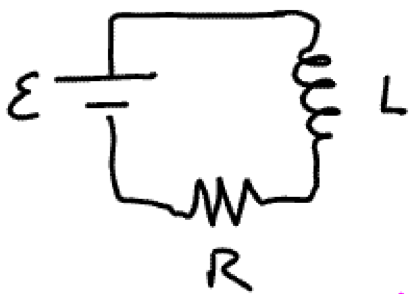
Physics 142 – November 6, 2008

- Exam Thurs. Nov. 13, 2008 class time Hoyt
  3x5 index card okay
  Expect formula sheet
- Q+A session Monday?

Last Time –

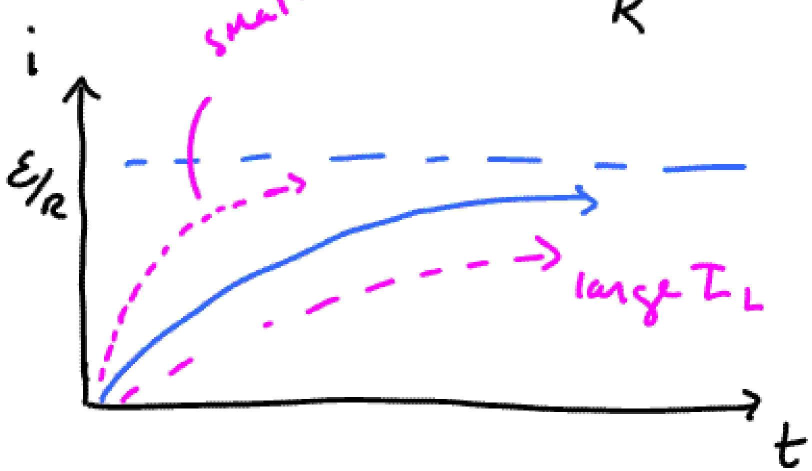
LR circuit

AT START of mp3 Audio file I mistakenly said this is the Nov 13 lecture ... meant to say Nov 6



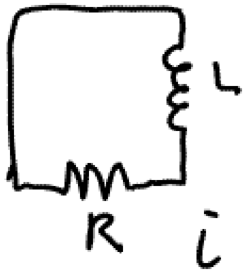
A

$$i = \frac{\varepsilon}{R}\left(1 - e^{-tR/L}\right) = \frac{\varepsilon}{R}\left(1 - e^{-t/\tau_L}\right)$$

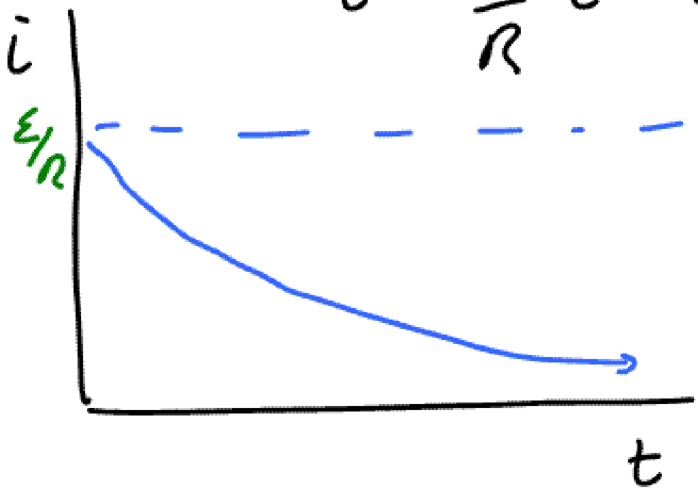


Induction time constant

$$\frac{L}{R} = \tau_L$$

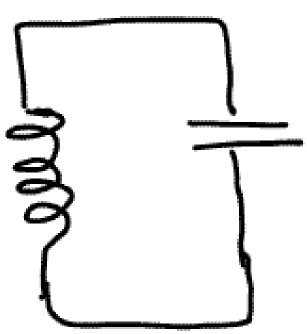


$$i = \frac{\mathcal{E}}{R} e^{-t/\tau_L} = i_0 e^{-t/\tau_L}$$



LC circuit

$$U = U_B + U_E = \frac{1}{2}Li^2 + \frac{q^2}{2C} \quad \text{(B)}$$



Look at $\frac{dU}{dt}$

$$\underbrace{0 = L\frac{d^2q}{dt^2}}_{\text{diff eqn}} + \frac{q}{C} \quad \text{(C)}$$

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

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

HARMONIC

Energy flow

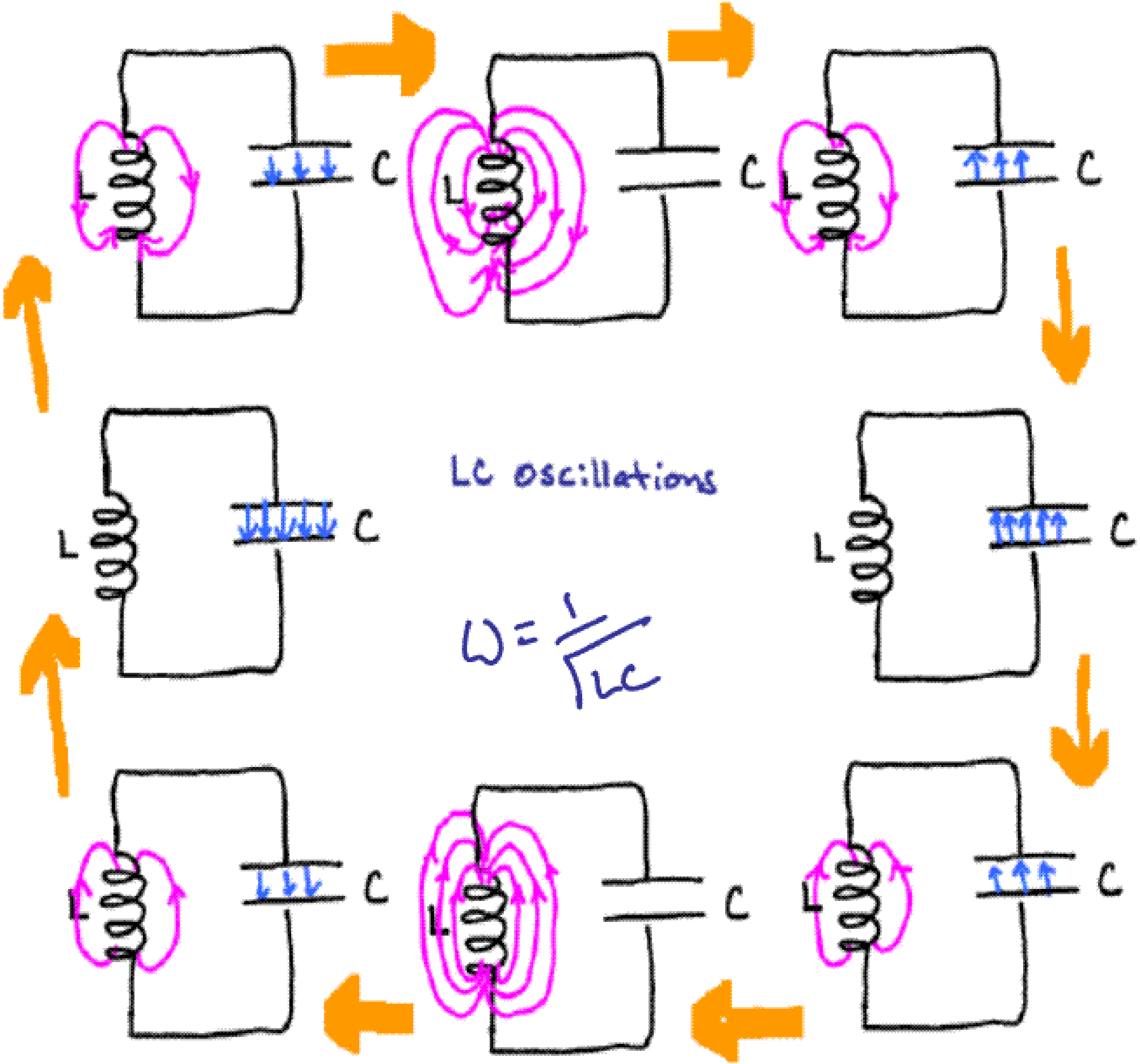
$$U_E = \frac{q^2}{2C} = \frac{Q^2}{2C}\cos^2(\omega t + \varphi) \quad \text{A}$$

$$U_B = \frac{1}{2}Li^2 = \frac{L}{2}Q^2\omega^2\sin^2(\omega t + \varphi) \quad \text{B}$$

Energy flows from capacitor to inductor + back
(E field) (B field)

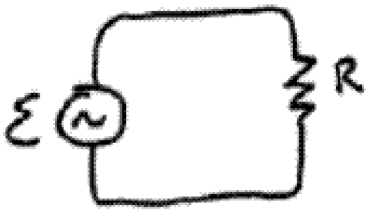
LC oscillations

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



~ follows Ohanian's Treatment

AC Circuits



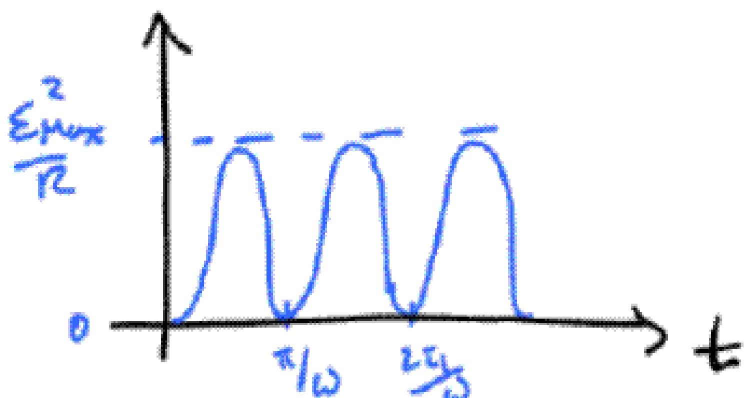
$$\mathcal{E} = \mathcal{E}_{max} \sin \omega t$$

Kirchoff $\quad \mathcal{E} - IR = 0$

$$I = \frac{\mathcal{E}}{R} = \frac{\mathcal{E}_{max} \sin \omega t}{R} \quad \text{(A)}$$

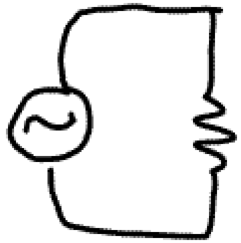
Instantaneous power dissipation

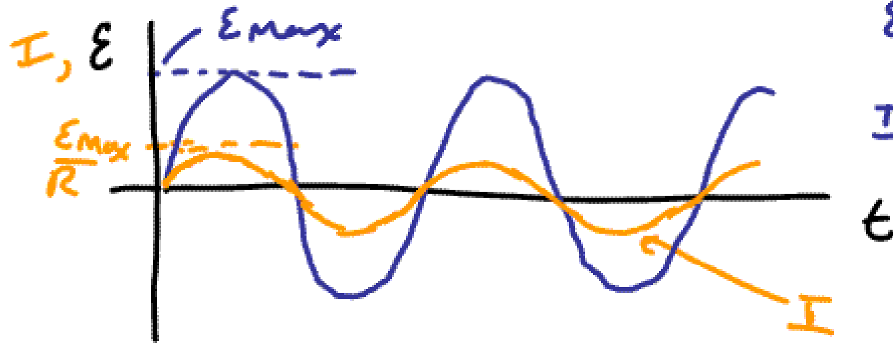
$$P = IV = I\mathcal{E} = \frac{\mathcal{E}_{max}^2}{R} \sin^2 \omega t$$



$\overline{\sin^2\theta} \to \frac{1}{2}$

Ave power $\boxed{\bar{P} = \frac{\mathcal{E}_{max}^2}{2R}}$





In phase

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

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

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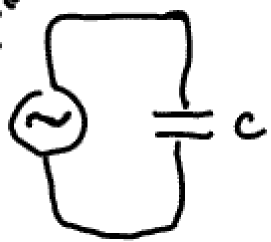
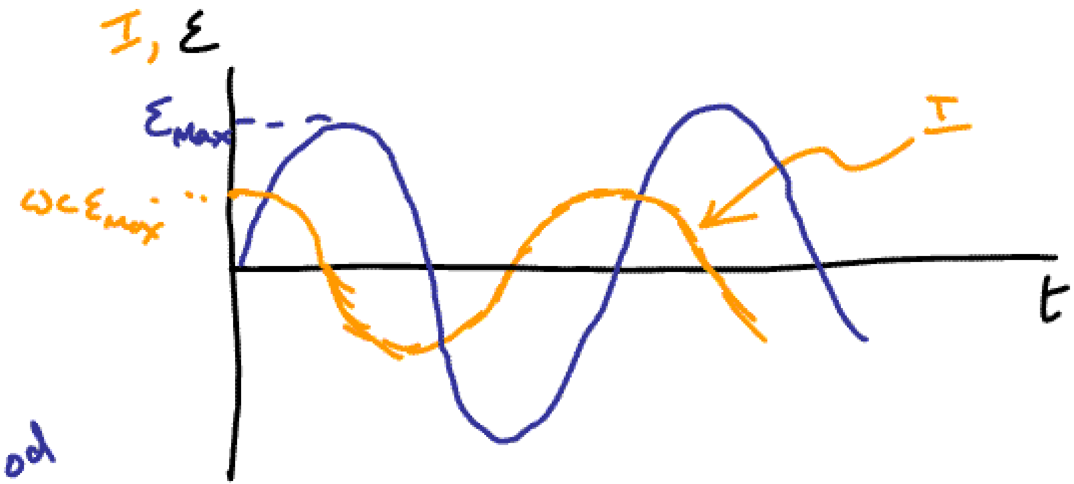
$\mathcal{E} = \mathcal{E}_{max} \sin \omega t$



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

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

A



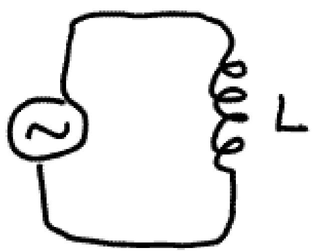
I "leads" EMF by 1/4 period cycle

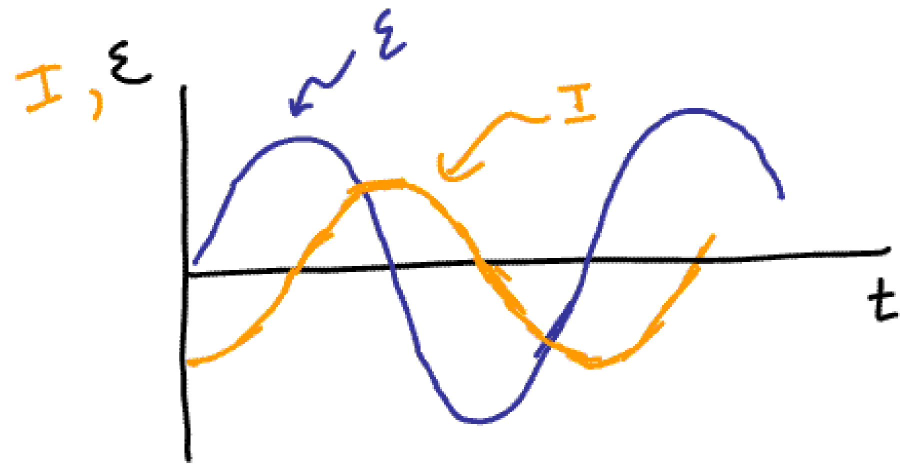
$V \sim IR$

$$\boxed{\frac{1}{\omega C}} I = \mathcal{E}_{max} \cos\omega t$$

plays role of Resistance in capacitive AC circuit

$X_c \equiv$ Capacative Reactance





$$\mathcal{E} - L\frac{dI}{dt} = 0$$

$$\frac{dI}{dt} = \frac{\mathcal{E}_{max} \sin\omega t}{L}$$

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

I "lags" EMF by $\frac{1}{4}$ cycle

$\omega L \equiv X_L \equiv$ Inductive Reactance

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

Think $V = IR$

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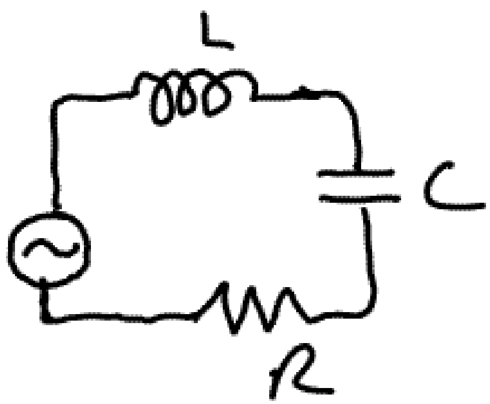


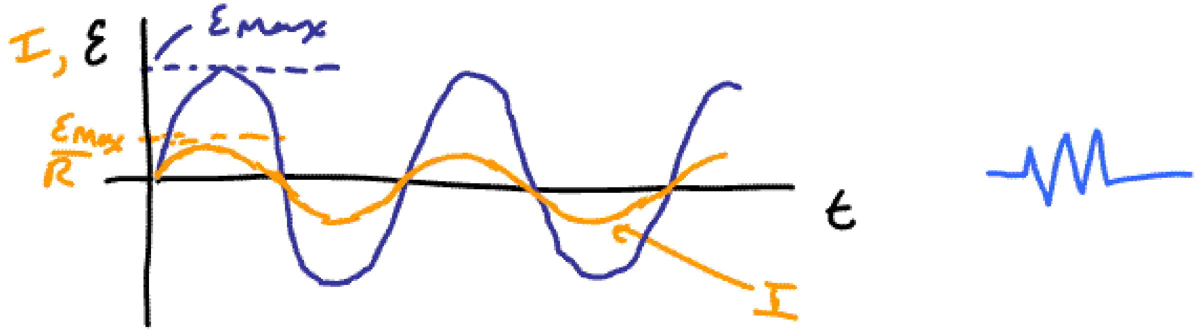
LRC circuit

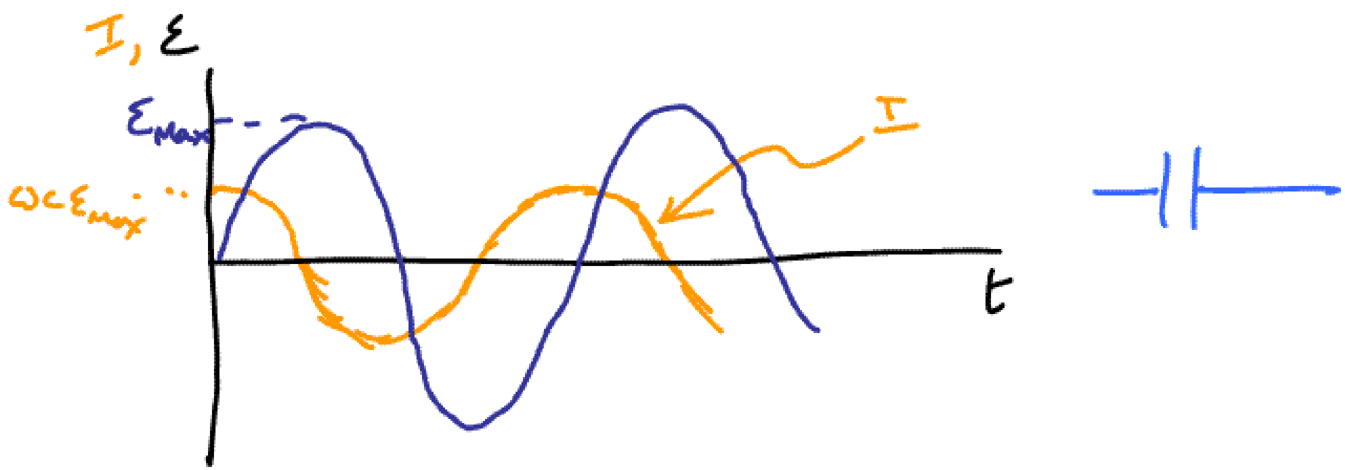
$\mathcal{E} = \mathcal{E}_{max} \sin \omega t$

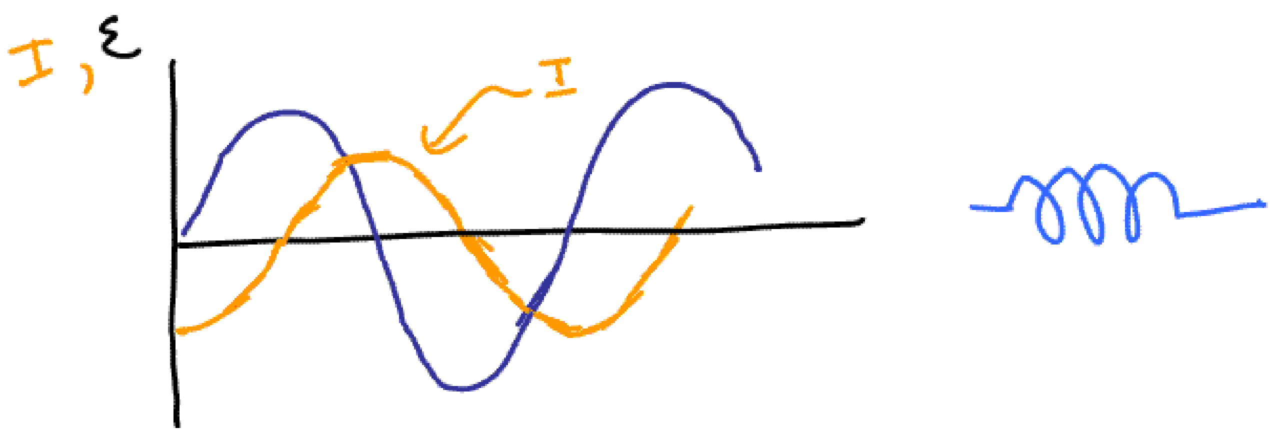
phase ?

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

?

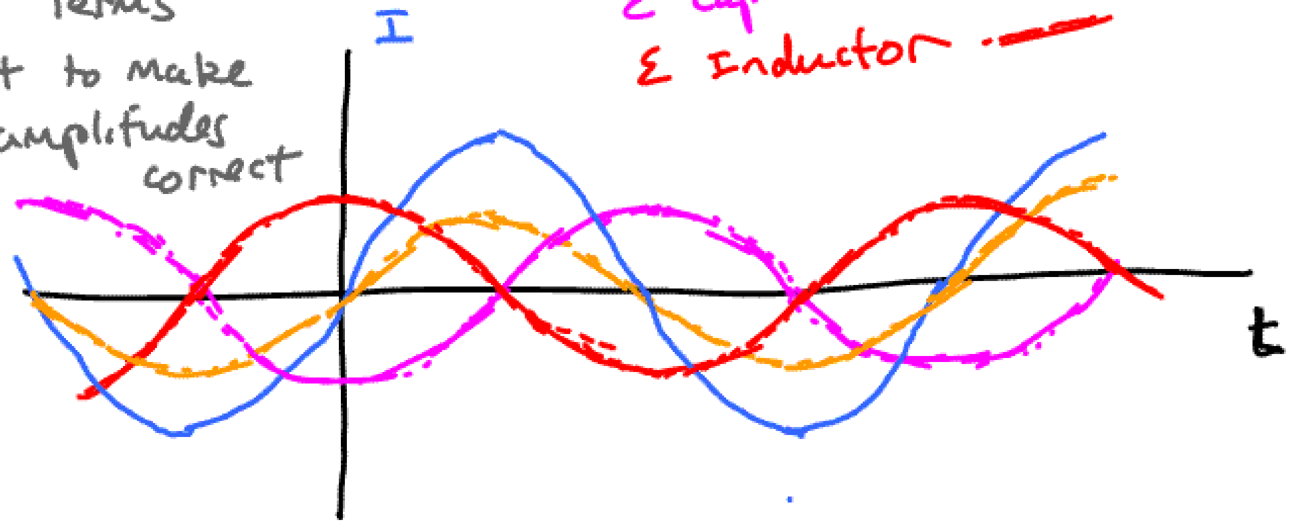

I, ε
εmax
εmax/R
t
I


I, ε
εmax
ωCεmax
I
t


I, ε
I

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 $\mathcal{E}$ 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

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

$$I_{Max} = \frac{\mathcal{E}_{Max}}{\sqrt{R^2 + (X_L + X_C)^2}}$$

plays Role of "R" in LRC circuit

$\equiv$ Impedance $\equiv Z$

(A) $\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

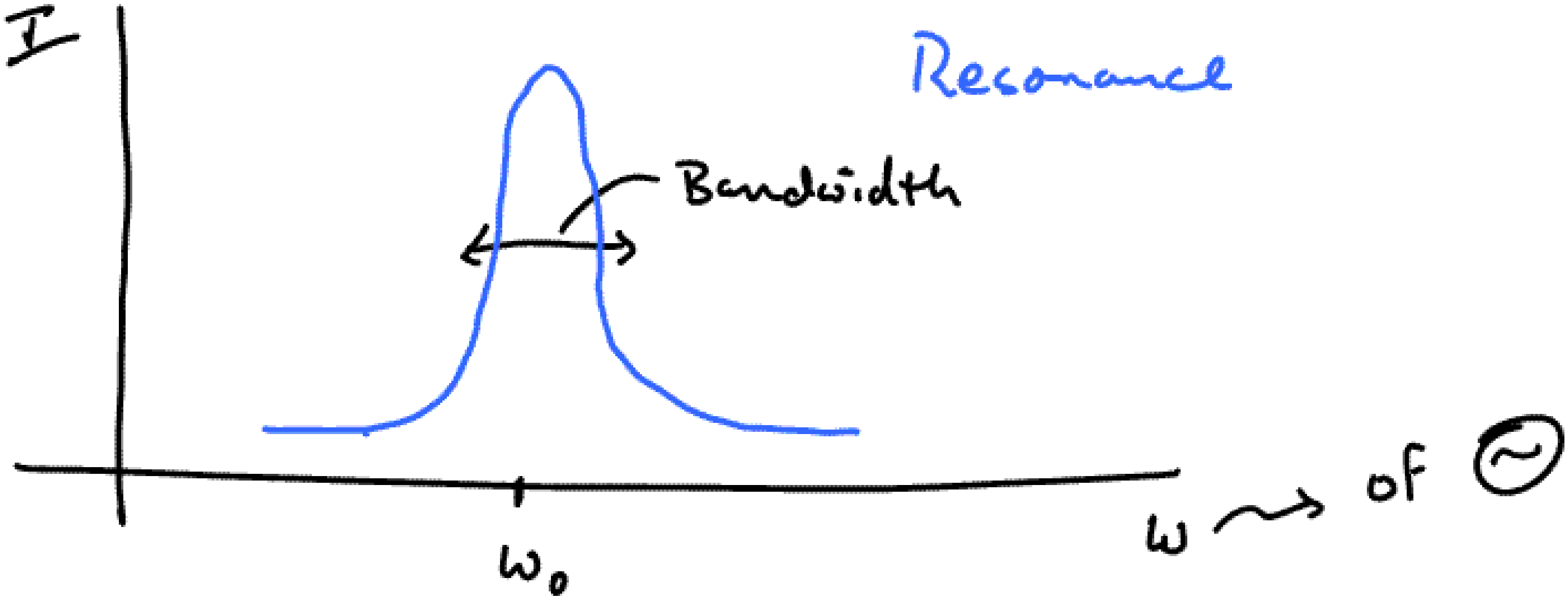
have (~) at freq ω

look at $\omega \to \omega_0 = \frac{1}{\sqrt{LC}}$

$$Z \to \sqrt{R^2 + \Big(\underbrace{\frac{L}{\sqrt{LC}} - \frac{\sqrt{LC}}{C}}_{\to 0}\Big)^2}$$ (B)

$\to$ Maximizes I

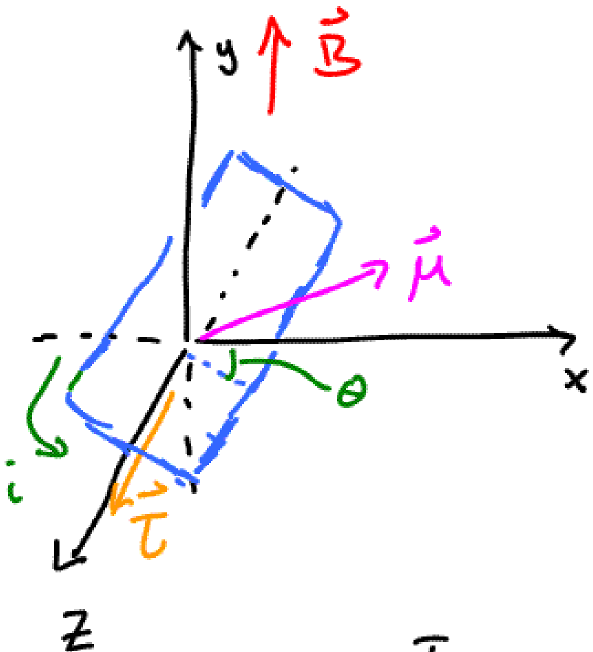
Resonance

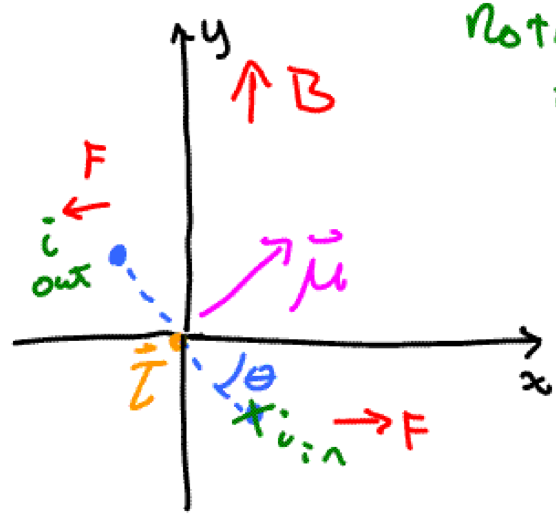


can imagine how useful this might be

Radio tuner for example ...

Magnetic fields in matter





Axis of Rotation is z-Axis

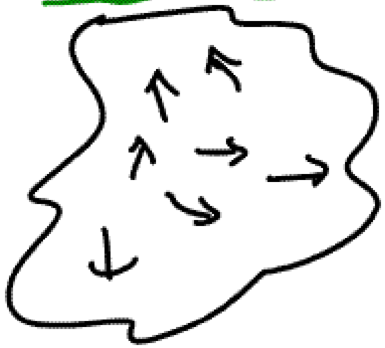
Torque on current loop = $\boxed{\vec{\mu}\times\vec{B} = \vec{\tau}}$
Dipole

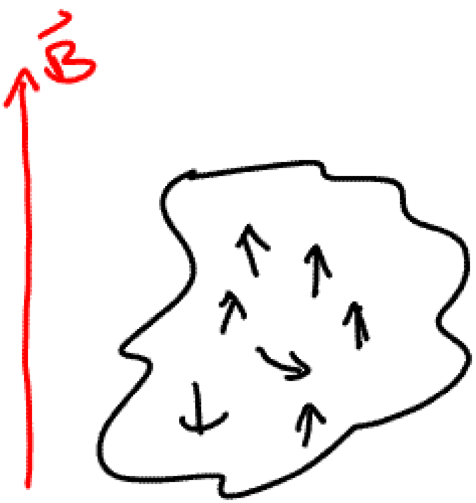
Dipole magnetic field

cross sect. Area of loop

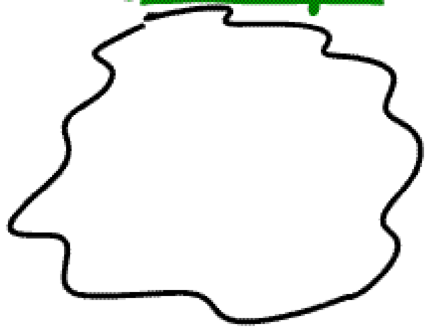
Define Magnetic Moment of current loop $\equiv I A = |\vec{\mu}|$

Paramagnetic



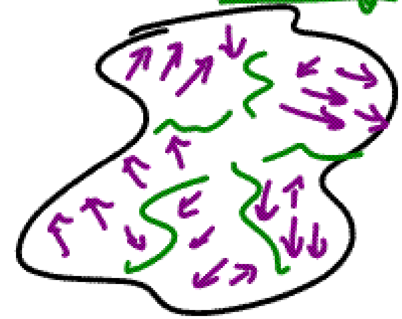


Diamagnetic



No Dipole

Ferromagnetic



Will come back to this . . .