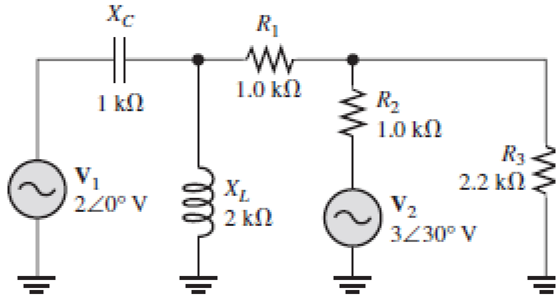
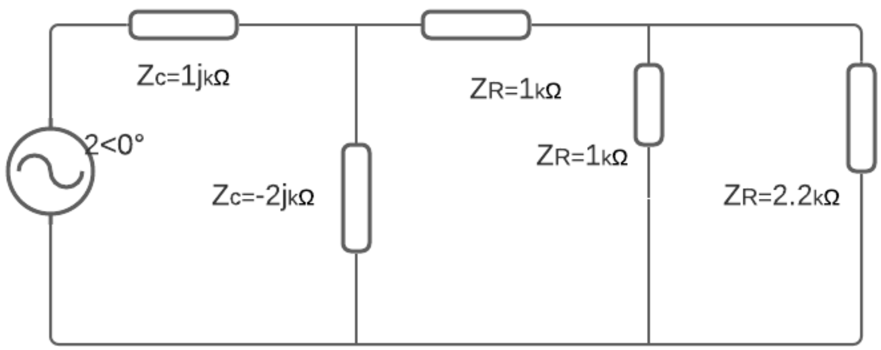
TEOREMA SE SUPERPOSICIÓN

1. Con el método de superposición, calcule la corriente a través de R3 en la figura 19-44.



Primer Análisis



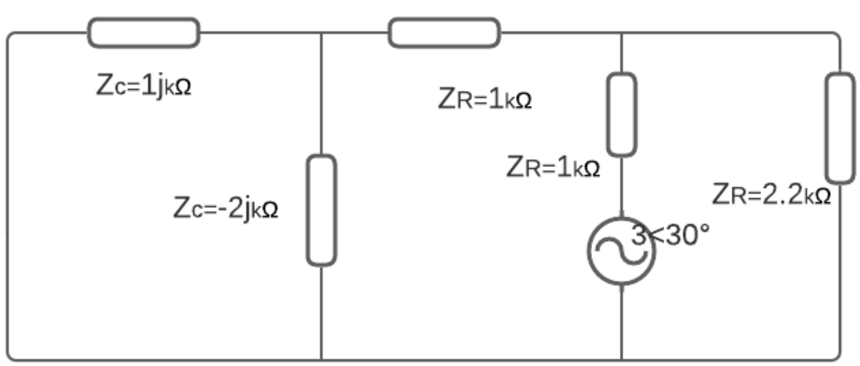
$$RT = \frac{1(2.2)}{1+2.2} + 1 = 1.69k\Omega$$

$$Zt = Xc + \frac{X_L R_T}{X_L + R_T} = 1\angle -90° + \frac{2\angle 90°(1.69\angle 0°)}{1.69 + j2} = 1\angle -9.64°$$

$$I_t = \frac{V}{Zt} = \frac{2\angle 0°}{1\angle -9.64°} = 2\angle 9.64° mA$$

$$I_{R3} = \frac{1}{2.2+1}(2\angle 9.64°) = 0.62\angle 9.64° mA$$

$$Segundo\ Analisis$$



$$Ze = \frac{Xc(X_L)}{Xc + X_L} + R = (\frac{1j(-2j)}{1j - 2j} + 1 = 1 + j2$$

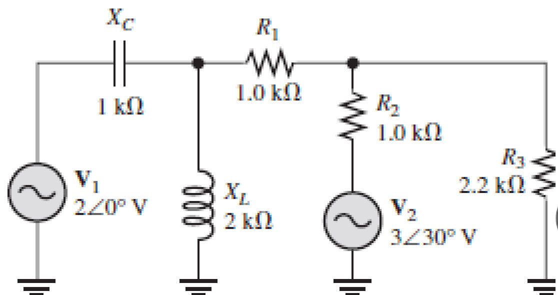
$$Zt = \frac{2.2(1+j2)}{2.2+1+j2} + 1 = \frac{2.2+j4.4}{3.2+j2} = 1.30\angle 31.43° + 1 = 2{,}22\angle 17.84°$$

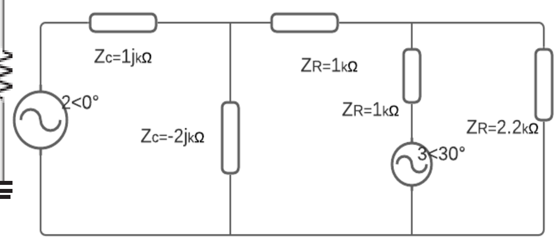
$$I_{R3} = \frac{V}{Zt} = \frac{3\angle 30°}{2{,}22\angle 17.84°} = 1.36\angle 12.17° A$$

$$Valor\ de\ la\ corriente$$

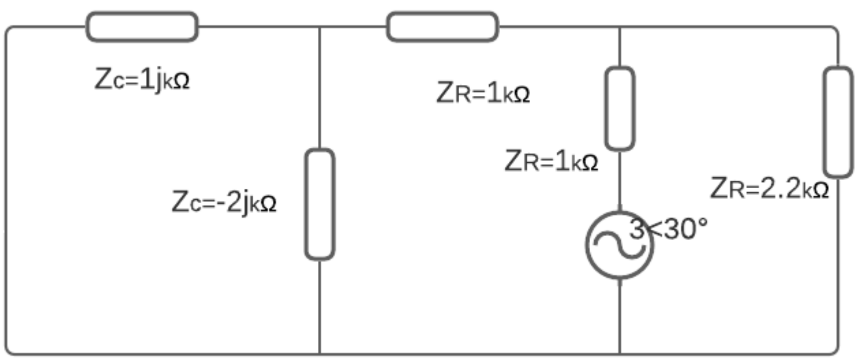
$$I_{R3} = 0.62\angle 9.64° + 1.36\angle 12.17° A = \mathbf{1.92\angle 11.70}° mA$$

2. Use el teorema de superposición para determinar la corriente y el voltaje a través de la rama R2 de la figura 19-44.





Primer Análisis

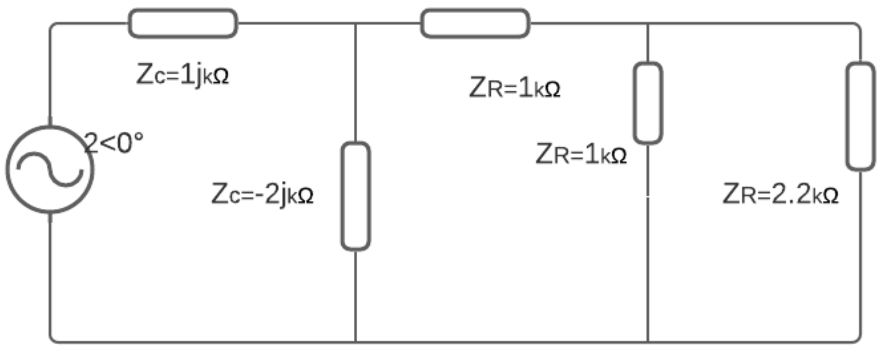


$$Zc||Zc2 + ZR = \frac{1j(-2j)}{1j-2j} = 2j + 1$$

$$Zt = \frac{(2j+1)(2.2)}{2j+1+2.2} + 1 = \frac{5.4+6.4j}{3.2+2j} = \frac{8.37\angle 49.84°}{3.77\angle 32°} = 2{,}22\angle 17.84°$$

$$I_{R2} = \frac{V}{Zt} = \frac{3\angle 30°}{2{,}22\angle 17.84} = 1.36\angle 12.17\ mA$$

Segundo Análisis



$$Ze1 = ZR3||ZR2 + ZR1 = \frac{2.2(1)}{2.2+1} + 1 = 1.69k\Omega$$

$$Zt = Xc + \frac{X_L R_T}{X_L + R_T} = 1\angle -90° + \frac{2\angle 90°(1.69\angle 0°)}{1.69 + j2} = 1\angle -9.64°$$

$$I_t = \frac{V}{Zt} = \frac{2\angle 0°}{1\angle -9.64°} = 2\angle 9.64° mA$$

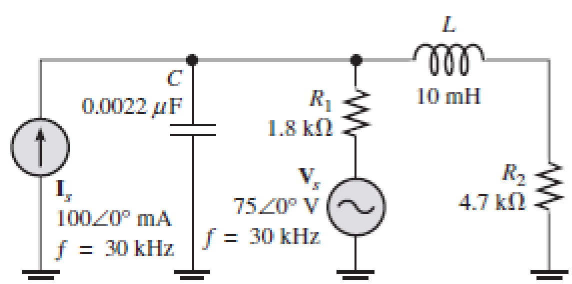
$$I_{R2} = \frac{2j}{2j+2} * (2\angle 9.64°) = 0.70\angle 45° mA$$

$$I_{R2} = 1.36\angle 12.17° + 0.70\angle 45° mA$$

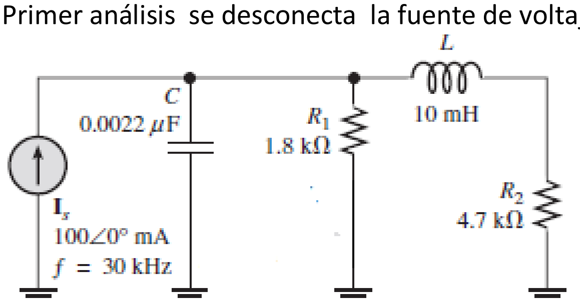
$$I_{R2} = 1.98\angle 23.20° mA$$

3. Con el teorema de superposición, calcule la corriente a través de R1 en la figura 19-45.

-



Primer análisis se desconecta la fuente de voltaje ca



Reactancia

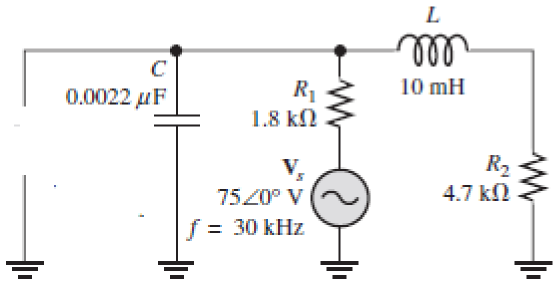
$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\pi 30kHz)(0.0022\mu F)} = 2.4k\Omega$$

Divisor de voltaje

$$I_{R1} = \left(\frac{2.4\angle -90°}{1.8 - j2.4}\right) * 100\angle 0° = 80\angle -36.87°mA$$

Segundo Análisis

Se desconecta la fuente de corriente



$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\pi 30kHz)(0.0022\mu F)} = 2.4k\Omega$$

$$X_L = 2\pi fL = 2\pi(30kHz)(10mH) = 1.88k\Omega$$

Impedancia Total

$$Zt = \frac{Xc * RL}{RL + Xc} + XL + R1 = \frac{2.4\angle -90°(4.7\angle 0°)}{4.7 - j2.4} + 1.88\angle 90° + 1.8\angle 0°$$

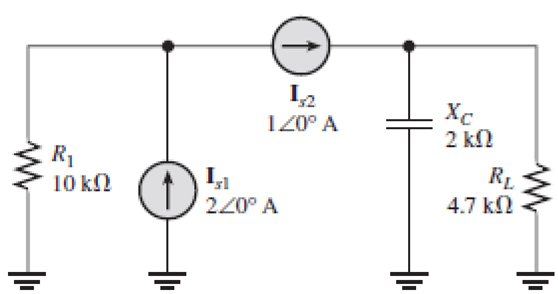
$$Zt = 2.77\angle -0.62°$$

$$I_{R1} = \frac{V}{Zt} = \frac{75\angle 0°}{2.77\angle -0.62°} = 27.07\angle 0.62°$$

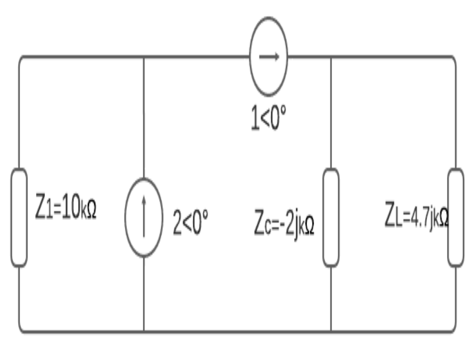
$$I_{R1} = 80\angle -36.87° - 27.07\angle 0.62°$$

$$I_{R1} = 60.33\angle -52.25\ mA$$

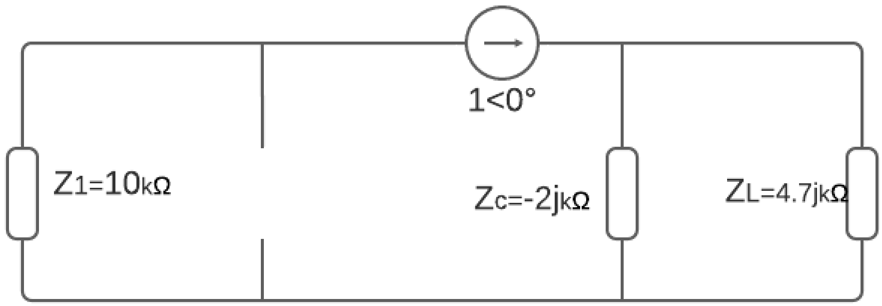
4. Con el teorema de superposición, determine la corriente a través de RL en cada circuito de la figura 19-46.



(a)



Primer Análisis



$$I_1 = 1 < 0°$$

Malla 2

$$-2j(I_2 - I_1) + 4.7jI_2 = 0$$

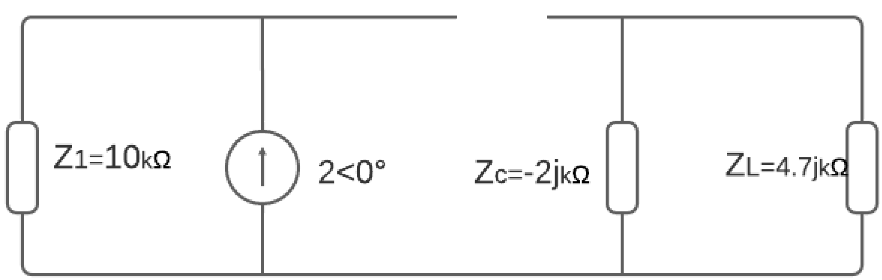
$$2.7jI_2 + 2jI_1 = 0$$

Remplazo la corriente I1 obteniendo el valor dela corriente I2

$$2.7jI_2 + 2\angle 90° * 1\angle 0° = 0$$

$$\boldsymbol{I_2 = -0.74\angle 0° A}$$

Segundo Análisis

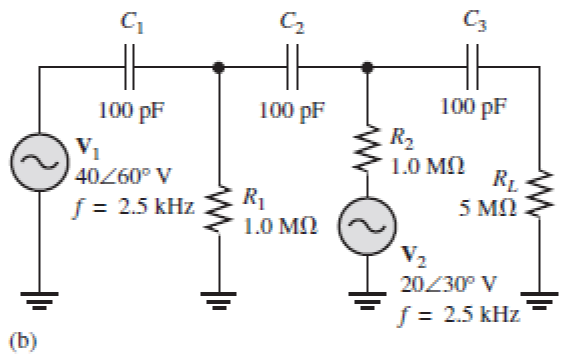


La corriente que circula por RL en este caso es cero

La corriente que circula por RL es

$$\boldsymbol{I_2 = 0.74\angle 0°}$$

Segundo Ejercicio

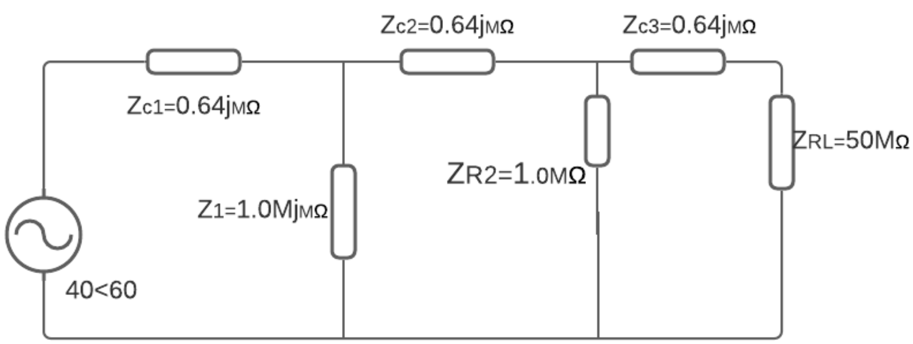


Primer Análisis

$$X_{C1}=\frac{1}{2\pi f C_1}=\frac{1}{2\pi(2.5kH_Z)(100pF)}=0.64M\Omega$$

$$X_{C2}=\frac{1}{2\pi f C_2}=\frac{1}{2\pi(2.5kH_Z)(100pF)}=0.64M\Omega$$

$$X_{C3}=\frac{1}{2\pi f C_3}=\frac{1}{2\pi(2.5kH_Z)(100pF)}=0.64M\Omega$$



$$Ze1=Zc3+ZRL=0.64j+50$$

$$Ze2=0.64j+\left[\frac{1j(0.50+0.64j)}{0.51+0.64j}\right]=\frac{48.72+33.28j}{0.51+0.64j}=\frac{58\angle 34.33°}{51\angle 0.72°}=1.14\angle 33.61°M\Omega$$

$$Zt=0.64j+\left[\frac{1(0.95+0.63j)}{1.95+0.63j}\right]=\frac{0.55+1.88j}{1.95+0.63j}=\frac{2\angle 34.33}{2\angle 0.72}=\mathbf{1\angle 55.80°M\Omega}$$

$$I_T=\frac{V}{ZT}=\frac{40\angle 60°}{1\angle 55.80°}=\mathbf{40\angle 4.12MA}$$

Divisor de corriente

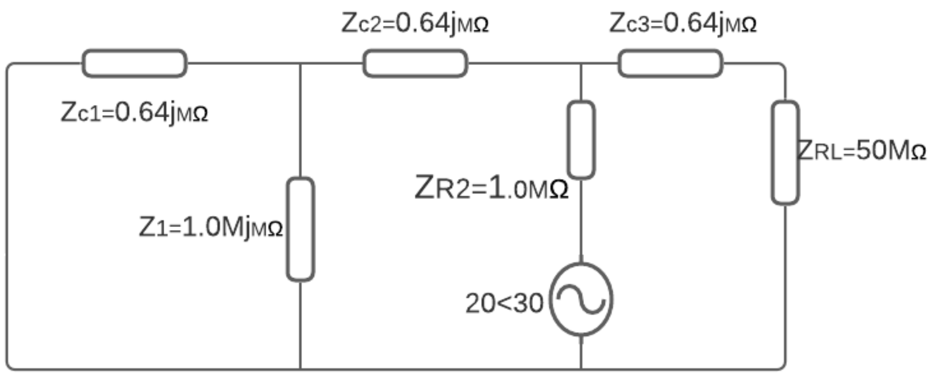
$$I_L = \frac{1j}{50 + 2.28j}(40\angle 4.12) = \mathbf{0.8\angle 91.52}\boldsymbol{MA}$$

Segundo análisis

$$X_{C1} = \frac{1}{2\pi f C_1} = \frac{1}{2\pi(2.5kH_Z)(100pF)} = 0.64M\Omega$$

$$X_{C2} = \frac{1}{2\pi f C_2} = \frac{1}{2\pi(2.5kH_Z)(100pF)} = 0.64M\Omega$$

$$X_{C3} = \frac{1}{2\pi f C_3} = \frac{1}{2\pi(2.5kH_Z)(100pF)} = 0.64M\Omega$$



$$Ze1 = Zc1||Z1 + Zc2 = \left[\frac{0.614j(1)}{1 + 0.64j}\right] + 0.64j = \frac{-0.41 + 1.28j}{1 + 0.64j}$$

$$Zt = 1 + 0.64j + \frac{-0.41 + 1.28j}{1 + 0.64j} = \frac{30.09 + 97.28j}{51 + 0.64j} = \frac{101.83\angle 72.81°}{51\angle 0.72°}$$

$$\boldsymbol{Zt = 2\angle 72.09°M\Omega}$$

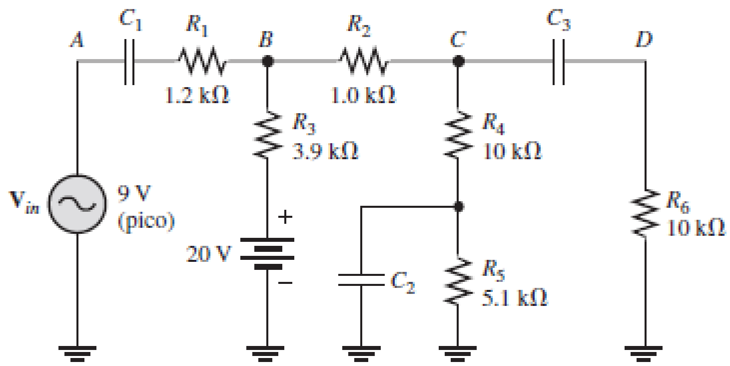
$$I = \frac{V}{Zt} = \frac{20\angle 30°}{2\angle 72.09°} = 10\angle -42.09°$$

$$\boldsymbol{I_L = 10\angle -42.09°}$$

Intensidad de corriente en el resistor RL se obtiene de la resta de la corriente obtenida en el primer caso con la corriente del segundo caso ya que las corrientes van en sentido opuesto

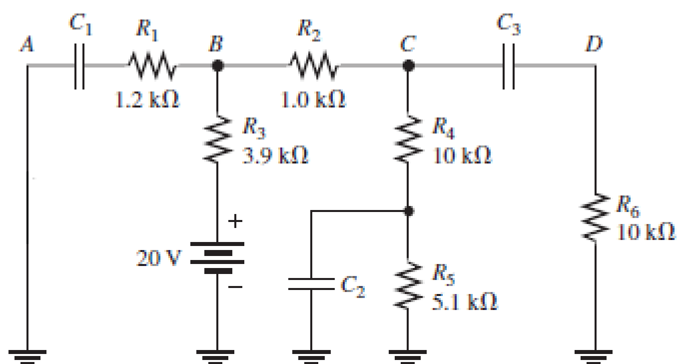
$$\boldsymbol{I_L = 10\angle 45.25MA}$$

5. Determine el voltaje en cada punto (A, B, C, D) señalado en la figura 19-47. Suponga XC _ 0 para todos los capacitores. Trace las formas de onda de voltaje en cada punto.



▲ FIGURA 19–47

Primer Análisis



$$NodoB$$

$$\frac{20-VB}{3.9}=\frac{VB+0}{1.2}+\frac{VB-Vc}{1}$$

$$Ec1: 2.09VB-Vc=5.13$$

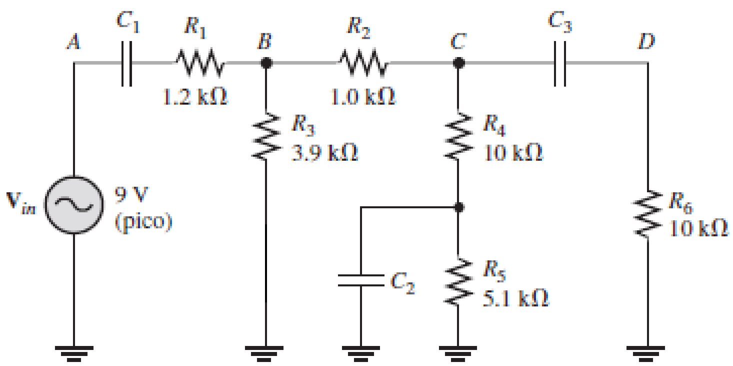
$$Nodo\ C$$

$$\frac{VB-VC}{1}=\frac{VC}{15.1}+\frac{VC}{10}$$

$$Ec2: VB=1.17Vc$$

$$VA=0 \qquad VB=14.82 \qquad Vc=4.18 \qquad VD=0$$

Segundo Análisis



$$NodoB$$

$$\frac{9-VB}{1.2}=\frac{VB}{3.9}+\frac{VB-Vc}{1}$$

$$Ec1: 2.09VB+Vc=7.5$$

$$Nodo\ C$$

$$\frac{VB-VC}{1}=\frac{VC}{15.1}+\frac{VC}{10}$$

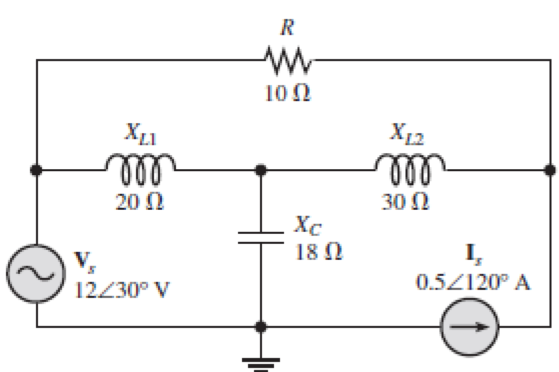
$$Ec2: VB=1.17Vc$$

$$VA=9 \qquad VB=2.22 \qquad Vc=2.18 \qquad VD=0$$

Voltaje en cada punto

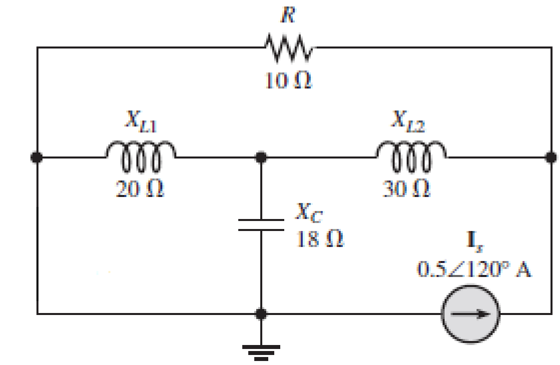
$$VA=9 \qquad VB=12.62 \qquad Vc=6.36 \qquad VD=0$$

6. Use el teorema de superposición para determinar la corriente en el capacitor de la figura 19-48.



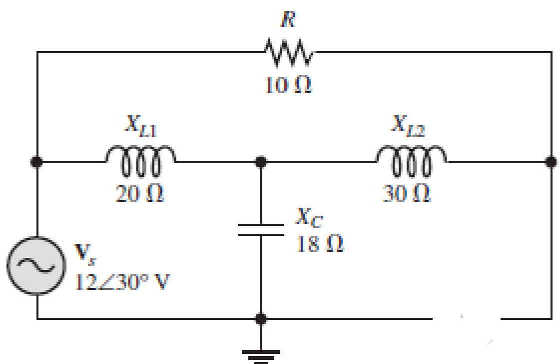
Primer análisis

Se desconecta la fuente de voltaje se procede al análisis



$$I_c = \frac{30\angle 0°}{30 - j18} * (0.5\angle 120°) = \frac{15\angle 120°}{35\angle -31°} = \mathbf{0.43\angle 151°}A$$

Segundo Análisis



$$Z_e = \frac{(10 + j30)(20j)}{10 + j50} = \frac{31.62\angle 71.56°(20\angle 90°)}{10 + 30j} = \frac{632.4\angle 161°}{60\angle 78.69°} = 10.54\angle 82.87°$$

$$Zt = 18\angle -90 + 10.54\angle 82.87 = \mathbf{7.66\angle -80.5°}$$

Ley de Ohm

$$I = \frac{V}{Zt} = \frac{12\angle 30°}{7.60\angle -80.15°}$$

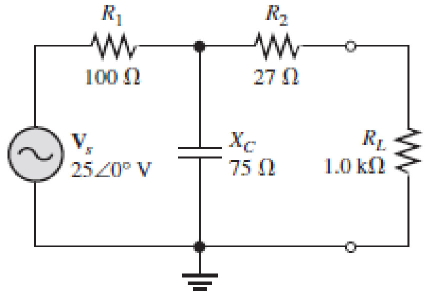
$$\boldsymbol{I = 1.57\angle -50.15°}$$

$$\boldsymbol{Ic} = 0.43\angle 151° - 1.57\angle -50.15°$$

$$\boldsymbol{Ic = 1.22\angle 124°}$$

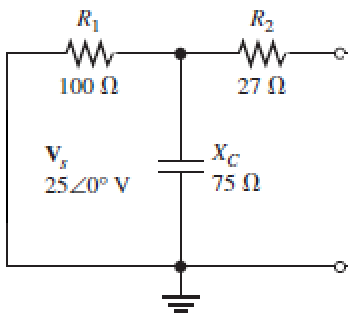
Teorema de Thévenin

7. En cada circuito de la figura 19-49, determine el circuito equivalente de Thévenin para la



parte vista por RL.

a)

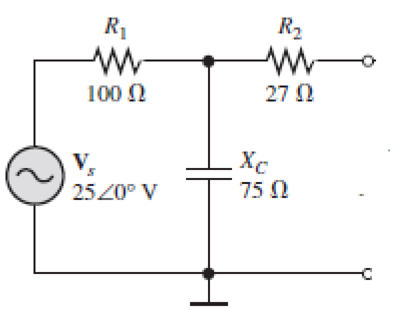


Impedancia

$$Z_{TH} = \frac{27\angle 0°(75\angle -90°)}{25 - j75} = \frac{2025\angle -90°}{79\angle 71.56°}$$

$$Z_{TH} = 25.63\angle -161.56°$$

Voltaje

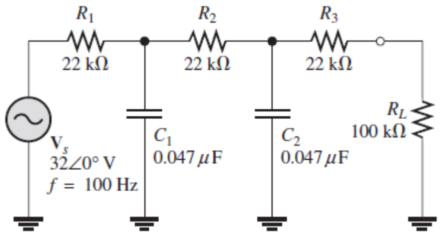


Divisor de voltaje

$$V_{TH} = \left(\frac{75\angle -90°}{100 - j75}\right) * 25\angle 0° = \frac{1875\angle -90°}{125\angle -36.6°} = 15\angle -53.4°$$

$$V_{TH} = 15\angle -53.4° V$$

8. Aplique el teorema de Thévenin y determine la corriente a través de la carga *RL* en la figura 19-50.



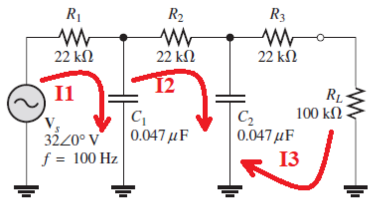
▲ FIGURA 19–50

$$X_C = \frac{1}{2 * \pi * 100 * 0.047} = 33.86\ k\Omega$$

$$z_1 = z_2 = (22 - j33.86)\ k\Omega$$

$$z_t = (22 - j33.86) + (22 - j33.86) + (22 + j0)\ k\Omega$$

$$z_t = (66 - j67.72)\ k\Omega$$



▲ FIGURA 19–50

Haciendo el estudio por mallas se obtiene los siguientes valores para las corrientes:

$$I_1 = (0.76 - j0.51)\ mA$$

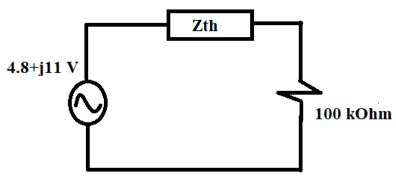
$$I_2 = (0.43 - j0.06)\ mA$$

$$I_3 = (0.048 + j0.11)\ mA$$

Con lo cual se puede calcular el voltaje en R_L.

$$V_{RL} = (0.048 + j0.11)mA * (100 + j0)R$$

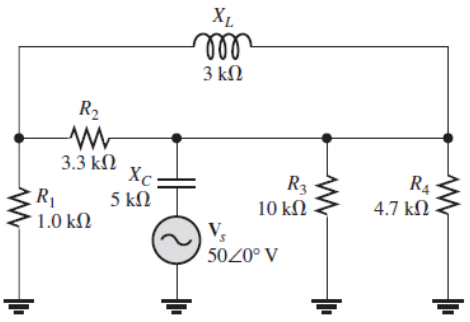
$$V_{RL} = 4.8 + j11\ V.$$



$$I_{RL} = \frac{4.8 + j11}{(100 + j0) + (66 - j67.72)}$$

$$I_{RL} = (1.6 + j66.9)\ \mu A$$

*__9.__ Aplique el teorema de Thévenin y determine el voltaje en $R4$ en la figura 19-51.



▲ FIGURA 19–51

$$R_{eq1} = R_1 \parallel R_2 = \frac{1 * 3.3}{1 + 3.3} = 0.767\ k\Omega$$

$$R_{eq2} = R_{eq1} \parallel R_3 = \frac{10 * 0.767}{10 + 0.767} = 0.712\ k\Omega$$

$$B_C = \frac{1}{5} = 0.2\ mS$$

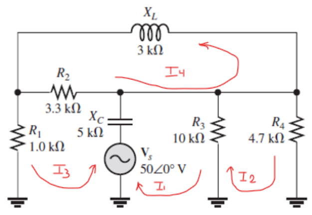
$$B_C = \frac{1}{0.712} = 1.4\ mS$$

$$Y = 1.4 + j0.2\ mS$$

$$Z = \frac{1}{1.4 + j0.2} = 0.7 - j0.1\ k\Omega$$

$$Z_T = \frac{(0.7 - j0.1) * (3 + j0)}{(0.7 - j0.1) + (3 + j0)} = 0.569 - 0.0656j\ k\Omega$$

Análisis por mallas:



$$(10 + j5)I_1 - 10I_2 = (50 + 0j)$$

$$-10I_1 + 14.7I_2 = 0$$

$$-j5I_1 + (4.3 + j5)I_3 = 0$$

$$-3.3I_3 + 6.3I_4 = 0$$

$$I_1 = 4.54 - 7.09j\ mA$$

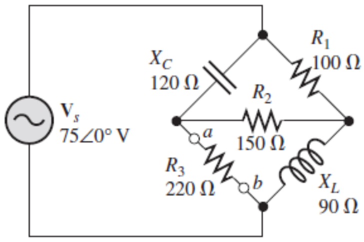
$$I_2 = 3.08 - 4.82j\ mA$$

$$I_3 = 6.12 - 1.83j\ mA$$

$$I_4 = 3.2 - 0.96j\ mA$$

$$V_{R3} = V_{R4} = (3.08 - 4.82j)(10 - 0j) = (30.8 - 48.2j)\ V$$

* **10.** Simplifique el circuito externo a *R*3 mostrado en la figura 19-52 a su equivalente de Thévenin.



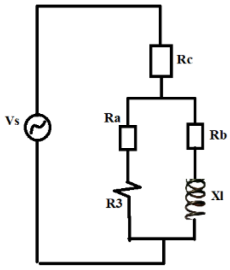
▲ FIGURA 19–52

Primeramente, se convertirá de Delta a Y el circuito que contiene Xc, R1 y R2.

$$R_a = \frac{(150 + j0) * (0 + j120)}{(150 + j0) + (0 + j120) + (100 + j0)} = 28.09 + j58.52\ \Omega$$

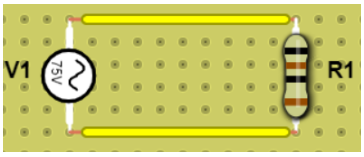
$$R_b = \frac{(100 + j0) * (150 + j0)}{(150 + j0) + (0 + j120) + (100 + j0)} = 48.76 - j23.41\ \Omega$$

$$R_a = \frac{(100 + j0) * (0 + j120)}{(150 + j0) + (0 + j120) + (100 + j0)} = 18.72 + 39.01\ \Omega$$



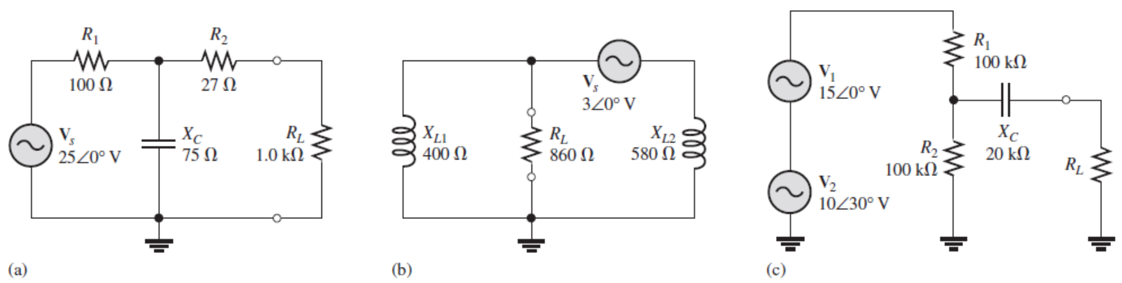
$$Z_{Th} = (20.14 + j39.79)\ \Omega$$

El circuito equivalente de thevenin queda de la siguiente manera con $Z_{Th} = (20.14 + j39.79)\ \Omega$ y $V_{Th} = 75 + j0\ V$



SECCIÓN 19–3 Teorema de Norton

11. Para cada circuito de la figura 19-49, determine el equivalente de Norton visto por *RL*.

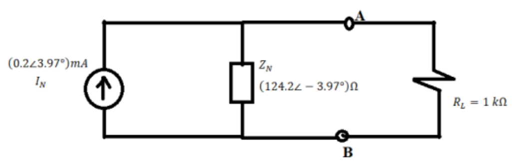


▲ FIGURA 19–49

a)

$$Z = (100\angle 0°) + \frac{(27\angle 0°)(75\angle -90°)}{(27\angle 0°) + (75\angle -90°)} = (124.2\angle -3.97°)\Omega$$

$$I = \frac{(25\angle 0°)}{(124.2\angle -3.97°)} = (0.2\angle 3.97°)mA$$

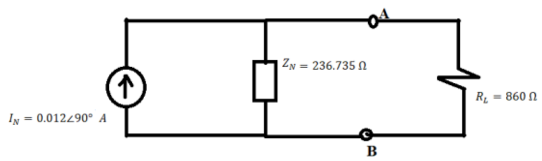


b)

$$\frac{1}{L_T} = \frac{1}{400} + \frac{1}{580}$$

$$L_T = 236.735\ \Omega$$

$$I = \frac{3\angle 0°}{236.735\angle -90°} = 0.012\angle 90°\ \ A$$



c)

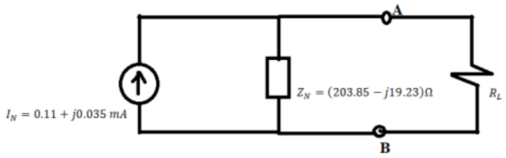
$$Z = (100\angle 0°) + \frac{(100\angle 0°)(20\angle -90°)}{(100\angle 0°) + (20\angle -90°)} = (203.85 - j19.23)\Omega$$

$$V_T = (15\angle 0°) + (10\angle 30°) = 23.66 + j5\ V$$

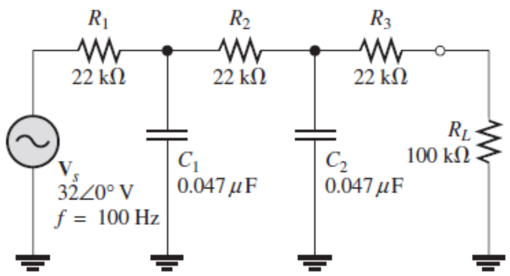
$$I = \frac{23.66 + j5}{203.85 - j19.23} = 0.11 + j0.035\ mA$$

$$Z_N = (203.85 - j19.23)\Omega$$

$$I_N = 0.11 + j0.035\ mA$$



12. Aplique el teorema de Norton y determine la corriente a través del resistor de carga *RL* en la figura 19-50.



▲ FIGURA 19–50

$$X_C = \frac{1}{2\pi * 100 * 0.047} = 33862.8\ \Omega$$

$$G = \frac{1}{22} = 45\mu S$$

$$B_C = \frac{1}{33862.8} = 30\mu S$$

$$Y = 54.08\angle 33.69°\ \mu S$$

$$Z = \frac{1}{54.08\angle 33.69°} = 15.39 - j10.25\ k\Omega$$

$$Z_T = 2 * (15.39 - j10.25) + (22 + j0) = 52.78 - 20.5j\ k\Omega$$

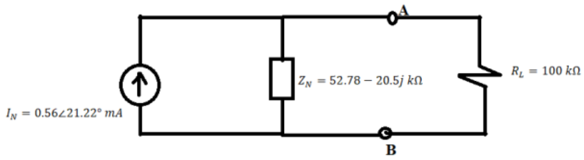
$$I = \frac{32\angle 0°}{56.62\angle - 21.22°} = 0.56\angle 21.22°\ mA$$

$$I_{RL} = \left(\frac{52.78 - j20.5}{(52.78 - j20.5) + (100 + j0)}\right) * (0.56\angle 21.22°) = 0.20\angle 7.45°\ mA$$

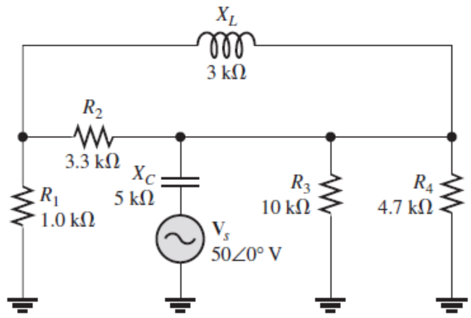
$$R_L = 100\ k\Omega$$

$$I_N = 0.56\angle 21.22°\ mA$$

$$Z_N = 52.78 - 20.5j\ k\Omega$$



* **13.** Aplique el teorema de Norton para determinar el voltaje en R_4 en la figura 19-51.



▲ FIGURA 19–51

$$R_{eq1} = R_1 \parallel R_2 = \frac{1 * 3.3}{1 + 3.3} = 0.767\ k\Omega$$

$$R_{eq2} = R_{eq1} \parallel R_3 = \frac{10 * 0.767}{10 + 0.767} = 0.712\ k\Omega$$

$$B_C = \frac{1}{5} = 0.2\ mS$$

$$B_C = \frac{1}{0.712} = 1.4\ mS$$

$$Y = 1.4 + j0.2\ mS$$

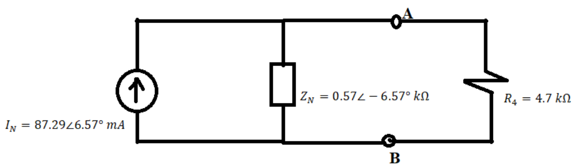
$$Z = \frac{1}{1.4 + j0.2} = 0.7 - j0.1\ k\Omega$$

$$Z_T = \frac{(0.7 - j0.1) * (3 + j0)}{(0.7 - j0.1) + (3 + j0)} = 0.569 - 0.0656j\ k\Omega$$

$$Z_N = 0.57\angle - 6.57°\ k\Omega$$

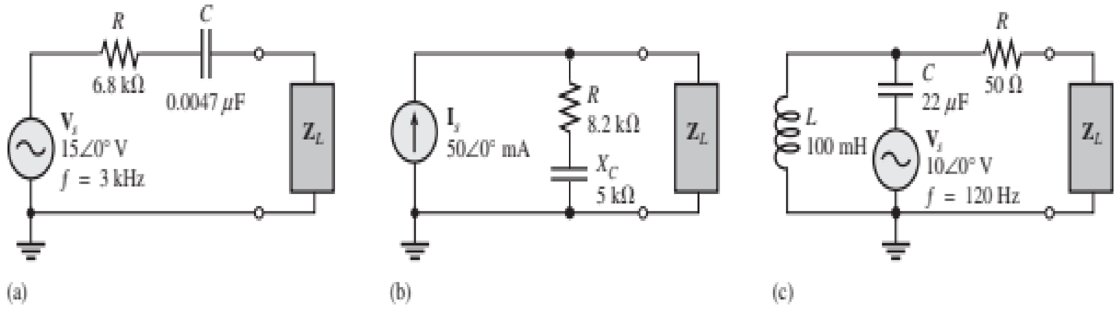
$$I_N = \frac{50\angle 0°}{0.57\angle - 6.57°} = 87.29\angle 6.57°\ mA$$

$$V_{R4} = (87.29\angle 6.57°) * (4.7\angle 0°) = 407.56 + j46.94\ V$$



SECCIÓN 19–4 Teorema de máxima transferencia de potencia

14. En cada circuito de la figura, se tiene que transferir potencia máxima a la carga RL. Determine el valor apropiado para la impedancia de carga en todos los casos.



a)

$$x_{c1} = \frac{1}{2\pi f c_1} = \frac{1}{2\pi(3\times10^3)(0.0047\times10^6)}$$

$$x_{c1} = 11.28\ k\Omega$$

$$x_{c1} = 11.28\ < \ -90°\ k\Omega$$

$$R_1 = 6.8\ < 0°\ k\Omega$$

Circuito en serie

$$Z_{th} = x_{c1} + R_1 = 11.28\ < \ -90°\ k\Omega + 6.8\ < 0°\ k\Omega$$

$$Z_{th} = (6800 - 11280i)\Omega = 13171.11 < -58.91°\ \Omega$$

Máxima transferencia de potencia

Complejo conjugado

$$Z_{th} = 6800 - 11280i\ \Omega$$

$$Z_L = 6800 + 11280i\ \Omega$$

b)

Circuito en serie

$$Z_n = R + x_{c1} = 8.2 < 0°\ k\Omega + 5 < 90°\ \text{k}\Omega$$

$$Z_n = (8.2 - 5i)k\Omega$$

Máxima transferencia de potencia

Complejo conjugado

$$Z_n = Z_{th} = (8.2 - 5i)\text{k}\Omega$$

$$Z_L = (8.2 + 5i)k\Omega$$

c)

$$x_c = \frac{1}{2\pi fc} = \frac{1}{2\pi 120Hz220F}$$

$$x_c = 60.28\ \Omega$$

$$x_c = 60.28 < -90°\ \Omega$$

$$x_L = 2\pi fL = 2\pi \cdot 120 \cdot 100 \times 10^{-3}$$

$$x_L = 62.8\ k\Omega = 62.8 < 90°\ \Omega$$

$$R = 50\ \Omega = 50 < 0°\ \Omega$$

R esta en serie con el paralelo de $x_L||x_c$

$$x_L||x_c = \frac{62.8 < 90 \cdot 60.28 < -90}{62.8 < 90 + 60.28 < -90} = 1502.21 < -90°\ \Omega$$

$$R + x_L||x_c = 50 < 0°\ \Omega + 1502.21 < -90°\ \Omega$$

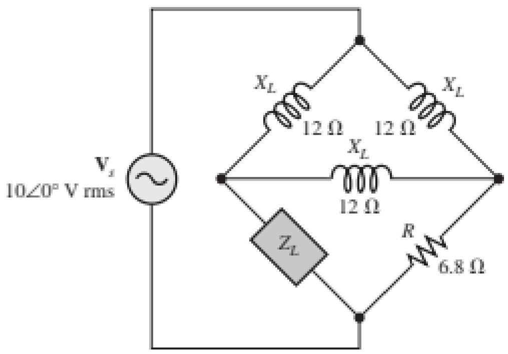
Máxima transferencia de potencia

Complejo conjugado

$$Z_{th} = 100 - 1502.21i$$

$$Z_L = 100 + 1502.21i$$

16. Determine la impedancia de carga requerida para transferir potencia máxima a Z_L en la figura. Determine la potencia real máxima.



Se apaga la fuente entonces

$$x_{L1} = 12\ \Omega = 12 < 90°\ \Omega$$

$$x_{L2} = 12\ \Omega = 12 < 90°\ \Omega$$

$$x_{L3} = 12\ \Omega = 12 < 90°\ \Omega$$

$$R_1 = 6.8\ \Omega = 6.8 < 0°\ \Omega$$

En serie,

$$x_{L1} + x_{L2} = 12 < 90°\ \Omega + 12 < 90°\ \Omega = 24 < 90°\ \Omega$$

$$x_A = x_{L1} + x_{L2}||x_{L3} = \frac{24 < 90°\ \Omega \cdot 12 < 90°\ \Omega}{24 < 90°\ \Omega + 12 < 90°\ \Omega} = 8 < 90°\ \Omega$$

En serie,

$$Z_{th} = x_A + R_1 = 8 < 90° + 6.8 < 0°\ \Omega = 13.6 + 8i$$

Máxima transferencia de Potencia

Complejo conjugado

$$Z_{th} = 13.6 + 8i = 15.77 < 30.46°$$

$$Z_L = 13.6 - 8i = 15.77 < -30.46°$$

$$Z_{tot} = \sqrt{(R_s + R_L)^2 + (x_L + x_c)}$$

$$Z_{tot} = \sqrt{(13.6 + 13.6)^2 + (8 + 8)}$$

$$Z_{tot} = 27.49$$

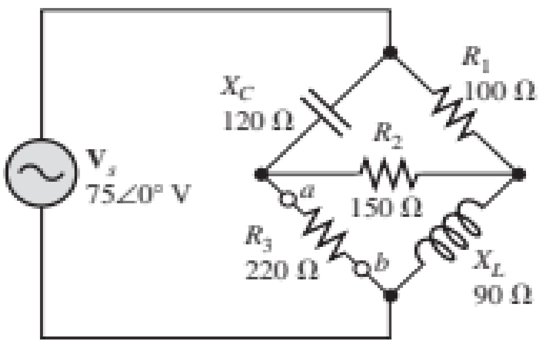
$$I = \frac{V_s}{Z_{tot}} = \frac{10}{27.49} = 0.3637$$

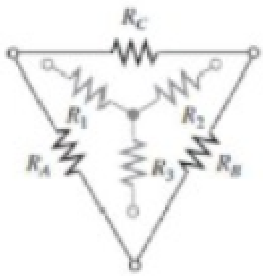
$$P_L = I^2 \cdot R_L$$

$$P_L = (0.3637)^2 \cdot 13.6$$

$$P_L = 1.8\ W$$

17. Se tiene que conectar una carga en el lugar de R2 en la figura para lograr transferencia de potencia máxima. Determine el tipo de carga y exprésela en forma rectangular.





$$Z_1 = \frac{R_3 R_3}{R_2 + R_3 + x_L} = \frac{220 \cdot 150}{150 + 220 + j90} = 84.20 - j20.4$$

$$Z_2 = \frac{R_2 x_L}{R_2 + R_3 + x_L} = \frac{150 \cdot j90}{150 + 220 + j90} = 8.37 + j34.4$$

$$Z_3 = \frac{R_3 x_L}{R_2 + R_3 + x_L} = \frac{220 \cdot j90}{150 + 220 + j90} = 12.28 + j50.52$$

$$Z_4 = Z_1 + x_c = 84.2 - j20.4 - j120 = 84.2 - j140.4$$

$$Z_5 = Z_2 + R_1 = 8.37 + j34.4 + 100 = 108.37 + j34.4$$

$$Z_6 = Z_4 || Z_5 = \frac{(84.2 - j140.4)(108.37 + j34.4)}{(84.2 - j140.4) + (108.37 + j34.4)} = 82.63 - j18.48$$

$$Z_L = Z_6 + Z_3 = (82.63 - j18.48) + (12.28 + j50.52)$$

$$\therefore Z_L = 94.91 + j32.04$$