Lab: Electric Field of a Flat Conducting Disk AP Physics

Background
We have essentially three ways of determine the electric field at a point in space, based on some source of electric charge:

1. Using $E = \int \frac{k \; dq}{r^2}$ over a distribution of charge;
2. Using Gauss's Law ($\Phi_c = \int \mathbf{E} \bullet d\mathbf{A} = \frac{q_{in}}{\varepsilon_0}$) along with an appropriately-chosen Gaussian surface; and,
3. Using $E_x = -\frac{dV}{dx}$.

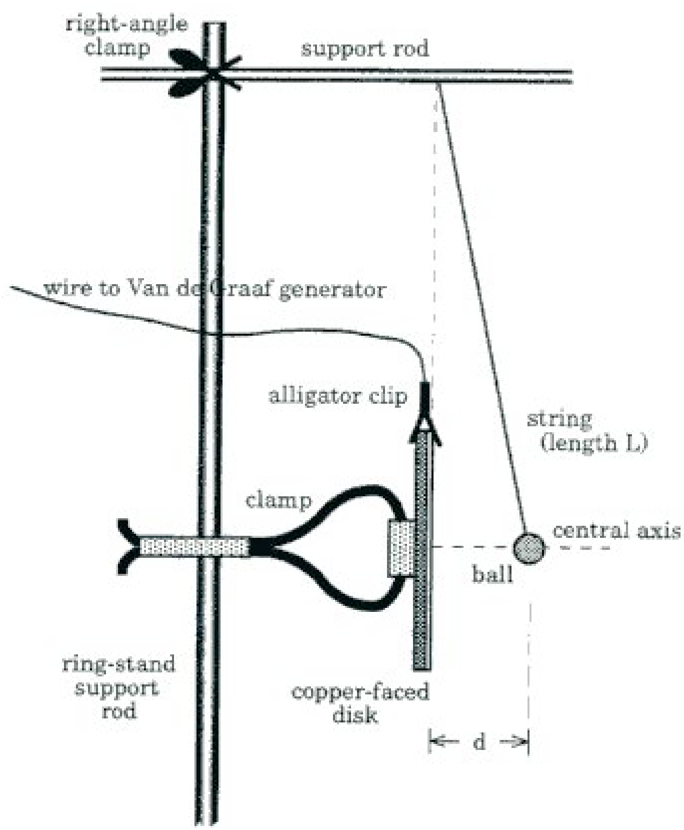
Objectives
Part A. Take measurements using the equipment that has been set up for you in the lab.
Part B. Perform calculations to determine the electric field in two of the three different ways.[1]

Equipment
Ring stand, right-angle clamp, support rod, Van de Graafff generator, wires and alligator clips, graphite-coated pith ball, flat conducting disk, string, meter stick

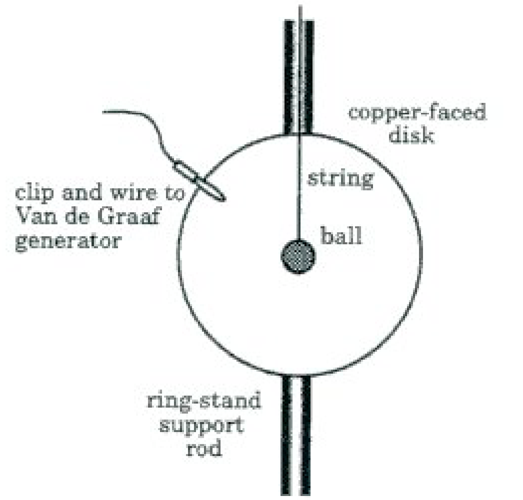
Procedure
Part A. Take Measurements (Group activity)
For this experiment, a flat, circular conducting disk of radius R is charged by conduction from a Van de Graaff generator. A graphite-coated pith ball (conducting) is suspended from a string of length L and allowed to tough the disk. When charge is conducted from the disk to the ball, the ball is repelled, and thus swings away from the disk where it will come to equilibrium in the position shown in the diagram.

With the ball in this position, measure the angle θ the string makes with the vertical, the distance d between the ball and the disk, and the surface voltage of the Van de Graaff generator (estimated by causing the disk to arc, and measuring the length of the spark: a 1000-Volt potential difference will cause a spark approximately 1mm in length), the mass m of the pith ball, the radius r of the pith ball, and the radius R of the conducting disk.

VIEW OF DISK SET-UP FROM SIDE



VIEW OF DISK SET-UP FROM FRONT



[1] This lab is heavily based on a lab written by Craig Fletcher, who also provided the graphics.

Lab: Electric Field of a Flat Conducting Disk — AP Physics

Part B. Perform calculations

1. Using $E = \int \frac{k\ dq}{r^2}$, derive a general, algebraic expression for the electric field along the central axis of a conducting disk, giving E in terms of the charge on the disk Q, the disk-pith ball distance d, the radius of the disk R, and appropriate constants. See your book for details on this derivation.

2. Use Gauss's Law to derive a general, algebraic expression for the electric field along the disk's axis very close to the disk's surface.

3. Show that the formula derived in question 1 is the same as the formula in question 2, if d is very small relative to R (i.e. d approaches 0).

4. Use a free-body diagram to do an analysis of the forces acting on the pith ball, and determine the electric force F_{e1} felt by the ball.

5. Using data values collected in the experiment and the equation derived above, determine the electric field created by the conducting disk at the location of the pith ball.
   NOTE: In order to do this, you'll need to know the charge Q on the disk. We can find Q by using the relationship $V = \frac{2kQ}{R^2}\left(\sqrt{d^2 + R^2} - d\right)$, with values collected in the experiment. Once you've got Q for the disk, you can use your derived equation to calculate E at the location of the pith ball.

6. Using data values collected in the experiment, determine the charge q on the pith ball.
   NOTE: We know $V_{ball} = V_{disk}$, and if we assume the small pith ball is a point charge, with V located at distance r from the center, we can use $V = k\frac{q}{r}$ to determine the charge q.

7. Knowing the electric field E (calculated in 5 above) and the charge on the pith ball (calculated in 6 above), determine the electric force F_{e2} felt by the ball.

8. Compare your results from analyses 4 & 7.

Questions

There are no additional questions for this lab.