9.3 At $t = -250/6\ \mu s$, a sinusoidal voltage is known to be zero and going positive. The voltage is next zero at $t = 1250/6\ \mu s$. It is also known that the voltage is 75 V at $t = 0$.

a) What is the frequency of v in hertz?

b) What is the expression for v?

9.20 a) Show that at a given frequency ω, the circuits in Fig. P9.19(a) and (b) will have the same impedance between the terminals a,b if

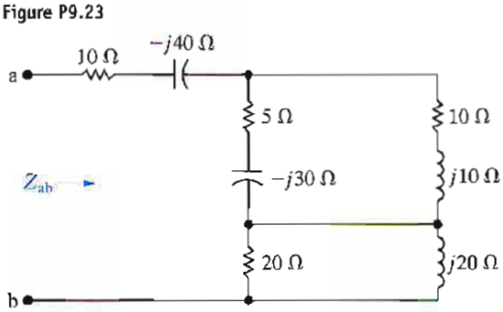
$$R_2 = \frac{R_1^2 + \omega^2 L_1^2}{R_1}, \qquad L_2 = \frac{R_1^2 + \omega^2 L_1^2}{\omega^2 L_1}.$$

(*Hint:* The two circuits will have the same impedance if they have the same admittance.)

b) Find the values of resistance and inductance that when connected in parallel will have the same impedance at 10 krad/s as a 5 kΩ resistor connected in series with a 500 mH inductor.

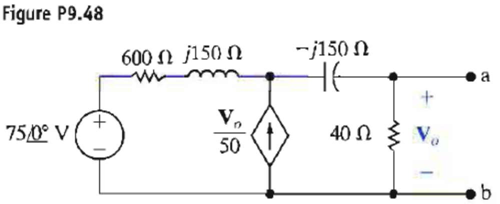
9.23 Find the impedance Z_{ab} in the circuit seen in Fig. P9.23. Express Z_{ab} in both polar and rectangular form.

Figure P9.23



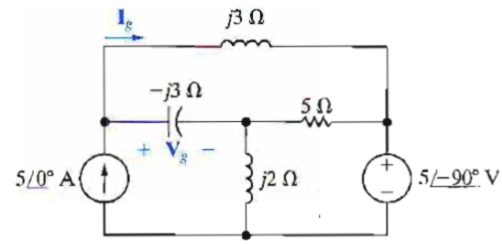
9.48 Find the Thévenin equivalent circuit with respect to the terminals a,b of the circuit shown in Fig. P9.48.

Figure P9.48



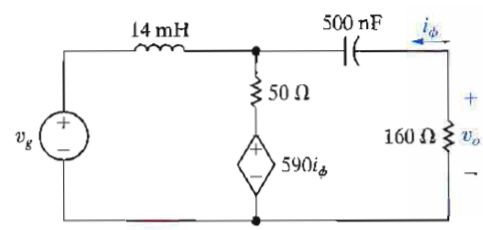
9.54 Use the node-voltage method to find the phasor voltage $\mathbf{V}_g$ in the circuit shown in Fig. P9.54.

Figure P9.54



9.61 PSPICE Use the mesh-current method to find the steady-state expression for v_o in the circuit seen in Fig. P9.61, if v_g equals $72 \cos 5000t$ V.

Figure P9.61

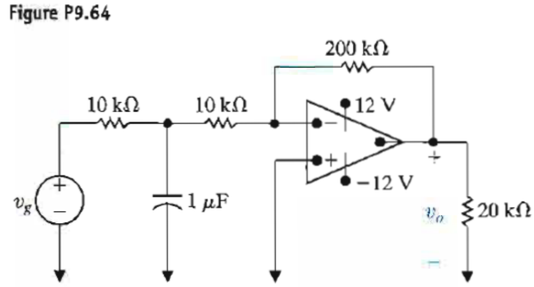


9.65 PSPICE The 1 μF capacitor in the circuit seen in Fig. P9.64 is replaced with a variable capacitor. The capacitor is adjusted until the output voltage leads the input voltage by 120°.

a) Find the values of C in microfarads.

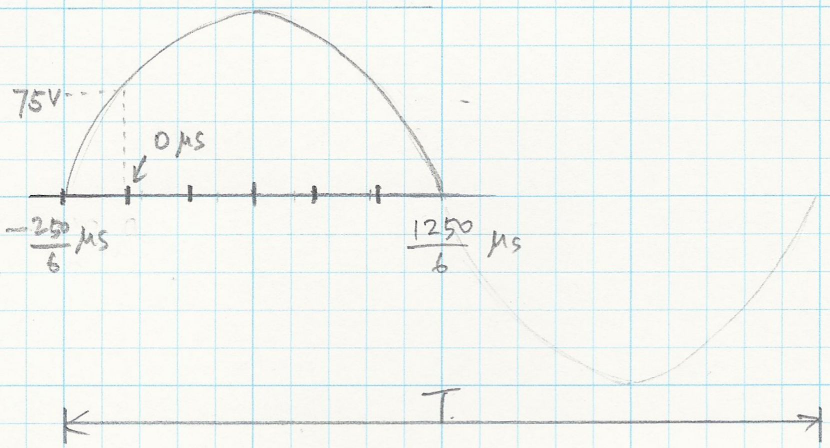
b) Write the steady-state expression for $v_o(t)$ when C has the value found in (a).

Figure P9.64



9.3.

(a).



$$\frac{T}{2} = \frac{1250}{6} + \frac{250}{6} = 250\,\mu s$$

$$T = 500\,\mu s$$

$$\therefore f = 1/T = 2000\ Hz$$

(b) for a sinusoidal waveform,

$$v = V_m \sin(\omega t + \theta)$$

$$\omega = 2\pi f = 4000\pi\ [rad/s]$$

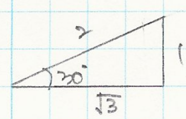
$$T : \frac{250}{6} = 360^\circ : \theta$$

$$\therefore \theta = \frac{250}{6} \times 360 \times \frac{1}{T} = 30^\circ$$

$$\rightarrow v = V_m \sin(4000\pi t + 30^\circ)$$

It is known that $v = 75\,V$ at $t = 0$.

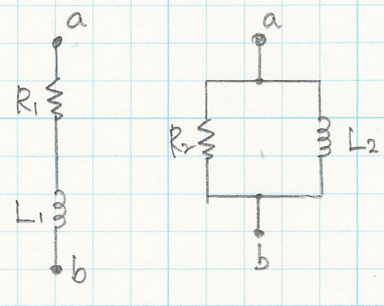
$$\therefore 75 = V_m \sin(30^\circ)$$
$$= V_m \cdot 1/2$$
$$\therefore V_m = 150\,V.$$



$$\rightarrow v = 150 \sin(4000\pi t + 30^\circ)$$

or $v = 150 \cos(4000\pi t - 60^\circ)$

9.20



(a) (b)

(a) for (a), the admittance

$$Y_a = \frac{1}{R_1 + Z_{L_1}} = \frac{1}{R_1 + j\omega L_1} = \frac{R_1 - j\omega L_1}{(R_1 + j\omega L_1)(R_1 - j\omega L_1)} = \frac{R_1 - j\omega L_1}{R_1^2 + \omega^2 L_1^2}$$

$$Y_b = \frac{1}{R_2} + \frac{1}{Z_{L_2}} = \frac{1}{R_2} + \frac{1}{j\omega L_2} = \frac{1}{R_2} - \frac{j}{\omega L_2}$$

By comparing Real & Imajinary parts of Y_a & Y_b

$Y_a = Y_b$ when

i) $\frac{1}{R_2} = \frac{R_1}{R_1^2 + \omega^2 L_1^2} \rightarrow R_2 = \frac{R_1^2 + \omega^2 L_1^2}{R_1}$

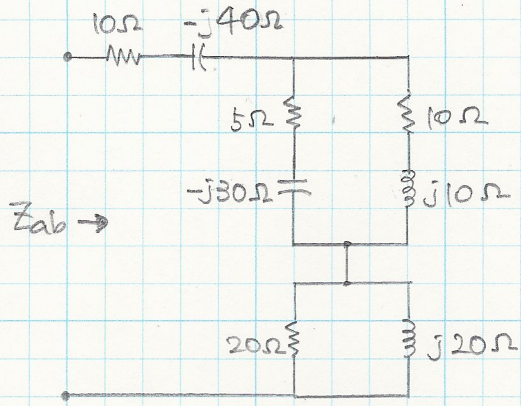
ii) $\frac{1}{\omega L_2} = \frac{\omega L_1}{R_1^2 + \omega^2 L_1^2} \rightarrow L_2 = \frac{R_1^2 + \omega^2 L_1^2}{\omega^2 L_1}$

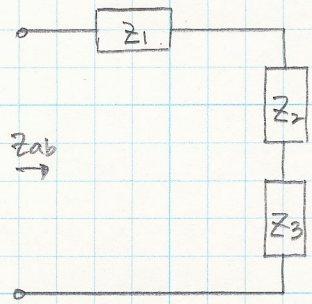
(b) $R_1 = 5k\Omega$, $L_1 = 500$ mH, $\omega = 10k$ rad/s $= 10^4$ rad/s.

$$R_2 = \frac{R_1^2 + \omega^2 L_1^2}{R_1} = \frac{(5\times10^3)^2 + (10^4 \times 500\times10^{-3})^2}{5\times10^3} = \underline{10\ k\Omega}.$$

$$L_2 = \frac{R_1^2 + \omega^2 L_1^2}{\omega^2 L_1} = \frac{(5\times10^3)^2 + (10^4\times500\times10^{-3})^2}{(10^4)^2\times 500\times10^{-3}} = \underline{1\ H}$$

9.23





$$Z_{ab} = Z_1 + Z_2 + Z_3$$

i) $Z_1 = 10 - j40\ \Omega$

ii) $Z_2 = (5 - j30) \mathbin{/\!/} (10 + j10)$

$$= \frac{(5-j30)(10+j10)}{(5-j30)+(10+j10)} = \frac{50 - j300 + j50 + 300}{15 - j20}$$

$$= \frac{350 - j250}{15 - j20} = \frac{(70 - j50)(3+j4)}{(3-j4)(3+j4)}$$

$$= \frac{210 - j150 + j280 + 200}{25}$$

$$= \frac{410 + j130}{25} = 16.4 + j5.2\ \Omega$$

iii) $Z_3 = (20) \mathbin{/\!/} (j20)$

$$= \frac{20 \times j20}{20 + j20} = \frac{j20}{1+j}$$

$$= \frac{j20(1-j)}{(1+j)(1-j)}$$

$$= \frac{20 + j20}{2} = 10 + j10\ \Omega$$

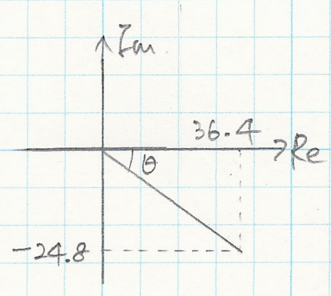
$\therefore\ Z_{ab} = Z_1 + Z_2 + Z_3$

$$= (10 - j40) + (16.4 + j5.2) + (10 + j10)$$

$$= 36.4 - j24.8$$

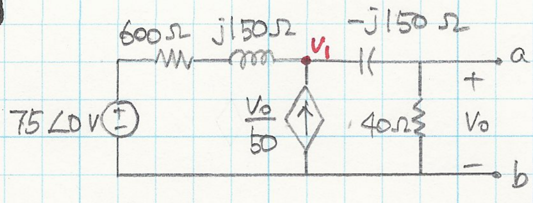
$$= \sqrt{36.4^2 + 24.8^2}\ \angle\theta$$

$$= 44.05\ \angle -34.27^\circ$$



$$\theta = \tan^{-1}(-24.8/36.4)$$
$$= -34.27^\circ$$

9.48



$$\rightarrow V_o = V_1 \cdot \frac{40}{40 - j150}$$

KCL at V_1 node

$$\frac{V_1 - 75}{600 + j150} - \frac{V_o}{50} + \frac{V_1}{40 - j150} = 0$$

$$\frac{V_1 - 75}{600 + j150} - \frac{4\cancel{0} V_1}{5\cancel{0}(40 - j150)} + \frac{V_1}{40 - j150} = 0$$

$$\frac{V_1 - 75}{600 + j150} + \frac{(-0.8 + 1.0) V_1}{40 - j150} = 0$$

$$\frac{V_1}{600 + j150} + \frac{0.2 V_1}{40 - j150} = \frac{75}{600 + j150}$$

$$\frac{V_1}{60 + j15} + \frac{V_1}{20 - j75} = \frac{5}{4 + j}$$

$$V_1(20 - j75) + V_1(60 + j15) = \frac{5}{\cancel{4+j}}\overset{15}{(\cancel{60+j15})}(20 - j75)$$

$$V_1(80 - j60) = 5 \times 15 (20 - j75)$$

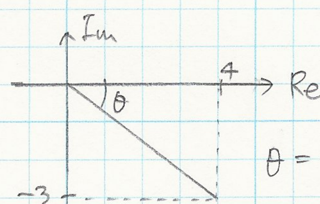
$$\therefore \quad V_1 = \frac{75(20 - j75)}{80 - j60} = \frac{75(4 - j15)}{16 - j12}$$

$$\rightarrow \quad V_{Th} = V_1 \cdot \frac{40}{40 - j150} = V_1 \cdot \frac{4}{4 - j15}$$

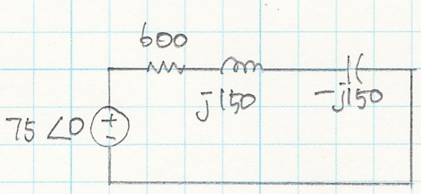
$$= \frac{75(4 - j15)}{16 - j12} \cdot \frac{4}{4 - j15} = \frac{75}{4 - j3}$$

$$= \frac{75 \angle 0^\circ}{\sqrt{4^2 + 3^2} \angle -36.87^\circ}$$

$$= 15 \angle 36.87^\circ$$

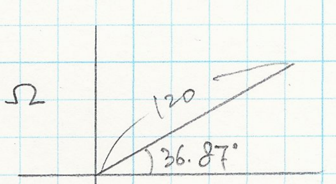


$$\theta = \tan^{-1}\left(\frac{-3}{4}\right) = -36.87^\circ$$



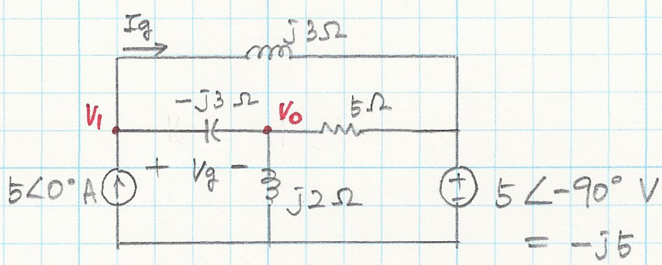
$$\downarrow I_{sc} = 75/600 = 0.125 \text{ A}$$

$$\therefore \quad Z_{Th} = \frac{V_{Th}}{I_{sc}} = \frac{15}{0.125} \angle 36.87^\circ = 120 \angle 36.87^\circ \ \Omega$$



$$\text{OR} \left(\begin{aligned} &= 120 \cdot \cos(36.87^\circ) + j\,120 \cdot \sin(36.87^\circ) \\ &= 96 + j\,72 \ \Omega \end{aligned} \right)$$

9.54



$= -j5$

i) at V_o node,

$$\frac{V_o}{j2} + \frac{V_o - (-j5)}{5} + \frac{V_o - V_1}{-j3} = 0$$

by multiplying 30

$$\frac{15V_o}{j} + 6(V_o + j5) + \frac{10(V_o - V_1)}{-j} = 0$$

$$-j15V_o + 6V_o + j30 + j10V_o - j10V_1 = 0$$

$$V_o(6 - j5) - j10V_1 = -j30 \quad \text{-----------} \ ①$$

ii) at V_1 node.

$$-5 + \frac{V_1 - V_o}{-j3} + \frac{V_1 - (-j5)}{j3} = 0$$

$$-j15 - (V_1 - V_o) + (V_1 + j5) = 0$$

$$-j10 + V_o = 0.$$

$$V_o = j10 \quad \text{-----------} \ ②$$

from ①, ② $\rightarrow$ $j10(6 - j5) - j10V_1 = -j30$

$$60 - j50 - 10V_1 = -30$$

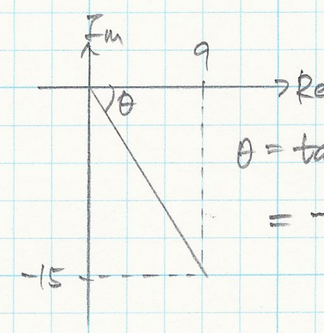
$$\therefore V_1 = 9 - j5.$$

$\rightarrow V_g = V_1 - V_o$

$$= (9 - j5) - (j10) = 9 - j15$$

$$= \sqrt{9^2 + 15^2}\ \angle\theta$$

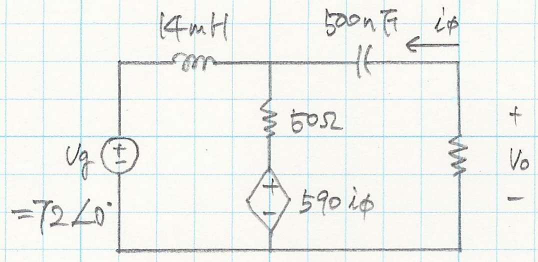
$$= 17.49\ \angle -59.04^\circ.$$



$$\theta = \tan^{-1}(-15/9)$$

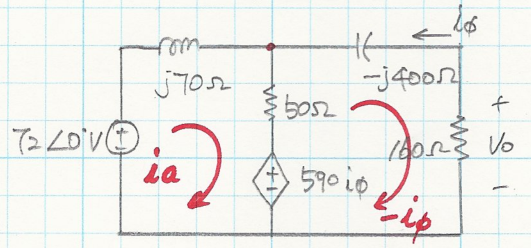
$$= -59.04^\circ$$

9.61



$V_g = 72 \cos 5000t$

↳ Let $V_g = 72\angle 0°$ V



$Z_L = j\omega L = j(5000 \times 14 \times 10^{-3}) = j70\ \Omega$

$Z_c = 1/j\omega C = -j/(5000 \times 500 \times 10^{-9}) = -j400\ \Omega$

i)
$$72 = j70\, i_a + 50\{i_a - (-i_\phi)\} + 590\, i_\phi$$
$$= j70\, i_a + 50(i_a + i_\phi) + 590\, i_\phi$$
$$72 = i_a(50 + j70) + i_\phi(640) \quad \text{------------- ①}$$

ii)
$$590\, i_\phi = 50(-i_\phi - i_a) - i_\phi(160 - j400)$$
$$0 = i_a(-50) + i_\phi(-590 - 50 - 160 + j400)$$
$$= i_a(-50) + i_\phi(-800 + j400)$$
$$i_a = i_\phi\left(\frac{-800 + j400}{50}\right) = i_\phi(-16 + j8) \quad \text{------- ②}$$

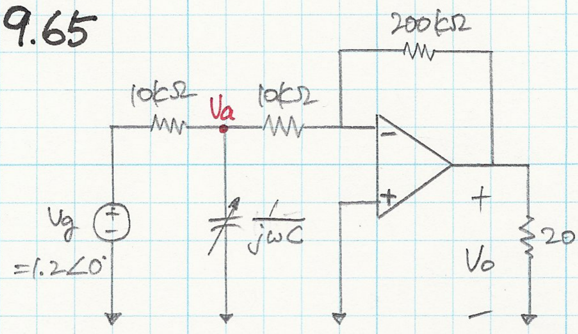
Solving ①, ②

$$72 = i_\phi(-16 + j8)(50 + j70) + i_\phi(640)$$
$$= i_\phi(-800 + j400 - j1120 - 560 + 640)$$
$$= i_\phi(-720 - j720)$$
$$\therefore i_\phi = \frac{-72}{720 + j720} = \frac{-1}{10 + j10}$$
$$= \frac{-(10 - j10)}{(10 + j10)(10 - j10)} = \frac{-10 + j10}{200}$$
$$= (-50 + j50)\ mA.$$

$$\therefore V_o = -i_\phi \cdot 160 = (50 - j50) \times 10^{-3} \times 160$$
$$= 8 - j8 = \sqrt{8^2 + 8^2}\ \angle{-45°} = 11.31\angle{-45°}$$

$$\therefore v_o = 11.31 \cos(5000t - 45°)$$

9.65



The capacitor is adjusted until the output voltage leads the input voltage by 120°.

$V_g = 1.2 \cos 100t$

$(V_g = 1.2\angle 0^\circ)$

(a)

ideal op-amp $V(-) = V(+)$

$\therefore V(-) = 0.$ (GND)

at Va node.

$$\frac{V_a - 1.2}{10000} + \frac{V_a}{1/j\omega C} + \frac{V_a}{10000} = 0.$$

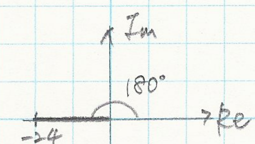
$$V_a\left(\frac{2}{10000} + j\omega C\right) = \frac{1.2}{10000}$$

$$\therefore V_a = \frac{1.2/10000}{2/10000 + j\omega C} = \frac{1.2}{2 + j\omega C \times 10^4} \quad \text{------ ①}$$

$$\frac{V_a}{10} = \frac{0 - V_o}{200} \rightarrow V_o = -20 V_a. \quad \text{------ ②}$$

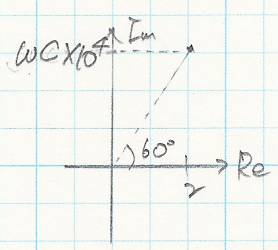
from ①, ② $V_o = -20 \cdot V_a$

$$= \frac{-20 \times 1.2}{2 + j\omega C \times 10^4} = \frac{-24}{2 + j\omega C \times 10^4}$$



$$= \frac{24\angle 180^\circ}{2 + j\omega C \times 10^4}$$

V_o leads V_a by 120°. ⟹ Denominator angle = 60°



$$\therefore \tan 60^\circ = \sqrt{3} = \frac{\omega C \times 10^4}{2}$$

$$\omega C \times 10^4 = \sqrt{3} \times 2 \qquad (\omega = 100)$$

$$\therefore C = \frac{2\sqrt{3}}{100 \times 10^4} = 3.46\ \mu F$$

(b) $$V_o = \frac{24\angle 180^\circ}{2 + j2\sqrt{3}} = \frac{24\angle 180^\circ}{\sqrt{2^2 + (2\sqrt{3})^2}\angle 60^\circ} = 6\angle 120^\circ$$

$$\therefore v_o = 6\cos(100t + 120^\circ)$$