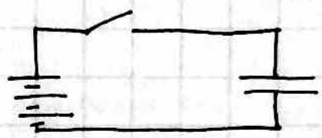
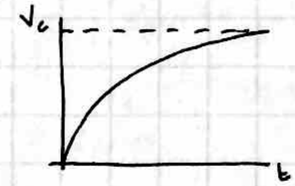
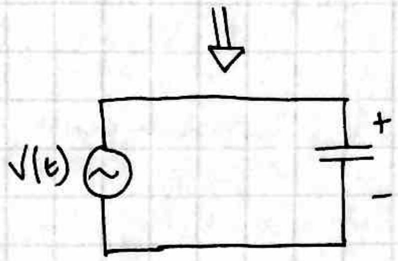
JANUARY 10, 2012

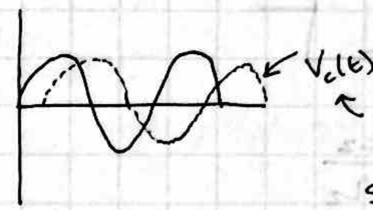
ENGR 202 STEADY STATE SINUSOIDAL RESPONCE OF LINEAR CIRCUITS





← NOT STEADY





VOLTAGE OF CAPACITOR

STEADY STATE → TIME DELAY WHEN KICKED ON

GIVEN A FREQUENCY, WHATS THE PHASE AND VOLTAGE?

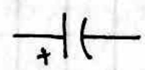
RESISTORS → CAPACITORS → INDUCTORS

RESISTOR:  [OHM] Ω

$\boxed{\text{OHMS LAW: } V = IR}$

PARRALLEL $R_T = \dfrac{R_1 R_2}{R_1 + R_2}$

WATTS LAW: $P = VI = I^2 R = \dfrac{V^2}{R}$

CAPACITOR:  'OR'  ← POLAR CAPACITOR, SAME FOR ANALYSIS PURPOSES.

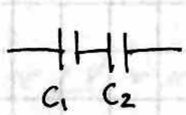
UNIT: [FARAD] F

$Q = CV$

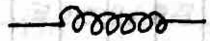
CAPACITANCE VOLTAGE

$\dfrac{dQ}{dt} = C\dfrac{dV}{dt}$ $E = \frac{1}{2}CV^2$

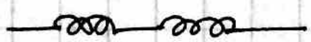
$I = \dfrac{dQ}{dt}$



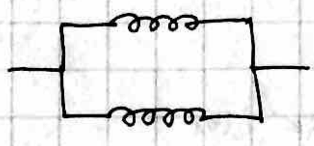
$C_{TOTAL} = \dfrac{C_1 C_2}{C_1 + C_2}$ PARALLLEL $= C_1 + C_2$

INDUCTORS:  [HENRY] $V = L\frac{dI}{dt}$

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



$I_T = L_1 + L_2$

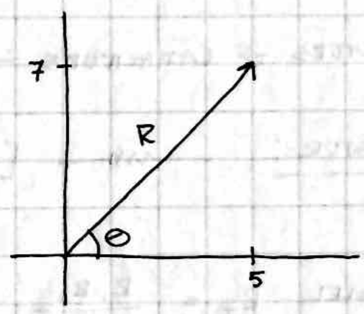


$I_T = \frac{L_1 L_2}{L_1 + L_2}$

COMPLEX NUMBERS:

$j = \sqrt{-1}$ $\quad j^2 = -1 \quad j^3 = -j$

$Z = X + jY$



$Z = 5 + j7$ OR

$Z = R\angle\theta$

READING NOTES (CHAPTER 9)

A SINUSOIDAL VOLTAGE:

$$V(t) = V_t \sin(\omega t) \qquad T = \frac{2\pi}{\omega} \text{ IS THE PERIOD}$$

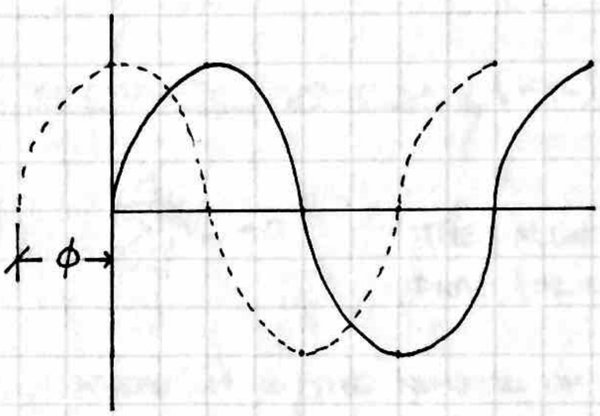
$$V_t = \text{AMPLITUDE}$$

A FUNCTION IS PERIODIC IF:

$$V(t + T) = V(t) \qquad f = \frac{1}{T} \text{ IS THE FREQUENCY}$$

MORE GENERAL VERSION:

$$V(t) = V_m \sin(\omega t + \phi)$$ WHERE ϕ IS THE PHASE



ADDITION OF SINUSOIDS:

$$A\cos\omega t + B\sin\omega t = C\cos(\omega t - \theta)$$ WHERE $C = \sqrt{A^2 + B^2}$ AND

$$\theta = \tan^{-1}\left(\frac{B}{A}\right)$$

PHASORS: A PHASOR IS A COMPLEX NUMBER THAT REPRESENTS THE PHASE AND AMPLITUDE OF A SINUSOID

$$Z = x + jy$$ WHERE $j = \sqrt{-1}$

$$Z = r\angle\phi = re^{j\phi}$$ WHERE r IS THE MAGNITUDE OF Z AND ϕ THE PHASE

ENGR 202 REVIEW NOTES (READING):

KIRCHOFF'S LAWS:

KIRCHOFF'S CURRENT LAW (KCL):

$$\sum_{n=1}^{N} i_n = 0$$

THE ALGEBRAIC SUM OF CURRENTS ENTERING A NODE (OR CLOSED BOUNDARY) IS ZERO

WHERE N IS THE NUMBER OF BRANCHES CONNECTED TO THE NODE

"THE SUM OF CURRENTS ENTERING THE NODE IS EQUAL TO THE SUM OF CURRENTS LEAVING THE NODE"

KIRCHOFF'S VOLTAGE LAW (KVL)

$$\sum_{m=1}^{M} v_m = 0$$

THE ALGEBRAIC SUM OF ALL VOLTAGES AROUND A CLOSED PATH (OR LOOP) IS ZERO

WHERE M IS THE NUMBER OF VOLTAGES IN THE LOOP (OR # OF BRANCHES)

"SUM OF VOLTAGE DROPS = SUM OF VOLTAGE RISES"

SERIES RESISTORS:

$$R_{EQ} = R_1 + R_2 + \sum_{n=1}^{N} R_n$$ WHERE $$V_1 = \frac{R_1}{R_1 + R_2} V$$ AND $$V_2 = \frac{R_2}{R_1 + R_2} V$$

IN GENERAL, FOR N RESISTORS IN SERIES, WITH SOURCE VOLTAGE V,

$$V_n = \frac{R_n}{R_1 + R_2 \ldots + R_n} V$$

THIS IS THE VOLTAGE DIVIDER EQUATION

ENGR 202 READING REVIEW CONT.

PARALLEL RESISTORS:

$$R_{EQ} = \frac{R_1 R_2}{R_1 + R_2}$$ FOR TWO RESISTORS IN PARRALLEL

$$\frac{1}{R_{EQ}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \frac{1}{R_N}$$ FOR MULTIPLE RESISTORS IN PARALLEL

$$i_1 = \frac{R_2}{R_1 + R_2} i \, ; \quad i_2 = \frac{R_1}{R_1 + R_2} i$$ CURRENT DIVIDER EQUATION

METHODS OF ANALYSIS:

* NODAL ANALYSIS: BASED ON SYSTEMATIC APPLICATION OF KIRCHOFFS CURRENT LAW. INTERESTED IN FINDING THE NODE VOLTAGES

STEPS TO DETERMINE NODE VOLTAGES:

1.) SELECT NODE AS REFERENCE, ASSIGN VOLTAGE VARIABLES TO THE REMAINING NODES (N-1)
2.) APPLY KCL TO EACH OF THE N-1 NON-REFFERENCE NODES, USE OHMS LAW TO EXPRESS BRANCH CURRENTS IN TERMS OF NODE VOLTAGES
3.) SOLVE THE RESULTING SIMULTANEOUS EQUATIONS

CURRENT FLOWS FROM A HIGHER POTENTIAL TO A LOWER POTENTIAL

$$\boxed{i = \frac{V_{HIGHER} - V_{LOWER}}{R}}$$

PASSIVE SIGN CONVENTION: IS SATISFIED WHEN CURRENT ENTERS THROUGH THE POSITIVE TERMINAL & SUPPLYING AND EXITS THROUGH POSITIVE ABSORBING.

NODAL ANALYSIS CONT.

NODAL ANALYSIS W/ VOLTAGE SOURCES

CASE 1: IF THE VOLTAGE SOURCE IS CONNECTED BETWEEN THE REFRENCE NODE AND NON-REFRENCE NODE, VOLTAGE OF NON-REFRENCE NODE = VOLTAGE OF VOLTAGE SOURCE.

CASE 2: IF THE VOLTAGE SOURCE (DEPENDENT OR INDEPENDENT) IS CONNECTED BETWEEN TWO NON-REFRENCE NODES, THE TWO N-R NODES FORM A SUPERNODE

SUPERPOSITION: BASED ON LINEARITY PRINCIPIL, DETERMINES CONTRIBUTION OF EACH INDEPENDENT SOURCE, THE ADDS THEM TO DETERMINE FINAL TOTAL.

STEPS TO APPLY SUPERPOSTION:

1.) "TURN OFF" ALL INDEPENDENT SOURCES EXCEPT ONE. FIND V OR I USING NORMAL METHODS.

2.) REPEAT STEP 1 FOR EACH OTHER INDEPENDENT SOURCE

3.) FIND ALL OTHER COMBINATIONS BY ADDING ALGEBRAICALLY ALL CONTRIBUTIONS.

VOLTAGE SOURCE "OFF" = SHORT CIRCUIT

CURRENT SOURCE "OFF" = OPEN CIRCUIT.

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GENERALLY SHOULD KEEP PHASOR ANGLES BETWEEN ~~0 A~~ $-180°$ AND $180°$

- ALWAY CHECK GEOMETRY FOR $\tan^{-1}$ SOLUTIONS

RESPONSE TO SINOSOIDAL SIGNALS

RESISTORS:

$$V = iR \text{ OR } i = \frac{V}{R} = \frac{A}{R}\sin(\omega t)$$

CAPACITOR:

$$I = C\frac{dV}{dt} = CA\cos(\omega t)\omega = \omega CA\sin(\omega t + 90°)$$

INDUCTOR:

$$V = L\frac{dI}{dt} \Rightarrow I = \frac{1}{L}\int V dt \Rightarrow I = \frac{-A}{\omega L}\cos(\omega t) = \frac{A}{\omega L}\sin(\omega t - 90°)$$

PHASOR NOTATION:

$$V(t) = V_p\cos(\omega t + \phi)$$

NOTE: COS CONSIDERED 'BASE' FUNCTION, DUE TO REAL PART IN EULERS EQUATION

$\downarrow$

EULER

$\downarrow$

$$V_p \, Re\{e^{j(\omega t + \phi)}\} \Rightarrow Re\{\underbrace{V_p e^{j\omega t}}_{\text{ONLY THING THAT CHANGES}} e^{j\phi}\}$$

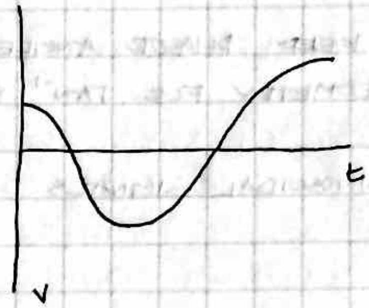
ONLY THING THAT CHAGES = COMPLEX NUMBER

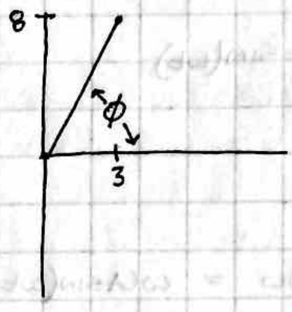
DOES CHANGE

$$\overline{V} = V_p e^{j\phi}$$

PHASORS CONTINUED:

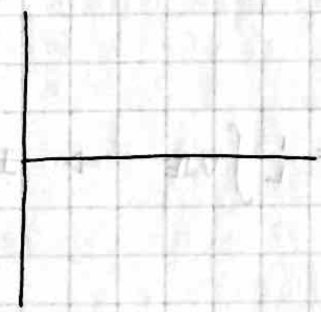
$\bar{V} = (3 + j8)$ VOLTS

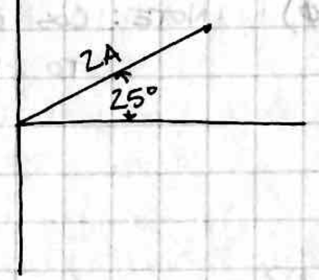




$V(t) = 8.54\cos(\omega t + 69.4)$

$I = 2A\angle 25°$





$I(t) = 2A\cos(\omega t + 25°)$

$\overline{V_2} = 3Ve^{j30°} \Rightarrow V(t) = 3V\cos(\omega t + 30°) \Rightarrow \overline{I_2} = j\ 50$ AMP

$\overline{V_3} = 5V \Rightarrow V_3(t) = 5V\cos(\omega t)$

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VALUES MUST BE IN RADIANS FOR EULERS IDENTITY

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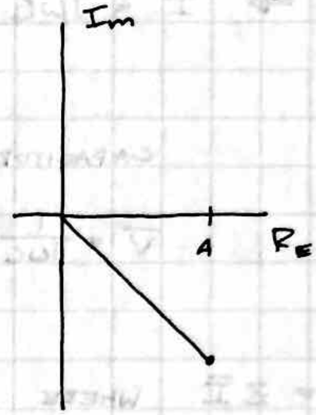
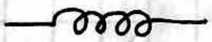
$\overline{V} = 20v \quad (4-4j) \quad \Rightarrow$



$20v\cos(\omega t - 45^\circ)\sqrt{2}(4)$



INDUCTOR:

$V = L\frac{di}{dt} \qquad i(t) = I_p\cos(\omega t + \phi)$

$= R_e(I_p e^{j\omega t} e^{j\phi}) \Rightarrow \overline{I} - I_p\angle\phi$

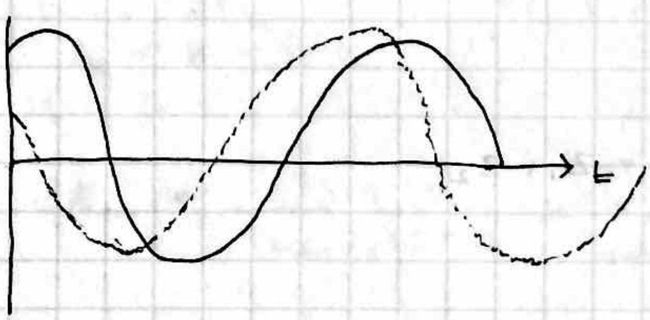
$v(t) = -\omega L\sin(\omega t + \phi) = \underbrace{-\omega L I_p \sin(\omega t + \phi)}$

$= R_E(I_p \omega L e^{j\omega t} e^{j\phi} e^{j90^\circ})$

$= R_E(I_p \omega L e^{j\omega t} e^{j\phi} j)$

$\overline{V} = j\omega L I_p \angle\phi$

$$\boxed{\overline{V} = j\omega L\overline{I}}$$



"ELI THE ICE MAN"

CAPACITOR :

$$i = C \frac{dv}{dt} \qquad \overline{V} = V_p \angle \phi$$

$$\overline{I} = j\omega C V_p \angle \phi \quad \Rightarrow \quad \overline{I} = j\omega C \overline{V}$$

INDUCTOR :

$$\overline{V} = j\omega L \overline{I}$$

CAPACITOR:

$$\overline{V} = \frac{1}{j\omega C} \overline{I}$$

RESISTOR :

$$\overline{V} = R\overline{I}$$

IN GENERAL , $\overline{V} = Z\overline{I}$ WHERE Z IS IMPEDENCE

$$Z = \underbrace{R}_{\text{RESISTANCE}} + j\underbrace{X}_{\text{REACTANCE}}$$

Z = COMPLEX (UNITS, OHMS Ω)
R = REAL
X = REAL (UNITS, OHMS Ω)

POISITIVE REACTANCE = INDU

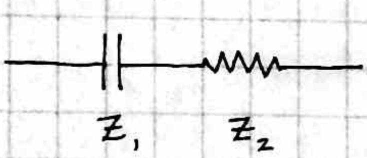
$\frac{1}{Z}$ = ADMITENCE (S, SIEMANS) OR $\mho$

$Y = G + jB$ WHERE G - CONDUCTANCE
B - SUSEPTANCES

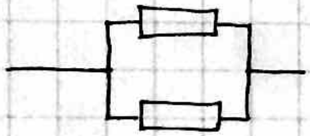
$$Z_{INDUCTOR} = j\omega L$$

$$Z_{CAPACITOR} = \frac{1}{j\omega C}$$

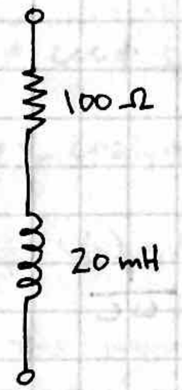
"THE IMPEDENCE TELLS YOU HOW HARD IT IS TO PUSH CURRENT THROUGH SOMETHING"



$$Z_{TOTAL} = Z_1 + Z_2$$



$$Z_{TOTAL} = \frac{Z_1 Z_2}{Z_1 + Z_2}$$



FREQUENCY MUST BE GIVEN.

DETERMINE Z_{TOT}

$f = 400\ Hz$

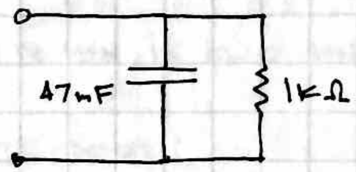
SOLUTION:

$Z_{TOT} = Z_1 + Z_2$

$Z_1 = R = 100\,\Omega$

$Z_2 = j\omega L = j2\pi\, 400\,Hz\; 20\,mH = 50\,\Omega$ WHERE $\Omega = 2\pi f$

$$\boxed{Z_{TOT} = 100 + j50\ \Omega}$$



$f = 1\,KHz$

$Z_{TOT} = ?$

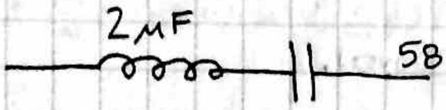
$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

$$Z_{1(CAP)} = \frac{1}{j\omega C} = -j3.39\,\Omega$$

NEGATIVE INDICATED CAPACITOR

$Z_2 = R = 1K\Omega$

$$Z_{TOT} = \frac{-j3.39\Omega \cdot 1K\Omega}{1K\Omega - j3.339\ \Omega} = \boxed{0.011 - 3.387j\ \Omega}$$



@ 1 MHz

$Z_{TOT} = ?$

$Z_{TOT} = j\omega L + \frac{1}{j\omega C}$ OR $Z_{TOT} = j\omega L - j\frac{1}{\omega C}$

(ALL COMPLEX — NO RESISTOR)

$$Z_{TOT} = j 2\pi \cdot 10^6 \frac{1}{SEC} 2\mu H - j \frac{1}{2\pi \cdot 10^6 \frac{1}{SEC} \cdot 58nF}$$

$$\boxed{Z_{TOT} = j\, 9.82\,\Omega}$$

CHAPTER 9 READING NOTES:

* $e^{\pm j\phi} = \cos\phi \pm j\sin\phi$ WHERE $R_E(e^{j\phi}) = \cos\phi$ AND $I_m(e^{j\phi}) = \sin\phi$

$v(t) = V_m\cos(\omega t + \phi) = R_E(V_m e^{j(\omega t+\phi)}) = Re(V_m e^{j\phi} e^{j\omega t}$

THUS; $v(t) = R_E(\bar{V} e^{j\omega t})$ WHERE $\bar{V} = V_m e^{j\phi} = V_m \angle\phi$

* $\bar{V}$ IS THE PHASOR REPRESENTATION OF $v(t)$. A PHASOR IS A COMPLEX REPRENTATION OF THE MAGNITUDE AND PHASE OF A SINUSOID.

* SWITCHING BACK AND FOURTH: PHASORS AND SINUSOIDS

TO OBTAIN THE SINUSOID FROM THE PHASOR, MULTIPLY THE PHASOR BY THE TIME FACTOR $e^{j\omega t}$ AND TAKE THE REAL PART.

TIME-DOMAIN REPRESENTATION:		PHASOR DOMAIN REPRESENTATION:
$v(t) = V_m\cos(\omega t + \phi)$	$\Longleftrightarrow$	$\bar{V} = V_m \angle\phi$

PHASOR DOMAIN IS ALSO KNOWN AS THE FREQUENCY DOMAIN

TIME-DOMAIN:		PHASOR DOMAIN:
$\frac{dv}{dt}$	$\Longleftrightarrow$	$j\omega\bar{V}$
$\int v\,dt$	$\Longleftrightarrow$	$\frac{\bar{V}}{j\omega}$

* CHARACTERISTICS OF $v(t)$ AND $\bar{V}$

1.) $v(t)$ IS INSTANTANEOUS OR TIME-DOMAIN, $\bar{V}$ IS FREQUENCY OR PHASOR-DOMAIN

2.) $v(t)$ IS TIME DEPENDENT, WHILE $\bar{V}$ IS NOT

3.) $v(t)$ IS ALWAYS REAL W/ NO COMPLEX PART. $\bar{V}$ IS GENERALLY COMPLEX

READING NOTES CONT.

* PHASOR RELATIONSHIPS FOR CIRCUIT ELEMENTS:

- RESISTOR: $\boxed{\bar{V} = IR}$

- INDUCTOR: $\boxed{\bar{V} = j\omega L I}$

- CAPACITOR: $\boxed{\bar{V} = \frac{I}{j\omega C}}$

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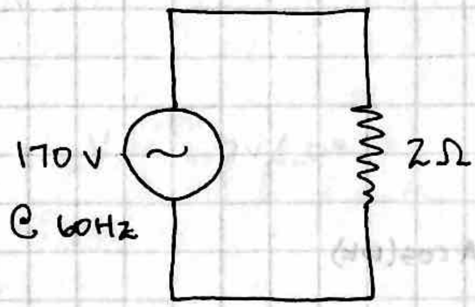
↓ 85A @ 60 Hz



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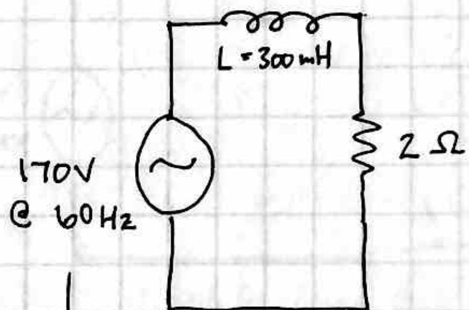
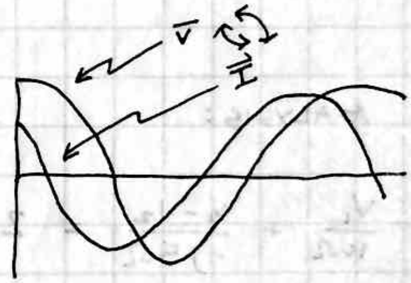


$\angle 0 \rightarrow 170\,\mathrm{v}\cos(2\pi\, 60\ \tfrac{1}{\mathrm{sec}}\, t) = V(t)$



$\cancel{I = VZ}$ $\qquad I = \frac{V}{Z}$

$Z_{RES} = 2\,\Omega$

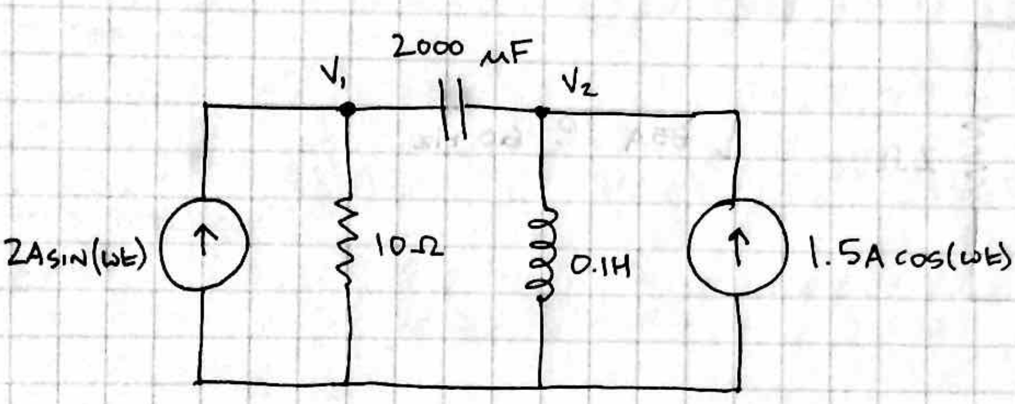
$Z_{IND} = j\omega L = j\,2\pi\, 60\,(0.3)$

$Z_{TOT} = (2 + j\,113.1)\,\Omega = 113\angle 89°$

$I = 1.5\angle -89°\ A$

INDUCTORS LIMIT CURRENT WITHOUT WASTING POWER

EXAMPLE



LOOKING FOR VOLTAGE @ V_1, V_2

$2A \angle -90$

$1.5 \angle 0$

$$Z_{CAP} = \frac{1}{j\omega C} = -j5\Omega$$

$$Z_{IND} = j\omega L = j10\Omega$$

NODE ANALYSIS:

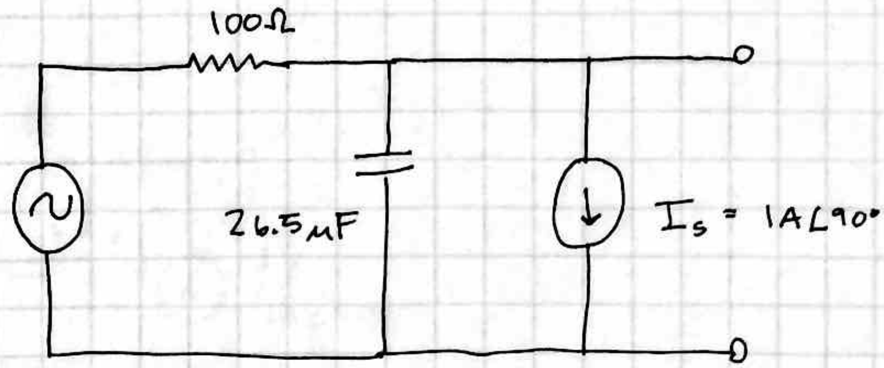
1.) $$\frac{V_1}{10\Omega} + \frac{V_1 - V_2}{-j5\Omega} = 2A \angle -90°$$

2) $$\frac{V_2 - V_1}{-j5\Omega} + \frac{V_2}{j10\Omega} = 1.5 \angle 0$$

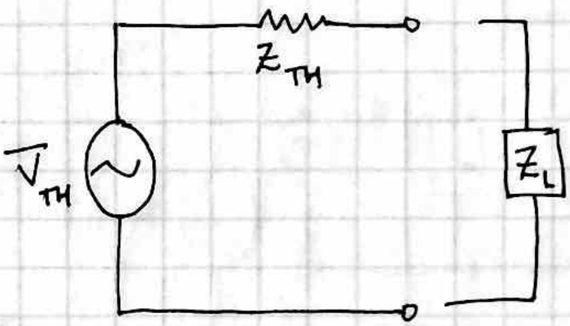
⇒ SOLVE FOR V_1 / V_2 ⇒ $V_1 = 14 + j8 = 16.1 \angle 29.7°$

EXAMPLE

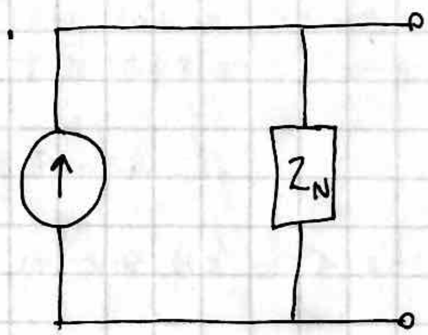
$V_s = 100V\angle 0°$



THEVININ :

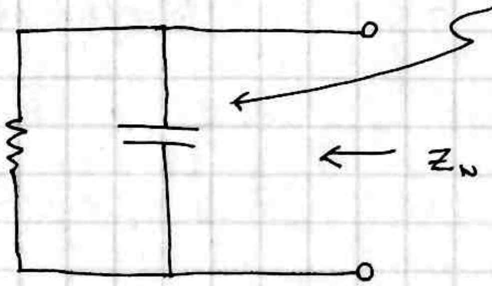


NORTON :



FIND Z_{TH} / Z_N

$$\frac{1}{j\omega C} = -j100\Omega$$



$$Z_N = \frac{(100\Omega)(-j100\Omega)}{(100\Omega)-(j100\Omega)} = 50 - j50\Omega$$

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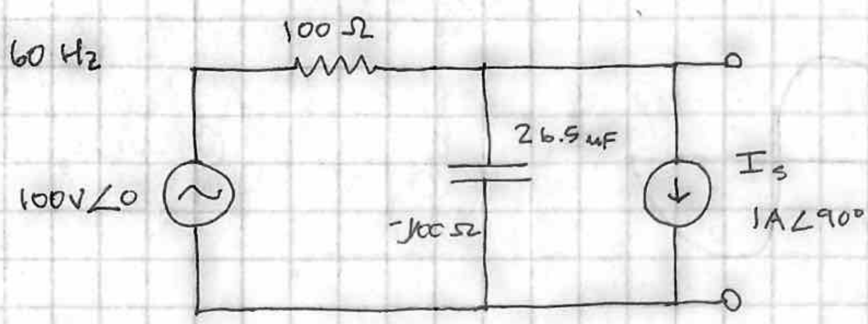
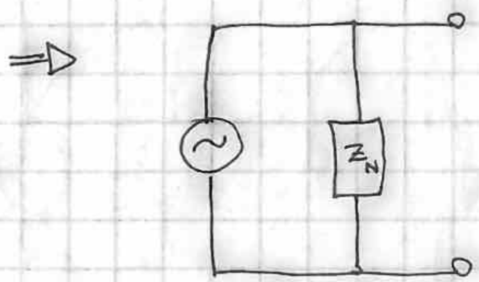


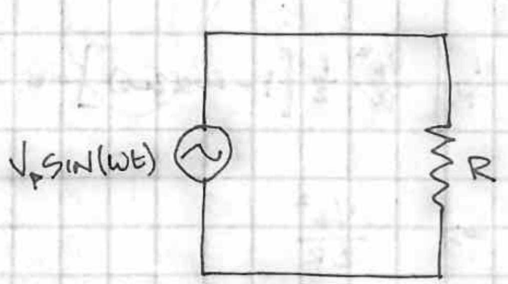


$$\boxed{V_{TH} = I_N Z_N}$$

NEW HW ON BLACKBOARD
- 6 PROBLEMS ("MORE INVOLVED")

* POWER

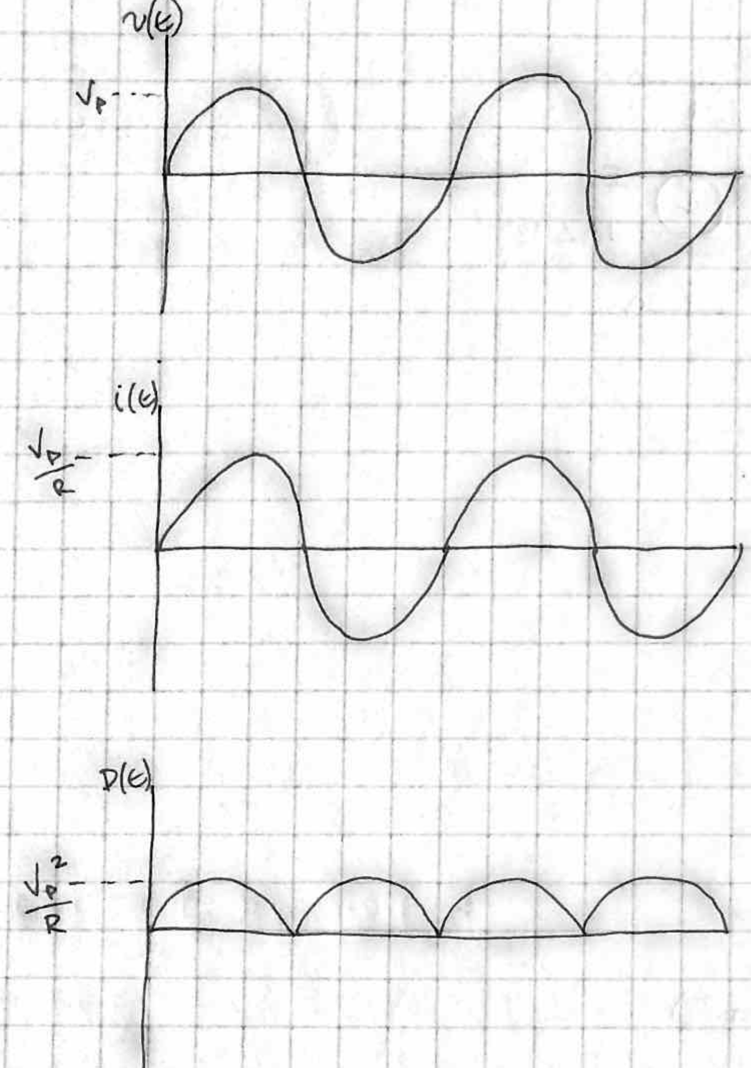
$P = v(t)\,i(t) \Rightarrow$ SO $\Rightarrow$ $P(t) = v(t)\,i(t)$



$v(t) = V_p \sin(\omega t)$

$i(t) = \frac{V_p}{R} \sin(\omega t)$

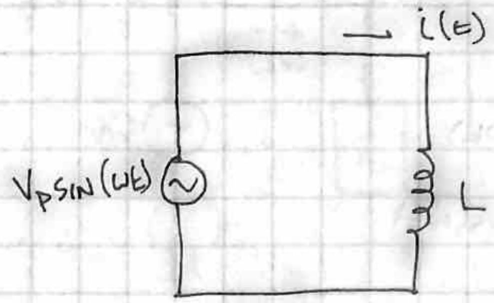
$p(t) = \frac{V_p^2}{R} \sin^2(\omega t)$ ⟸ INSTANTANEOUS POWER

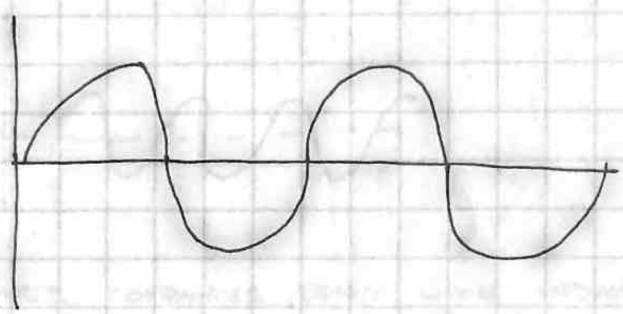


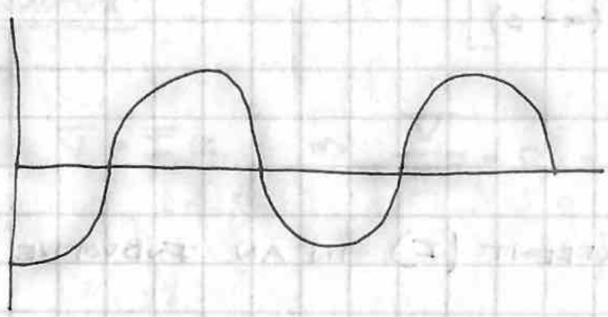
$$p(t) = \frac{V_p^2}{R}\,\frac{1}{2}\left[1 - \cos(2\omega t)\right] = p(t) = \frac{V_p^2}{R}\sin^2(\omega t)$$

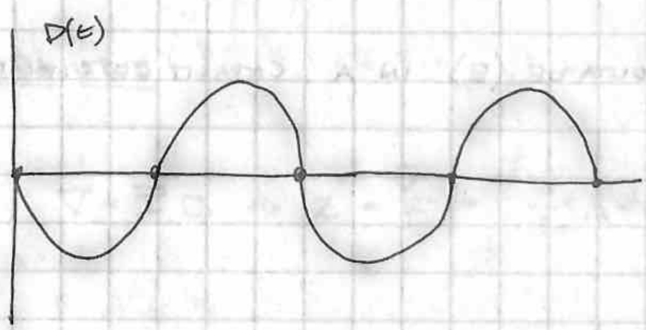
$$P_{AVE} = \frac{1}{T}\int_0^T p(t)\,dt \Rightarrow P_{AVE} = \frac{1}{T}\int \frac{V_p^2}{R}\,\frac{1}{2}\left[1 - \cos(2\omega t)\right] dt$$

$$\frac{V_p^2}{2RT}\left[\int_0^T 1\,dt - \int_0^T \cos(2\omega t)\,dt\right] \Rightarrow \dots \Rightarrow \frac{V_p^2}{2R}$$



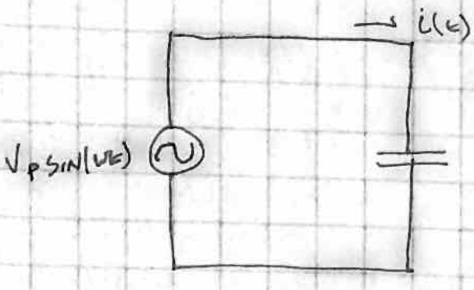






$P_{AVE} = 0$ INDUCTIVE LOAD

$$p(t) = v(t)\,i(t) = \frac{-V_p^2}{\omega L}\left(\frac{1}{2}\sin(2\omega t)\right)$$



$$v(t) = V_p \sin(\omega t)$$

$$i(t) = \omega V_p L \cos(\omega t)$$

TRIG IDENTITIES:

$$\sin^2\theta = \frac{1}{2}\left[1 - \cos(2\theta)\right]$$

$$\sin\theta\cos\theta = \frac{1}{2}\sin(2\theta)$$

$$\cos\alpha + \cos\beta = \frac{1}{2}\left[\cos(\alpha+\beta) + \cos(\alpha-\beta)\right]$$

<u>ELI</u> THE <u>ICE</u> MAN

* ELI: VOLTAGE (E) LEADS CURRENT (I) IN AN INDUCTIVE CIRCUIT (L)

* ICE: (I) CURRENT LEADS VOLTAGE (E) IN A CAPACITIVE CIRCUIT.

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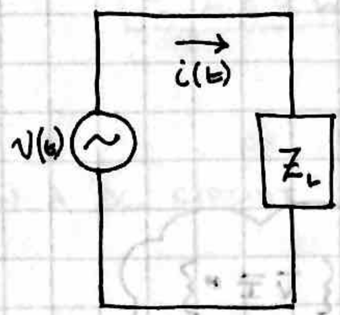


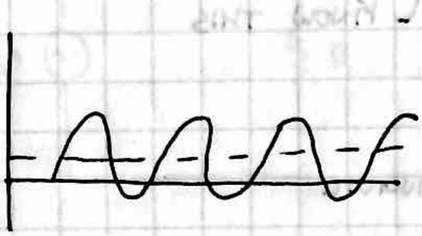
$i(t) = I_p \cos(\omega t + \phi_i)$
$v(t) = V_p \cos(\omega t + \phi_v)$

$p(t) = I_p V_p \cos(\quad)\sin(\quad)$

$= V_p I_p \left[\underbrace{\cos(\phi_v - \phi_i)}_{\text{NO DEPENDENCE ON TIME = DIRECT CURRENT}} + \cos(2\omega t + \phi_v + \phi_i)\right]$

1/2

ALSO, THIS IS THE POWER FACTOR



POWER COMPANIES DON'T LIKE INDUCTIVE/CAPACITIVE LOADS

RESISTOR:

$$\bar{V} = \bar{I}R \Rightarrow \frac{\bar{V}}{\bar{I}} = R = \frac{V_p}{I_p}\frac{\angle\phi_v}{\angle\phi_i} = \frac{V_p}{I_p}\underbrace{\angle\phi_v - \phi_i}$$

HAS TO = 0 FOR RESISTOR

$\cos(0) = 1$ POWER FACTOR

CAPACITOR:

$$\bar{V} = \bar{I}Z \Rightarrow Z = \frac{\bar{V}}{\bar{I}} = \frac{V_p}{I_p}\angle\phi_v - \phi_i = \frac{1}{j\omega C} = \frac{1}{\omega C}\angle -90$$

$\cos(-90) = 0$ POWER FACTOR

"LEADING"

= CAPACATIVE LOAD

INDUCTOR:

$$\frac{V_p}{I_p}\angle\phi_v - \phi_i = j\omega L = \omega L\angle +90^\circ$$

PF = 0 "LAGGING"

= INDUCTIVE LOAD

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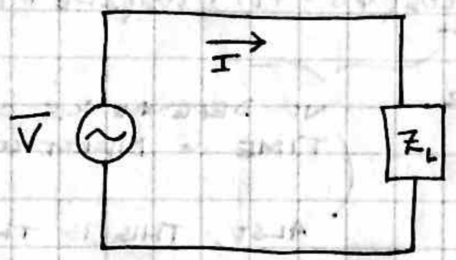
GENERAL LOAD:

$\bar{Z} = |Z| \angle \phi_Z \Rightarrow PF = \cos(\angle \phi_Z)$



$$\boxed{P_{AVE} = \frac{1}{2} Re\{\bar{V}\bar{I}^*\}}$$

KNOW THIS

$V = V\angle\phi_v$ $\quad I = I_p \angle \phi_i$ COMPLEX CONJUGATE

$I^* = I_p \angle -\phi_i$

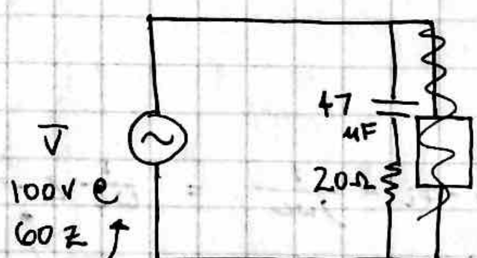
$\bar{V}\bar{I}^* = V_p I_p \angle \phi_v - \phi_i \Rightarrow Re\{\bar{V}\bar{I}^*\} = V_p I_p \cos(\phi_v - \phi_i)$

½

$P_{AVE} = \frac{1}{2} Re\{I Z I^*\} = \frac{1}{2} Re\{|I^*| Z\} = \frac{1}{2} |I|^2 Z$

$Re\{Z\}$

EX.



$P_{AVE} = \frac{1}{2} Re\{\bar{V}\bar{I}\}$ 'OR'

$I = \frac{V}{Z}$ WHERE $Z = 20\Omega + \frac{1}{j\omega C}$

$= 20\Omega - j56\Omega$

$= 60\Omega \angle -70.5°$

$\angle 0$

$I = 100V\angle 0$

$I = \frac{100V\angle 0}{60\Omega\angle -70.5} = \boxed{1.67A \angle 70.5°}$

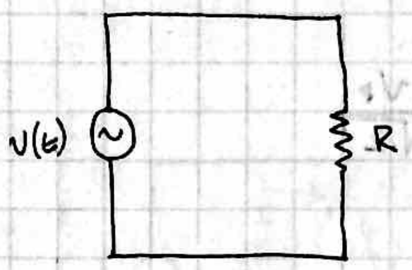
$P_{AVE} = \frac{1}{2} Re\{\bar{V}\bar{I}^*\}$

$P_{AVE} = \frac{1}{2} Re\{(100\angle 0)(1.67A\angle -70.5)\}$

$= \frac{1}{2} \mathrm{Re}\{1.67W \angle -70.5°\}$

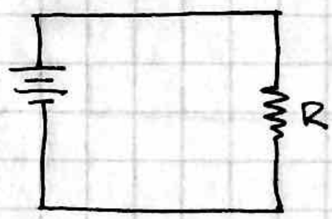
$$\boxed{= 27.8 \text{ W}}$$

NOW A DC CIRCUIT:



$$p(t) = v(t)\, i(t) = \frac{v(t)^2}{R}$$

$$P_{AVE} = \frac{1}{T}\int_0^T \frac{v^2(t)}{R}\, dt$$



$$P_{AVE} = \frac{V_{DC}^2}{R}$$

$$P_{AVE} = \frac{1}{R}\frac{1}{T} = \left(\sqrt{\int_0^T v^2(t)\, d}\right)^2 \Rightarrow P_{AVE} = \frac{V_{EFF}^2}{R}$$

$$V_{EFF} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\, dt}$$

ROOT MEAN SQUARED

$$\boxed{V_{RMS} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\, dt}}$$

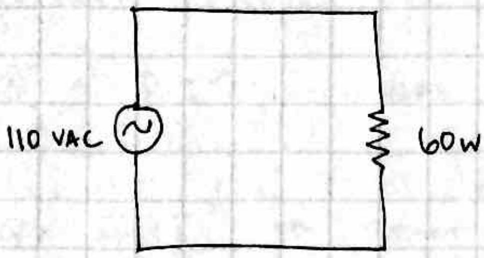
$$v(t) = V_p \sin(\omega t)$$

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T V_p^2 \sin^2(\omega t)\, dt}$$

$$= \sqrt{\frac{V_p^2}{T}\int_0^T \frac{1}{2}(1 - \cos^2(2\omega t)\, dt}$$

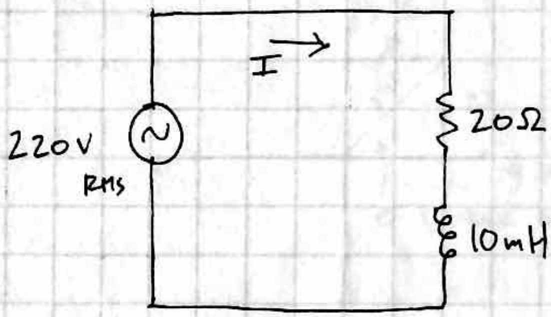
$$= \sqrt{\frac{V_p^2}{T}\int_0^T \frac{1}{2}} = \sqrt{\frac{V_p^2}{2}} = \frac{V_p}{\sqrt{2}}$$

$$\boxed{V_{RMS} = \frac{V_p}{\sqrt{2}}}$$



$$P = \frac{(V_{RMS})^2}{R}$$

$$\boxed{R = 201\,\Omega}$$



$$Z = 20\Omega + j\omega L$$

$$= 20 + j377\,\Omega$$

$$= 20.35\,\Omega\angle 10.7^\circ$$

$$I = \frac{220V}{20.75\,\Omega\angle 10.7} = 10.81\,A\angle -10.7^\circ$$

$$P = (220\,V_{RMS})(10.81) = 2378\,W$$

$$P_{AVE} = Re\{\bar{V}\,I^*\}$$

$$P_{AVE} = (220\angle 0^\circ)(10.8\angle 10.7)$$

$$\boxed{= 2337\,W}$$

$* \; S = VI$

$$P = |S|\underbrace{\cos(\phi_v - \phi_i)}_{PF}$$

$$\frac{P}{S} = P.F.$$

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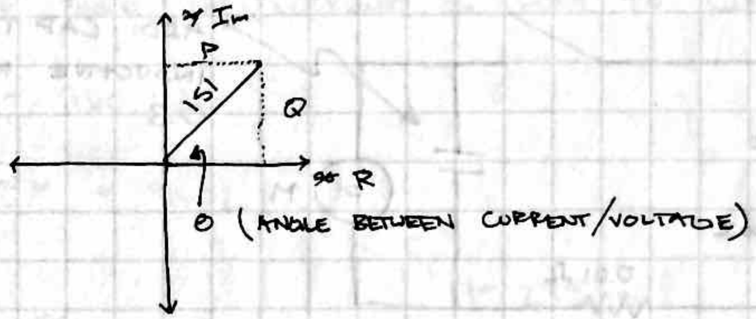
COMPLEX POWER:

$\bar{S} = \bar{V} I^*$ WHERE $P = R_e\{\bar{S}\}$ ← REAL POWER

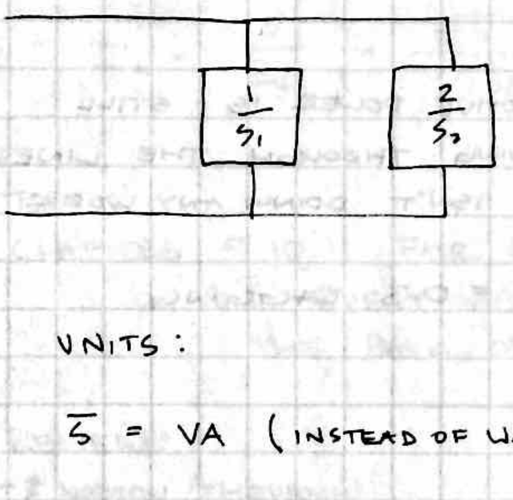
$Q = I_m\{\bar{S}\}$ ⇒ REACTIVE POWER

$|\bar{S}| = S = VI^*$ ⇒ "APPARENT POWER"



$PF = \frac{P}{S} = \cos\phi$

LAGGING = INDUCTIVE LOADS



$\bar{S}_{TOT} = \bar{S}_1 + \bar{S}_2$

$P_{TOT} = P_1 + P_2$

$Q_{TOT} = Q_1 + Q_2$

UNITS:

$\bar{S}$ = VA (INSTEAD OF WATTS)

$P = R_e\{S\}$ W (WATTS)

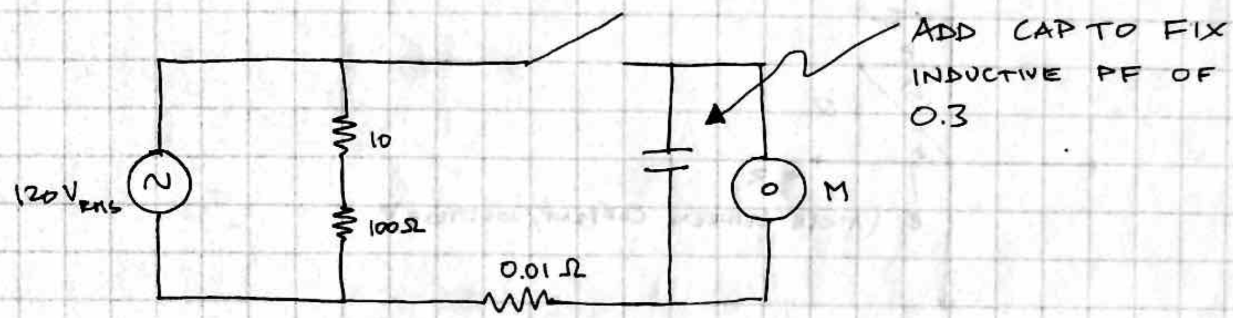
$Q = I_m\{\bar{S}\}$ (VAR) ← NOT "REAL POWER"

MOTOR NAMEPLATE :

$\frac{1}{3} H_P = 745.7 W$

* RATED HP RATING = MECHANICAL OUTPUT POWER, NOT ELECTRICAL INPUT.

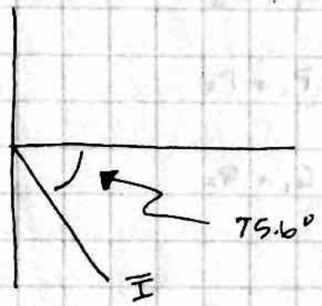
* S.F. "SERVICE FACTOR" TIMES YOU CAN OVERLOAD THE MOTOR



$V = 120V \angle 0^\circ$ $\qquad I = \frac{11.2A}{\sqrt{2}} = 8A_{RMS}$

$\phi_v - \phi_i = \frac{3.5ms}{16.66ms} \Rightarrow$ PHASE DIFFERENCE BY 75.6°

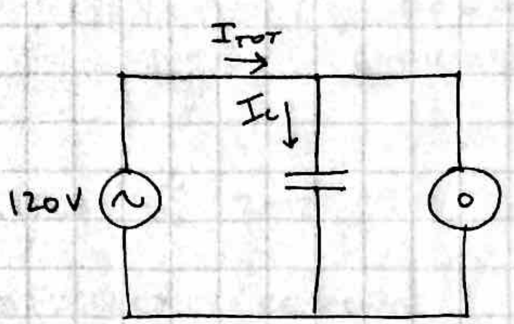
$A = 8A_{RMS} \angle -75.6$



REACTIVE POWER IS STILL FLOWING THROUGH THE LINES BUT ISN'T DOING ANY WORK

PF = 0.3 LAGGING

FEBURARY 9, 2012



$\overline{V} = 120V\angle 0°$

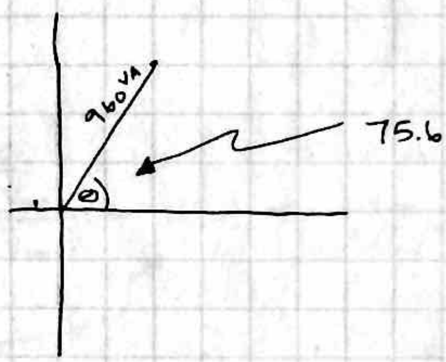
$\overline{I}_L = 8A \angle -75°$

$= 2 - j\,7.75\,A$

GCFI: MEASURES CURRENT OUT OF ONE PLUG INTO ANOTHER TO MAKE SURE NO CURRENT IS LOST TO GROUND.

$S = VI = 960\ VA$

$\overline{S} = \overline{V}\,\overline{I}^* = 960\angle 75°$



$P = 239\ W$
$Q = 930\ VAR$

$\boxed{PF = 0.3}$

$$I_c = \frac{V}{Z_c} = \frac{\overline{V}}{1/j\omega C} = Vj\omega C = 7.75$$

TEST:

CHAPTERS 9, 10, 11 FAIR GAME, NOTHING W/ OP-AMP
≈3 QUESTIONS. KNOW QUESTIONS FROM THE BACK OF BOOK.

REVIEW:

- Z NORTON / THEVENIN
- CURRENT / VOLTAGE DIVISION
- ALL EQUATIONS

$$S = I_{RMS}^2 Z = \frac{V_{RMS}^2}{Z^*} = V_{RMS} I_{RMS}^*$$

$$P_{MAX} = \frac{V_{TH}^2}{8R_{TH}}$$

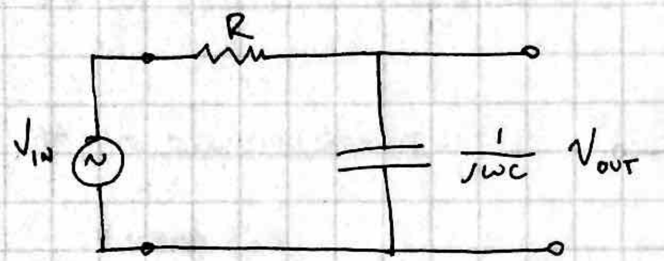
$$P_{AVE} = \frac{1}{2}\mathrm{Re}\{V I^*\}$$

FEB, 9TH, 2012

V= 480 V , PF = 93%
HP = 5 , EFFICIENCY 81%

FEB 16TH, 2012

*FREQUENCY RESPONSE



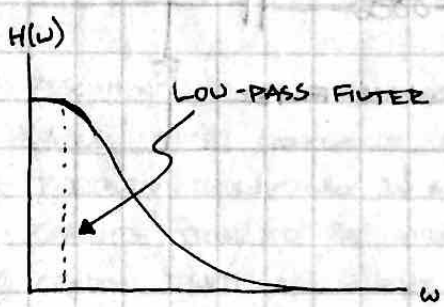
$$\bar{V}_{OUT} = V_{IN}\left(\frac{\frac{1}{j\omega C}}{R + 1/j\omega C}\right)$$

LOW-PASS FILTER

$$\frac{\bar{V}_{OUT}}{\bar{V}_{IN}} = H(\omega) = \frac{1}{1 + j\omega RC} \qquad \frac{1}{RC} = \omega_0$$

UNITS 'SECONDS'

TRANSFER FUNCTION



$$|H(\omega)| = \sqrt{\left(\frac{1}{1+j\,\omega/\omega_0}\right)^2 + \left(\frac{1}{1-j\,\omega/\omega_0}\right)^2}$$

$$= \sqrt{\frac{1}{1 + \omega^2/\omega_0^2}}$$

FOR $\omega \ll \omega_0$, $|H(\omega)| \Rightarrow 1$

FOR $\omega_0 \gg \omega$, $|H(\omega)| \Rightarrow \frac{\omega_0}{\omega} = 0$

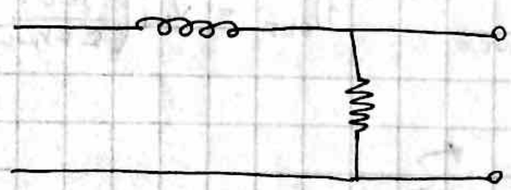
FOR $\omega = \omega_0$, $|H(\omega)| \Rightarrow \frac{1}{\sqrt{2}}$

* PHASE RESPONCE

$$H(\omega) = \frac{1}{1 + j\,\omega/\omega_0}\,\frac{(1 - j\,\omega/\omega_0)}{1 - j\,\omega/\omega_0} = \frac{1 - j\,\omega/\omega_0}{1 + \omega^2/\omega_0^2} \Rightarrow$$

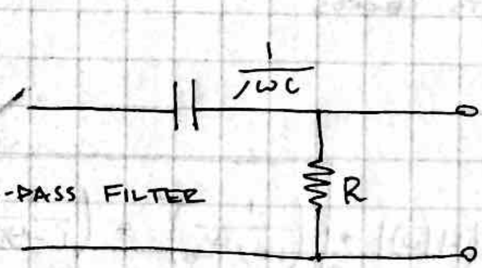
$$H(\omega) = \frac{1}{1 + \omega^2/\omega_0^2} - j\,\frac{\omega/\omega_0}{1 + \omega^2/\omega_0}\,, \quad \angle H(\omega) = \tan^{-1}\left(\frac{-\omega}{\omega_0}\right)$$

SIMILAR TO :

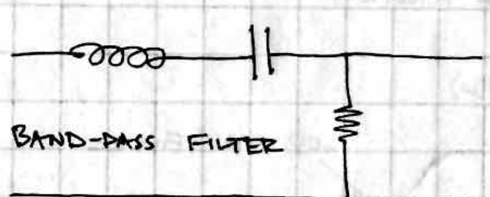


$$DB \cong \log\left(\frac{P_{OUT}}{P_{IN}}\right) \Rightarrow 10\log\left(\frac{V_{OUT}^2}{V_{IN}^2}\right) = 20\log\left(\frac{V_{OUT}}{V_{IN}}\right)$$

dB_m = "DECIBEL w/ RESPECT TO A MILLIVOLT" = $20 \log \frac{V_{OUT}}{V_{IN}}$



HIGH-PASS FILTER



BAND-PASS FILTER

CHAPTER 14 READING NOTES

* FREQUENCY RESPONCE: THE FREQUENCY RESPONSE OF A CIRCUIT IS THE VARIATION IN ITS BEHAVIOR WITH CHANGE IN SIGNAL FREQUENCY.

* TRANSFER FUNCTION: THE TRANSFER FUNCTION $H(\omega)$ IS THE FREQUENCY DEPENDENT RATIO OF PHASOR OUTPUT $Y(\omega)$ TO PHASOR INPUT $X(\omega)$.

$$\boxed{H(\omega) = \frac{Y(\omega)}{X(\omega)}} \Rightarrow \boxed{H(\omega) = \frac{N(\omega)}{D(\omega)}}$$

* THE DECIBEL SCALE:

HISTORICALLY,

$$\boxed{G = \text{NUMBER OF BELLS} = \log_{10}\left(\frac{P_2}{P_1}\right)}$$

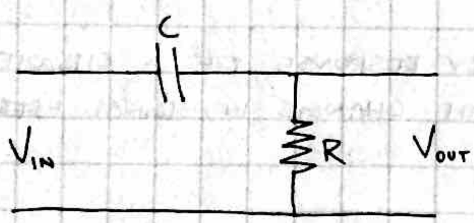
$$\boxed{G_{dB} = 10\log_{10}\left(\frac{P_2}{P_1}\right)} \quad \text{AND} \quad \boxed{G = 20\log_{10}\left(\frac{V_2}{V_1}\right)}$$

* BODE PLOTS: A BODE PLOT IS A SEMI-LOG PLOT OF THE MAGNITUDE (IN DECIBELS) AND THE PHASE (IN DEGREE'S) OF A TRANSFER FUNCTION VERSUS FREQUENCY.

* RESONANCE: RESONANCE IS A CONDITION OF AN RLC CIRCUIT IN WHICH THE CAPACITIVE AND INDUCTIVE REACTANCES ARE EQUAL, THEREBY RESULTING IN A PURELY RESISTIVE IMPEDENCE. THEIR TRANSFER CIRCUITS TEND TO BE HIGHLY FREQUENCY SELECTIVE, SO THEY ARE OFTEN USED AS FILTER CIRCUITS

* FILTERS: A FILTER IS A CIRCUIT DESIGNED TO PASS SIGNALS WITH CERTAIN FREQUENCY'S, AND REJECT OR ATTENUATE OTHERS.

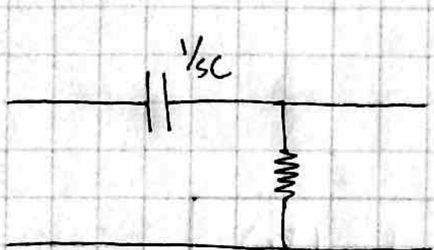
* HIGH-PASS FILTER:



$$H(\omega) = \frac{V_{OUT}(\omega)}{V_{IN}(\omega)} = \frac{R}{R + 1/j\omega C} = \frac{j\omega RC}{1 + j\omega RC}$$

$$\omega / \omega_0 = \frac{1}{RC} \qquad \boxed{H(\omega) = \frac{j\omega/\omega_0}{1 + j\omega/\omega_0}}$$

IN LAPLACE DOMAIN:

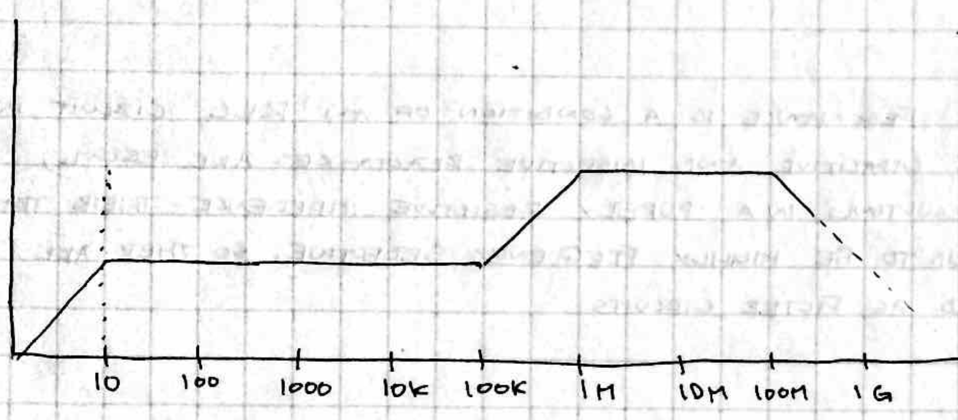


$$\boxed{s = j\omega}$$

IN GENERAL, ANY TRANSFER FUNCTION CAN BE WRITTEN IN A FORM WITH "ZEROS" ON TOP, AND POLES ON "BOTTOM"

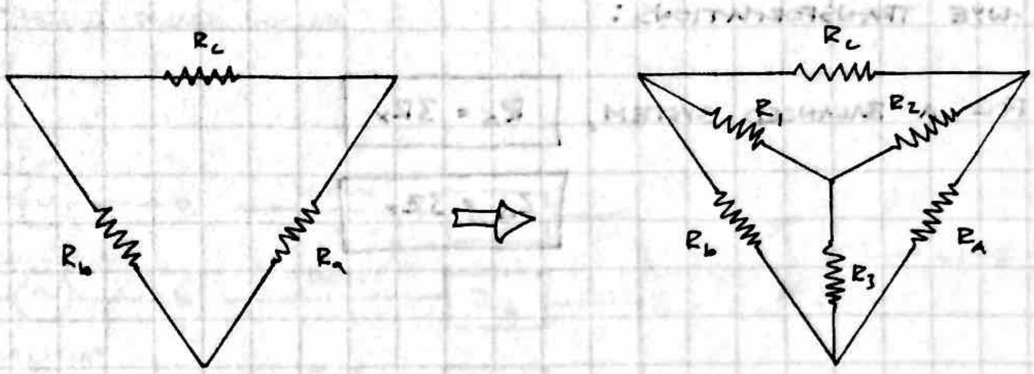
$$H(s) = \frac{45s\,(1 + s/2\pi\, 10KHz)}{(1 + 2/s\pi\, 10Hz)(1 + s/2\pi\, 100kHz)(1 + s/2\pi\, 100MHz)}$$

F	P	
0	Z	+20
10	P	0
10K	Z	+20
100K	P	0
100M	P	-20



NEXT STEP IS TO FIND SCALE

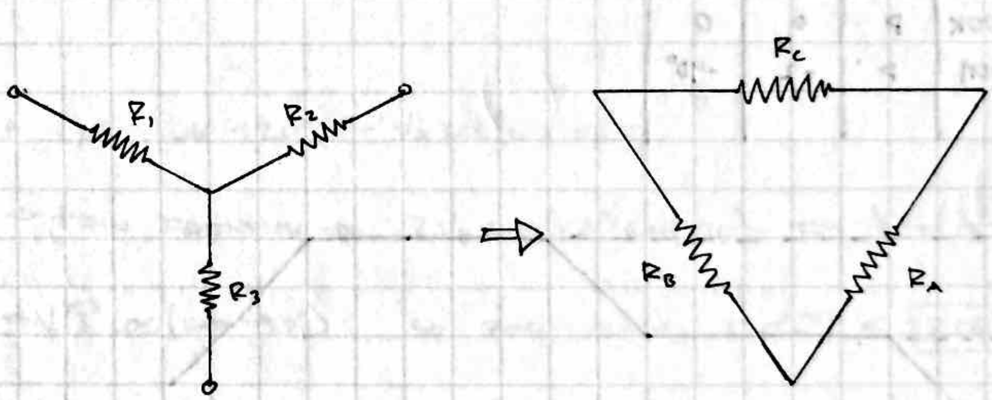
* DELTA TO WYE CONVERSION:



EACH RESISTOR IN THE WYE NETWORK IS THE PRODUCT OF THE TWO ADJACENT Δ BRANCHES, DIVIDES BY THE SUM OF THE THREE Δ RESISTORS

$$\boxed{R_1 = \frac{R_b R_c}{R_A + R_B + R_C}} \quad \boxed{R_2 = \frac{R_A R_C}{R_A + R_B + R_C}} \quad \boxed{R_3 = \frac{R_A R_B}{R_A + R_B + R_C}}$$

* WYE TO DELTA CONVERSIONS:



EACH RESISTOR IN THE DELTA NETWORK IS THE PRODUCT OF ALL POSSIBLE WYE RESISTORS TAKEN TWO AT A TIME, DIVIDED BY THE OPPOSITE Y RESISTOR.

$$\boxed{R_A = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}} \quad \boxed{R_B = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}} \quad \boxed{R_C = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}}$$

2/28/2012

DELTA-WYE TRANSFORMATIONS:

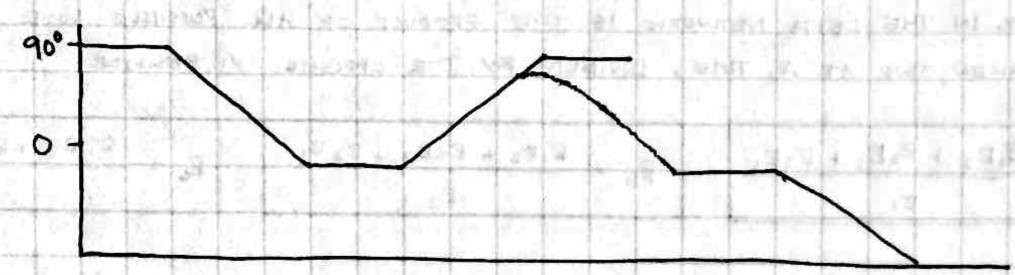
FOR A BALANCED SYSTEM, $\boxed{R_\Delta = 3R_Y}$

$\boxed{Z_\Delta = 3Z_Y}$

TRANSFER FUNCTION:

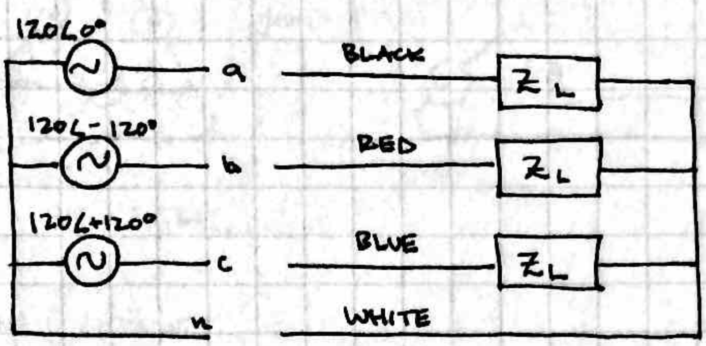
$$H(s) = \frac{Ks(1 + s/2\pi 10K)}{(1 + s/2\pi 10)(1 + s/2\pi 100K)(1 + s/2\pi 100M)}$$

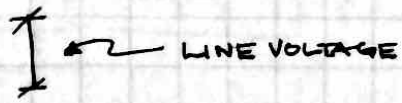
f	P/Z	SLOPE	ϕ
0	Z	+20	+90°
10	P	0	0
10K	Z	+20	+90°
100K	P	0	0
100M	P	-2	-90°

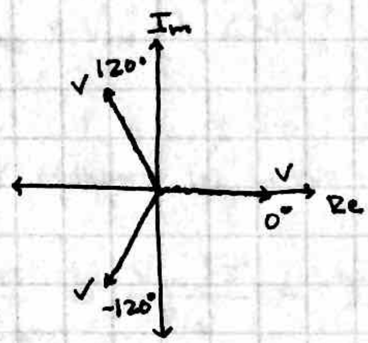


2/28/2012

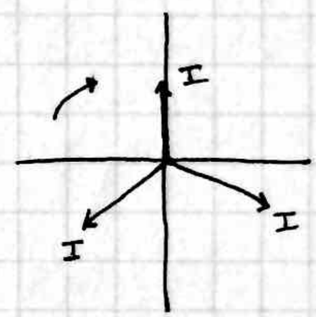
* THREE-PHASE POWER







⇒ CURRENT ⇒

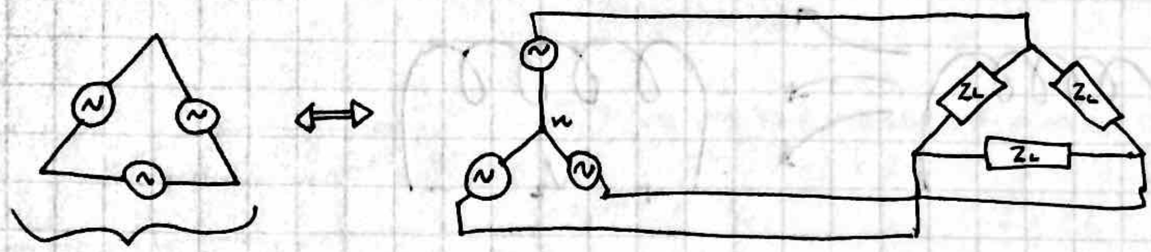


$$V_{BC} = V_p \cos(\omega t - 120°) - V_p \cos(\omega t + 120)$$

⇒ TRIG IDENTITY ⇒ $2V_p \sin(\omega t)\sin(120)$ ⇒ $\cancel{2}V_p\left(\frac{\sqrt{3}}{\cancel{2}}\right)\cos(\omega t - 90°)$

$= V_p\sqrt{3}\cos(\omega t - 90°)$, SO FOR $120°V$, $120°\sqrt{3}$ = $\boxed{208V}$

3/6/2012



NO NEUTRAL

LINE VOLTAGE:

- $V_{AB} = V_{AN}\sqrt{3}\angle 30^\circ$

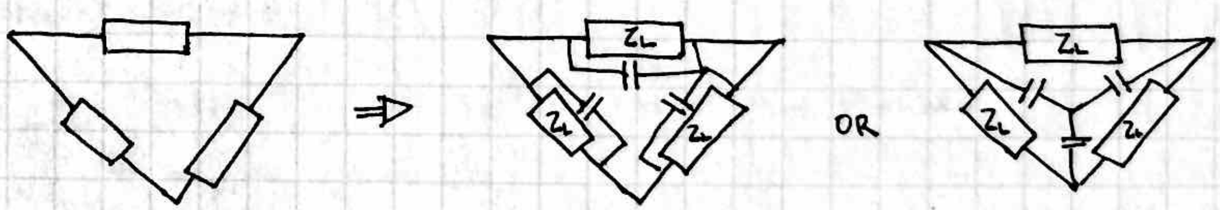
PHASE CURRENT IN LOAD:

- $\dfrac{V_{AB}}{Z_\Delta} = \dfrac{V_{AN}\sqrt{3}}{Z_\Delta} = I\phi$

ONLY RESISTIVE COMPONENT OF Z_Y

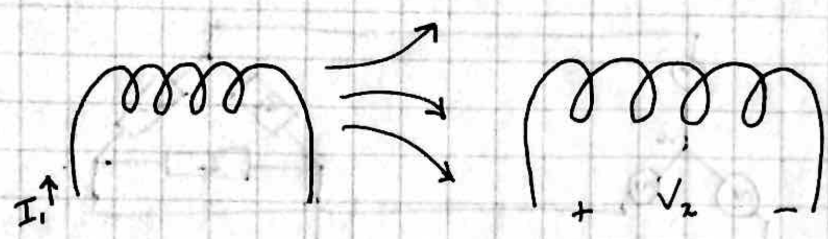
POWER IN LOAD: $|I_{LINE}|^2(R_Y)(3) =$

POWER FACTOR CORRECTION CAN BE USED ON 3-PHASE SYSTEMS AS WELL



FINAL AT 7:30AM AT GILF AUD!

3/6/2012



FARADAY'S LAW:

"MECHANICAL COUPLING"

$$V_2 = \frac{d\phi}{dt} N_2$$

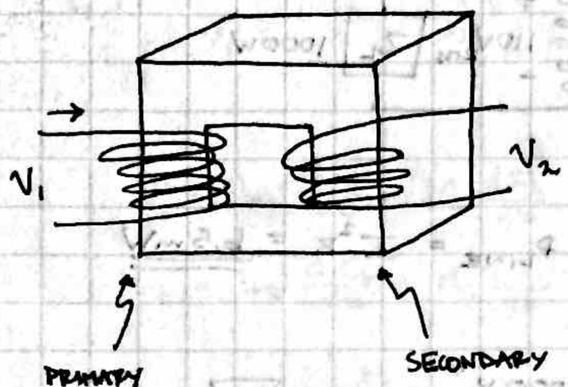
$$\phi = B\,\text{AREA} \quad , \quad \phi \propto I_1$$

$$V_2 = \underbrace{N_2 K}_{\text{CONSTANT}} \frac{dI_1}{dt}$$

$$V_2 = L \frac{dI}{dt} \text{ , so } N_2 K \to L \quad \& \quad \Rightarrow V_2 = M_{21} \frac{dI}{dt}$$

$$M_{12} = M_{21}$$

3/8/2012



IRON ~~IN~~ CHANNELS MAGNETIC FLUX

$\phi_1 = \phi_2$

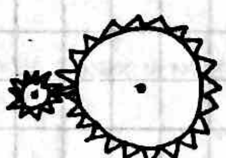
$V_1 = \frac{d\phi_1}{dt} N_1 , \quad V_2 = \frac{d\phi_2}{dt} N_2$

$\frac{V_2}{V_1} = \frac{N_2}{N_1} \quad P_2 = P_1 = V_2 I_2 = V_1 I_1$

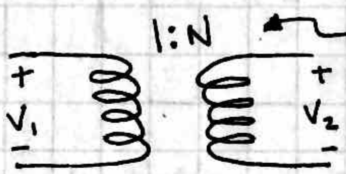
$\frac{I_2}{I_1} = \frac{N_1}{N_2}$

MUST BE A TIME-VARYING FIELD (AC ONLY) REASON POWER DISTRIBUTION IS AC AROUND COUNTRY.

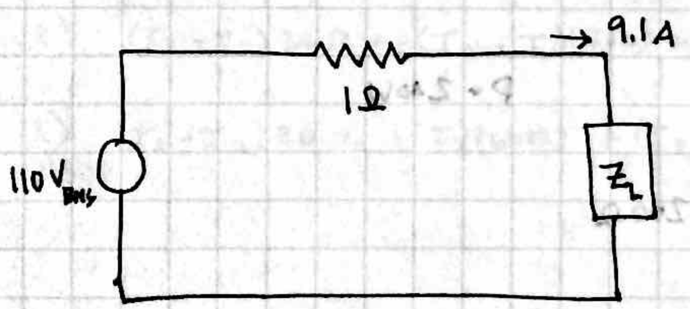
ANALOGOUS TO A GEARBOX:



CIRCUIT DIAGRAM:

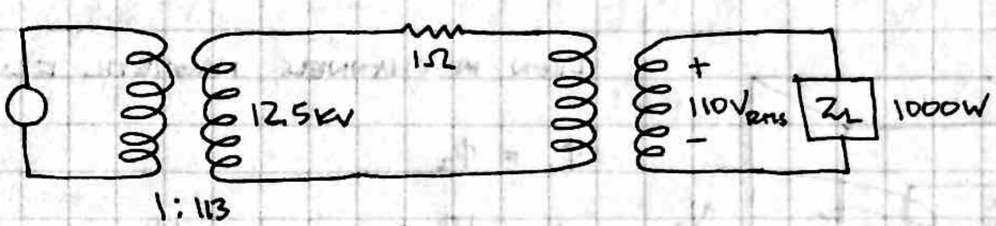


RATIO OF TURNS THAT MATTERS



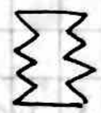
$P_{LINE} = (9.1)^2 (1\Omega) = \underline{82W}$

INSTEAD TRANSFORM:



$I_{LINE} = \frac{9.1A}{113} = 80mA$, $P_{LINE} = I^2R = \underline{\underline{6.5mW}}$

"EVERY LITTLE INSULATOR IS ABOUT 15,000 V"

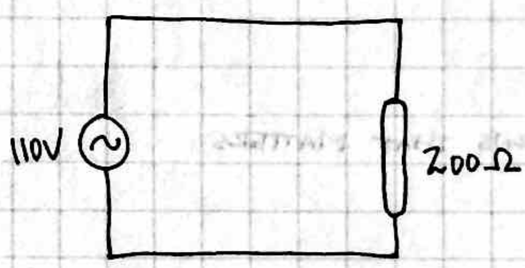


$\bar{V}_2 = N\bar{V}_1$, $I_2 = \frac{1}{N}\bar{I}_1$

$N\bar{V}_1 = \frac{1}{N}\bar{I}_1 Z_L$

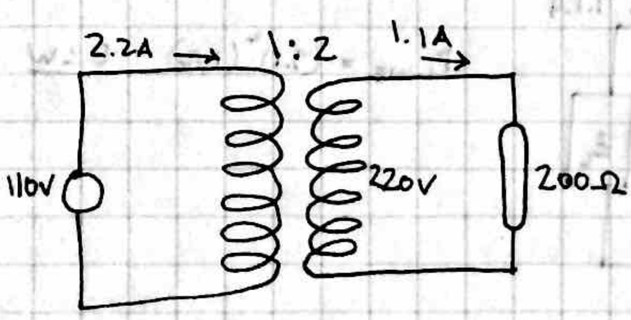
HIGH-IMPEDENCE DUE TO TRANSFORMER

HOT DOG:

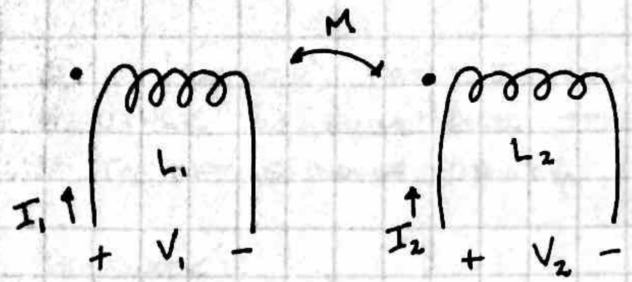


~40s

INSTEAD:

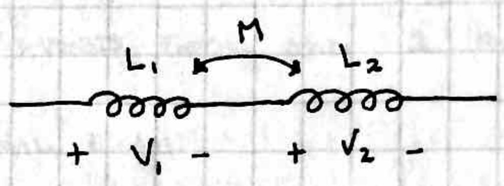


P = 240W



$$V_1 = L_1 \frac{dI_1}{dt} + M \frac{dI_2}{dt} \qquad \overline{V_1} = j\omega L_1 I_1 + j\omega M I_2$$

$$V_2 = L_2 \frac{dI_2}{dt} + M \frac{dI_1}{dt} \qquad \overline{V_2} = j\omega L_2 I_2 + j\omega M \overline{I}$$



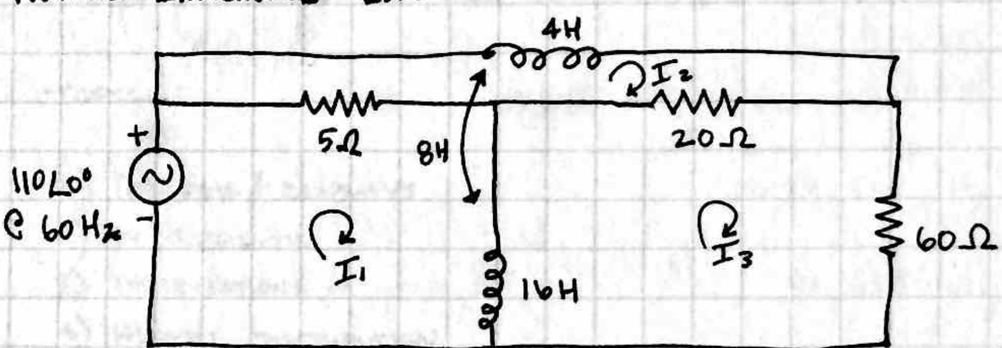
$$V_1 = j\omega L_1 I + j\omega M I$$

$$V_2 = j\omega L_2 \overline{I} + j\omega M \overline{I}$$

$$\overline{V_1} + \overline{V_2} = V_{TOTAL} = j\omega \underbrace{(L_1 + L_2 + 2M)} \overline{I}$$

$$L_{EQ} = L_1 + L_2 + 2M$$

MUTUAL INDUCTANCE EX:



* DOTS ONLY COME IN FOR MUTUAL INDUCTANCE *

1.) $-110\angle 0° + (I_1 - I_2)5\Omega + (I_1 - I_3)j\omega 16H + \overbrace{\overline{I}_2(j\omega 8H)}^{\text{FROM MUTUAL IND.}}$

2.) $(I_2 - I_3)20\Omega + (I_2 - I)(5\Omega) + I_2(j\omega 4H) + (I_1 - I_3)(j\omega 8H)$

3.) $(I_3 - I_2)20\Omega + I_3(60\Omega) + (I_3 - I)(j\omega 16H) - I_2 j\omega 8H$