CHAPTER 2 PROBLEMS

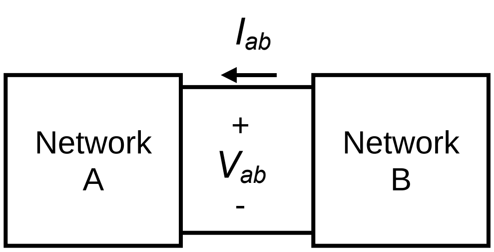
2.1 We observe that at a given point on a wire 6.242×10^{20} electrons flow past left to right in 20 seconds.
a. Find the current passing through the point.
b. The current flows from left to right or right to left?

> *a.* $Q = (6.242 \times 10^{20})(1.602\ 10^{-19}) = 100\ C$
> $I = Q / T = 100 / 20 = 5\ A$
> *b. current flows from right to left.*

2.2 Two large metal plates are charged so that the voltage between them is "V". We remove one electron from the top plate and force it to the bottom plate, a process that requires 0.001602 pJ.
a. Find "V".
b. Which plate is positive?

> *a.* $V = W / Q = (1.602 \times 10^{-15}) / (1.602\ 10^{-19}) = 1 \times 10^{4} = 10\ kV$
> *b. the top plate*

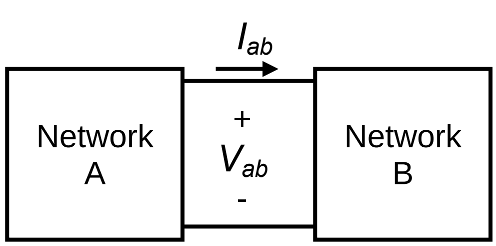
2.3 In the figure, Vab = -80 V and Network B ***absorbs*** *800 W.*
a. Find "I_{ab}".
b. Does Network A absorb or deliver power?



$$\boldsymbol{a}.\quad -\boldsymbol{I}_{ab} = \frac{800}{\boldsymbol{V}_{ab}} = \frac{800}{-80} = -10\ \boldsymbol{A};\quad \boldsymbol{I}_{ab} = 10\ \boldsymbol{A};$$

$\boldsymbol{b}.$ A delivers; B absorbs

2.4 In the figure, Vab = -80 V and Network B ***absorbs*** *800 W.*
a. Find "I_{ab}".
b. Does Network A absorb or deliver power?



$$a. \quad I_{ab} = \frac{800}{V_{ab}} = \frac{800}{-80} = -10\ A$$

b. A delivers; B absorbs

2.5 In Fig. 2.5, Vbd = 7 V; Vco = 13 V; Ido = 3 A; and Iao = -8 A.
a. How many nodes does the circuit have?
b. How many branches does the circuit have?
c. Find Idb.
d. Find Vao.
e. Find the power absorbed by each element.
f. Show the powers in (f) add to zero.

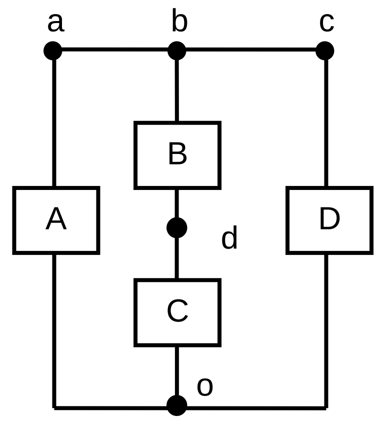


Fig. P2.5

a. 3 nodes *b. 4 branches*

c. Idb = -3A *d. Vao = Vco = 13 V*

e.
$P_A = V_{ao}I_{ao} = 13(-8) = -104\ W$
$P_B = V_{bd}I_{bd} = 7(3) = 21\ W$
$P_C = V_{do}I_{do} = 6(3) = 18\ W$
$P_D = V_{co}I_{co} = 13(5) = 65\ W$

f. $P_A + P_B + P_C + P_D = (-104) + (21) + (18) + (65) = 0$

2.6 In Fig. 2.6, suppose y(t) is the voltage across element X. Accurately sketch the current through if X is a….
a. 2 Ω resistor.
b. 2 H inductor.
c. 2 F capacitor.

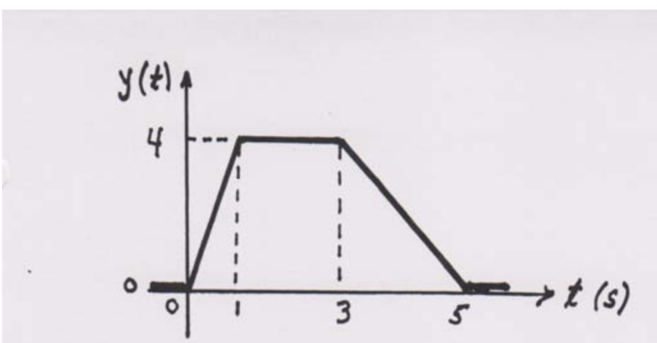
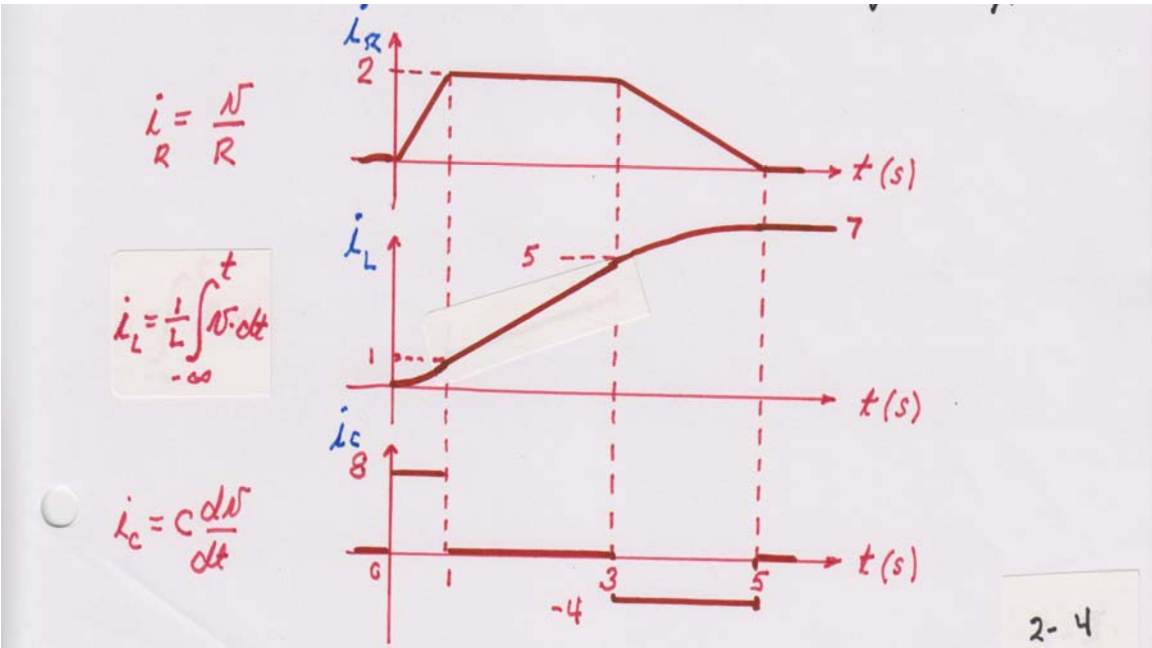


Fig. 2.6

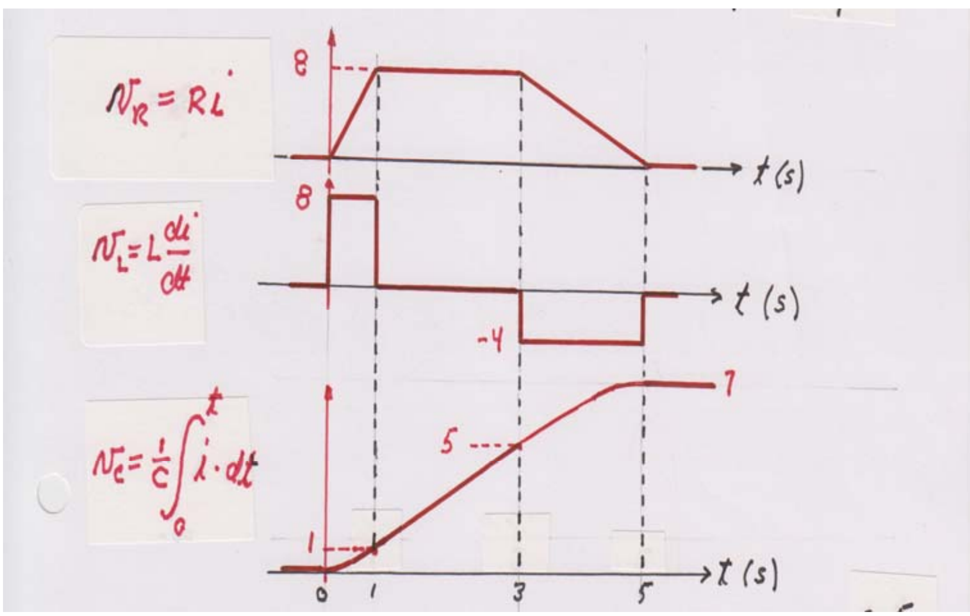


2.7 In Fig. 2.6, suppose y(t) is the current through element X. Accurately sketch the voltage through if X is a….

a. 2 Ω resistor.

b. 2 H inductor.

c. 2 F capacitor.



2.8 *a. Define "dc" in a circuits context.*
b. Prove that capacitors present open circuits to dc.
c. Prove that inductors present short circuits to dc.

a. "dc" when applied to voltages or currents means constant in time.

$$b.\quad i = C\frac{dv}{dt} = C\frac{d(\text{"constant"})}{dt} = 0 \quad (oc)$$

$$c.\quad v = L\frac{di}{dt} = L\frac{d(\text{"constant"})}{dt} = 0 \quad (sc)$$

2.9 *a. Define "ac" in a circuits context.*
b. Find the current through a 26.525 mH inductor if v(t) = 169.7cos(377t)
c. Find the current through a 0.26525 mF capcitor if v(t) = 169.7cos(377t)

a. "ac" when applied to voltages or currents means time variation is sinusoidal.

$$b.\quad i = \frac{1}{L}\int v(t)\cdot dt = \frac{1}{0.26525}\int (169.7\cos(377t))\cdot dt = +16.97\sin(377t)$$

$$c.\quad i = C\frac{dv}{dt} = (0.00026525)\frac{d(169.7\cos(377t))}{dt} = -16.97\sin(377t)$$

2.10. In Fig. P2.10, find all branch voltages and currents.

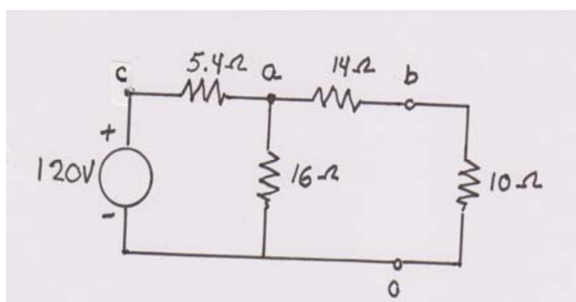


Fig. P2.10

$$\text{Source current} = I_{oc} = \frac{120}{5.4 + \dfrac{16(14+10)}{16+(14+10)}} = 8\ A$$

$$V_{oc} = 120\,V \qquad I_{oc} = 8\ A = I_{ca}$$

$$V_{ca} = (5.4)I_{ca} = 43.2\,V \qquad V_{ao} = 120 - 43.2 = 76.8\,V$$

$$I_{ao} = \frac{V_{ao}}{16} = 4.8\ A \qquad I_{ao} = \frac{V_{ao}}{14+10} = 3.2\ A = I_{bo}$$

$$V_{ab} = 14I_{ab} = 44.8\,V \qquad V_{bo} = 10I_{bo} = 32\,V$$

2.11. Continuing Problem 2.10, find all branch powers. Show that Tellegen's theorem is satisfied.

$$\boldsymbol{P}_{ca} = \boldsymbol{V}_{ca} \cdot \boldsymbol{I}_{ca} = (43.2)(8) = 345.6\ \boldsymbol{W}$$
$$\boldsymbol{P}_{ab} = \boldsymbol{V}_{ab} \cdot \boldsymbol{I}_{ab} = (44.8)(3.2) = 143.36\ \boldsymbol{W}$$
$$\boldsymbol{P}_{ao} = \boldsymbol{V}_{ao} \cdot \boldsymbol{I}_{ao} = (76.8)(4.8) = 368.64\ \boldsymbol{W}$$
$$\boldsymbol{P}_{bo} = \boldsymbol{V}_{bo} \cdot \boldsymbol{I}_{bo} = (32)(3.2) = 102.4\ \boldsymbol{W}$$
$$\text{Total absorbed Power} = 960.00\ \boldsymbol{W}$$
$$\text{Total delivered Power} = \boldsymbol{V}_{co} \cdot \boldsymbol{I}_{oc} = (120)(8) = 960.00\ \boldsymbol{W}$$
$$\text{Tellegen's theorem is satisfied } (\boldsymbol{P}_{abs} = \boldsymbol{P}_{dev})$$

2.12. Refer to Fig. P2.10.
a. Reduce the left side of the circuit (looking left from port b-0) to its Thevenin equivalent.
b. Use the Thevenin equivalent to compute V_{bo} and I_{bo}

a. Disconnect the 10 Ω resistor at port b-o. Then

$$\boldsymbol{I}_{ca} = \frac{120}{5.4+16} = 5.6075\ \boldsymbol{A}$$
$$\boldsymbol{V}_{ca} = (5.4)\cdot \boldsymbol{I}_{ca} = 30.28\ \boldsymbol{V}$$
$$\boldsymbol{V}_{ao} = 120 - \boldsymbol{V}_{ca} = 89.72\ \boldsymbol{V}$$
$$\boldsymbol{V}_{bo} = \boldsymbol{V}_{ao} = 89.72\ \boldsymbol{V} \quad (\text{since } \boldsymbol{V}_{ab} = 0)$$
$$\text{Hence, } \boldsymbol{V}_T = \boldsymbol{V}_{bo} = 89.72\ \boldsymbol{V}$$

Looking into port b-o with the source set to zero:

$$\boldsymbol{R}_{bo} = 14 + \frac{5.4(16)}{5.4+16} = 18.0374\ \Omega = \boldsymbol{R}_T$$

b. Reconnect the 10 Ω resistor at port b-o. Then

$$\boldsymbol{I}_{bo} = \frac{89.72}{10+18.0374} = 3.2\ \boldsymbol{A}$$
$$\boldsymbol{V}_{bo} = 10 \cdot \boldsymbol{I}_{bo} = 32\ \boldsymbol{V}$$

which checks with results from Problem 2.10.

2.13 $\boldsymbol{v}(\boldsymbol{t}) = 650.54\cos(377\boldsymbol{t} - 20^0)\quad \boldsymbol{V}$

Find V_{MAX}, $\boldsymbol{f}, \boldsymbol{\omega}, \boldsymbol{\alpha}$, and $\boldsymbol{T}$.

$$\boldsymbol{V_{MAX}} = 650.54\,\boldsymbol{V} \qquad \boldsymbol{\omega} = 377\ \boldsymbol{rad}\ /\ \boldsymbol{s}$$

$$\boldsymbol{f} = \frac{\boldsymbol{\omega}}{2\boldsymbol{\pi}} = 60\ \boldsymbol{Hz} \qquad \boldsymbol{T} = \frac{1}{\boldsymbol{f}} = 16.67\ \boldsymbol{ms} \qquad \boldsymbol{\alpha} = -20^0$$

2.14 $\boldsymbol{v}(\boldsymbol{t}) = 650.54\cos(377\boldsymbol{t} - 20^0)$

a. Evaluate $V_{RMS} = \dfrac{V_{MAX}}{\sqrt{2}}$

b. Derive V_{RMS} from $\boldsymbol{V_{RMS}} = \sqrt{\dfrac{1}{\boldsymbol{T}}\displaystyle\int_{t_0}^{t_0+T} \boldsymbol{v}(\boldsymbol{t})^2 \cdot \boldsymbol{dt}}$

c. Evaluate the phasor $\bar{\boldsymbol{V}}$

a. $\boldsymbol{V_{RMS}} = \dfrac{650.54}{\sqrt{2}} = 460\,\boldsymbol{V}$

b. Let $\boldsymbol{\theta} = 377\boldsymbol{t} \quad \boldsymbol{\alpha} = -20^0 \quad \boldsymbol{\theta}_0 = 377\boldsymbol{t}_0 \quad \boldsymbol{V_{MAX}} = 650.54$

$$\hat{\boldsymbol{v}} = \boldsymbol{V_{MAX}}\cos(377\boldsymbol{t} - 20^0) = \boldsymbol{V_{MAX}}\cos(\boldsymbol{\theta} + \boldsymbol{\alpha})$$

$$\boldsymbol{V_{RMS}} = \sqrt{\frac{1}{\boldsymbol{T}}\int_{t_0}^{t_0+T} \boldsymbol{v}(\boldsymbol{t})^2 \cdot \boldsymbol{dt}} = \sqrt{\frac{1}{2\boldsymbol{\pi}}\int_{\theta_0}^{2\pi+\theta_0} \hat{\boldsymbol{v}}(\boldsymbol{\theta})^2 \cdot \boldsymbol{d\theta}}$$

$$\boldsymbol{V_{RMS}} = \boldsymbol{V_{MAX}}\sqrt{\frac{1}{2\boldsymbol{\pi}}\int_{\theta_0}^{2\pi+\theta_0} \cos^2(\boldsymbol{\theta} + \boldsymbol{\alpha}) \cdot \boldsymbol{d\theta}} = \boldsymbol{V_{MAX}}\sqrt{\frac{1}{2\boldsymbol{\pi}}\int_{\theta_0}^{2\pi+\theta_0} \left(\frac{1 + 2\cos\left(2(\boldsymbol{\theta} + \boldsymbol{\alpha})\right)}{2}\right) \cdot \boldsymbol{d\theta}}$$

$$\boldsymbol{V_{RMS}} = \boldsymbol{V_{MAX}}\sqrt{\frac{1}{2\boldsymbol{\pi}}\left\{\left.\frac{\boldsymbol{\theta}}{2}\right|_{\theta_0}^{2\pi+\theta_0} + \int_{\theta_0}^{2\pi+\theta_0} \cos\left(2(\boldsymbol{\theta} + \boldsymbol{\alpha})\right) \cdot \boldsymbol{d\theta}\right\}}$$

$$= \boldsymbol{V_{MAX}}\sqrt{\frac{1}{2\boldsymbol{\pi}}\left\{\boldsymbol{\pi} + \int_{\theta_0}^{2\pi+\theta_0} \cos\left(2(\boldsymbol{\theta} + \boldsymbol{\alpha})\right) \cdot \boldsymbol{d\theta}\right\}}$$

Now $\displaystyle\int_{\theta_0}^{2\pi+\theta_0} \cos\left(2(\boldsymbol{\theta} + \boldsymbol{\alpha})\right) \cdot \boldsymbol{d\theta} = \left.\frac{\sin\left(2(\boldsymbol{\theta} + \boldsymbol{\alpha})\right)}{2}\right|_{\theta_0}^{2\pi+\theta_0}$ Let $2\boldsymbol{\theta_o} + \boldsymbol{\alpha} = \boldsymbol{\beta}$

$$\int_{\theta_0}^{2\pi+\theta_0} \cos\left(2(\boldsymbol{\theta} + \boldsymbol{\alpha})\right) \cdot \boldsymbol{d\theta} = \frac{\sin\left(4\boldsymbol{\pi} + \boldsymbol{\beta}\right) - \sin\left(\boldsymbol{\beta}\right)}{2}$$

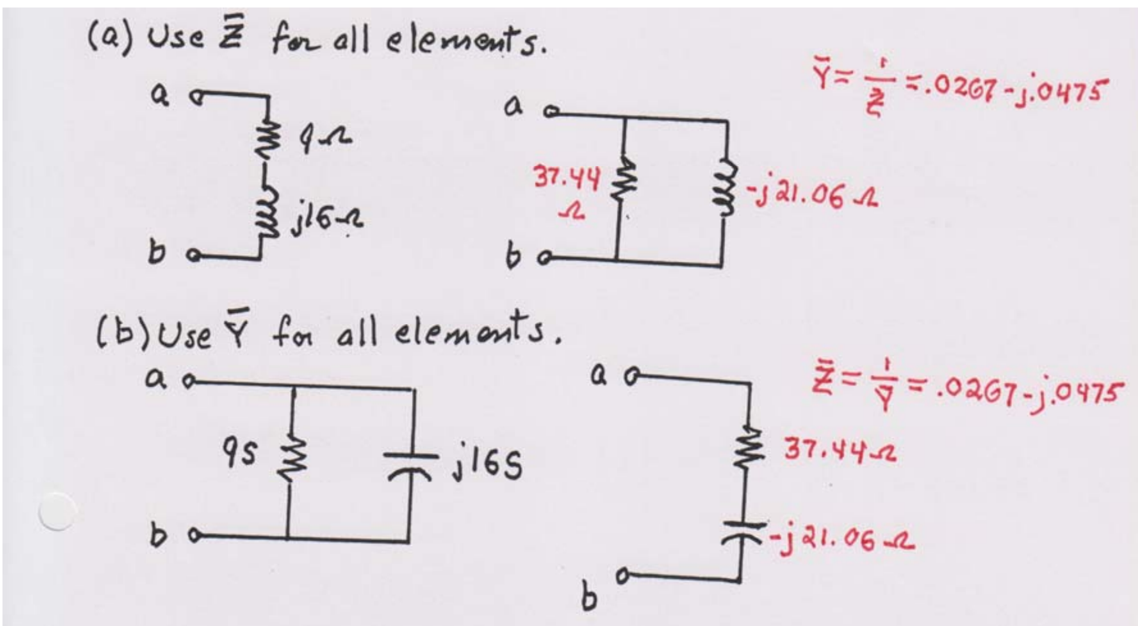
$$= \frac{\sin\left(4\boldsymbol{\pi}\right)\cos\left(\boldsymbol{\beta}\right) + \cos\left(4\boldsymbol{\pi}\right)\sin\left(\boldsymbol{\beta}\right) - \sin\left(\boldsymbol{\beta}\right)}{2} = \frac{0 + (1)\sin\left(\boldsymbol{\beta}\right) - \sin\left(\boldsymbol{\beta}\right)}{2} = 0$$

$\boldsymbol{V_{MAX}} = \boldsymbol{V_{MAX}}\sqrt{\dfrac{1}{2\boldsymbol{\pi}}\{\boldsymbol{\pi} + 0\}} = \dfrac{\boldsymbol{V_{MAX}}}{\sqrt{2}}$ **QED** **c.** $\bar{\boldsymbol{V}} = 460\angle -20^0\ \boldsymbol{V}$

2.15. *Complete the table for f = 1 kHz.*

	$\bar{Z}$ (Ω)	$\bar{Y}$ (mS)
100 Ω	100 + j0	10 + j0
31.83 mH	0 + j200	0 − j5
0.7958 μF	0 − j200	0 + j5

2.16. *Convert the circuits as indicated.*

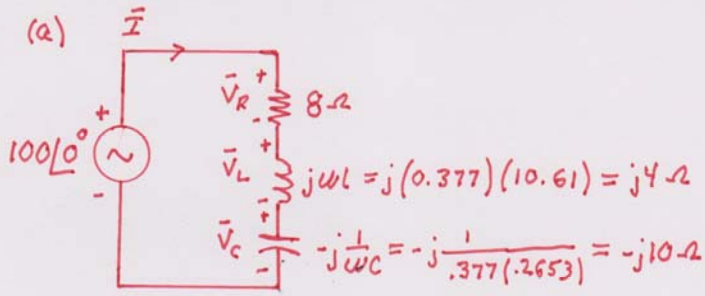


2.16. *Consider a series circuit identical to Fig. 2.11a, except that R = 8 Ω; L = 10.61 mH; and C = 0.2653 mF.*

a. Draw the ac circuit.

b. Solve for $\bar{I}$, $\bar{V}_R$, $\bar{V}_L$, and $\bar{V}_C$.

(a)



(b)

$$\bar{I} = \frac{100\angle 0^\circ}{8 + j4 - j10} = \frac{100\angle 0^\circ}{8 - j6} = 10\angle +36.9^\circ \text{ A}$$

$$\bar{V}_R = R\bar{I} = 80\angle +36.9^\circ \text{ V}$$

$$\bar{V}_L = \bar{Z}_L \bar{I} = j4(10\angle 36.9^\circ) = 40\angle 126.9^\circ \text{ V}$$

$$\bar{V}_C = \bar{Z}_C \bar{I} = -j10(10\angle 36.9^\circ) = 100\angle -53.1^\circ \text{ V}$$

2.17. Continuing Problem 2.16, determine the complex power absorbed by each element, and show that Tellegen's theorem is satisfied.

$$\bar{S}_R = \bar{V}_R \cdot \bar{I}^* = 80\angle 36.9^0 \left(10\angle 36.9^0\right)^* = 800 + j0$$

$$\bar{S}_L = \bar{V}_L \cdot \bar{I}^* = 40\angle 126.9^0 \left(10\angle 36.9^0\right)^* = 0 + j400$$

$$\bar{S}_c = \bar{V}_c \cdot \bar{I}^* = 100\angle -53.1^0 \left(10\angle 36.9^0\right)^* = 0 - j1000$$

$$\bar{S}_{LOAD} = \bar{S}_R + \bar{S}_L + \bar{S}_C = (800 + j0) + (0 + j400) + (0 - j1000)$$

$$\bar{S}_{LOAD} = 800 - j600$$

$$\bar{S}_{SOURCE} = \bar{V}_S \cdot \bar{I}^* = 100\angle 0^0 \left(10\angle 36.9^0\right)^* = 800 - j600$$

$$\bar{S}_{SOURCE} = \bar{S}_{LOAD}$$

Therefore Tellegen's theorem is satisfied.

2.18 There is a particularly important practical design situation that requires an understanding of ac circuits, complex power, and power factor. Utilities prefer that their customers operate at unity pf because this corresponds to maximum (real) delivered power at minimum current. To encourage maximum pf operation, the utility rate structure imposes a penalty for low pf operation. Hence, it is to a customer's advantage to "correct" their pf to near unity. This is called "the pf correction problem", and is presented here. A customer draws a single-phase load of 1000 kVA @ 7.2 kV; pf = 0.6 lagging. He wishes to install pf correcting capacitors as shown in Fig. P2.18 to correct the metered pf to 0.92 lagging. Size the capacitors.

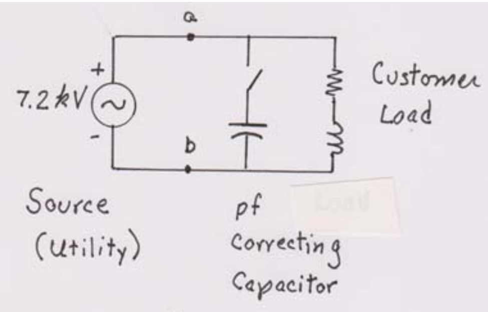


Fig. P2.18

$$\text{a. } S_{LOAD} = 1000\angle 53.1^0 = 600 + \boldsymbol{j}800$$
$$S_{SOURCE} = 1000\angle 53.1^0 = 600 + \boldsymbol{j}(800 - \boldsymbol{Q_C})$$
$$\boldsymbol{\theta} = \cos^{-1}(0.92) = 23.1^0$$
$$\boldsymbol{Tan}(\boldsymbol{\theta}) = 0.4260 = \frac{(800 - \boldsymbol{Q_C})}{600}$$
$$(800 - \boldsymbol{Q_C}) = 255.6 \quad \boldsymbol{Q_C} = 544.4\ \boldsymbol{k}\text{ var}$$

The pf correcting capacitor is rated at 544.4 kvar 7.2 kV

2.19 Repeat Problem 2.18 if the load is 3-phase 12.47 kV 1000 kVA pf = 0.6 lagging.

$$\text{a. } S_{LOAD} = 1000\angle 53.1^0 = 600 + \boldsymbol{j}800$$
$$S_{SOURCE} = 1000\angle 53.1^0 = 600 + \boldsymbol{j}(800 - \boldsymbol{Q_C})$$
$$\boldsymbol{\theta} = \cos^{-1}(0.92) = 23.1^0$$
$$\boldsymbol{Tan}(\boldsymbol{\theta}) = 0.4260 = \frac{(800 - \boldsymbol{Q_C})}{600}$$
$$(800 - \boldsymbol{Q_C}) = 255.6 \quad \boldsymbol{Q_C} = 544.4\ \boldsymbol{k}\text{ var}$$

Assuming a wye connection, the three pf correcting capacitors are each rated at 181.5 kvar 7.2 kV. If connected in delta, each should be rated at 181.5 kvar 12.47 kV.

2.20 Consider the waveform of Example 2.17.
a. What is the frequency of the 6^{th} harmonic?
b. From Table 2.2, write the expression for the 6^{th} harmonic
c. Compute the RMS value of the 6^{th} harmonic:

a. $f = 6f_0 = 600$ Hz; $\omega = 2\pi f = 3770$ rad/s

b. $\boldsymbol{v}_6(\boldsymbol{t}) = 20.19 \cdot \cos(3770\boldsymbol{t} - 108^0)$

c. $V_6 = 14.28$ V

2.21 *Consider a series circuit consisting of R = 10 Ω; L = 20 mH; C = 50 μF, and a source such that*

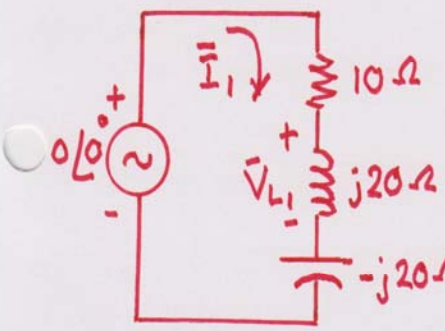
$$v(t) = 100\sqrt{2}\cdot\cos(\omega_0 t) + 30\sqrt{2}\cdot\cos(3\omega_0 t) \quad V$$

$$\text{where } \omega_0 = 1000\ rad/s$$

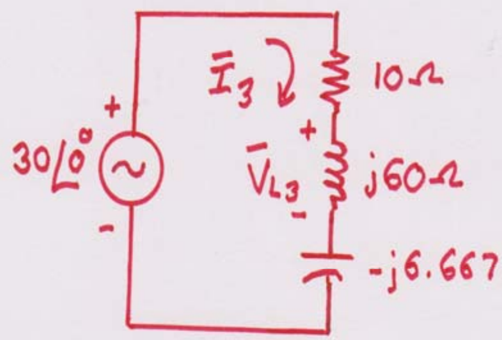
a. Draw the ac circuit at the fundamental frequency. Solve for the fundamental phasor inductor current and voltage.
b. Draw the ac circuit at the 3rd harmonic frequency. Solve for 3rd harmonic phasor inductor current and voltage.
c. Find the RMS inductor current and voltage.
d. Find the current $i(t)$
e. Find the average power delivered by the source.

$\boxed{\bar{V} = 100\angle 0^0 V}$

(a) Fundamental



(b) 3rd Harmonic



$$\bar{I}_1 = \frac{100\angle 0^\circ}{10 + j0} = 10\angle 0^\circ\ A \qquad \bar{I}_3 = \frac{30\angle 0^\circ}{10 + j53.33} = 0.5529\angle{-79.4^\circ}$$

$$\bar{V}_{L_1} = j20\,\bar{I}_1 = 200\angle 90^\circ \qquad \bar{V}_{L_3} = j60\,\bar{I}_3 = 33.17\angle 10.6^\circ$$

(c) $I = \sqrt{I_1^2 + I_3^2} = 10.02\ A \qquad V_L = \sqrt{V_{L_1}^2 + V_{L_3}^2} = 202.7\ V$

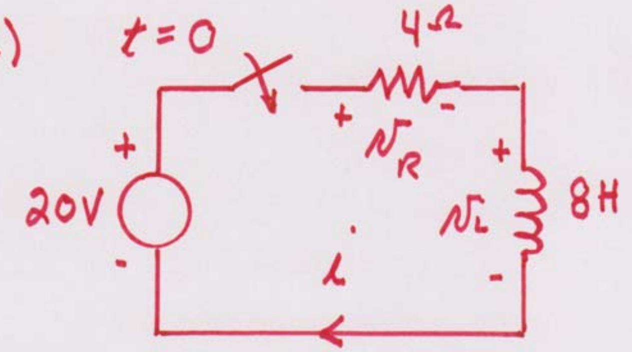
(d) $i = 10\sqrt{2}\cos(\omega_0 t) + .5529\sqrt{2}\cos(3\omega_0 t - 79.4^\circ)$

(e) $P = V_1 I_1 \cos\theta_1 + V_3 I_3 \cos\theta_3 = 100(10) + 30(.5529)\cos(79.4^\circ)$

$= 1003.05\ W$

2.22. a. Copy the RL circuit of Fig. 2.18a, using 20 V, 4 Ω, and 8 H for E, R, and L, respectively. Find the current and all voltages for t > 0, given that $i(0) = 0$.
b. Repeat (a) if $i(0) = -5\ A$.

(a)



$i(\infty) = \frac{20}{4} = 5A$

$\tau = \frac{L}{R} = \frac{8}{4} = 2s$

$i = 5\left(1 - e^{-t/2}\right)$

$v_R = 4 \cdot i = 20\left(1 - e^{-t/2}\right)$

$v_L = L\frac{di}{dt} = 8\left(0 + \frac{5}{2}e^{-t/2}\right) = 20\, e^{-t/2}$

Note: $v_R + v_L = 20V$

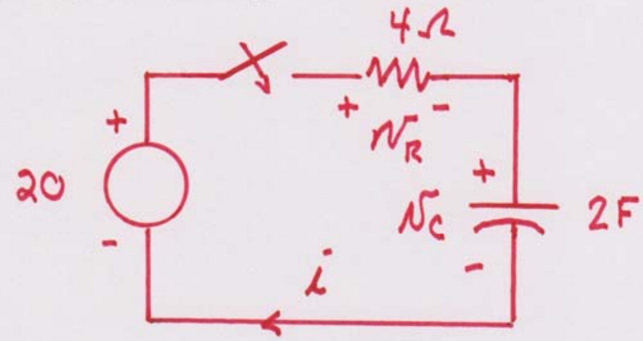
(b) $i(0) = -5\ A$: $i = 5\left(1 - 2e^{-t/2}\right)$

$v_R = 4 \cdot i = 20\left(1 - 2e^{-t/2}\right)$

$v_L = L\frac{di}{dt} = 8\left(0 - 5e^{-t/2}\right) = +40\, e^{-t/2}$

Note: $v_R + v_L = 20$

2.23. a. Copy the RC circuit of Fig. 2.18b, using 20 V, 4 Ω, and 2 F for E, R, and C, respectively. Find the current and all voltages for t > 0, given that $v_C(0) = 0$.
b. Repeat (a) if $v_C(0) = -10$ V.



(a) $v_C(\infty) = 20\text{V}$ $\quad \tau = R \cdot C = 8\text{s}$

$$v_C = 20(1 - e^{-t/8}) \qquad i = C\frac{dv_C}{dt} = 2\left(\frac{20}{8}\right)e^{-t/8}$$

$$v_R = R \cdot i = 20e^{-t/8}\ \text{V} \qquad = 5e^{-t/8}\ \text{A}$$

Note that $v_C + v_R = 20\text{V}$

(b) $$v_C = 20(1 - 1.5e^{-t/8}) \qquad i = C\frac{dv_C}{dt} = 2\left(\frac{-30}{-8}\right)e^{-t/8}$$

$$v_R = R \cdot i = 30e^{-t/8} \qquad = 7.5e^{-t/8}$$

2.24. It is argued that the current must be continuous through an inductor in the R-L case, and similarly the voltage must be continuous across a capacitor in the R-C case. Discuss the issue.

Assume a circuit with any number of R's and sources and one inductor. Use Thevenin's theorem at the inductor terminals to a series circuit consisting of a source, one R, and one L.

Recall for the inductor: $\boldsymbol{v = L \cdot \frac{di}{dt}}$

If the current is discontinuous and finite, at the point of discontinuity, the voltage must be infinite. But by KVL, this infinite voltage must be counterbalanced by a second infinite voltage (v_∞) of opposite polarity around the series loop. Observe that

v_∞ cannot appear across the source (by definition).

v_∞ cannot appear across the resistor because that would require infinite current (by Ohm's law). The current is already constrained to be finite.

Hence the current cannot be discontinuous.

Assume a circuit with any number of R's and sources and one capacitor. Use Thevenin's theorem at the inductor terminals to a series circuit consisting of a source, one R, and one C.

Recall for the capacitor: $\boldsymbol{i = C \cdot \frac{dv}{dt}}$

If the voltage is discontinuous and finite, at the point of discontinuity, the current must be infinite. But this infinite current would flow through the resistor, causing an infinite voltage by Ohm's law. But by KVL, this infinite voltage must be counterbalanced by a second infinite voltage (v_∞) of opposite polarity around the series loop. Observe that

v_∞ cannot appear across the source (by definition).

v_∞ cannot appear across the capacitor because this violates the original premise (the voltage is discontinuous; not infinite)

Hence the voltage cannot be discontinuous.

These arguments can be extended to the (almost) general case, with arbitrary numbers of R, L, C elements and sources..

There are some ideal situations where the rules fail, or at least must be modified. For example, consider a dc source (E) in series with an open switch and an uncharged capacitor. When the switch is closed, the capacitor voltage goes from zero to E in zero time, and hence is discontinuous. The current is a delta function $\delta(t)$ of weight Q = CE, which means the current was infinite (in the limit) for zero (in the limit) time. But note that this circuit had zero resistance! Physical circuits will always have some resistance (excluding the superconducting case).

2.25. Given Circuit in Fig. P2.25, element X is a 2 H inductor. If the switch is **closed** at t = 0, find and sketch i(t).

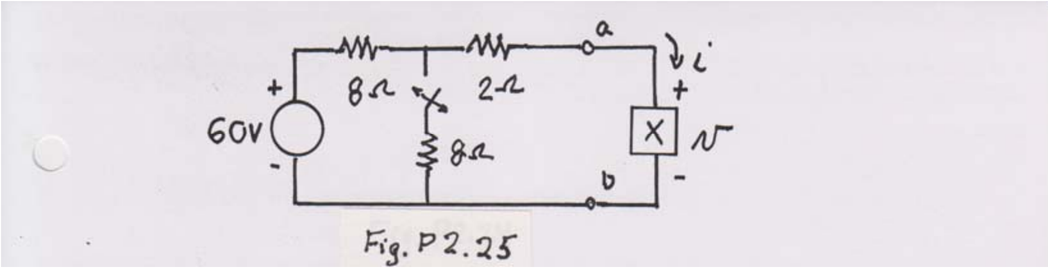
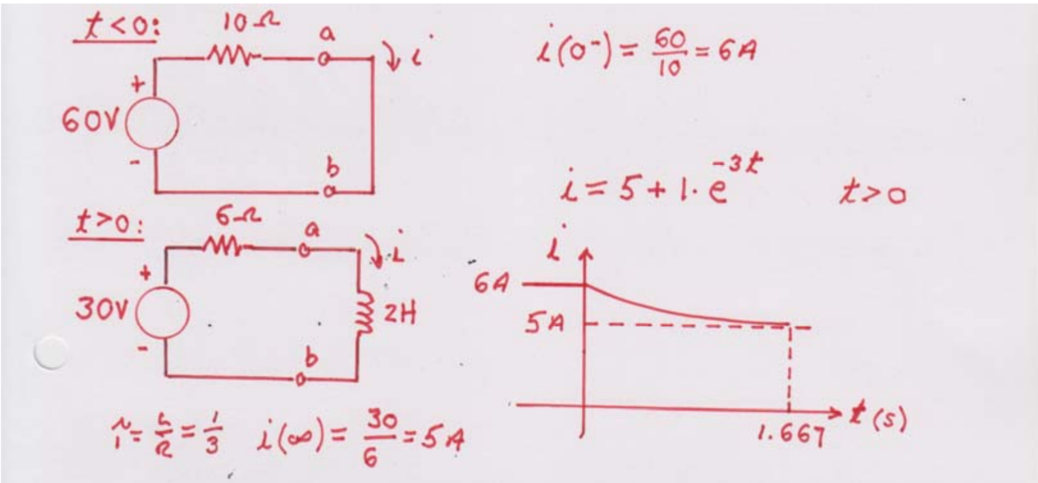
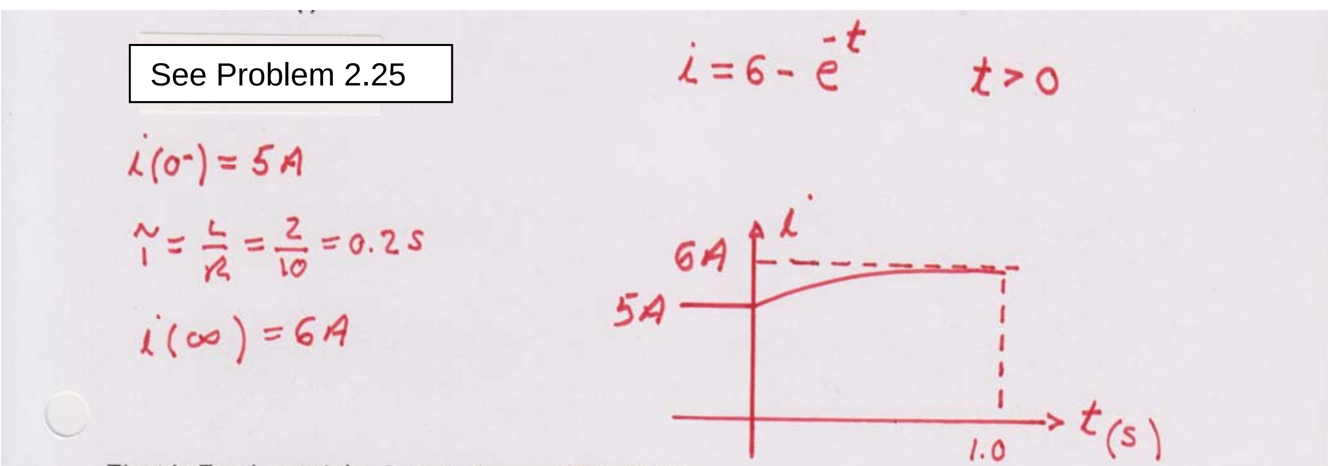


Fig. P2.25

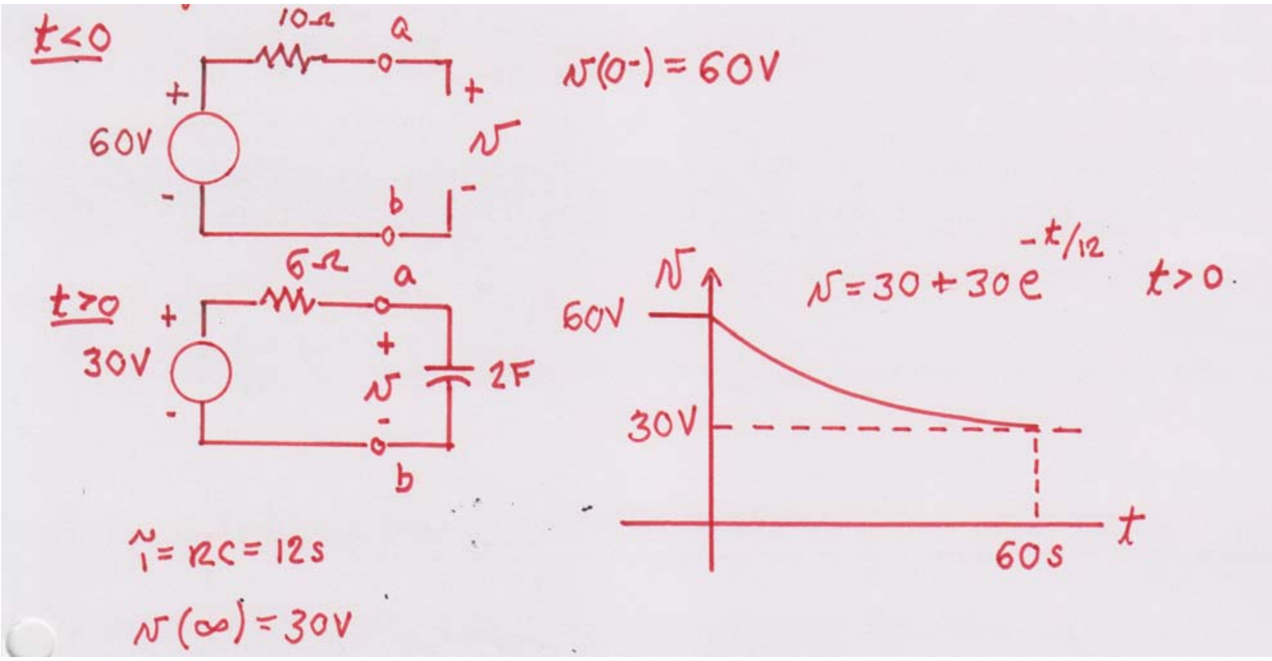


2.26. Given Circuit in Fig. P2.25, element X is a 2 H inductor. If the switch is **opened** at t = 0, find and sketch i(t).



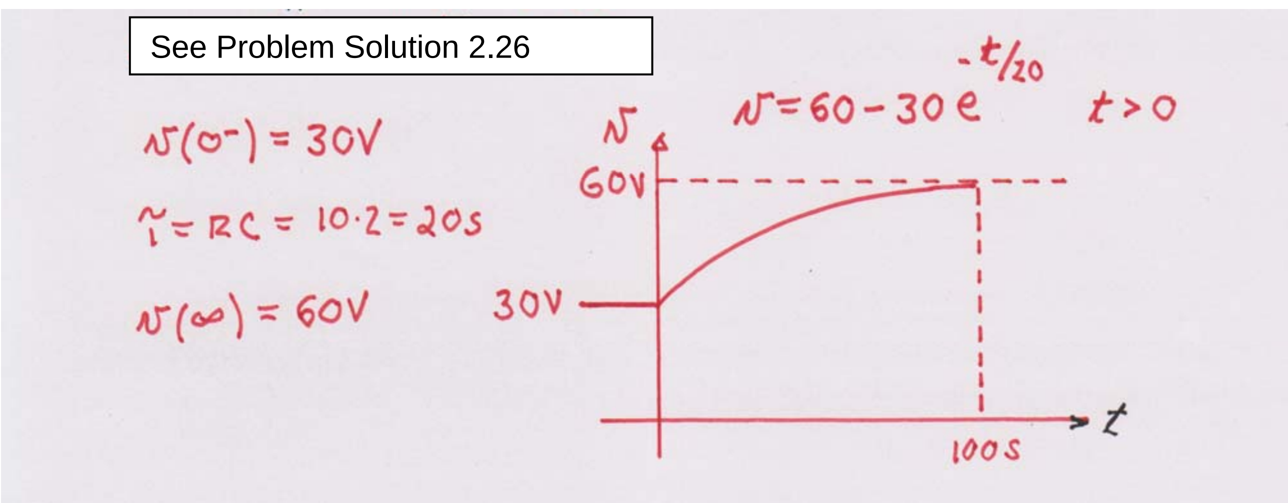
2.27. Given the circuit in Fig. P2.25, element X is a 0.5 F capacitor. If the switch is **closed** at t = 0, find and sketch v(t).

See Problem 2.25



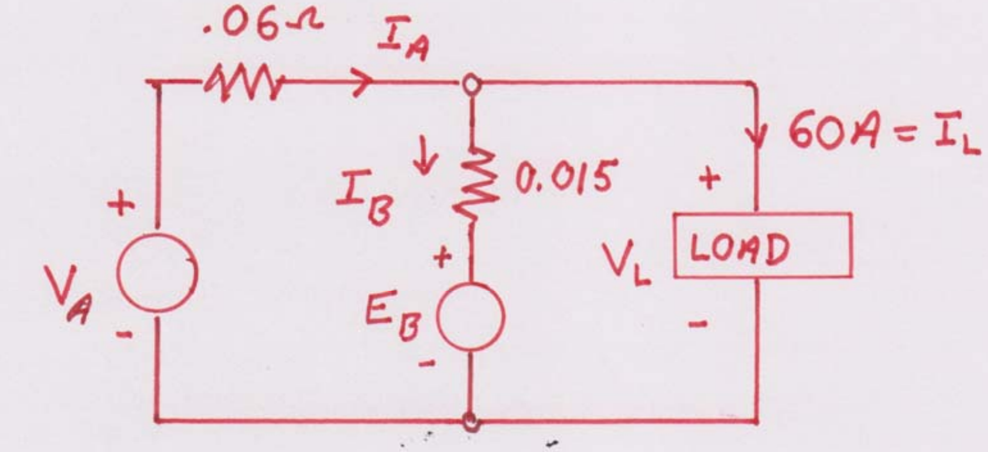
2.28. Given Circuit in Fig. P2.25, element X is a 0.5 F capacitor.. If the switch is **opened** at t = 0, find and sketch v(t).

See Problem Solution 2.26



2.29 Consider the automotive electrical system described in Section 2.8.

a. Re-draw the circuit of Fig. 2.22 (omitting irrelevant parts).
b. The car is running at 55 mph; the battery is at 90% charge; and the electrical system delivers a load current of 60 A. Find the system voltage, the alternator current and internal voltage, and the battery current and internal voltage.



@ 90% charge. $k_Q = 0.9$

$$E_B = 11.2 + 1.4(0.9) = 12.46$$

@ $I_B = 20A$

$$V_L = 12.46 + (.015)(20) = 12.76V$$

which is > 12.6 V (too high)

Hence $I_B = \dfrac{12.6 - 12.46}{.015} = 9.333\,A$

$$I_A = I_L + I_B = 69.33\,A$$

$$V_A = 12.6 + .06\,(69.33) = 16.76V$$

2.30 Consider a residential electrical system application, as discussed in Section 2.9. The loads are as follows:

AB	12 kVA @ pf = 0.8 lagging
AN	7 kVA @ pf = unity
BN	8 kVA @ pf = 0.9 leading

a. Draw an appropriate ac circuit to model the situation (two sources; three loads).
b. There are six phasor currents in the circuit of (a). Solve for all six.

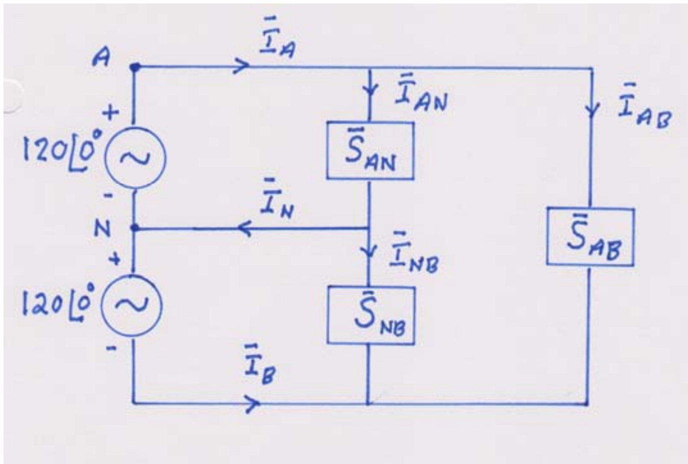


Fig. 2.26. Circuit Model

$$\bar{\boldsymbol{S}}_{AN} = 7\angle 0^0 = 7 + \boldsymbol{j}0$$
$$\bar{\boldsymbol{S}}_{BN} = 8\angle -25.8^0 = 7.2 - \boldsymbol{j}3.487$$
$$\bar{\boldsymbol{S}}_{AB} = 12\angle 36.9^0 = 9.6 + \boldsymbol{j}7.2$$
$$\bar{\boldsymbol{S}}_{AB} + \bar{\boldsymbol{S}}_{AN} + \bar{\boldsymbol{S}}_{BN} = 23.8 + \boldsymbol{j}3.713$$
$$\bar{\boldsymbol{I}}_{AB} = \left(\frac{\bar{\boldsymbol{S}}_{AB}}{\bar{\boldsymbol{V}}_{AB}}\right)^* = 50.0\angle -36.9^0 \ \boldsymbol{A}$$
$$\bar{\boldsymbol{I}}_{AN} = \left(\frac{\bar{\boldsymbol{S}}_{AN}}{\bar{\boldsymbol{V}}_{AN}}\right)^* = 58.3\angle 0.0^0 \ \boldsymbol{A}$$
$$\bar{\boldsymbol{I}}_{NB} = \left(\frac{\bar{\boldsymbol{S}}_{NB}}{\bar{\boldsymbol{V}}_{NB}}\right)^* = 66.7\angle 25.8^0 \ \boldsymbol{A}$$

$$\bar{\boldsymbol{I}}_{A} = \bar{\boldsymbol{I}}_{AB} + \bar{\boldsymbol{I}}_{AN} = 102.8\angle -17.0^0 \ \boldsymbol{A}$$
$$\bar{\boldsymbol{I}}_{B} = -\left(\bar{\boldsymbol{I}}_{BA} + \bar{\boldsymbol{I}}_{NB}\right) = 100.0\angle -0.5^0 \ \boldsymbol{A}$$
$$\bar{\boldsymbol{I}}_{N} = \bar{\boldsymbol{I}}_{AN} - \bar{\boldsymbol{I}}_{NB} = 29.1\angle 266.7^0 \ \boldsymbol{A}$$

	V (V)	P(kW)	Q(kvar)	I (A)
Load A-N	120	7.000	0.000	58.3 @ 0.0°
Load B-N	120	7.200	-3.487	66.7 @ 25.8°
Load A-B	240	9.600	7.200	50.0 @-36.9°
Winding N-A	120	11.800	3.600	102.8 @-17.0°
Winding B-N	120	12.000	0.113	100.0 @-0.5°
Neutral O-N	---	-----	-----	29.1 @ 266.7°
Winding a-b	7200	23.800	3.713	3.346 @-8.9°