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

Department of Physics
Indian Institute of Technology - Kanpur

## Assignment-2

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**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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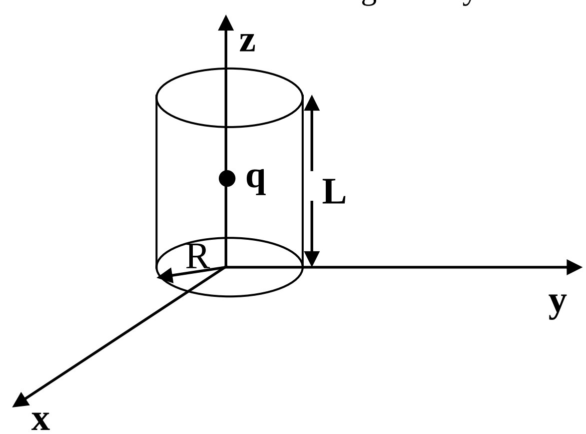
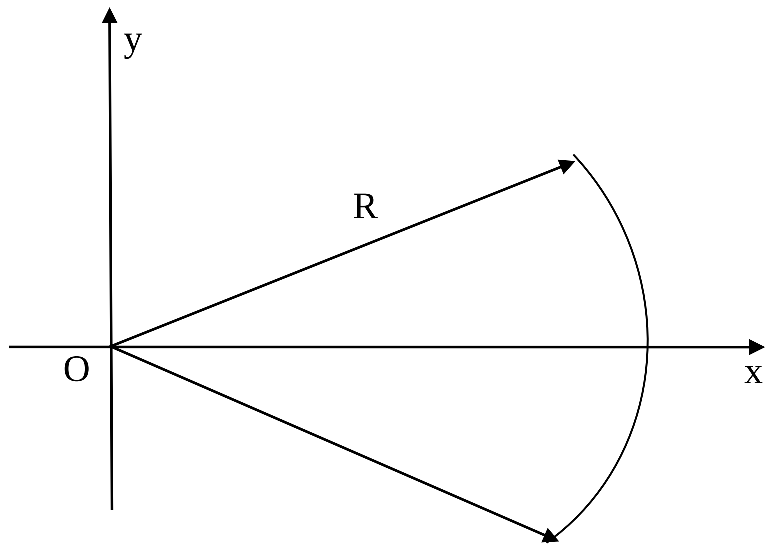
1. The gravitational force between two "point-like" masses is very similar in its mathematical form to the electrostatic force between two concentrated charges ("point-like"). The magnitude of these two forces are however vastly different. To illustrate this, consider an example. Somewhere in outer space are two identical spherical dust grains, 50 μm in diameter, with mass density 2.5 g/cm$^3$ . They are at a distance d meters apart. If the grains were electrically neutral, free of other external forces, and have negligible relative velocity initially, they would eventually collide gravitationally.

   Now suppose that both grains are electrically charged, each having n "extra" electrons. Find the minimum value of n that would prevent the gravitational collision. Compare this with the approximate total number of electrons contained in one grain.

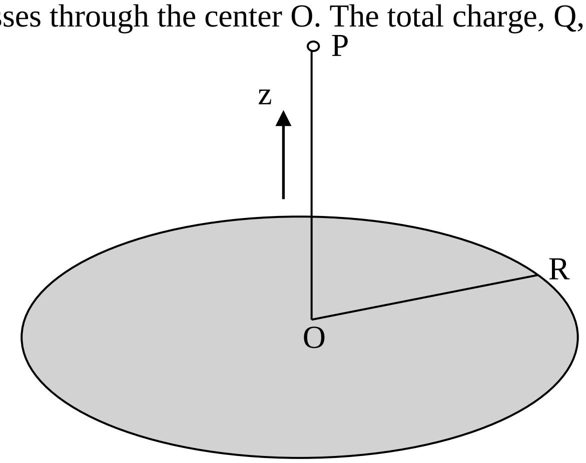
2. A point charge $q$ is located at the midpoint of the axis of a cylinder of radius R and height $L$. Calculate the electric flux through the cylindrical curved surface.




3. Consider a dielectric rod of negligible thickness in the form of an arc having radius R and a continuous charge distribution of line charge density λ. Find the electric field at the center of the arc (at O).




4. A disc of radius R carries a uniform surface charge density σ (see figure below) The z axis passes through the center O. The total charge, Q, on the disk is thus $Q = \pi R^2 \sigma$ .




(a) What is the electric field (magnitude and direction) at a point P a distance z above center of the disc?.

(b) Plot E(z) as a function of z for all positive z's. Use R as your unit on the abscissa; use $Q/(4\pi\varepsilon_o R^2)$ as your unit for E(z).

(c) Using Binomial expansion for $(z^2 + R^2)^{1/2}$, find simplified expressions for E(z) in two limiting cases:
(i) $z^2 << R^2$ (ii) $z^2 >> R^2$.

In your calculations retain only the first non-vanishing term of your expansion.

(d) Compare your result in case (ii) with the result you can obtain "effortlessly" by making use of Coulomb's Law for a point-like charge.

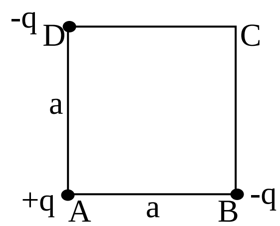
(e) Using Gauss's law (choose a proper "pillbox"), calculate E(z) near point O for case (i); compare your answer with (c).

(f) **<u>Challenge problem:</u>** Using the differential form of Gauss's law find $E_\rho$ near the axis OP, where $E_\rho$ is the $\rho$ component of the electric field in cylindrical coordinates.

5. Find the electric field everywhere using Gauss's law for: (i) a spherical shell of radius R carrying a uniform surface charge density (ii) an infinitely-long cylinder of radius R carrying a uniform volume charge density (iii) an infinite plane slab of thickness d with a uniform volume charge density. Plot the variation of E with z.

6. Calculate the potential for the charge distributions given in problem 5.

7. (a) 3 charges are situated at the corners of a square (side *a*) as shown below. How much work is required to bring in another charge +*q*, from far away, and place it at the fourth corner?
   (b) How much work is required to assemble the whole configuration of the 4 charges?




8. Consider a model of the hydrogen atom where the negative charge is distributed spherically around the positive charge at the center. The electron cloud has the density $\rho(\vec{r}) = -\left(\frac{e}{\pi a^3}\right)\exp\left(\frac{-2r}{a}\right)$, where a is the Bohr radius. Calculate the interaction energy between the electron cloud and the nucleus (proton) in a few ways (i) finding the potential at the center (r = 0) due to the electron cloud and interacting with the proton charge (ii) Can also be thought of as the potential due to the proton interacting with the electron cloud charge density $\rho(\vec{r})$ (iii) Even can be thought of (in Bohr model) as an electron moving in an orbit of radius "a" and interacting with proton potential at that point.

9. Two identical spheres carrying uniform charge densities $-\rho$ and $+\rho$, respectively, are placed so that they partially overlap. Calculate the electric field in the overlap region in terms of $\vec{s}$, the vector from the center of the negatively-charged sphere to the center of the other sphere.