

EX.

(7.3) (a)

THE BREAK FREQ.

OCCURS WHEN

$$c\omega^2 = \frac{B}{C}$$

$$\Rightarrow \omega = \sqrt{\frac{B}{C}}$$

(b) FOR LARGE FREQUENCY, $V \cong \frac{AW}{\sqrt{c\omega^2}}$

$$= \frac{A}{\sqrt{c}}$$

USING THE RULE THAT THE SLOPE IS 20N dB PER DECADE WHEN THE OUTPUT IS PROPORTIONAL TO ω^N , WE FIND THAT THE SLOPE IN THIS CASE IS ZERO.

(c) FOR LOW FREQUENCY, $V \cong \frac{AW}{\sqrt{B}}$.

USING THE ABOVE RULE, THE SLOPE IS 20dB PER DECADE.

END

CHAPTER 7 - PROBLEMS

(7.1) (a) $Z_1 = \frac{1}{j2\pi \cdot 10^8 \cdot 10^{-6}} = -1.59 \cdot 10^{-3} j \text{ OHM}$

(b) $1.59 \cdot 10^{-3}$ (c) $+1.59 \cdot 10^{-3} j$

(7.2) 60 Hz: $X = 2\pi \cdot 60 \cdot 10^{-3} = 0.38 \Omega$

1 MHz: $X = 2\pi \cdot 10^6 \cdot 10^{-3} = 6280 \Omega$

(7.3) (a) $X = (2\pi \cdot 10^6 \cdot 10^{-8})^{-1} = 15.9 \Omega$

(b) $X = (2\pi \cdot 10^8 \cdot 10^{-8})^{-1} = 0.159 \Omega$

7.4 (1) $\underline{z}_L = j\omega L = j\omega(10\mu)\Omega$

$|\underline{z}_L| > 1000\Omega \Rightarrow |j\omega(10\mu)| > 1000$
 $\Rightarrow \underline{\omega} > 10^8 \text{ rad/sec}$

(2) $\underline{z}_C = \frac{1}{j\omega C} = \frac{1}{j\omega(10\mu)}\Omega$

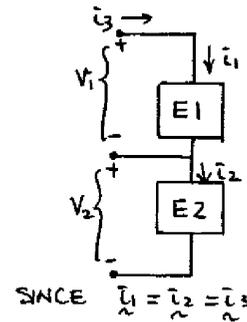
$|\underline{z}_C| > 1000\Omega \Rightarrow \left| \frac{1}{j\omega(10\mu)} \right| > 1000$
 $\Rightarrow \underline{\omega} < 100 \text{ rad/sec}$

7.5 LET $\underline{i}_1, \underline{v}_1$ AND $\underline{i}_2, \underline{v}_2$ BE THE CURRENTS AND VOLTAGES FOR ELEMENT 1 AND 2 RESPECTIVELY. THEN $\underline{v}_1 = \underline{z}_1 \underline{i}_1$; $\underline{v}_2 = \underline{z}_2 \underline{i}_2$

LET $\underline{v}_3 = \underline{v}_1 + \underline{v}_2$

THEN $\underline{v}_3 = \underline{v}_1 + \underline{v}_2$
 $= \underline{z}_1 \underline{i}_1 + \underline{z}_2 \underline{i}_2$
 $= \underline{z}_1 \underline{i}_3 + \underline{z}_2 \underline{i}_3$
 $= \underline{z}_1 (\underline{i}_1 + \underline{i}_2)$
 $= \underline{z}_3 \underline{i}_3$

$\therefore \underline{z}_3 = \underline{z}_1 + \underline{z}_2$

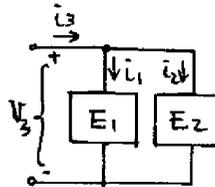


SINCE $\underline{i}_1 = \underline{i}_2 = \underline{i}_3$

7.6 THIS IS SIMILAR TO LAST PROBLEM EXCEPT THAT $\underline{v}_3 = \underline{v}_2 = \underline{v}_1$ AND $\underline{i}_3 = \underline{i}_2 + \underline{i}_1$

$\therefore \underline{i}_3 = \underline{i}_1 + \underline{i}_2$
 $= \frac{\underline{v}_1}{\underline{z}_1} + \frac{\underline{v}_2}{\underline{z}_2}$
 $= \underline{v}_3 \left[\frac{\underline{z}_1 + \underline{z}_2}{\underline{z}_1 \underline{z}_2} \right]$
 $= \underline{v}_3 / \underline{z}_3$

$\therefore \underline{z}_3 = \frac{\underline{z}_1 \underline{z}_2}{\underline{z}_1 + \underline{z}_2}$



$$\textcircled{7.7} \quad \underline{Z} = R + \frac{1}{j\omega C} = R - \frac{j}{\omega C}$$

$$= 100 - \frac{j}{(1000 \times 2\pi)(1\mu)}$$

$$\text{RESISTANCE} = \underline{100 \Omega}$$

$$\text{REACTANCE} = -\frac{1}{(1000 \times 2\pi)(1\mu)} = \underline{\underline{-159.2 \Omega}}$$

$$\textcircled{7.8} \quad \underline{Z} = \frac{R - j\omega R^2 C}{1 + \omega^2 R^2 C^2}$$

$$\text{RESISTANCE} = \text{Re}[\underline{Z}] = \frac{R}{1 + \omega^2 R^2 C^2}$$

$$= \frac{100}{1 + (1000 \times 2\pi \times 100 \times 1\mu)^2}$$

$$= \underline{71.7 \Omega}$$

$$\text{REACTANCE} = \frac{-j \text{Im}[\underline{Z}]}{j} = \frac{-\omega R^2 C}{1 + \omega^2 R^2 C^2} = \underline{\underline{-45.2 \Omega}}$$

$$\textcircled{7.9} \text{ (a)} \quad \underline{Z} = R + \frac{1}{j\omega C} = 100 - \frac{j}{10^{-4}\omega} \Omega$$

$$\text{(b)} \quad \underline{Z} = \frac{R \left(\frac{1}{j\omega C}\right)}{R + \frac{1}{j\omega C}} = \frac{R}{j\omega RC + 1} = \frac{R(1 - j\omega RC)}{1 + (\omega RC)^2}$$

$$\therefore \underline{Z} = \frac{100 - j\omega(100)^2(1\mu)}{1 + \omega^2(100)^2(1\mu)^2}$$

$$= \underline{\underline{\frac{100 - 0.01\omega j}{1 + \omega^2(10^{-8})}}}}$$

$$\text{(c)} \quad \underline{Z} = R + \frac{\frac{1}{j\omega C} \cdot (j\omega L)}{\frac{1}{j\omega C} + j\omega L} = R + \frac{j\omega L}{1 - \omega^2 LC}$$

$$= 100 + \frac{j\omega(32\text{m})}{1 - \omega^2(32\text{m})(1\mu)}$$

$$= \underline{\underline{100 + \frac{j32 \times 10^{-3} \omega}{1 - \omega^2 \times 32 \times 10^{-9}} \Omega}}$$

$$\textcircled{7.10} \quad \text{LET } \underline{i} = A e^{j\alpha}, \quad \underline{Z} = B e^{j\beta}$$

$$\text{THEN } \underline{v} = \underline{i} \underline{Z} = AB e^{j(\alpha + \beta)}$$

$$|\underline{v}| = AB$$

$$\text{SINCE } |\underline{i}| = A, \quad |\underline{Z}| = B, \quad |\underline{v}| = |\underline{i}| |\underline{Z}|$$

$$(7.11) (a) \underline{z} = 100 - \frac{j}{10^{-6}(1000 \times 2\pi)} \Omega$$

$$|\underline{z}| = 187.96 \Omega \Rightarrow \text{AMPLITUDE OF THE CURRENT} \\ = 100/187.96 = \underline{0.532 A}$$

$$(b) \underline{z} = \frac{100 - j(1000 \times 2\pi)(0.01)}{1 + (1000 \times 2\pi)^2 (10^{-8})}$$

$$= 71.7 - j45.2 \Omega \\ |\underline{z}| = 85 \Omega \Rightarrow |\underline{i}| = 100/85 = \underline{1.18 A}$$

$$(7.12) \underline{z} = A + jB ; \text{CURRENT} = \underline{i} \\ \text{HENCE } \underline{v} = \underline{z}\underline{i}$$

$$P_{AVG} = \frac{1}{2} \text{Re}[\underline{v}\underline{i}^*] = \frac{1}{2} \text{Re}[\underline{z}\underline{i}\underline{i}^*] \\ = \frac{1}{2} \text{Re}[\underline{i}^2 \underline{z}] \\ = |\underline{i}|^2 A \\ = \underline{A |\underline{i}|^2 / 2}$$

$$(7.13) \underline{z} = A + jB ; \text{VOLTAGE} = \underline{v} \\ \text{HENCE } \underline{i} = \underline{v}/\underline{z}$$

$$P_{AVG} = \frac{1}{2} \text{Re}[\underline{v}\underline{i}^*] = \frac{1}{2} \text{Re}[\underline{v}\underline{v}^*/\underline{z}^*]$$

$$P_{AVG} = \frac{|\underline{v}|^2}{2} \text{Re}[\underline{1}/\underline{z}^*] = \frac{|\underline{v}|^2}{2} \frac{A}{\sqrt{A^2 + B^2}}$$

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$$(7.14) (1) \text{PARALLEL R AND L AT } \omega$$

$$\underline{z} = \frac{R(j\omega L)}{R + j\omega L} \Rightarrow \underline{Y} = \frac{1}{\underline{z}} = \frac{R + j\omega L}{j\omega RL} \\ = \frac{-\omega L + Rj}{-\omega RL}$$

$$\therefore \text{CONDUCTANCE} = \text{Re}[G] = \frac{1}{R} \Omega$$

$$\text{SUSCEPTANCE} = \frac{1}{j} \text{Im}[G] = \frac{-1}{\omega L} \Omega$$

$$(2) \text{SERIES R AND L}$$

$$\underline{z} = R + j\omega L \Rightarrow \underline{Y} = \frac{1}{\underline{z}} = \frac{1}{R + j\omega L} \\ = \frac{R - j\omega L}{R^2 + (\omega L)^2}$$

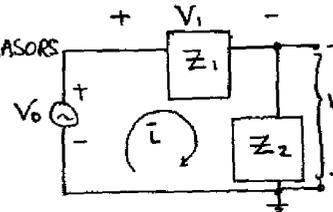
$$\therefore \text{CONDUCTANCE} = \frac{R}{R^2 + \omega^2 L^2} \Omega$$

$$\text{SUSCEPTANCE} = \frac{-\omega L}{R^2 + \omega^2 L^2} \Omega$$

$$(7.15) \text{BY KVL FOR PHASORS}$$

$$\sum_{k=1}^n \underline{v}_k = 0$$

$$\Rightarrow -\underline{v}_0 + \underline{i}z_1 + \underline{i}z_2 = 0$$



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$$\Rightarrow \tilde{i} = \frac{V_0}{\tilde{z}_1 + \tilde{z}_2}$$

$$\text{HENCE } \tilde{V} = \tilde{i} \tilde{z}_2 = \frac{V_0 \cdot \tilde{z}_2}{\tilde{z}_1 + \tilde{z}_2}$$

7.16 FROM KCL

$$\frac{V - V_0}{\tilde{z}_1} + \frac{V}{\tilde{z}_2} = 0$$

$$\Rightarrow \tilde{z}_2 V - \tilde{z}_2 V_0 + \tilde{z}_1 V = 0$$

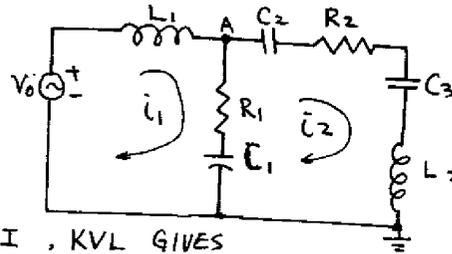
$$\Rightarrow \tilde{V} = \frac{\tilde{z}_2 V_0}{\tilde{z}_1 + \tilde{z}_2}$$

7.17 FROM 5.36, $\tilde{z}_1 = 100 - j159.2 \Omega$

FROM 5.37, $\tilde{z}_2 = 71.7 - j45.2 \Omega$

$$\begin{aligned} \therefore \tilde{V} &= \frac{(71.7 - j45.2) 100 e^{j20^\circ}}{71.7 - j45.2 + 100 - j159.2} \\ &= \frac{(84.8 e^{j-32.2^\circ}) (100 e^{j20^\circ})}{171.7 - j204.4} \\ &= \frac{848 e^{j-12.2^\circ}}{267 e^{-j50^\circ}} \\ &= \underline{\underline{3.18 e^{j37.8^\circ}}} \end{aligned}$$

7.18



FOR LOOP I, KVL GIVES

$$-V_0 + \tilde{i}_1 (j\omega L_1) + (\tilde{i}_1 - \tilde{i}_2) \left(R_1 - \frac{j}{\omega C_1} \right) = 0$$

$$\Rightarrow \tilde{i}_1 \left[R_1 + j(\omega L_1 - \frac{1}{\omega C_1}) \right] + \tilde{i}_2 \left(-R_1 + \frac{j}{\omega C_1} \right) = V_0 \quad \text{--- (1)}$$

FOR LOOP II, USING KVL

$$(\tilde{i}_2 - \tilde{i}_1) \left(R_1 - \frac{j}{\omega C_1} \right) + \tilde{i}_2 \left[R_2 + j(\omega L_2 - \frac{1}{\omega C_2} - \frac{1}{\omega C_3}) \right] = 0$$

$$\Rightarrow \tilde{i}_1 \left[-R_1 + \frac{j}{\omega C_1} \right] + \tilde{i}_2 \left[(R_1 + R_2) + j(\omega L_2 - \frac{1}{\omega C_1} - \frac{1}{\omega C_2} - \frac{1}{\omega C_3}) \right] = 0 \quad \text{--- (2)}$$

7.19 USING KCL, WE GET AT NODE A

$$\frac{V_A - V_0}{\tilde{z}_1} + \frac{V_A}{\tilde{z}_2} + \frac{V_A}{\tilde{z}_3} = 0 \quad \text{--- (*)}$$

WHERE

$$\tilde{z}_1 = j\omega L_1$$

$$\tilde{z}_2 = R_1 - \frac{j}{\omega C_1}$$

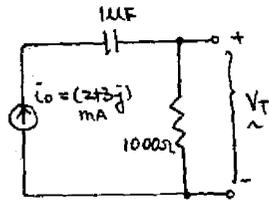
$$\tilde{z}_3 = R_2 + j(\omega L_2 - \frac{1}{\omega C_2} - \frac{1}{\omega C_3})$$

FROM (*) WE GET $\underline{V}_A = \frac{V_0 / \underline{Z}_1}{1/\underline{Z}_1 + 1/\underline{Z}_2 + 1/\underline{Z}_3}$

HENCE $\underline{V}_A = \frac{V_0}{1 + \frac{\underline{Z}_1}{\underline{Z}_2} + \frac{\underline{Z}_1}{\underline{Z}_3}}$
 $= \frac{V_0}{\left[1 + \frac{j\omega L_1}{R_1 - \frac{j}{\omega C_1}} + \frac{j\omega L_1}{R_2 + j(\omega L_2 - \frac{1}{\omega C_2} - \frac{1}{\omega C_3})} \right]}$

7.20 (1) $V_T =$ OPEN-CIRCUIT VOLTAGE

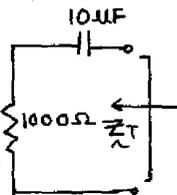
$\underline{V}_T = \underline{I}_0 \underline{Z}_R$
 $= (2+3j) \cdot 1\text{KMV}$
 $= \underline{2+3j}$ VOLT



\underline{Z}_T IS SEEN FROM THE OUTPUT TERMINALS WHEN THE SOURCE IS SET TO ZERO

$\underline{Z}_T = 1000 - \frac{j}{230(\mu\text{A})}$
 $= \underline{(1000 - j434.8)\Omega}$

THIS SUBCIRCUIT WILL PROVIDE \underline{Z}_T



7.21 WE ASSUME THAT NOTHING IS CONNECTED TO THE TWO TERMINALS AT THE RIGHT. AS $f \rightarrow \infty$ THE CAPACITORS ACT AS SHORT CIRCUITS, THUS THE CURRENT THRU R IS SIMPLY \underline{I}_0 . (ACTUALLY THIS WOULD EVEN BE TRUE FOR SMALL f , PROVIDED THE TWO TERMINALS ARE DISCONNECTED.)

7.22

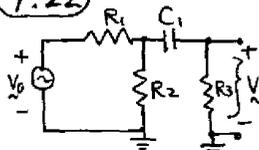
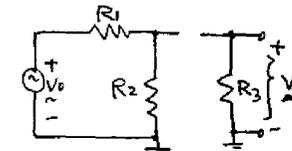
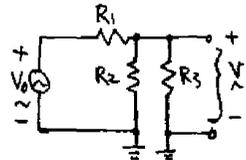


FIG 5.17 (a)



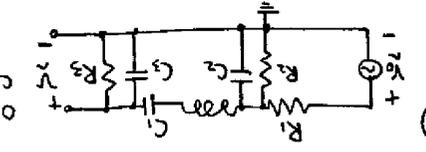
(1) $\omega \rightarrow \infty \Rightarrow \underline{Z}_{C_1} \rightarrow \infty$
 $\Rightarrow \underline{V} \rightarrow 0$



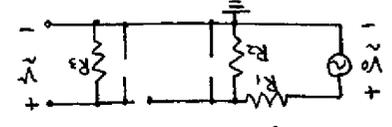
(2) $\omega \rightarrow 0 \Rightarrow \underline{Z}_{C_1} \rightarrow 0$

$\Rightarrow \underline{V} = \frac{R_2 / R_3}{R_1 + R_2 / R_3} \cdot \underline{V}_0 = \frac{R_2 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1} \cdot \underline{V}_0$

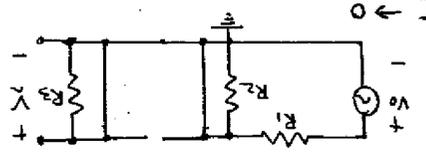
7.23 ORIGINAL CIRCUIT



(1) $\omega \rightarrow 0 \Rightarrow \tilde{Z}_C \rightarrow \infty; \tilde{Z}_L \rightarrow 0$



SAME AS IN 5.49(c)



$\omega \rightarrow \infty \Rightarrow \tilde{Z}_C \rightarrow 0; \tilde{Z}_L \rightarrow \infty$

SO THE ACTUAL CIRCUIT HAS A LIMITED BANDWIDTH BECAUSE OF THE EXISTENCE OF THE INDUCTANCES AND THE CAPACITANCES. (2) THE PARASITES AFFECT THE CIRCUIT THE MOST AT HIGH FREQUENCIES.

7.24 THE CURRENT THRU R IS SIMPLY I_0 . THE VOLTAGE ACROSS THE SOURCE IS $V = I_0 (R + 1/j\omega C)$. THUS $P_{AV} = \frac{1}{2} R E (Y I_0^*) = \frac{1}{2} I_0^2 R E (R + 1/j\omega C)$

$$= \frac{1}{2} I_0^2 R$$

7.25 NOW $\tilde{V} = V_0, \tilde{I} = \frac{V_0}{R + 1/j\omega C}$

$$V_0 = \frac{R + 1/j\omega C}{R^2 + 1/(\omega C)^2}$$

$$P_{AV} = \frac{1}{2} \frac{V_0^2}{R^2 + 1/(\omega C)^2} R E (R + 1/j\omega C)$$

$$= \frac{1}{2} \frac{V_0^2 R (\omega C)^2}{1 + R^2 (\omega C)^2}$$

7.26 $\tilde{V} = \tilde{I}_0 \frac{jR\omega L}{jR\omega L (R - j\omega L)}$

$$P_{AV} = \frac{1}{2} R E (Y \tilde{I}_0^*) = \frac{1}{2} \tilde{I}_0^2 R E \left[\frac{jR\omega L (R - j\omega L)}{jR\omega L (R - j\omega L)} \right]$$

$$= \frac{1}{2} \frac{|\tilde{I}_0|^2 R (\omega L)^2}{R^2 + (\omega L)^2} = \frac{1}{2} \cdot \frac{100 (50.27)^2}{(100)^2 + (50.27)^2} = 1.01 \text{ mW}$$

7.27 THE CURRENT THRU R IS
(FROM PREVIOUS PROB.)

$$\underline{i}_R = \frac{\underline{V}}{R} = \underline{i}_0 \frac{j\omega L}{R + j\omega L}$$

THE POWER DISSIPATED IN R IS

$$P = \frac{1}{2} \operatorname{Re}(\underline{V} \underline{i}_R^*) = \frac{1}{2} \operatorname{Re}[(\underline{i}_R R) \underline{i}_R^*]$$

$$= \frac{1}{2} |\underline{i}_R|^2 R = \frac{|\underline{i}_0|^2}{2} \frac{(\omega L)^2 R}{R^2 + (\omega L)^2}$$

OF COURSE THIS AGREES WITH THE
POWER PRODUCED BY THE SOURCE,
SINCE L, BEING AN ENERGY-STORAGE
ELEMENT, CONSUMES NO AVERAGE POWER.

7.28 (1) CHANGE IN DECIBELS = $20 \log \frac{16}{6}$

$$= \underline{8.52 \text{ dB}}$$

(2) FROM 60 TO 160V, $\Delta \text{dB} = 20 \log \frac{160}{60}$

$$= 8.52 \text{ dB}$$

WHICH IS THE SAME AS IN (1) SINCE THE
INCREASE OF ORDER OF MAGNITUDE IS THE
SAME. (3) FROM 160 TO 60V, CHANGE
IN DECIBELS IS -8.52 dB

7.29 DECIBELS = $20 \log \frac{V}{V_{\text{REF}}}$

$$V_{\text{REF}} = \frac{V}{10^{\frac{\text{DECIBELS}}{20}}}$$

$$= \frac{14 \text{ V}}{10^{\frac{82.92}{20}}} \cong \underline{1 \text{ mV}}$$

7.30 LET THE QUANTITY BE V

$$\frac{V_{\text{NEW}}}{V_{\text{OLD}}} = 10^{\frac{12.2}{20}} = 1.122$$

THEREFORE THAT QUANTITY IS 12.2%
LARGER

7.31 FROM EXAMPLE 7.11 $\frac{V_3}{V_1} = \frac{WRC}{\sqrt{1+(WRC)^2}}$

AT LOW FREQUENCY $\frac{V_3}{V_1} \cong WRC$

ACCORDING TO THE RULE FOR SLOPE OF BODE
PLOT OF W^N , SLOPE IS 20 dB/decade.

7.31 (CONT'D) FOR FIG 7.30 WE OBSERVE THAT A FACTOR OF 10 INCREASE IN ω GIVES 20 dB INCREASE IN V_L . THUS
20 dB/DECADE

7.32 SLOPE = $20 \log \frac{V_{NEW}}{V_{REF}}$
 $= (20 \log 2) / \text{OCTAVE}$
 $= 6.03 \text{ dB / OCTAVE}$

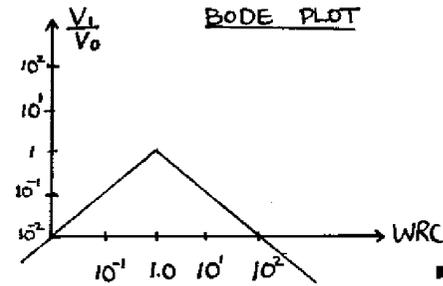
7.33 $\text{dB} = 20 \log \frac{K/\omega_2}{K/\omega_1} = 20 \log \frac{\omega_1}{\omega_2}$

WHEN ω_2 IS TWICE ω_1 , INCREASE
 IN $\text{dB} = 20 \log \frac{1}{2} = -6.0 \text{ dB}$
 WHEN ω_2 IS TEN TIMES ω_1 , INCREASE
 IN $\text{dB} = 20 \log \frac{1}{10} = -2.0 \text{ dB}$

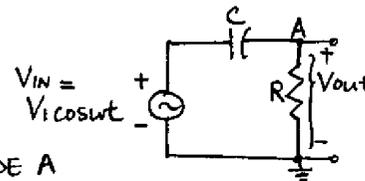
7.34 $V_i = \frac{V_o \omega (RC)}{1 + \omega^2 (RC)^2}$

AS $\omega \rightarrow 0$, $V_i \rightarrow 0$; $V_i \cong V_o RC \omega$
 AS $\omega \rightarrow \infty$, $V_i \rightarrow 0$; $V_i \cong V_o / (RC \omega)$

CORNER FREQUENCY IS WHERE $\omega RC = 1$
 i.e. $\omega = 1/RC$. USING THE RULE THAT
 THE SLOPE IS 20 dB / DECADE WHEN
 THE OUTPUT IS PROPORTIONAL TO ω^n ,
 SLOPE IS 20 dB / decade FOR SMALL ω ,
 SLOPE IS -20 dB / decade FOR LARGE ω .



7.35



WRITE A NODE

EQUATION AT NODE A

$$\frac{V_{OUT}}{R} + C \frac{d}{dt} (V_{OUT} - V_i \cos \omega t) = 0$$

UPON REARRANGEMENT, WE GET

$$\frac{d}{dt} V_{OUT} + \frac{V_{OUT}}{RC} = \omega V_i \sin \omega t$$

THE SOLUTION OF V_{OUT}

MUST BE OF THE FORM $V_{out} = V_3 \sin(\omega t + \phi)$
 THESE UNKNOWN CAN BE FOUND BY
 SUBSTITUTING V_{out} INTO THE ABOVE EQN.
 THUS $V_3 \omega \cos(\omega t + \phi) + \frac{1}{RC} V_3 \sin(\omega t + \phi)$
 $= \omega V \sin \omega t$

EXPANDING THE ARGUMENTS, WE GET
 $[V_3 \omega \cos \phi + \frac{V_3}{RC} \sin \phi] \cos \omega t +$
 $[-V_3 \omega \sin \phi + \frac{V_3}{RC} \cos \phi - V_1 \omega] \sin \omega t = 0$

HENCE $V_3 \omega \cos \phi + \frac{V_3}{RC} \sin \phi = 0$ — (A)

AND $-V_3 \omega \sin \phi + \frac{V_3}{RC} \cos \phi - V_1 \omega = 0$ — (B)

FROM (A) $\tan \phi = -(\omega RC)$
 $\Rightarrow \sin \phi = \frac{-(\omega RC)}{\sqrt{1 + (\omega RC)^2}}$; $\cos \phi = \frac{1}{\sqrt{1 + (\omega RC)^2}}$

NOW SUBSTITUTING INTO (B), WE GET

$$\frac{V_1}{V_3} = \frac{\sqrt{1 + (\omega RC)^2}}{\omega RC}$$

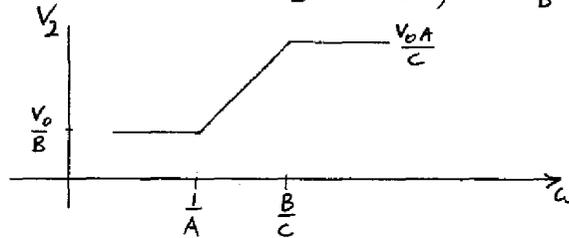
$$\therefore |V_{out}| = V_3 = \frac{V_1 \omega RC}{\sqrt{1 + (\omega RC)^2}}$$

7.36 $\lim_{\omega \rightarrow 0} V_2 = \frac{V_0}{B}$ $\lim_{\omega \rightarrow \infty} V_2 = \frac{V_0 A}{C}$

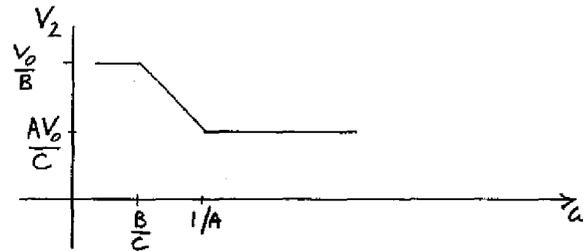
THE BREAK FREQUENCY ASSOCIATED WITH THE NUMERATOR (AT WHICH SLOPE INCREASES BY 20 dB/DECADE) IS $\omega_N = \frac{1}{A}$.

THE BREAK FREQ. ASSOCIATED WITH THE DENOMINATOR (AT WHICH SLOPE DECREASES BY 20 dB/DECADE) IS $\omega_D = \frac{B}{C}$.

(A) IN THIS CASE $\omega_D > \omega_N$, $\frac{A}{C} > \frac{1}{B}$



(b) NOW $\omega_N > \omega_D$, AND $\frac{1}{B} > \frac{A}{C}$



THE GRAPHS OF THESE 3 FREQUENCY RESPONSES ARE SHOWN ON NEXT PAGE.

AT ω_3 , $|\tilde{z}| = R = 60\Omega$
 $\omega_3 = \frac{\sqrt{100\pi^2 mH}}{L} = 10000 \text{ rad/sec}$

(3) $L = 1mH, C = 10\mu F, R = 60\Omega$

AT ω_2 , $|\tilde{z}| = R = 30\Omega$
 $|\tilde{z}| = \frac{0.03 \omega \Omega}{\sqrt{10^{-6} \omega^2 + 900(5 \times 10^{-9} \omega^2 - 1)^2}} = 30$

$\omega_{RL} = \frac{\sqrt{500\pi^2 mH}}{L} = 14142 \text{ rad/sec}$
 $L = 1mH, C = 5\mu F, R = 30\Omega$

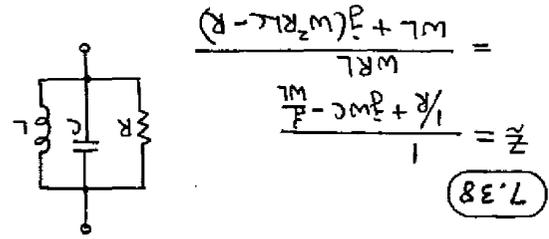
AT ω_1 , $|\tilde{z}| = R = 30\Omega$
 $|\tilde{z}| = \frac{0.03 \omega \cdot \Omega}{\sqrt{10^{-6} \omega^2 + 900(10^{-8} \omega^2 - 1)^2}} = 30$

$\therefore \omega_{R1} = \frac{\sqrt{100\pi^2 mH}}{L} = 10000 \text{ rad/sec}$

(1) $L = 1mH, C = 10\mu F, R = 30\Omega$

END OF R.
 DIFFERENTIATING $|\tilde{z}|$ w.r.t ω AND SET IT TO ZERO, WE GET $\omega = \frac{1}{\sqrt{LC}}$ WHICH IS INDEPENDENT OF R.

$\therefore |\tilde{z}| = \frac{WRL}{[W^2L^2 + R^2(W^2LC - 1)^2]^{1/2}}$



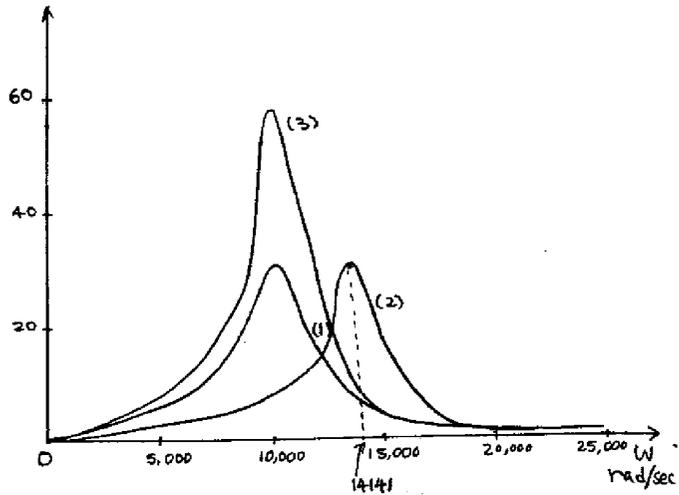
$$\tilde{z} = \frac{1}{\frac{1}{R} + j\omega C - \frac{j}{\omega L}} = \frac{WRL}{W^2RLC - R}$$

$\Rightarrow \frac{10mC}{800 \times 2\pi} = \frac{1}{C} \Rightarrow C = 3.96 \mu F$

THERE IS A MINIMUM AT $\omega = \frac{1}{\sqrt{LC}}$

$$\begin{aligned} \tilde{z} &= z_R + z_C + z_L \\ &= R - \frac{j}{\omega C} + j\omega L \\ &= R + j(\omega L - \frac{1}{\omega C}) \\ |\tilde{z}| &= [R^2 + (\omega L - \frac{1}{\omega C})^2]^{1/2} \\ &= [R^2 + (1 - W^2LC)^2]^{1/2} \end{aligned}$$

7.37



7.39 THE IMPEDANCE IN PARALLEL WITH THE V-SOURCE IS

$$\frac{Z_R Z_L Z_C}{Z_R Z_L + Z_R Z_C + Z_L Z_C} = \frac{j\omega L}{(1 - \omega^2 LC) + j\omega L/R}$$

(a) AT RESONANCE $\omega^2 LC = 1$ and $Z = R$.

THUS $|i_0| = V_0/R$.

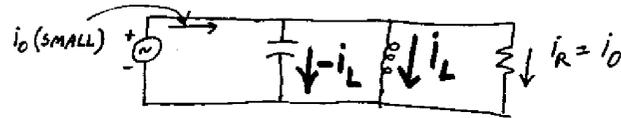
(b) $|i_L| = V_0/\omega L$

(c) $|i_L/i_0| = |i_L|/|i_0| = \frac{R}{\omega L}$. AS

$R \rightarrow \infty$, $|i_L/i_0| \rightarrow \infty$. THIS IS POSSIBLE

BECAUSE $X_L = -X_C$, and HENCE $i_L = -i_C$.

THUS A LARGE CURRENT THROUGH L IS CANCELLED BY A NEGATIVE CURRENT THRU C.



7.40 EQT. (5.37) IS $|Z(\omega)| = \frac{R^2 + (\omega L)^2}{(1 - \omega^2 LC)^2 + (\omega RC)^2}$

$|Z(\omega)|$ HAS A MAXIMUM AT ω SUCH THAT $\frac{d}{d\omega} |Z(\omega)| = 0$. BY CARRYING OUT THE DIFFERENTIATION,

A QUADRATIC EQUATION RESULTS WHICH CAN BE SOLVED FOR TWO VALUES OF ω , ω_1 AND ω_2 WHERE $\omega_1 < \omega_R < \omega_2$. THE ALGEBRA REQUIRED IS VERY LENGTHY AND IT IS EASIER TO FIND $(\omega_2 - \omega_1)$ DIRECTLY, WHICH IS FOUND TO BE (AFTER ASSUMING $\frac{R^2 C}{L} \ll 1$)

$$BW = (\omega_2 - \omega_1) \approx \frac{R}{L} = \frac{R\omega_R}{L\omega_R} = \frac{\omega_R}{Q}$$

7.41 $\underline{Z}_L = (10 - j20)\Omega$ WOULD BE THE SAME. INSTEAD OF A SERIES ARRANGEMENT, WE CHOOSE A PARALLEL ARRANGEMENT.

TO HAVE A NEGATIVE REACTANCE IN A PARALLEL ARRANGEMENT, WE NEED A RESISTOR WITH A CAPACITOR IN PARALLEL.

$$\begin{aligned} \underline{Z}_{LOAD} &= \frac{1}{\frac{1}{R} + j\omega C} = \frac{R}{1 + j\omega RC} \\ &= \frac{R - j\omega RC^2}{1 + (\omega RC)^2} \\ &= (10 - 20j)\Omega \end{aligned}$$

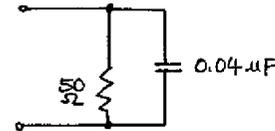
HENCE $\frac{R}{1 + (\omega RC)^2} = 10\Omega$ AND $\frac{\omega RC^2}{1 + (\omega RC)^2} = 20\Omega$

$$\Rightarrow \omega RC = 2$$

$$\therefore \frac{R}{1 + 4} = 10\Omega \Rightarrow R = \underline{\underline{50\Omega}}$$

$$\text{ALSO } C = \frac{2}{\omega R} = \frac{2 \cdot \text{sec}}{10^6 (50\Omega)} = \underline{\underline{0.04 \mu\text{F}}}$$

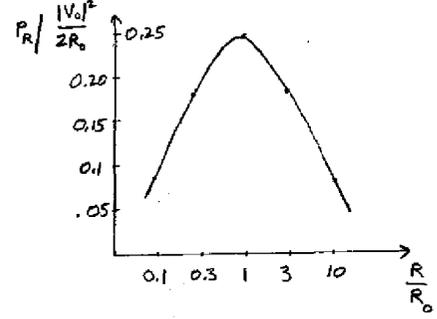
THE REQUIRED LOAD IS IN THE SKETCH



7.42 $P_R = \frac{1}{2} \left| \frac{V_o R}{R+R_o} \right|^2 / R$

$$= \frac{|V_o|^2}{2} \frac{R}{(R+R_o)^2} = \frac{|V_o|^2}{2R_o} \cdot \left(\frac{R}{R_o} \right) \left[1 + \left(\frac{R}{R_o} \right) \right]^{-2}$$

$\frac{R}{R_o}$	$P_R / \frac{ V_o ^2}{2R_o}$
0.1	0.083
0.3	0.178
1.0	0.25
3.0	0.188
10.0	0.083



7.43 LET THE LOAD BE $R_L + jX_L$.
 THEN $\tilde{i} = \frac{V_T}{(R_T + R_L) + j(X_T + X_L)}$

THE TIME-AV POWER DISSIPATED IN L IS

$$P = \frac{1}{2} |\tilde{i}|^2 R_L = \frac{|V_T|^2}{2} \frac{R_L}{(R_T + R_L)^2 + (X_T + X_L)^2}$$

THIS IS MAXIMIZED BY CHOOSING $X_L = -X_T$ (OBVIOUS) AND $R_L = R_T$ (PREVIOUS PROBLEM, OR BY SETTING $dP/dR_L = 0$.) WITH THESE CHOICES, $P_{max} = \frac{|V_T|^2}{2} \frac{R_L}{(R_L + R_L)^2} = \frac{|V_T|^2}{8R_L}$

7.44 LET THE LOAD BE $R_L + jX_L$.
 THE CURRENT THRU THE LOAD (CURRENT DIVIDER FORMULA) IS

$$\tilde{i}_L = \tilde{i}_N \frac{\tilde{Z}_N}{\tilde{Z}_N + \tilde{Z}_L}$$

THE POWER DISSIPATED IN L IS

$$P = \frac{1}{2} |\tilde{i}_L|^2 R_L = \frac{|\tilde{i}_N|^2 (R_N^2 + X_N^2) R_L}{2 (R_N + R_L)^2 + (X_N + X_L)^2}$$

THE FACTOR $\frac{R_L}{(R_N + R_L)^2 + (X_N + X_L)^2}$ IS MAXIMIZED

AS IN THE PRECEDING PROBLEM, WITH $X_L = -X_N$, $R_L = R_N$; ITS MAX. VALUE IS $\frac{1}{4R_N}$.

THUS

$$P_{max} = \frac{|\tilde{i}_N|^2 (R_N^2 + X_N^2)}{8R_N}$$

(THIS CAN BE CHECKED BY CONVERTING THE NORTON SOURCE INTO A THEVENIN SOURCE. THEN $V_T = \tilde{i}_N \tilde{Z}_N$, $R_T = R_N$, AND THE ABOVE RESULT AGREES WITH PREVIOUS PROB.)

7.45 IN THE LIMIT $D \rightarrow 0$ IT IS LIKE THERE IS NO DASHPOT. RESULT 7.42 BECOMES IDENTICAL WITH (7.40), GIVING UNDAMPED RESONANT MOTION.

WHEN $D \rightarrow \infty$, THE DASHPOT IS LIKE A RIGID CONNECTION. (ANY NON-ZERO $\frac{d(\text{length})}{dt}$ WOULD REQUIRE AN INFINITELY LARGE FORCE. THIS LENGTH IS CONSTANT.) EQ. (7.42) REDUCES TO $|y| = H$. THIS IS BECAUSE M IS IN THIS LIMIT RIGIDLY CONNECTED TO THE WHEEL.

CHAPTER 8 - EXERCISES

EX.

8.1 (a) IN STEADY STATE, VOLTAGE ACROSS INDUCTOR IS ZERO. THEREFORE $V_D(t=0^-) = 0$.

(b) $\bar{i}_1 = \bar{i}_{R_2}$ SINCE $V_D(t=0^-) = 0$ AND NO CURRENT FLOWS THROUGH R_1 .

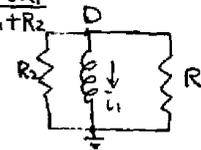
$$\therefore \bar{i}_1 = \bar{i}_{R_2} = \frac{V_0 - V_D}{R_2} = \frac{V_0}{R_2}$$

(c) CURRENT THROUGH L CANNOT CHANGE INSTANTANEOUSLY

(RULE 2). SO $i_1(t=0^+) = i_1(t=0^-) = \frac{V_0}{R_2}$

$$V_D = -\bar{i}_1 R_1 R_2 = -\bar{i}_1 \frac{R_1 R_2}{R_1 + R_2}$$

$$\therefore V_D(t=0^+) = -\frac{V_0 R_1}{R_1 + R_2}$$



d) FOR L , $V_D = L \frac{di_1}{dt}$ AT $t=0^+$ — (1)

BUT FROM OHM'S LAW $V_D = i_1 (R_1 // R_2)$

$$\Rightarrow \frac{di_1}{dt} = \frac{dV_D}{dt (R_1 // R_2)} \quad \text{--- (2)}$$

FROM (1) & (2)

$$V_D = \frac{L}{R_1 // R_2} \frac{dV_D}{dt}$$

$$\Rightarrow \frac{dV_D}{dt} = \frac{V_D}{L} (R_1 // R_2) = \frac{-V_0 R_1}{R_1 + R_2} \left(\frac{R_1 R_2}{L(R_1 + R_2)} \right)$$

$$= -\frac{V_0 R^2 R_2}{(R_1 + R_2)^2 L}$$