1 (a) In the network shown in Figure 1, two voltage sources act on the load impedance connected between A, B. If the load is variable in both resistance and reactance, what load Z_L will receive the maximum power and what is the value of the maximum power? Use Millman's theorem.

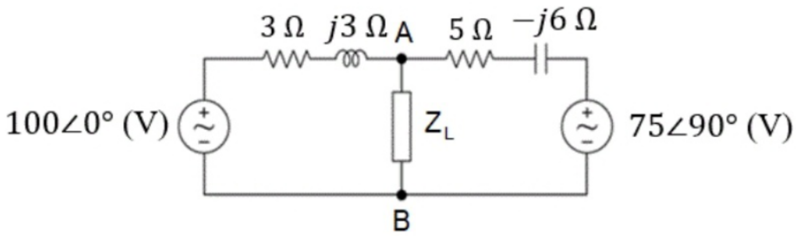
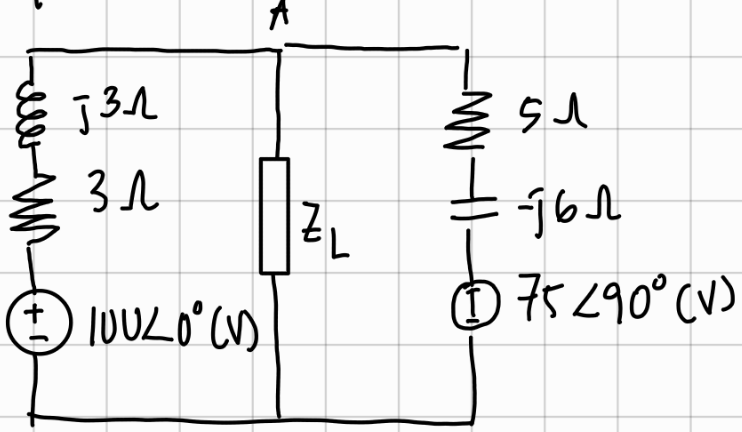
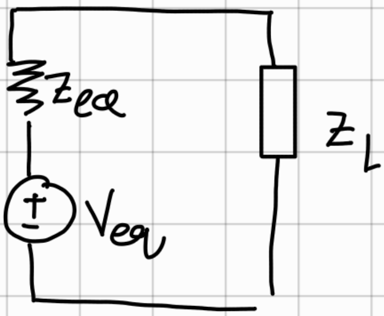


Fig. 1. The circuit for question 1(a)

[7 marks]

Equivalent circuit





$$\frac{1}{Z_{eq}} = \frac{1}{3+j3\,\Omega} + \frac{1}{5j6}$$

$$= \frac{91}{366} + \frac{25}{366} j\ \Omega^{-1}$$

$$Z_{eq} = \frac{273}{73} - \frac{75}{73} j\ \Omega$$

$$V_{eq} = \frac{\dfrac{100}{3+j3} + \dfrac{75j}{5-j6}}{\dfrac{91+25j}{366}\ \Omega^{-1}}$$

$$= 23.9333 - j48.883\ V$$

$$= 54.427\angle -63.913^\circ$$

$V_1 = 100\angle 0^\circ$

$= 100$

$V_2 = 75\angle 90^\circ$

$= 75j$

$V = IR$

$= \frac{V}{R}$

$P = VI$

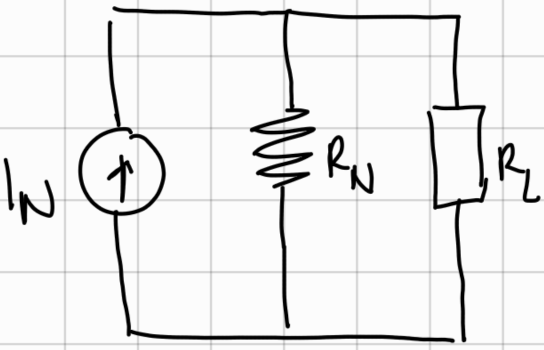
$= \frac{V^2}{R}$

$$I_L = \frac{V}{Z_{eq} + Z_L}$$

$$\frac{V^2}{R} > 0$$

$$\frac{(54.427 \angle -63.913)^2}{\frac{273-75j}{73} + Z_L} > 0$$

$$\frac{273 - j75}{73} + Z_L > 0$$



$$Z_L < -\frac{(273 - j75)}{73}$$

$$Z_L < -\frac{273}{73} + j\frac{75}{73}$$

$$Z_L < -3.73972 + j1.0274$$

$Z_L = 0$

$$P = \frac{V^2}{R}$$

$$= \frac{(54.427 \angle -63.913^\circ)^2}{\frac{273 - j75}{73}}$$

$$= -291.861 - j705.86$$

$$= 763.82 \angle -112.5^\circ$$

$$E = I_N \times R_N$$

(b) Consider the circuit in Figure 2, operating in steady state at a particular frequency. The values of the parameters are $X_1 = 40\ \Omega$, $X_2 = 40\ \Omega$, $B_1 = 1/80\ mho$. Find the impedances Z_i and Z_L so that the circuit is matched.

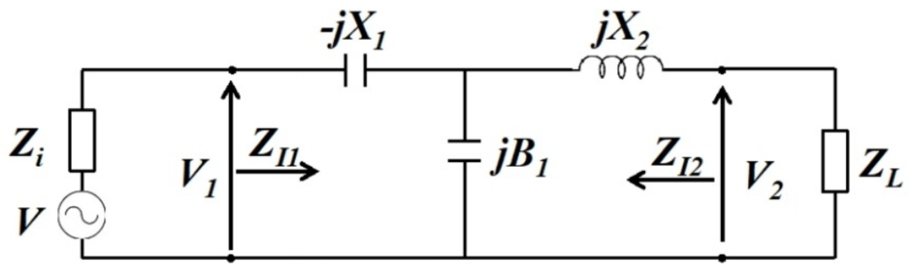


Fig. 2. The circuit for question 1(b)

[10 marks]

Question 2

(a) Find and draw the Norton equivalent to the circuit shown in Figure 4 (with respect to the terminals A and B). The values of the components are $V_0 = 8\ V$, $R_1 = 4\ \Omega$, $R_2 = 1\ \Omega$, and $R_L = 5\ \Omega$.

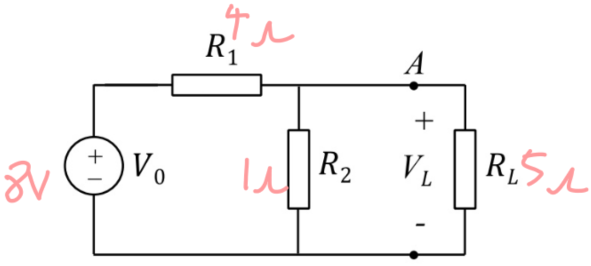
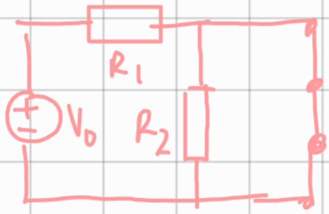


Fig. 4. The circuit for question 2(a)

[5 marks]

Norton's equivalent circuit

1. Remove the Z_L/R_L & replace with short circuit



2. Find I_{Norton} by calculating the current through the short circuit where the load was

3. Find R_{Norton} by creating open circuit where the load resistor is shorting all voltage sources & by open circuiting all the current sources.

Total resistance (except R_L)

$= R_1 + R_2$ $\qquad R_1 + \left(\frac{1}{R_2}\right)^{-1}$

$= (4+1)\ \Omega$

$= 5\ \Omega$ $\qquad = \left(\frac{1}{4} + \frac{1}{1}\right)^{-1}$

$I_{total} = \frac{8}{5} = 1.6A$ $\qquad = 0.8\ \Omega$

$I_{total} = \frac{8}{0.8} = 10A$

Voltage drop across R_1

$V = IR$

$= 1.6(4)$

$= 6.4V$ — logical

$V_2 = 8 - 6.4$

$= 1.6V$

$V = IR$

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

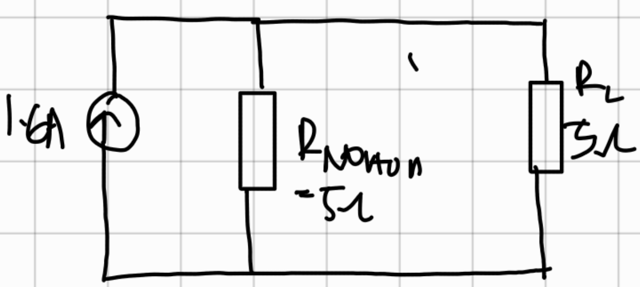
$= 1.6V$

$I_{Norton} = 1.6A$

$R_{Norton} = R_1 + R_2$

$= 5\ \Omega$

Equivanlent circuit



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(b) Consider the circuit in Figure 5. Using mesh analysis, find the values of i_1, i_2, and i_3 when $V_0 = 4\ V$, $I_0 = 1\ A$, $R_1 = R_2 = 2\ \Omega$, $R_3 = 3\ \Omega$, and $R_4 = 4\ \Omega$.

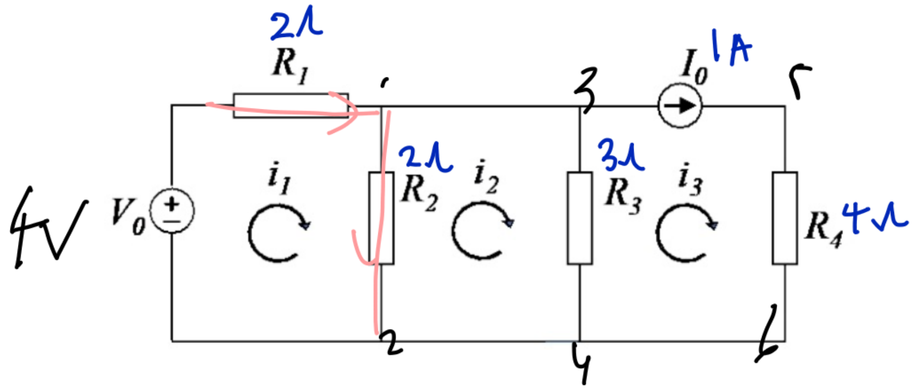

Fig. 5. The circuit for question 2(b)

[8 marks]

Mesh analysis

$V_0 = i_1R_1 + (i_1 - i_2)R_2$

$0 = (i_2 - i_1)R_2 + (i_2 - i_3)R_3$

$(i_3 - i_2)R_3 + (i_3 + i_0)R_4 = 0$

$3(i_3 - i_2) + 4(i_3 + 1) = 0$

$7i_3 - 3i_2 + 4 = 0$

$7i_3 - 3i_2 = -4$ — (3)

$4 = 2i_1 + 2(i_1 - i_2)$

$4 = 4i_1 - 2i_2$

$2 = 2i_1 - i_2$ — (1)

$2(i_2 - i_1) + 3(i_2 - i_3) = 0$

$5i_2 - 2i_1 - 3i_3 = 0$ — (2)

$i_1 = \frac{2 + i_2}{2}$

$i_3 = \frac{-4 + 3i_2}{7}$

into (2)

$5i_2 - \cancel{2}\left(\frac{2 + i_2}{\cancel{2}}\right) - 3\left(\frac{-4 + 3i_2}{7}\right) = 0$

$5i_2 - 2 - i_2 + \frac{12}{7} - \frac{9}{7}i_2 = 0$

$4i_2 - \frac{9}{7}i_2 = \frac{2}{7}$

$\frac{19}{7}i_2 = \frac{2}{7}$

$i_2 = \frac{2}{19}$ A

$i_1 = \frac{2 + \left(\frac{2}{19}\right)}{2} = \frac{40}{38}$ A

$i_3 = \frac{-4 + 3\left(\frac{2}{19}\right)}{7} = -\frac{10}{19}$ A

$I_1 = \frac{40}{38}$ A $I_2 = \frac{2}{19}$ A $I_3 = \frac{-10}{19}$ A check

(a) Describe what are meant by characteristic impedance and phase velocity. Explain when propagation constant becomes purely an imaginary number.

[6 marks]

Question 3

(b) A 75 Ω coaxial transmission line has a length of 2.0 cm and is terminated with a load impedance of $37.5+j75$ Ω. Find the input impedance to the line, the reflection coefficient at the load and the reflection coefficient at the input and the SWR on the line for a wave traveling along the line with the wavelength of 16.0 cm.

$\lambda = 16.0\,cm$

[8 marks]

$Z_L = 37.5 + j75$ $\quad l = 0.02$

$$Z_{in} = Z_0 \frac{Z_L + Z_0 \tan(\beta l)}{Z_0 + Z_L \tan(\beta l)}$$

$$\beta = \frac{2\pi}{\lambda} = \frac{2\pi}{0.16} = 39.2699$$

$$= 75 \frac{(37.5+j75) + 75 \tan(39.2699(0.02))}{(75 + (37.5+j75)\tan(39.2699(0.02))}$$

$$= 39.2728 + 73.9597i \ \Omega$$

$$\Gamma_{load} = \frac{(Z_L - Z_0)}{(Z_L + Z_0)} = \frac{37.5+j75-75}{37.5+j75+75} = \frac{-37.5+j75}{112.5+j75} = \frac{1}{13} + \frac{8}{13}j$$

$$= 0.6202$$

$$\Gamma_{input} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} = \frac{39.2728+i73.9547-75}{39.2728+i73.9547+75}$$

$$= \left|\frac{-35.7272+i73.9547}{114.2728+i73.9547}\right|$$

$$= |0.07484 + 0.59874i|$$

$$= 0.6034$$

$$SWR = \frac{1+|\Gamma_{in}|}{1-|\Gamma_{in}|} = \frac{1+0.6034}{1-0.6034}$$

$$= 4.043$$

c