Electric Field Around a Conductor

Equipment List

Qty	Items	Part Numbers
1	Voltage Sensor	CI-6503
1	Equipotential and Field Mapper Kit	PK-9023
1	Power Supply, 15 VDC	SE-9720
1	Silver (nonconductive) Pen & Conductive Ink Pen	

Introduction

The purpose of this activity is to determine the shape and magnitude of the electric field and equipotentials around charge configurations and parallel plate configurations on a piece of conductive paper.

Background

An electric field is the effect produced by the existence of an electric charge, such as an electron (negative charge), proton (positive charge), or ion (charged atom) in the volume of space or medium that surrounds it. Another charge placed in the volume of space surrounding the "source" charge has a force exerted on it. The electric force applied by two charges on each other can be obtained from Coulomb's law:

$$F_e = k \frac{|q_1||q_2|}{r^2} \text{ where } k = \frac{1}{4\pi\varepsilon_0} = 8.99 x 10^9 N \cdot m^2/C^2$$

and $\varepsilon_0 = 8.85 \, x \, 10^{-12} \, C^2/N \cdot m^2$ is the permittivity constant, r is the separation distance and q is the electric charges.

The force of attraction or repulsion between point charges at rest act along the lines joining the two charges. If there are more than 2 charges, then the equation above holds for each pair of charges and the net force can be found on each charge by using the superposition principle as the vector sum of the forces exerted on the charge by all of the other charges.

The electric field, $\vec{E}$, at any point is defined by the electrostatic force that would be exerted on a positive test charge q_0 placed there $\vec{E} = \frac{\vec{F}}{q_0} = \frac{kq}{r^2}$. The SI units for Electric Fields are volts/meter or V/m. Because electric fields are a force, it is a vector quantity consisting of both magnitude and direction. The directions arise from the net charge on the conductor; if the net charge is positive the electric fields radiate outwards, while negative net charges radiate inwards. So when there are two unlike charges, the field lines will originate from the positive charge and terminate on the negative charge.
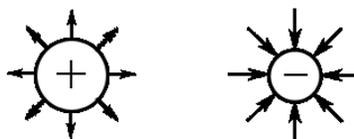

Figure 1: Positive charges radiate outwards. Negative charges accept charges or radiate inwards.
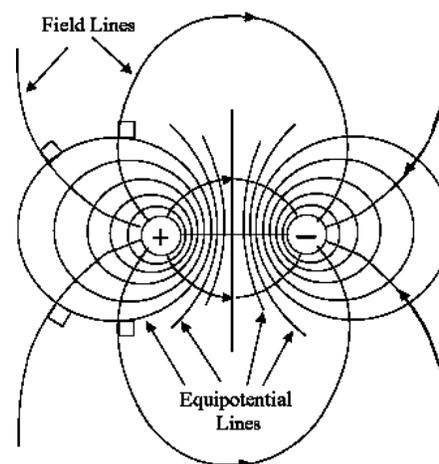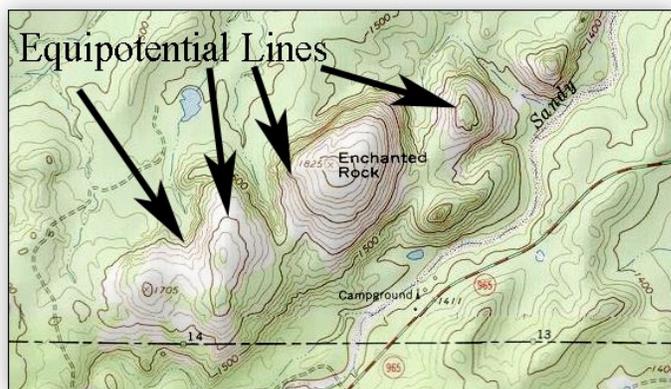
Figure 2: Topographic map showing how elevations are similiar to Equipotential Lines. Pick a line on the topo. map and the elevation will remain constant, similiarly the equipotential lines will remain constant once chosen.

As mentioned earlier, electric field lines help provide a means for visualizing the magnitude and direction of electric fields. Similarly, equipotential lines show where every point on that line has the same potential, for example 5V, similar to that of a topographical map shown above.

It is important to note that the electric field vector at any point is tangent to a field line through that point as you can see with the right angle indicators. Likewise, equipotential lines that are closer together show a stronger electric field and as the you become farther from the charges, the electric field will become weaker shown by the distance between field lines becoming greater.


SAFETY REMINDER

- Follow directions for using the equipment.

- Don't exceed 10 volts from the power supply.

- Always have the corkboard beneath the conductive paper during the activity.

THINK SAFETY ACT SAFELY BE SAFE!


Setup & Procedure

1. Use a conductive ink pen to draw two "point charges" on a piece of conductive paper. (Note: Place the conductive paper, printed side up, on a smooth hard surface whenever you use the conductive ink pen.)

2. Let the ink dry on the paper and then attach the paper to a corkboard using the metal pushpins.

3. Set up the PASCO Interface and the computer and start *Capstone*.

4. Connect the Voltage Sensor & Power Amplifier (Ch. C) to the interface.

5.   Create a new experiment and add the Voltage Sensor & Power Amplifier (Ch. C) to the software.

- Set the sampling rate of the Voltage Sensor to 1.00 Hz

- Set the Power Amplifier under *Signal Generator* to have a 'DC' waveform for signal output and set the *DC Voltage* to 5 V.

- Change the properties of 'Voltage, Ch __ (V)' under the '*Data Summary*' Tools Bar on the left hand side of Capstone and click on the 'Numerical Format' dropdown menu. Change the 'Fixed Decimals' to 2 places.

- Open 'Digits' readout of the "Voltage, Ch__ (V)" from the voltage sensor.

6.   Attach one cable from the red (positive) port of the power amplifier to one 'point charge' on the conductive paper.
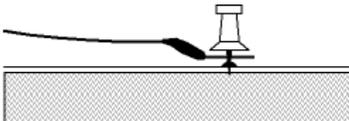
7.   Attach one cable from the black (negative) port of the power amplifier and the black cable of the volt meter to the other 'point charge' on the conductive paper.

8.   Use the red cable from the voltage sensor as your probe and make 8 equally spaced measurements (as indicated by the red arrows shown on the sample conductive paper below, the 8th being the negative terminal) and record your data in the table below.

9.   Next, move the voltage probe around and mark off 7-10 points to help indicate where the 1V, 2V, 2.5V, 3V, & 4V equipotential lines are. Once the 7-10 points are made for each equipotential, draw a smooth line connecting them and label its potential. Each lab partner should draw at least one equipotential line.

10.   Repeat the process for the two line charges drawn on the conductive paper.
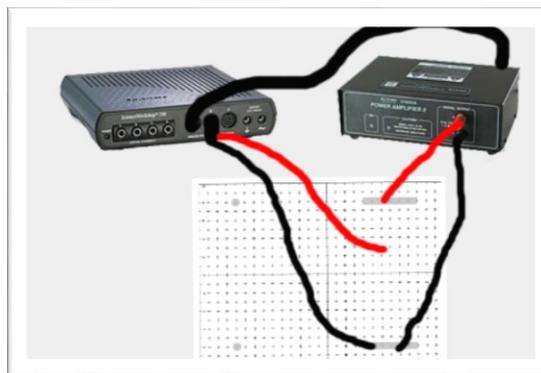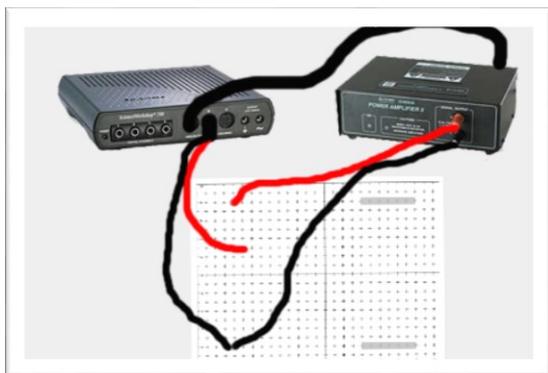
Part 2:

1.   Hold together the ends of the voltage leads of the Voltage Sensor so that the two tips are a fixed distance apart

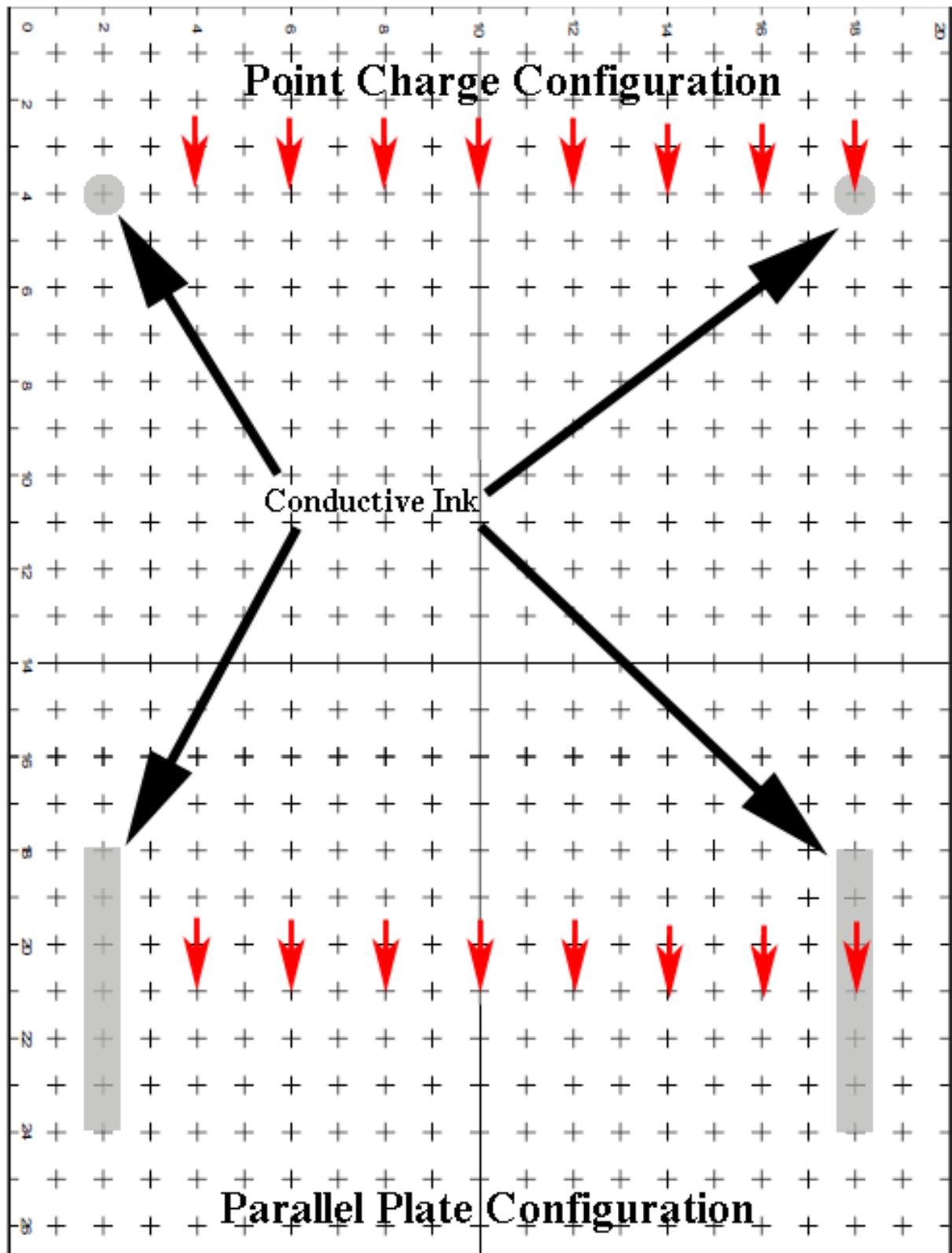2.   Adjust the voltage of the power supply to 5 volts.
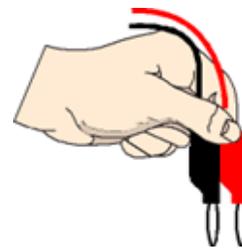
3.   Hold the voltage leads at an angle so the tip of the black voltage lead touches the conductive paper at the point of an arrow and the tip of the red voltage lead does not quite touch the paper.

4.   Tilt the voltage leads upright so both tips touch the conductive paper. Look at the voltage in the Digits display in *Capstone*.

5.   Keep the black tip stationary but *slowly pivot the red tip side-to-side*. As you move the red tip, watch the voltage in the display. When the displayed voltage is the highest, stop moving the tip of the red voltage lead.

6.   Draw an arrow on the conductive paper from the tip of the black lead to the tip of the red lead.

7.   Move the tip of the black lead to the head of the new arrow.

8.   Repeat the action by moving the tip of the red lead from side-to-side until the new voltage is at its highest value. Draw an arrow in the direction of the highest voltage.

9.   Continue this procedure all the way across the paper to the other charge.

10.   Move the voltage leads back to the negative pushpin and select a new point near the pushpin at which to place the tip of the black lead.

11.   Continue the process of drawing arrows in the direction of the highest voltage until your new set of arrows forms another distinct line. Map about 5 or 6 lines.
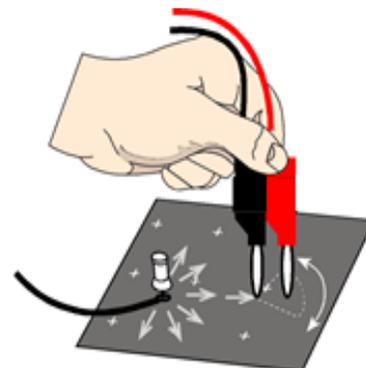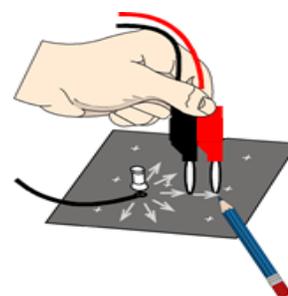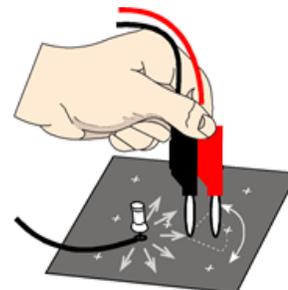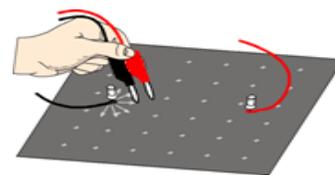
After you map the electric field, turn off the power supply and click Stop in *Capstone*.

Preparing to Record Data

Remember to read the recording data procedure before you begin. Data recording is easier if a person handles the voltage leads of the Voltage Sensor and a second person operates the computer. Everyone should try to read data from the voltage probe.

Point Charge Configuration

Conductive Ink

Parallel Plate Configuration
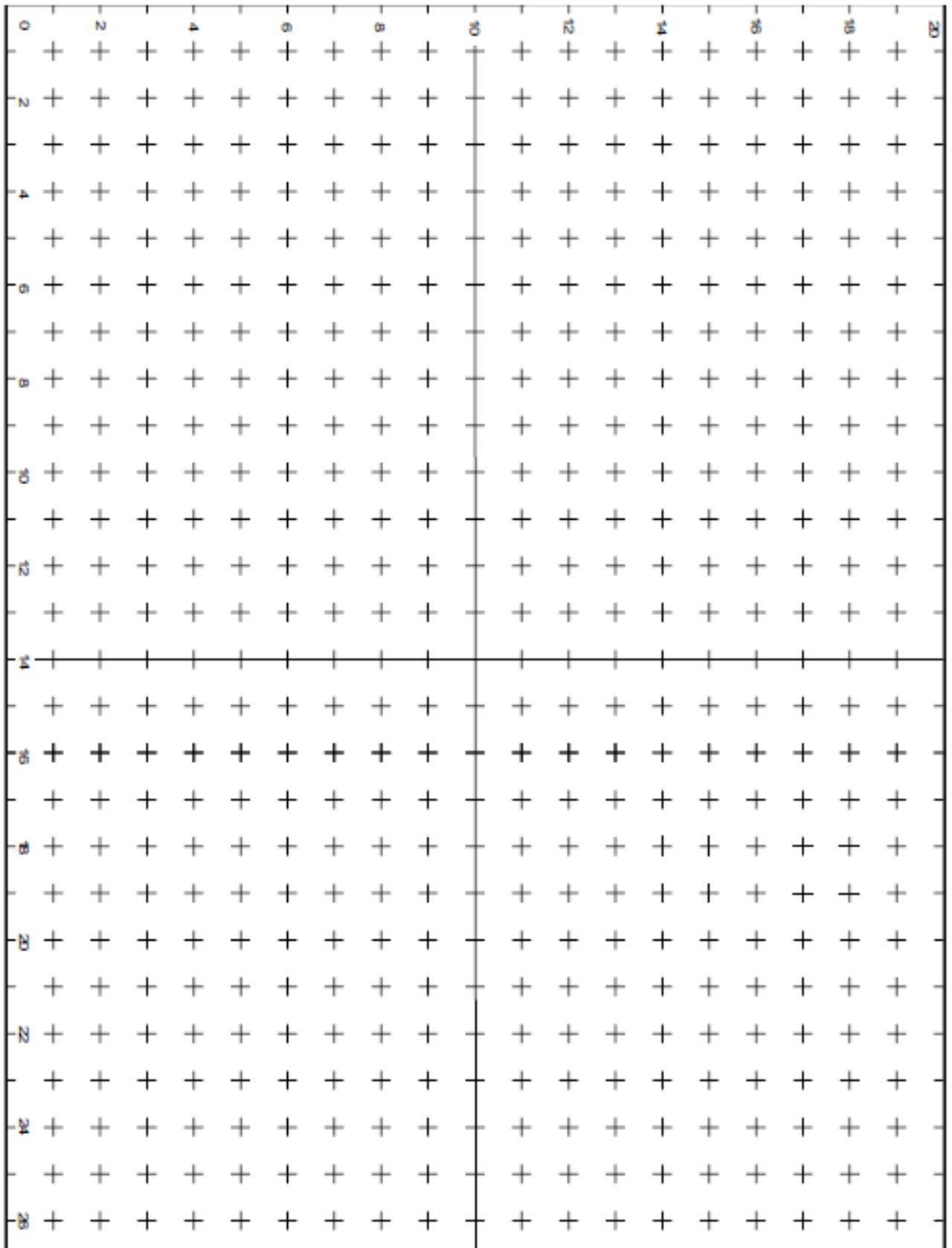
2 (unlike) Point Charges						
Vfinal (V)	Vinitial (V)	ΔV (V)	Xfinal (cm)	Xinitial (cm)	ΔX (cm)	E (V/cm)
	5.00			0.00		
0.00						

Sample Calculations:

Parallel Plate Configuration						
Vfinal (V)	Vinitial (V)	ΔV (V)	Xfinal (cm)	Xinitial (cm)	ΔX (cm)	E (V/cm)
	5.00			0.00		
0.00						

Sample Calculations:

Lab Report: Electric Field Around a Conductor

Name: _____

Prediction

What is the shape of the electric field around an isolated electric charge?

What is the shape of the electric field if there are two charges near each other?

Analysis Questions

1. Using the blank copy of the conductive paper included, sketch each configuration (2 unlike point charges & parallel plate configuration) and show the electric field lines and the equipotential lines.

2. Do your results support your predictions? If not, explain possible sources of error.

3. What is the relationship between the density of the equipotential lines, the density of the electric field lines and the strength of the electric field?

4. What would happen if you place your hand on the conductive paper while taking a measurement? Does it affect the measurement? Why or why not?

5. In the background it is shown that the equation for the electrical field is $\vec{E} = \frac{\vec{F}}{q_0} = \frac{kq}{r^2}$. Using dimensional analysis, show that N/C equals V/m for the electrical field.