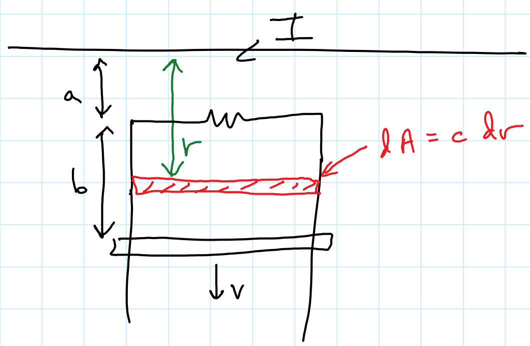
Phy 4B 6/20

Tuesday, June 20, 2017 5:33 PM

Goals for the Lecture:

1) Understand energy oscillations in LC circuits, including the natural frequency of the circuit, and be able to solve problems using energy conservation
2) Conceptually understand that RLC circuits are like damped harmonic oscillators
3) Understand that rms values are a type of "average" value used in AC circuit calculations and that, for sin and cos functions, the rms value is the maximum value divided by $\sqrt{2}$
4) Understand that capacitors and inductors can hinder the flow of electrons in a circuit and that we call this property reactance. Understand how the reactance changes with frequency for capacitors and inductors. Be able to solve circuit problems in the limit as the frequency goes to zero and as the frequency goes to infinity.
5) Understand transformers, the turns ratio, step up and step down transformers and be able to solve problems involving transformers.

From exam:



$$\mathcal{E} = \frac{d}{dt}\left[\int \vec{B}\cdot d\vec{A}\right] = \frac{d}{dt}\left[\int_a^{a+b} \frac{\mu_0 I}{2\pi r}\, c\, dr\right]$$

$$= \frac{d}{dt}\left[\frac{\mu_0 I c}{2\pi} \ln\left(\frac{a+b}{a}\right)\right]$$

both changing in time

so, chain rule

$$= \frac{\mu_0 c}{2\pi}\left[\frac{dI}{dt}\ln\left(\frac{a+b}{a}\right) + I \frac{d}{dt}\ln\left(\frac{a+b}{a}\right)\right]$$

($I \to 0$) at $t = 4s$, $I = 0$

$I = 32 - 2t^2$

$I' = -4t$

$$= \frac{\mu_0 c}{2\pi}\left[4t \ln\frac{a+b}{a} + 0\right]$$

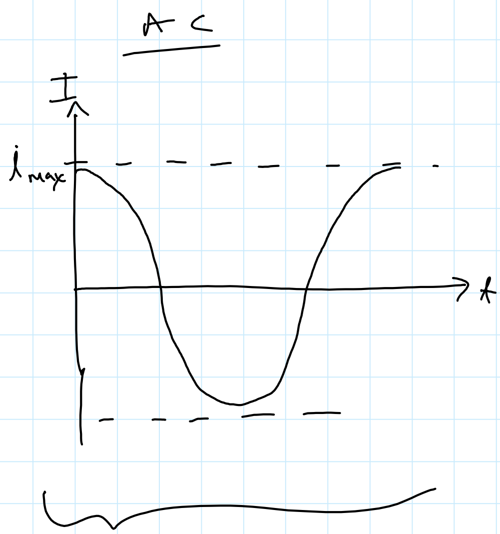
$$= \frac{8\mu_0 c}{\pi} \ln\left(\frac{a+b}{a}\right)$$

AC circuits

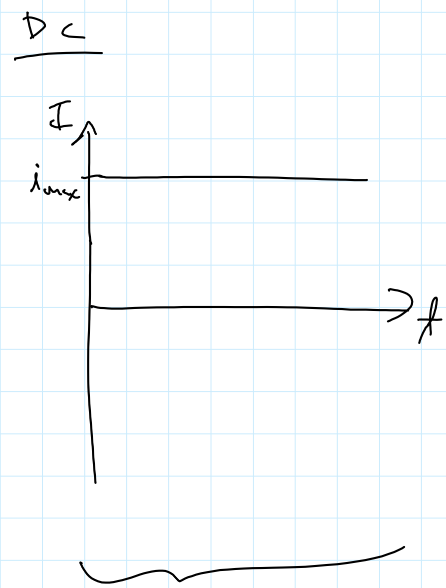
Power in a resistor:

$$P = i^2 R$$

(i ← instantaneous current)



much of the time the current is below i_{max}



current is always at i_{max}

RMS - root-mean-square

$$I_{rms} = \sqrt{\overline{i^2}}$$

For sin and cos: $I_{rms} = \frac{I_{max}}{\sqrt{2}}$

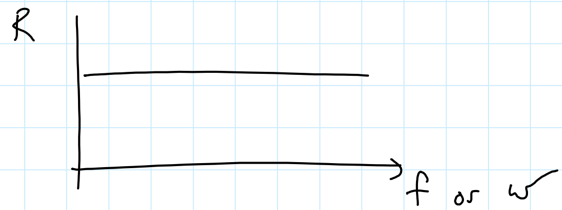
$$P_{ave} = I_{rms}^2 R$$

$$V_{rms} = \frac{V_{max}}{\sqrt{2}}$$

120 VAC → 120 V = V_{rms}

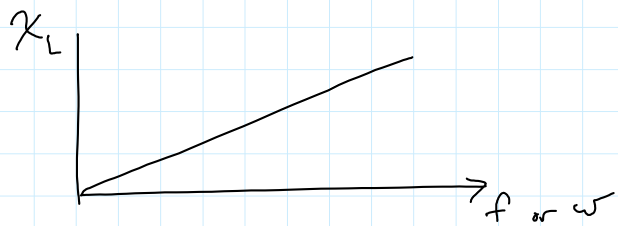
170 V = V_{max}

Resistor:



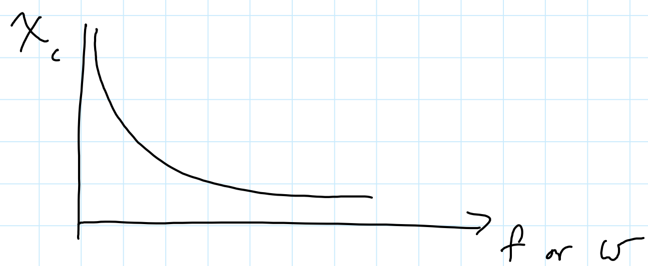
Inductor

$X_L = \omega L$

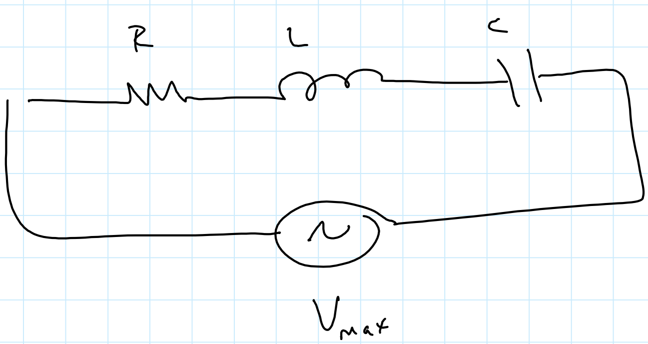


Capacitor

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



RLC circuit

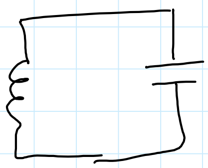


Impedance: $Z = \sqrt{R^2 - (X_L - X_C)^2}$

$$V_{max} = I_{max} Z$$

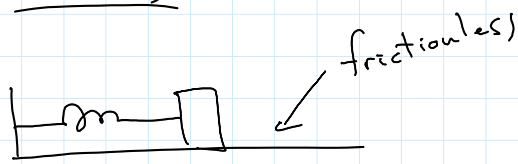
Resonance:

Circuit | **Analogy**



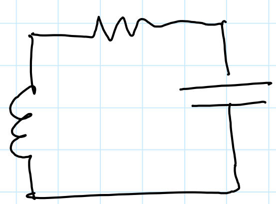
LC circuit

energy transferred back and forth between B & E fields

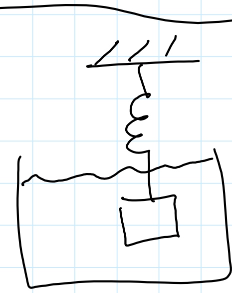


frictionless harmonic oscillator

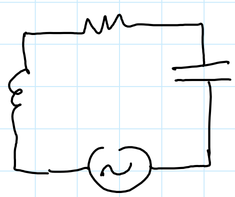
energy transferred back and forth between PE and KE



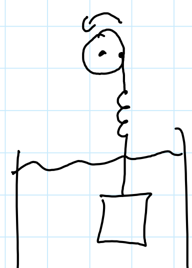
RLC circuit



damped harmonic oscillator



driven RLC circuit



driven, damped harmonic oscillator

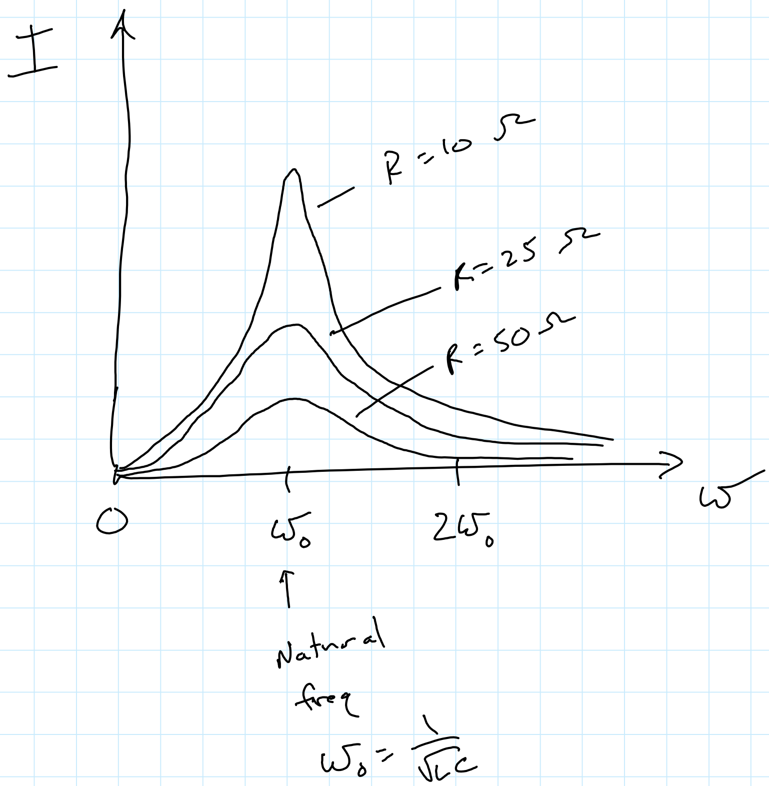
If the EMF oscillates with the Natural freq of the circuit $\left(\omega = \frac{1}{\sqrt{LC}}\right)$

the circuit responds with a large current

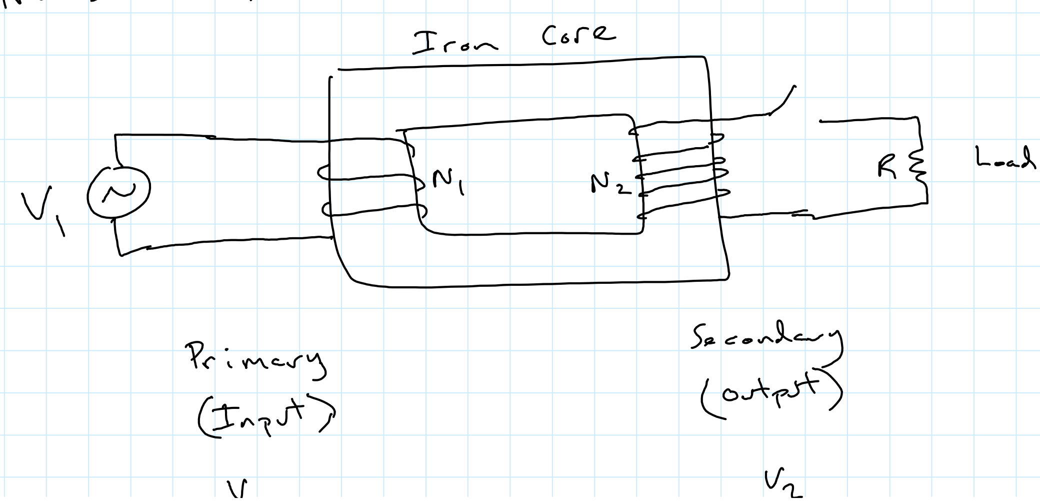
Like pushing someone on a swing

→ if you push with the Natural freq of the oscillator

the Amplitude becomes large



Transformers:



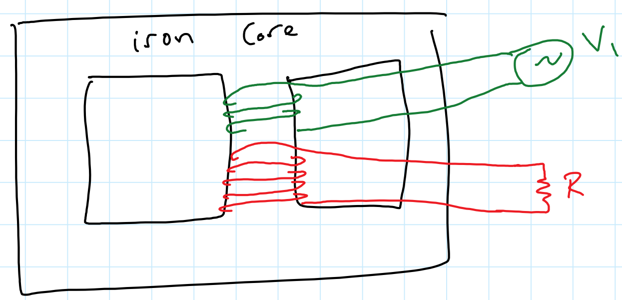
(Input)

V_1 $\qquad$ V_2

N_1 $\qquad$ N_2

Ideal transformer: No energy loss

Real world: 90-99 %



Let's look at Power:

$$P_1 = I_1 V_1 \quad \text{and} \quad P_2 = I_2 V_2$$

if ideal:

$$P_1 = P_2$$

$$I_1 V_1 = I_2 V_2$$

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

Since: $V_1 = -N_1 \frac{d\Phi_B}{dt}$

and $V_2 = -N_2 \frac{d\Phi_B}{dt}$

↑ Same for both

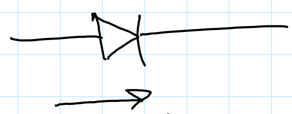
$$V_2 = \frac{N_2}{N_1} V_1 \qquad I_2 = \frac{N_1}{N_2} I_1$$

if Voltage goes up ↑ current goes down ↗

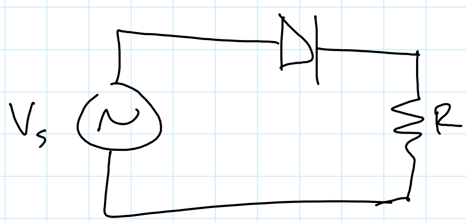
$$P_1 = P_2$$

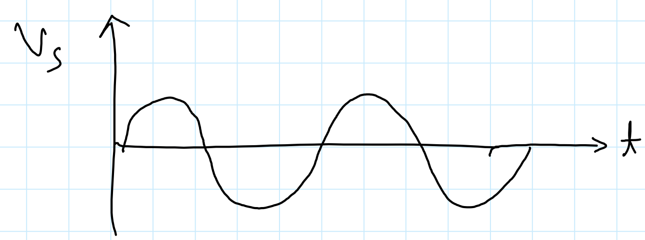
Rectifier: converts AC to DC

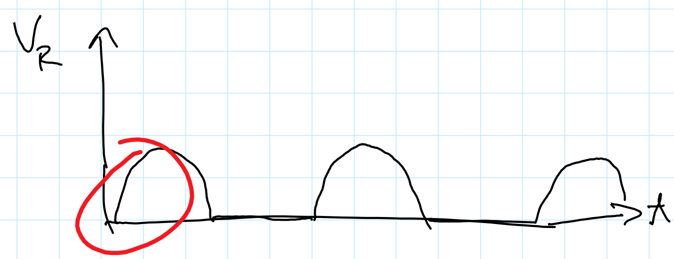
Diode: Like a one-way value for current



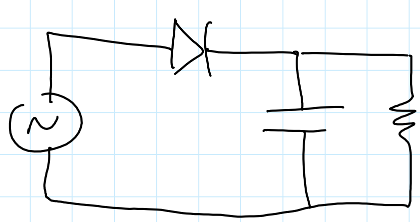
current can only flow this direction

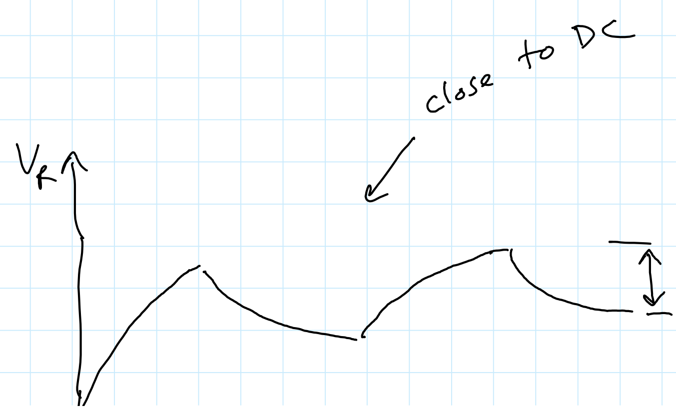


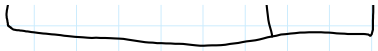


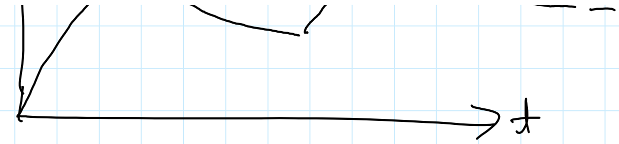


add a capacitor:

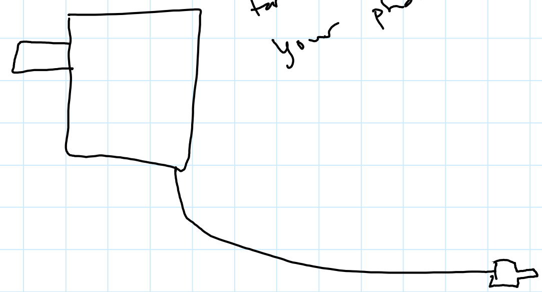


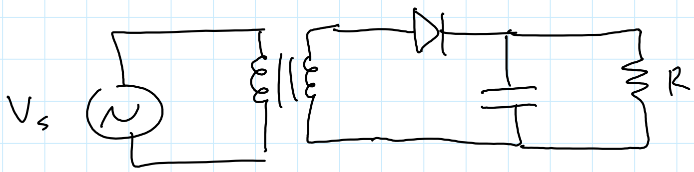






Include a transformer:





supply 120 V from wall outlet

step down transformer to the battery voltage (maybe 9V) but still AC

Approximate DC at desired voltage for your device

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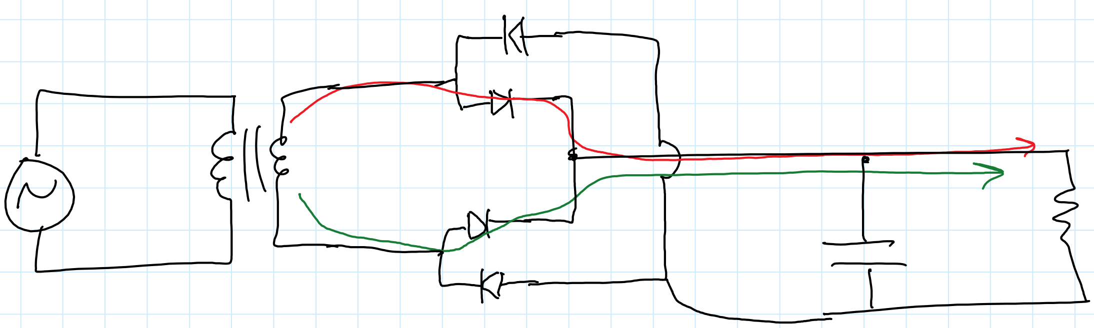
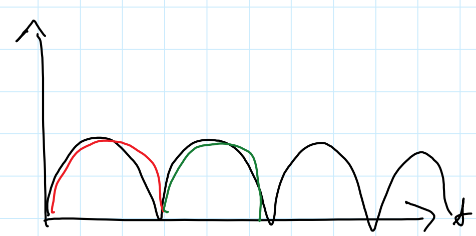
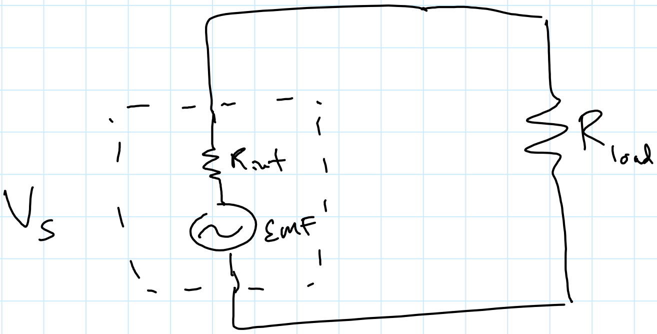
4 diodes are better:



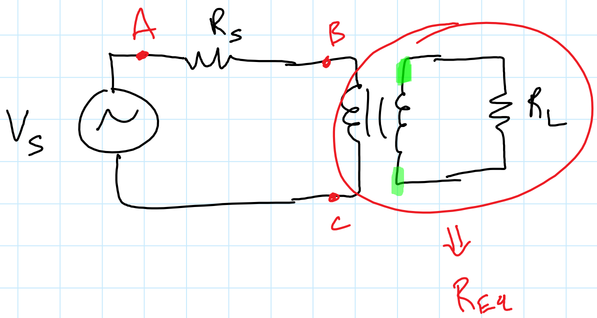
V_{cap}





when $R_{int} = R_{load}$
you get maximum power delivered to load

by choosing appropriate turns ratio a transformer can be used to match the load Resistance for max. power transfer:



$R_L = 50\ \Omega$ (load resistance)

turns ratio: $N_1 : N_2$ is $5:2$

$V_s = 80\ V_{rms}$

$V_L = 25\ V_{rms}$

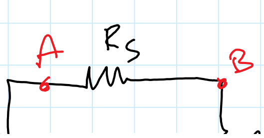
what is R_s? source internal resistance

Want current in Primary → use secondary current to find it:

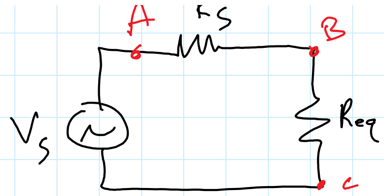
$V_L = I_2 R_L$

$I_2 = \frac{V_L}{R_L} = 0.5\ A$

$I_1 = \frac{N_2}{N_1} I_2 = 0.2\ A$



Voltage on Primary of transformer
↓
$\Delta V_p = V_1 = \frac{N_1}{N_2} V_2 = 62.5\ V$



$$\Delta V_{BC} = V_1 = \frac{N_1}{N_2} V_2 = 62.5\ V$$

$$V_s = V_{R_s} + V_{R_{eq}}$$

$$80 = I_1 R_s + 62.5$$

$$R_s = \frac{17.5}{0.2} = 87.5\ \Omega$$

Maxwell's Equations:

$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$$

Gauss's Law
→ charged particles create electric fields

$$\oint \vec{B} \cdot d\vec{A} = 0$$

Gauss's Law for Magnetism
→ there are No magnetic monopoles

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

Faraday's Law
→ a changing magnetic field creates an electric field

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

Ampere-Maxwell Law
1st part → currents create magnetic fields

2nd Part → Changing E fields create magnetic fields

we Need one more:

$$\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$$

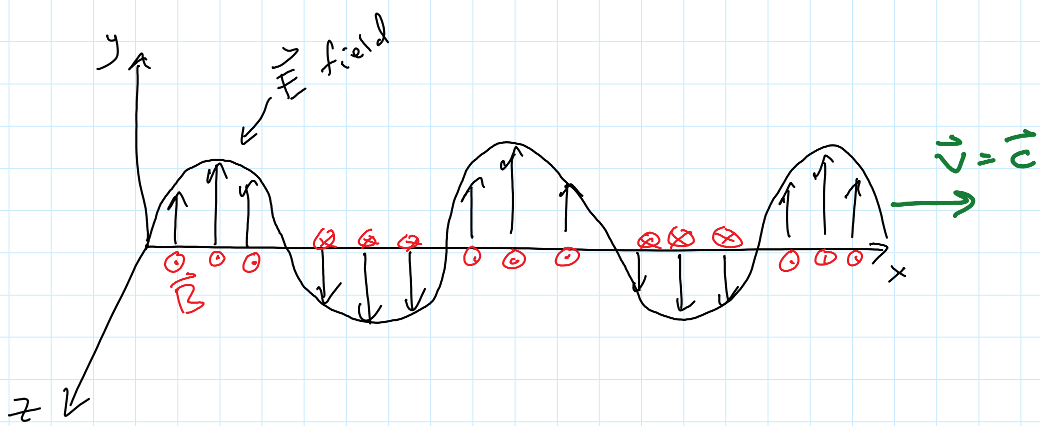
Lorentz Force Law

Classical Physics:

Phy 4A
- Newton's 1st Law
- " 2nd Law
- " 3rd Law
- " Law of gravity

Phy 4B
- Gauss's Law
- " " for mag.
- Faraday's Law
- Ampere - Maxwell Law
- Lorentz force Law

Phy 4C
- 1st Law of thermodynamics
- 2nd " " "



$$V = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3.00 \times 10^8 \ \frac{m}{s} = c$$

speed of light

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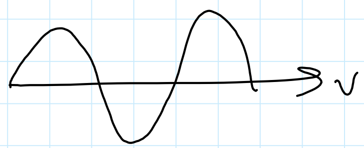
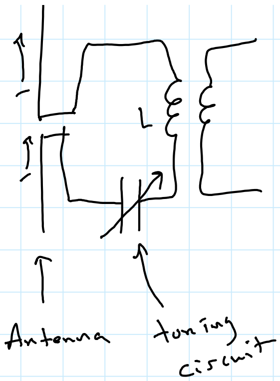
antenna:

E field signal

Antenna acts like a little voltage source





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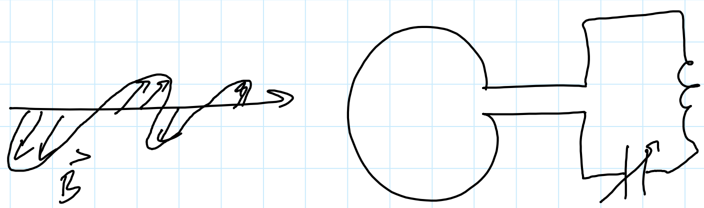

changing B field

Electro-magnetic Spectrum:

Radio waves microwaves Infrared visible light ultra-violet x-rays gamma rays

Low freq.	high frequency
Long wavelength	short wavelength
Low energy	high energy

speed of a wave: $v = \lambda f$

λ ← wavelength

f ← frequence

visible Light

Red orange yellow green blue violet

Red orang yello gree blue viol

indigo

$\lambda = 700$ nm

400 nm