RESEARCH ABOUT EQUIPOTENTIAL LINES IN ELECTRICITY

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A R T I C L E I N F O

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A B S T R A C T

To investigate equipotential lines, two electrodes are inserted into water and particles movement in electric field due to high voltage are illustrated. A supply and a voltmeter are used to determine electric potential at various locations to investigate how equipotential lines deviate from our expectations for different conditions and liquids.

Keywords :*Equipotential Lines, Liquid, Electric Field*

1. Introduction

Equipotential lines of each type of electrode are illustrated to find particles movement in electric field due to a high voltage electrodes. Any significant variation in shape of potential lines in different conductivity of different liquids should be considered and theoretical assumptions with experimental data will help to analyze the results.

2. Materials and Methods

To observe this phenomenon we have used several liquids such as tap water, water with salt, alcohol and oil and different types of electrode (Fig. 1).

Fig. 1: Types of electrode

When two electrodes are connected to a high voltage (Fig. 2), potential lines are observed which differ in various liquids.

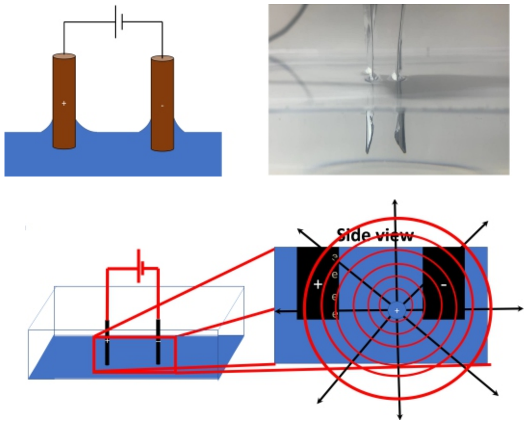

Fig. 2: Electric Potential Lines

Electric Potential lines are shown in macroscopic and microscopic view (Fig. 3).

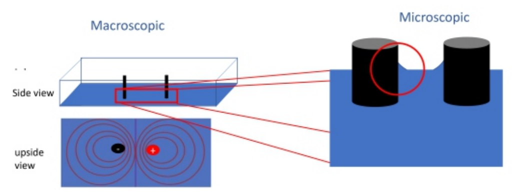

Fig. 3: Macroscopic and Microscopic view

3. Theory

As Poisson's Equation (Eq. 1):

$$\nabla . E = \frac{\rho}{\varepsilon_0} \qquad E = -\nabla V \tag{1}$$

Therefore potential relates to charge density by Poisson's equation (Eq. 2) which for charge free space it is zero (Eqs. 2 and 3).

$$\nabla^2 V = -\frac{1}{\varepsilon}\rho \tag{2}$$

$$\nabla^2 V = 0 \tag{3}$$

The potential of each point (Eqs. 4-6):

$$\psi = \frac{q}{|r - r_0|} + \frac{-q}{|r - r_0'|} \tag{4}$$

$$= \frac{q}{\sqrt{(x-x0)^2 + (y-y0)^2 + (z-z0)^2}} - \frac{q}{\sqrt{(x-x0)^2 + (y-y0)^2 + (z-z0)^2}}$$

$$dA = dx\, dy$$

$$\frac{\partial \psi}{\partial n} = -\frac{\partial \psi}{\partial z} = \frac{-2qz_0}{[(x-x0)^2 + (y-y0)^2 + z0^2]^{\frac{3}{2}}} \tag{5}$$

$$\Phi_{(r0)} = \frac{1}{4\pi}\int dxdy\Phi\ (z = 0 \tag{6}$$

and Electric field (Eqs. 7-9):

$$\nabla \times E = 0 \qquad \Rightarrow E = -\nabla V \tag{7}$$

but in electro dynamics (Eqs. 8-11):

$$\nabla \times E \neq 0 \tag{8}$$

$$\nabla . B = 0 \tag{9}$$

$$\nabla \times E = \frac{-\partial B}{\partial t} \qquad \Rightarrow \nabla \times E = \frac{-\partial\,(\nabla \times A)}{\partial t} \tag{10}$$

$$\Rightarrow \nabla \times \left(E + \frac{\partial\,(\nabla \times A)}{\partial t}\right) = 0$$

$$\text{so } E = -\nabla V - \frac{\partial A}{\partial t} \tag{11}$$

Green's Theory: It states that any two scalar (Φ, ψ) inside a volume (V)having a boundary surface A satisfies the following relationship (Eqs. 12- 13):

$$\int_V dV(\Phi \nabla^2 \psi - \psi \nabla^2 \Phi) = \oint_A dA\left(\Phi \frac{\partial \psi}{\partial n} - \psi \frac{\partial \Phi}{\partial n}\right) \tag{12}$$

$$\nabla^2 \psi = -4\pi q \delta^{(3)}(r - r_0) \tag{13}$$

$\delta^{(3)}$: Delta function in three-dimensional space
Φ : electric potential
ψ: auxiliary field

Potential of each point (Eqs. 14-15)

$$\Phi_{(r0)} = -\frac{1}{4\pi q} \oint_A \left(\Phi \frac{\partial \psi}{\partial n} - \psi \frac{\partial \Phi}{\partial n}\right) dA \tag{14}$$

Boundary conditions for Φ :
Dirichlet $\Rightarrow \psi = 0$
Neumann $\Rightarrow \nabla \psi = 0$
then (Eq. 15):

$$\Phi_{(r0)} = -\frac{1}{4\pi q} \oint_A \Phi \frac{\partial \psi}{\partial n} dA \tag{15}$$

4. Experiment

In this research we have used linear , point and Concentric electrodes in liquids (Figs. 4-8).

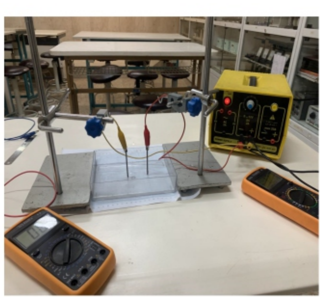

Fig. 4: Experimental setup

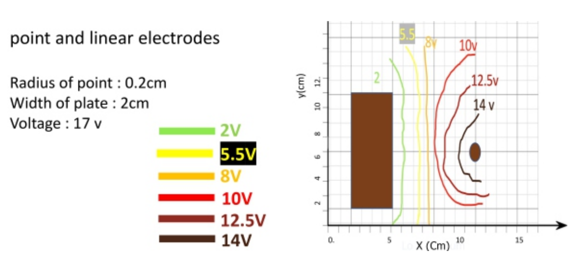

Fig. 5: Potential lines in Point and linear electrodes

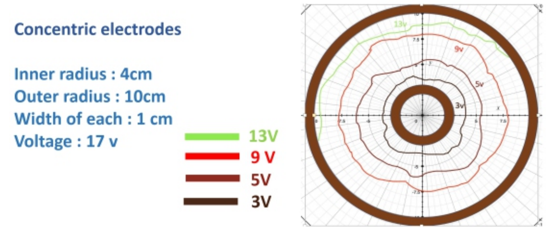

Fig. 6: Potential lines in concentric electrodes

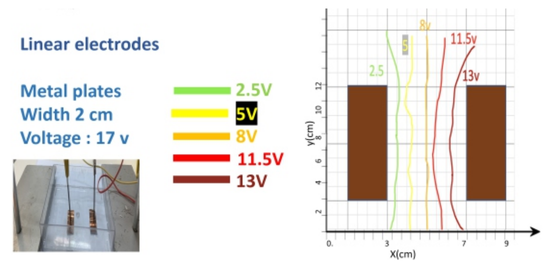

Fig. 7: Potential lines in linear electrodes

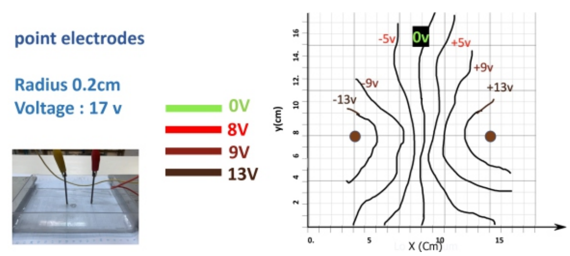

Fig. 8: Potential lines in point electrodes

This experiment is done with various liquids and the results are analyzed (Fig. 9).

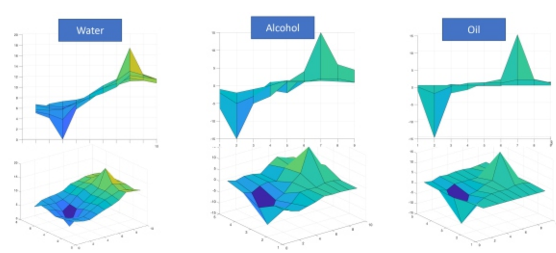

Fig. 9: Analysis of experiments in different liquids

By simulation all the results are compared in different electrodes (Figs. 10-13).

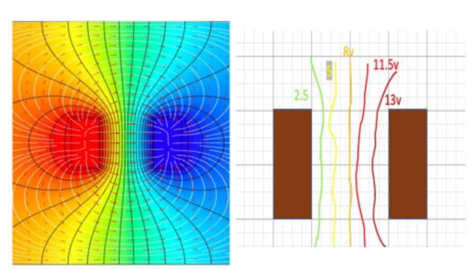

Fig.10: Simulation and experiments comparison in linear electrode

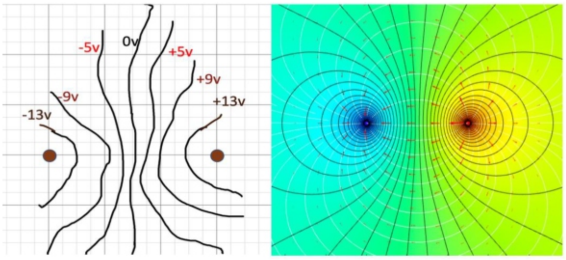

Fig.11: Simulation and experiments comparison in point electrode

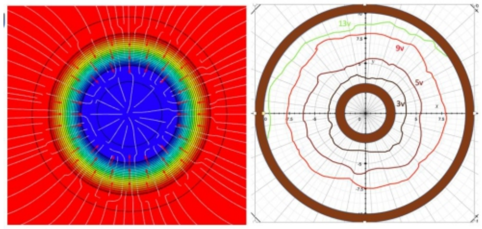

Fig.12: Simulation and experiments comparison in concentric electrode

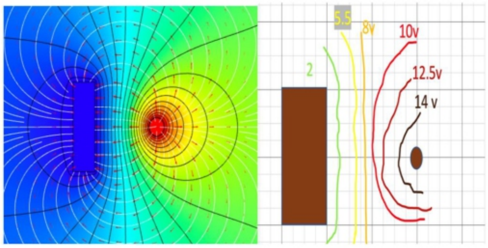

Fig.13: Simulation and experiments comparison in linear/ point electrode

5. Conclusion

Equipotential lines of each type of electrode were illustrated . There wasn't any significant variation in shape of potential lines in different conductivity of liquids. By changing dielectric constant of liquid potential lines varied. Theoretical expectation and experimental results were compared.

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