/60	20 /30

University of Jordan — EE212 - Electric Circuits II — Second Exam — Wednesday, 06/4/2016
Department of Electrical Engineering — Summer Semester 2014-2015 — Time: 15:00 - 16:30 pm

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Section 1 Dr. Mohammed Abuelhaj Section 3 Dr. Eyad Feilat Section 4 Mohammed Abuelhaj

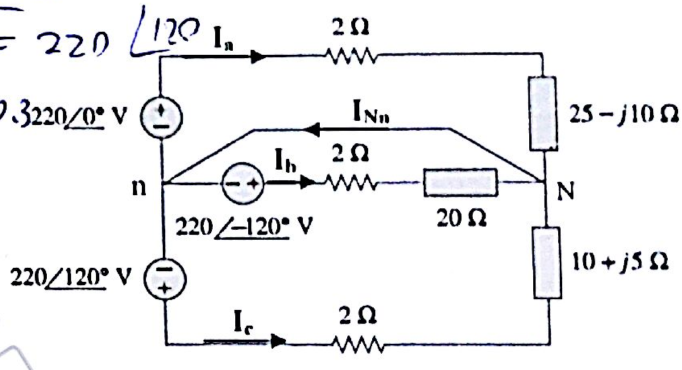
Questions 1 (6 points)

If the source voltage in the figure below is 220 V_{rms}, determine the source currents and the current in the neutral line, I_{nN}.

I_a	I_b	I_c	I_{Nn}
$7.64\angle 20.3$	$10\angle -120$	$16.92\angle 97.38$	$10.77\angle 90$

$V_{an} = 220\angle 0$ $V_{bn} = 220\angle -120$

$V_{cn} = 220\angle 120$



6

$$I_a = \frac{220}{2+25-10j} = 7.64\angle 20.3$$

$$I_b = \frac{220\angle -120}{22} = 10\angle -120$$

$$I_c = \frac{220\angle 120}{2+10+5j} = 16.92\angle 97.38$$

$$I_{Nn} = I_a + I_b + I_c = 10.77\angle 90$$

Questions 2 (6 points)

In the balanced three-phase Y-Δ system shown in the figure, find

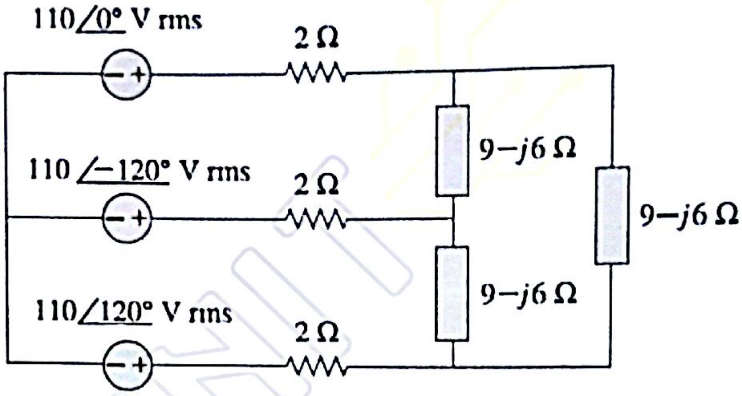
a. the ***magnitude*** of the line current I_L

b. the total average power delivered to the load.

$\lvert I_L \rvert$	P_{tot}
20.42	6256.7

4

balanced



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

$$\frac{9-6j}{3} = 3-2j$$

$$I_L = \frac{110}{2+3-2j} = 20.42 \angle 21.8$$

$$I_L = I_P = 20.42 \angle 21.8$$

$$P_{tot} = 3(V_P I_P \cos(\theta_v - \theta_i))$$

$$= 3(110 \times 20.42 \cos(0-21.8))$$

$$= 6256.7$$

2

Questions 3 (6 points)

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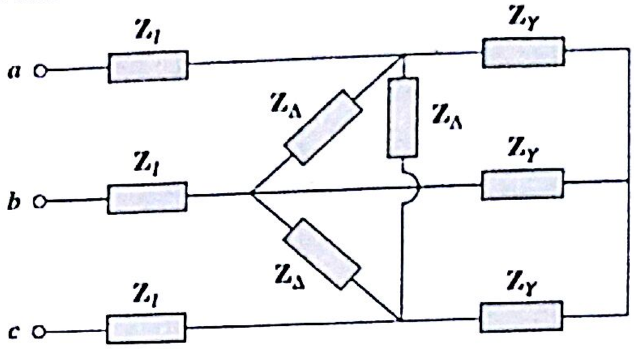
The circuit in the figure is excited by a balanced three-phase source with a line voltage of 210 V_{rms}. If $Z_l = 1 + j1\ \Omega$, $Z_\Delta = 24 - j30\Omega$, and $Z_Y = 12 + j5\ \Omega$, determine the magnitude of the line current of the combined loads, and the magnitude of the phase current in the delta load.

I_L (line)	I_P (phase in Δ)
13.66	7.88



$V_L = 210 \angle 0°$ (refrence)

$Z_l = 1 + j$

$Z_D = 24 - 30j$

$Z_Y = 12 + j5$

$D \to Y$

$\frac{Z_D}{3} = 8 - 10j$

$Z_P = \frac{Z_D}{3} \parallel Z_Y$

$= (8-10j) \parallel (12+5j)$

$= \frac{(8-10j)(12+5j)}{8-10j+12+5j}$

$= 7.81 - 2.04j$

$Z_T = Z_P + Z_l$

$= 7.81 - 2.04j + 1 + 1j$

$= 8.81 - 1.04j\ \Omega$

$V_P = \frac{210}{\sqrt{3}} \angle -30$

$I_P = \frac{I_L}{\sqrt{3}}$

$I_L = \frac{210 \angle -30}{\sqrt{3}(8.81 - 1.04j)} = \boxed{13.66 \angle -23.26}$

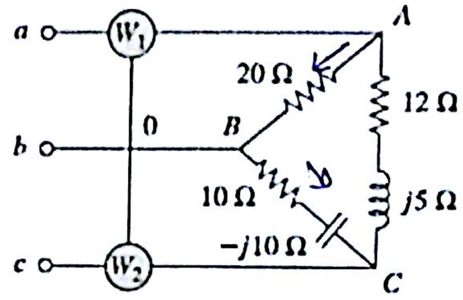
$=$

Questions 4 (9 points)

In the figure below, two wattmeters are properly connected to the unbalanced load supplied by a balanced source such that $V_{ab} = 208\angle 0°$ V_{rms} with positive phase sequence.

a. Determine the reading of each wattmeter.

b. Calculate the total apparent power absorbed by the load.



W_1	W_2	$\lvert S_{tot} \rvert$
2586.25	4808.3	8338.16

$V_{ab} = 208\angle 0$

$V_{bc} = 208\angle -120$

$V_{ca} = 208\angle 120$

$I_{AB} = \frac{208\angle 0}{20}$

$= 10.4 A$

$I_{BC} = \frac{208\angle -120}{10-10j}$

$= 14.7\angle -75$

$I_{CA} = \frac{208\angle 120}{12+5j}$

$= 16\angle 97.3°$

I_a, I_c

$I_a = I_{AB} - I_{CA}$

$I_c = I_{CA} - I_{BC}$

$I_a = 20.16\angle -51.92$

$I_c = 30.63\angle 100.98$

$W_1 = V_{ab} \cdot I_a \cos(\theta_v - \theta_i)$

$= 208 \cdot 20.16 \cos(0 + 51.92)$

$= 2586.25 w$

$W_2 = V_{cb} \cdot I_c \cos(\theta_v - \theta_i)$

$= 208 \cdot 30.63 \cos(60 - 101)$

$= 4808.3 w$

$V_{bc} = 208\angle 120$

$V_{cb} = 208\angle 60$

$P_T = 7394.53$

$Q_T = \sqrt{3}(4808.3 - 2586.25)$

$= 3848.7$ VAR

6

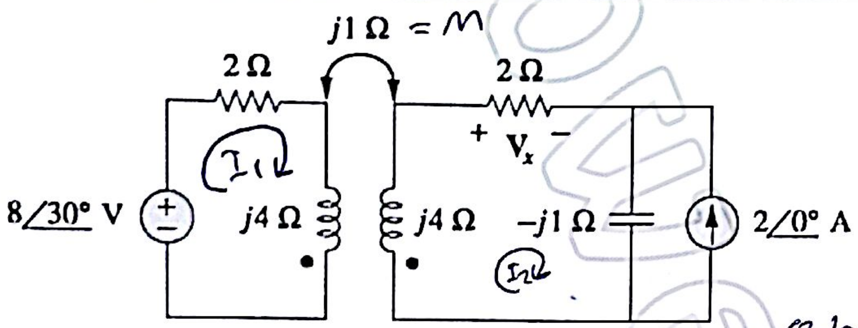
Questions 5 (7 points)

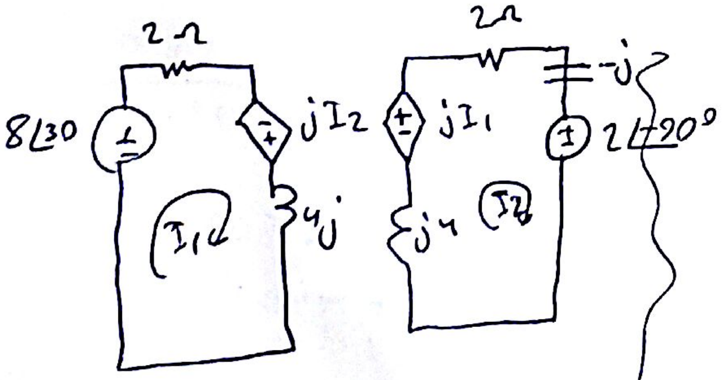
In the shown network,

a. use source transformation to write down the two mesh equations that govern the current relations in the circuit in their simplest form.

b. Find V_x.

Equation (1)	$I_1(2+4j)+I_2(-j) = \cancel{8\angle 30^\circ}$	V_x
Equation (2)	$I_1(-j)+I_2(2+3j) = \cancel{2j}$	$1.896\angle 144.38$





mesh ①

$$\boxed{8\angle 30 = I_1(2+4j) - jI_2} \quad --(1)$$

mesh ②

$$I_2(4j+2-j) - jI_1 + (-2j) = 0$$

$$\boxed{I_1(-j) + I_2(2+3j) = 2j} \quad --(2)$$

$$I_1 = \frac{I_2(2+3j) - 2j}{j}$$

$$I_1 = (3-2j)I_2 - 2 \rightarrow \text{substitute } ①$$

$$8\angle 30 = (2+4j)((3-2j)I_2 - 2) - jI_2$$

$$8\angle 30 = (-2-17j)I_2 - 4 - 8j$$

$$I_2 = 0.\cancel{9}48\angle 144.38$$

$$V_x = I_2 \times \cancel{2}$$

$$= 1.896\angle 144.38$$

Question 6 (8 points)

6

For the circuit shown in the figure, find:

a. the self-impedance of the primary circuit Z_{11}.

b. the self-impedance of the secondary Z_{22}.

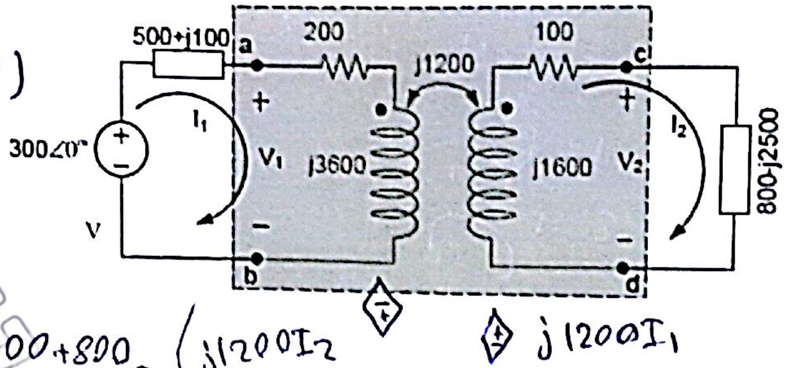
c. the source and load currents I_1 and I_2.

Z_{11}	Z_{22}	I_1	I_2
~~2500+3600j~~ 1000+4400j	100+1600j	0.063 $\angle -71.56°$	0.059 $\angle 63.43$

mesh ①

$300 = I_1(500+100j+200+3600j) - I_2(j1200)$

mesh ②



$-(j1200)I_1 + I_2(j1600+100+800-2500j) = 0$ ($j1200 I_2$) ($j1200 I_1$)

$-(j1200)I_1 + I_2(900-900j) = 0$

$$\boxed{I_1 = \frac{(900-900j)\,I_2}{j1200}}$$

$$Z_{11} = 200+3600j + \frac{(1200)^2}{100+1600j+800-2500j}$$

$= 200+3600j + 800+800j$

$= 1000+4400j$

mesh ①

$300 = I_1(700+3700j) - I_2(1200j)$

$300 = (2250-3300j-1200j)\,I_2$

$I_2 = 0.059 \angle 63.43$

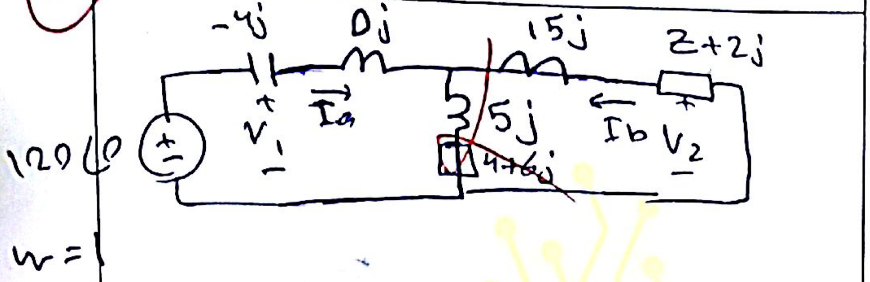
$I_1 = 0.063 \angle -71.56$

3

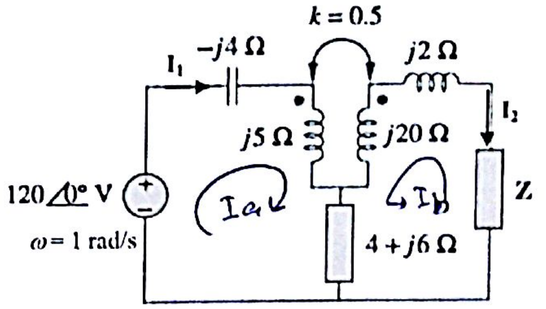
Question 7 (9 points)

For the circuit shown in the figure, replace the transformer by its T- equivalent model to find the Thevenin equivalent to the left of the load Z.

T-equivalent (draw and label)



Z_{TH}	V_{TH}
-0.985-11.27j	



$M = 0.5\sqrt{L_1 L_2}$ $L_1 = 5j$

$= 0.5\sqrt{5\times 20}$ $L_2 = 20j$

$= 5j$

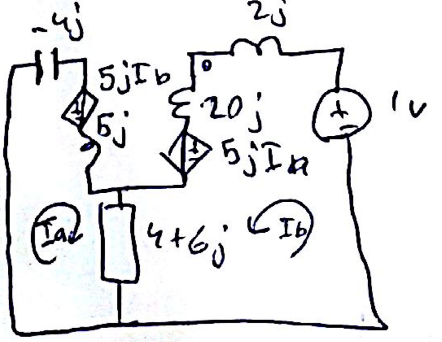
$= L_1 - M = 5 - 5 = 0j$

$L_2 - M = 20 - 5 = 15j$

$M = 5j$

Zth → test soure 1V

$Z = \frac{1}{-I_2}$



mesh 1

$I_a(-4j + 5j + 4 + 6j) + I_b(5j + 4 + 6j) = 0$

$I_a(4 + 7j) + I_b(4 + 11j) = 0$

$I_a = \frac{(4+11j)}{-(4+7j)} I_b$

mesh 2 $4 + 28j$

$1 = I_b(2j + 20j + 4 + 6j) + I_a(5j + 4 + 6j)$

$1 = I_b(4 + 28j) + I_a(4 + 11j)$

$I_b = 0.088\angle{-85}$

$Z_{th} = -0.985 - 11.27j$

mesh 1

$120\angle 0 = I_a(4 + 7j) + I_b(4 + 11j)$

mesh 2

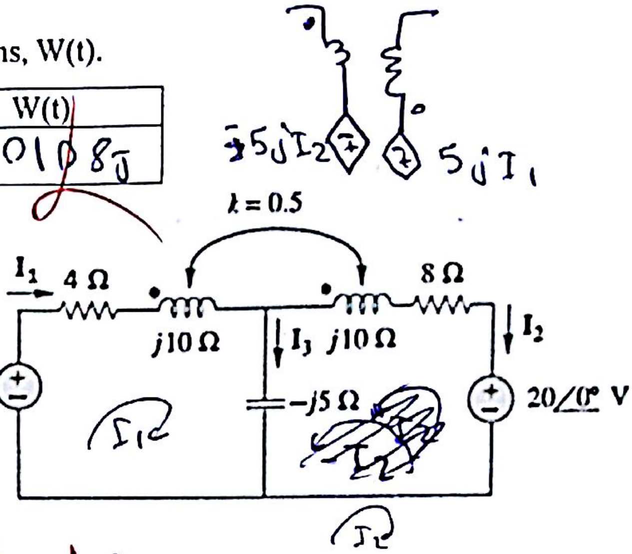
$I_b(3.015 + 16.73j) + I_a(4 + 11j) = 0$

$I_a = \frac{(3.015 + 16.73j)}{-(4+11j)} I_b$

Question 8 (9 points)

For the circuit shown in the figure, if $\omega = 1{,}000$ rad/s, determine
a. the currents I_1 and I_2.
b. the energy stored in the coupled coils at $t = 2$ ms, W(t).

I_1	I_2	W(t)
$1.87\angle -141.34$	$2.846\angle 132.2$	0.0108 J



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$\omega = 1000$ rad/s

$M = 0.5\sqrt{100}$

$= 5j$

mesh ①

$12\angle 90 + I_1(4 + 10j - 5j) + I_2(5j - 5j) = 0$

$I_1(4+5j) = -12(\angle 90)$

$\boxed{I_1 = 1.87\angle -141.34}$

mesh ②

$I_2(-5j + 10j + 8) + 20 + 5jI_1 = 0$

$I_2(5j+8) + 20 + (5j)(1.87\angle -141.34) = 0$

$\boxed{I_2 = 2.846\angle 132.2}$

$M =$

$L_1 = 0.01$ H

$L_2 = 0.01$ H

$w = \frac{1}{2}(0.01)(1.67)^2 + \frac{1}{2}(0.01)(-1.12)^2 + (0.005)(1.67)(-1.12)$

$= 0.0108$ J

$i_1 = 1.87\cos(1000t - 141.34)$

$i_2 = 2.846\cos(1000t + 132.2)$

$t = 2$ms $\quad \omega t = 2 \to 2 \times 57.3 \to 114.6°$

$i_1 = 1.87\cos(114.6 - 141.34) = 1.67$

$i_2 = 2.846\cos(114.6 + 132.2) = -1.12$

$w = \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 + M i_1 i_2$

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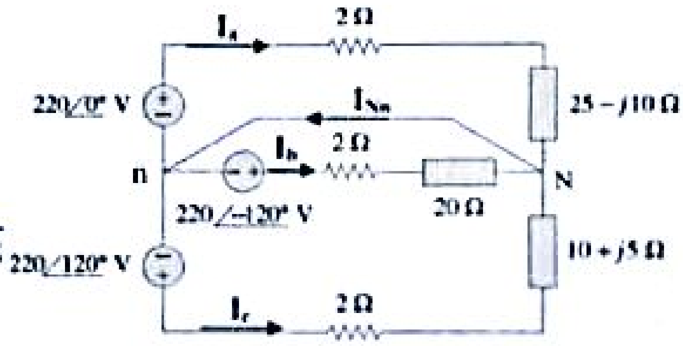
Section 1 **Dr. Mohammed Abuelhaj** **Section 3** **Dr. Eyad Feilat** **Section 4** **Mohammed Abuelhaj**

<u>Questions 1 (6 points)</u>

If the source voltage in the figure below is 220 V_{rms}, determine the source currents and the current in the neutral line, I_{Nn}.

I_a (A)	I_b (A)	I_c (A)	I_{Nn} (A)
$7.6\angle 20.3°\ A$	$10\angle -120°\ A$	$16.9\angle 97.4°\ A$	$10.8\angle -90°\ A$

<u>Solution:</u>



For phase a,

$$\mathbf{I}_a = \frac{\mathbf{V}_{an}}{\mathbf{Z}_A + 2} = \frac{220\angle 0°}{27 - j10} = \frac{}{28}$$

For phase b,

$$\mathbf{I}_b = \frac{\mathbf{V}_{bn}}{\mathbf{Z}_B + 2} = \frac{220\angle -120°}{22} = 10\angle -120°$$

For phase c,

$$\mathbf{I}_c = \frac{\mathbf{V}_{cn}}{\mathbf{Z}_C + 2} = \frac{220\angle 120°}{12 + j5} = \frac{220\angle 120°}{13\angle 22.62°} = 16.923\angle 97.38°$$

The current in the neutral line is

$$\mathbf{I}_n = -(\mathbf{I}_a + \mathbf{I}_b + \mathbf{I}_c) \text{ or } -\mathbf{I}_n = \mathbf{I}_a + \mathbf{I}_b + \mathbf{I}_c$$

$$-\mathbf{I}_n = (7.166 + j2.654) + (-5 - j8.667) + (-2.173 + j16.783)$$

$$\mathbf{I}_n = 0.007 - j10.77 = \underline{10.77\angle 90°\text{A}}$$

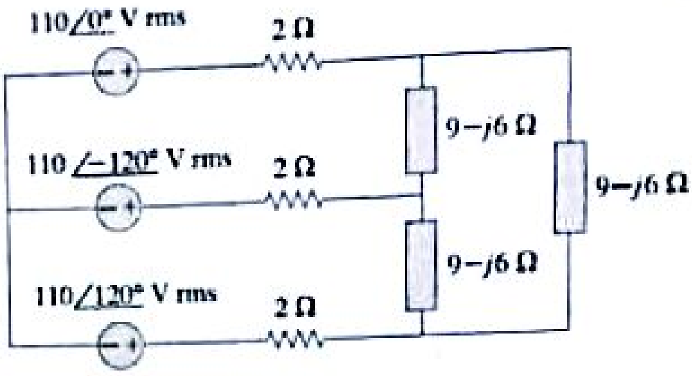
$$\underline{I_{Nn} = -I_n = 10.8\angle -90°\ A}$$

Questions 2 (6 points)

In the balanced three-phase Y-Δ system shown in the figure, find

a. the ***magnitude*** of the line current I_L

b. the total average power delivered to the load.



$\lvert I_L \rvert$ (A)	P_{tot} (W)
20.4 A	3744 W

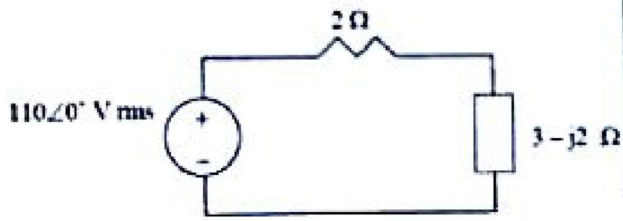
Solution:

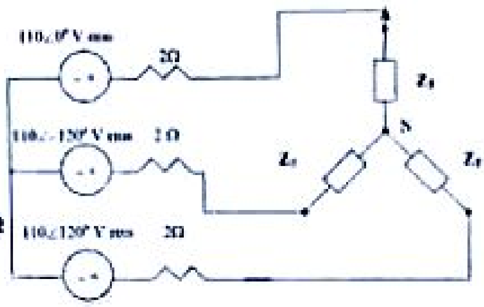
Convert the delta load to Y as shown below.

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

$$Z_Y = \frac{9-j6}{3} = 3-j2\ \Omega$$

We consider the single phase equivalent shown below.





$$I_a = \frac{110}{2+3-j2} = 20.4265 < 21.8^\circ$$

$$I_L = \lvert I_a \rvert = \underline{20.43\ \text{A}}$$

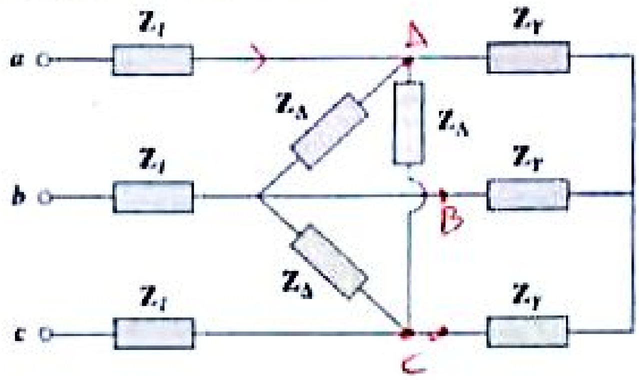
$$S = 3\lvert I_a\rvert^2 Z_Y = 3(20.43)^2(3-j2) = 4514\angle{-33.96^\circ} = 3744 - j2522$$

$$P = \text{Re}(S) = \underline{3744\ \text{W}}.$$

Questions 3 (6 points)

The circuit in the figure is excited by a balanced three-phase source with a line voltage of 210 V_{rms}. If $Z_l = 1 + j1\ \Omega$, $Z_\Delta = 24 - j30\Omega$, and $Z_Y = 12 + j5\ \Omega$, determine the magnitude of the line current of the combined loads, and the magnitude of the phase current in the delta load.

$I_{L\ (line)}$ (A)	$I_{p\ (phase\ in\ \Delta)}$ (A)
13.66 A	~~5.47 A~~ 4.97



Solution:

Convert the delta load, Z_Δ, to its equivalent wye load.

$$Z_{Y\epsilon} = \frac{Z_\Delta}{3} = 8 - j10$$

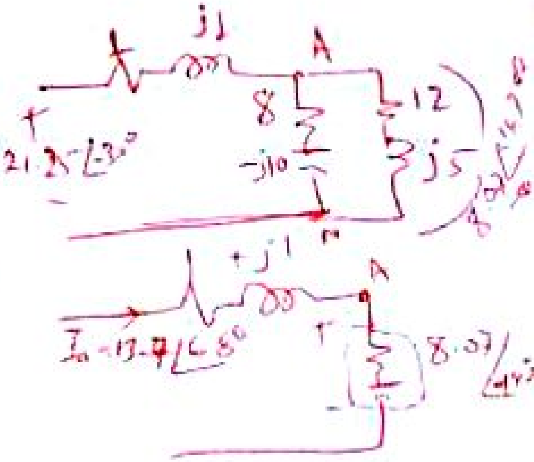
$$Z_p = Z_Y \parallel Z_{Y\epsilon} = \frac{(12 + j5)(8 - j10)}{20 - j5} = 8.076\angle{-14.68°}$$

$$Z_p = 7.812 - j2.047$$ $= 8.07\angle{-14.7°}\ \Omega$

$$Z_T = Z_p + Z_L = 8.812 - j1.047$$

$$Z_T = 8.874\angle{-6.78°}$$

We now use the per-phase equivalent circuit.



$$I_a = \frac{V_p}{Z_p + Z_L}, \qquad \text{where } V_p = \frac{210}{\sqrt{3}}$$ $= 121.2$ V

$$I_a = \frac{210}{\sqrt{3}(8.874\angle{-6.78°})} = 13.66\angle 6.78°$$

$$I_L = |I_a| = \underline{13.66\ \text{A}}$$

$$I_{p\Delta} = \frac{I_{L\Delta}}{\sqrt{3}} = \frac{\frac{V_{ph}}{Z_{Y\epsilon}}}{\sqrt{3}} = \frac{\frac{210/\sqrt{3}}{\sqrt{8^2+10^2}}}{\sqrt{3}} = \frac{\frac{210/\sqrt{3}}{\sqrt{8^2+10^2}}}{\sqrt{3}} = \frac{\frac{121.24}{12.81}}{\sqrt{3}} = \frac{9.45}{\sqrt{3}} = 5.46\ A$$

190.24 8.6 4.49 4.97 A

$V_{AN} = 13.7\angle 6.8° \cdot 8.07\angle{-14.7°}$

$= 110.24\angle{-7.9°}$ V

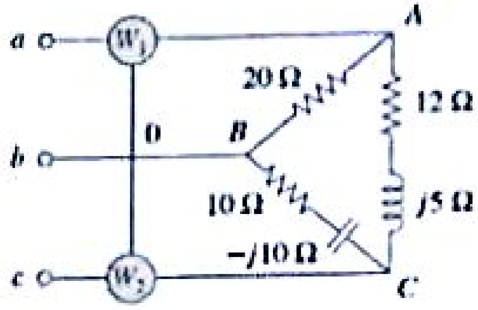
$V_{AB} = 190.9\angle 37.9°$

Questions 4 (9 points)

In the figure below, two wattmeters are properly connected to the unbalanced load supplied by a balanced source such that $V_{ab} = 208\angle 0°$ V_{rms} with positive phase sequence.

a. Determine the reading of each wattmeter.

b. Calculate the total apparent power absorbed by the load.



W_1 (W)	W_2 (W)	$\lvert S_{tot}\rvert$ (VA)
2589 W	4808 W	8335 VA

0 0 1

Solution

If $V_{ab} = 208\angle 0°$, $V_{bc} = 208\angle -120°$, $V_{ca} = 208\angle 120°$.

$$I_{AB} = \frac{V_{ab}}{Z_{Ab}} = \frac{208\angle 0°}{20} = 10.4\angle 0°$$

$$I_{BC} = \frac{V_{bc}}{Z_{BC}} = \frac{208\angle -120°}{10\sqrt{2}\angle -45°} = 14.708\angle -75°$$ 1

$$I_{CA} = \frac{V_{ca}}{Z_{CA}} = \frac{208\angle 120°}{13\angle 22.62°} = 16\angle 97.38°$$

$$I_{aA} = I_{AB} - I_{CA} = 10.4\angle 0° - 16\angle 97.38°$$
$$I_{aA} = 10.4 + 2.055 - j15.867$$
$$I_{aA} = 20.171\angle -51.87°$$ 1

$$I_{cC} = I_{CA} - I_{BC} = 16\angle 97.83° - 14.708\angle -75°$$
$$I_{cC} = 30.64\angle 101.03°$$

$$P_1 = |V_{ab}||I_{aA}|\cos(\theta_{V_{ab}} - \theta_{I_{aA}})$$ 1
$$P_1 = (208)(20.171)\cos(0° + 51.87°) = \mathbf{2590\ W}$$

0
$$P_2 = |V_{cb}||I_{cC}|\cos(\theta_{V_{cb}} - \theta_{I_{cC}})$$
But $V_{cb} = -V_{bc} = 208\angle 60°$

$$P_2 = (208)(30.64)\cos(60° - 101.03°) = \mathbf{4808\ W}$$

$P_T = P_1 + P_2$ 0

$= 7398$

$Q_T = \sqrt{3}(4808 - 2590) = 3841$

1

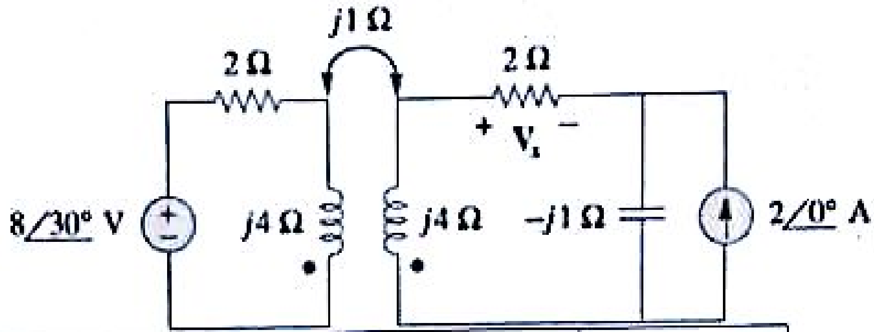
$S_T = \sqrt{P_T^2 + Q_T^2}$.

Questions 5 (7 points)

In the shown network,

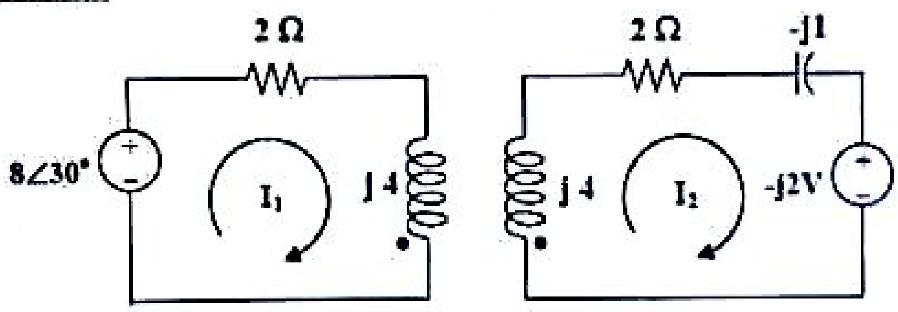
a. use source transformation to write down the two mesh equations that govern the current relations in the circuit in their simplest form.

b. Find V_x.



Equation (1)	$(2+j4)I_1 - jI_2 = 8\angle 30°$	V_x (V)
Equation (2)	$-jI_1 + (2+j3)I_2 = 2\angle 90°$	$2.07\angle 21.1° V$

Solution



For loop 1,

$$8\angle 30° = (2 + j4)I_1 - jI_2 \quad (1)$$

For loop 2,

$$((j4 + 2 - j)I_2 - jI_1 + (-j2) = 0$$

or

$$I_1 = (3 - j2)i_2 - 2 \quad (2)$$

Substituting (2) into (1),

$$8\angle 30° + (2 + j4)2 = (14 + j7)I_2$$

$$I_2 = (10.928 + j12)/(14 + j7) = 1.037\angle 21.12°$$

$$V_x = 2I_2 = \underline{2.074\angle 21.12°}$$

Question 6 (8 points)

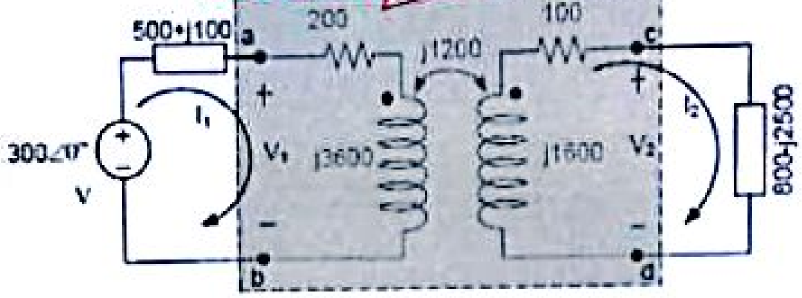
For the circuit shown in the figure, find:

a. the self-impedance of the primary circuit $\mathbf{Z}_{11}$.
b. the self-impedance of the secondary $\mathbf{Z}_{22}$.
c. the reflected impedance as seen by the primary coil $\mathbf{Z}_r$.
d. the source and load currents $\mathbf{I}_1$ and $\mathbf{I}_2$.

(0.02 - j0.06) (0.026 + j0.053)

Z_{11} (Ω)	Z_{22} (Ω)	Z_r (Ω)	I_1 (mA)	I_2 (mA)
$700 + j3700\Omega$	$900 - j900\Omega$	$800 + j800\Omega$	~~$263.25\angle -71.6° mA$~~	$59.63\angle +63.4° mA$

3765 ∠79 1272 ∠-45 0.063 ∠-71



Solution:

$$Z_{22} = R_2 + j\omega L_2 + Z_L = (R_L + R_2) + j(X_2 + X_L)$$

$$\mathbf{Z}_r = \frac{\omega^2 M^2}{R_2 + j\omega L_2 + \mathbf{Z}_L} = \quad \mathbf{Z}_r = \frac{\omega^2 M^2}{|\mathbf{Z}_{22}|^2}\left[(R_L + R_2) - j(\omega L_2 + X_L)\right]$$

Mesh 1 $\quad V_S = (Z_S + R_1 + j\omega L_1)I_1 - j\omega M I_2$

Mesh 2 $\quad 0 = -j\omega M I_1 + (Z_L + R_2 + j\omega L_2)I_2$

$Z_{11} = R_1 + j\omega L_1 + Z_S$ **Self impedance of the primary**

$Z_{22} = R_2 + j\omega L_2 + Z_L$ **Self impedance of the secondary**

$$\mathbf{V}_S = \mathbf{Z}_{11}\mathbf{I}_1 - j\omega M \mathbf{I}_2$$
$$0 = -j\omega M \mathbf{I}_1 + \mathbf{Z}_{22}\mathbf{I}_2$$

$$\mathbf{I}_2 = \frac{j\omega M}{\mathbf{Z}_{22}}\mathbf{I}_1$$

$$\mathbf{V}_S = \frac{\mathbf{Z}_{11}\mathbf{Z}_{22} + \omega^2 M^2}{\mathbf{Z}_{22}}\mathbf{I}_1 = \left(\mathbf{Z}_{11} + \frac{\omega^2 M^2}{\mathbf{Z}_{22}}\right)\mathbf{I}_1$$

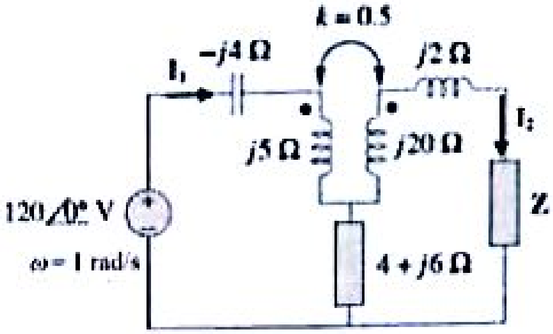
$$\mathbf{I}_1 = \frac{\mathbf{Z}_{22}}{\mathbf{Z}_{11}\mathbf{Z}_{22} + \omega^2 M^2}\mathbf{V}_S \qquad \text{Primary Current}$$

$$\mathbf{I}_2 = \frac{j\omega M}{\mathbf{Z}_{11}\mathbf{Z}_{22} + \omega^2 M^2}\mathbf{V}_S = \frac{j\omega M}{\mathbf{Z}_{22}}\mathbf{I}_1 \qquad \text{Secondary Current}$$

Question 7 (9 points)

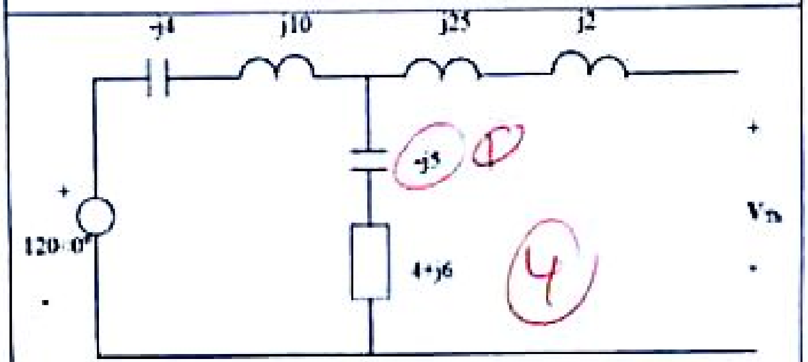
For the circuit shown in the figure, replace the transformer by its T- equivalent model to find the Thevenin equivalent to the left of the load **Z**.

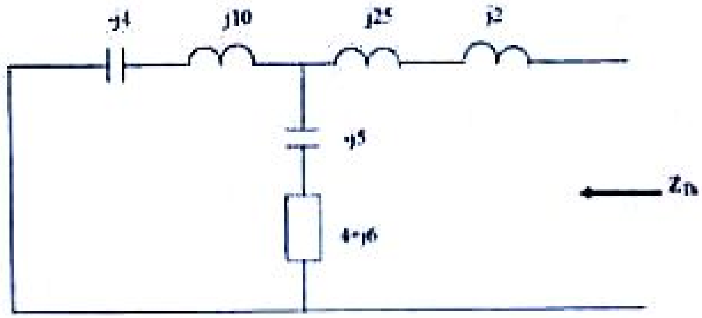
V_{TH} (V)	Z_{TH} (Ω)
$61.37\angle -46.2° V$	$2.2 + j29.1Ω$ $29.2\angle 85.65°Ω$



Solution

T-equivalent (draw and label)





$$V_{Th} = \frac{4+j}{4+j+j6}(120) = \underline{61.37\angle -46.22°\ \text{V}}$$ 2

$$Z_{Th} = j27 + (4+j)//(j6) = j27 + \frac{j6(4+j)}{4+j7} = \underline{2.215 + j29.12Ω}$$ 2

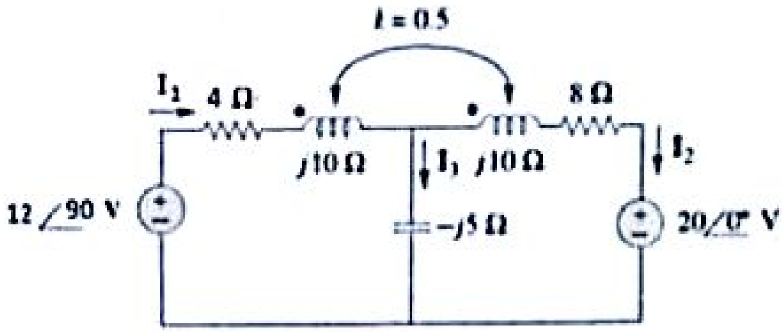
Question 8 (9 points)

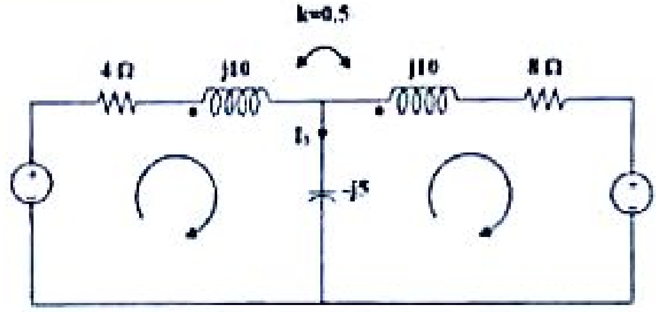
For the circuit shown in the figure, if $\omega = 1{,}000$ rad/s, determine

a. the currents $\mathbf{I}_1$ and $\mathbf{I}_2$.

b. the energy stored in the coupled coils at $t = 2$ ms, W(t).

$\mathbf{I}_1$ (A)	$\mathbf{I}_2$ (A)	W(t) (mJ)
$2.46\angle 72.2°\ A$	$0.88\angle -97.5°\ A$	~~43.7~~ 23.2





Solution

For mesh 1. $\quad j12 = (4 + j10 - j5)I_1 + j5I_2 + j5I_2 = (4 + j5)I_1 + j10I_2 \quad (1)$

For mesh 2. $\quad 0 = 20 + (8 + j10 - j5)I_2 + j5I_1 + j5I_1$

$$-20 = +j10I_1 + (8 + j5)I_2 \quad (2)$$

$$\begin{bmatrix} j12 \\ 20 \end{bmatrix} = \begin{bmatrix} 4 + j5 & +j10 \\ +j10 & 8 + j5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}, \quad \Delta = 107 + j60, \quad \Delta_1 = -60 - j296, \quad \Delta_2 = 40 - j100$$

$I_1 = \Delta_1/\Delta = \underline{\mathbf{2.462\angle 72.18°\ A}}$ $\qquad i_1 = 2.462\cos(1000t + 72.18°)$ A

$I_2 = \Delta_2/\Delta = \underline{\mathbf{0.878\angle -97.48°\ A}}$ $\qquad i_2 = 0.878\cos(1000t - 97.48°)$ A

$I_3 = I_1 - I_2 = \underline{\mathbf{3.329\angle 74.89°\ A}}$

At $t = 2$ ms, $1000t = 2$ rad $= 114.6°$. $\quad i_1 = 0.9736\cos(114.6° + 143.09°) = -2.445$

$i_2 = 2.53\cos(114.6° + 153.61°) = +0.8391$

The total energy stored in the coupled coils is

$$w = 0.5L_1i_1^2 + 0.5L_2i_2^2 + Mi_1i_2$$

Since $\omega L_1 = 10$ and $\omega = 1000$, $L_1 = L_2 = 10$ mH, $M = 0.5L_1 = 5$mH

$w = 0.5(10)(-2.445)^2 + 0.5(10)(+0.8391)^2 + 5(-2.445)(+0.8391) \rightarrow$ **$w = 43.67$ mJ**