Physics III
ISI B.Math
End of Semester Back paper Exam December 28, 2011

Total Marks: 75
Time: 3 hours
Answer ALL

Question 1. Total Marks:7+8

a.) Two infinite parallel planes carry equal but opposite uniform surface charge with surface charge densities $+\sigma$ and $-\sigma$. Find the electric fields in each of the three regions (between the plates and on each side of both the plates)

b.) Two spheres, each of radius R and carrying uniform volume charge densities $+\rho$ and $-\rho$ are placed so that they partially overlap. Let $\overrightarrow{d}$ be the vector from the positive center to the negative center. Show that the field in the region of overlap is constant and find its value.

Question 2. Total Marks:5+5+5

a.) A conducting material is one that has "free charges" which will move under an electric field. Consider a net charge Q placed inside a piece of conducting material. Experimentally it is found the charges will rearrange themselves until, within a very short time, a static configuration is reached. Show that after static situation is reached

i.) The charge density inside the conducting material is zero.
ii.) The electric field just outside the conducting material is normal to the conducting surface.

b.) Show that even in a non static configuration, the magnetic field will remain constant inside a "perfect conductor"(for a perfect conductor, conductivity is infinite which means that electric field inside is identically zero).

[Please provide quantitative arguments using, for example, Maxwell's equations]

Question 3. Total Marks:15

Show that the Ampere's law (for example its differential form) is not consistent with conservation of charge except when the charge density is constant in time. Modify the differential form of the Ampere's law so that it is valid in all situations. Show that the modified equation is consistent with continuity equation (related to conservation of charge).

Question 4. Total Marks:6+6+3

A square loop of side a lies in x-y plane with one side parallel to the x-axis and at a distance s from a long wire which carries a current I in the x direction.

a.) Find the flux through the loop.

b.) If the loop is pulled directly away from the wire at speed v, what is the emf generated? In what direction (clockwise or counterclock wise) will the current flow?

c.) What is the emf generated if the loop is pulled with velocity v to the right parallel to the wire?

Question 5. Total Marks:4+4+7

a.) Which of the following electric fields can or cannot represent a monochromatic light bouncing between two parallel mirrors placed on the x axis? Assume these mirrors to be perfect reflectors. Justify your answer in each case.

i.) $E_0 \cos(kx - wt)\overrightarrow{e_x}$

ii.) $E_0 \cos(kx - wt)\overrightarrow{e_z}$

iii.) $E_0 \cos(kx - wt)\overrightarrow{e_z} + E_0 \cos(kx + wt)\overrightarrow{e_z}$

iv.) $E_0 \cos(kx - wt)\overrightarrow{e_x} + E_0 \cos(kx + wt)\overrightarrow{e_y}$

where $\overrightarrow{e_x}, \overrightarrow{e_y}, \overrightarrow{e_z}$ are unit vectors and E_0 is a constant with appropriate units.

b.) Show that $E_0 \cos(kz)\cos(wt)(\overrightarrow{e_x} + \overrightarrow{e_y})$ is a valid electric field for an electromagnetic wave propagating in vacuum. Find the corresponding magnetic field.