# Physics 102: Problem Set 12 (Optional)

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**Due date: 5th of January, 2013.** **For all problems show all work!**

1. Using Gauss' law calculate the electric field as a function of the variable *r* (radius) for the following systems: **(a)** a sphere with constant charge density *ρ* **(b)** a cylinder with constant charge density *ρ*, and **(c)** as a function of distance from an infinite plane with surface charge density *σ*. Sketch the electric field lines in all cases.
2. Calculate the potential for the systems in problem **1. (a)** and **(b)**. Indicate the radius of reference (where the potential is set to zero). Calculate also the potential as a function of *z* for a system with two infinite planes one at $z=d/2$ the other at $z=-d/2$ with charges *σ* and -*σ* respectively. Indicate again the point of reference. Sketch the equipotential surfaces in all cases.
3. Consider a parallel plate capacitor with area *A* and separation *d*. **(a)** Show that if a conducting slab of equal area but width $w<d$ is inserted between the plates such that the areas are all parallel, then the capacitance of the new system is independent of where exactly the slab is placed (i.e. independent of how close it is placed to any of the plates). Calculate the capacitance of the total system. **(b)** Calculate if the slab is a dielectric with dielectric constant *K*.
4. A potential difference *V* is applied to a wire of cross sectional area *A*, length *L*, and resistivity *ρ*. You want to change the applied potential difference and change the dimensions of the wire so the power dissipated is increased by a factor of *30* and the current is increased by a factor of *4*. What should the new values of *L* and *A* be?
5. **(a)** Young and Freedman (13th edition) 26.81. **(b)** Young and Freedman (13th edition) 26.90.
6. An ion of mass *m* and charge *q* is accelerated through a potential difference, and is then allowed to enter a region in which there is a magnetic field **B** perpendicular to the velocity of the ion. Calculate the radius of the motion of the ion.
7. A closed loop of wire carries a current *I*. The loop is in a uniform magnetic field **B.** Show that the total magnetic force on the loop is zero. Does this result hold if the magnetic field is not uniform?
8. The current density of a current carrying wire is given as a function of radius as $j(r) = j_0(1-(r/r_0)^3)$. Calculate the **(a)** total current carried by the wire and **(b)** the magnetic field as a function of the radius *r*.
9. A wooden cylinder is surrounded by a rectangular wire. The wire runs around the cylinder longitudinally, in other words, the two long sides along the *z* direction, the short sides along the diameter of the cylinder. The plane of the wire loop includes the axis of the cylinder. The cylnder has mass *m*, length *L*. The cylinder is placed on an inclined plane with inclination angle θ. A uniform magnetic field of strength *B* is present, pointing vertically up. What is the magnitude and direction of a current which will prevent the cylinder from rolling down?
10. Two conducting tracks of negligible resistance are parallel and make an angle *θ* with the horizontal. They are a distance *l* apart from each other. At the bottom they are connected via a conducting segment of length *l* with negligible resistance. A vertical magnetic field of strength B exists throughout the region. A rod with mass *m* and length *l*, and resistance *R* is placed on the tracks so that a rectangular circuit is formed. **(a)** Calculate the steady state terminal velocity

of the rod. **(b)** Show that the rate at which thermal energy is being generated in the rod is equal to the rate at which the rod is losing gravitational potential energy.

***11.*** Young and Freedman (13$^{th}$ edition) 31.56.

**12.** Young and Freedman (13$^{th}$ edition) 32.38.