

Electromagnetic Field Theory

Week 13

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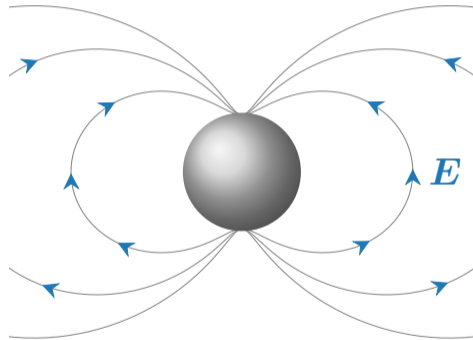
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1. Faraday's Law of Induction
2. Inductance
3. Magnetic Field Energy





Faraday's Law of Induction

Motional electromotive (emf) force

$$U_{\text{emf}} = \oint_l \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi}{dt}.$$

Faraday's law of induction

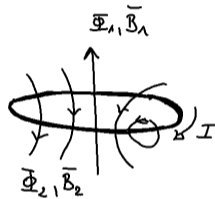
$$\oint \mathbf{E} \cdot d\mathbf{l} = -\iint \frac{\partial \mathbf{B}}{\partial t} \cdot d\mathbf{S}.$$

Faraday's law of induction in differential form

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}.$$



Lenz's Law





Ideal Transformer

Current

$$\frac{i_1}{i_2} = \frac{N_2}{N_1}$$

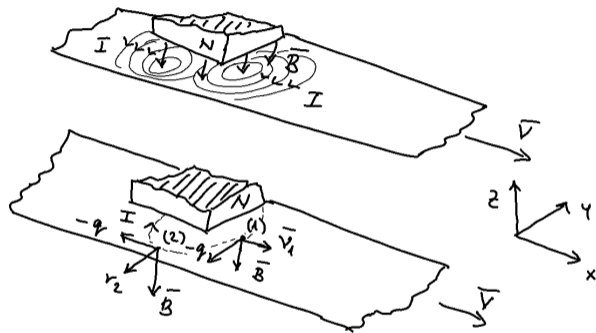
and voltage

$$\frac{u_1}{u_2} = \frac{N_1}{N_2}$$

transformation of ideal transformer.



Eddy Currents





Static and Dynamic Definition

Static definition

$$L = \frac{\Phi_t}{I} \quad [\text{H}].$$

Dynamic definition

$$u(t) = L \frac{di}{dt}.$$



Mutual Inductance

Mutual inductance M_{21}

$$\Phi_2 = M_{21}I_1.$$

Neumann Formula

$$\Phi_2 = \frac{\mu_0}{4\pi} I_1 \oint_{l_1} \oint_{l_2} \frac{d\mathbf{l}_1 \cdot d\mathbf{l}_2}{R} = M_{21}L_1.$$



Energy in Magnetic Field

Using currents and potential

$$W = \frac{1}{2} \iiint_V \mathbf{A} \cdot \mathbf{J} \, dV, \quad [\text{J}].$$

Using magnetic field

$$W = \frac{1}{2} \iiint_V \mathbf{H} \cdot \mathbf{B} \, dV, \quad [\text{J}].$$

Questions?

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