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	