PHY 103: General Physics 2 (2014 – 2015, Semester – I)

Department of Physics

Indian Institute of Technology - Kanpur

Assignment-3

Note: The questions marked with circles are to be solved by the students as Home Work. These will not be solved in the tutorials. The students are encouraged to clear any doubts on these questions during the office hours of tutors.

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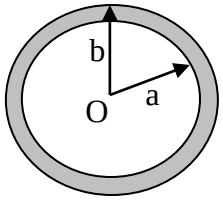
1. The potential of some charge configuration is given by

$$V(\vec{r}) = A\frac{e^{-\lambda r}}{r},$$

Find the electric field **E**(**r**), the charge density ρ (**r**), and the total charge Q.

2. A hollow spherical shell has charge density $\rho = k/r^2$, in the region $a < r < b$. Find the potential at the center "O" using infinity as the reference point. Plot the electric field as a function of r.

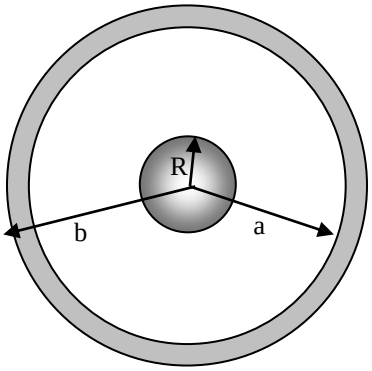


③ A hollow metallic sphere is initially uncharged. Now imagine that a positive point charge q is placed somewhere (not in the middle) inside the sphere without touching the walls.

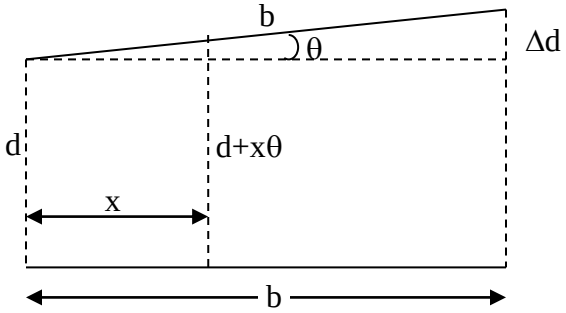
   a. Qualitatively what is the charge distribution on the inner surface of the metal and what is it on the outer surface? Indicate (make a sketch) the relative concentration of induced surface charge densities using the symbols "+" and "-". Make a fairly careful sketch of the electric field lines inside and outside the sphere.
   b. Suppose that you move the charge q around inside the cavity. Does the charges distribution on the outer surface of the sphere change?. Explain your answer.
   c. You now bring the point charge q in contact with the inner surface of the sphere. What is the charge distribution then on the inner surface and on the outer surface?. Make a fairly careful sketch of the electric field lines inside the sphere and outside.

4. A metal sphere of radius R, carrying charge q, is surrounded by a thick concentric metal shell (inner radius a, outer radius b). The shell caries no net charge. (a) Find

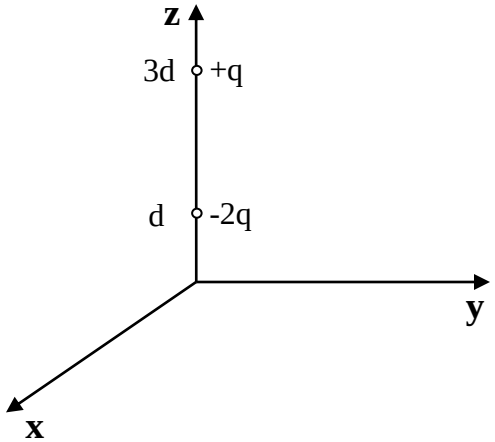
the surface charge density σ at R, at a, and at b. (b) Find the potential at the center, using infinity as the reference point. (c) Now the outer surface is touched to a grounding wire, which lowers the potential to zero (same as at infinity). How do the answers to (a) and (b) change?. (see figure on next page)



⑤ A square plate capacitor of side b is built in such a manner that one of its plates is tilted relative to the other. The tilt angle θ is very small (the plates are equipotential). The geometric parameters of this capacitor are depicted in the figure below. Compute the capacitance of this configuration.



⑥ Find the force on the charge +q in the figure below. The XY plane is a grounded conductor.



7. A uniform line charge λ per unit length is placed on an infinite straight wire, a distance *d* above a grounded conducting plane. (Let's say that the wire runs parallel to the *X*-axis and directly above it, and the conducting plane is the *XY* plane.)
   (a) Find the potential in the region above the plane.
   (b) Find the charge density σ induced on the conducting plane.

8. A point charge *q* is situated a distance *a* from the centre of a conducting sphere, held at a potential V_o (relative to infinity). The radius of the sphere is *R*. What are the image charges and what are their positions? Find the force of attraction between a point charge and a neutral conducting sphere.

9. A point charge q is situated a distance *a* from the center of a grounded conducting sphere of radius R (R < a).

   (a) Show that:

$$V(r,\theta) = \frac{1}{4\pi\varepsilon_o}\left[\frac{q}{\sqrt{r^2 + a^2 - 2ar\cos\theta}} - \frac{q}{\sqrt{R^2 + (ra/R)^2 - 2ar\cos\theta}}\right]$$

   where *r* and θ are the usual spherical polar coordinates, with the z axis along the line through q.

   (b) Find the induced surface charge distribution on the sphere as a function of θ. Integrate this to obtain the total induced charge. (What should it be?)