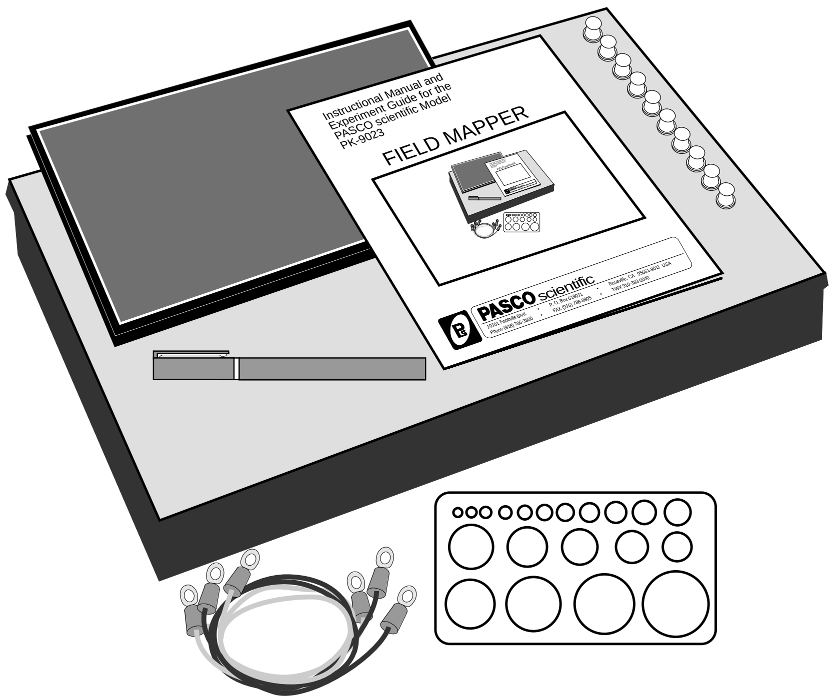
Instruction Manual and Experiment Guide for the PASCO scientific Model PK-9023

012-04346B

05/91

EQUIPOTENTIAL AND FIELD MAPPER



$5.00

PASCO scientific ®

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Copyright Notice

Limited Warranty

PASCO scientific warrants this product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. This warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of a manufacturing defect or improper use by the customer shall be made solely by PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment, after repair, will be paid by PASCO scientific.

Equipment Return

Should this product have to be returned to PASCO scientific, for whatever reason, notify PASCO scientific by letter or phone BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

NOTE: NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION.

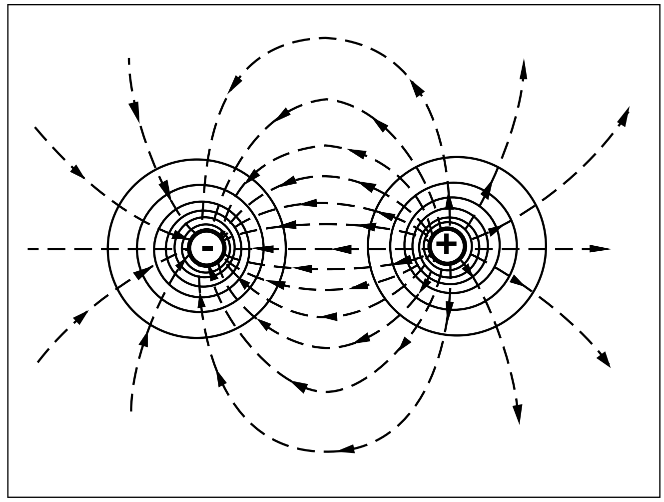
When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

1. The carton must be strong enough for the item shipped.
2. Make certain there is at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
3. Make certain that the packing material can not shift in the box, or become compressed, thus letting the instrument come in contact with the edge of the box.

Introduction

The PASCO scientific MODEL PK-9023 Field Mapper consists of two basic elements. The first is a carbon impregnated paper in the resistance range of 5 KΩ to 20 KΩ per square. This paper forms the conducting medium or space between the electrodes. The second element is a conductive ink dispensed from a pen. The ink is produced from silver particles in a suspension liquid. As the ink dries, the silver flakes settle on top of each other forming a conductive path, (or conductive ink electrodes). The resistance of the ink is between .03 and .05 Ω/cm for a 1 mm wide line.

Because the paper has a finite resistance, a current must flow through it to produce a potential difference. This current is supplied by the conductive ink electrodes which causes a potential drop to occur across the paths. Because of the large difference between the ink's resistance and the resistance of the paper, this potential drop is less than 1% of that produced across the paper. Therefore, for all practical purposes the potential drop across the electrodes may be considered negligible.



Equipotential and Field Lines

It would be desirable that the potential measuring instrument have an infinite impedance. An electrometer such as the PASCO Model ES-9054B would be optimal, however, a standard electronic voltmeter such as PASCO's SE-9589 Handheld Digital Multimeter with a 10 MΩ (or higher) input impedance is sufficient. Since this impedance is at least 100 times greater than that of the paper, the greatest distortion of the field which can be produced by the voltmeter is approximately 1%.

Equipment

The PK-9023 Field Mapper includes:

- 100 sheets of conductive paper with 23 x 30 cm grid
- a silver conductive ink pen for approximately 200 ft of continuous line
- a corkboard working surface
- 10 push pins for attaching the paper to the board
- 3 wires for connecting the conductive paths
- a circle template for drawing the conductive paths.
- a large plastic tray for storing the paper and other supplies
- Instruction manual and experiment guide.

The following supplies can be ordered separately from PASCO scientific

Conductive ink pen — Model No. PK-9031B

100 sheets of 23 x 30 cm conductive paper with cm grid — Model No. PK-9025A

100 sheets of 30 x 46 cm conductive paper (without grid) — Model No. PK-9026A

Equipment Setup

> **IMPORTANT:**
>
> The silver conductive ink reaches its maximum conductivity after 20 minutes drying time. For optimal results plan the timetable for conducting the experiments and correlate drawing the conductive ink paths accordingly.

1. Plan and sketch the layout (size, shape and relative spacing) of the charged paths to be studied on a piece of scratch paper. These paths can be any two dimensional shape, such as straight or curved lines, circles, dots, squares, etc. Since the charged paths will actually be conductive ink electrodes, they will be referred to as electrodes.
2. Draw the electrodes on the black paper (see Figure 1).

> **NOTE:** This is the most difficult and crucial part of the experiment. Follow these steps carefully.

a. Place the conductive paper, printed side up, on a smooth hard surface. **DO NOT** attempt to draw the electrodes while the paper is on the corkboard.

b. Shake the conductive ink pen (with the cap on) vigorously for 10-20 seconds to disperse any particle matter suspended in the ink.

c. Remove the cap. Pressing the spring loaded tip lightly down on a piece of scrap paper while squeezing the pen barrel firmly starts the ink flowing. Drawing the pen slowly across the paper produces a solid line. Drawing speed and exerted pressure determines the path width. (see Figure 2)

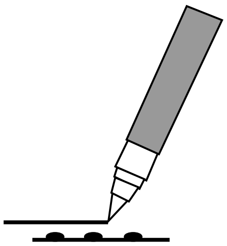


Figure 2

d. Once a satisfactory line is produced on the scrap paper, draw the electrodes on the black conductive paper. If the line becomes thin or spotty, draw over it again. A solid line is essential for good measurements.

The line will be air dry in 3-5 minutes at room temperature. However, the medium won't reach maximum conductivity until after 20 minutes drying time.

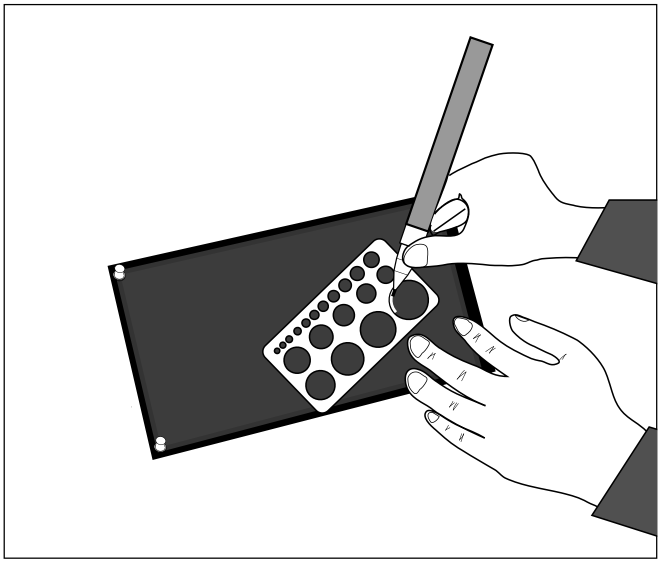


Figure 1

e. A plastic template is included with the PASCO scientific Field Mapper, for drawing circles. (see Figure 3) Place the template on the conductive paper and draw the circles with the conductive ink pen. (If desired, you may first draw the circle template with a soft lead pencil and trace over the pencil line with the ink.)

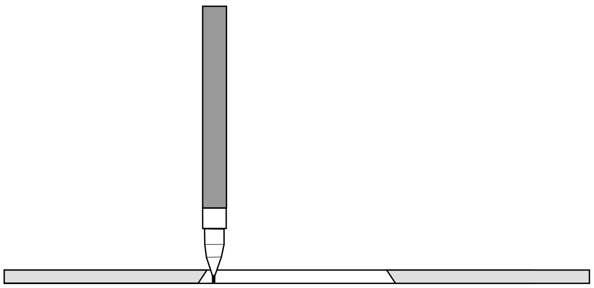


Figure 3

3. Mount the conductive paper on the corkboard using one of the metal push pins in each corner.

4. Connect the electrodes to a battery, DC power supply, or any other potential source in the 5 to 20 VDC range using the supplied connecting wires. (see Figure 4) The potential source should be capable of supplying 25 mA. (If possible, the potential should be equal to the full scale reading of the electronic voltmeter used in the experiment.)

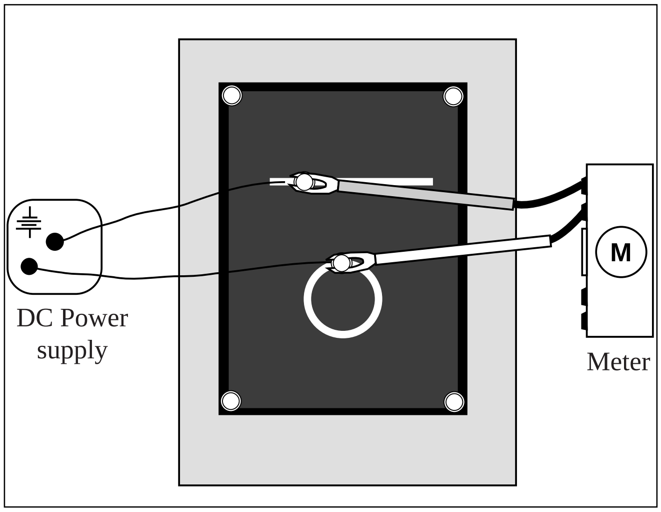


Figure 4

a. Place the terminal of a connecting wire over the electrode, then stick a metal push pin through its terminal and the electrode into the corkboard. Make certain that the pin holds the terminal firmly to the electrode. (see Figure 5).

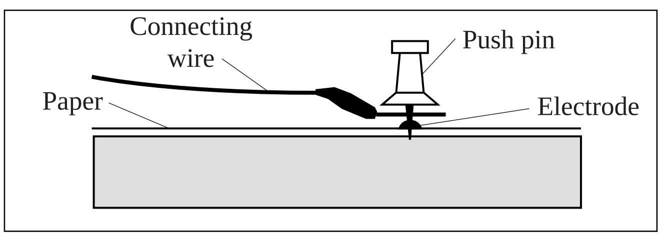


Figure 5

> **NOTE:** Check that the surface of the terminal which touches the electrode is clean. A dirty path may result in a bad contact.

Connect the other end of the wire to the battery.

> **THE ELECTRONIC VOLTMETER**
>
> Two specifications which a voltmeter must meet in order to be used with the PASCO scientific Field Mapper are
>
> • first, an input impedance of 10 MΩ or higher
> • second, a full scale range which is equal to or higher than the potential used across the electrodes.
>
> Any commercial electronic voltmeter, either digital or analog, that meets these specifications is adequate. The PASCO ES-9054B Electrometer or the SE-9589 Handheld Digital Multimeter are recommended.

5. To check the electrodes for proper conductivity connect one voltmeter lead near the push pin on an electrode. Touch the voltmeter's second lead to other points on the same electrode. If the electrode has been properly drawn, the maximum potential between any two points on the same electrode will not exceed 1% of the potential applied between the two electrodes.

> **NOTE:** This test can only be made if the potential source is connected across the two electrodes.

If the voltage across the same electrode is greater than 1% of the voltage applied between the two electrodes, then remove the paper from the corkboard and draw over the electrodes a second time with the conductive ink.

6. Equipotentials are plotted by connecting one lead of the voltmeter (the ground) to one of the electrode push pins. This electrode now becomes the reference. The other voltmeter lead (the probe) is used to measure the potential at any point on the paper simply by touching the probe to the paper at that point.

To map an equipotential, move the probe until the desired potential is indicated on the voltmeter. Mark the paper at this point with a soft lead or light-colored lead pencil. Continue to move the probe, but only in a direction which maintains the voltmeter at the same reading. Continue to mark these points. Connecting the points produces an equipotential line.

7. To plot field gradients (field lines), neither lead of the voltmeter is connected to an electrode. Instead, the two leads of the voltmeter will be placed on the conductive paper side-by-side at a set distance of separation (one centimeter is a useful separation to use). It is best to tape the two leads of the voltmeter together for this procedure (see Figure 7). The technique is to use the voltmeter leads to find the direction from an electrode that follows the path of greatest potential difference from point-to-point.

> **NOTE:** Do Not attempt to make measurements by placing the leads on the grid marks on the conductive paper. Touch the voltmeter leads only on the solid black areas of the paper. It may be necessary to use a higher voltmeter sensitivity for this measurement than was used in measuring equipotentials.

To plot the field lines on the conductive paper, place the voltmeter lead connected to ground near one of the dipoles. Place the other voltmeter lead on the paper and note the voltmeter reading. Now pivot the lead to several new positions while keeping the ground lead stationary (see Figure 7). Note the voltmeter readings as you touch the lead at each new spot on the paper. When the potential is the highest, draw an arrow on the paper from the ground lead to the other lead (see Figure 8). Then move the ground lead to the tip (head) of the arrow. Repeat the action of pivoting and touching with the front lead until the potential reading in a given direction is highest. Draw a new arrow. Repeat the action of putting the ground lead at the tip (head) of each new arrow and finding the direction in which the potential difference is highest. Eventually , the arrows drawn in this manner will form a field line. Return to the dipole and select a new point at which to place the voltmeter's ground lead. Again probe with the other lead until the direction of highest potential difference is found. Draw an arrow from the ground lead to the other lead, and repeat the process until a new field line is drawn. Continue selecting new points and drawing field lines around the original dipole (see Figure 6).

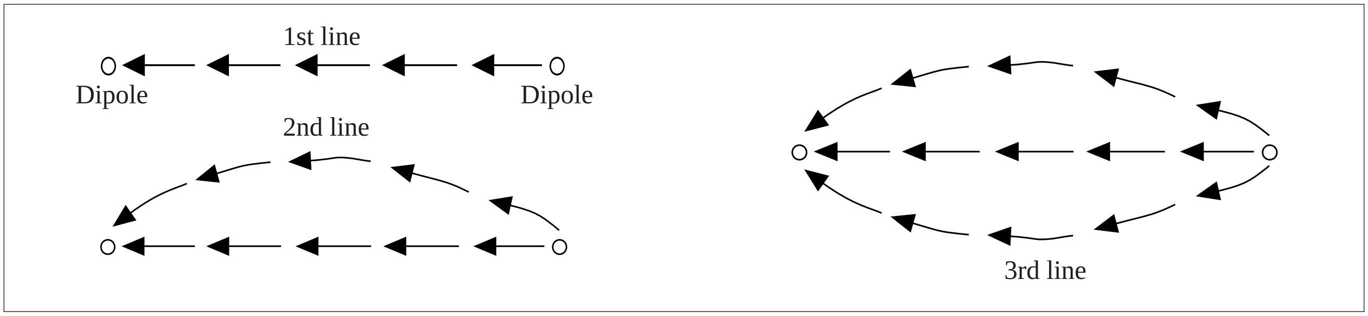


Figure 6 (Example of 3 field lines between unlike dipoles)

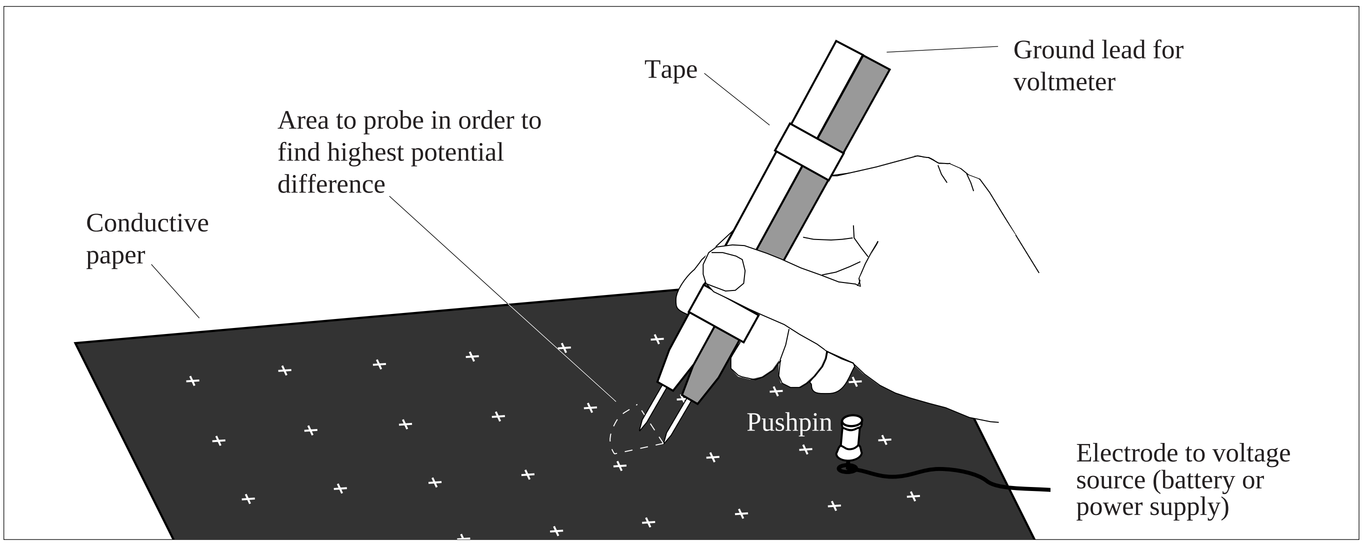


Figure 7

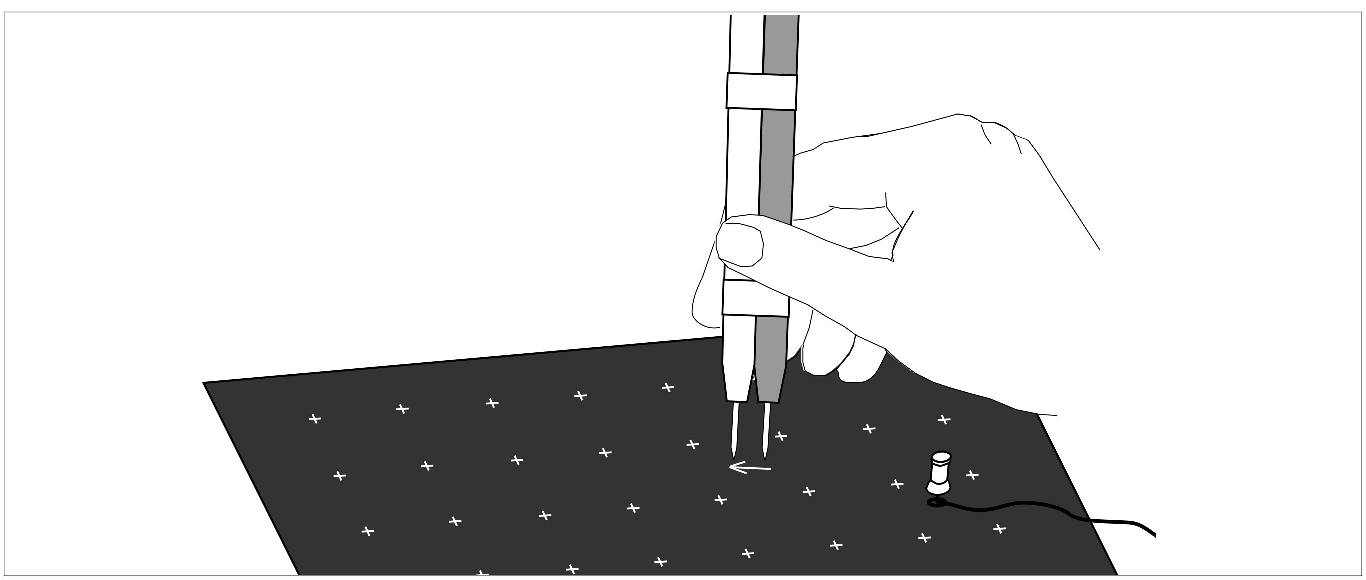


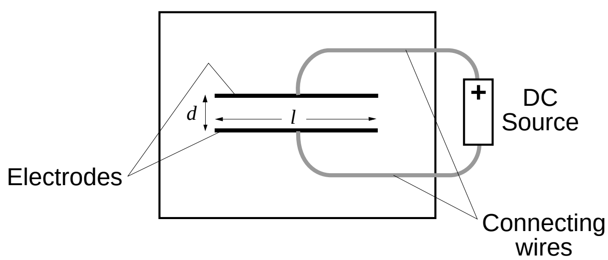
Figure 8

Experiments

The following are only some suggested experiments in mapping equipotentials and field gradients using the PASCO Field Mapper. The true value of the equipment, lies in its complete flexibility permitting the user to design any system of charged bodies and then to map the equipotentials and field gradients.

NOTE: Only power supply connections are shown in the following schematics. Voltmeter connections are not shown because they vary depending on whether equipotentials or field gradients are being mapped.

Parallel Plate Capacitor



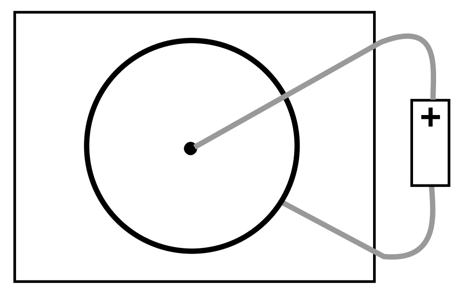
Questions

What is the field outside the capacitor plates?

How does the ratio of the plate length (l) versus separation (d) affect the fringing effect at the edges of the plates?

What redesign of the plates, or perhaps extra electrodes, could help eliminate the fringing effect?

Point Source and Guard Ring



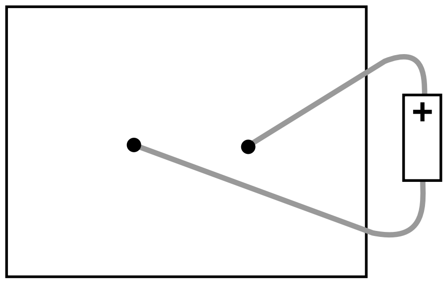
Questions

What relation can be derived between the distance from the center of the point source and the equipotential value?

Would this same relation hold if the system were three dimensional?

What purpose does the large outer ring serve in this experiment?

Dipoles of Opposite Charge



Questions

What is the relation between the direction of a maximum value field gradient and equipotential line at the same point? (A geometrical relation is desired.)

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What effect does the finite size of the black paper have on the field?

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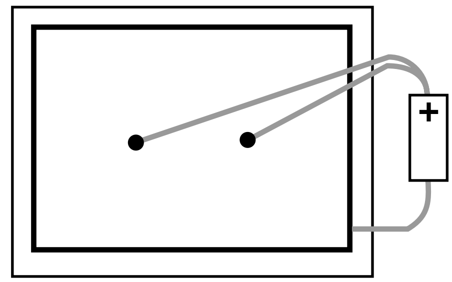
Dipoles of Like Charge



Questions

How does the field of this configuration compare with dipoles of opposite charge? (See experiment "Dipoles of Opposite Charge".)

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What distortion of the field is produced by the large electrode around the perimeter of the paper?

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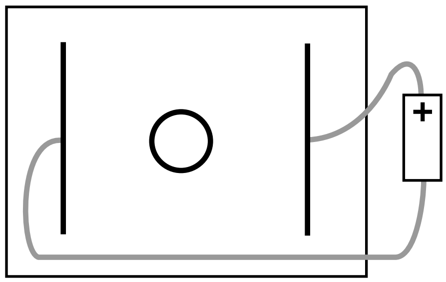
Floating Electrode



Before drawing the circular electrode, map the equipotentials of the two straight electrodes. Draw the circular electrode and again map the equipotentials.

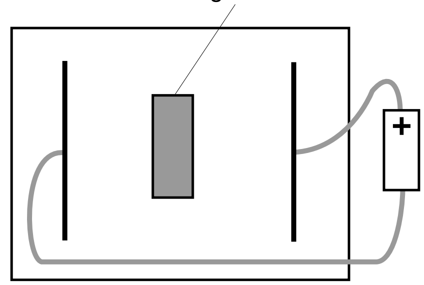
Questions

How does the circular electrode distort the field?

What is the potential of the circular electrode? Of the area inside the electrode?

What effect would moving the circular electrode have?

Floating Insulator



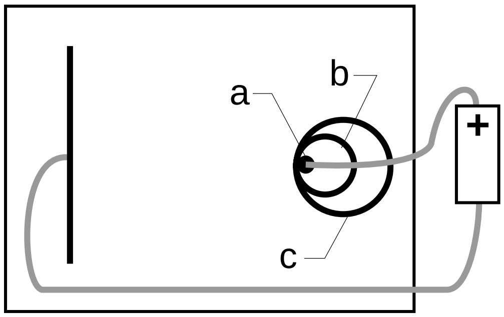
Before cutting the rectangular insulator, map the equipotentials of the two straight electrodes. Cut out a rectangular section of the paper and again map the equipotentials.

Questions

How does the rectangular insulator distort the field?

What effect would moving the rectangular insulator have?

Line and Circular Source



Draw only the line and point source "a." Map the equipotentials. Add circular electrode "b" and again map the equipotentials. Add circular electrode "c" and again map the equipotentials.

Questions

How is the spacing of equipotentials affected by the increasing diameter of the circular electrode?

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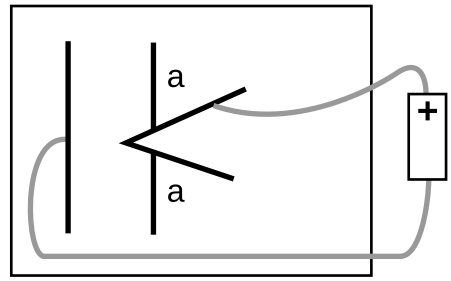
Line and "Sharp" Point



At first, do not draw the two electrodes marked "a." Map the equipotentials. Add the electrodes "a" and again map the equipotentials.

Questions

What effect did adding the extra electrodes have on the spacing of the equipotentials (field strength) around the point?

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Why did the field strength change even though the radius of the point did not change?

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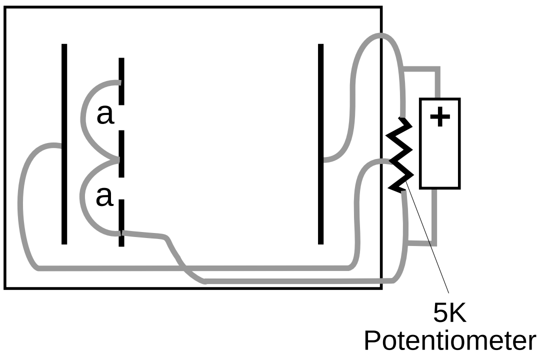
Triode

Equipment needed but not supplied: 5K Potentiometer



Use a 5 K potentiometer to provide three potentials. Connect the three short electrodes with wires "a." Do not let these wires touch the black paper except at the conductive ink electrodes.

Questions

How is the field in the area between the short electrodes affected by the potential between the short electrodes and the closer, long electrode?

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Could this paper model of a triode act as an amplifying device? If not, why not?

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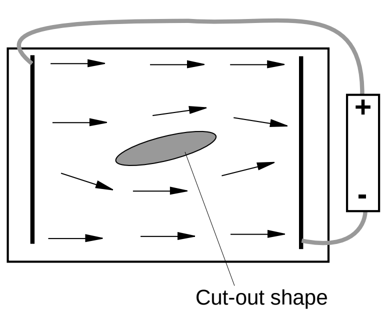
Fluid Mechanics Experiments



The PASCO Field Mapper can also be used to examine fluid flow. In many fluid systems the velocity potential satisfies the Laplace equations (so does the electromagnetic potential). Consequently, there is a direct analogy between fluid flow and electric fields. In particular, the velocity potential of an incompressible fluid where the flow is both steady and not rotational satisfies the Laplace equation. A steady flow of water is a good approximately of this type of flow. Now the flow is generated by "sources" which supply fluid and "sinks" which absorb fluid. We are interested in the "streamlines" which can be thought of as lines traced out by a particular particle in the fluid. The streamlines begin at the sources and end at the sinks.

Turning to the Field Mapper, we need to draw electrodes in the shape of the sources and sinks in the fluid flow to be examined. Then the electric field lines which we plot coincide with the streamlines in the fluid flow. (Remember that the electric field lines are perpendicular to the equipotential lines.) If there is some fixed obstruction in the fluid glow, we can represent it by cutting the same shape from the conductive paper. The schematic drawing shows a fluid flow which is analogous to the flow in a section of pipe (with frictionless walls). This source is a straight line at the left, the sink is a straight line at the right. The tear-drop shaped section cut out of the middle is some obstruction. The field lines are the corresponding streamlines.

To use the Field Mapper to examine fluid flows, follow these steps.

1. Make sure that the fluid is incompressible and the flow is not rotational and steady.
2. Draw electrodes on the conductive paper in the same shape and position as the sources and sinks in the flow.
3. Cut out sections of the conductive paper in the same shape and position as the obstructions in the fluid.
4. Connect a battery between the sources and sinks. All sources should be connected to the same side of the battery. All sinks should be connected to the opposite side.
5. Plot the equipotentials and draw lines perpendicular to these. You can also pick any point and determine the direction of the maximum field gradient. This is the direction of the streamlines at that point.

Notes

Appendix

MATERIAL SAFETY DATA SHEET

Planned Products
303 Potrero Street
Suite 53
Santa Cruz, CA 95060 USA
Tel: 408-459-8088
Fax: 408-459-0426

2200

Date 1/1/87
Page 1 of 2

I. PRODUCT IDENTIFICATION

2200 CONDUCTOR
Silver Conductive Material

CLASS	RATING
Health hazard:	1 Slight
Flammabilty hazard:	2 Moderate
Reactivity hazard:	0 Minimal

Appearance and odor: Silver color, organic ester odor

II. HAZARDOUS INGREDIENTS & EXPOSURE LIMITS

This material is a silver pigmented paint and contains organic ester solvents.
Threshold limits of 100 ppm or less is recommended.

III. TYPICAL PHYSICAL & CHEMICAL CHARACTERISTICS

Boiling Point:	125-150°C	Solubility in water:	v. sl. sol.
Vapor:	10-20 mm @ 20°C	Specific gravity:	1.65
Vapor Density:	2.2	pH:	N/A
% volatile (vol):	approximately 50%	Evaporation rate:	0.85
Freezing Point:	Below - 40 F	(Butyl Acetate = 1.0)	

IV. FIRE, EXPLOSION, & REACTIVITY HAZARD DATA

Flash point:	37°C closed cap
Autoignition temperature:	Not listed
Extinguishing media:	Carbon dioxide or foam type
Special fire-fighting procedures:	None
Unusual fire & explosion hazards:	None
Stability considerations:	Stable
Incompatability with:	Stong oxidizers such as acids
Hazardous decompositoin products:	None
Hazardous products of composition:	None
Hazardous polymerization:	Will not occur

We cannot anticipate all conditions under which this information and our products, or the products of other manufacturers in combination with our products, may be used. We accept no responsibility for results obtained by the application of this information or the safety and suitability of our products, either alone or in a combination with other products. Users are advised to make their own tests to determine the safety and suitability of each such product or product combination for their own purposes. Unless otherwise agreed in writing, we sell the products without warranty. Buyers and users assume all responsibility and liability for loss or damage arising from the handling and use of our products, whether used alone or in combination with other products.

Planned Products
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Santa Cruz, CA 95060 USA
Tel: 408-459-8088
Fax: 408-459-0426

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2200

V. HEALTH HAZARD DATA

Signs & symptoms of over exposure in the workplace

Eyes:	May cause irritation
Skin:	Prolonged exposure causes dermatitis, possible rash
Ingestion:	Unknown

EMERGENCY & FIRST AID PROCEDURES:

Eyes:	Wash immediately with warm water
Skin:	Wash with soap and warm water
Inhalation:	Remove to fresh air
Ingestion:	Possible POISON in high doses. Immediately call Physician

Medical conditions generally recognized as being aggravated exposure:

In high concentrations, will cause possible lightheadedness, narcosis and respiratory irritation
Primary routes of entry: Inhalation and skin contact.

VI. SPILL & LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:

Soak up with absorbant such as vermiculite. Place in sealed metal containers.
Waste Disposal Method: Place in sealed metal cans and return to supplier for disposal.

VII. APPLICABLE CONTROL MEASURES

Appropriate hygenic practices:	Throughly wash hands after use. Avoid skin contact.
Personal protective equipment	Safety glasses and gloves recommended.
Work practices:	Follow good laboratory practices.
Handling and storage precautions:	Store in sealed containers in a cool place away from open flames.
Engineering controls:	Area of use should be well ventilated.

Technical Support

Feedback

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

To Reach PASCO

For technical support, call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

fax: (916) 786-3292

e-mail: techsupp@PASCO.com

web: www.pasco.com

Contacting Technical Support

Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

➤ If your problem is with the PASCO apparatus, note:

- Title and model number (usually listed on the label);
- Approximate age of apparatus;
- A detailed description of the problem/sequence of events. (In case you can't call PASCO right away, you won't lose valuable data.);
- If possible, have the apparatus within reach when calling to facilitate description of individual parts.

➤ If your problem relates to the instruction manual, note:

- Part number and revision (listed by month and year on the front cover);
- Have the manual at hand to discuss your questions.