Physics 142 - November 4, 2008

Election day
Happy

- Lecture Thursday - online PDF + Mp3
  class will NOT be meeting

- Exam 2 - Week from Thursday
  HoyT - During normal lecture time

Lecture: OcT 2 (dielectrics) — OcT 30 (inductance)

LR, LC circuits, AC circuits + beyond NOT on Exam 2

TexT: chapters 26 (Dielectrics), 27 - 31, 36

but NOT section 31.6 on LR circuits

Prob Sets: P.S. 4 (probs 13-15), P.S. 5-9

Workshops: Workshops 5-9

Induction

Last Time

$$\mathcal{E} = \oint \vec{E} \cdot d\ell = -\frac{d\phi_M}{dt}$$

Induced EMF

$$\phi_M \equiv \int_{loop} \vec{B} \cdot d\vec{A}$$

Faraday's Law

Lenz's Law – An induced current in a closed conducting loop will appear in such a way as to oppose the change that created it.

Gives direction of induced effect

$$\phi_m = L i$$

$L \equiv$ constant of self-inductance

$$\mathcal{E} = -\frac{d\phi_m}{dt} = -L\frac{di}{dt}$$

 $\equiv L$

units Henrys

$$\boxed{\mathcal{E} = -L\frac{di}{dt}}$$

$$\phi_{m_{2}} = M i_{1}$$

$$\phi_{m_{1}} = M i_{2}$$

same "M" cross-talk dictated by geometry

$M \equiv$ constant of mutual inductance

$$\mathcal{E}_{2 \text{ by } 1} = -M\frac{di_1}{dt}$$

$$\mathcal{E}_{1 \text{ by } 2} = -M\frac{di_2}{dt}$$

unless problem is specifically about mutual inductance ... usually treat inductance in a circuit as self-inductance

Energy density in the fields:

$$\boxed{u_E = \frac{\epsilon_0 E^2}{2}} \quad \boxed{u_B = \frac{B^2}{2\mu_0}}$$

general — say nothing about circuits or sources or boundary conditions!

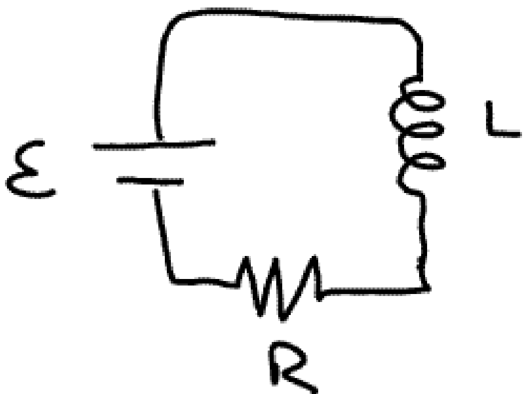
Energy in Inductor

$$U = \frac{1}{2} L I^2$$

similar to $U_{capacitor} = \frac{1}{2} C V^2$

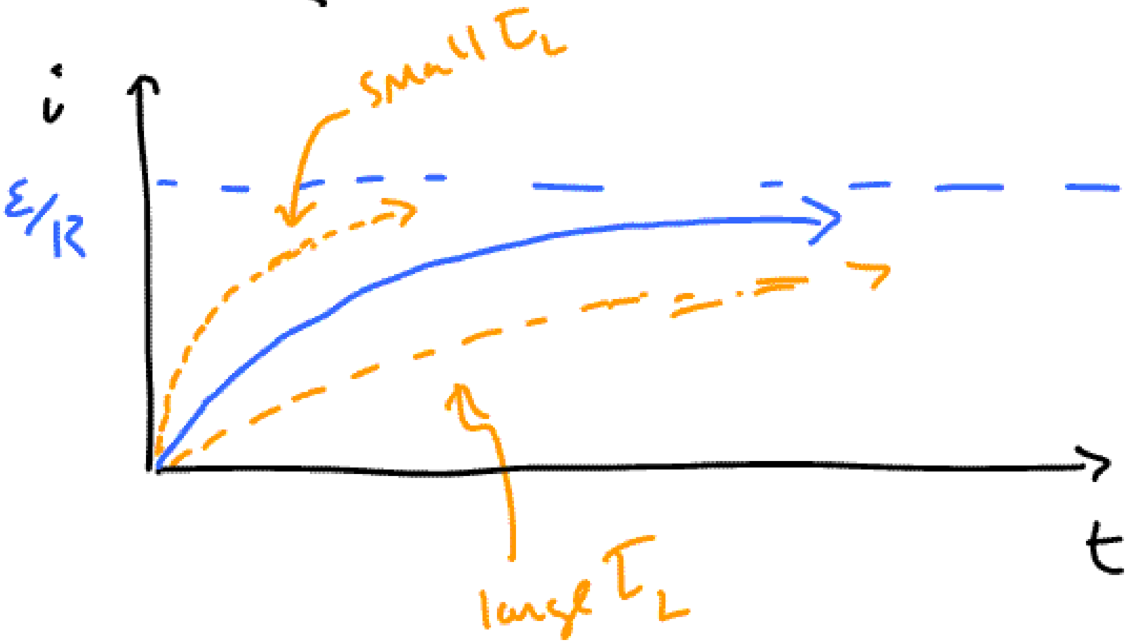
LR circuit

$\Sigma V = 0$ around circuit



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

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

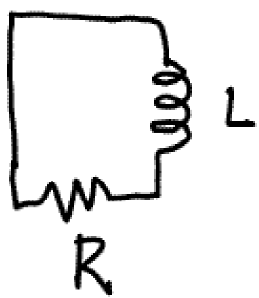


Inductive time constant $\equiv \tau_L = \frac{L}{R}$

$V = iR$ (v across R)

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

at some large t later, short L across R

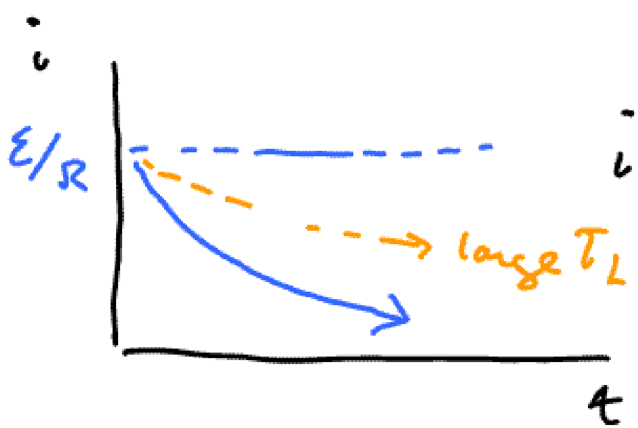


$$0 = iR + L\frac{di}{dt}$$

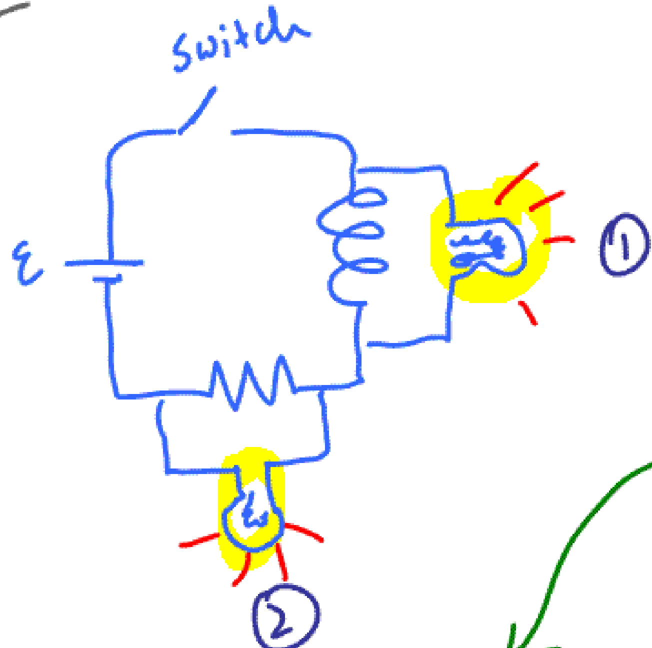
after i reaches asymptotic value of ε/R

$$i = \frac{\varepsilon}{R} e^{-t/\tau_L}$$

$$i = i_0 e^{-t/\tau_L}$$



Demo



did demo -

Turn switch on
what happens to
light bulbs?

Turn switch off
What happens
to light bulbs?

early time

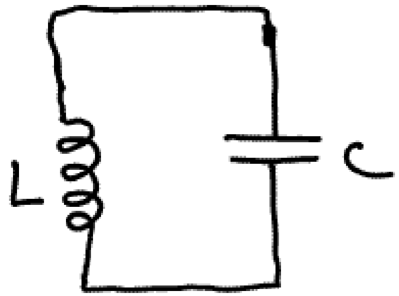
Switch on $\quad i = 0, \frac{di}{dt}$ big $\rightarrow$ 2 off 1 bright

Some time later i increases 2 gets brighter

$\frac{di}{dt}$ less 1 dims

LC circuit

imagine that capacitor is fully charged at $t=0$



$R \to 0$

$$U = U_E + U_B = \frac{q^2}{2C} + \frac{Li^2}{2}$$

$$\frac{1}{2}CV^2 = \frac{1}{2}\frac{q^2}{C}$$

$$\frac{dU}{dt} = 0 = \frac{2q}{2C}\frac{dq}{dt} + \frac{L}{2}2i\frac{di}{dt}$$

$$\frac{dq}{dt}$$

$$0 = L\frac{di}{dt} + \frac{q}{C}$$

SHM

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

$$m\frac{d^2x}{dt} = -kx \qquad \underbrace{m\frac{d^2x}{dt^2} + kx = 0}$$

$\hookrightarrow$ SHM $\omega = \pm\sqrt{\frac{k}{M}}$

SHM in $q(t)$ w/ $\omega \sim \pm\frac{1}{\sqrt{LC}}$

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

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

$$i = \frac{dq}{dt} = -\omega Q\sin(\omega t + \phi)$$

Look at energy flow ...

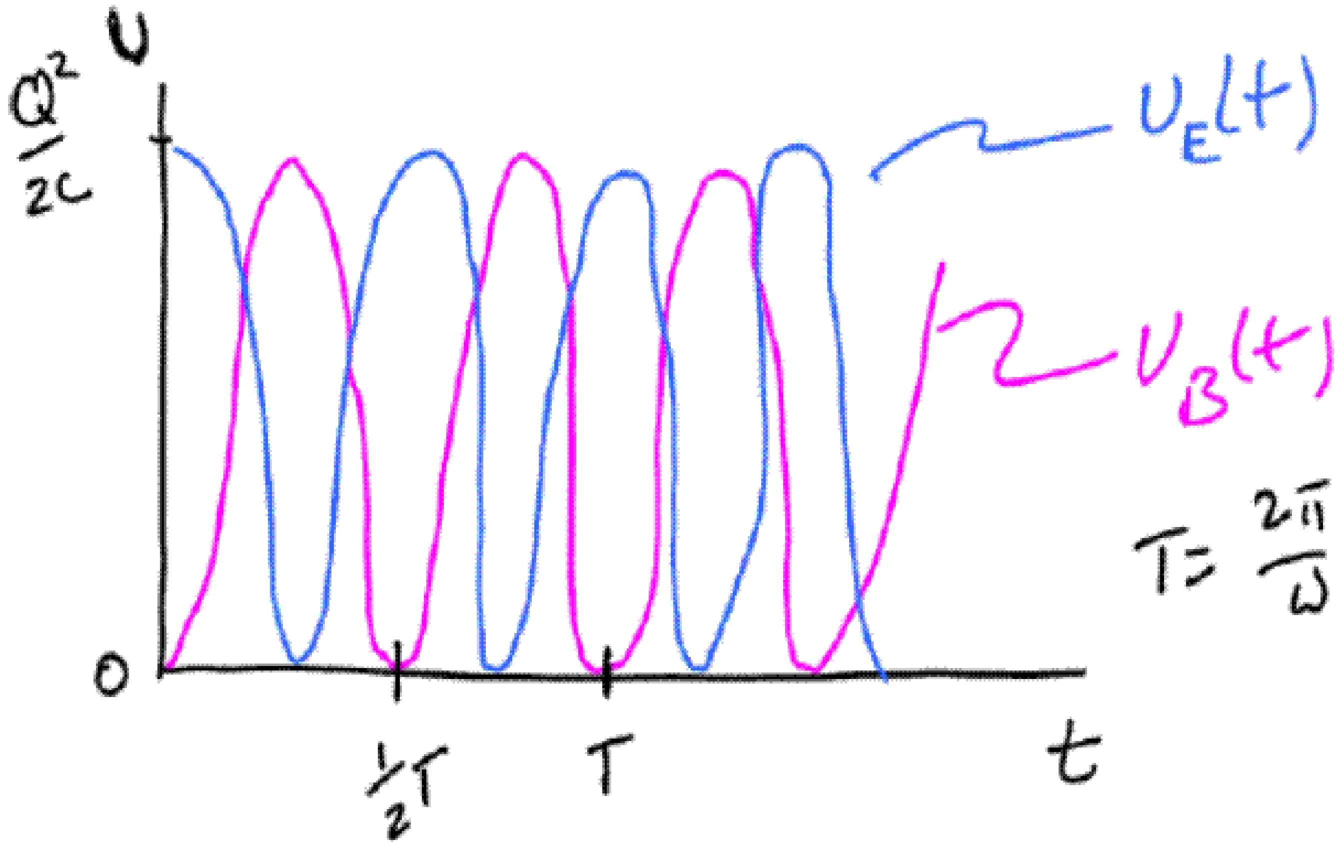
$$U_E = \frac{q^2}{2C} = \frac{Q^2}{2C}\cos^2(\omega t + \phi)$$

Energy in capacitor stored as $\vec{E}$ field

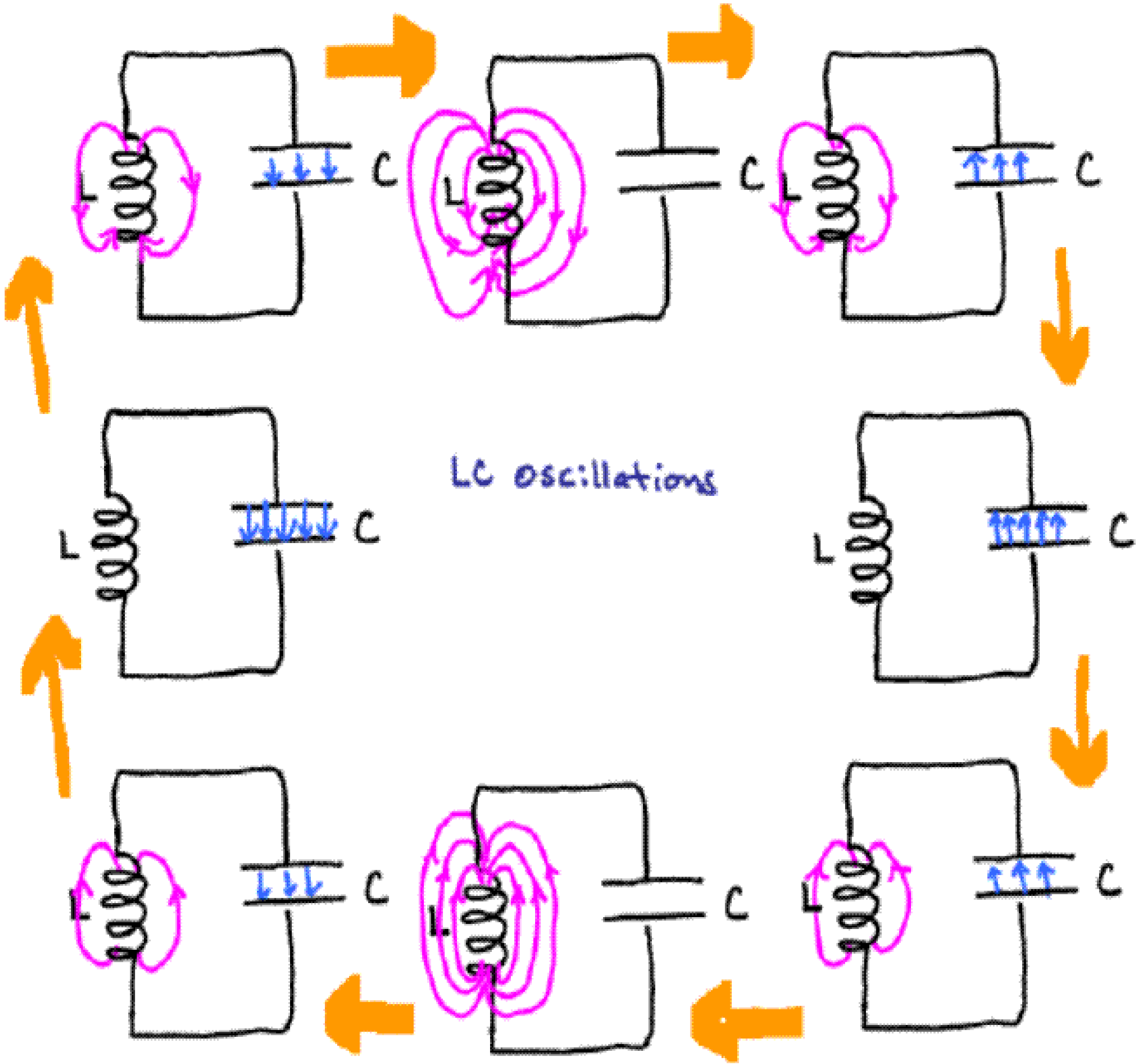
$$U_B = \frac{1}{2}Li^2 = \frac{L}{2}Q^2\omega^2\sin^2(\omega t + \phi)$$

Energy stored in B field in inductor

LC Oscillations



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


LC oscillations
L
C