Lab 11.1 Electric Field Strength & Electric Potential

The purposes of this activity are to:

- determine the electric potential as a function of distance from a point [spherical] source.
- determine the direction of greatest change in potential near a point [spherical] source.
- calculate the electric field strength as a function of distance from a point [spherical] source.
- relate the electric field strength to the greatest rate of change of the potential.

Student Outcomes

At the completion of this lab activity the students will be able to:

- determine the contours of an equipotential surface.
- show that the electric potential near a point [spherical] source decreases with the inverse of the distance from the source.
- show that the electric field strength near a point [spherical] source varies inversely with the square of the distance from the center of the source.
- calculate the electric field strength from the change in electric potential as a function of distance.

Procedure

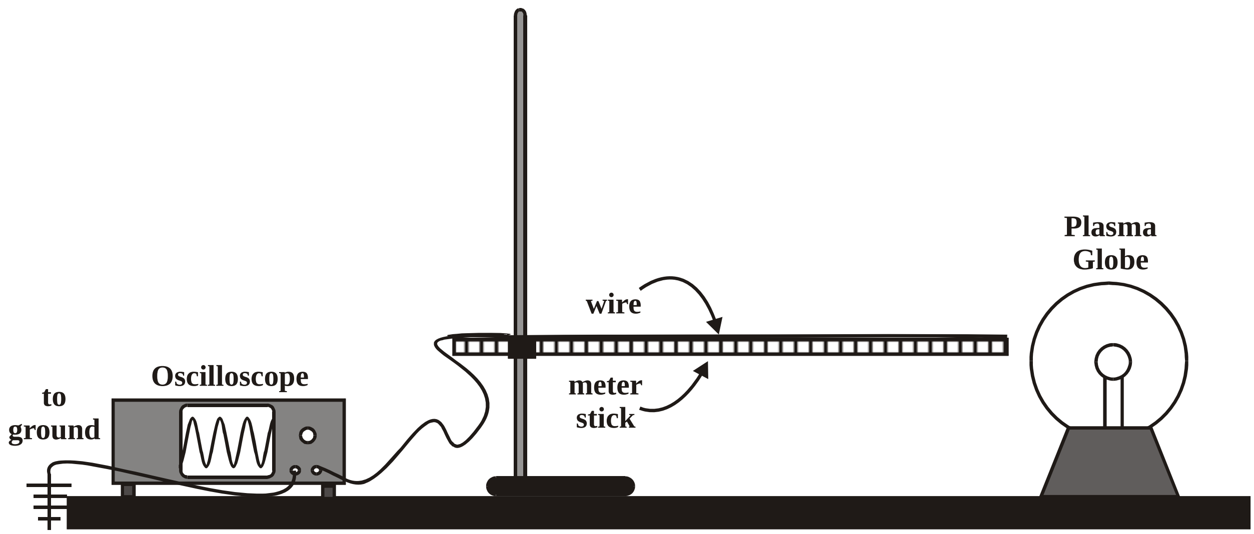
This is a laboratory procedure where students will be measuring the electric potential at various points in the vicinity of a Plasma Globe and then use those data to determine and plot the electric potential and the electric fields as well as to determine the relationship between them.

Background Theory

According to Coulomb's Law the electric field near a point source should vary according to $E = kq/r^2$ and the electric potential should vary according to $V = kq/r$. Coulomb's Law can be justified using a geometric approach where the electric field expands equally in all directions such that the resulting field density varies inversely with the square of the distance from the center of the sphere since the area encompassed by the expanding electric field increases with the area of the expanding spherical surface $A = 4\pi r^2$. Therefore, the intensity of the field varies with the inverse square of the distance from the center of the point [spherical] source. Since the potential difference between two points in an electric field is equal to the strength of the electric field times the distance between those two points there is a very specific relationship between electric field and potential. Any change in position perpendicular to the electric field vector should result in no significant change in electric potential because no work is done if there is no force. The **Plasma Globe**, the source of the electric potential in this experiment, consists of a high frequency Tesla coil varying the potential of a wad of steel wool enclosed within a small sphere approximately 4.0 cm. in diameter. This small sphere is then enclosed by a larger sphere with an approximate diameter of 20 cm. The volume between the two spheres is evacuated to approximately 500 milliTorr which consists of a mixture of Noble gases.

As the voltage on the steel wool is made negative, positive charges within the globe are attracted to the inner sphere while negative particles are attracted to the inner surface of the outer globe thus generating an electric field within the plasma. As the potential between the spheres is increased, at some point the breakdown voltage is reached at which time the gaseous atoms within the globe become ionized forming a plasma. The areas of plasma formation undergo a reduction in resistance thus providing pathways for the plasma current to flow between the two surfaces. These plasma currents collide with atoms of Noble gas within the globe driving them to higher energy levels. As these excited atoms return to the ground state, some of the transitions generate the characteristic spectra of the particular gas. The potential between the surfaces of the inner and outer spheres is varied at frequencies in the kiloHertz range [~25,000 Hz at approximately 200 Volts.]

As a net charge builds up between the outside of the inner sphere and the inside of the outer sphere the resulting electric field would inhibit the plasma currents that are responsible for the emission filaments. Therefore, the polarity of the power supply is reversed frequently so as to not saturate the inner surface of the outer sphere or the outer surface of the inner sphere. In the case of the **Plasma Globe** the rapidly changing potential of the steel wool ball generates alternating positive and negative charges in the steel wool electrode and thus, for all practical purposes, behaves like a radio broadcast station. The probe [wire] behaves like an antenna and compares the potential at the end of the probe nearest the Plasma Globe with a corresponding point far enough away from the globe that the potential at the other end of the probe is effectively ground.



Procedure

1. Acquire an oscilloscope and adjust the settings on the scope to measure 5-10 Volts per cm on the vertical axis and a frequency of ~20 microseconds on the x-axis.

2. Attach a wire approximately 2.0 meters long to the end of the oscilloscope probe and then run the wire parallel to a wooden or plastic meter stick.

3. Tape the wire into place with the end of the wire running parallel to the end of the meter stick as shown to the right.

4. Mount the back end of the meter stick using a perpendicular clamp attached to a ring stand with the operational end of the wire approximately 1.0 cm from the globe and with the meter stick parallel to the tabletop.

5. Make sure that the table surface near the Plasma Globe is clear of all objects to a distance of at least 1.0 meter. [Including you and the oscilloscope, as your physical presence will affect the electric potential in the vicinity of the globe.

6. Measuring the electric potential as a function of distance from the center of the Plasma Globe.
   a. Measure the electric potential by placing the tip of the wire that is connected to the oscilloscope probe approximately 1.0 cm from the surface of the Plasma Globe.

Distance from Plasma Globe [m]	Potential Difference [V]	Distance from the center of the Plasma Globe [m]

b. Record the maximum point of the signal on the oscilloscope as the maximum potential at that particular point near the globe. [The exact value will not remain constant because the intermittent discharging of current through the plasma generates small, unpredictable changes in the signal present on the oscilloscope screen.]

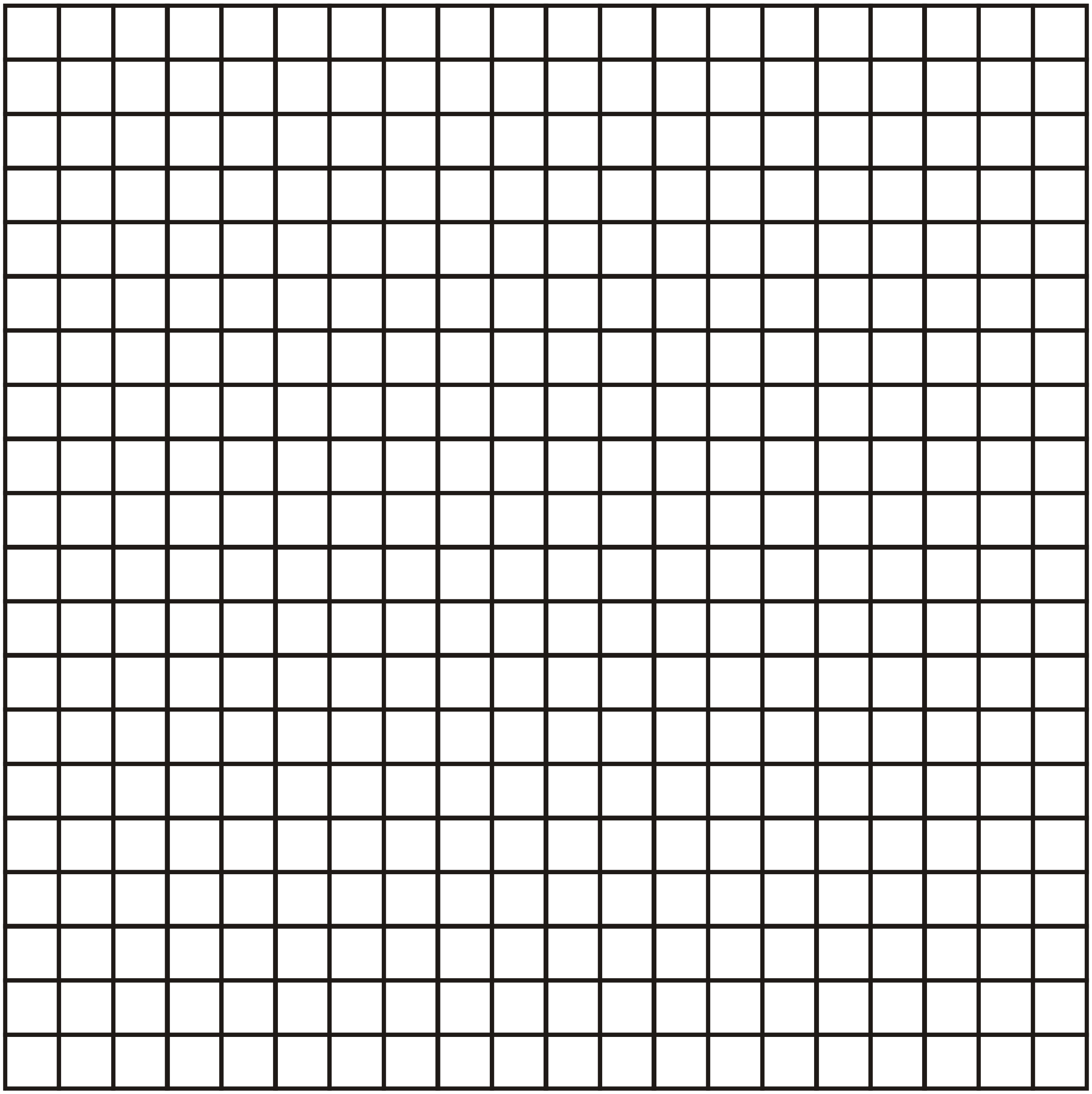
c. Gradually move the probe farther from the globe recording the maximum potential as a function of distance from the globe [every ~5 cm would be appropriate] until the readings approach background [about 50 cm from the surface of the Plasma Globe].

d. Measure and record the diameter of the Plasma Globe determine the radius of the globe and add the radius to each of the distances measured from the surface of the Plasma Globe.

e. Plot a graph below comparing the electric potential as a function of the distance from the center of the globe.

Electrostatic Potential vs. Distance

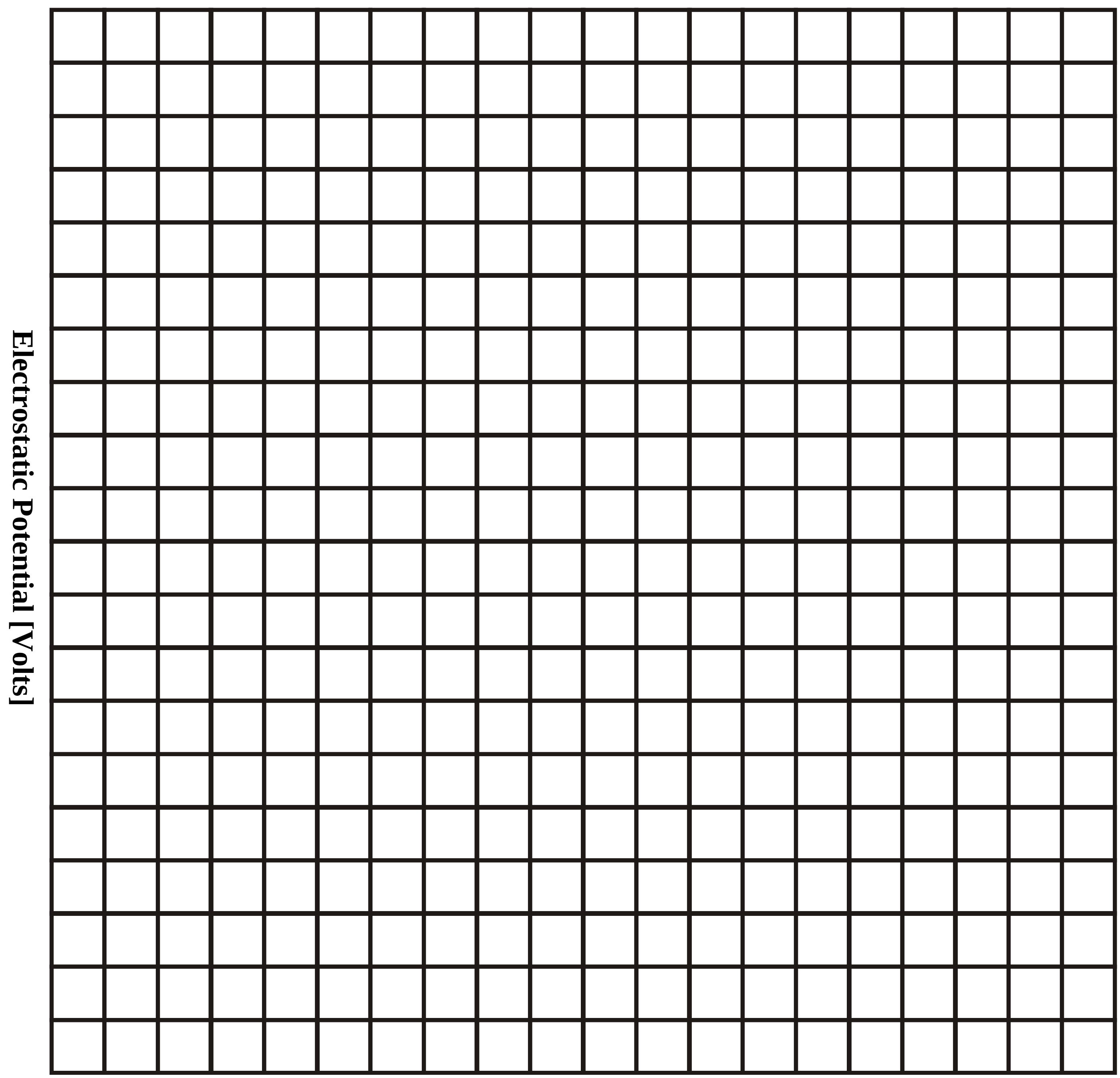
Electrostatic Potential [Volts]



Distance from Center of Globe [m]

f. From the general shape of the graph determine a likely relationship between the electric potential near a point [spherical] source and from your determination re-plot the points into a straight line and then determine the equation describing the electric potential as a function of distance from the plasma globe.

Electrostatic Potential vs. ????



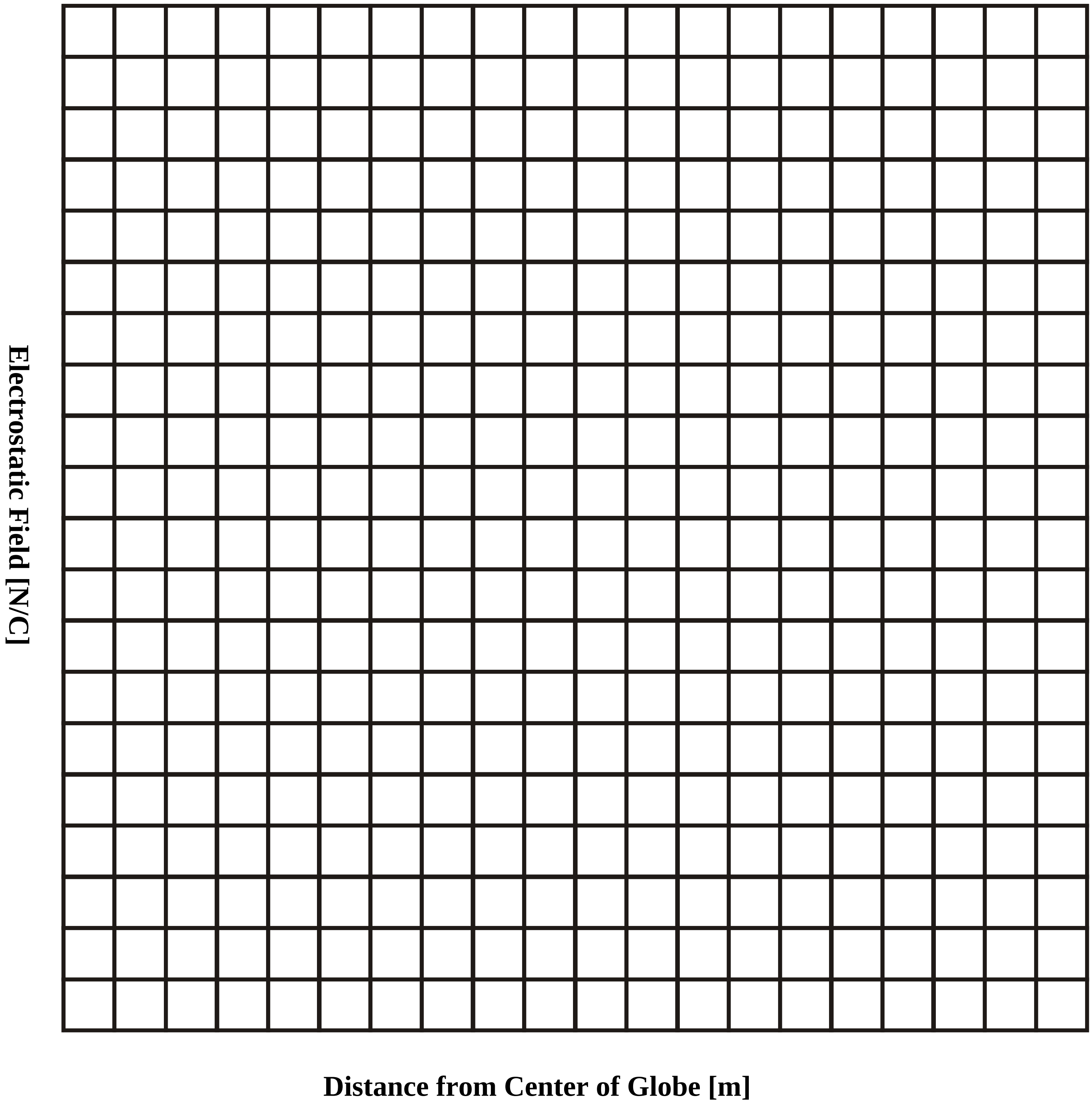
g. Test your equation at a random point from your data table and show that your equation can successfully predict the electric potential at that random point.

7. Determining the electric field intensity as a function of distance from the center of the Plasma Globe.
   a. Calculate the electric field strength for each point pair collected above by dividing the difference in the electric potential ΔV by the difference in position Δx.

Distance from Plasma Globe [m]	**Potential Difference [V]**	**Distance from the center of the Plasma Globe [m]**	**Electric Field Strength [N/C] E = ΔV/ΔX**

   b. Plot a graph comparing the electric field strength as a function of distance from the center of the Plasma Globe.

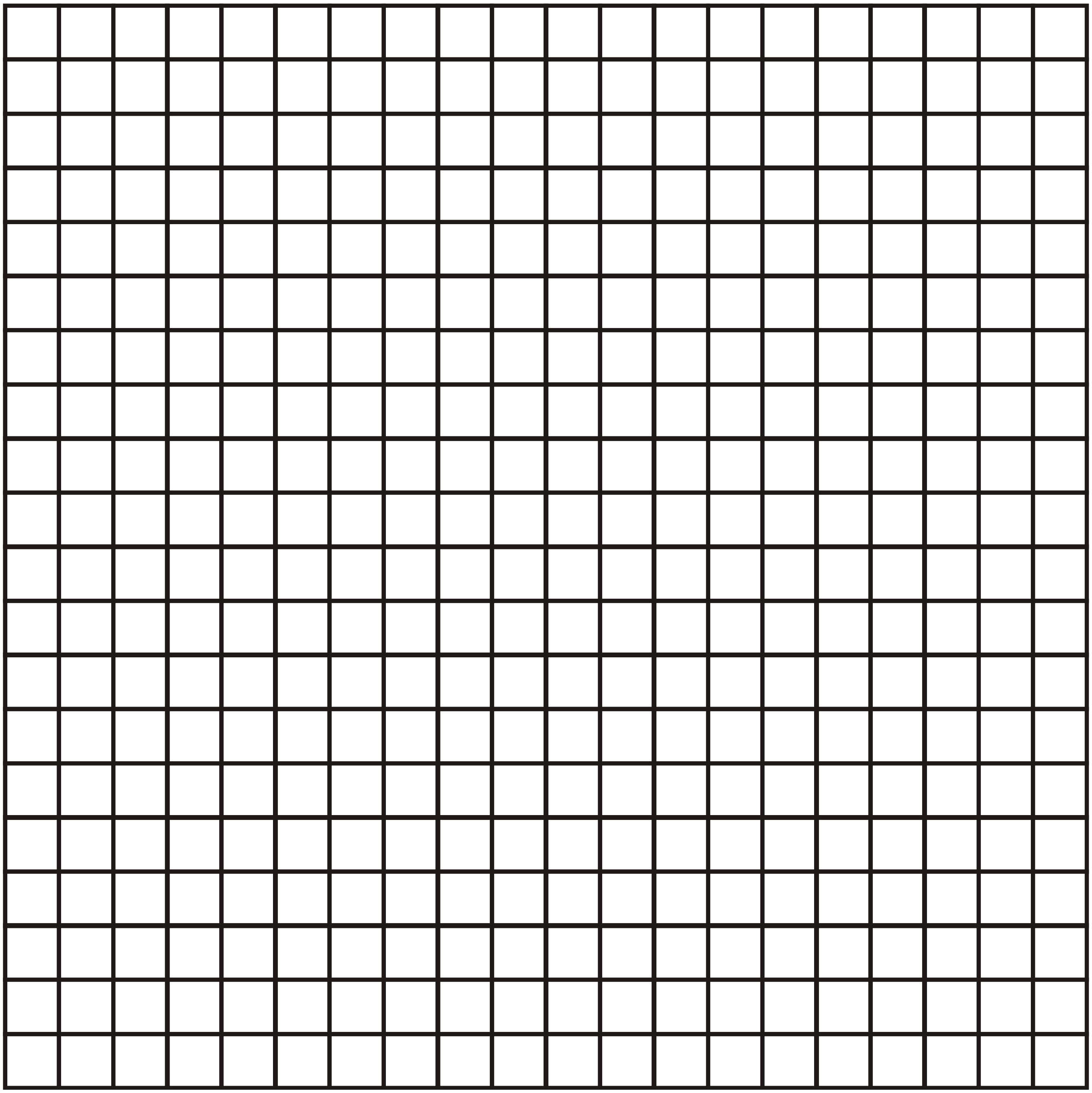
Electrostatic Field vs. Distance



c. From the general shape of the resulting graph determine [make an intelligent guess!] as to the relationship between the **electric field strength** and the **distance** from the center of the Plasma Globe.

d. Use the shape of the graph above to re-plot the points so as to produce a straight line and from this straight line determine the equation that describes the electric field strength as a function of distance from the center of the sphere.

Electrostatic Field vs. ?????



e. Test your equation at a random point from your data table and show that your equation can successfully predict the electric potential at that random point.

8. Determining the shape of equipotential surfaces near the Plasma Globe.
   a. Place the oscilloscope probe approximately 5 cm from the Plasma Globe and measure the electric potential.
   b. Move to the probe to some other point near the globe where the electric potential is the same and record the position.
   c. Repeat this procedure until you can come to some conclusion about the shape of the equipotential surface near the Plasma Globe. [Suggested technique for the determining the points for the equipotential surface - hang a thread with a plumb from the end of the probe and record the point on a piece of construction paper placed under the Plasma Globe.]