PHYS 1120 Discussion 3:
Electric Field and Electric Potential

Key Ideas

Electric field E tells the force F applied to an electric charge q in the field: $\vec{F} = q\vec{E}$. Coulomb's law tells us that the magnitude of the electric field E a distance r from an electric charge q must be $= kq/r^2$.

The **electric potential** V at some position tells the electric potential energy per charge there. This is conventionally defined as the work needed to bring the charge to that position from infinite distance. The formula for the electric potential V a distance r from a charge q is $V = kq/r$. The SI **unit** of electric potential is the J/C, or **volt**, abbreviated V. **Voltage** is the electric potential difference between two points. Electric field points in the direction downhill in potential.

Gauss's law relates the **electric flux** $\Phi = EA$ from an electric field E passing through a closed surface with area A. It is proportional to the electric charge q enclosed within the surface by the formula $\Phi = q/\varepsilon_0$.

Problems

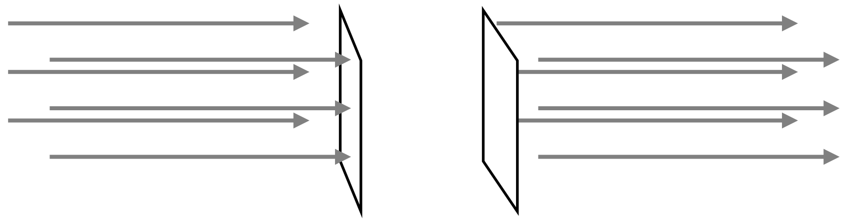
As usual, there is no room on this sheet. Use scratch paper.

1. Two opposite point charges are placed with the positive one at (0.5, 0, 0) m and the negative one at (–0.5, 0, 0) m. Midway between the charges at the origin, the magnitude of the electric field they create is 1 N/C.
   a. What are the values of the charges?
   b. You could laboriously calculate the magnitude and direction of the electric field at any point in space around these charges, but that probably wouldn't give you much insight into the physics. Instead, sketch field lines to illustrate the electric field.
   c. What is the electric potential at the point midway between the two charges?
   d. Where is the electric potential higher: near the positive charge or near the negative charge?
   e. Sketch paths to show surfaces of equal electric potential (isopotential surfaces) on the field line diagram you made in part b. Draw the lines in a way that it is easy to distinguish between the field lines and the isopotential surfaces.

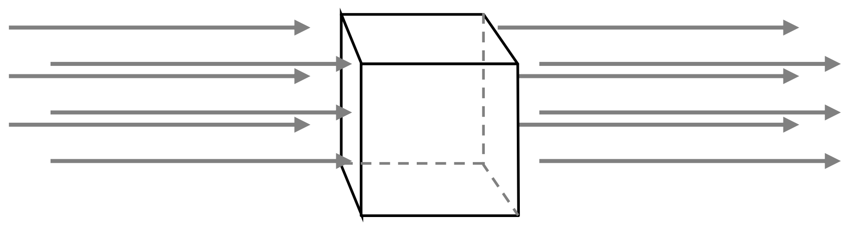
2. Suppose the positive charge of problem 1 is replaced by a negative charge of the same magnitude.
   a. Sketch the field and potential.
   b. What is the electric potential at the point midway between the two charges?

3. Two parallel, uncharged, conducting plates are placed inside and perpendicular to a uniform electric field.

   a. Sketch the charge distributions on and the electric field between the plates.



   b. What happens if the two plates are connected to each other with four square conducting sheets to make a conducting box?



4. A conducting spherical shell bearing a negative charge $-Q$ is located somewhere in space.

   a. Use Gauss's law to determine the electric field outside the sphere.

   b. Use what we know about electric fields inside conductors to determine the electric field inside the sphere.

   c. Use Gauss's law to confirm what you just decided about the electric field inside the sphere.

   d. What do you know about the electric *potential* inside the sphere?

      i. Is it positive, negative, or zero?

      ii. Is it higher, lower, or the same as the electric potential at the outside surface of the sphere?

   e. How are the electric field and potential resulting from this charged conducting sphere related to the field and potential that would be created by a point charge of the same value?