PHYSNET

MISN-0-506

DIELECTRICS; DISPLACEMENT VECTOR

Electricity and Magnetism

Project PHYSNET Physics Bldg. Michigan State University East Lansing, MI

DIELECTRICS; DISPLACEMENT VECTOR

by

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Title: **Dielectrics; Displacement Vector**

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Input Skills:

1. Vocabulary: electric field, potential, electric flux, gaussian surface (MISN-0-504); energy gap, semiconducting (MISN-0-344).
2. Given an electrostatic potential, compute the electric field (MISN-0-504).
3. State Gauss's law in integral and differential form (MISN-0-504).

Output Skills (Knowledge):

K1. Vocabulary: ideal dielectric material, polarized dielectric, polarization, bound charge densities, electric displacement vector, Gauss's law for the displacement vector, electric susceptibility, permittivity, linear dielectric, dielectric constant.

K2. State the definition of the electric field in an isotropic dielectric medium.

K3. State the exact theoretical expressions for the electrostatic potential and the electric field inside or outside a dielectric.

Output Skills (Problem Solving):

S1. Given the polarization in a dielectric medium, calculate the bound charge densities and the electric field inside and outside the dielectric.

S2. Given a free charge distribution in a homogeneous, isotropic, linear dielectric fluid of specified permittivity, calculate the displacement, electric field, polarization and bound charge densities.

External Resources (Required):

1. J. Reitz, F. Milford and R. Christy, *Foundations of Electromagnetic Theory*, 4th Edition, Addison-Wesley (1993).

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New authors, reviewers and field testers are welcome.

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1. Introduction

An insulator is a substance whose electrons or ions cannot move about under the influence of an applied electric field. (In general, such substances consist of neutral polyatomic molecules, except for the rare gases - helium, neon, argon, xenon, and radon - which are monatomic in nature and some crystals whose energy gaps are so large that their semiconducting properties are negligible).

A conductor, on the other hand, is a substance whose electrons are free to move even under the influence of very small electric fields until the charge carriers experience no *net* force. Thus, under static conditions the electric field in a conductor vanishes so that the conductor forms an equipotential region. In an insulator, however, electric fields can exist as well as potential gradients due to the fact that the bound charges are not free to move until they experience no net force. It should be pointed out that there are no *perfect* insulators, as all substances have some measurable conductivity. In this unit, however, all effects resulting from their small conductivity are neglected.

Insulators also have a property of *molecular polarizability*. That is, the presence of an electric field may shift the positive and negative charges away from their average positions within a molecule. Thus, charge is redistributed on individual molecules. The effects of this redistribution are observable in the absence of appreciable conductivity is redistribution of charge involves the motion of one or more electrons per atom over subatomic distances. This unit studies the macroscopic effects of these subatomic motions.

The response of the insulator to an external field is described by introducing the polarization vector $\vec{P}(\vec{r})$. The definition of the electric field inside the dielectric is very carefully given. An auxiliary vector displacement $\vec{D}(\vec{r})$ is introduced. Gauss' Law can be expressed in terms of the displacement vector $\vec{D}$ and the free charge.

2. Procedures

1. Read sections 4-1 to 4-6 of the text, including the introduction to Chapter 4.

2. Write down or underline in the text the definitions and explanations called for in Output Skill K1.

3. Write down the *definition* of the electric field $\vec{E}$ in an isotropic dielectric as given in the marked sentence near the top of page 105. Include Fig. 4-3 as part of the definition.

4. Read Sec. 4-6, "Point charge in a dielectric fluid," very carefully. Solve problem 4-6. Be prepared to calculate any one of the physical quantities listed in Output Skill S2 for both of these situations.

5. Solve Problems 4-1, 4-2, 4-3, 4-5.

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