

ELECTRIC FIELD

OBJECT

1. To examine certain electric fields; in particular to map the equipotential lines of an electric field depending on the electrode configurations.
2. To draw the lines of force.
3. To evaluate the error of measurement.

THEORY

Electrostatic fields can be investigated in several ways: numerically, graphically, by direct measuring and by modeling. In this experiment we will use the last approach. The principle of such modeling is based on the fact that different physical processes are described by the same equations. For modeling electrostatic fields, we use their similarity with electric current fields. The similarity between these two fields can be demonstrated by the following equations

$$\mathbf{j} = \gamma \mathbf{E} \qquad \mathbf{D} = \varepsilon \mathbf{E},$$

where \mathbf{j} is the current density, γ is conductivity, \mathbf{E} is electric field, \mathbf{D} is electric displacement and ε is the permittivity of the medium. We can also write

$$J = \iint_S \mathbf{j} d\mathbf{S} \qquad \psi = \iint_S \mathbf{D} d\mathbf{S},$$

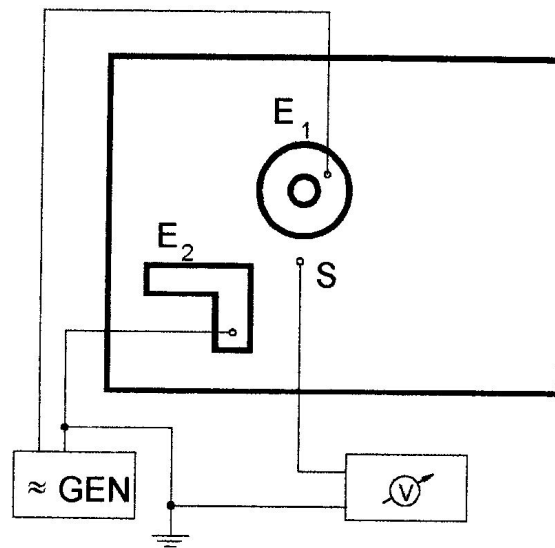
where J is current and $d\mathbf{S}$ is a vector associated with an elementary surface dS . The electric flux is denoted as ψ . For the electrostatic field and electric current field we can also write

$$\operatorname{div} \mathbf{j} = 0 \qquad \operatorname{div} \mathbf{D} = 0.$$

From these equations it can be seen that there is an analogy between the following physical quantities

\mathbf{j}	and	\mathbf{D}
J	and	ψ
γ	and	ε .

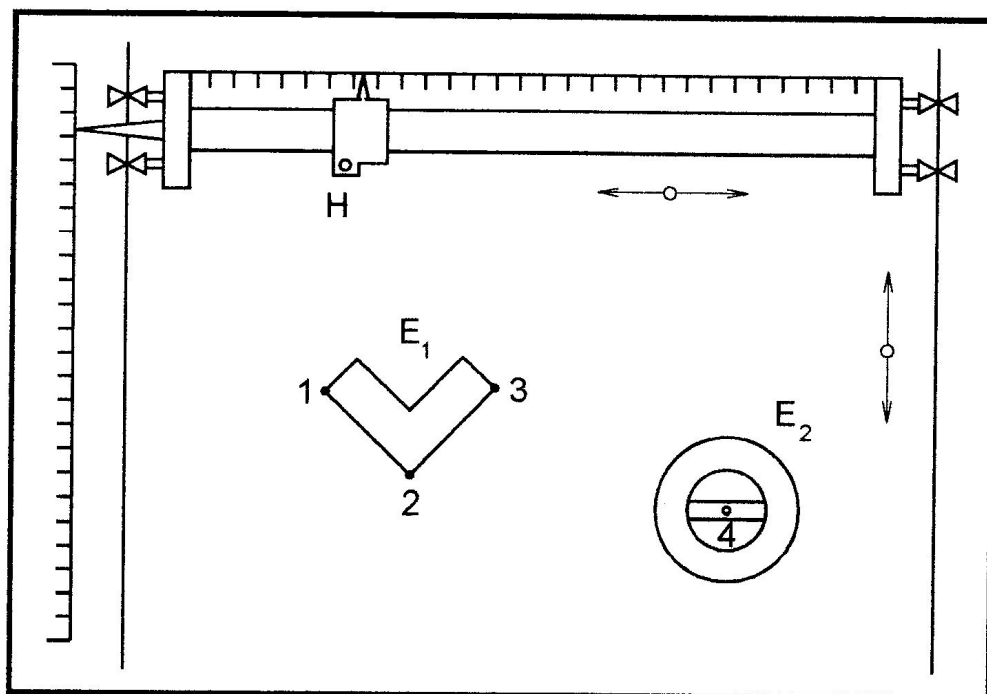
The electric current field for the purpose of modeling can be realized in various ways, for example, using a network of resistors, resistor paper or an electrolytic tank. In this experiment we use an electrolytic tank. The electrolytic tank is a relatively big but shallow vessel, made of an insulator, filled with an electrolytic solution. A sketch of the experimental apparatus is shown in the following figure.



Experimental apparatus.

On the bottom of the electrolytic tank are placed the electrodes E_1 and E_2 . The conductivity of the electrodes must be higher than the conductivity of the solution. The electrodes are usually made of iron. An electric field is produced by connecting the electrodes to a low frequency generator GEN. Alternating current is used to eliminate polarization effects, which can disturb the measurements.

Points of equal potential are discovered by a movable exploring probe S connected to a sensitive voltmeter V. The series of points, all of the same potential, define an equipotential line. In this way the entire field pattern is explored.



Detail of the tank with orthogonal scales.

PROCEDURE

1. Arbitrarily place two electrodes in the tank. The electrode must be placed within the area designated on the bottom of the tank.
2. The position of the electrodes is determined with a pointer, which is inserted into the holder H of the probe, see-preceding figure. To do this we use two orthogonal scales that are attached to the side of the electrolytic tank and to the movable positioner. Draw the shape of the electrodes on to millimeter paper.
3. Connect the AC generator to the electrodes.
4. Insert the probe S into the holder of the electrode. The point of the probe should be inserted 1 - 2 mm below water level.
5. Switch on the generator and voltmeter.
6. Using the movable positioner, find the points of equal potential. The potential is measured with the voltmeter V. Transfer the equipotential point directly to the paper.
7. Move the probe to another point of equal potential and continue in order to find a series of equipotential points in the field. Special attention must be devoted to the points near the sharp edges of the electrodes.
8. Plot the distribution of the electric field. The equipotential lines obtained will be spaced to show an equal drop in potential 1 V between successive lines. Lines of force or electric field lines are everywhere perpendicular to equipotential lines.
9. Determine the magnitude of the maximum electric field using the following equation

$$E = \frac{\Delta \varphi}{\Delta s},$$

where $\Delta\varphi$ is the change in potential in the distance Δs .

10. Repeat the same operation for the second configuration of electrodes.
11. Estimate the relative error of measurement of the electric field E .

SEMESTER PROJECT INSTRUCTIONS

Create a program, which will calculate and draw equipotential lines and force lines for two various configurations consisting of two electrodes each. You can choose from the same electrode shapes like in our laboratory, especially **L** shape, **I** shape, **V** shape or **O** shape. DC potentials of electrodes are +5V and -5V, you are to calculate and draw equipotential lines +4V, +3V, ...0V, ...-3V and -4V. At least 10 force lines should be drawn in addition to this. The program should enable moving of electrodes (after entering new coordinates in the textbox, for example) and redrawing the electric field map.

Finally, the program should be able to calculate electric field intensity at given coordinates.