

Comparison of Dielectric and Magnetic Properties

Here is a quick and simple comparison of dielectric and magnetic *definitions* and *laws*

Basics

Dielectric Behavior		Magnetic Behavior	
Charge q			<i>No equivalent</i>
Electrical field \underline{E}			Magnetic field \underline{H}
Electrical displacement \underline{D}			(Magnetic) Induction \underline{B}
Permittivity constant of vacuum ϵ_0			Permeability constant of vacuum μ_0
Relative dielectric constant of material ϵ_r			Relative permeability constant of material μ_r
<i>From Maxwell equations</i>		<i>From Maxwell equations</i>	
Connection between dielectric flux density \underline{D} , electrical field \underline{E} , and relative dielectric constant ϵ_r	$\underline{D} = \epsilon_0 \cdot \epsilon_r \cdot \underline{E}$	$\underline{B} = \mu_0 \cdot \mu_r \cdot \underline{H}$	Connection between <i>magnetic flux density</i> \underline{B} , <i>magnetic field</i> \underline{H} , and <i>relative (magnetic) permeability</i> μ_r
Formulation with electrical Polarization \underline{P} in the material caused by the electrical field	$\underline{D} = \epsilon_0 \cdot \underline{E} + \underline{P}$	$\underline{B} = \mu_0 \cdot \underline{H} + \underline{J}$	Formulation with <i>magnetic polarization</i> \underline{J} in the material caused by the magnetic field
<i>Justified by theory of polarization mechanisms</i>		<i>Justified by theory of magnetization mechanisms</i>	
Material "law" describing \underline{P} as response of a material to a field \underline{E} and defining the dielectric susceptibility χ Note exception: <i>Ferroelectricity</i>	$\underline{P} = \epsilon_0 \cdot \chi \cdot \underline{E}$	$\underline{J} = \mu_0 \cdot \chi_{\text{mag}} \cdot \underline{H}$	Material "law" describing \underline{J} as response of a material to a field \underline{H} and defining the <i>magnetic susceptibility</i> χ_{mag} Note exception: <i>Ferromagnetism</i>
Relation between χ and ϵ_r	$\chi = \epsilon_r - 1$	$\chi_{\text{mag}} = \mu_r - 1$	Relation between χ_{mag} and μ_r
Definition of \underline{P} as material property in terms of electrical dipole moment $\underline{\mu}$ and density \underline{N}_V	$\underline{P} = \langle \underline{\mu} \rangle \cdot \underline{N}_V$	$\underline{J} = \langle \underline{m} \rangle \cdot \underline{N}_V$	Definition of \underline{J} as material property in terms of <i>magnetic moments</i> \underline{m} and density \underline{N}_V
		$\underline{M} = \underline{J} / \mu_0$	Definition of <i>magnetization</i> \underline{M}
		$\underline{M} = \chi_{\text{mag}} \cdot \underline{H}$	Relations between \underline{M} and \underline{H}

Next, let's compare mechanisms that lead to polarization

Dielectric Polarization		Magnetic Polarization	
<i>Electronic polarization</i>			<i>Diamagnetism</i>
Induce dipole moments by displacing electrons and nuclei. Weak for spherical atoms. Stronger for covalent bonds. Important for optics.	$\epsilon_r \approx 1,0001 \dots 30$	$\mu_r \approx 0,9999$	Induce precession of electrons. Always very weak and opposite to field. Not important.
<i>Orientation polarization</i>			<i>Paramagnetism</i>
Average small orientation of fluctuating existing dipoles. Only in <i>liquids</i> ; can be large. Not important.	$\epsilon_r \approx 2 \dots 100$	$\mu_r \approx 1,0001$	Average small orientation of existing dipoles free to rotate in <i>solids</i> . Always small; not important. Extreme case: <i>Ferromagnetism</i> .

<i>Ionic polarization</i>			No direct counterpart
Net dipole moment from distribution of charges. Important.	$\epsilon_r \approx 2 \dots 100$		
<i>Ferroelectricity</i> Natural dipoles defined by crystallography are lined up. Important.	$\epsilon_r > 1000$	$\mu_r > 1000$	<i>Ferromagnetism</i> Natural magnetic moments are lined up in any directions (with crystal directions preferred). Extremely important.