Physics 303 Classical Electrodynamics
Practice questions and problems for I-Midsem

1. **Uniqueness theorem** Suppose ϕ_1 and ϕ_2 are two solutions for Laplace equation prove that the two are same except for any additive constants

2. **Types of Boundary conditions** There are two types of boundary conditions used in electrostatic problems called the Dirichlet and Neumann. Can you explain these?

3. **Method of images** A charge q is placed in front of a grounded metal plane. Use the method of images to find the potential at all regions. Estimate the charge q density on the surface of the metal. Estimate the charge q' that will give the right solution. What is the work done in assembling a charge in front of a metal sheet.

4. **Dipole** A dipole consists of 2 opposite charges $+q$ and $-q$ separated by a distance d. What is the field and potential due to the dipole ? What is the expression for interaction energy between two dipoles of moment p_1 and p_2

5. **Capacitance** One can define absolute capacitance as $C = Q/V$. The differential capacitance is defined as $C_{diff} = \frac{\partial Q}{\partial V}$ at some conditions like constant temperature. C_{diff} is measured when there is a changing voltage or current (e.g rms value in presence of an AC current) with limit of δV going to zero. If the dielectric material shows linear behaviour then $C_{diff} = C$. Can any of these quantities C or C_{diff} take a negative value . (Hint : write the potential energy stored in a capacitor at constant voltage or charge)

6. **Metal Sphere in constant $\vec{E}$ field**
   A metal sphere of radius a is placed in a constant electric field $\vec{E}$. Find the potential at all regions outside the sphere.

7. **Leaky Capacitor** Real Dielectric materials have some small leakage currents. For practical purposes it may have very low conductance or high resistance (say of the order of several $M\Omega$) so it is still possible to build a capacitor out of it but the charge does decay over long time intervals. If its dielectric constant of a material is ϵ and conductance σ find the time constant of a charged capacitor. (Hint : Evaluate electric flux through a capacitor with charge Q and voltage V using Gauss's law. Evaluate the Electric flux in presence of a small current using Ohm's law in the form $\vec{J} = \sigma\vec{E}$. Equate the net electric flux in both cases to get a time constant RC .) If you cannot derive this try to guess it from dimensional analysis.

8. **Dielectric Sphere in constant $\vec{E}$ field/** A dielectric sphere is placed in a constant electric field. Can you get the potential outside the surface and the induced surface charges. The susceptibility of the sphere is linear with a dielectric constant ϵ.

9. **Spherical Cavity in a Dielectric Slab** Consider a large dielectric bar of dielectric constant ϵ. It has a small spherical void of radius r and a linear dielectric constant ϵ. Evaluate the field inside the cavity and outside it.

10. **Doppler effect in light** A light source of frequency ω is moving with a speed v with respect to a stationary observer. The speed v is comparable to speed of light c say $v/c = 0.3C$. Define an appropriate four vector for frequency or wavelength of light and calculate the Doppler shift as seen by the observer.

11. Field Transformations A constant electric field $\vec{E}$ is in the x direction and a constant magnetic field $\vec{B}$is pointing in the Z direction. How do these fields transform with respect to an observer moving in the X-direction.

    Practise other problmes and questions posed during lectures.