

Lorentz Force Equation



In 1895, **Hendrik Lorentz** added the **E-field** to **Oliver Heaviside's** magnetic force to state his final **electromagnetic (EM) force equation**:

$$\mathbf{F}_t = q_t [\mathbf{E}(\mathbf{x}_t) + \mathbf{v}_t \times \mathbf{B}(\mathbf{x}_t)]$$

\mathbf{F}_t – 3D vector force (N – Newtons)

\mathbf{x}_t – 3D vector location (m – meters)

\mathbf{v}_t – 3D vector velocity (m/s – meter/second)

q_t – scalar charge (C – **Coulomb**) ($1 \text{ C} \approx -6.2 \times 10^{18} \text{ e}^-$)

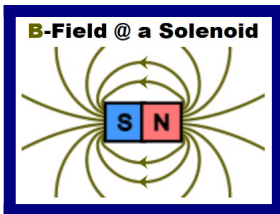
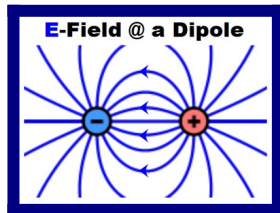
$\mathbf{E}(\mathbf{x}_t)$ – 3D **electric field** vector (N/C – Volts/meter). **E-fields** define EM forces assuming near infinite propagation speeds & static states. **E-fields** undergo **work**, store & expend **energy**.

$\mathbf{B}(\mathbf{x}_t)$ – 3D **magnetic field** vector (T – Tesla). **B-fields** set corrections due to a finite **EM propagation speed** ($c \approx 10^9 \text{ ft/s} \approx 10^9 \text{ kph}$). **B-fields** do **NO** work (W_B).

$$\mathbf{F}_B \equiv q_t(\mathbf{v}_t \times \mathbf{B}) \quad \Rightarrow \quad \mathbf{F}_B \perp \mathbf{v}_t \quad \& \quad \mathbf{F}_B \perp \mathbf{B}$$

$$d\ell_t \approx \mathbf{v}_t \Delta t \quad \Rightarrow \quad W_B \equiv (\mathbf{F}_B \cdot d\ell_t) = (\mathbf{F}_B \cdot \mathbf{v}_t) \Delta t = q_t [(\mathbf{v}_t \times \mathbf{B}) \cdot \mathbf{v}_t] \Delta t = 0 \quad \Rightarrow \quad W_B = 0$$

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