is located at an equal distance x_o normal from two semi-infinite conducting planes at right angle to each other, as shown in figure 2. Using the method of image charge:
(a). Please find all the image charges in the problem: their magnitudes, signs and locations (please draw them). Please explain in careful steps and details your reasoning.
(b). On a separate drawing, please draw the electric field lines due to +q and all its image charges, first, everywhere by ignoring the conducting planes.
(c). Then, on another separate drawing, reintroduce the conducting planes, and redraw the electric field lines in region(s) where there are field lines, and also draw the equipotential lines.
For (b) and (c), please draw enough density of lines so that the patterns of lines are clear!
(d). Please calculate the force (either (magnitude and direction) or components) on +q due to all its image charges.

3. (25 points)
In a two-electrode vacuum tube, gas of electrons (meaning lots and lots of electrons) are emitted from a high temperature (hot) flat surface metal plate of area=A, and collected by another flat surface plate parallel to the hot emitter plate, at a distance d away, as shown in detail in figure 3. The distance d is small compared to $\sqrt{A}$, the lateral dimensions of the plates, so you can ignore the fringe effect. After some time, in a steady state, effectively or macroscopically, the electric potential between the plates is given by V(x) = k $x^{4/3}$, where x is the distance from the emitter, and k is some constant. The mass of

electron is m, and the charge of electron is -e.
(a). Please calculate the electric field **E** as a function of x in between the two plates: $0 < x < d$.
(b). Use Gauss Law explicitly: to calculate the surface charge density σ_e on the emitter plate (i.e. the left plate).
(c). Use Gauss Law explicitly: to calculate the surface charge density σ_c on the collector plate (i.e. the right plate).
(d). Please calculate the charge density $\rho(x)$ as a function of x for $0 < x < d$.
The electrons are emitted with zero velocity at the hot emitter plate.
(e). Use conservation of energy to calculate the velocity of the electron v is a function of x, for $0 < x < d$.
(f). Please calculate the current density **j**(x) as a function of x for $0 < x < d$.

4. (25 points)

A particle of charge +Q and mass m is released from rest at a distance of z_o from the surface of a large grounded conducting plate (the plate is level with the x-y plane at z=0. See figure 4. Using method of image charge, we know that the particle is attracted by the plate, and moves towards it. Please ignore gravity in this problem.
(a). What is the potential energy of the particle as a function of its distance z from the plate?
(b). What is the kinetic energy of the particle as a function of its distance z from the plate? (ignore radiation process).
Extra credit (maybe ~5 points, say):
(c). What happens when the particle reaches z=0? What is its kinetic energy? Is this physical? Please describe. And if not, what is then happening near z=0?