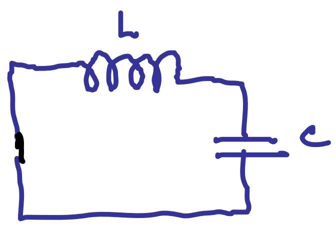
Physics 142 - November 11, 2014

- Only 1 request for project group meeting so far ...

Last Time

Looked at LC circuit (DC)



Fully charged capacitor at $t=0$

Look at time dependence of energy flow

Find $$0 = L\frac{d^2q}{dt^2} + q/C$$

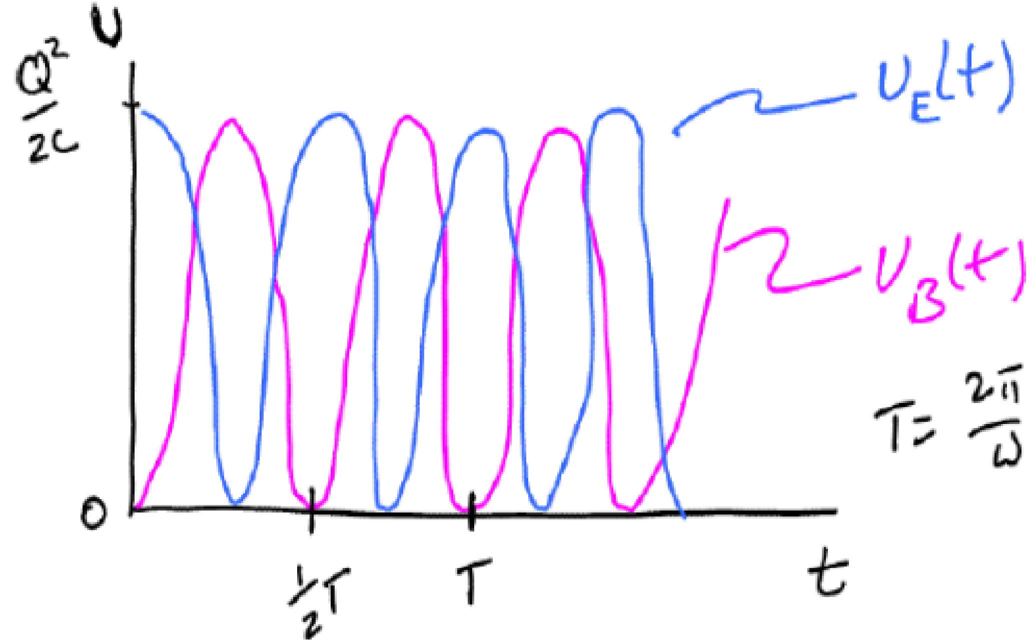
SHM for q on capacitor!

$$q(t) = Q\cos(\omega t + \phi)$$

$\omega^2 = \frac{1}{LC}$

$$i(t) = -\omega Q \sin(\omega t + \phi)$$

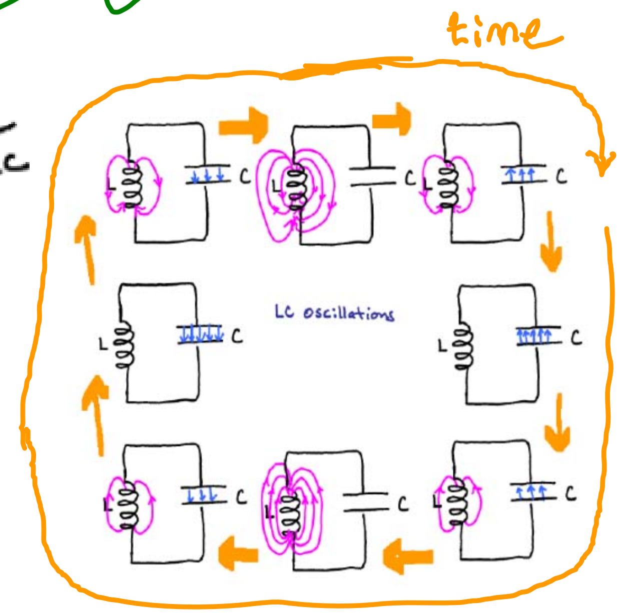
LC Oscillations



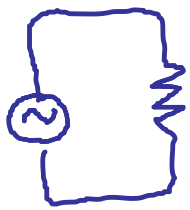
$$\frac{q^2(t)}{2C}$$

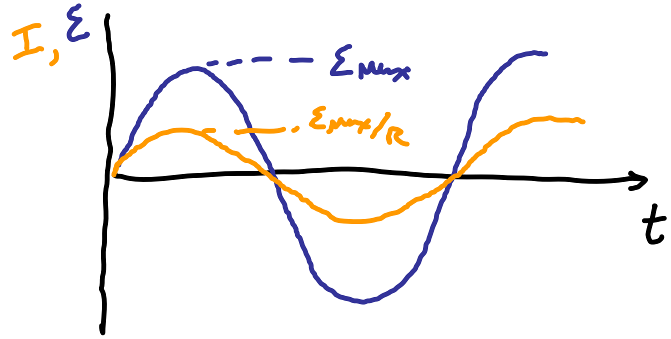
$$\frac{L\,i^2(t)}{2}$$

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{LC}$$



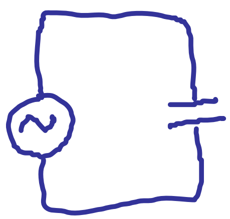
AC circuits





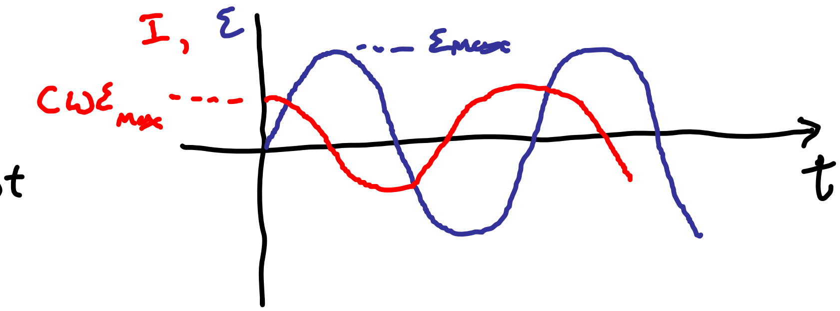
$\mathcal{E} = IR$

so I in phase w/ $\mathcal{E}$



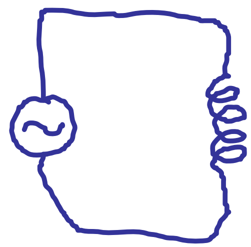
$Q = C\mathcal{E} = C\mathcal{E}_{max}\sin\omega t$

$I = \frac{dQ}{dt} = C\omega\mathcal{E}_{max}\cos\omega t$



$I \frac{1}{\omega C} \sim \mathcal{E}$

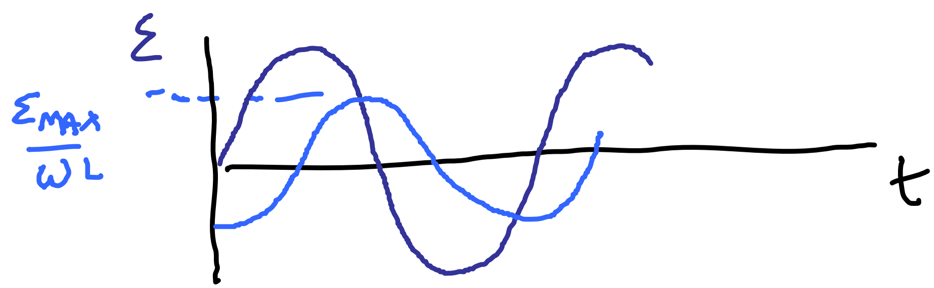
"Resistance" - Capacitive Reactance X_c



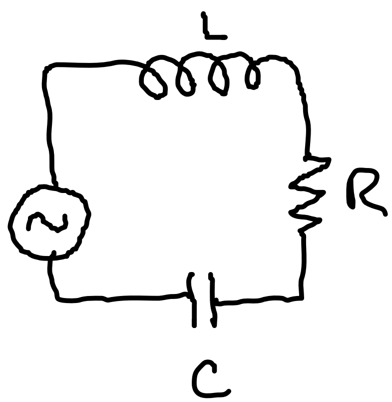
$$\mathcal{E} = -L\, di/dt$$

$$I = -\frac{\mathcal{E}_{max}}{\omega L} \cos \omega t$$

$$I \underbrace{\omega L}_{\text{Inductive Reactance } X_L} \sim \mathcal{E}$$



LRC circuit



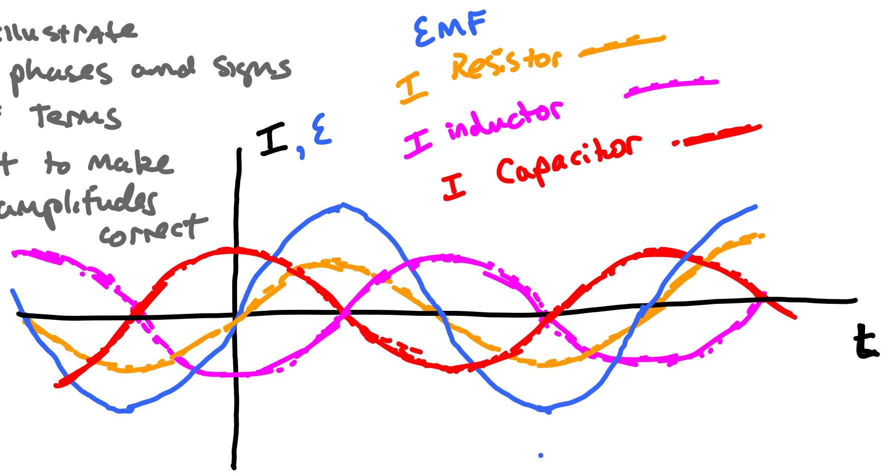
$$\mathcal{E} = \mathcal{E}_{max} \sin \omega t$$

Assume $I = I_{max} \sin(\omega t + \phi)$

? ?

Graph to illustrate relative phases and signs of EMF Terms

No attempt to make relative amplitudes correct



$$\mathcal{E} = \underbrace{\Delta V_R}_{R I_{max} \sin(\omega t + \phi)} + \underbrace{\Delta V_c}_{X_c I_{max} \cos(\omega t + \phi)} + \underbrace{\Delta V_L}_{-X_L I_{max} \cos(\omega t + \phi)}$$

often people use a graphical analysis with I and ε vectors rotating in a plane → phasors [see Ohanian p.1047]

I think earlier edition of Ohanian did a nice treatment using Math + Trig ID's → get

$$\tan\phi = \frac{X_L - X_C}{R}$$

$$I_{max} = \frac{\mathcal{E}_{max}}{\left\{\left[\sqrt{R^2 + (X_L - X_C)^2}\right]\right\}}$$

Impedance $\equiv Z$

plays the Role of Resistance in LRC circuit

$\circlearrowleft \to$ EMF has ω

what happens if $\omega \to \omega_0 = \frac{1}{\sqrt{LC}}$

$X_L = \omega L$

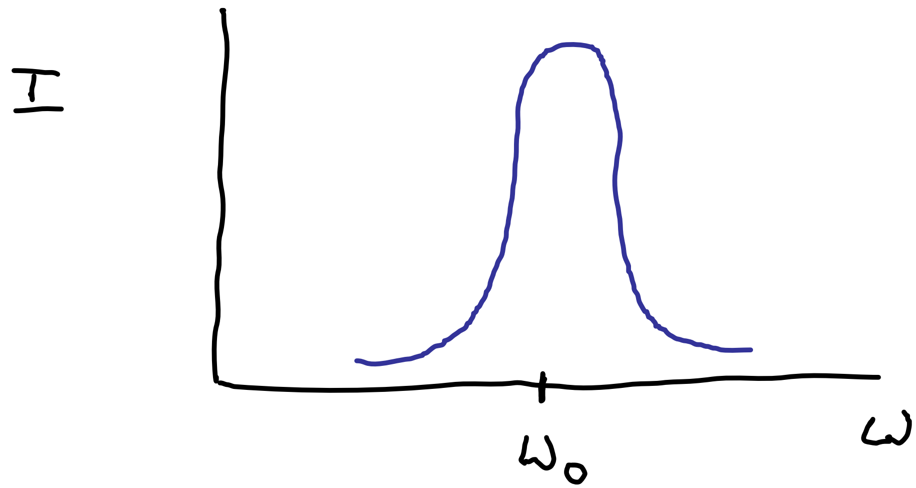
$X_C = \frac{1}{\omega C}$

$$\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} \to 0 \text{ as } \omega \to \omega_0$$

$\frac{1}{\sqrt{LC}}$

$\frac{L}{\sqrt{LC}} = \sqrt{L/C}$

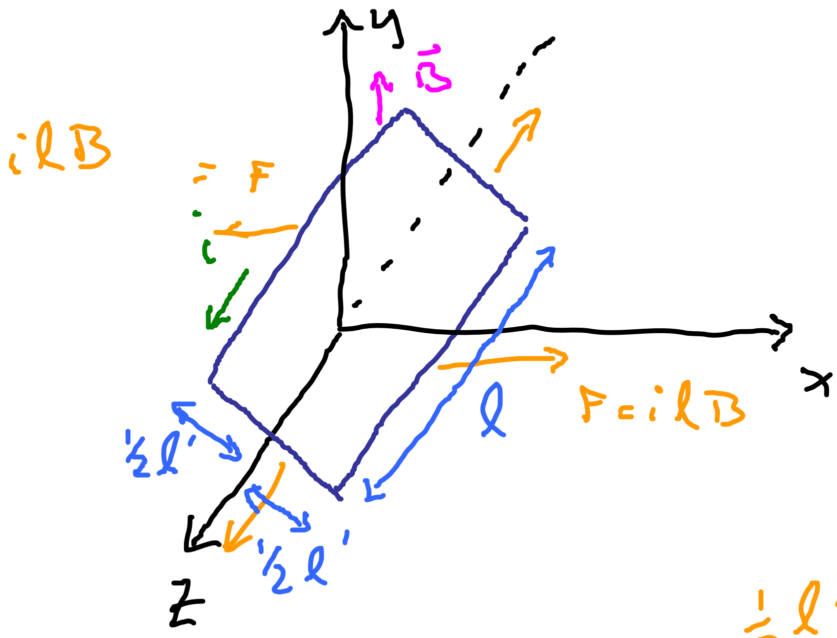
$\frac{\sqrt{LC}}{C} = \sqrt{L/C}$

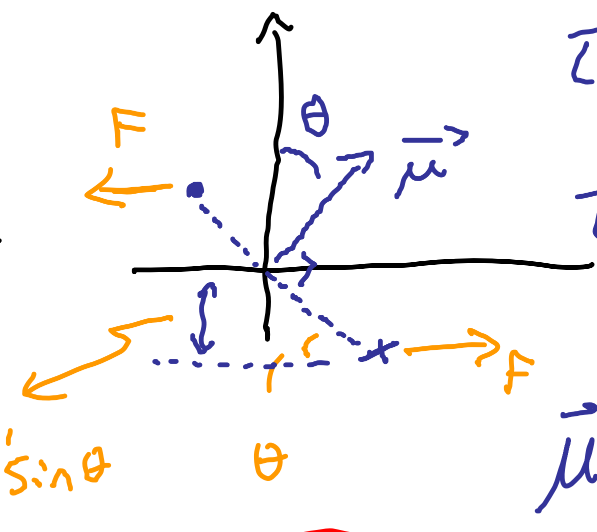


Resonance

Magnetic Fields in Matter

rectangular current loop
free to rotate at z axis





$$\tau = 2F\,\frac{1}{2}\ell' \sin\theta$$

$$\tau = i\underbrace{\ell\ell'}_{A}\sin\theta\, B$$

$$\vec{\mu} = iA\hat{n}$$

$$\mu = iA$$

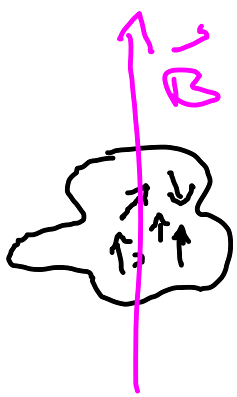
$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

Magnetism in Materials

Paramagnetic Materials

natural Dipoles

Random direction

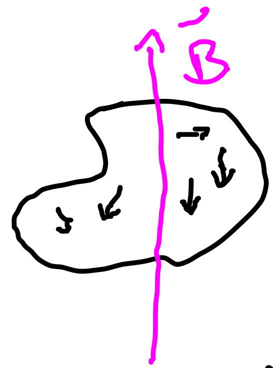


Torques cause Alignment

$\vec{B}$ increased

Diamagnetic materials

No inherent dipoles



induced dipoles oppose $\vec{B}$

$\vec{B}$ weakened

Ferromagnetic Materials

local domains

Strong dipoles

$\vec{B}$ increased

$$B_{\text{in Material}} = \boxed{\mu_0 \left(\boxed{1 + \underbrace{\chi_m}_{\equiv \text{Magnetic Susceptibility}}} \right)} B_{\text{external or "free"}}$$

Relative Permeability $\equiv K_m$

$\mu_0 K_m$
$\equiv$ Permeability, μ

Hysteresis loop