Lecture 41 outline: 11/30/2020

- Final Exam, Thursday 12/10 @1:30 pm

  Remote, via Zoom
- Final homework due Friday.
- HW 10-01 – mag. dipole approx. (eqn 5.88)
- After today can do problems 1–9 and 14.
- Self Inductance
- Mutual Inductance

Faraday's Law

$$\varepsilon = -\frac{\partial \Phi_B}{\partial t}$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{\partial \Phi_B}{\partial t}$$

$$\varepsilon = -\frac{\partial}{\partial t} \int \vec{B} \cdot d\vec{a}$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{\partial}{\partial t} \int \vec{B} \cdot d\vec{a}$$

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

Electric Dipole

$$\vec{p} = q\,\vec{d}$$

$$V = \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}$$

$$\vec{E} = -\nabla V$$

$$\vec{E} = \frac{p}{4\pi\epsilon_0}\frac{\left(2\cos\theta\,\hat{r} + \sin\theta\,\hat{\theta}\right)}{r^3}$$

Magnetic Dipole

$$\vec{m} = I\,\vec{a}$$

$$\vec{A} = \frac{\mu_0}{4\pi}\frac{\vec{m}\times\hat{r}}{r^2}$$

$$\vec{B} = \nabla\times\vec{A}$$

$$\vec{B} = \frac{m\,\mu_0}{4\pi}\frac{\left(2\cos\theta\,\hat{r} + \sin\theta\,\hat{\theta}\right)}{r^3}$$

Mutual Inductance:

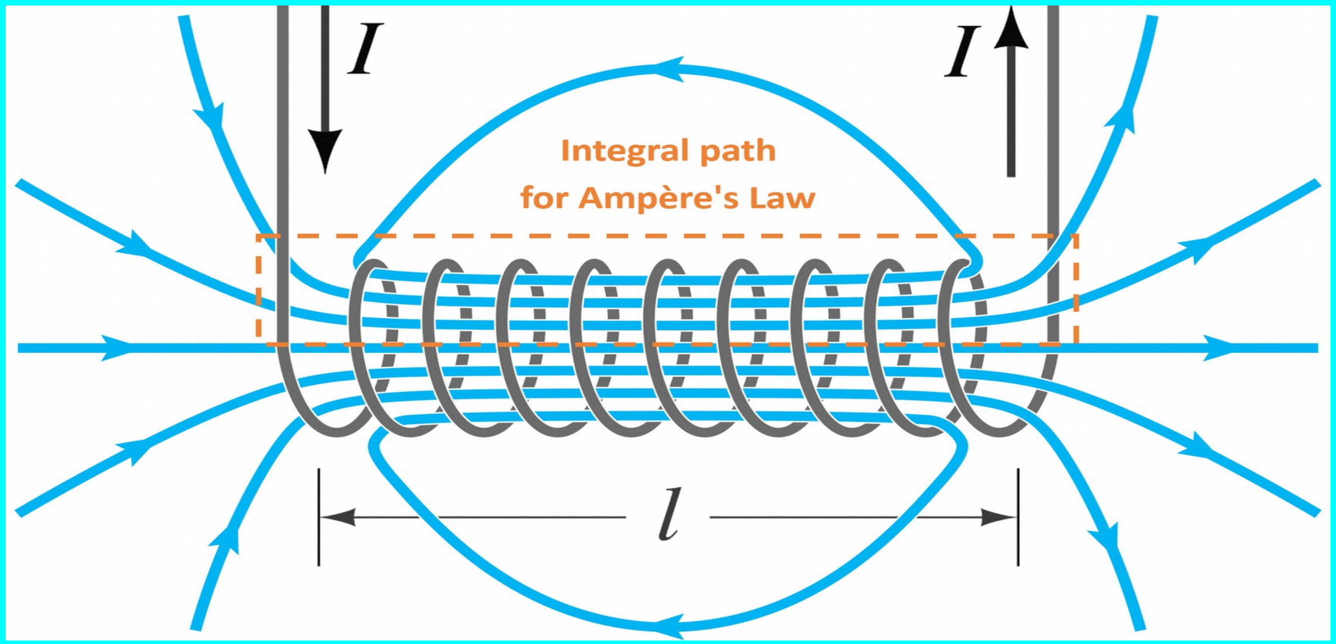
- Change the current in coil 2 and you create a changing EMF on coil 1

Self Inductance:

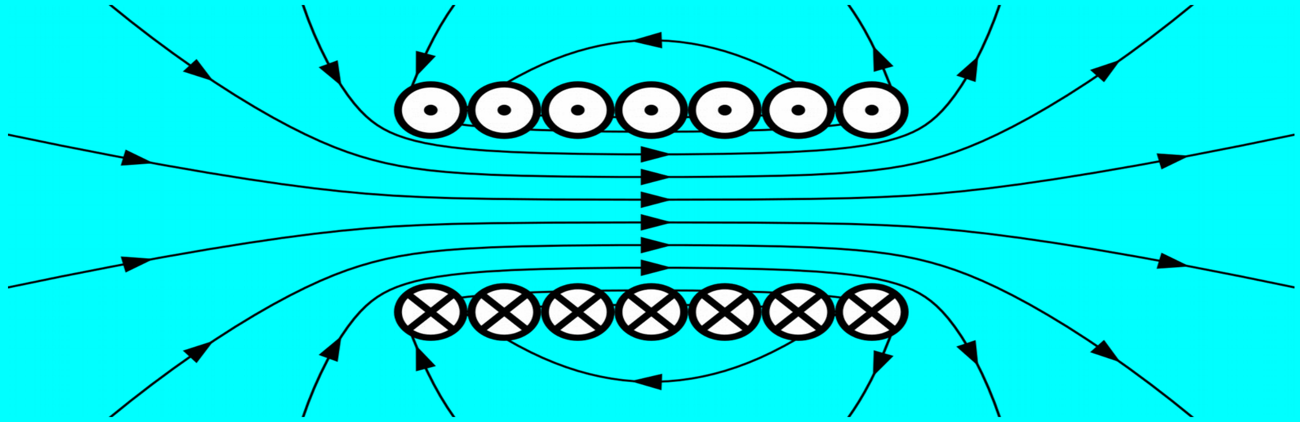
- Change the current in a coil and it creates its own EMF (Voltage) to try to stop you.

Electric	Magnetic
$Q_1 = C_1 V_1$	$\frac{dI}{dt} = -\frac{\varepsilon}{L}$ $\quad I = -\frac{\Phi_B}{L}$
$Q_1 = C_{21} V_2$	$\frac{dI_1}{dt} = -\frac{\varepsilon_2}{M_{21}}$ $\quad I_1 = -\frac{\Phi_{B_2}}{M_{21}}$

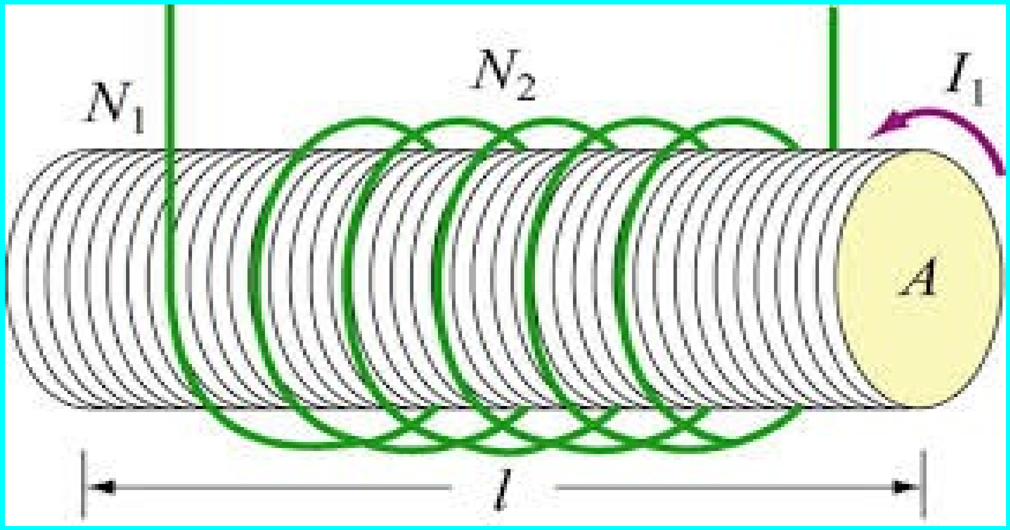
Self Inductance of a solenoid (problem 8):



$$\varepsilon = -\frac{\partial \Phi_B}{\partial t}$$



Mutual Inductance of two solenoids:



Lenz's Law "Back EMF":

- Lenz's law is the minus sign in Faraday's law
- If you try to increase B through a loop, a current in the loop tries to prevent it from increasing
- This induced current also produces an opposing magnetic field, as we saw with eddy currents and the magnet that would not fall onto the copper plate

Mutual Inductance

Ampere's Law

(with displacement current)

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \epsilon_0 \frac{\partial}{\partial t} \Phi_E$$

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \epsilon_0 \frac{\partial}{\partial t} \int \vec{E}\cdot d\vec{a}$$

$$\int \nabla \times \vec{B}\cdot d\vec{a} = \mu_0 \epsilon_0 \frac{\partial}{\partial t} \int \vec{E}\cdot d\vec{a}$$

$$\nabla \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

Faraday's Law

$$\oint \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t} \Phi_B$$

$$\oint \vec{E}\cdot d\vec{l} = -\frac{\partial}{\partial t} \int \vec{B}\cdot d\vec{a}$$

$$\int \nabla \times \vec{E}\cdot d\vec{a} = -\frac{\partial}{\partial t} \int \vec{B}\cdot d\vec{a}$$

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