Review for Exam 1

$\boxed{\text{Chapter 21 : Electric Charge}}$

charge on proton $q_p = e = 1.60 \times 10^{-19}\,C$
charge on electron $q_e = -e = -1.60 \times 10^{-19}\,C$

charge is quantized $\Rightarrow$ $\boxed{q = ne}$ $n = \pm 1, \pm 2, \ldots$

<u>conservation of charge</u>

Coulomb's law $\Rightarrow$ $\boxed{F = \dfrac{K|q_1||q_2|}{r^2}}$

$$K = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9\ Nm^2/c^2$$

$$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$$

$\Rightarrow$ direction of force along line joining two particles

$\downarrow$

like charges repel
opposite charges attract

Two Shell Theorems

1) a shell of uniform charge can be treated as if all the charge were concentrated at its center

2) there is no net electrostatic force on a charged particle inside a shell of uniform charge

$\downarrow$ both theorems are proved using Gauss' law principle of superposition $\Rightarrow$ $\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots$

must add forces like vectors

Chapter 22: Electric Fields

$\Rightarrow$ you measure $\vec{E}$ at a given point by placing a small positive test charge q_0 at that point

$$\boxed{\vec{E} = \vec{F}/q_0}$$

for a point charge $\Rightarrow$ $\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}}$

$\vec{E}$ points away from a + charge
$\vec{E}$ points towards a − charge

know electric field lines

Binomial expansion : if $x << 1$ $(1+x)^n \approx 1 + nx$

$(1-x)^n \approx 1 - nx$

electric field from dipole $\Rightarrow$ $\boxed{E = \frac{1}{2\pi\varepsilon_0} \frac{p}{z^3}}$

dipole moment $\boxed{p = q d}$

$\vec{p}$ points from − to + charge

continuous charge distributions $\lambda = q/L$

$\sigma = q/A$ $\rho = q/V$

$\Rightarrow$ for a continuous charge distribution $\boxed{dE = \frac{1}{4\pi\varepsilon_0} \frac{dq}{r^2}}$

$E = \int dE = \frac{1}{4\pi\varepsilon_0} \int \frac{dq}{r^2}$

know how to use!

* must take into account fact that $\vec{E}$ is a vector

$$\boxed{E = \frac{1}{4\pi\varepsilon_0} \frac{q z}{(z^2+R^2)^{3/2}}}$$

$\vec{E}$ a distance z above a charged ring along central axis

$$\boxed{E = \frac{\sigma}{2\varepsilon_0}\left(1 - \frac{z}{\sqrt{z^2+R^2}}\right)}$$

$\vec{E}$ a distance z above the center of a charged disk

$\Rightarrow$ force on a point charge in an external electric field :

$$\boxed{\vec{F} = q\vec{E}}$$

if $q > 0$, $\vec{F}$ is in same direction as $\vec{E}$

if $q < 0$, $\vec{F}$ is in opposite direction as $\vec{E}$

SKIP

$\boxed{\tau = \vec{p} \times \vec{E}}$ torque on dipole in uniform $\vec{E}$-field

$\boxed{U = -\vec{p} \cdot \vec{E}}$ potential energy of dipole in uniform $\vec{E}$-field

Chapter 23: Gauss' Law

electric flux $\boxed{\Phi = \vec{E} \cdot \vec{A}}$

↓ applies for uniform $\vec{E}$ field and flat surface of area A

in general ⇒ $\boxed{\Phi = \int \vec{E} \cdot d\vec{A}}$

Gauss' Law ⇒ $\boxed{\oint \vec{E} \cdot d\vec{A} = q_{encl}/\varepsilon_0}$

* Gauss' law is always true but it is not always useful

* know the properties of an isolated conductor (isolated from ground):

1) $\vec{E} = 0$ everywhere inside conductor

2) all excess charge resides on surface

3) $\vec{E} \perp$ to surface of conductor & has magnitude $\boxed{E = \sigma/\varepsilon_0}$

$\boxed{q = \int \rho \, dV}$

⇒ if ρ is only a function of r:

$q = \int \rho(r) \, dV$ $\quad dV = 2\pi r L \, dr$ cylinder

$\quad dV = 4\pi r^2 \, dr$ sphere

$$\boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$$ → E a distance r from an infinite line of charge

$$\boxed{E = \sigma/2\varepsilon_0}$$ → E from an infinite nonconducting sheet of charge

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}$$ → E outside sphere of charge

$$\boxed{E = \frac{q\,r}{4\pi\varepsilon_0 R^3}}$$ → E inside uniformly charged sphere

Chapter 24: Electric Potential

$V = U/q \longrightarrow \boxed{\Delta V = \Delta U/q = -W/q}$ W → work done by electric field

$1\,V/m = 1\,J/C \qquad 1\,eV = 1.60 \times 10^{-19}\,J$

$$\boxed{V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}}$$

$\boxed{V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}}$ → potential from a point charge assuming $V = 0$ at $r = \infty$

$V > 0$ for a + charge

$V < 0$ for a − charge

* V is a scalar

⇒ for a collection of point charges $\boxed{V = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n} q_i/r_i}$

for a conducting sphere of radius R:

$V = \frac{1}{4\pi\varepsilon_0} q/R \qquad r \le R$

$V = \frac{1}{4\pi\varepsilon_0} q/r \qquad r > R$

* know properties of equipotential surfaces

$$\boxed{V = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{r}}$$ → potential from a continuous charge distribution assuming $V = 0$ at ∞

$$E = -\frac{\partial V}{\partial s} \longrightarrow \boxed{E_x = -\frac{\partial V}{\partial x} \quad E_y = -\frac{\partial V}{\partial y} \quad E_z = -\frac{\partial V}{\partial z}}$$

* $\vec{E}$ points in direction of decreasing potential

⇒ for spherical symmetry $E_r = -\frac{\partial V}{\partial r}$

⇒ if $\vec{E}$ is uniform $E = -\frac{\Delta V}{\Delta s}$

$$\boxed{U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}}$$ electric potential energy between two point charges (assuming $U = 0$ at $r = \infty$)

* any excess charge on an isolated conductor will arrange itself on the surface such that all points of the conductor are at the same potential

↓

if one conductor touches another conductor, both conductors will come to the same potential

Chapter 25: Capacitance

$\boxed{C = q/V}$ $\boxed{q = CV}$

C only depends on the geometry of the capacitor, not q or V

for a parallel plate capacitor: $\boxed{V = Ed}$

$$\boxed{C = \varepsilon_0 A/d}$$

for a cylindrical capacitor: $\boxed{C = 2\pi\varepsilon_0 \frac{L}{\ln(b/a)}}$

for a spherical capacitor: $\boxed{C = 4\pi\varepsilon_0 \frac{ab}{b-a}}$

for an isolated sphere: $\boxed{C = 4\pi\varepsilon_0 R}$

SKIP

Combinations of Capacitors

capacitors in parallel: $\boxed{C_{eq} = C_1 + C_2 + \ldots}$

capacitors in series: $\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots}$

* capacitors in parallel have the same V as their C_{eq}

* capacitors in series have the same q as their C_{eq}

energy stored by a capacitor: $\boxed{U = \frac{1}{2} q^2/C = \frac{1}{2} CV^2 = \frac{1}{2} qV}$

energy density $\boxed{u = \frac{1}{2} \varepsilon_0 E^2}$

$\Rightarrow$ the capacitance increases when a dielectric material is inserted between the plates

$\downarrow$

$\boxed{C = K C_0}$ $\qquad K \rightarrow$ dielectric constant

* when a region of space is completely filled with a dielectric, all electrostatic equations having ε_0 are replaced with $K\varepsilon_0$

$\Rightarrow$ the effect of a dielectric is to weaken the electric field that is already present

$$\boxed{E = E_0/K}$$

Review for Test #2

Chapter 26: Current & Resistance

current $\boxed{i = \frac{dq}{dt}}$ units of $i \rightarrow$ amp (A) $\boxed{1\,A = 1\,C/s}$

conventional current $\Rightarrow$ flow of hypothetical + charge from + to − terminal of battery

in reality, electrons flow in opposite direction

$\boxed{i = \int \vec{J} \cdot d\vec{A}}$ → always applies

current density $\boxed{J = i/A}$ $[J] = A/m^2$

applies if i is uniform and parallel to $d\vec{A}$

drift speed $\boxed{V_d = \frac{i}{nAe}}$

$V_d = J/ne \longrightarrow \boxed{\vec{J} = (ne)\vec{V}_d}$

definition of resistance $\boxed{R = V/i}$ units of $R \rightarrow$ ohm (Ω)

$\boxed{1\,\Omega = 1\,V/A}$

resistivity $\boxed{\rho = E/J}$ units of $\rho \rightarrow \Omega m$

$$\vec{E} = \rho \vec{J}$$

conductivity $\boxed{\sigma = 1/\rho}$ → units of $(\Omega m)^{-1}$

$$\boxed{\vec{J} = 1/\rho\, \vec{E} = \sigma \vec{E}}$$

resistance of a conducting wire ⇒ $\boxed{R = \rho L/A}$

$$\boxed{\begin{aligned} \rho - \rho_0 &= \rho_0 \alpha (T - T_0) \\ R - R_0 &= R_0 \alpha (T - T_0) \end{aligned}}$$

α → temp. coeff. of resistivity

units of α are $(K)^{-1}$ or $(C^\circ)^{-1}$

"Ohm's Law" → $\boxed{V = iR \qquad i = V/R \qquad R = V/i}$

a conductor obeys Ohm's law if R is a constant independent of magnitude & polarity of voltage

$\boxed{P = iV}$ → holds true for <u>any</u> electrical device

$$\boxed{\begin{aligned} P &= i^2 R \\ P &= V^2/R \end{aligned}}$$ → only holds true for resistors

Chapter 27: Circuits

emf $\mathcal{E}$ → defined as $\boxed{\mathcal{E} = dW/dq}$

voltage across a battery with internal resistance r is given by :

$$\boxed{V = \mathcal{E} - i r}$$

for n resistors in series : $\boxed{R_{eq} = \sum_{i=1}^{n} R_i}$

for n resistors in parallel : $\boxed{\frac{1}{R_{eq}} = \sum_{i=1}^{n} \frac{1}{R_i}}$

* resistors in series have same i as R_{eq}

* resistors in parallel have same V as R_{eq}

Kirchoff's junction rule ⇒ $\boxed{i_{in} = i_{out}}$

Kirchoff's loop rule ⇒ $\boxed{\sum V = 0 \text{ around any closed loop}}$

↓

algebraic sum of the changes in potential around any closed loop is zero sign conventions for Kirchoff's loop rule:

emf devices → going through emf device from − to + terminal, the change in potential is $+\mathcal{E}$

↓ from + to − terminal, change in potential is $-\mathcal{E}$

resistors → going through resistor in same direction as current, the change in potential is $-iR$

↓ in opposite direction as current, the change in potential is $+iR$

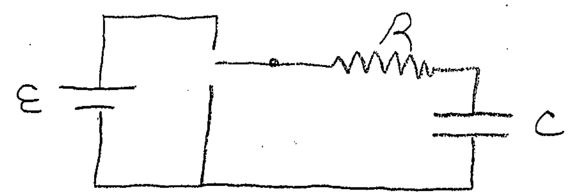
* if you do not know the direction of the current, assume a direction → if i comes out negative, your assumed direction was wrong

⇒ for an emf device $\boxed{P = i\mathcal{E}}$

* know how to calculate the potential difference between 2 points or the potential at one point given the potential at another point

ammeter → very small R (connected in series)

voltmeter → very large R (connected in parallel)



RC Circuits

charging a capacitor:

$$\boxed{q = q_0 (1 - e^{-t/\tau}) = C\mathcal{E}(1 - e^{-t/\tau})}$$

$$\boxed{V = q/C = \mathcal{E}(1 - e^{-t/\tau})}$$

$$\boxed{i = dq/dt = \mathcal{E}/R \; e^{-t/\tau}}$$

$$\boxed{\tau = RC}$$

capacitive time constant

discharging a capacitor:

$$\boxed{q = q_0 e^{-t/\tau}}$$

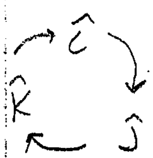
$$\boxed{i = dq/dt = -(q_0/RC)\, e^{-t/\tau}}$$

Chapter 28: Magnetic Fields

$\boxed{\vec{F}_B = q\vec{V} \times \vec{B}}$ ⟶ magnitude of $F_B = qvB\sin\theta$

↓

<u>direction given by RHR</u> ⟹ curl fingers of right hand from $\vec{V}$ into $\vec{B}$, thumb points in direction of $\vec{F}$ on a positive charge (opposite direction if charge is negative)



$\hat{i} \times \hat{j} = \hat{k}$ $\hat{j} \times \hat{i} = -\hat{k}$
$\hat{j} \times \hat{k} = \hat{i}$ $\hat{k} \times \hat{j} = -\hat{i}$
$\hat{k} \times \hat{i} = \hat{j}$ $\hat{i} \times \hat{k} = -\hat{j}$

<u>Joe's RHR</u> ⟹
thumb ⟶ $\vec{V}$
fingers ⟶ $\vec{B}$
palm ⟶ $\vec{F}$

$$\vec{V} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ V_x & V_y & V_z \\ B_x & B_y & B_z \end{vmatrix} = \hat{i}\begin{vmatrix} V_y & V_z \\ B_y & B_z \end{vmatrix} - \hat{j}\begin{vmatrix} V_x & V_z \\ B_x & B_z \end{vmatrix} + \hat{k}\begin{vmatrix} V_x & V_y \\ B_x & B_y \end{vmatrix}$$

* $\vec{F}_B$ is always $\perp$ to both $\vec{V}$ and $\vec{B}$

↓

magnetic fields can not change the speed of a moving charged particle, only the direction of the particle

unit of $\vec{B}$ ⟶ tesla (T) $\boxed{1\,T = 1\,N/Am}$

⟹ if both $\vec{E}$ & $\vec{B}$ fields are present : $\boxed{\vec{F} = q(\vec{E} + \vec{V} \times \vec{B})}$

⇒ for crossed $\vec{E}$ + $\vec{B}$ fields in opposition, the net force on a charged particle is zero if :

$$\boxed{V = E/B}$$

Circulating Charged Particle

$$\boxed{r = \frac{mv}{qB}} \qquad \boxed{T = \frac{2\pi m}{qB}} \qquad \boxed{f = \frac{qB}{2\pi m}}$$

above equation apply if $\vec{V} \perp \vec{B}$

⇒ if $\vec{V}$ is not $\perp$ to $\vec{B}$, the particle moves in a helical path

radius of helix $\boxed{r = \dfrac{m V_\perp}{qB}}$ $\qquad V_\perp = V \sin\Theta$

pitch $\boxed{p = V_{\parallel} T}$ $\qquad V_{\parallel} = V \cos\Theta$

magnetic force on a current-carrying wire ⇒ $\boxed{\vec{F} = i\vec{L} \times \vec{B}}$

magnitude of $F = iLB \sin\Theta$

direction of $\vec{F}$ from RHR ⇒ curl fingers of RH from $\vec{L}$ (which is in direction of conventional current) into $\vec{B}$, thumb points in direction of $\vec{F}$

⇒ the net force on a closed current-carrying loop of wire in a uniform $\vec{B}$-field is zero

↓ however, current loop may experience a torque

$$\boxed{\tau = N i A B \sin\theta}$$

magnetic dipole moment $\boxed{\mu = N i A}$

↓

direction of $\vec{\mu}$ ⇒ curl fingers of RH in direction of conventional current, thumb points in direction of $\vec{\mu}$

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

⇒ potential energy of a magnetic dipole in an external magnetic field is given by:

$$\boxed{U = -\vec{\mu} \cdot \vec{B}}$$

Chapter 29: Magnetic Fields Due to Currents

Biot-Savart law $\Rightarrow$ $\boxed{d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\, d\vec{s} \times \vec{r}}{r^3}}$

magnitude $\boxed{dB = \frac{\mu_0}{4\pi} \frac{i\, ds \sin\theta}{r^2}}$

direction of $d\vec{B}$ is given by $d\vec{s} \times \vec{r}$

$\boxed{\vec{B} = \int d\vec{B}}$

$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{Tm/A} \approx 1.26 \times 10^{-6}\ \mathrm{Tm/A}$

long (infinite) straight wire $\Rightarrow$ $\boxed{B = \frac{\mu_0 i}{2\pi r}}$

semi-infinite straight wire $\Rightarrow$ $\boxed{B = \frac{\mu_0 i}{4\pi r}}$

center of circular arc of radius R and angle ϕ (in radians) $\Rightarrow$ $\boxed{B = \frac{\mu_0 i \phi}{4\pi R}}$

force between two parallel currents $\Rightarrow$ $\boxed{F = \frac{\mu_0 L i_1 i_2}{2\pi d}}$

* parallel currents attract, antiparallel currents repel

Ampere's law $\Rightarrow$ $\boxed{\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{encl}}$

RHR for Ampere's law $\Rightarrow$ curl fingers of RH in direction of Amperian loop; currents in general direction of thumb are +, currents in opposite direction are −

inside long straight wire with uniform current density $\Rightarrow$ $\boxed{B = \left(\frac{\mu_0 i}{2\pi R^2} \right) r}$

ideal solenoid $\Rightarrow$ $\boxed{B = \mu_0 i n}$ n = # turns per unit length

B inside solenoid

B = 0 outside ideal solenoid

inside toroid $\boxed{B = \frac{\mu_0 i N}{2\pi} \frac{1}{r}}$ B = 0 outside toroid

skip

$\boxed{\vec{B}(z) = \frac{\mu_0}{2\pi} \frac{\vec{\mu}}{z^3}}$ → $\vec{B}$ a distance z above center of a current carrying coil

$\boxed{\mu = N i A}$

Chapter 30: Induction and Inductance

magnetic flux $\boxed{\Phi_B = \int \vec{B} \cdot d\vec{A}}$ units of $\Phi_B \rightarrow$ weber Wb

$\boxed{1\,Wb = 1\,Tm^2}$

$\Rightarrow$ if $\vec{B}$ is uniform and in same direction as $\vec{A}$ $\boxed{\Phi = BA}$

* anytime Φ_B through a conducting loop changes, an emf $\mathcal{E}$ is induced in the loop

$\downarrow$

Faraday's law $\Rightarrow$ $\boxed{\mathcal{E} = -N\, d\Phi_B/dt}$

Lenz's law $\Rightarrow$ an induced emf gives rise to a current whose magnetic field opposes the original change in flux that caused it

EMF Produced in a Moving Conductor

$\mathcal{E} = BLv$ (motional emf)

$i = \mathcal{E}/R = BLv/R$

$F = \dfrac{B^2L^2v}{R}$ $\longrightarrow$ force required to pull loop at constant velocity

$P = B^2L^2v^2/R$ $\longrightarrow$ rate at which force does work + rate at which resistor dissipates energy

* understand eddy currents conceptually

* a changing magnetic flux produces an electric field

Faraday's law of induction $\Rightarrow$ $\boxed{\oint \vec{E} \cdot d\vec{s} = -d\Phi_B/dt}$

inductance of an inductor $\Rightarrow$ $\boxed{L = N\Phi_B/i}$

units of L is henry (H) $\boxed{1\,H = 1\,Tm^2/A}$

for an ideal solenoid $\rightarrow$ $\boxed{L = \mu_0 n^2 A l}$

$$\mu_0 = 4\pi \times 10^{-7}\ Tm/A$$
$$= 4\pi \times 10^{-7}\ H/m$$

self-induced emf $\Rightarrow$ $\boxed{\mathcal{E}_L = -L\,di/dt}$

$\mathcal{E}_L$ opposes change of current through it

RL circuits

rise of current : $\boxed{i = \mathcal{E}/R\,(1 - e^{-t/\tau_L})}$

inductive time constant $\boxed{\tau_L = L/R}$

* can get V_R from $V_R = iR$ and $\mathcal{E}_L$ from $\mathcal{E}_L = -L\,di/dt$

$$\boxed{\mathcal{E}_L = -L\,di/dt = -\mathcal{E}\,e^{-t/\tau_L}}$$

decay of current : $\boxed{i = i_0\,e^{-t/\tau_L}}$

$$\boxed{\mathcal{E}_L = -L\,di/dt = i_0 R\,e^{-t/\tau_L}}$$

energy stored in $\vec{B}$-field of inductor $\Rightarrow$ $\boxed{U_B = \tfrac{1}{2} L i^2}$

magnetic energy density $\Rightarrow$ $\boxed{u = \tfrac{1}{2}\,B^2/\mu_0}$

energy per unit volume at any point in a $\vec{B}$-field

Review of Chapter 31: EM Oscillations & AC

⇒ an EM oscillator (LC circuit) is analagous to a mechanical oscillator (mass on a spring)

$$q = Q\cos(\omega t + \phi) \qquad \omega = 2\pi f = \frac{1}{\sqrt{LC}}$$

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

$$E = U_E + U_B = \tfrac{1}{2}\, q^2/C + \tfrac{1}{2} L i^2$$

$$E = \tfrac{1}{2}\, Q^2/C = \tfrac{1}{2} L I^2$$

⇒ if there is resistance in the circuit, the EM oscillations die out because energy is dissipated by the resistor

↓

$$q = Q e^{-Rt/2L}\cos(\omega' t + \phi)$$

$$\omega' = \sqrt{\omega^2 - (R/2L)^2}$$

Three Simple Circuits

↓ R, L, or C connected to alternating emf source

$$\mathcal{E} = \mathcal{E}_m \sin\omega_d t = \mathcal{E}_m \sin 2\pi f_d t$$

$$i = I\sin(\omega_d t - \phi)$$

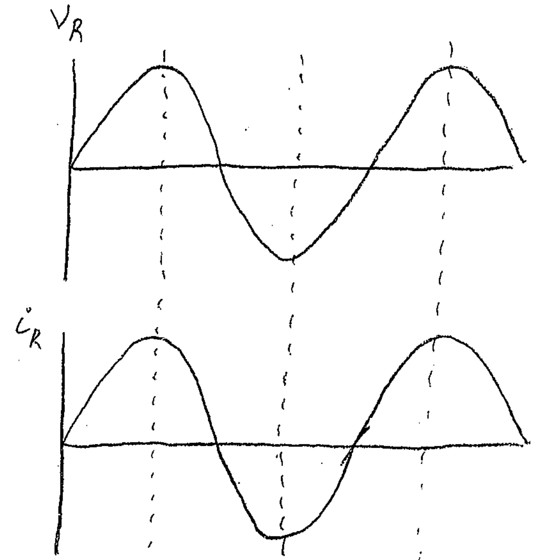
resistive load

$$i_R = I_R \sin(\omega_d t - \phi)$$

$$I_R = V_R / R$$

$$\phi = 0$$

$\downarrow$ current in phase with voltage



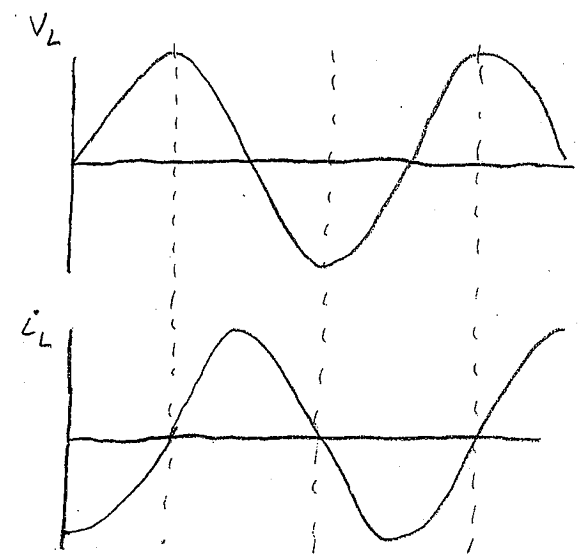
inductive load

$$i_L = I_L \sin(\omega_d t - \phi)$$

$$I_L = V_L / X_L \qquad X_L = \omega_d L$$

$$\phi = 90^\circ$$

$\downarrow$ current peaks after voltage



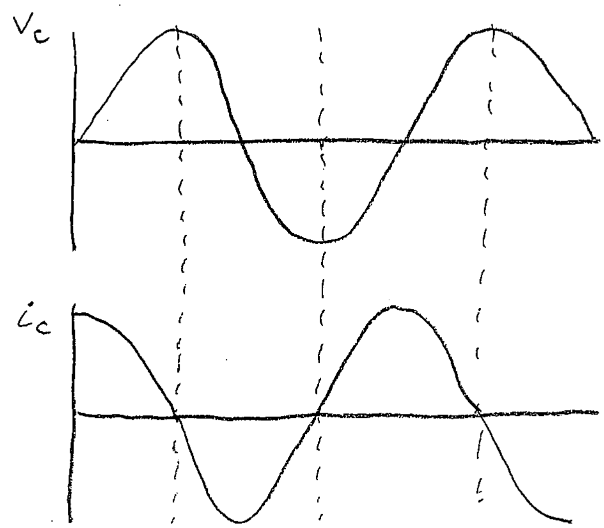
capacitive load

$$i_C = I_C \sin(\omega_d t - \phi)$$

$$I_C = V_C / X_C \qquad X_C = \frac{1}{\omega_d C}$$

$$\phi = -90^\circ$$

$\downarrow$ current peaks before voltage



circuit element	resistance or reactance	amplitude relation	phase constant	phase of current
resistor	R	$V_R = I_R R$	0	in phase with V_R
inductor	$X_L = \omega_d L$	$V_L = I_L X_L$	$+90°$	lags V_L by $90°$
capacitor	$X_C = 1/\omega_d C$	$V_C = I_C X_C$	$-90°$	leads V_C by $90°$

ELI "positively" is the ICE man

$\Rightarrow$ know phasors conceptually

Series RLC circuit $\longrightarrow$ R, L, & C all connected in series to an alternating emf source

$$\mathcal{E} = \mathcal{E}_m \sin \omega_d t$$

$$i = I \sin(\omega_d t - \phi)$$

$$I = \mathcal{E}_m / Z \qquad Z = \sqrt{R^2 + (X_L - X_C)^2}$$

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

1) $X_L > X_C$ (mainly inductive) $\phi > 0$ current lags emf

2) $X_C > X_L$ (mainly capacitive) $\phi < 0$ current leads emf

3) $X_L = X_C$ (resonance) $\phi = 0$ current in phase with emf

$\Rightarrow$ resonance occurs when $\omega_d = \omega = 1/\sqrt{LC}$

at resonance, Z is a minimum ($Z = R$) and current is a maximum

1) $\omega_d = \omega$ $\quad X_C = X_L$ $\quad$ resonance $(\phi = 0)$

2) $\omega_d < \omega$ $\quad X_C > X_L$ $\quad$ mainly capacitive $(\phi < 0)$

3) $\omega_d > \omega$ $\quad X_L > X_C$ $\quad$ mainly inductive $(\phi > 0)$

Power in AC Circuits

$I_{rms} = I/\sqrt{2}$ $\qquad V_{rms} = V/\sqrt{2}$ $\qquad \mathcal{E}_{rms} = \mathcal{E}/\sqrt{2}$

$P_{ave} = I_{rms}^2 R$ $\qquad P_{ave} = I_{rms}\,\mathcal{E}_{rms}\cos\phi$

power factor

Transformers

$$V_s = V_p \frac{N_s}{N_p}$$

$N_s > N_p$ step-up transformer

$N_s < N_p$ step-down transformer

$$I_s = I_p \frac{N_p}{N_s}$$