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Homework #2

9.67. $R_1 = 5\,K\Omega$ $R_4 = 40\,k\Omega$ $V_g = 2\cos 10^6 t$

$R_2 = 100\,k\Omega$ $C_1 = 10\,PF$ $= 2\angle 0°$

$R_3 = 20\,k\Omega$ $C_2 = 100\,PF$ $= 2$

Admittance:

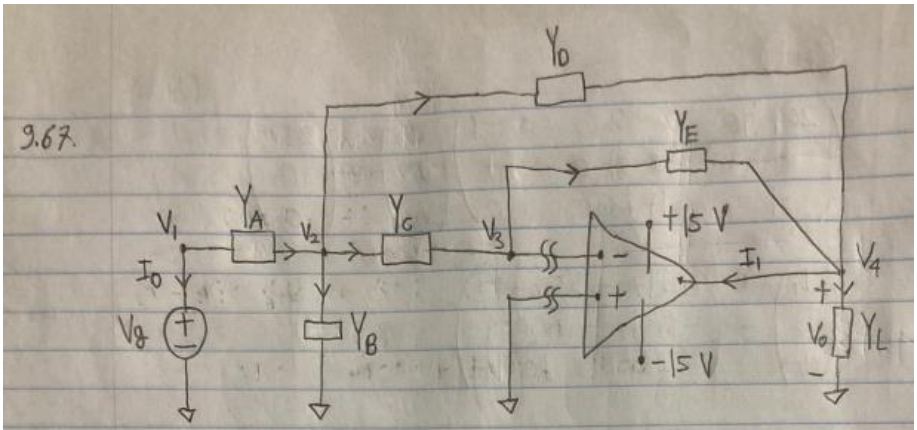
$$Y_A = \frac{1}{R_1} = \frac{1}{5000} = 2 \cdot 10^{-4}$$

$$Y_D = \frac{1}{R_2} = \frac{1}{100000} = 10^{-5}$$

$$Y_C = \frac{1}{R_3} = \frac{1}{20000} = 5 \cdot 10^{-5}$$

$$Y_L = \frac{1}{R_4} = \frac{1}{40000} = 2.5 \cdot 10^{-5}$$

9.67.



$$Y_E = j\omega C_1 = j(10^6)(10 \cdot 10^{-12}) = j10^{-5}$$

$$Y_B = j\omega C_2 = j(10^6)(100 \cdot 10^{-12}) = j10^{-4}$$

KCL:

1) $I_0 + I_A = 0 \longrightarrow V_1 = V_g$

2) $-I_A + I_D + I_B + I_C = 0$

3) $-I_C + I_E = 0$

4) $-I_E + I_L + I_1 - I_D = 0 \longrightarrow V_3 = 0$

$I_A = Y_A (V_1 - V_2)$

$I_B = Y_B V_2$

$I_C = Y_C (V_2 - V_3)$

$I_D = Y_D (V_2 - V_4)$

$I_E = Y_E (V_3 - V_4)$

$I_L = Y_L V_4$

$I_0 = ?$

$I_1 = ?$

1) $V_1 = V_g = 2$

2) $-Y_A(V_1 - V_2) + Y_0(V_2 - V_4) + Y_B V_2 + Y_C(V_2 - V_3) = 0$

From ①: $-2\cdot10^{-4}(2 - V_2) + 10^{-5}(V_2 - V_4) + j10^{-4} V_2 + 5\cdot10^{-5}(V_2 - V_3) = 0 \quad \cdot 10^7$

$-2000(2 - V_2) + 100(V_2 - V_4) + jV_2 + 500(V_2 - V_3) = 0$ ——— ②

3) $-Y_C(V_2 - V_3) + Y_E(V_3 - V_4) = 0$

$-5\cdot10^{-5}(V_2 - V_3) + j10^{-5}(V_3 - V_4) = 0 \quad \cdot 10^8$

$-5000(V_2 - V_3) + j(V_3 - V_4) = 0$ ——— ③

4) $V_3 = 0$

Based on ④ → ② & ③ become:

2) $-100V_4 - 500V_3 + (2600 + j)V_2 = 4000$
$-100V_4 - 500(0) + (2600 + j)V_2 = 4000$
$-100V_4 + (2600 + j)V_2 = 4000$

3) $-jV_4 + (5000 + j)V_3 - 5000V_2 = 0$
$-jV_4 + (5000 + j)(0) - 5000V_2 = 0$
$-jV_4 - 5000V_2 = 0$

organize ② & ③:

$$\begin{pmatrix} -100 & 2600 + j \\ -j & -5000 \end{pmatrix} \begin{pmatrix} V_4 \\ V_2 \end{pmatrix} = \begin{pmatrix} 4000 \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} V_4 \\ V_2 \end{pmatrix} = \begin{pmatrix} -39.999 + j0.208 \\ j0.008 \end{pmatrix}$$

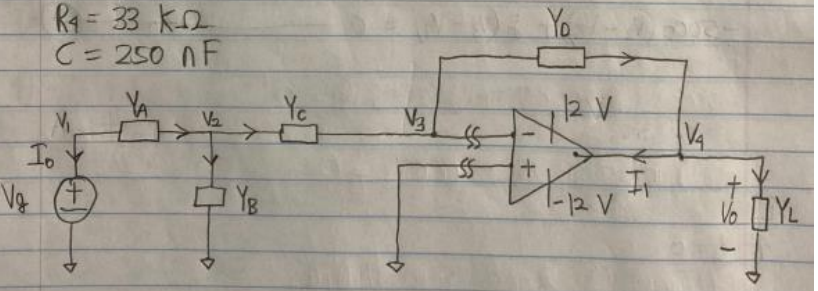
$V_0(t) = V_4 = -39.999 + j0.208$
$= 39.99954 \cos(10^6 t - 0.298)$

9.69. $R_1 = R_2 = 20\ K\Omega$ $\quad V_g = 4\cos 200t = 4\angle 0° = 4\ V$

$R_3 = 10\ K\Omega$

$R_4 = 33\ K\Omega$

$C = 250\ nF$



$Y_A = \frac{1}{20000} = 5 \cdot 10^{-5}$

$Y_B = j(200)(250 \cdot 10^{-9}) = j5 \cdot 10^{-5}$

$Y_C = \frac{1}{20000} = 5 \cdot 10^{-5}$

$Y_D = \frac{1}{10000} = 10^{-4}$

Cont.

9.69. KCL:

1) $I_0 + I_A = 0 \longrightarrow V_g = V_1 = 4$
2) $-I_A + I_B + I_C = 0$
3) $-I_C + I_D = 0$
4) $-I_D + I_1 + I_L = 0 \longrightarrow V_3 = 0$

1) $V_g = V_1 = 4$

2) $-Y_A(V_1 - V_2) + Y_B V_2 + Y_C(V_2 - V_3) = 0$

$-5 \cdot 10^{-5}(V_1 - V_2) + j5 \cdot 10^{-5} + 5 \cdot 10^{-5}(V_2 - V_3) = 0 \quad \cdot 20000$

$-V_1 + V_2 + j + V_2 - V_3 = 0$

$-4 + 2V_2 - 0 = -j \longrightarrow 2V_2 = 4 - j$

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3) $-I_C + I_D = 0$

$-Y_C(V_2 - V_3) + Y_D(V_3 - V_4) = 0$

$-5 \cdot 10^{-5}(V_2 - V_3) + 10^{-4}(V_3 - V_4) = 0 \quad \cdot 20000$

$-V_2 + V_3 + 2V_3 - 2V_4 = 0$

$-V_2 + 3V_3 - 2V_4 = 0$

$-V_2 - 2V_4 = 0 \quad \cdot -1$

$V_2 + 2V_4 = 0$

$$\begin{pmatrix} 2 & 0 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} V_2 \\ V_4 \end{pmatrix} = \begin{pmatrix} 4 - j \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} V_2 \\ V_4 \end{pmatrix} = \begin{pmatrix} 2 - j0.5 \\ -1 + j0.25 \end{pmatrix}$$

$V_0(t) = V_4 = -1 + j0.25$

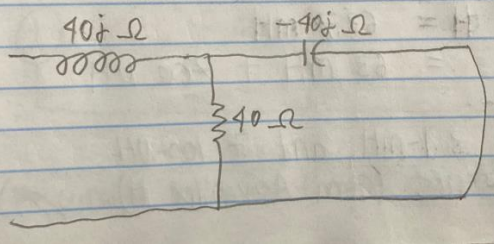
$= 1.03077 \cos(200t - 14.03624°)$

10.44. a. Find Max power transferred: $Z_L = Z_{th}^*$

$$Z_{8mH} = j(5000)(8 \cdot 10^{-3}) = 40j$$

$$Z_{5\mu F} = \frac{1}{j(5000)(5 \cdot 10^{-6})} = -40j$$

No dependent sources → Turn off all independent sources:



(cont.)

10.44 a. $Z_{40} \| Z_{5\mu F} = \frac{(40)(-40j)}{40 - 40j} = \frac{-40j}{1-j} = 20 - 20j$

$$Z_{th} = Z_{8mH} + Z_{40} \| Z_{5\mu F}$$
$$= 40j + 20 - 20j$$
$$= 20 - 20j$$

Max power transferred (Impedance for it):

$$Z_L = Z_{th}^*$$
$$= \underline{20 + 20j\ \Omega}$$

b. $V_g = 80 \cos 5000t = 80\angle 0° = 80\ V$

$$I = \frac{V_g}{R_{th} + R_L} = \frac{80}{20 + 20j + 20 - 20j}$$
$$= \frac{80}{40} = 2\ A$$

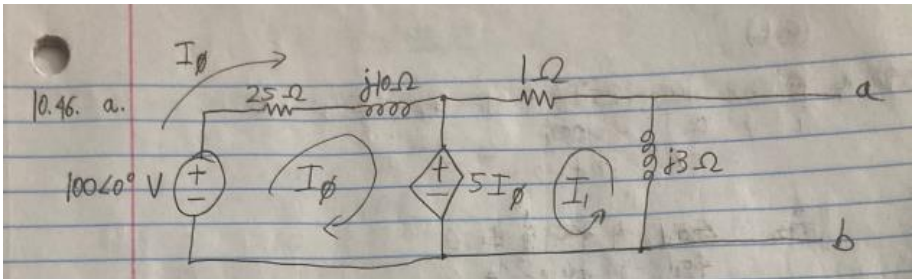
$$P = |I|^2 R_L = (2^2)(20) = \underline{80\ W}$$

c. $R_L = 10 + 10 = 20\ \Omega$
(20 Ω can be constructed using 2 10 Ω resistors from Appendix H.)

$$X_L = 2\pi \cdot 50L$$
$$20 = 2\pi \cdot 50L$$
$$L = 0.0637\ H = 63.7\ mH$$
$$= 63\ mH + 700\ \mu H$$

Connect 6 10-mH, 3 1-mH, and 7 100-μH inductors all in series (from Appendix H).

10.46. a.



KVL: $-100 + 25I_\phi + j10 \cdot I_\phi + 5I_\phi = 0$

$(30 + j10)I_\phi = 100$

$$I_\phi = \frac{100}{30 + j10} = 3 - j$$

$j3 \cdot I_1 + 1 \cdot I_1 - 5I_\phi = 0$

$(j3 + 1)I_1 - 5(3 - j) = 0$

$(j3 + 1)I_1 - (15 - j5) = 0$

$(j3 + 1)I_1 = 15 - j15$

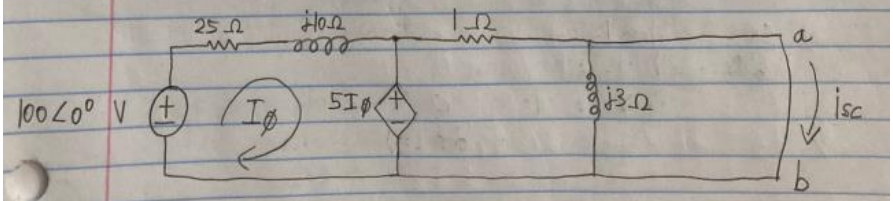
$$I_1 = \frac{15 - j15}{j3 + 1} = -j5$$

$V_{th} = V_{ab} = V_{j3\Omega} = Z_{j3} \cdot I_1$

$= (j3)(-j5)$

$= 15$ V

Find Z_{th}:



(No current will flow through j3 Ω inductor due to i_{sc}.)

(cont.)

10.46. a. KVL: $-100 + 25I_\phi + j10 \cdot I_\phi + 5I_\phi = 0$

$$I_\phi = \frac{100}{30 + j10} = 3 - j$$

$-5I_\phi + 1 \cdot i_{sc} = 0$

$-5(3 - j) + i_{sc} = 0$

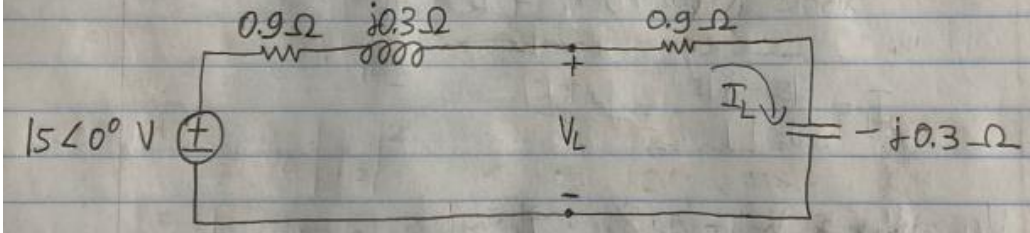
$i_{sc} = 5(3 - j)$

$= 15 - 5j$

$$Z_{th} = \frac{V_{th}}{i_{sc}} = \frac{15}{15 - 5j} = 0.9 + 0.3j$$

$Z_L = Z_{th}^* = 0.9 - 0.3j$

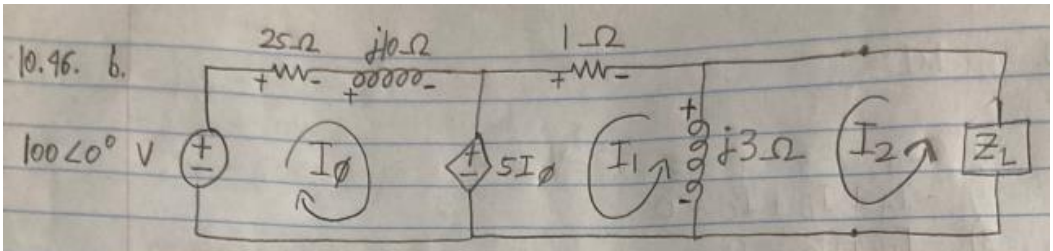
$Z_L = Z_{th}^* = 0.9 - 0.3j$



$$I_L = \frac{15}{0.9 + j0.3 + 0.9 - j0.3} = 8.33 \text{ A}$$

$$P_L = |I_L|^2 (0.9) = \underline{62.5 \text{ W}}$$

10.46. b.



$$S_{total} = S_{100V} + S_{25\Omega} + S_{j10\Omega} + S_{5I_\phi} + S_{1\Omega} + S_{j3\Omega}$$
$$= 100 I_\phi + (I_\phi)^2 (25) + (I_\phi)^2 (j10) + 5I_\phi (I_\phi - I_1) + (I_1)^2 (1) + (I_1)^2 (j3)$$

$$= 100 I_\phi + (30 + j10)(I_\phi)^2 - 5 I_\phi I_1 + (I_1)^2 (1 + j3)$$

$$= 100(3 - j) + (30 + j10)(3 - j)^2 - 5(3 - j)(-j5) + (-j5)^2 (1 + j3)$$

$$= 600 - 200j = P + jQ_L$$

P Q

$P_{total} = 600$ W

$$\frac{P_L}{P_{total}} = \frac{62.5}{600} = 0.10417 = \underline{10.417\ \%}$$