Comparison of Dielectric and Magnetic Properties

Basics

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

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

Next, let's compare mechanisms that lead to polarization

Dielectric Polarization		**Magnetic Polarization**	
Electronic polarization			*Diamagnetism*
Induce dipole moments by displacing electrons and nuclei. Weak for spherical atoms. Stronger for covalent bonds. Important for optics.	$\epsilon_r \approx 1{,}0001 \ldots 30$	$\mu_r \approx 0{,}9999$	Induce precession of electrons. Always very weak and opposite to field. Not important.
Orientation polarization			*Paramagnetism*
Average small orientation of fluctuating existing dipoles. Only in *liquids*; can be large. Not important.	$\epsilon_r \approx 2 \ldots 100$	$\mu_r \approx 1{,}0001$	Average small orientation of existing dipoles free to rotate in *solids*. Always small; not important. Extreme case: *Ferromagnetism*.
Ionic polarization			No direct counterpart

Net dipole moment from distribution of charges. Important.	**$\epsilon_r \approx$ 2 ... 100**		
Ferroelectricity Natural dipoles defined by crystallography are lined up. Important.	**ϵ_r > 1000**	**μ_r > 1000**	*Ferromagnetism* Natural magnetic moments are lined up in any directions (with crystal directions preferred). ***Extremely*** important.