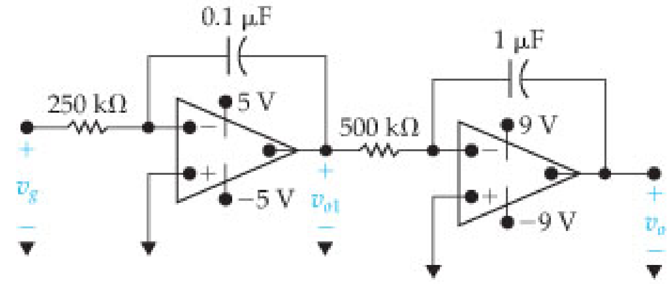
Problem 8.60 PSpice|Multisim

No energy is stored in the circuit shown in the figure when the input voltage v_g jumps instantaneously from 0 to 25 mV. The initial values of voltage are $v_{o1}(0) = 5\ \mathrm{V}$ and $v_o(0) = 8\ \mathrm{V}$.



Part A

Find the equation for $v_o(t)$ for $0 \le t \le t_{\mathrm{sat}}$

Express your answer in terms of t, where t is in seconds.

ANSWER:

v_o = V

Part B

How long does the circuit take to reach saturation?

Express your answer with the appropriate units.

ANSWER:

t =

Problem 9.3

Consider the sinusoidal voltage
$v(t) = 35 \cos\left(400\pi t + 60^\circ\right)$ V.

Part A

What is the maximum amplitude of the voltage?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

v_{max} =

Part B

What is the frequency in hertz?

Express your answer using three significant figures.

ANSWER:

f = Hz

Part C

What is the frequency in radians per second?

Express your answer using three significant figures.

ANSWER:

ω = rad/s

Part D

What is the phase angle in radians?

Express your answer using three significant figures.

ANSWER:

θ = rad

Part E

What is the phase angle in degrees?

Express your answer using three significant figures.

ANSWER:

θ = $^{\circ}$

Part F

What is the period?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

T =

Part G

What is the first time after $t = 0$ that $v = 0\ \mathrm{V}$?

Express your answer to three significant figures and include the appropriate units.

ANSWER:

t =

Part H

The sinusoidal function is shifted $5/6\ \mathrm{ms}$ to the right along the time axis. What is the expression for $v(t)$?

ANSWER:

- $35\cos(400\pi t + 2\pi/3)\ \mathrm{V}$
- $35\sin(400\pi t + 2\pi/3)\ \mathrm{V}$
- $35\cos(400\pi t)\ \mathrm{V}$
- $35\sin(400\pi t)\ \mathrm{V}$

Part I

What is the minimum value of milliseconds that the function must be shifted to the left if the expression for v(t) is $35\sin(400\pi t)\ \mathrm{V}$?

Express your answer using three significant figures.

ANSWER:

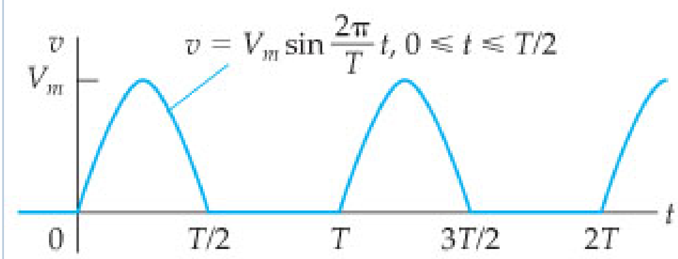
$t =$ ms

Problem 9.7

Part A

Find the rms value of the half-wave rectified sinusoidal voltage shown in the figure.

Express your answer in terms of V_m.



ANSWER:

V_{rms} = V

Problem 9.11

Select the correct expression for combination the following sinusoidal functions into a single trigonometric expression:

Part A

$y = 30\cos(200t - 160^\circ) + 15\cos(200t + 70^\circ)$.

ANSWER:

- $y = -23.4\cos(200t - 171^\circ)$
- $y = 23.4\cos(200t + 171^\circ)$
- $y = 0$
- $y = -23.4\cos(200t + 171^\circ)$
- $y = 23.4\cos(200t - 171^\circ)$

Part B

$y = 90\sin(50t - 20^\circ) + 60\cos(50t - 70^\circ)$.

ANSWER:

- $y = 0$
- $y = -141.3\cos(50t + 94.2^\circ)$
- $y = 141.3\cos(50t - 94.2^\circ)$
- $y = -141.3\cos(50t - 94.2^\circ)$
- $y = 141.3\cos(50t + 94.2^\circ)$

Part C

$y = 50\cos(5000t - 60^\circ) + 25\sin(5000t + 110^\circ) - 75\cos(5000t - 30^\circ)$.

ANSWER:

- $y = 0$
- $y = 16.7\cos(5000t - 171^\circ)$
- $y = -16.7\cos(5000t - 171^\circ)$
- $y = 16.7\cos(5000t + 171^\circ)$
- $y = -16.7\cos(5000t + 171^\circ)$

Part D

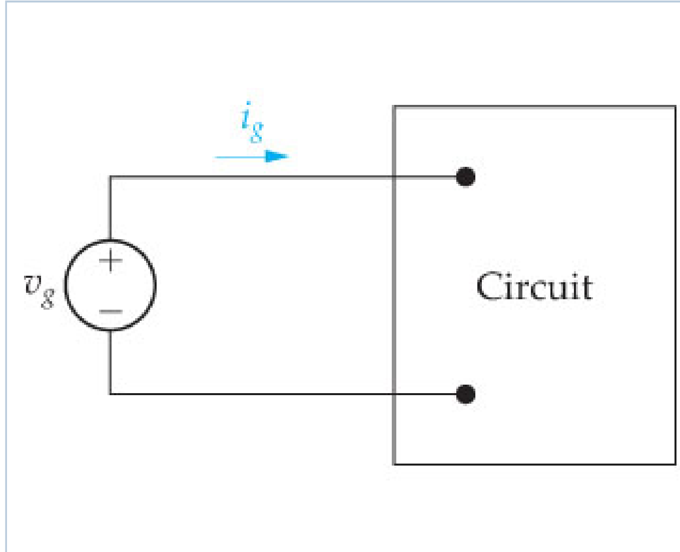
$y = 10\cos(\omega t + 30^\circ) + 10\sin\omega t + 10\cos(\omega t + 150^\circ)$.

ANSWER:

- $y = -10\cos(\omega t + 153^\circ)$
- $y = 10\cos(\omega t - 153^\circ)$
- $y = 0$
- $y = -10\cos(\omega t - 153^\circ)$
- $y = 10\cos(\omega t + 153^\circ)$

Problem 9.14

The expressions for the steady-state voltage and current at the terminals of the circuit seen in the figure are
$v_g = 310\cos(5000\pi t + 75^\circ)$ V,
$i_g = 4\sin(5000\pi t + 106^\circ)$ A



Part A

What is the impedance seen by the source?

Enter your answer using polar notation. Express argument in degrees.

ANSWER:

Z = Ω

Part B

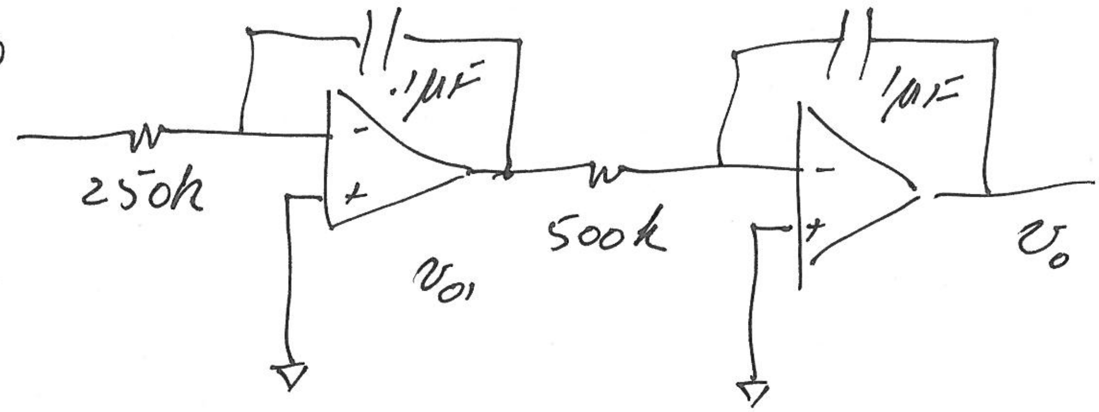
By how many microseconds is the current out of phase with the voltage?

Express your answer with the appropriate units.

ANSWER:

t =

8.60



$$v_g = \begin{cases} 0 ; & t < 0 \\ 25\,mV ; & t > 0 \end{cases} \qquad \begin{aligned} v_{01}(0) &= 5V \\ v_o(0) &= 8V \end{aligned}$$

1ST STAGE NODAL $\quad \dfrac{v_n - v_g}{250k} + 0.1\mu F \dfrac{d}{dt}(v_n - v_{01}) = 0$

$$v_p = v_n = 0$$

$$\Rightarrow \frac{dv_{01}}{dt} = -\frac{v_g}{250k\Omega \times 0.1\mu F} = -40 v_g \quad (1)$$

SIMILARLY, $\quad \dfrac{dv_o}{dt} = \dfrac{-v_{01}}{500k\Omega \times 1\mu F} = -2 v_{01} \quad (2)$

DIFFERENTIATE EQ (2) : $\quad \dfrac{d^2 v_o}{dt^2} = -2 \dfrac{dv_{01}}{dt} \quad (3)$

SUB EQ (1) INTO EQ (3) :

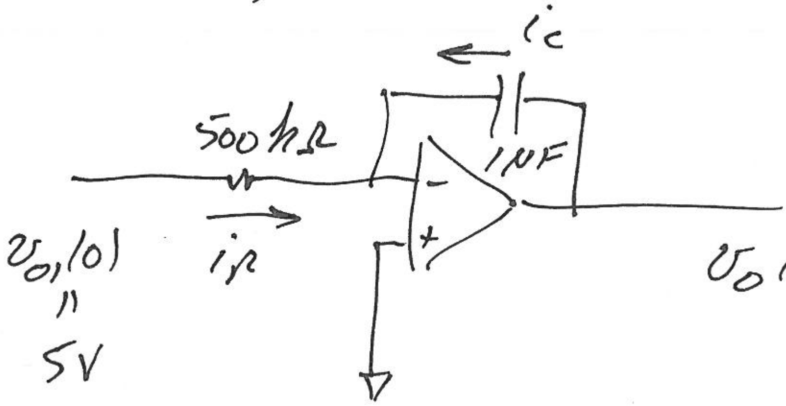
$$\frac{d^2 v_o}{dt^2} = 80 v_g(t) = 2 \quad \text{FOR } t > 0$$

INTEGRATE: $\frac{dv_0}{dt} = 2t + K_1$

INTEGRATE: $v_0(t) = t^2 + K_1 t + K_2$

APPLY INITIAL COND: $v_0(0) = 8 \Rightarrow K_2 = 8\,V$

TO GET K_1, INSPECT 2^{ND} STAGE AT $t=0$



KCL AT NEG TERMINAL

$$\frac{v_{01}(0)}{R} + C\frac{d\,v_0(t)}{dt}\bigg|_{t=0} = 0$$

$$\Rightarrow \frac{dv_0(t)}{dt}\bigg|_{t=0} = -\frac{v_{01}(0)}{RC} = -10\,V/s$$

BUT $\frac{dv_0(t)}{dt} = 2t + K_1 \Rightarrow K_1 = -10\,V/s$

$\therefore v_0(t) = t^2 - 10t + 8\,V$

2ND STAGE SATURATES WHEN $v_o(t) = \pm 9V \equiv l$

THIS IS WHEN $t^2 - 10t + 8 = l$

$$t^2 - 10t + 8 - l = 0$$

$$t = \frac{+10 \pm \sqrt{10^2 - 4(8-l)}}{2}$$

$$t = 5 \pm \sqrt{25 - 8 + l}$$

EARLIEST SOL'N IS $5 - \sqrt{25 - 8 - 9} = 2.17$ SEC

CHECK $v_o(2.17) = -9V$

CHECK 1ST STAGE AT THIS TIME

FROM EQ (1), $v_{o1}(t) = -40 v_s t + K_3$

INITIAL CONDITION: $v_{o1}(0) = 5V = K_3$

$$v_{o1}(t) = -t + 5$$

$v_{o1}(2.17) = 2.83V$ - OK

9.3

$$v(t) = 25\cos(400\pi t + 60°)\ V$$

a) MAX AMPLITUDE IS WHEN $\cos(\ldots) = 1$

$$\boxed{v(t)_{max} = 25\ V}$$

b) FREQ IN HZ? $400\pi = \omega = 2\pi f$

$$400\pi = 2\pi f \rightarrow f = \frac{400\pi}{2\pi}$$

$$\boxed{f = 200\ Hz}$$

c) FREQ IN RAD/S?

FROM PART b, $\boxed{\omega = 400\pi\ RAD/S}$

d) PHASE ANGLE IN RAD?

$$\varphi = 60° \times \frac{\pi\ RAD}{180°}$$

$$\boxed{\varphi = \pi/3\ RAD}$$

e) PHASE ANGLE IN DEG?

FROM PART d, $\boxed{\varphi = 60°}$

9.3, CONT'D. ②

F) PERIOD IN ms ?

$$T = \frac{1}{F} = \frac{1}{200\,Hz} = 0.005\,S$$

$$\boxed{T = 5\,ms}$$

g) FIRST TIME AFTER $t=0$ THAT $v(t)=0$?

$v(t) = 0$ WHEN ARG OF COSINE $= \pi/2$

$$400\pi t + 60°\left(\frac{\pi}{180°}\right) = \frac{\pi}{2}$$

$$400\pi t = \frac{\pi}{2} - \frac{\pi}{3} = \frac{(3-2)\pi}{6}$$

$$t = \frac{\pi}{6}\,\frac{1}{400\pi} = \frac{1}{2,400}\,s$$

$$\boxed{t = 4.17 \times 10^{-4}\,s = 0.417\,ms}$$

h) SHIFT $v(t)$ $\frac{5}{6}$ ms TO RIGHT. WHAT IS EXPRESSION FOR $v(t)$?

SHIFT = 5/6 ms ~~t~~ ~~5/6 ms 5/r°~~

$$\text{FRACTION OF PERIOD} = \frac{5/6\,ms}{5\,ms} = \frac{1}{6}$$

EXPRESSED IN DEGREES: $\frac{1}{6}\,360 = 60°$

9.3, CONT'D.

SHIFT IS 60°, BUT DO WE ADD TO OR SUBTRACT FROM EXISTING 60° PHASE?

FOR ANSWER CONSIDER PART (g). IF WE SUBTRACT 60° FROM EXISTING 60°, THE $v(t)$ REACHES 0 V AT

$$400\pi t = \frac{\pi}{2} \rightarrow t = \frac{\pi}{2}\frac{1}{400\pi} = \frac{1}{800} \text{ s}$$

OR $t = 1.25$ ms

THIS IS 5/6 ms LATER THAN TIME IN PART (g)

$$\therefore \boxed{v(t) = 25\cos(400\pi t) \text{ V}}$$

i) WHAT IS MIN TIME ms FOR SHIFT TO LEFT YIELDING

$$v(t) = 25\sin(400\pi t) \text{ ?}$$

WANT $25\cos(400\pi t + 60° + \phi)$

$$= 25\sin(400\pi t)$$

9.3, CONT'D.

SHIFT TO LEFT BY ADDING PHASE

MAKE COS LOOK LIKE SIN – SHIFT LEFT BY $\frac{3\pi}{2} = 270°$

$$60° + \varphi = 270°$$

$$\varphi = 210°$$

FRACTION OF PERIOD = $\frac{210°}{360°}$

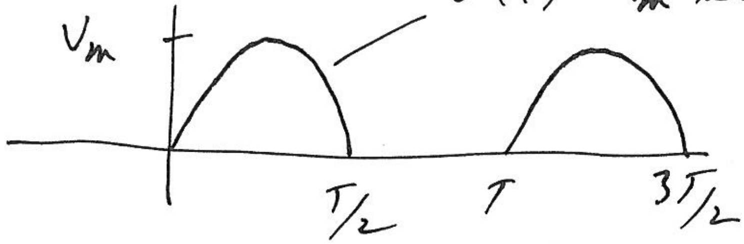
PERIOD $= 5\,ms$ (PART F)

LEFT-SHIFT IN ms $= \frac{210}{360}\, 5\,ms$

$$\boxed{\text{SHIFT} = 2.92\,ms}$$

9.7
~~9.8~~

$v(t) = V_m \sin\left(\frac{2\pi}{T}\right)t; \quad 0 \le t \le T/2$



$$\text{RMS VOLTAGE} = \left[\frac{1}{T}\int_0^{T/2}\left(V_m \sin\left(2\pi/T\right)t\right)^2 dt\right]^{1/2}$$

$$\text{C.O.V.}: \text{LET } x = 2\pi/T\, t; \; dx = \frac{2\pi}{T}\, \cancel{dx}\, dt$$

$$= \left[\frac{1}{T}\int_0^{\pi}\left(V_m \sin x\right)^2 \frac{T}{2\pi}\, dx\right]^{1/2}$$

$$= \left[\frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin^2 x\, dx\right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi}\int_0^{\pi} \frac{1}{2}\left(1 - \overset{0}{\cancel{\cos 2x}}\right) dx\right]^{1/2}$$

$$= \left[\frac{V_m^2}{4\pi}\, x \Big|_0^{\pi}\right]^{1/2}$$

$$\text{RMS VOLTAGE} = V_m/2$$

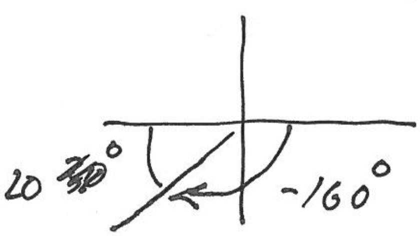
a) $y = 30\cos(200t - 160^\circ) + 15\cos(200t + 70^\circ)$

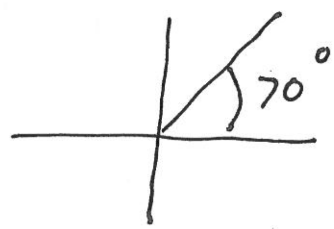
b) $y = 90\sin(50t - 20^\circ) + 60\cos(200t - 70^\circ)$

c) $y = 50\cos(5000t - 60^\circ) + 25\sin(5000t + 110^\circ)$
$\qquad - 75\cos(5000t - 30^\circ)$

d) $y = 10\cos(\omega t + 30^\circ) + 10\sin(\omega t)$
$\qquad + 10\cos(\omega t + 150^\circ)$

a)





$$30\angle -160^\circ + 15\angle 70^\circ$$
$$= -30\angle 20^\circ + 15\angle 70^\circ$$
$$= (-30\cos 20^\circ + 15\cos 70^\circ) + j(-30\sin 20^\circ + 15\sin 70^\circ)$$
$$= -23.06 + j\,3.83$$
$$= 23.38\angle -9.44^\circ = 23.38\angle 170.56$$

$$\boxed{y = 23.38\cos(200t + 170.56)}$$

b) $90\sin(50t - 20^\circ) + 60\cos(200t - 70^\circ)$

DIFFERENT FREQUENCIES
CANNOT COMBINE

9.11 a) ELABORATION

$$30\angle -160 + 15\angle 70$$

$$= 30\cos(-160) + j\,30\sin(-160)$$

$$+ 15\cos(70) + j\,15\sin(70)$$

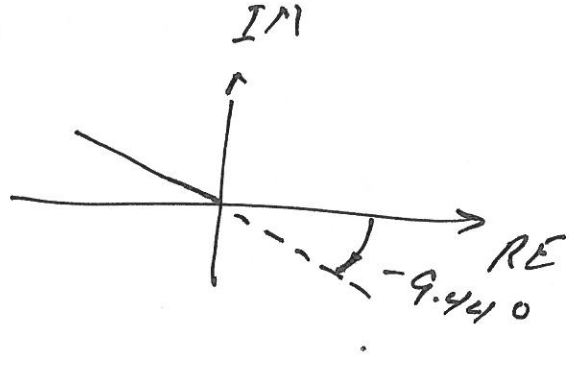
$$= [30\cos(160) + 15\cos(70)]$$

$$+ j[-30\sin(160) + 15\sin(70)]$$

$$= -23.38 + j\,3.83$$

$$= 23.38\angle -9.44^\circ$$

THIS AS CALCULATED BY $\tan^{-1}(3.83/23.38)$



RESULT ACTUALLY IN 2ND QUADRANT

$\Rightarrow$ MUST ADD 180° TO ANSWER

$$\therefore\ y = 23.38\cos(200t + 170.56^\circ)$$

ASSUME TYPO IN TEXT – SHOULD BE

$$y = 90 \sin(50t - 20°) + 60 \cos(50t - 70°)$$

$$= 90 \cos(50t - 20° - 90°) + 60 \cos(50t - 70°)$$

$$= 90 \angle -110 + 60 \angle -70$$

$$= -90 \angle 70° + 60 \angle -70$$

$$= -90 \cos 70° - 90 \sin 70°$$

$$+ 60 \cos(-70) + j \overset{60}{\sin}(-70°)$$

$$= (-90 \cos 70 + 60 \cos 70) + j(-90 \sin 70 - 60 \sin 70°)$$

$$= -10.26 - j140.95$$

$$= 141.33 \angle 85.84 = 141.33 \angle -94.16$$

$$\boxed{y(t) = 141.33 \cos(50t - 94.16)}$$

c) $y = 50 \cos(\omega t - 60°) + 25 \sin(\omega t + 110°)$
$\quad - 75 \cos(\omega t - 30°)$

$$= 50 \cos(\omega t - 60°) + 25 \cos(\omega t + 110° - 90°)$$
$$- 75 \cos(\omega t - 30°)$$

9.11, CONT'D.

$$y = 50\angle{-60^\circ} + 25\angle{20^\circ} - 75\angle{-30^\circ}$$

$$= 50\cos(-60) + 25\cos(20) - 75\cos(-30)$$

$$+ j\left(50\sin(-60) + 25\sin(20) - 75\sin(-30)\right)$$

$$= -16.46 + j\,2.75$$

$$= 16.69\angle{-9.48^\circ}$$

$$\boxed{\begin{aligned} y &= 16.69\cos(5000t - 9.48^\circ) \\ &= 16.69\cos(5000t + 170.52^\circ) \end{aligned}}$$

d) $y = 10\cos(\omega t + 30^\circ) + 10\sin(\omega t) + 10\cos(\omega t + 150^\circ)$

$$= 10\cos(\omega t + 30^\circ) + 10\cos(\omega t - 90^\circ) + 10\cos(\omega t + 150^\circ)$$

$$= 10\angle{30^\circ} + 10\angle{-90^\circ} + 10\angle{150^\circ}$$

$$= \left(10\cos(30) + 10\cos(-90) + 10\cos(150)\right)$$

$$+ j\left(10\sin(30) + 10\sin(-90) + 10\sin(150)\right)$$

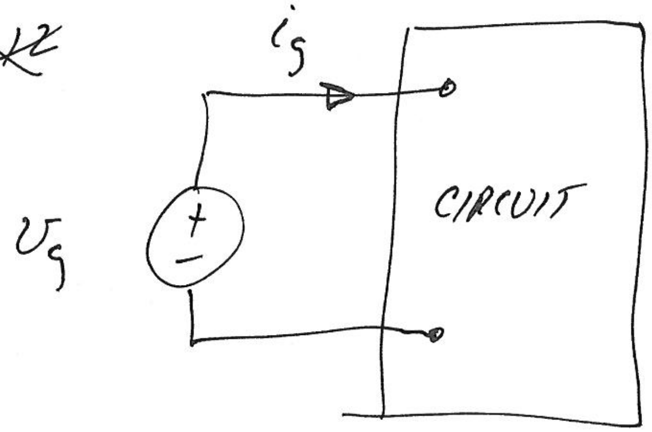
9.11, CONT'D.

$$y = 0 + j0$$

$$\boxed{y = 0}$$

9.14

~~9.12~~



$$v_g = 300\cos(5{,}000\pi t + 78^\circ)\,V$$

$$i_g = 6\,\mathrm{SIN}(5{,}000\pi t + 123^\circ)\,A$$

$$i_g = 6\cos(5{,}000\pi t + 123^\circ - 90^\circ)\,A$$

$$= 6\cos(5{,}000\pi t + 33^\circ)\,A$$

$$\mathcal{P}\{v_g\} = \bar{V}_g = 300e^{j78^\circ}$$

$$\mathcal{P}\{i_g\} = \bar{I}_g = 6e^{j33^\circ}$$

$$\bar{V}_g = z\bar{I}_g \longrightarrow z = \frac{\bar{V}_g}{\bar{I}_g}$$

$$z = \frac{300e^{j78^\circ}}{6e^{j33^\circ}} = 50e^{j45^\circ}$$

9.14

~~9.12~~, CONT'D.

a) $z = 50e^{j45°}$

b) $v_g = V_m \cos(\omega t + \varphi)$

$$\omega = 5{,}000\pi = 2\pi f = \frac{2\pi}{T}$$

$$\Rightarrow T = \frac{2\pi}{5{,}000\pi} = 4\times10^{-4}\,s$$

$$= 400\mu s$$

PHASE DELAY BETWEEN VOLTAGE & CURRENT IS 45°. THIS IS

$\frac{45°}{360°} = \frac{1}{8}$ OF A PERIOD OR

$$\frac{1}{8}\,400\mu s = 50\mu s$$