

7.1: Comparison of Electrostatics and Magnetostatics

Students encountering magnetostatics for the first time have usually been exposed to electrostatics already. Electrostatics and magnetostatics exhibit many similarities. These are summarized in Table 7.1.1. The elements of magnetostatics presented in this table are all formally introduced in other sections; the sole purpose of this table is to point out the similarities. The technical term for these similarities is *duality*. Duality also exists between voltage and current in electrical circuit theory.

Table 7.1.1: A summary of the duality between electrostatics and magnetostatics

	electrostatics	magnetostatics
Sources	static charge	steady current, magnetizable material
Field intensity	\mathbf{E} (V/m)	\mathbf{H} (A/m)
Flux density	\mathbf{D} (C/m ²)	\mathbf{B} (Wb/m ² =T)
Material relations	$\mathbf{D} = \epsilon \mathbf{E}$	$\mathbf{B} = \mu \mathbf{H}$
	$\mathbf{J} = \sigma \mathbf{E}$	
Force on charge q	$\mathbf{F} = q\mathbf{E}$	$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$
Maxwell's Eqs. (integral)	$\oint_S \mathbf{D} \cdot d\mathbf{s} = Q_{encl}$	$\oint_S \mathbf{B} \cdot d\mathbf{s} = 0$
	$\oint_C \mathbf{E} \cdot d\mathbf{l} = 0$	$\oint_C \mathbf{H} \cdot d\mathbf{l} = I_{encl}$
Maxwell's Eqs. (differential)	$\nabla \cdot \mathbf{D} = \rho_v$	$\nabla \cdot \mathbf{B} = 0$
	$\nabla \times \mathbf{E} = 0$	$\nabla \times \mathbf{H} = \mathbf{J}$
Boundary Conditions	$\hat{\mathbf{n}} \times [\mathbf{E}_1 - \mathbf{E}_2] = 0$	$\hat{\mathbf{n}} \times [\mathbf{H}_1 - \mathbf{H}_2] = \mathbf{J}_s$
	$\hat{\mathbf{n}} \cdot [\mathbf{D}_1 - \mathbf{D}_2] = \rho_s$	$\hat{\mathbf{n}} \cdot [\mathbf{B}_1 - \mathbf{B}_2] = 0$
Energy storage	Capacitance	Inductance
Energy density	$w_e = \frac{1}{2} \epsilon E^2$	$w_m = \frac{1}{2} \mu H^2$
Energy dissipation	Resistance	

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