Physics 102 Electromagnetism

Practice questions and problems Tutorial 1 ad 2

1. Consider a vector field $\vec{F} = (2xz^3 + 6y)\hat{i} + ()6x - 2yz)\hat{j} + (3x^2z^2 - y^2)\hat{k}$. Prove this is a conservative field.

2. Feynman makes a remark that matter is usually neutral. If someone creates around $\sim 1\%$ disturbance of a charge imbalance in a human being the electrostatic forces are big enough to lift planet earth. Make a crude calculation to prove or disprove this statement. You will have to setup the proble, qualittatively e.g, assume a person weights 60Kg and is composed of 90% water and estimate the force assuming an equal charge is present in earth. You need to only worry about the order of magnitude and not the exact values. (Such problems are called Fermi problems. Find out what are Fermi problems)

3. Consider a vector field $\vec{C}$ derived from a curl of another vector $\vec{B}$. Find the divergence of this vector.

4. Consider a vector $\mathbf{A} = \hat{r}r^n$ where $\hat{r} = \mathbf{r}/r = \hat{i}x + \hat{j}y + \hat{k}z$. Find $\nabla.\mathbf{A}$. (i) What is the value of the divergence for $n = 1$ in a space of 3 dimensions and 2 dimensions . (ii) What is the value of the divergence for $n = -2$ and $n = -3$

5. Two long thin wires carry a linear has a charge density λ_1, λ_2 per unit length. Find the force per unit length due to wire 1 on wire 2 if they are separated by a distance b

6. i) What is the energy stored in a capacitor with capacitance C charged to a value Q ? ii)A parallel plate capacitor of area $A = l \times w$ with separation d. Evaluate the capacitance and charge at a fixed voltage when the gap if filled with (i) air and (ii)with a dielectric FR-4 (the light green plastic in PCBs) of dielectric constant $\epsilon = 4$.

7. A point q charge is placed at a distance d before a grounded metal plane. (a)Use the image method to write the potential (b)solve for the charge density and the force on the charge. (c). Suppose there are 2 grounded planes separated by a distance d and you can place a charge anywhere in-between. Find the force on the charge.

8. A parallel plate capacitor of area $A = l \times w$ with separation d is filled partially with a dielectric slab of dielectric constant e_1 find out what happens when the condenser plates are set to a constant charge Q. (Hint : use the result for energy stored in terms of charge and capacai-tance in a previous problem)

9. Consider a circular sheet of charge with density σ per unit area. If the radius of the disc is $b$find the field at a distance a from the circle. Evaluate the field at point a when the sheet is of infinite dimensions.

10. A large parallel plate capacitor has a separation d and is lying in the X-Y plane with the top plate positive and the bottom plate negative.

A ball of mass m is charged to a value $+Q$ and released from the top plate with a speed v along the x-axis just below the top plate. Solve for the trajectory of the ball if $\vec{g}$ is acting downward along the z-axis.

11. Arrive at Poisson and Laplace equations from the differential form of Gauss' law.

12. When charges accelerate they radiate energy. This means electrons moving around the nuclei like a planetary motion will not be stable. If one considers only a static arrangement of an electron and a proton it will not be stable. The text showed some arguments using Gauss' law. Can you assume Laplace's equation holds in the region between the two charges and show a condition for stable equilibrium is not satisfied.

13. A dipole of moment $\vec{p}$ is subject to a uniform external field. Find the force and torque on the dipole. What is the potential energy of a dipole in external field.

14. You are standing on a very long highway and watching cars that approach you. When the cars are too far away the head lights appear to be a single lamp. When they approach a little closer you are able to see the two headlights separately. Can you find out if you can use this to comment on dipole fields.