Constants (Elementary Charges)
(C) coulomb $= 6.25\times10^{18}\,e^-$'s
$k = 9\times10^9\ N\cdot m^2/C^2$
$\epsilon_0 = 8.85\times10^{-12}\ C^2/N\cdot m^2$
$c = 3\times10^8\ m/s$
$e = 1.6\times10^{-19}\ C$
$m_p = 1.67\times10^{-27}\ kg$
$m_e = 9.11\times10^{-31}\ kg$
$\mu_0 = 4\pi\times10^{-7}\ T\cdot m/A$
$h = 6.63\times10^{-34}\ J/s$

Prefixes:
$P = 10^{15}$, $f = 10^{-15}$
$T = 10^{12}$, $p = 10^{-12}$
$G = 10^9$, $n = 10^{-9}$
$M = 10^6$, $\mu = 10^{-6}$
$k = 10^3$, $m = 10^{-3}$
$h = 10^2$, $c = 10^{-2}$

Geometry: Cylinder $A = 2\pi r^2 + 2\pi r h$
Sphere $A = 4\pi r^2$, $V = \frac{4}{3}\pi r^3$
Cylinder $V = \pi r^2 h$
Cone $A = \pi r(r + \sqrt{h^2 + r^2})$, $V = \pi r^2(\frac{h}{3})$
Circle $C = 2\pi r$, $A = \pi r^2$
Ellipse $A = \pi ab$

$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$
$c^2 = a^2 + b^2 - 2ab\cos C$
$\sin^2\theta + \cos^2\theta = 1$
$\sin(2\theta) = 2\sin\theta\cos\theta$

27 $N_e = i_e\Delta t$, $i_e = N_e A v_d$
where v_d = drift speed
A = area
i_e = electrons per second

Conventional Current: $I = e\cdot i_e$, $I = \frac{Q}{\Delta t}$
$E = \frac{\Delta V}{L}$, $I = \frac{\Delta V}{R}$, $R = \frac{\rho L}{A}$
Conductivity: $\sigma = \frac{n e^2 \tau}{m}$
Current Density: $I = J\cdot A$, $J = \sigma\cdot E$
Resistivity: $\rho = \frac{1}{\sigma} = \frac{m}{ne^2\tau}$

28 DC Circuits

Loop Law: $\sum_{loop} V_i = 0$
$\Delta V = +\mathcal{E}$; $\Delta V = -\mathcal{E}$; $\Delta V = -IR$

Power: $P = IV$, $P_{bat} = \mathcal{E}V$
Resistor dissipate: $P_R = IV = I^2R = \frac{V^2}{R}$

Equivalent Resistance: $R_{eq} = R_1 + R_2 + R_3$
$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1}$

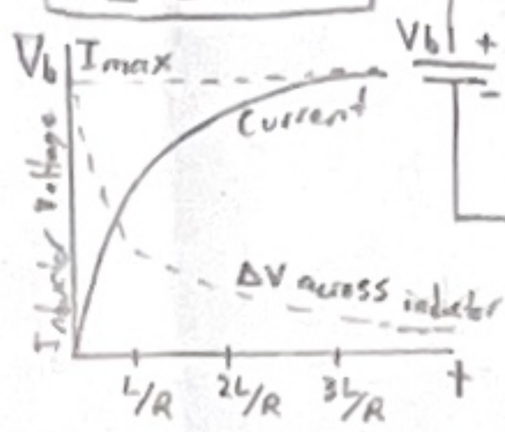
Ohm's Law: $I = \frac{\Delta V}{R}$
10V, 10V, $-5V$, 100Ω, 5V, $-5V$, 100Ω, 0V

Junction Law: $\sum I_{in} = \sum I_{out}$
$I_1 + I_2 = I_3$

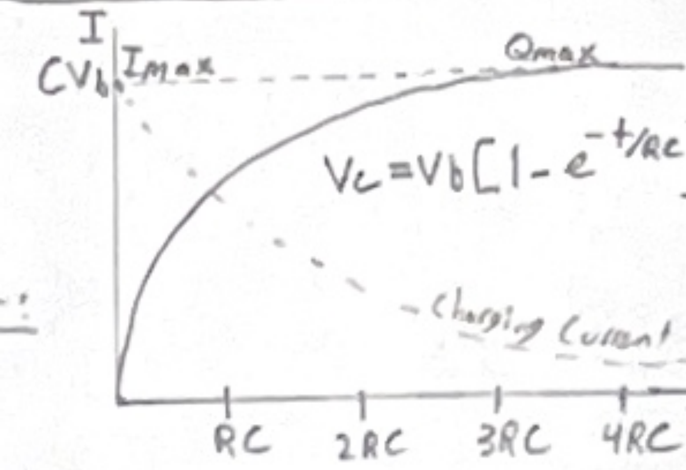
Capacitors: $C = \frac{Q}{\Delta V}$
$C_{eq} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)^{-1}$
$C_{eq} = C_1 + C_2 + C_3$
"Capacitors in parallel all have the same ΔV" "Capacitors in series all have the same charge"

Parallel Plate: $C = \frac{\epsilon_0 A k}{d}$
Dieletric: $C = kC_0$ where k is the dielectric constant
Energy: "Capacitors store energy in the electric field" $U_c = \frac{1}{2}C(\Delta V)^2$
Density: $U_E = \frac{1}{2}k\epsilon_0 E^2$ where k is dielectric constant
Electric Field: $E = \frac{\Delta V}{d}$

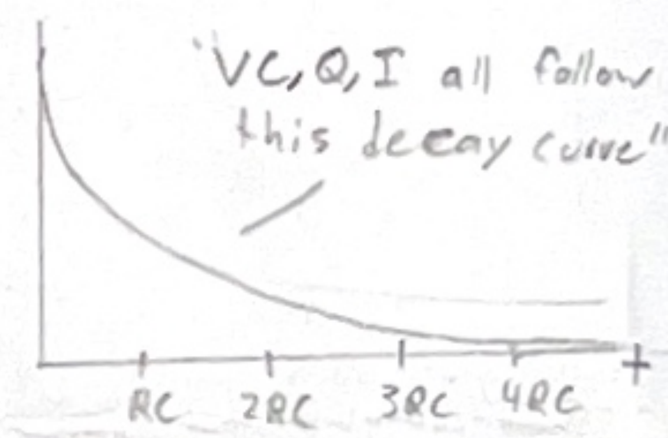
Inductors: $L_{eq} = L_1 + L_2 + L_3$
$L_{eq} = \left(\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}\right)^{-1}$
$\mathcal{E} = -L\frac{\Delta I}{\Delta t}$
Volt·second / Ampere = Henry

RL Circuit
*Note $\tau = \frac{L}{R}$


$V_b = V_R + V_L$
$V_b = IR + L\frac{\Delta I}{\Delta t}$
Current: $I = \frac{V_b}{R}(1 - e^{-tR/L})$
Voltage across inductor: $V_L = V_b e^{-tR/L}$
When $t = 0$: $I = 0$, $V_R = 0$, $V_L = V_b$
When $t = \infty$: $I = \frac{V_b}{R}$, $V_R = V_b$

RC Circuit
$(\frac{1}{10})RC$ = short, $5RC$ = long
Charging Capacitor: $V_b = V_R + V_C$
$V_b = IR + \frac{Q}{C}$
Charge on Capacitor: $Q = CV_b[1 - e^{-t/RC}]$
Charging Current: $I = \frac{V_b}{R}e^{-t/RC}$


When $t = 0$: $Q = 0$, $V_C = 0$, $I = \frac{V_b}{R}$
When $t = \infty$: $Q = CV_b$, $V_C = V_b$, $I = 0$

Discharging Capacitor: $V_C = \frac{Q}{C} = IR$
@ $t = 0$: $V_C = V_0$, $Q = CV_0$, $I = \frac{V_0}{R}$
$V_C = V_0 e^{-t/RC}$
$Q = CV_0 e^{-t/RC}$
$I = \frac{V_0}{R}e^{-t/RC}$
Note $\tau = RC$


22/23 Electric Field

Coulomb's Law: $\vec{F} = \frac{kq_1q_2}{(K)r^2}\hat{r}$
"$\hat{r}$ always points away from q_1, source of the field"
Superposition
Electric Field of a point Charge: $\vec{E} = \frac{1}{4\pi\epsilon_0}\cdot\frac{q}{r^2}\hat{r} = \frac{kq}{r^2}\hat{r}$
Dipole Moment: $\vec{p} = q\vec{d}$
$\vec{E}$ Field: $\vec{E} = \frac{1}{4\pi\epsilon_0}\cdot\frac{p}{r^3}$
$\vec{E} = \frac{1}{4\pi\epsilon_0}\cdot\frac{2p}{r^3}$
$\vec{F} = q\vec{E}$, $\vec{a} = \frac{q\vec{E}}{m}$
Dipole in an $\vec{E}$ field: $\tau = pE\sin\theta$

Charge Density
Linear: $\lambda = Q/L$ (charge per meter)
Surface: $\sigma = Q/A$ (charge per square meter)
Volume: $\rho = Q/V$ (per meter cubed)

24 Gauss's Law

$\oint\vec{E}\cdot d\vec{A} = \frac{q}{\epsilon_0}$
$\Phi_E = \oint\vec{E}\cdot d\vec{A}$
gaussian surface
① if $\vec{E}\parallel\vec{A}$; $\Phi_E = 0$
② if $\vec{E}\perp\vec{A}$; $\Phi_E = EA$
*if $\Phi_E = 0$; there is no enclosed charge and vice versa

Point Charge: $\vec{E} = \frac{kQ}{r^2}$
Sphere of Uniform Charge: $\vec{E} = \frac{kQ}{r^2}$; $r > R$; $\vec{E} = \frac{kQr}{R^3}$; $r < R$
Conducting Sphere: $\vec{E} = \frac{kQ}{r^2}$, $r > R$; $\vec{E} = 0$; $r < R$
Infinite Line: Gaussian S. $\vec{E} = \frac{\lambda}{2\pi r\epsilon_0}$
Conducting Cylinder: (∞) $\vec{E} = \frac{\lambda}{2\pi\epsilon_0 r}$; $r \geq R$; $\vec{E} = 0$; $r < R$
Uniform Cylinder of Charge: (∞) $\vec{E} = \frac{\lambda}{2\pi\epsilon_0 r}$; $r \geq R$; $\vec{E} = \frac{\lambda r}{2\pi\epsilon_0 R^2}$; $r < R$
Sheet of Charge: (∞) $\vec{E} = \frac{\sigma}{2\epsilon_0}$
Parallel Plate Capacitor: $\vec{E} = \begin{cases}\frac{\sigma}{\epsilon_0}; & \text{inside}\\ 0; & \text{outside}\end{cases}$
Finite Line: $\vec{E} = \frac{k\lambda}{r}\left[\frac{b}{(r^2+b^2)^{1/2}} + \frac{a}{(r^2+a^2)^{1/2}}\right]$
Ring of Charge: $\vec{E} = \frac{(k)(\lambda)(2\pi)(R)(r)}{(r^2+R^2)^{3/2}}$
Disk of Charge: $\vec{E} = k\sigma2\pi\left[1 - \frac{r}{\sqrt{r^2+R^2}}\right]$
Pipe of Charge: $\vec{E} = \frac{\rho(R_1^2 - R_2^2)}{2r\epsilon_0}$
Uniform Slab of Charge: (∞) $\vec{E} = \begin{cases}\frac{\rho d}{\epsilon_0}; & \text{outside}\\ \frac{\rho z}{\epsilon_0}; & \text{inside}\end{cases}$
Finite Line: $\vec{E} = \frac{k\lambda L}{x(x-L)}$

25 Electric Potential

Dipole: $V = \frac{kp\cos\theta}{r^2}$; $r >> d$
Point Charge: $V = \frac{kQ}{r}$
Superposition: $V = \frac{kQ_1}{r_1} + \frac{kQ_2}{r_2} + \frac{kQ_3}{r_3}$
Conservation of Energy: $KE_i + qV_i = KE_f + qV_f$
Change in potential: $V_a - V_b = kQ\left[\frac{1}{r_a} - \frac{1}{r_b}\right]$
Potential Energy: $U = qV$
Point Charge: (2) $U = \frac{kq_1q_2}{r}$; Dipole: $U = -pE\cos\theta$
Line of Charge: $V = k\lambda\ln\left[\frac{b + \sqrt{b^2+d^2}}{-a + \sqrt{a^2+d^2}}\right]$
Ring of Charge: $V = \frac{k\lambda2\pi R}{r}$
Disk of Charge: $V = k\sigma2\pi\left[\sqrt{z^2+R^2} - z\right]$
Conducting Sphere: $V = \frac{kQ}{R}$; inside, $V = \frac{kQ}{r}$; outside
Constant Electric Field: $E = \frac{\Delta V}{d}$
Work: $W = q\Delta V$
Voltage from $\vec{E}$ field: $\Delta V = \frac{dW}{q} = \int\vec{E}\cdot d\vec{s}$
$V_f - V_i = -Ed$
$V_f - V_i = -Ed\cos\theta$
$V_f - V_i = -\int\vec{E}\cdot d\vec{s}$
$\vec{E}$ field from Voltage: $\vec{E} = E_x\hat{\imath} + E_y\hat{\jmath} + E_z\hat{k}$
$\vec{E} = -\frac{dV}{dx}\hat{\imath} - \frac{dV}{dy}\hat{\jmath} - \frac{dV}{dz}\hat{k}$

29/30 Magnetic Field

Lorentz Force Law: $\vec{F} = q\vec{v}\times\vec{B} = qvB\sin\theta$
Current in a Field: $\vec{F} = I\vec{L}\times\vec{B} = ILB\sin\theta$
Bio-Savart Law
Moving Point Charge: $\vec{B} = \frac{\mu_0}{4\pi}\cdot\frac{q\vec{v}\times\hat{r}}{r^2}$
Long Straight Wire: $\vec{B} = \frac{\mu_0 I}{2\pi r}$
Center of a Current Loop: $\vec{B} = \frac{\mu_0 I}{2R}$
On-axis of Loop: $B_z = \frac{\mu_0}{4\pi}\cdot\frac{2\pi R^2 I}{(z^2+R^2)^{3/2}}$
Amperes Law: $\oint\vec{B}\cdot d\vec{r} = \mu_0 I + \mu_0\epsilon_0\frac{d\Phi_E}{dt}$
Inside a long Solenoid: $\vec{B} = \frac{\mu_0 N I}{L}$
Cylinder Conductor: Current density: $I = J\pi R^2$
$B = \frac{\mu_0 r I}{2\pi R^2}$; $r < R$
$B = \frac{\mu_0 I}{2\pi R}$; $r = R$
$B = \frac{\mu_0 I}{2\pi r}$; $r > R$
Inside a Toroid: $B = \frac{\mu_0 N I}{2\pi r}$ where r is the center width
Force Between Wires: $F = \frac{\mu_0 I_1 I_2}{2\pi r}\cdot L$
Interactions
Torque Loop: $\vec{\tau} = \vec{\mu}\times\vec{B} = \mu B\sin\theta$ where $\vec{\mu} = I\vec{A}$
Cyclotron: Radius of orbit: $r_{cyc} = \frac{mv}{qB}$
$f_{cyc} = \frac{qB}{2\pi m}$
Magnetic Flux: $\Phi_m = \vec{A}\cdot\vec{B} = AB\cos\theta$
Magnetic Gauss Law: $\oint\vec{B}\cdot d\vec{A} = 0$

How to change Flux
① Loop moves through a $\vec{B}$ field
② Loop changes area or rotates
③ $\vec{B}$ field increases or decreases
$\vec{B}$ up and increasing: $\vec{B}$ induced down, Current induced CW
$\vec{B}$ up and decreasing: $\vec{B}$ induced up, Current induced CCW
$\vec{B}$ down and increasing: $\vec{B}$ induced up, Current induced CCW

Sphere Uniform with hole: $V_{tot} = \frac{4}{3}\pi(R^3 - a^3)$
$V_i = \frac{4}{3}\pi(r^3 - a^3)$
$\vec{E} = \frac{kQ}{r^2}\left(\frac{r^3 - a^3}{R^3 - a^3}\right)$
Finite Line: $\vec{E} = \frac{(k)(\lambda)(L)}{x(x-L)}$

Faraday's Law

$\mathcal{E} = \left|\frac{d\Phi_M}{dt}\right|$

Voltage Generated $= \frac{-N\Delta(BA)}{\Delta t}$

Induced Current: $I = \frac{\mathcal{E}}{R}$

Two ways to induce Current:

1. Motional EMF: $\mathcal{E} = VLB$, $\Delta V = VLB$
2. Changing Magnetic Field: $\oint \vec{E}\cdot d\vec{r} = -\frac{d\Phi_M}{dt}$

Inductors

Solenoid: $L = \frac{\mu_0 N^2 A}{L}$

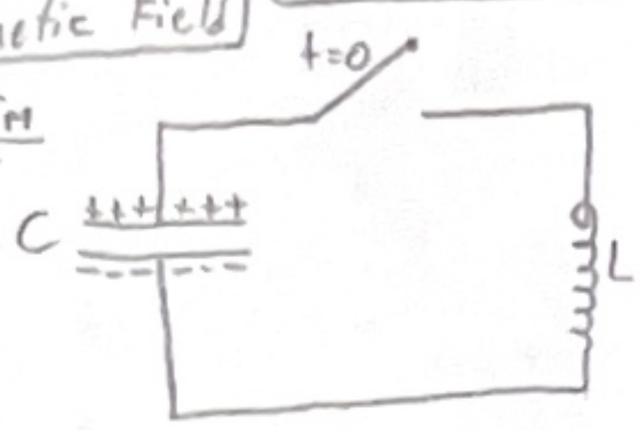
Potential difference: $\Delta V_L = -L\frac{\Delta I}{\Delta t}$

Energy stored in $\vec{B}$ Field

$U_L = \frac{1}{2}LI^2$

Energy density: $U_B = \frac{1}{2\mu_0}B^2$

LC Circuit

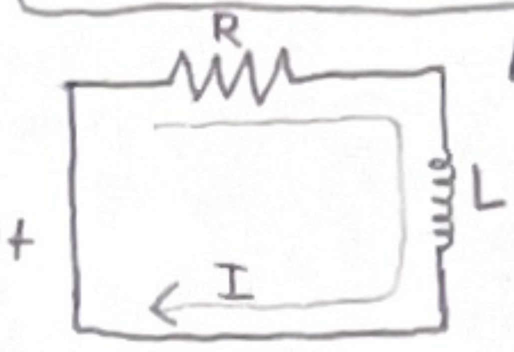


Charge on the Capacitor: $Q(t) = Q_0\cos\omega t$

Current through the inductor: $I = \omega Q_0\sin\omega t = I_{max}\sin\omega t$

Angular frequency: $\omega = \sqrt{\frac{1}{LC}}$

LR Circuit "Discharge"



$\Delta V_r + \Delta V_L = 0$

$I_0 = \frac{\Delta V_{bat}}{R}$

$I = I_0 e^{-tR/L}$

32 AC Circuits

Root Mean Squared

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

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

$\mathcal{E}_{rms} = \frac{\mathcal{E}_0}{\sqrt{2}}$

Resistor Circuit

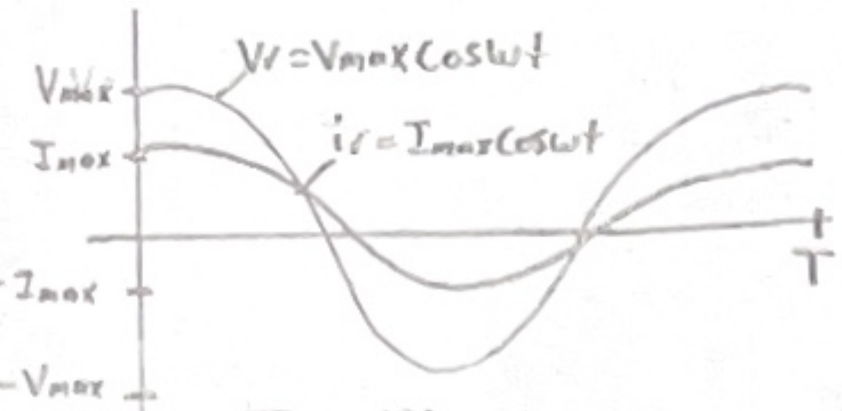
$V_{max} = \mathcal{E}_0$ (For this)

$I_{max} = \frac{V_{max}}{R}$

resistor Voltage: $V_r = i_r R$, $V_r = V_{max}\cos\omega t$

Instantaneous Current: $i_r = \frac{V_r}{R} = \frac{V_{max}\cos\omega t}{R}$

$i_r = I_{max}\cos\omega t$

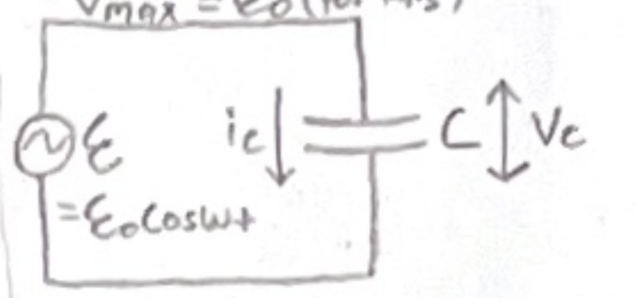


In Phase

Capacitor Circuits

V_{max} is the max voltage across the Capacitor*

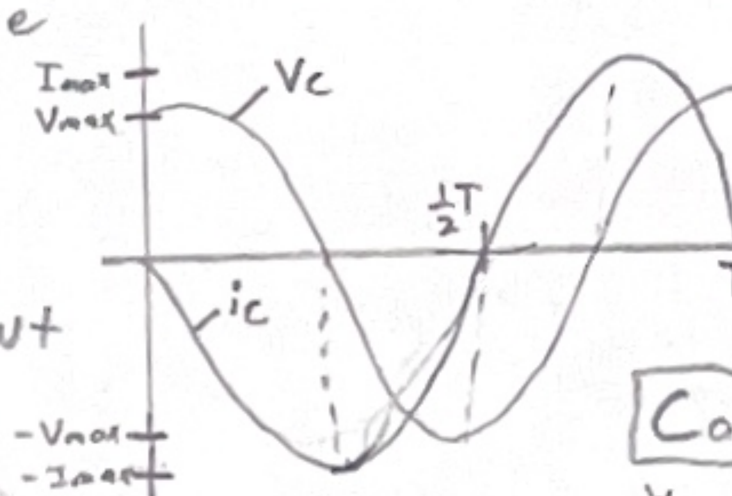
$V_{max} = \mathcal{E}_0$ (For this)



$V_c = V_{max}\cos\omega t$

Charge on Capacitor: $q = CV_c = CV_{max}\cos\omega t$

instantaneous Current: $i_c = \omega CV_c\cos(\omega t + \frac{\pi}{2})$



Out of Phase. Current leads Voltage by $\pi/2$

Capacitive Reactance

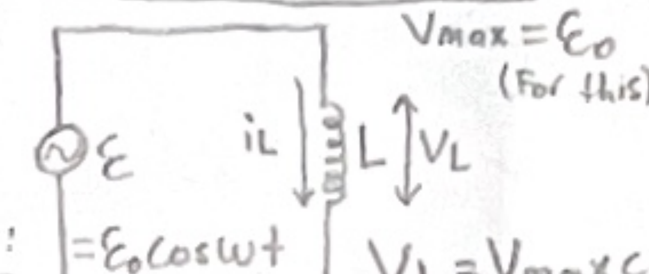
$X_c = \frac{1}{\omega C}$ *Large at Low frequencies

$I_{max} = \frac{V_{max}}{X_c}$ "or" $V_{max} = I_{max}X_c$

Inductor Circuit

$V_{max} = \mathcal{E}_0$ (For this)

V_{max} is the max Voltage across the inductor



instantaneous Current: $i_L = I_{max}\cos(\omega t - \frac{\pi}{2})$

where $I_{max} = \frac{V_{max}}{X_L}$

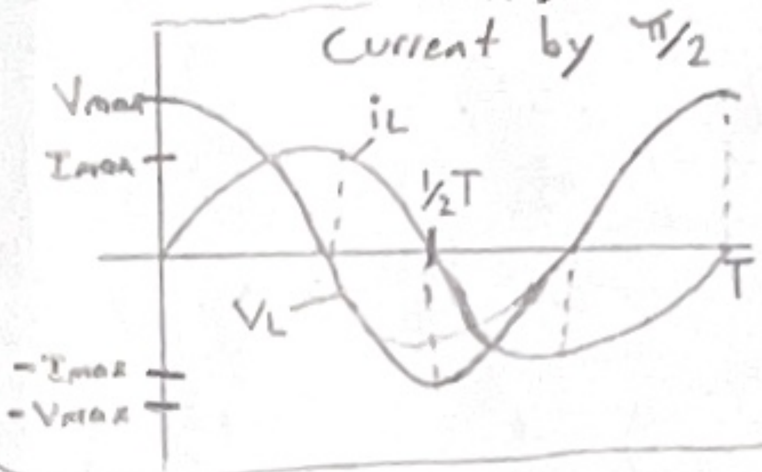
$V_L = V_{max}\cos\omega t$

$I_{max} = \frac{V_{max}}{X_L}$

Inductive Reactance

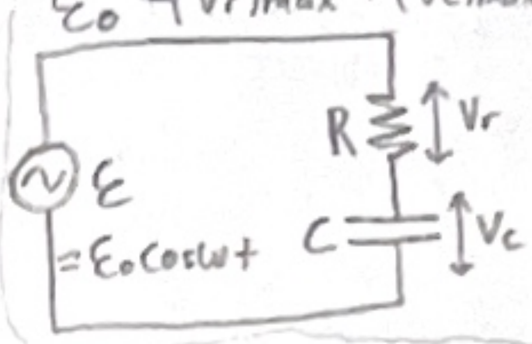
$X_L = \omega L$ *Large at high frequencies

Out of Phase. Voltage leads Current by $\pi/2$



RC Filter Circuit

$\mathcal{E}_0^2 = (V_r)_{max}^2 + (V_c)_{max}^2$



Peak Values

$I_{max} = \frac{\mathcal{E}_0}{\sqrt{R^2 + X_c^2}}$

*Note: $(I_r)_{max} = (I_c)_{max} = I_{max}$

$(V_r)_{max} = (I_{max})R = \frac{\mathcal{E}_0 R}{\sqrt{R^2+X_c^2}}$

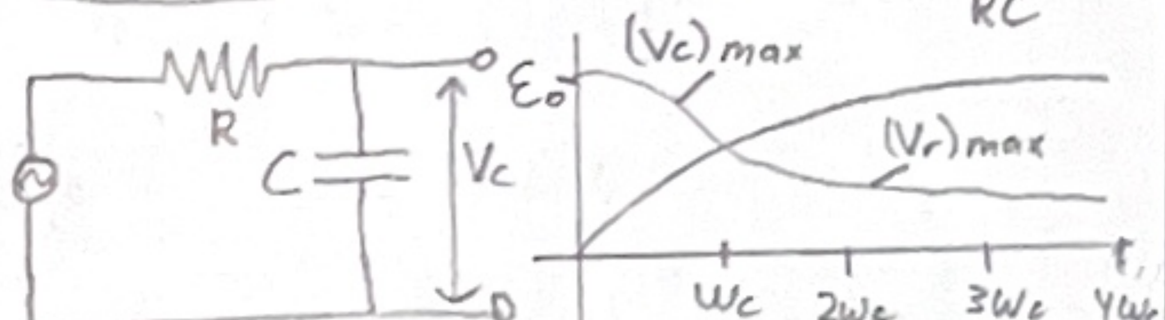
$(V_c)_{max} = (I_{max})X_c = \frac{\mathcal{E}_0 X_c}{\sqrt{R^2+X_c^2}}$

Crossover Frequency

$f_c = \frac{\omega_c}{2\pi}$

ω_c occurs when $(V_r)_{max} = (V_c)_{max}$; $\omega_c = \frac{1}{RC}$

Low Pass Filter



$\omega < \omega_c$; Transmits

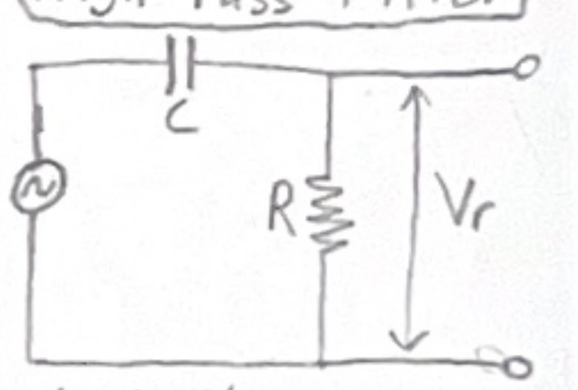
$\omega > \omega_c$; Blocks

Lets Low frequencies pass

$\lim_{\omega\to 0}(V_c)_{max} = \mathcal{E}_0$

$\lim_{\omega\to\infty}(V_r)_{max} = \mathcal{E}_0$

High Pass Filter

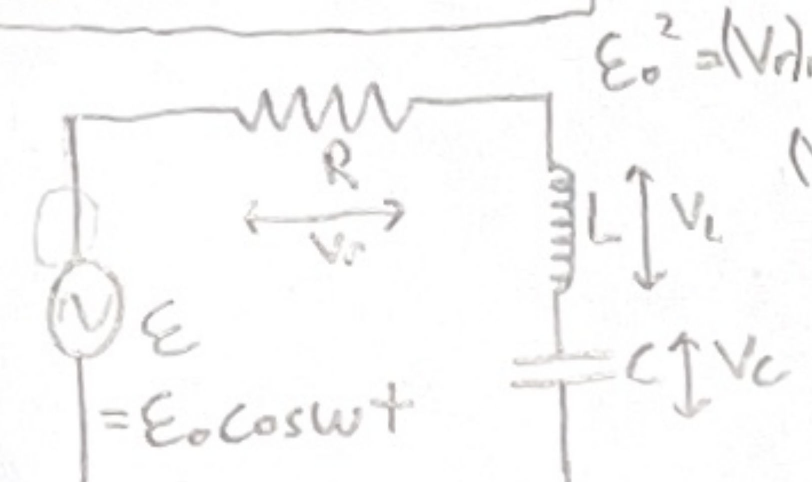


$\omega > \omega_c$; Transmits

$\omega < \omega_c$; Blocks

Lets high frequencies pass

Series RLC Circuit



$\mathcal{E}_0^2 = (V_r)_{max}^2 + [(V_L)_{max} - (V_c)_{max}]^2$ *if opposite, make ϕ negative

$(V_L)_{max} > (V_c)_{max}$ (assumed by diagram)

instantaneous Current: $i = I_{max}\cos(\omega t - \phi)$, ϕ = Phase angle

Peak Current: $I_{max} = \frac{\mathcal{E}_0}{\sqrt{R^2 + (X_L - X_c)^2}}$

Peak Voltages:

$(V_r)_{max} = (I_{max})(R)$

$(V_L)_{max} = (I_{max})(X_L)$

$(V_c)_{max} = (I_{max})(X_c)$

$\mathcal{E}_0^2 = [R^2 + (X_L - X_c)^2]I_{max}^2$

Impedance

"measured in Ω's"

$Z = \sqrt{R^2 + (X_L - X_c)^2}$

so... $I_{max} = \frac{\mathcal{E}_0}{Z}$

Phase Angle

$(V_r)_{max} = \mathcal{E}_0\cos\phi$

$\phi = \tan^{-1}\left(\frac{X_L - X_c}{R}\right)$

$\phi < 0$	$\phi = 0$	$\phi > 0$
Current Leads, $\omega < \omega_0$	In Phase, $\omega = \omega_0$	$\mathcal{E}$ leads, $\omega > \omega_0$

Resonance

"where current is maxed"

occurs when: $X_L = X_c$

$\omega_0 = \frac{1}{\sqrt{LC}}$ (resonance frequency)

$Z = R$ at resonance

so $I_{max} = \frac{\mathcal{E}_0}{R}$

Power

instantaneous Power: $p = i\mathcal{E}$

Resistor: instantaneous: $p_r = (I_r)_{max}^2 R\cos^2\omega t$

avg power dissipated by Resistor: $(P_r)_{avg} = (I_{rms})^2 R = \frac{(V_{rms})^2}{R} = I_{rms}V_{rms}$

avg power Supplied by EMF: $(P_{source})_{avg} = (I_{rms})(\mathcal{E}_{rms})$ [R circuit]

Capacitor: instantaneous lost: $p_c = -\frac{1}{2}\omega C(V_c)_{max}^2\sin(2\omega t)$ "positive when giving back power"

"Average power dissipate for P_L and $P_c = 0$"

Average Power Supplied by EMF

$(P_{source})_{avg} = \frac{1}{2}(I_{max})\mathcal{E}_0\cos\phi = (I_{rms})(\mathcal{E}_{rms})\cos\phi$

where $\cos\phi$ is the power factor

Maxwell's equations in the Vacuum:

E Guass: $\oint\vec{E}\cdot d\vec{A} = \frac{Q}{\epsilon_0}$ 0

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

Faraday: $\oint\vec{E}\cdot d\vec{r} = -\frac{d\Phi_B}{dt}$

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

31 Electromagnetic Waves

Wave equation

$\frac{d^2E}{dx^2} = \epsilon_0\mu_0\frac{d^2E}{dt^2}$

$\frac{d^2B}{dx^2} = \epsilon_0\mu_0\frac{d^2B}{dt^2}$

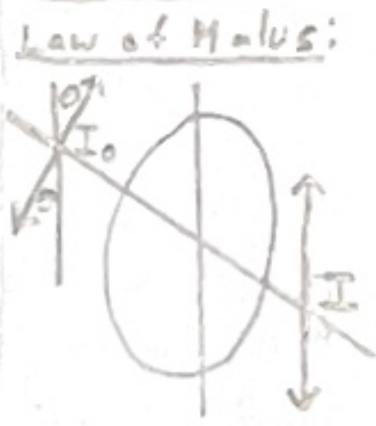
Wave speed

$V = \frac{\omega}{k}$, $E = cB$

$V = \frac{1}{\sqrt{\epsilon_0\mu_0}}$, $f\lambda = c$, $k = 2\pi/\lambda$

Polarization

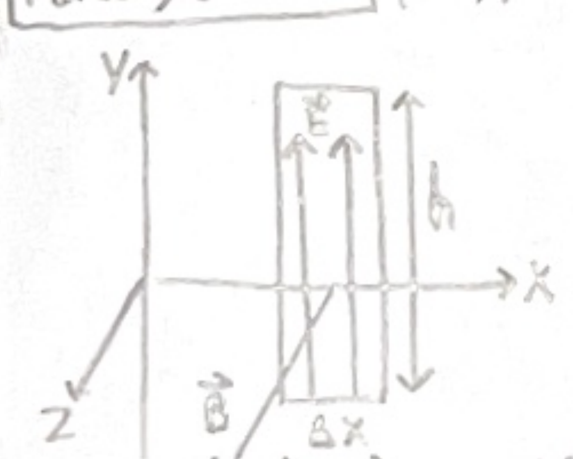
Law of Malus:



$I = I_0\cos^2\theta$

where I is the intensity of the wave. θ is the angle between the field and the polarizer axis

Faraday's Law (x-y) Plane



$\frac{d\Phi_B}{dt} = h\Delta x\frac{dB}{dt}$

$\frac{dE}{dx} = -\frac{dB}{dt}$

Connecting E and B

$E_y(x,t) = E_0\sin(kx - \omega t)\hat{j}$

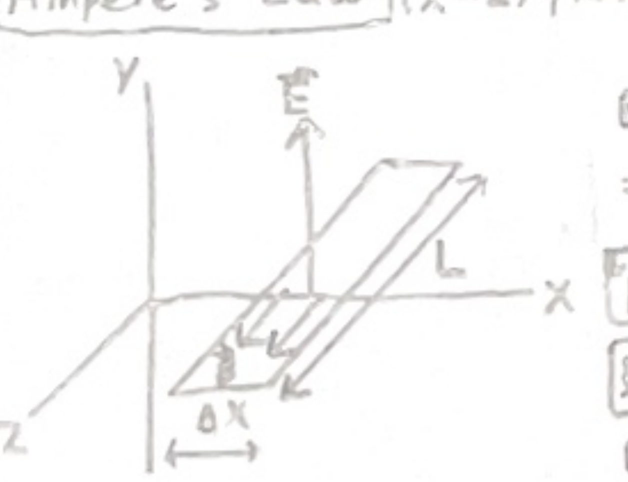
$= E_0\sin\left[2\pi\left(\frac{x}{\lambda} - ft\right)\right]\hat{j}$

$B_z(x,t) = B_0\sin(kx - \omega t)\hat{k}$

$= B_0\sin\left[2\pi\left(\frac{x}{\lambda} - ft\right)\right]\hat{k}$

Note: $E_0 = \lambda f B_0$

Ampere's Law (x-z) plane



$\frac{d\Phi_E}{dt} = L\Delta x\frac{dE}{dt}$

$\frac{dB}{dx} = -\epsilon_0\mu_0\frac{dE}{dt}$

Energy and Intensity

Poynting Vector ($\vec{S}$): $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B}$

$S_{max} = \frac{E_0^2}{c\mu_0}$

$I = \frac{Power}{Area}$

$|S| = c\epsilon_0 E^2$

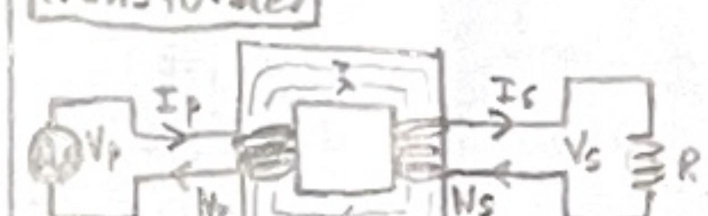
Intensity (I) $= S_{avg} = \frac{1}{2c\mu_0}E_0^2 = \frac{c\epsilon_0}{2}E_0^2 = \frac{E_0^2}{2\mu_0 c}$

$= S_{avg}$

radiation pressure: $P_{rad} = \frac{P/A}{c} = \frac{I}{c}$

radiation force: $F = \frac{Power}{c} = \frac{U/\Delta t}{c} = \frac{\Delta p}{c}$ (momentum)

Transformer



$V_P = \mathcal{E} = -N_P A\frac{\Delta B}{\Delta t}$; $V_S = -N_S A\frac{\Delta B}{\Delta t}$

$\frac{V_S}{V_P} = \frac{N_S}{N_P}$

Power: $P_P = V_P I_P = V_S I_S = P_S$

$V_S = \frac{N_S}{N_P}V_P$

$N_S > N_P$; Step up

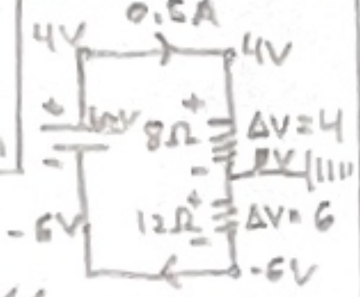
$N_P > N_S$; Step down

Angular: $\omega = \frac{2\pi}{T} = 2\pi f$

$f = 1/T$, $T \sim \lambda$

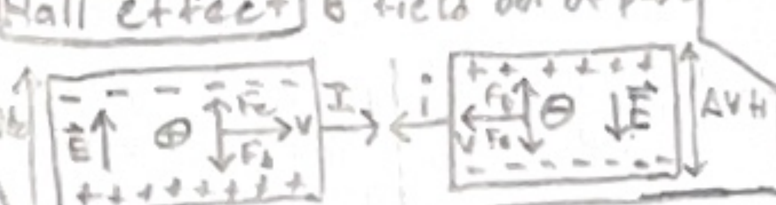
$f = c/\lambda$; $\lambda = c/f$

Ground: Changes nothing except specific voltages



Hall effect

$\vec{B}$ field out of page



$\Delta V_H = \frac{IB}{tne}$

$qvB = \frac{mv^2}{r}$

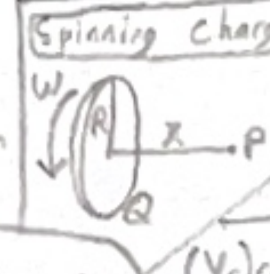
Units:

- Current – A
- Charge – C
- E/ΔV – V
- R/X_L/Z – Ω
- Power – W
- Capacitance – F
- Φ_E – V·m

Key:

- Inductance – H
- Φ_B – Wb
- E field – V/m
- B field – T

Spinning Charged disk

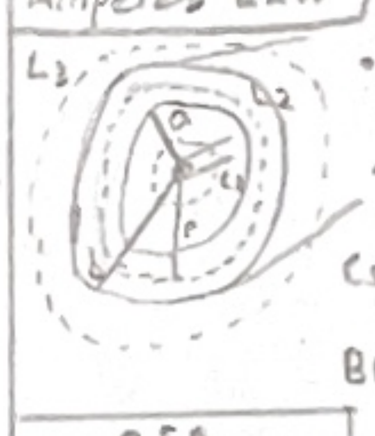


$\vec{B} = \frac{\mu_0\omega Q}{2\pi R^2}\left[\sqrt{x^2+R^2} + \frac{x^2}{\sqrt{x^2+R^2}} - 2x\right]$

Ring Spin: $\vec{B} = \frac{\mu_0}{4\pi}\frac{QR^2\omega}{(R^2+x^2)^{3/2}}$

Rotating Coil in a $\vec{B}$ field: $\mathcal{E} = NBA\omega\sin\omega t$

Amperes Law



Given:

- ∞ thin wire with Current = I
- Thick shell, uniform charge density with current = −2I

Find: B(r) = ?

$\oint\vec{B}\cdot d\vec{l} = \mu_0 I$ (L_1)

$\oint Bdl\cos 0 = \mu_0 I$

$\oint\vec{B}\cdot d\vec{l} = \mu_0(-2I + I)$ (L_1)

$\oint Bdl\cos 0 = -\mu_0 I$

$\oint\vec{B}\cdot d\vec{L} = \mu_0\left(I - 2I\cdot\frac{A_2}{A_{tot}}\right)$ (L_2)

$\oint Bdl\cos\theta = \mu_0\left(I - 2I\frac{\pi(r^2-a^2)}{\pi(b^2-a^2)}\right)$

$B2\pi r = \mu_0 I\left(1 - \frac{2(r^2-a^2)}{b^2-a^2}\right)$

$B = \frac{\mu_0 I}{2\pi r}\left(1 - \frac{2(r^2-a^2)}{b^2-a^2}\right)$; $a < r < b$

$B2\pi r = \mu_0 I$

$B = \frac{\mu_0 I}{2\pi r}$; $r < a$

$B2\pi r = -\mu_0 I$

$B = -\frac{\mu_0 I}{2\pi r}$; $r > b$

Parallel RLC Circuit

$X_L = \omega L$, $X_c = \frac{1}{\omega C}$

$I_r = \frac{V}{R}$, $I_L = \frac{V}{X_L}$, $I_c = \frac{V}{X_c}$

$Z = \left[\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_c} - \frac{1}{X_L}\right)^2}\right]^{-1}$

$I_s = \sqrt{I_r^2 + (I_L - I_c)^2}$

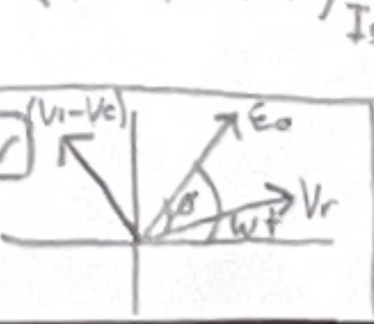
$(V_r)_{rms} = I_{rms}R$

$(V_c)_{rms} = I_{rms}X_c$

$(V_L)_{rms} = I_{rms}X_L$

$(V_s)_{rms} = I_{rms}Z$

Series RLC Phasor



Flip Coil

Flux before: NBA

Flux after: $-NBA$

$\Phi_B = -2NBA$

$\Delta Q = \frac{2NBA}{R}$

$B = \frac{\Delta QR}{2NA}$

Rail Gun (Motional EMF)

"Work done by Pulling or pushing exactly matches Resistor dissipate"

Power $= Fv = \frac{v^2 L^2 B^2}{R}$