Griffiths EM Ch 7 - Electrodynamics

Ohm's Law: $V = IR$ $\qquad P = I^2 R = VI$

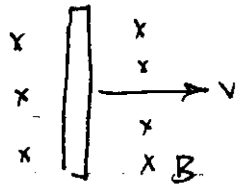
$$\mathbf{E} = J\rho = \frac{J}{\sigma}$$

resistivity $\quad$ conductivity

Electromotive force $\mathcal{E} \equiv \int \frac{\vec{F}}{q} \cdot d\vec{l}$, $\vec{F}_E = q\vec{E}$

(volts)

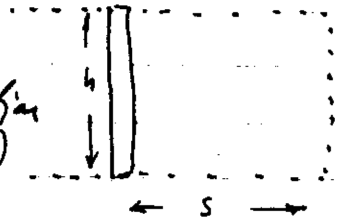
① Motional Emf



$\vec{F}_B = q\,\vec{v} \times \vec{B}$ DIRECTION?

$\vec{F} \rightarrow$

② charge separation $\rightarrow \vec{E}$ $(\rightarrow I)$



③ $\mathcal{E} = \int \vec{E} \cdot d\vec{l} =$ ______

Consider changing magnetic flux $\frac{d}{dt} \int B \cdot dA = Bh \frac{ds}{dt}$

④ $\frac{d\Phi_B}{dt} = \frac{d}{dt} \int \bar{B} \cdot d\bar{A}$

⑤ Compare to $\mathcal{E}$: FARADAY'S LAW:

CHANGING MAGNETIC FLUX $\xleftrightarrow{\text{CAUSES}}$ ELECTROMOTIVE FORCE

INDUCTANCE: $\mathcal{E} = -L\frac{dI}{dt}$, $\Phi_B = LI$

EM Ch 7 Faraday's Law + Giancoli Ch. 29 (p 734) ELECTRODYNAMICS

$\frac{d\Phi_B}{dt}$ = Changing magnetic flux $\frac{d}{dt}\int \vec{B}\cdot d\vec{A} = -\mathcal{E}$ = electromotive force = emf through a loop

↑ which opposes change in flux

Electromotive force $\mathcal{E} = \Delta V = -\int \vec{E}\cdot d\vec{l}$ = potential difference

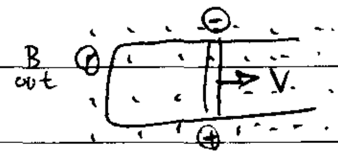
$= -\int \frac{\vec{F}}{q}\cdot d\vec{l}$ or voltage

Differential form of Faraday's Law: $\nabla\times\vec{E} = -\frac{\partial B}{\partial t}$ (Griffiths p. 302)

Example: motional emf (Griffiths p. 294, Giancoli p. 739)

motion → changing loop area → changing flux → emf

$dA = l\,dx \rightarrow \frac{dA}{dt} = lv \rightarrow \mathcal{E} = Blv$



Motional emf from Lorentz force:

motion → force on charges → E → equilibrium

$F = qE = qvB \rightarrow \mathcal{E} = El = vBl$

Emf can make a current flow: $V = IR$

Example 7.1 (286)

$E = \eta J = \rho J = \frac{1}{\sigma} J$

This requires a force, and costs power. Ex 29-4 (740)

Power: Force · velocity $= \frac{dEnergy}{dt}$

$\therefore P = \frac{d}{dt} qV = IV = I^2R$

Generators: (7.10, 300), (Ex 29.5, 741) $\mathcal{E} = -NBA\frac{d}{dt}\cos\omega t = \omega NBA\sin\omega t$

Inductance and Transformers

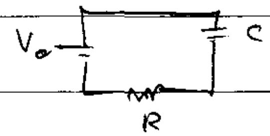
Ex 7.10 / 312, Giancoli Ch 30   Prob. 7.54 / 338, Ch. 29-6 / 744

Transformer = 2 solenoids which share flux: Power$_1$ = Power$_2$: $V_1 I_1 = V_2 I_2$

$$V_i = N_i \frac{d\Phi}{dt} \rightarrow \frac{d\Phi_1}{dt} = \frac{d\Phi_2}{dt}$$

$$\frac{V_1}{N_1} = \frac{V_2}{N_2} \rightarrow N_1 I_1 = N_2 I_2$$

Recall capacitance $C = \frac{Q}{V}$. Do problem 7.2 / 290

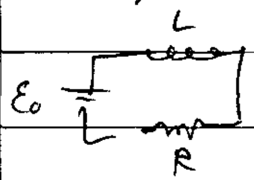


$$V = \frac{Q}{C} = \frac{I}{R} = \frac{1}{R}\left(-\frac{dQ}{dt}\right)$$

$$Q(t) = CV_0 e^{-t/RC}$$

Similarly, INDUCTANCE $L = \frac{N\Phi}{I}$. See Ex. 7.12 / 314

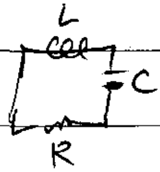
Voltage across inductor $V = \frac{d\Phi}{dt} = L\frac{dI}{dt}$



$$\Sigma V = 0$$

$$\mathcal{E}_0 - L\frac{dI}{dt} = IR \rightarrow I(t) = \frac{\mathcal{E}_0}{R}\left[1 - e^{-\frac{R}{L}t}\right]$$

Recall you have done these together in mechanics!



Giancoli 766

$$\Sigma V = 0 \rightarrow V_L + V_R + V_C = 0 \rightarrow -L\frac{dI}{dt} - IR + \frac{Q}{C} = 0$$

$$L\frac{d^2Q}{dt^2} + R\frac{dQ}{dt} + \frac{Q}{C} = 0$$

$$Q(t) = Q_0 e^{-Rt/2L}\cos(\omega_d t + \phi) \quad \text{where damped } \omega_d = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Inductance, like capacitance, depends only on GEOMETRY, not on Q, I, or V:

$$L_{solenoid} = \frac{N}{I} A \cdot B = \frac{N}{I} A \frac{\mu_0 I N}{l} = \frac{\mu_0 N^2 A}{l} \quad \text{Giancoli p. 759}$$

$$L_{toroid} = \frac{\mu_0 N^2 h}{2\pi} \ln\left(\frac{b}{a}\right) \quad \text{Griffiths Ex. 7.11 / 313}$$

NEXT WEEK - MAXWELL EQNS + ENERGY