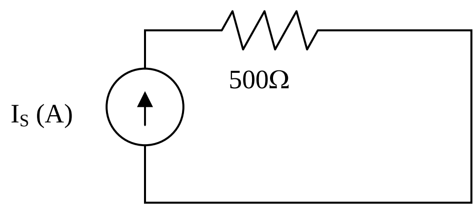
NAME:___SOLUTIONS______

EEE 202 **TEST 1** **Sep. 23, 2011**

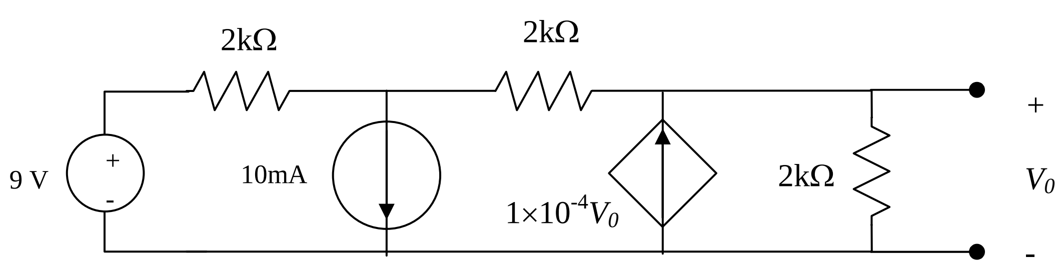
2 Problems, Equal Credit, Closed-book/notes

Problem 1. In the following circuit, the unknown current source provides 1W of power. Find the value of the source current "I_S."



$$P = I_s V_s, \qquad V_s = R I_s \Rightarrow P = R I_s^2 \Rightarrow I_s = \sqrt{\frac{1}{500}} = 0.045(A)$$

Problem 2. Develop a set of equations to compute V_0 in the following circuit. Express your answers in matrix form.



Nodal Analysis

After writing the nodal equations, we obtain the following matrix form

$$\begin{bmatrix} 1 & 0 & 0 \\ \frac{1}{2k} & -\frac{1}{2k}-\frac{1}{2k} & \frac{1}{2k} \\ 0 & \frac{1}{2k} & -\frac{1}{2k}-\frac{1}{2k}+1e-4 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 9 \\ 0.01 \\ 0 \end{bmatrix}, V_0 = V_3 = -4.23$$

Loop Analysis

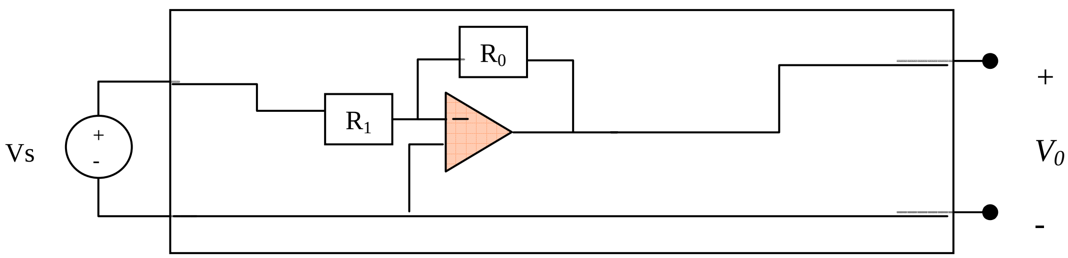
After writing the loop equations (one super-mesh), we obtain the following matrix form

$$\begin{bmatrix} 2k & 2k & 2k \\ 1 & -1 & 0 \\ 0 & -1 & 1-(1e-4)(2k) \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 9 \\ 0.01 \\ 0 \end{bmatrix}, V_0 = 2kI_3 = -4.23$$

EEE 202, TEST 2, 10/07/2011 **NAME:___SOLUTIONS___**

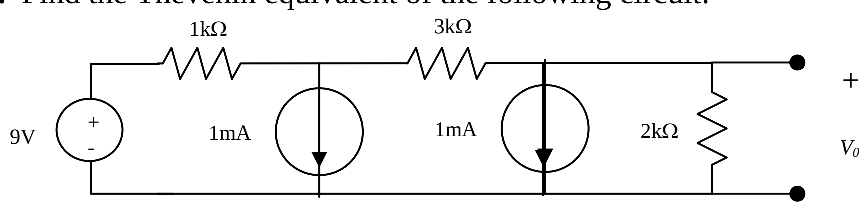
2 Problems, 30', Closed Book&Notes, 1 sheet of formulae allowed

Problem 1. The following op-amp amplifier with $R_1 = 1k\Omega$ and $R_0 = 50k\Omega$ is used to amplify a sensor voltage Vs in the range [0-1]mV. Find the output voltage V_0 and the maximum current drawn from the sensor, when Vs = 0.7mV.



$$V_0 = -\frac{R_0}{R_1}V_s = -(50)(0.7)mV = -35mV$$
$$i_s = \frac{(V_s - 0)}{R_1} = \frac{0.7m}{1k} = 0.7\mu A$$

Problem 2. Find the Thevenin equivalent of the following circuit:

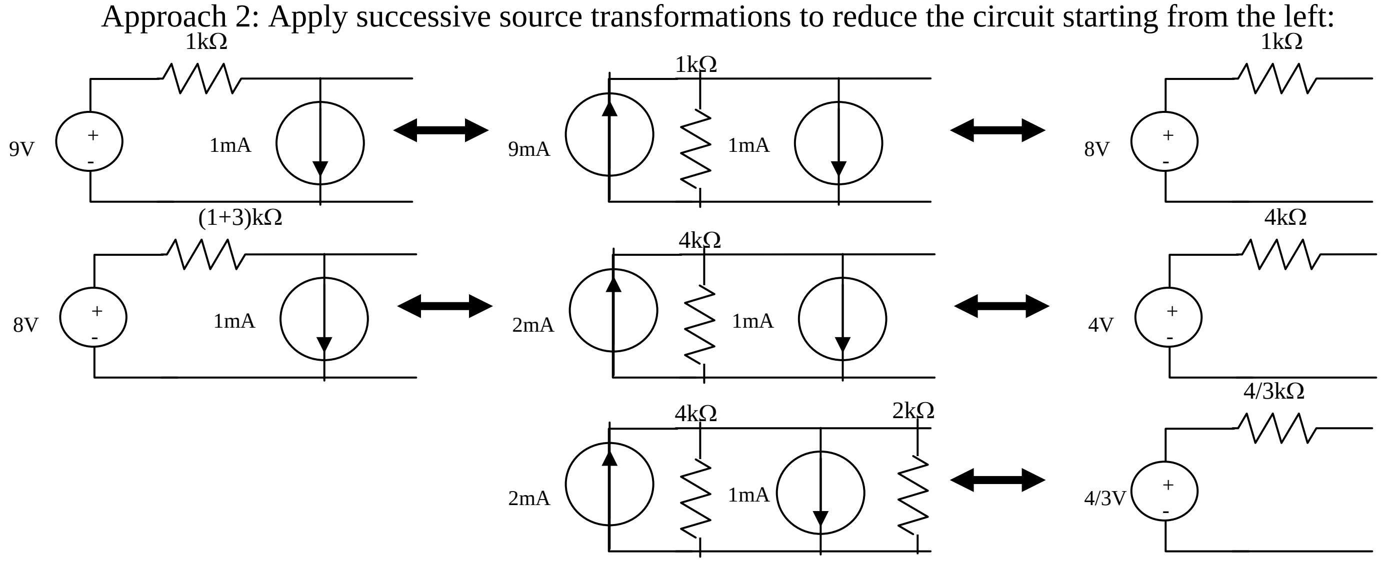


Approach 1: Apply Nodal analysis to find I_{sc}, shorting the 2k resistance. This is easier because the short reduces the number of nodes. There are 2 nodes, V_1=9V and V_2. We have

$$\frac{V_2 - 9}{1k} + \frac{V_2}{3k} + 1m = 0 \Rightarrow V_2 = 6$$

To compute I_{sc} observe that the current out of the 3k resistor is $V_2/3k = 1m + I_{sc}$, hence, I_{sc} = 1mA. Next, the Thevenin resistance of the circuit is (1k+3k)||2k = (4/3)kΩ. Hence, Voc = (4/3)V.

Approach 2: Apply successive source transformations to reduce the circuit starting from the left:



EEE 202: TEST 3 **NAME:____SOLUTIONS_______**

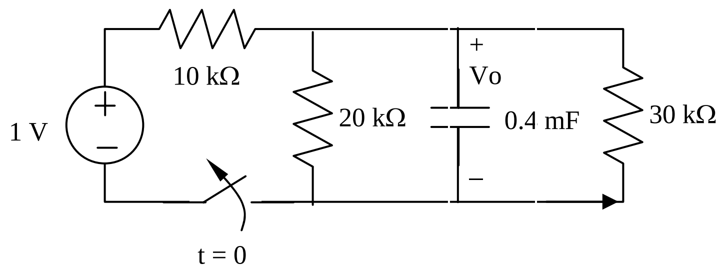
3 Problems, equal credit, 50', Closed Book&Notes, 1 sheet of formulae allowed

Problem 1.

1. A circuit voltage is described by $3\frac{dv}{dt} + 2v = 4\sin(t)$; $v(0)=1$. Find its time constant.

$$\mathrm{T} = \frac{3}{2} = 1.5(s)$$

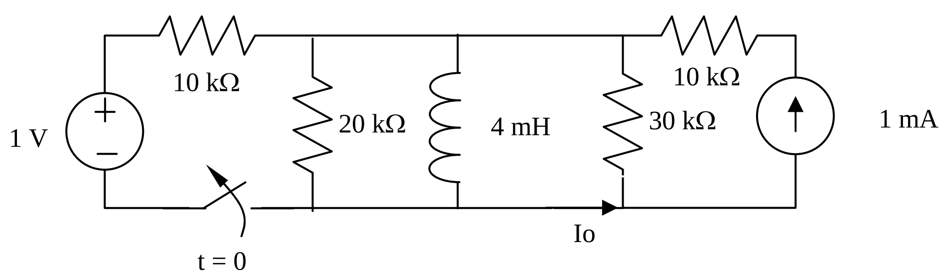
Problem 2. In the following circuit, find the voltage V_o for t > 0.



Vo is a continuous variable.

1. t < 0, From voltage division: $Vo(0) = \frac{20k||30k}{10k+(20k||30k)}Vs = \frac{12k}{10k+12k}1 = \frac{6}{11} = 0.55(V)$
2. t > 0, $Vo(\infty) = 0(V)$
3. t > 0, $R_{TH} = 20k||30k = 12k(\Omega) \Rightarrow T = R_{TH}C = 0.4m \times 12k = 4.8(s)$
4. t > 0, $Vo(t) = FV + (IC - FV)e^{-\frac{t}{R_{TH}C}} = 0.55e^{-\frac{t}{4.8}}(V)$

Problem 3. In the following circuit, find the current I_o for t > 0.



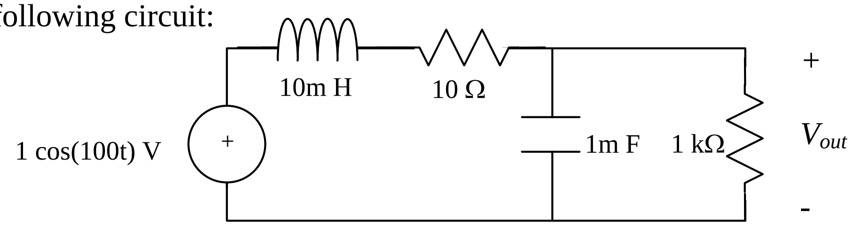
Io is a possibly discontinuous variable.

1. t < 0, Perform a source transformation of the voltage source (Is =0.1mV, Rs 10k||20k = 6.7k). Then, at steady-state, the inductor current is the sum of the two current sources $I_L(0) = 0.1m + 1m = 1.1m(A)$
2. t > 0, Replace inductor with a current source to find IC for Io: 3 loops with currents I1, I2, I3 (clock-wise, left-to-right), and loop equations $I1 - I2 = 1.1m, I3 = -1m, 6.7kI1 + 30k(I2 - I3) = 0$, from which, $Io(0) = -I2 = \frac{37.3}{36.7}m = 1.02m(A)$.
3. t > 0, Replace inductor with a short: $Io(\infty) = 1m(A)$, (i.e., all the current from the source).
4. t > 0, $R_{TH} = 20k||30k = 12k(\Omega) \Rightarrow T = \frac{L}{R_{TH}} = \frac{1}{3}\mu(s)$
5. t > 0, $Io(t) = 1m + 20\mu\, e^{-3Mt}(A)$ (where, M = 1e6).

EEE 202, TEST 4 **NAME:____SOLUTIONS____**

Closed-book/notes, 3 problems, equal credit, 1 sheet of formulae allowed

For the following circuit:



Problem 1: Find the steady-state voltage at the ~~100~~1000 Ohm resistor (Vout).

At 100rad/s: 10mH => j, 1mF => -10j, 1mF||1k => 0.1-10j

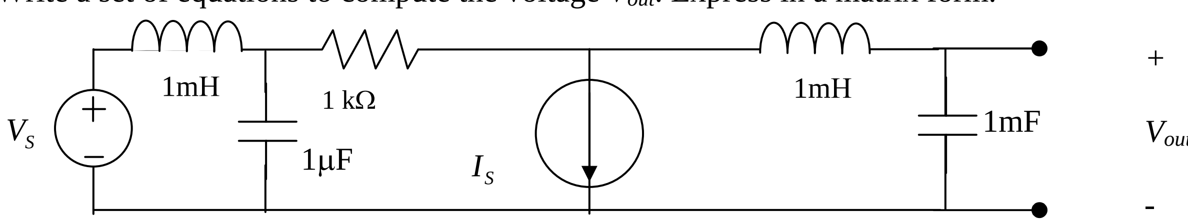
Voltage division: $V_{out} = 1\angle 0 \frac{0.1-10j}{j+10+0.1-10j} = 0.50 - 0.55j = 0.74\angle -48^o$

Problem 2: Find the average power dissipated by the ~~100~~1000 Ohm resistor.

Current: $I_R = \frac{V_{out}}{1k} = 0.74m\angle -48^o$

Power: $P_{av} = \frac{1}{2}\frac{|V_{out}||I_R|}{1k}cos(\theta_v - \theta_i) = \frac{1}{2}0.74^2 m = 0.27m(W)$

Problem 3. In the following circuit, $I_S(t) = 0.001\cos(100t)$ (A), $V_S(t) = 2\cos(100t+30^o)$ (V). Write a set of equations to compute the voltage V_{out}. Express in a matrix form.



$I_S = 0.001\angle 0, V_S = 2\angle 30^o, Z_L = j(100)(0.001) = j0.1, Z_{C1} = -j10k, R_{C2} = -j10$

Loop analysis:

$-2\angle 30 + I_1 j0.1 + (I_1 - I_2)(-j10k) = 0$

$I_2 - I_3 = 0.001\angle 0$ or

$(I_2 - I_1)(-j10k) + I_2(1k) + I_3(j0.1 - j10) = 0$

$V_{out} = I_4(-j10)$

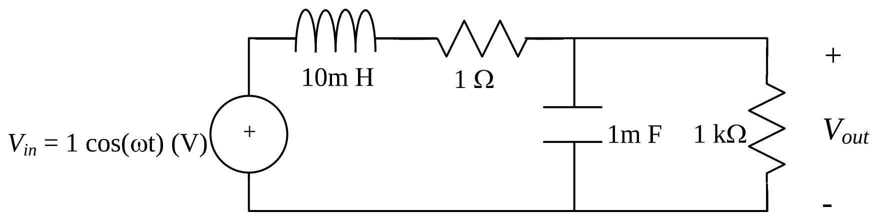
$$\begin{bmatrix} -j(10k-0.1) & j10k & 0 \\ 0 & 1 & -1 \\ j10k & 1k - j10k & -j9.9 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} -2e^{\frac{j\pi}{6}} \\ 1m \\ 0 \end{bmatrix} = \begin{bmatrix} -1.73 - j1.00 \\ 0.001 \\ 0 \end{bmatrix}$$

Computing in MATLAB, $V_{out} = (-10.2 + j27.2)m = 29.1m\angle 110.7^o(V)$

EEE 202, TEST 5 **NAME:____SOLUTIONS____**

Closed-book/notes, 2 problems, equal credit, 1 sheet of formulae allowed

Problem 1: For the following circuit



Find:

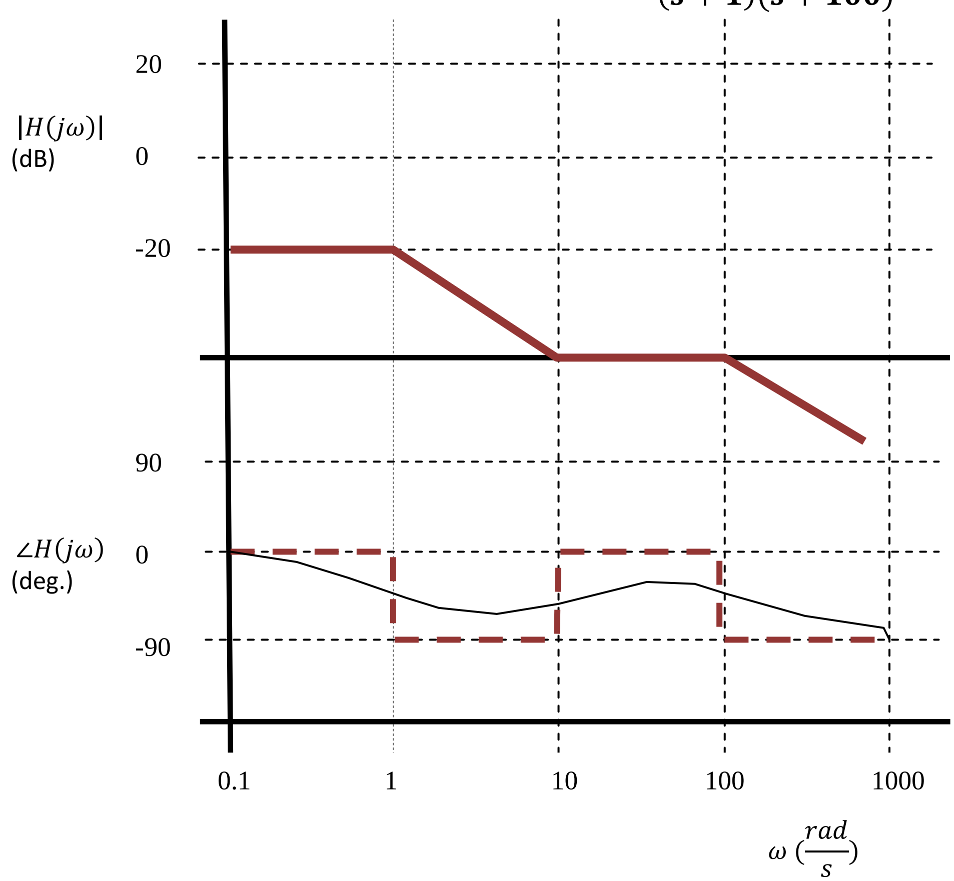
The transfer function $\frac{V_{out}}{V_{in}} = \frac{\left(sC+\frac{1}{R2}\right)^{-1}}{sL+R1+\left(sC+\frac{1}{R2}\right)^{-1}} = \frac{1}{(sL+R1)\left(sC+\frac{1}{R2}\right)\ \ +1} = \frac{1}{s^2LC+s\left(R1C+\frac{L}{R2}\right)+1+\frac{R1}{R2}} =$

$$\frac{1/LC}{s^2+s\left(\frac{R1}{L}+\frac{1}{R2C}\right)+\frac{1}{LC}\left(1+\frac{R1}{R2}\right)} = \frac{1/10\mu}{s^2+s\left(\frac{1}{10m}+\frac{1}{1k1m}\right)+\frac{1}{10m1m}\left(1+\frac{1}{1k}\right)} = \frac{100{,}000}{s^2+s(101)+100{,}100} = \frac{100{,}000}{s^2+s101+(316.4)^2}$$

- The resonant frequency $\omega_0 = 316.4(\text{rad/s})$
- The damping ratio $\zeta = \frac{101}{(2)(316.4)} = 0.16$
- The quality factor $Q = \frac{1}{2\zeta} = 3.13$

Problem 2: Sketch the Bode plot (magnitude and phase) for the transfer function

$$\boldsymbol{H(s) = \frac{s+10}{(s+1)(s+100)}}$$



Corner Frequencies
Zeros: 10
Poles: 1, 100
DC-gain: 1/10=-20dB

3.8 Find I_o in the network in Fig. P3.8 using nodal analysis.

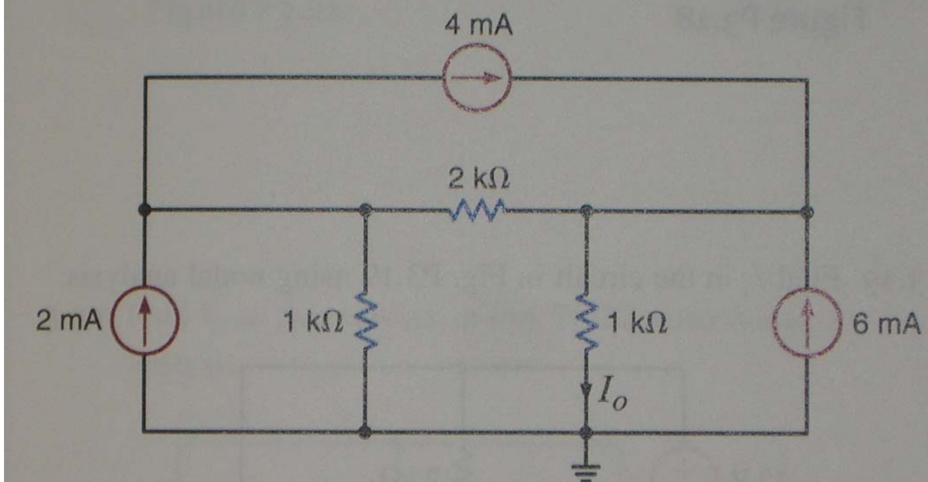


Figure P3.8

3.36 Find V_o in the network in Fig. P3.36 using nodal analysis.

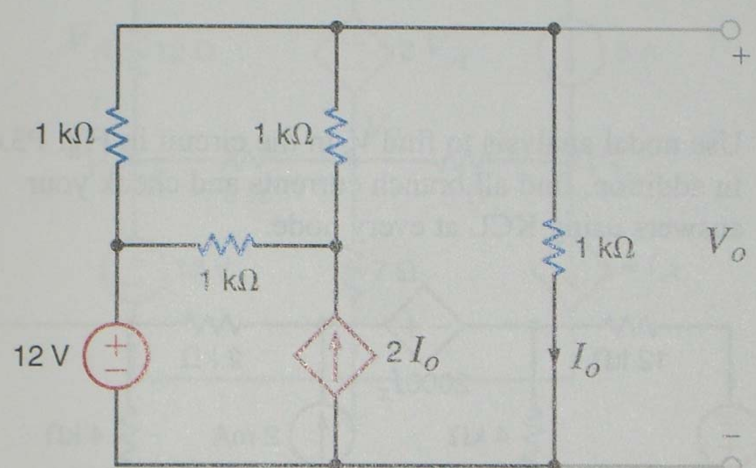


Figure P3.36

3.65 Find V_o in the network in Fig. P3.65 using loop analysis.

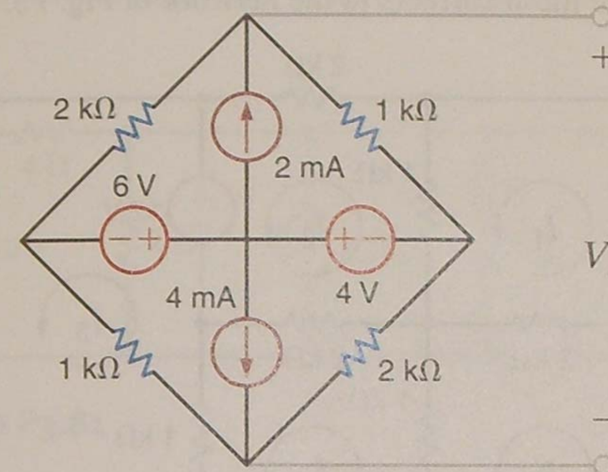


Figure P3.65

3.66 Find V_o in the circuit in Fig. P3.66 using loop analysis.

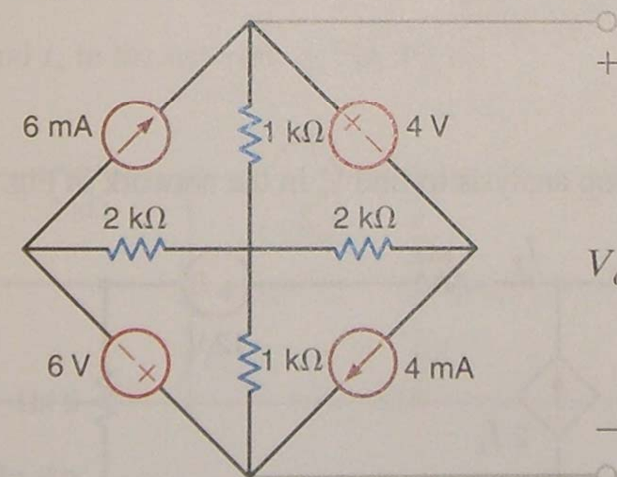
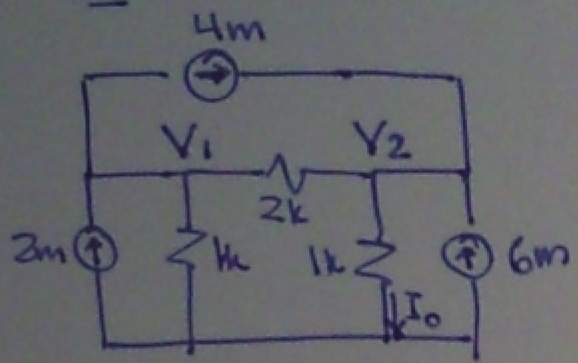


Figure P3.66

EEE202 HW 1.2 SOLUTIONS

3.8



$$2m - 4m - \frac{V_1}{1k} + \frac{V_2 - V_1}{2k} = 0$$

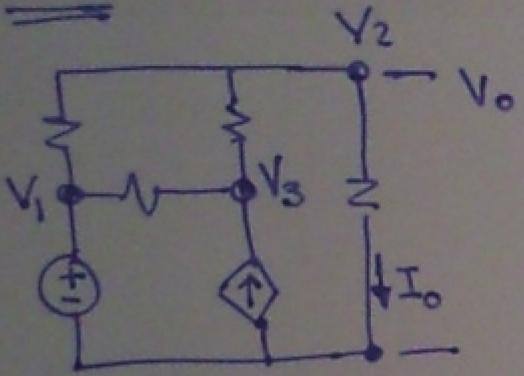
$$\frac{V_1 - V_2}{2k} - \frac{V_2}{1k} + 6m + 4m = 0$$

$$\begin{bmatrix} -\frac{1}{1k} - \frac{1}{2k} & \frac{1}{2k} \\ \frac{1}{2k} & -\frac{1}{1k} - \frac{1}{2k} \end{bmatrix} \begin{matrix} V_1 \\ V_2 \end{matrix} = \begin{bmatrix} 2m \\ -10m \end{bmatrix}$$

$$I_o = V_2/1k$$

$$\boxed{I_o = 7m\,(A)} \longleftarrow \overset{\Rightarrow}{(\text{MATLAB})} \begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} 1 \\ 7 \end{pmatrix} (V)$$

3.36



$$V_1 = 12$$

$$\frac{V_1 - V_2}{1k} + \frac{V_3 - V_2}{1k} + \frac{0 - V_2}{1k} = 0$$

$$\frac{V_1 - V_3}{1k} + 2I_o + \frac{V_2 - V_3}{1k} = 0$$

$$I_o = V_2/1k$$

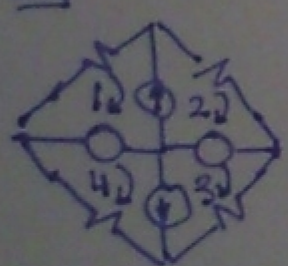
$$\boxed{V_o = V_2 = 12\,(V)} \longleftarrow$$

$$\rightarrow A \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = b$$

$$A = \begin{bmatrix} 1/1k & -1/1k - 1/1k - 1/1k & 1/1k \\ 1 & 0 & 0 \\ 1/1k & 1/1k + 2\,1/1k & -1/1k - 1/1k \end{bmatrix}$$

$$b = \begin{bmatrix} 0 \\ 12 \\ 0 \end{bmatrix} \Rightarrow \begin{pmatrix} V_1 \\ V_2 \\ V_3 \end{pmatrix} = \begin{bmatrix} 12 \\ 12 \\ 24 \end{bmatrix}$$

3.65



$$I_1 - I_2 = -2m$$

$$I_3 - I_4 = -4m$$

$$I_1 2k + I_2 1k + I_3 2k + I_4 1k = 0$$

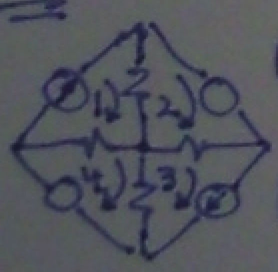
$$I_1 2k + I_2 1k - 4 + 6 = 0$$

$$V_o = I_2 1k + I_3 2k$$

$$\rightarrow \begin{bmatrix} 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ 2k & 1k & 2k & 1k \\ 2k & 1k & 0 & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} -2m \\ -4m \\ 0 \\ -2 \end{bmatrix} \Rightarrow \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} -\frac{4}{3}m \\ \frac{2}{3}m \\ -\frac{2}{3}m \\ \frac{10}{3}m \end{bmatrix}$$

$$\Rightarrow \boxed{V_o = -\tfrac{2}{3}\,(V)}$$

3.66



$$I_1 = 6m$$

$$(I_2 - I_1)1k + 4 + (I_2 - I_3)2k = 0$$

$$I_3 = 4m$$

$$(I_4 - I_1)2k + (I_4 - I_3)1k + 6 = 0$$

$$V_o = (I_1 - I_2)1k + (I_4 - I_3)1k$$

$$\rightarrow \begin{bmatrix} 1 & 0 & 0 & 0 \\ -1k & 1k+2k & -2k & 0 \\ 0 & 0 & 1 & 0 \\ -2k & 0 & -1k & 2k+1k \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} 6m \\ -4 \\ 4m \\ -6 \end{bmatrix} \Rightarrow \begin{matrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{matrix} = \begin{matrix} 6m \\ 3.55m \\ 4m \\ 3.33m \end{matrix}$$

$$\Rightarrow \boxed{V_o = 2\,(V)}$$

EEE202 HW1 SOLUTIONS

PR. 1.37 $P = 6 I_x$, where by KCL $I_x + 2 = 2I_x$.

$\Rightarrow I_x = 2A \Rightarrow P = 12W$, Absorbed

PR. 1.43 Perform a power balance:

$P_1 = 6 \times 8 = +48$, $P_2 = 4 \times 10 = +40$, $P_3 = I_o \times 6$

$P_4 = 2 \times 16 = +32$, $P_5 = 6 \times 1 = +6$. $P_6 = 8 \times 3 = 24$

Source 1 $= -24 \times 6 = -144$, Source 2 $-3 \times 4 I_x = -3 \times 8 = -24$

(all in W). $\Rightarrow I_o = 18/6 = 3(A)$.

PR. 2.35 $R_{eff} = \left(\frac{4}{4R} + \frac{1}{4R}\right)^{-1} = \frac{4R}{5}$, $100 \frac{5}{4R} = 50 \Rightarrow R = 2.5$ (Ω)

PR. 2.43 $P = I \cdot 2V_x$

KVL 1: $-20 + 10k\,I + 2V_x + 5kI - 10 + 2kI + 3kI + 10kI = 0$

KVL 2 $-V_x - 10 + 2kI + 3kI = 0$

$\Rightarrow V_x = -3.75$ (V)
$I = 1.25$ mA.
$\Rightarrow P = -9.375$ mW absorbed
($\Rightarrow$ 9.375 mW supplied)

PR. 2.46 KVL1: $-20 + 10I + 20I + V_2 = 0$
KVL2: $-V_1 + 20I + V_2 = 0$
$\Rightarrow I = 2$, $V_2 = -40$ (V)

PR. 2.48 Find the node voltage first: $12\text{ mA} \times (12k \| 12k \| 6k)$
$= 36V$

$\Rightarrow I_o = V/R = -36/12k = -3$ mA (notice current orientation)

PR. 2.58 Top half: $R_{eff} = 4 \| 0 \| 6 = 0$

Bottom half: $R_{eff} = 8 \| 0 \| (10+2) = 0$

$\Rightarrow R_{AB} = 0$

4.11 Assuming an ideal op-amp in Fig. P4.11, determine the value of R_X that will produce a voltage gain of 26.

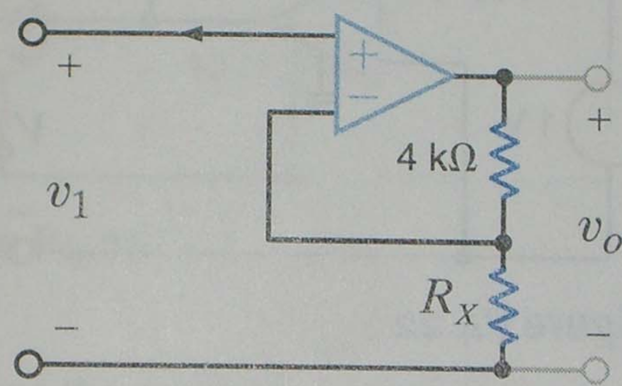


Figure P4.11

4.25 Determine the relationship between v_1 and i_o in the circuit shown in Fig. P4.25.

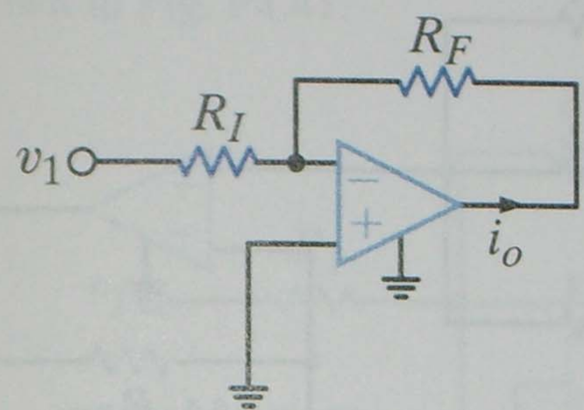


Figure P4.25

5.20 Use superposition to find V_o in the network in Fig. P5.20.

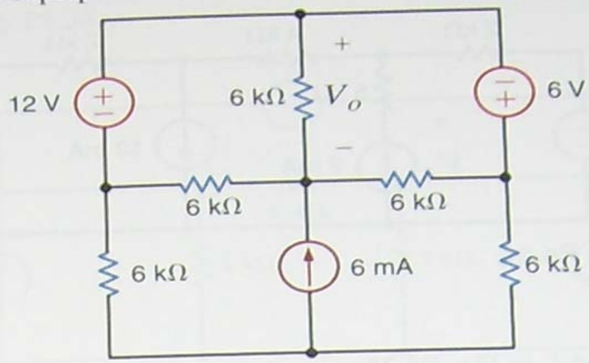


Figure P5.20

5.33 Use Thévenin's theorem to find I_o in the circuit using Fig. P5.33.

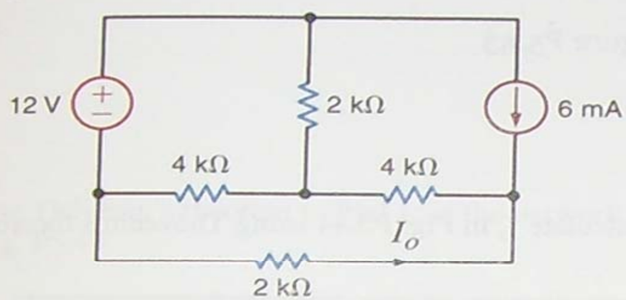


Figure P5.33

5.52 Use Norton's theorem to find I_o in the circuit in Fig. P5.52.

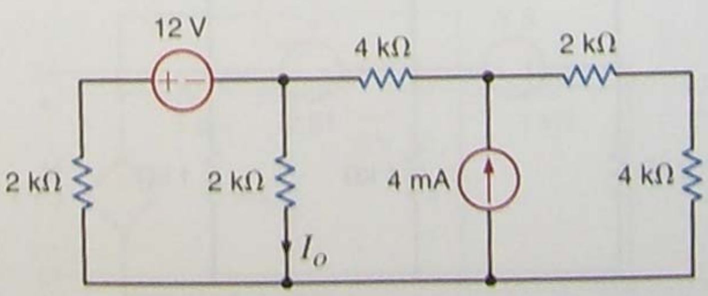


Figure P5.52

5.49 Given the linear circuit in Fig. P5.49, it is known that when a 2-kΩ load is connected to the terminals A–B, the load current is 10 mA. If a 10-kΩ load is connected to the terminals, the load current is 6 mA. Find the current in a 20-kΩ load.

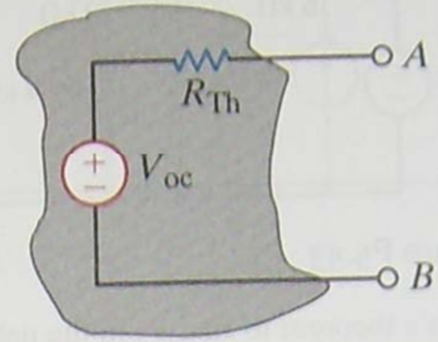


Figure P5.49

5.87 Find V_o in the network in Fig. P5.87 using source transformation.

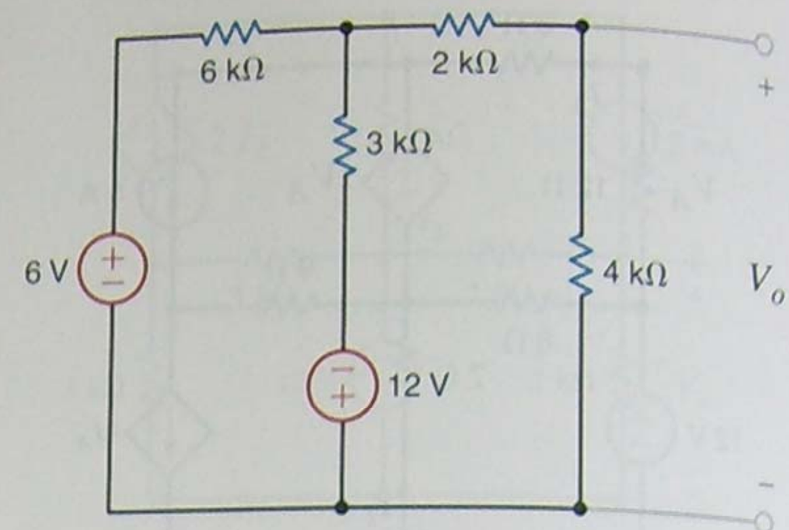


Figure P5.87

EEE 202 HW 2 SOLUTIONS

4.11 At the inverting node of the op-amp: $\dfrac{v_o - v_-}{4k} + \dfrac{0 - v_-}{R_x} = 0$

Under the ideal op-amp assumption $v_- = v_+ = v_1$

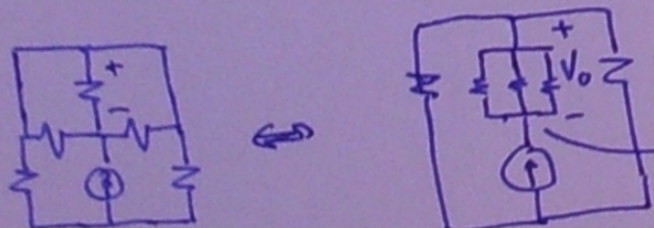
$\therefore\ v_o = 4K\left(\dfrac{1}{4K} + \dfrac{1}{R_x}\right) v_1 = 26\,v_1 \Rightarrow \dfrac{4k}{R_x} = 25 \Rightarrow \boxed{R_x = 160\,\Omega}$

4.25 Ideal Op amp : $v_- = v_+ = 0 \Rightarrow \dfrac{v_1 - 0}{R_1} + i_o = 0 \Rightarrow \boxed{i_o = -\dfrac{v_1}{R_1}}$

(For a constant voltage v_1, this becomes a constant current supply to a variable load R_F)

5.20 Superposition: Eliminate all sources except one at a time and add up the results.

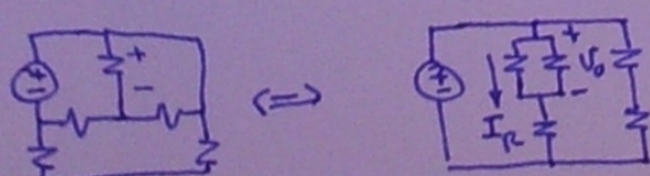
1).



$R_{eff} = 6k \| 6k \| 6k = 2k$

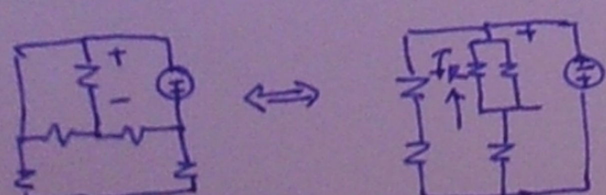
$\Rightarrow V_{o1} = -\ 6m\ 2k = -12V$

2).



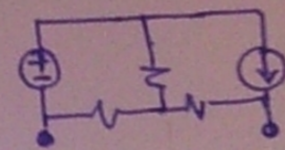
$I_R = \dfrac{12}{9k}$; $V_{o2} = I_R \cdot 3k = 4V$

3)



$I_R = \dfrac{6}{9k}$; $V_{o3} = -\dfrac{6}{9k} \cdot 3k = -2V$

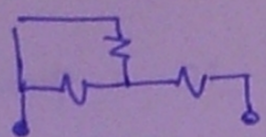
$\therefore\ v_o = v_{o1} + v_{o2} + v_{o3} \Rightarrow \boxed{v_o = -10\ V}$

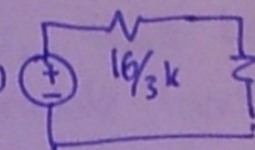
5.33 Find the Thevenin equivalent of 

E.g. use loop analysis I_1 I_2

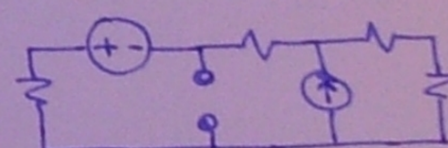
$$-12 + 2k(I_1 - I_2) + 4k I_1 = 0 \Big\} \Rightarrow I_1 = 4m$$
$$I_2 = 6m$$

$\Rightarrow$ $V_{oc} = -I_1 4k - I_2 4k = -40\,(V)$.

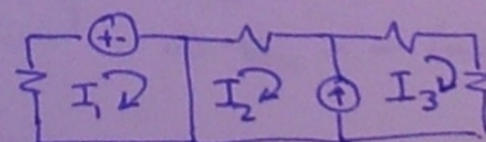
$\Rightarrow$ R_{TH} :  $= \left(\frac{1}{2k} + \frac{1}{4k}\right)^{-1} + 4k = \frac{16}{3}k\,(\Omega)$

Applying to the circuit : 

$$I = \frac{-40}{2k + \frac{16}{3}k} = -\frac{60}{11}m\,(A) = -5.45\,mA.$$

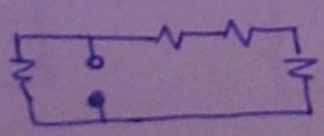
5.52 Find the Norton equivalent of 

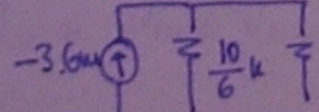
$\Rightarrow$ short the terminals to compute I_{sc}

e.g. loop analysis : 

$$I_{sc} = I_1 - I_2$$
$$2kI_1 + 12 = 0$$
$$4k I_2 + 2k I_3 + 4k I_3 = 0$$
$$I_3 - I_2 = 4m$$

e.g. MATLAB $\Rightarrow$ $I_{sc} = -3.6\,m(A)$

$\Rightarrow$ R_{TH} :  $R_{TH} = 2k \,\|\, (2k + 4k + 4k) = \frac{10}{6}k\,(\Omega)$

Applying to the circuit : 

Using current division

$$I_o = -3.6m \frac{10/6\,k}{10/6\,k + 2k} = -\frac{36}{22}m$$

$$\boxed{I_o = -1.64\,mA}$$

5.49

1. $R_L = 2k \quad I = 10m(A) = \dfrac{V_{oc}}{R_{TH} + 2k}$

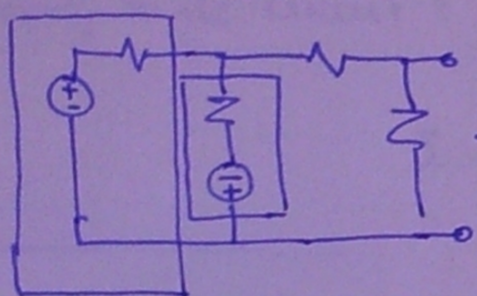
2. $R_L = 10k \quad I = 6m(A) = \dfrac{V_{oc}}{R_{TH} + 10k}$

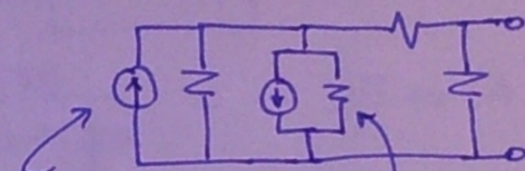
$\Rightarrow R_{TH} = 10k\ (\Omega)$

$\Rightarrow V_{oc} = 120\ (V)$

$\therefore$ for $R_L = 20k$, $\boxed{I = \dfrac{120}{10k + 20k} = 4\,mA}$

5.87 Source Transformations as indicated

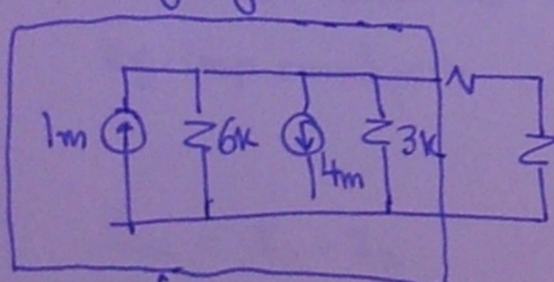


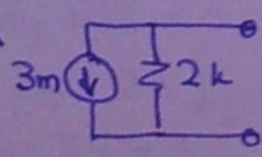


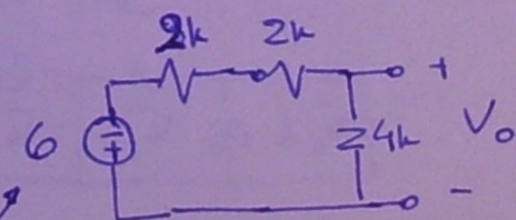
$I_1 = 6/6k = 1m \qquad I_2 = \dfrac{12}{3k} = 4m$

$R_1 = 6k \qquad R_2 = 3k$

Rearranging







$V = 3m \cdot 2k$

Applying Voltage division, $V_o = -6 \cdot \dfrac{4k}{2k + 2k + 4k} = -\dfrac{24}{8}$

$\Rightarrow \boxed{V_o = -3\ (V)}$

6.13 The current flowing through a 5-μF capacitor is shown in Fig. P6.13. Find the energy stored in the capacitor at $t = 1.4$ ms, $t = 3.3$ ms, $t = 4.3$ ms, $t = 6.7$ ms, and $t = 8.5$ ms.

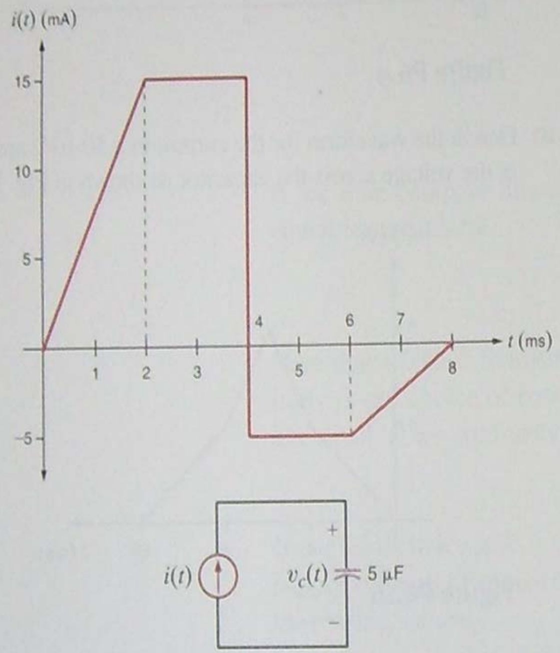


Figure P6.13

6.55 Determine C_T in the circuit in Fig. P6.55 if all capacitors in the network are 6 μF.

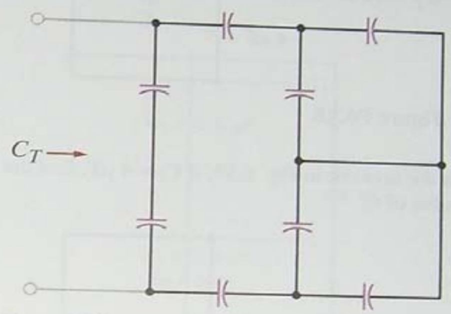


Figure P6.55

6.56 Find C_T in the circuit in Fig. P6.56 if all capacitors are 6 μF.

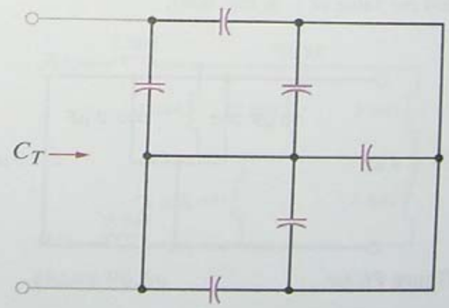


Figure P6.56

7.46 Find $i_o(t)$ for $t > 0$ in the network in Fig. P7.46 using the step-by-step method.

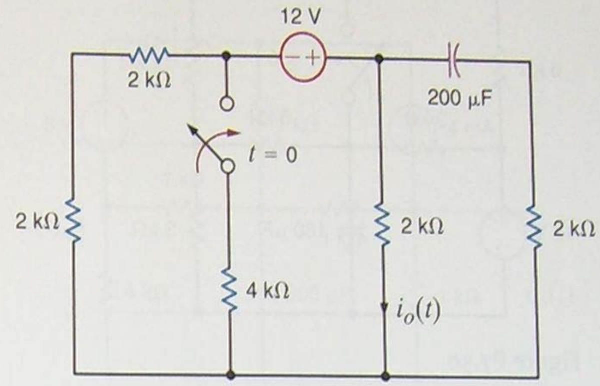
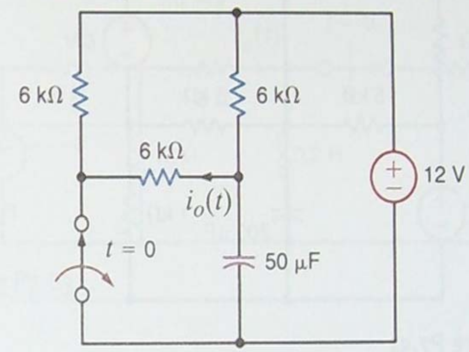


Figure P7.46

7.47 Use the step-by-step method to find $i_o(t)$ for $t > 0$ in the network in Fig. P7.47.



6.27 The voltage across a 2-H inductor is given by the waveform shown in Fig. P6.27. Find the waveform for the current in the inductor.

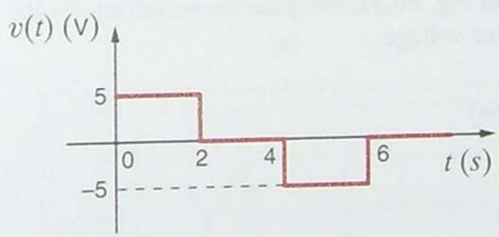


Figure P6.27

6.47 Calculate the energy stored in both the inductor and the capacitor shown in Fig. P6.47.

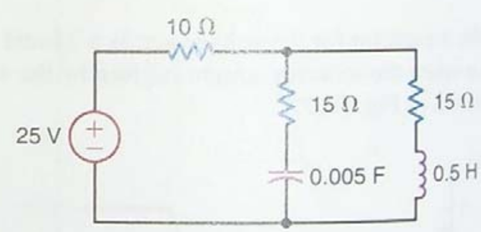


Figure P6.47

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6.13 $i = C\frac{dv}{dt}$ or $v(t) = \frac{1}{C}\int_{-\infty}^{t} i(\tau)d\tau = v(t_0) + \frac{1}{C}\int_{t_0}^{t} i(\tau)d\tau$

$\therefore$ for $t \in [0, 2m]$, $v(t) = \frac{1}{5\mu}\int_0^t \frac{15}{2}\tau\, d\tau = \underline{7.5E5\, t^2}$ (in V)

at $t = 2ms$, $v(2m) = 3V$

for $t \in [2m, 4m]$ $v(t) = v(2m) + \frac{15m}{5\mu}(t-2m) = \underline{3 + 3E3(t-2m)}$

at $t = 4ms$, $v(4m) = 9V$

for $t \in [4m, 6m]$ $v(t) = v(4m) - \frac{5m}{5\mu}(t-4m) = 9 - 1E3(t-4m)$

at $t = 6m$, $v(6m) = 7V$

for $t \in [6m, 8m]$ $v(t) = v(6m) + \frac{1}{5\mu}\cdot\left[\frac{5m}{2m}\frac{(t-6m)^2}{2} - 5m(t-6m)\right]$

$= 7 + \frac{1}{4}E6(t-6m)^2 - 1E3(t-6m)$

at $t = 8$, $v(8) = 6V$

The energy stored in the capacitor is $\frac{1}{2}Cv^2$, so

at $t = 1.4ms$, $v(1.4m) = 1.47 \rightarrow E = \frac{1}{2}5\mu \cdot 1.47^2 = \underline{5.4\mu J}$

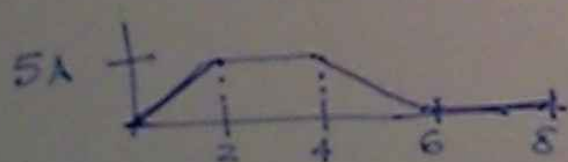
$t = 3.3ms$, $v(3.3m) = 6.9 \rightarrow \underline{E = 119\ \mu J}$

$t = 4.3ms$, $v(4.3m) = 8.7 \Rightarrow \underline{E = 189\ \mu J}$

$t = 6.7ms$, $v(6.7m) = 6.42 \Rightarrow \underline{E = 103\ \mu J}$

$t = 8.5ms$, $v(8.5m) = 6 \rightarrow \underline{E = 90\mu J}$

6.27 $v(t) = L\frac{di}{dt}$ or $i = \frac{1}{L}\int v \Rightarrow$ the graph for $i(t)$ is



To find the peak, we note that the slope is $V/L = 5/2$ so

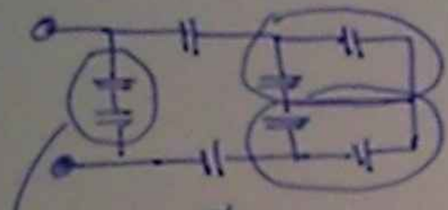
$\frac{1}{2}\int_0^2 5\, dt = 5$ (A)

6.47

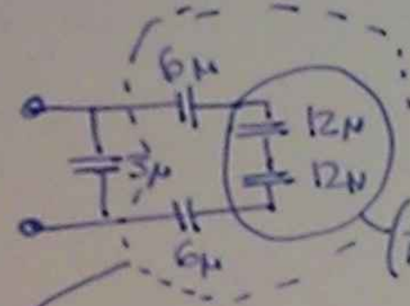
$$V_C = \frac{15}{15+10}\,25 = 15(V) \Rightarrow E_C = \frac{1}{2}CV^2 = \frac{1}{2}\cdot 5\mathrm{E}{-3}\cdot 15^2 = 0.56\,J$$

$$I_L = \frac{25\,(V)}{(10+15)(\Omega)} = 1\,(A) \Rightarrow E_L = \frac{1}{2}LI^2 = \frac{1}{2}\,0.5\cdot 1^2 = 0.25\,J$$

6.55



$6\mu + 6\mu = 12\mu$ $\longrightarrow$



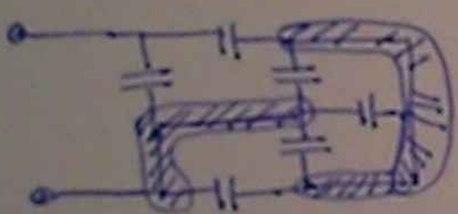
$\left(\frac{1}{6\mu}+\frac{1}{6\mu}\right)^{-1} = 3\mu$

$\left(\frac{1}{12\mu}+\frac{1}{12\mu}\right)^{-1} = 6\mu$

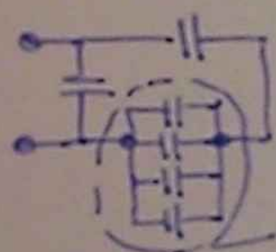
$\left(\frac{1}{6\mu}+\frac{1}{6\mu}+\frac{1}{6\mu}\right)^{-1} = 2\mu$

$$\Rightarrow C_{eff} = 3\mu + 2\mu = \underline{\underline{5\,\mu F}}$$

6.56

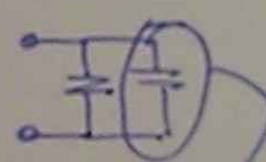


$\longrightarrow$



$4\times 6\mu$

$\longrightarrow$



$\left(\frac{1}{24\mu}+\frac{1}{6\mu}\right)^{-1} = \frac{24}{5}\mu$

$$\Rightarrow C_{eff} = \frac{24}{5}\mu + 6\mu = \underline{\underline{\frac{54}{5}\,\mu F}}$$

7.46

The step-by-step method for discontinuous variables (i.e. other than capacitor voltages and inductor currents) can be described as follows

I. Solve for v_C (or i_L) & Replace Cap (or Ind.) by a voltage (or current) source $v_C(t)$ (or $i_L(t)$) and solve the resulting circuit.

II. 1) Find $v_C(0^-)$ (or $i_L(0^-)$) with the $t<0$-circuit.

2) Set $v_C(0^+) = v_C(0^-)$ (or $i_L(0^+) = i_L(0^-)$) and substitute the capacitor with a voltage source $v_C(0^+)$ (or, the inductor with a current source $i_L(0^+)$).

3) Compute the initial condition for the variable of interest, say x, such that $x(0^+)$ = value for the $t>0$-circuit (with the caps replaced by voltage sources).

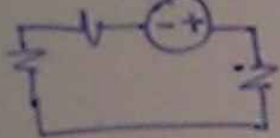
4). Compute $x(\infty)$ for the $t>0$ circuit

5) Compute R_{TH} as seen by the capacitor (or inductor) for the $t>0$ circuit.

6) $x(t) = x(\infty) + [x(0) - x(\infty)]\, e^{-t/\tau}$; $\tau = R_{TH}C$ (or R_{eq}/L).

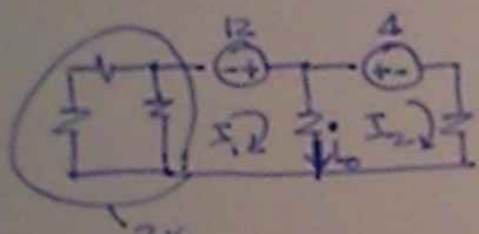
For our problem,

1) $t<0$



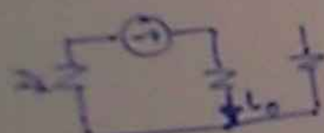
$$V_{0^-} = \frac{2k}{6k}\, 12 = 4\,V$$

3) $t>0$



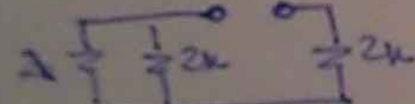
$$I_1\, 2k - 12 + 2k\,(I_1 - I_2) = 0$$
$$4 + 2k\,I_2 + 2k\,(I_2 - I_1) = 0$$
$$\Rightarrow I_1 = \frac{10}{3}\,mA,\quad I_2 = \frac{4}{6}\,mA$$
$$\rightarrow \underline{i_0(0^+) = I_1 - I_2 = 8/3\,mA}$$

4) $t>0$



$$\Rightarrow i_0(\infty) = \frac{12}{4k} = 3\,mA$$

5) $t>0$



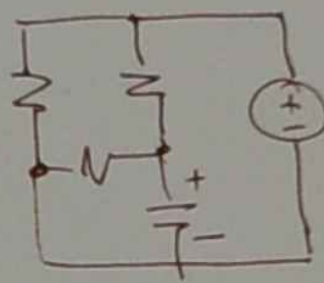
$$\Rightarrow R_{TH} = \left(\frac{1}{2k} + \frac{1}{2k}\right)^{-1} + 2k = 3k\,\Omega$$

6). $i_0(t) = 3m + \left(8/3\,m - 3m\right) e^{-t/0.6}$ (A)

where $0.6 = \tau = R_{eq} \cdot C = 3k\ 200\mu = 600\ ms$

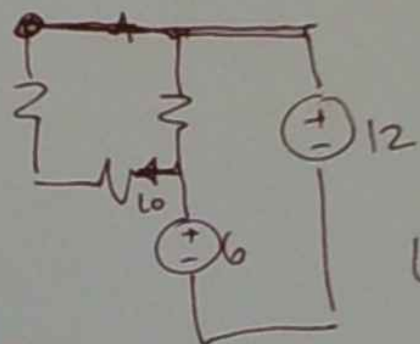
7.47

$t<0$



$$V_c(0)=\frac{(12)(6k)}{6k+6k}=6\,(V)$$

$t>0$

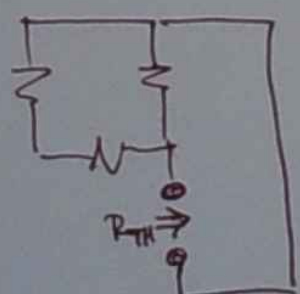


$$i_o(0)=-\frac{(12-6)}{6k+6k}$$

$$=\frac{1}{2}\,mA$$

$t>0 \qquad i_o(\infty)=0$

$$\Rightarrow\ i_o(t)=\frac{1}{2}m\,e^{-t/\tau} \qquad \tau=R_{TH}C=200m=0.2\,s$$



$$R_{TH}=6k\,\|\,(6k+6k)=4k$$

$$C=50\mu \ \Rightarrow\ \tau=200\,ms$$

8.28 Calculate $v_C(t)$ in Fig. P8.28.

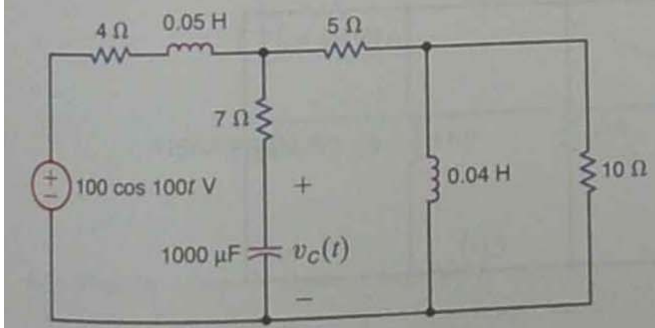


Figure P8.28

8.30 Find $v_o(t)$ and $i_o(t)$ in Fig. P8.30.

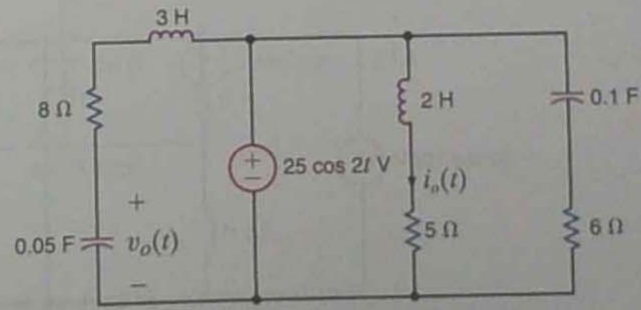


Figure P8.30

8.48 In the network in Fig. P8.48, $\mathbf{I}_o = 4\,\underline{/0°}$ A. Find $\mathbf{I}_x$.

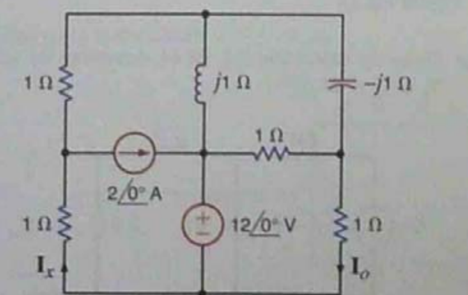


Figure P8.48

8.71 Use loop analysis, to find $\mathbf{V}_o$ in the circuit in Fig. P8.71.

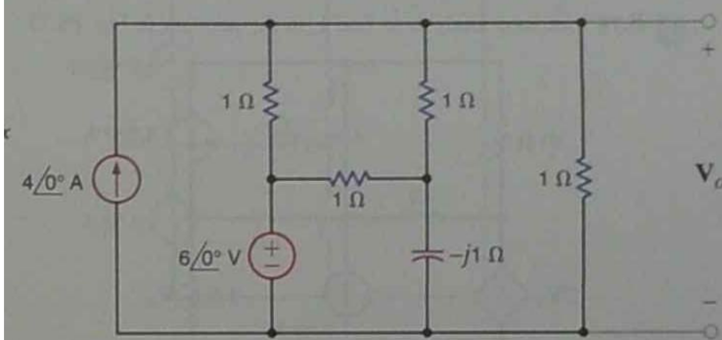


Figure P8.71

8.47 In the network in Fig. P8.47, $\mathbf{V}_o$ is known to be $4\,\underline{/45°}$ V. Find **Z**.

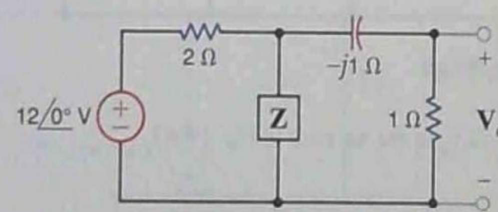


Figure P8.47

9.28 Determine the average power absorbed by the 2-kΩ output resistor in Fig. P9.28.

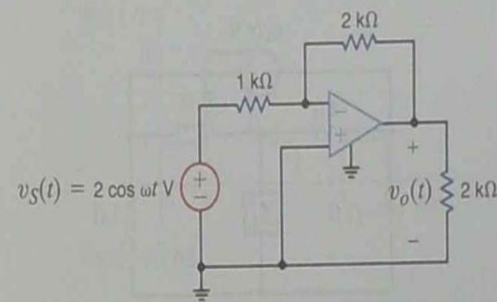


Figure P9.28

9.8 Find the instantaneous power supplied by the source in the network in Fig. P9.8.

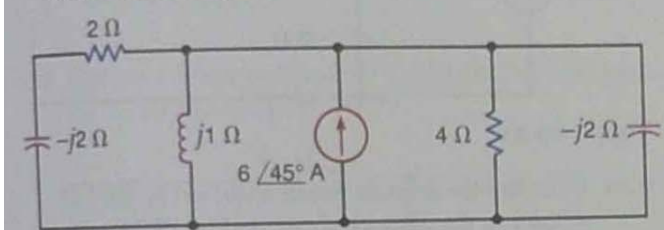


Figure P9.8

9.12 Find the average power absorbed by the 2-Ω resistor in the network in Fig. P9.12 and the total power supplied.

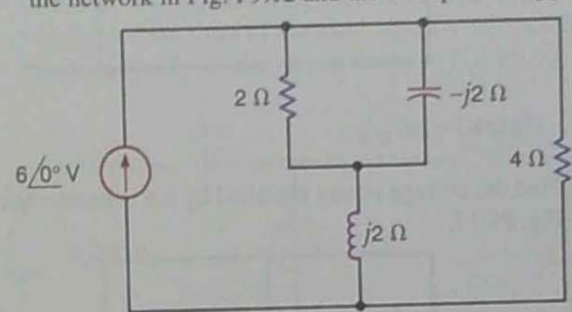


Figure P9.12

9.29 Determine the impedance $\mathbf{Z}_L$ for maximum average power transfer and the value of the maximum power transferred to $\mathbf{Z}_L$ for the circuit shown in Fig. P9.29.

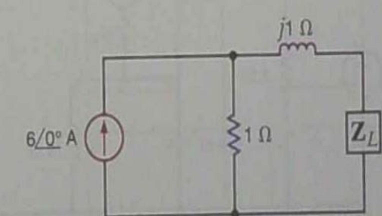


Figure P9.29

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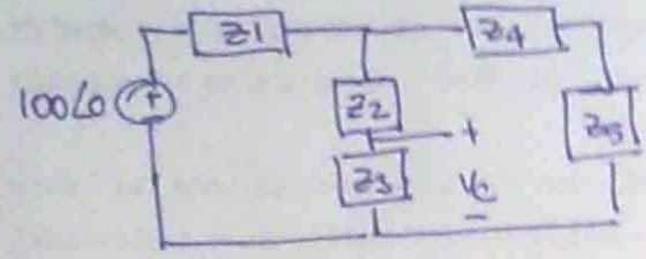
8.28



where: $Z_1 = 4 + 0.05j\,100$

$Z_2 = 7$

$Z_3 = 1/j\,100\,1000\,E{-6}$

$Z_4 = 5$

$Z_5 = \left(\frac{1}{0.04j\,100} + \frac{1}{10}\right)^{-1}$

Then, $V_c = Z_3(I_1 - I_2)$

$$-100\angle 0 + Z_1 I_1 + (Z_2 + Z_3)(I_1 - I_2) = 0$$

$$(Z_4 + Z_5)\, I_2 + (Z_3 + Z_2)(I_2 - I_1) = 0$$

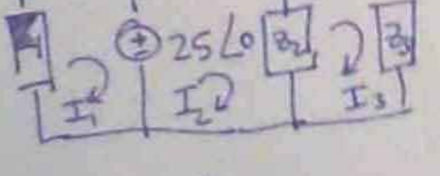
$$\Rightarrow \begin{bmatrix} Z_1 + Z_2 + Z_3 & -Z_3 - Z_2 \\ -Z_3 - Z_2 & Z_2 + Z_3 + Z_4 + Z_5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 100 \\ 0 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 8.06 - 4.01j \\ 4.19 - 6.07j \end{bmatrix} \Rightarrow V_c = 20.6 - 38.7j$$

$$= 43.8\angle -62^\circ$$

$$\Rightarrow \boxed{V_c(t) = 43.8\cos(100t - \underbrace{62^\circ}_{-1.08\text{ rad}})}$$

8.30



where: $Z_1 = 8 + 3j\,2 + \frac{1}{j\,2\cdot 0.05}$

$Z_2 = 2j\,2 + 5$

$Z_3 = \frac{1}{j\cdot 0.1\cdot 2} + 6$

$V_o = \frac{1}{j2\cdot 0.05}(-I_1)$

$I_o = I_2 - I_3$

$= 25\angle 0 \cdot \frac{1}{Z_2}$

$+ Z_1 I_1 + 25\angle 0 = 0$

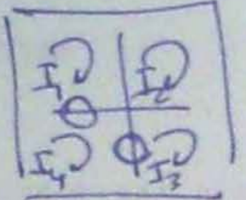
$\Rightarrow V_o = \frac{25\angle 0}{j\cdot 2\cdot 0.05}\cdot\frac{1}{Z_1}$

$\Rightarrow V_o = 12.5 - 25j = 28\angle -63.4^\circ$

$I_o = 3.05 - 2.44j = 3.9\angle -38.7$

$$\Rightarrow \boxed{\begin{aligned} V_o(t) &= 28\cos(2t - 63.4^\circ) \\ i_o(t) &= 3.9\cos(2t - 38.7^\circ) \end{aligned}}$$

8.48



$-I_1 + I_4 = 2\angle 0$

$I_2(-j) + (I_2 - I_3)1 + (I_2 - I_1)j = 0$

CAN SIMPLIFY to $I_x = I_3$ from problem data

$(I_3 - I_2)1 + I_3 \cdot 1 - 12\angle 0 = 0$

$I_1 \cdot 1 + (I_1 - I_2)j + 12\angle 0 + I_4 \cdot 1 = 0$

$I_x = I_4$

$$\Rightarrow \begin{bmatrix} -1 & 0 & 0 & 1 \\ -j & -j+1+j & -1 & 0 \\ 0 & -1 & 1+1 & 0 \\ 1+j & -j & 0 & 1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} 2 \\ 0 \\ 12 \\ -12 \end{bmatrix} \Rightarrow \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} 2.59 + 3.65j \\ 4.71 - 5.18j \\ 8.35 - 2.59j \\ -0.59 + 3.65j \end{bmatrix}$$

$\Rightarrow I_x = 3.69 \angle 99.2^\circ$

NOTE: - Real part $< 0 \Rightarrow$ 180° correction is needed
- I_3 is NOT as given (obviously a typo)

8.47

$V_o = V_z \cdot \dfrac{1}{1-j}$ (V_z: voltage across z)

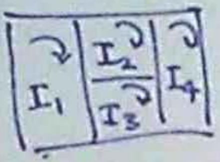
$V_z = V_s \cdot \dfrac{z \parallel (1-j)}{2 + (z \parallel (1-j))}$ (V_s: voltage of source)

$\Rightarrow 12(z \parallel (1-j)) = (1-j)(4\angle 45)(2 + (z \parallel (1-j)))$

$\Rightarrow z \parallel (1-j) = \dfrac{2(1-j)(4\angle 45)}{12 - (1-j)(4\angle 45)} = 1.78$

$\Rightarrow \left(\frac{1}{z} + \frac{1}{1-j}\right)^{-1} = 1.78 \Rightarrow \boxed{z = 0.24 + 1.97j = 1.98\angle 83^\circ}$

8.71



$$I_1 = 4\angle 0$$
$$(I_2 - I_1)\cdot 1 + (I_2 - I_4)\cdot 1 + (I_2 - I_3)\cdot 1 = 0$$
$$-6\angle 0 + (I_3 - I_2)\cdot 1 + (I_3 - I_4)\cdot(-j) = 0$$
$$(I_4 - I_3)(-j) + (I_4 - I_2)\cdot 1 + I_4 \cdot 1 = 0$$

$$V_0 = I_4 \cdot 1$$

$$\Rightarrow \begin{bmatrix} 1 & 0 & 0 & 0 \\ -1 & 1+1+1 & -1 & -1 \\ 0 & -1 & 1-j & j \\ 0 & -1 & j & -j+1+1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} 4 \\ 0 \\ 6 \\ 0 \end{bmatrix} \Rightarrow \begin{matrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{matrix} = \begin{matrix} 4 \\ 5.29 + 0.82j \\ 7.18 + 3.29j \\ 4.71 - 0.82j \end{matrix}$$

$$\Rightarrow V_0 = 4.71 - 0.82j = 4.78\angle -9.9^\circ$$

9.8

$$Z_{eff} = \left(\frac{1}{-j2} + \frac{1}{4} + \frac{1}{j1} + \frac{1}{2-j2} \right)^{-1} = 1.6 + 0.8j = 1.79\angle 26.6^\circ$$

$$\Rightarrow V_s = I_s Z_{eff} = (6\angle 45)(1.79\angle 26.6) = 10.73\angle 71.6$$

$\Rightarrow$ Source Power $P(t) = -\ V_s(t)\, i_s(t)$ ($-$: supplied power)

$$= -6\cos(\omega t + 45)\cdot 10.73\cos(\omega t + 71.6) \quad (W)$$

Notes:

1. $P(t)$ is not represented by a phasor, it is a product of $\cos \omega t$ - terms.
2. The product of the phasors V_s and I_s is not Power
3. ω here is not given
4. The average power is $P_{AV} = \dfrac{|V_s||I_s|}{2} \cos(\angle V_s - \angle I_s)$

$$\Rightarrow P_{AV} = \frac{1}{2}\, 6 \times 10.73 \cos(26.6) = 28.79 \ (W)$$

9.8 $z_{eff} = 1.79\angle 26.6$

$$\cancel{V}_S = (6\angle 45)\cdot(1.79\angle 26.6) = 10.73\angle 71.6$$

$$P(t) = V(t)I(t) = 6\cos(\omega t+45)\cdot 10.73(\cos(\omega t+71.6))$$

$$= 64.4\cos(\omega t+45)\cos(\omega t+71.6)$$

Note $V\cdot I$ the product of phasors is not P.

$$P_{AV} = \frac{1}{2}64.4\cos(45-71.6)$$

$$= \frac{1}{2}64.4\cos(26.6) = 28.79$$

$$P_R = \frac{1}{2}\cdot 10.73^2\cdot\frac{1}{4} = 14.39$$

---

2 cos

OpAmp : $V_o = -\frac{2k}{1k}V_s$

$$I_o = V_o/2k$$

$$\frac{1}{2}|V_o||I_o|\cdot\cos(\angle V_o-\angle I_o)$$

$|V_s| = 2$

$$= \frac{1}{2}\left|\frac{2k}{1k}\right||V_s|\cdot\left|\frac{2k}{1k}V_s\right|\cdot\frac{1}{2k}$$

$$= \frac{1}{2}|2V_s||2V_s|\cdot 1/2k$$

$$\frac{1}{2}4\cdot 4\cdot 1/2k = 1/1k\ (w) = 1mW$$

9.12 $Z_{TOT} = \left(\frac{1}{4}+\frac{1}{Z_1}\right)^{-1} = \cdots = 0.92+0.62j$

$$Z_1 = j2 + \left(\frac{1}{2}+\frac{1}{-2j}\right)^{-1} = 1+j$$

Source Voltage: $V_s = I_s Z_{TOT} = 5.54+3.69j = 6.66\angle 33.7°$

Avg. Pow source: $P_s = -\frac{1}{2}\cdot|V_s||I_s|\cdot\cos(\angle V_s - \angle I_s) = -\frac{1}{2}(6.66)(6)\cos(33.7°)$

$$= \boxed{-16.6}\ (W)$$

AvG Pow 4Ω: $P_{4\Omega} = \frac{1}{2}|V_{4\Omega}||I_{4\Omega}| \cos 0° = \frac{1}{2}|V_s|\left|\frac{V_s}{4}\right| = 5.54\ (W)$

RESISTANCE

$\Rightarrow$ AvG Pow 2Ω $= P_{2\Omega} = -(P_S+P_4) = \boxed{11.08\ (W)}$

Alt. Computation:

$$V_{2\Omega} = V_s \frac{(1/2 - 1/2j)^{-1}}{2j+(1/2-1/2j)^{-1}} = 3.69-5.54j$$

$$I_{2\Omega} = V_{2\Omega}/R$$

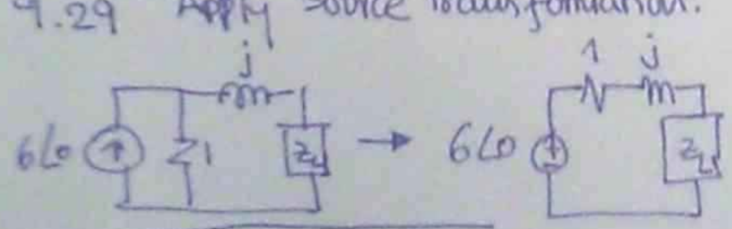
$$P_{2\Omega} = \frac{1}{2}|V_{2\Omega}||I_{2\Omega}|\cos 0 = 11.08\ (W)$$

9.28 For an ideal opamp, $V_o = -\frac{2k}{1k}V_s \Rightarrow I_o = V_o\cdot\frac{1}{2k}$

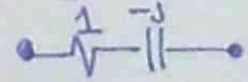
AVG Pow: $P = \frac{1}{2}|V_o||I_o|\cdot\cos 0 = \frac{1}{2}\cdot 4\cdot 4/2k = \boxed{4m\ (W)}$

RESISTIVE LOAD

9.29 Apply source transformation:



$\Rightarrow Z_{TH} = 1+j \Rightarrow \boxed{Z_{L,OPT} = Z_{TH}^* = 1-j}$

$Z_{L,OPT}$: 

12.43 A variable-frequency voltage source drives the network in Fig. P12.43. Determine the resonant frequency, Q, BW, and the average power dissipated by the network at resonance.

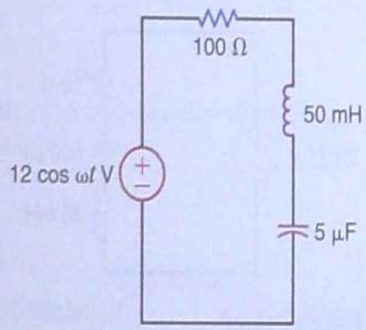


Figure P12.43

12.44 In the network in Fig. P12.44, the inductor value is 10 mH, and the circuit is driven by a variable-frequency source. If the magnitude of the current at resonance is 12 A, $\omega_0 = 1000$ rad/s, and $L = 10$ mH, find C, Q, and the bandwidth of the circuit.

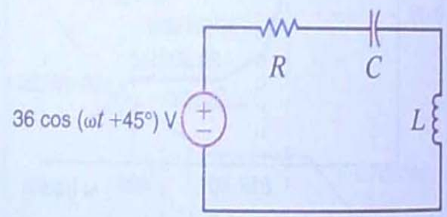


Figure P12.44

12.26 Sketch the magnitude characteristic of the Bode plot for the transfer function

$$\mathbf{H}(j\omega) = \frac{+6.4(j\omega)}{(j\omega + 1)(-\omega^2 + 8j\omega + 64)}$$

12.27 Find $\mathbf{H}(j\omega)$ if its magnitude characteristic is shown in Fig. P12.27.

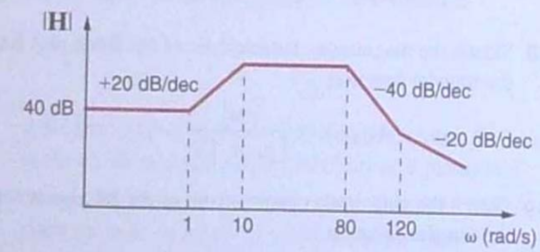


Figure P12.27

12.8 Find the transfer impedance $\mathbf{V}_o(s)/\mathbf{I}_s(s)$ for the netwo shown in Fig. P12.8.

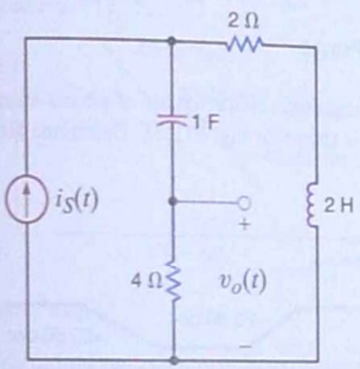


Figure P12.8

12.9 Draw the Bode plot for the network function

$$\mathbf{H}(j\omega) = \frac{j\omega 4 + 1}{j\omega 20 + 1}$$

12.10 Draw the Bode plot for the network function

$$\mathbf{H}(j\omega) = \frac{j\omega}{(j\omega + 1)(0.1j\omega + 1)}$$

12.21 Sketch the magnitude characteristic of the Bode plot for the transfer function

$$\mathbf{H}(j\omega) = \frac{10(5j\omega + 1)}{(100j\omega + 1)(0.02j\omega + 1)}$$

12.22 Sketch the magnitude characteristic of the Bode plot for the transfer function

$$\mathbf{H}(j\omega) = \frac{0.1(2j\omega + 1)}{j\omega(0.1j\omega + 1)(0.01j\omega + 1)}$$

12.23 Sketch the magnitude characteristic of the Bode plot for the transfer function

$$\mathbf{H}(j\omega) = \frac{0.5(10j\omega + 1)(j\omega + 1)}{j\omega(0.1j\omega + 1)(0.01j\omega + 1)^2}$$

12.30 Determine $\mathbf{H}(j\omega)$ from the magnitude characteristic of the Bode plot shown in Fig. P12.30.

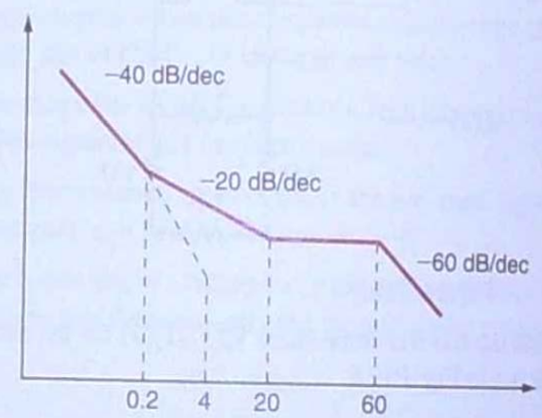


Figure P12.30

EEE 202 HW 5 SOLUTIONS

12.43 $Z = 100 + 50E\text{-}3\, j\omega + \dfrac{1}{5E\text{-}6\, j\omega} = R + Ls + \dfrac{1}{Cs}$; $s = j\omega$

$I = \dfrac{V}{Z} = V \cdot \dfrac{s/L}{s^2 + R/L\, s + \frac{1}{LC}} \Rightarrow \omega_0 = \sqrt{\dfrac{1}{LC}} = \boxed{2{,}000\text{ rad/s}}$

$\zeta = \dfrac{R}{2}\sqrt{\dfrac{C}{L}} = 1/2$

$Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}} = \dfrac{1}{2\zeta} = \boxed{1}$

$BW = \dfrac{\omega_0}{Q} = \boxed{2000\text{ rad/s}}$

$P_{AV} = \dfrac{1}{2}|V_M||I_M|\cos\theta$

$= \dfrac{|V_M|^2}{2} \cdot \dfrac{1}{|Z|} \cdot \cos(\angle Z)$

$= \dfrac{72}{|Z|} \cdot \cos(\angle Z)$; At Resonance, $\omega = \omega_0$ the magnitude and phase expressions are $\left|\dfrac{1}{Z}\right| = \dfrac{\omega_0/L}{\left[\left(\frac{1}{LC} - \omega_0^2\right)^2 + \left(\frac{R}{L}\omega_0\right)^2\right]^{1/2}} = \dfrac{1}{R}$

$\angle Z = 90 - \tan^{-1}\left(\dfrac{R/L}{0}\right) = 0°$. (At resonance, $\dfrac{1}{Z} = \dfrac{1}{R}$, real, positive)

$\Rightarrow P_{AV} = \dfrac{72}{100} = \boxed{0.72\ (W)}$

12.44 $I = \dfrac{V}{Z} = V \cdot \dfrac{s/L}{s^2 + R/L\, s + 1/LC}$

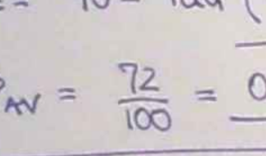
$|I(\omega_0)| = 12$

$\left.\begin{aligned} \omega_0 &= \frac{1}{\sqrt{LC}} = 1E3 \\ L &= 10E\text{-}3 \end{aligned}\right\} \Rightarrow \boxed{C = 0.1E\text{-}3}$ (F)

$|I(\omega_0)| = 36\, \dfrac{1/\sqrt{LC} \cdot 1/L}{\left[\left(1/LC - 1/LC\right)^2 + R^2/L^2\, 1/LC\right]^{1/2}} = \dfrac{36}{R} = 12 \Rightarrow \boxed{R = 3\,\Omega}$

$\therefore Q = \dfrac{1}{R} \cdot \sqrt{\dfrac{L}{C}} = \boxed{\dfrac{10}{3}}$, $BW = \dfrac{\omega_0}{Q} = \boxed{300\text{ rad/s}}$

12.8



$I_1 = I_s$

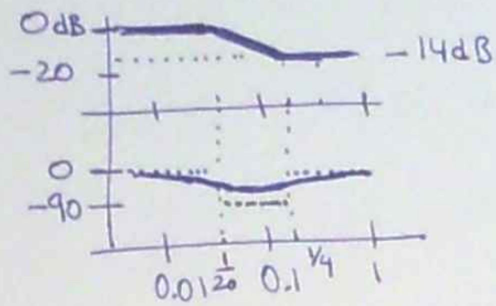
$(I_2 - I_1)\left(4 + \frac{1}{s}\right) + I_2(2 + 2s) = 0$

$\Rightarrow I_2 = I_s\, \dfrac{4 + 1/s}{6 + 2s + 1/s} = I_s\, \dfrac{4s + 1}{2s^2 + 6s + 1}$

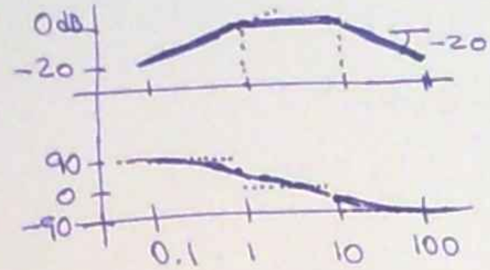
$V_o = (I_1 - I_2)\, 4 = \boxed{I_s\, \dfrac{8s^2 + 8s + 4}{2s^2 + 6s + 1}}$

CORNER FREQUENCIES — BODE PLOT

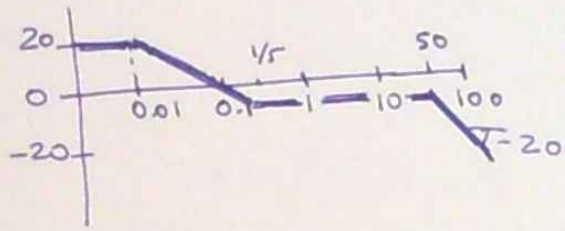
12.9 $\dfrac{4j\omega+1}{20j\omega+1}$ zero $1/4$, pole $1/20$



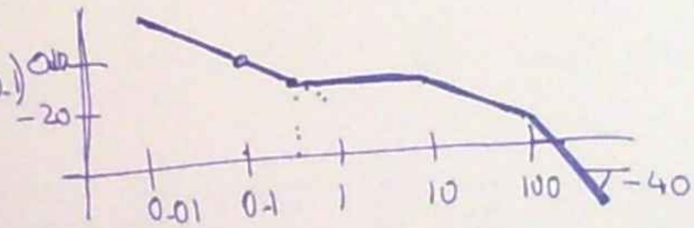
12.10 $\dfrac{j\omega}{(j\omega+1)(0.1j\omega+1)}$ zero 0 (0dB @ 1), pole 1, 10



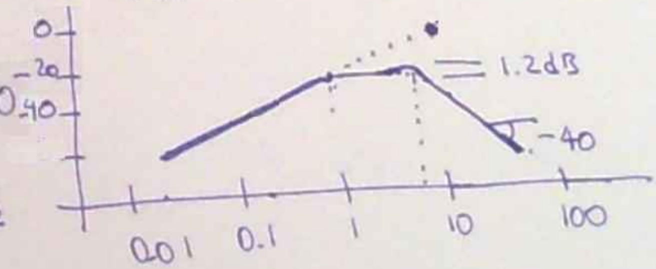
12.21 $\dfrac{10\,(5j\omega+1)}{(100j\omega+1)(0.02j\omega+1)}$ zero $1/5$, pole $1/100$, 50



12.22 $\dfrac{0.1\,(2j\omega+1)}{j\omega(0.1j\omega+1)(0.01j\omega+1)}$ zero : $1/2$, pole : 0 (0dB @ 0.1), 10, 100



12.26 $\dfrac{6.4\,j\omega}{(j\omega+1)(-\omega^2+8j\omega+64)}$ zero 0 (0dB @ 10), pole 1, $\omega_0=8$, $\zeta=1/2$



12.27 Corner frequencies: zero: 0.1, 120

pole: 10, 80 (x2)

DC gain: 40dB (100)

- No phase information
  ⇒ assume minimum phase i.e., all poles, zeros in left half plane.
- Cannot distinguish resonance
  ⇒ assume $\zeta=1$

$$\therefore H(s) = 100\,\frac{\left(\frac{1}{0.1}s+1\right)\left(\frac{1}{120}s+1\right)}{\left(\frac{1}{10}s+1\right)\left(\frac{1}{80}s+1\right)^2} \quad (s=j\omega)$$

12.30 $$H(s) = \left(\frac{4}{j\omega}\right)^2 \frac{\left(\frac{1}{0.2}s+1\right)\left(\frac{1}{20}s+1\right)}{\left(\frac{1}{60}s+1\right)^3}$$

zero: 0.2, 20

pole 0 (x2) 0dB @ 4

60 (x3)

14.6 Use Laplace transforms and nodal analysis to find $i_1(t)$ for $t > 0$ in the network shown in Fig. P14.6. Assume zero initial conditions.

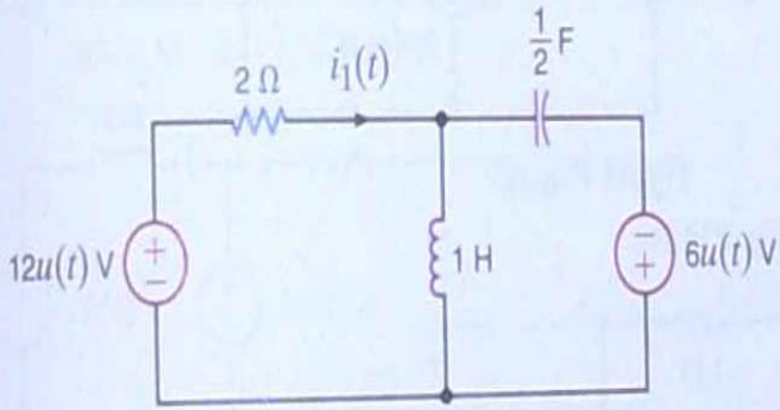


Figure P14.6

14.7 Use Laplace transforms to find $v(t)$ for $t > 0$ in the network shown in Fig. P14.7. Assume zero initial conditions.

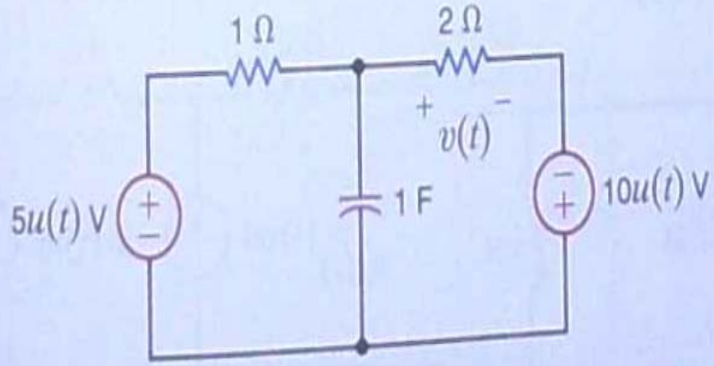


Figure P14.7

14.11 Find $v_o(t)$, $t > 0$, in the network shown in Fig. P14.11 using nodal analysis.

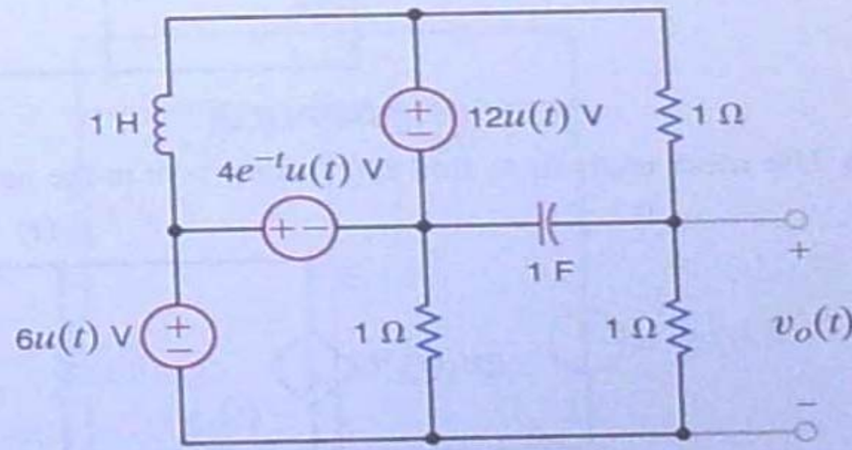


Figure P14.11

12.85 Given the second-order low-pass filter in Fig. P12.85, design a filter that has $H_o = 100$ and $f_c = 5$ kHz. Set $R_1 = R_3 = 1$ kΩ, and let $R_2 = R_4$ and $C_1 = C_2$. Use an op-amp model with $R_i = \infty$, $R_0 = 0$, and $A = (2)10^5$.

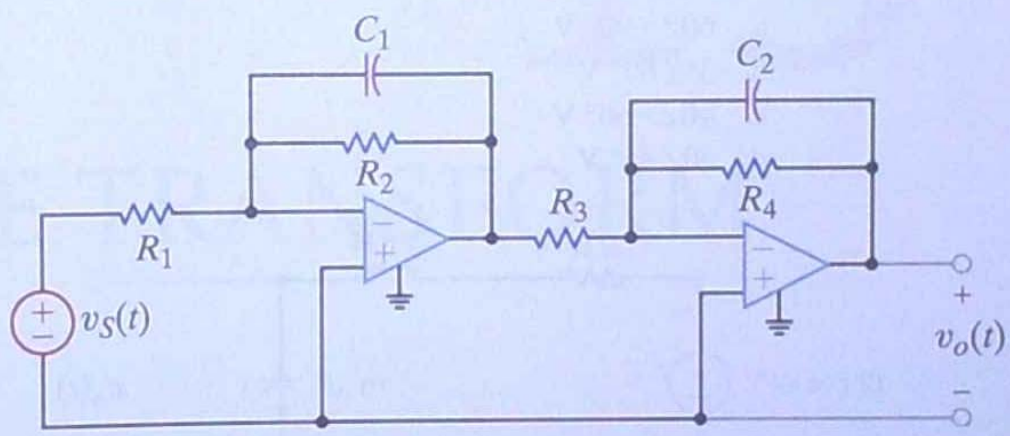
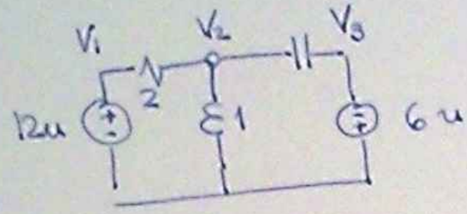


Figure P12.85

EEE 202 HW 6 SOLUTIONS

PR. 14.6



$$i_1(t) = \frac{V_1 - V_2(t)}{2} = \frac{12}{2}u(t) - \frac{V_2(t)}{2}$$

Node 1: $V_1 = 12 \cdot \frac{1}{s}$

Node 2: $\frac{V_2 - V_1}{2} + \frac{V_2 - V_3}{1/Cs} + \frac{V_2}{1s} = 0$

$$\Rightarrow \frac{V_2 - V_1}{2} + \frac{1}{2}s(V_2 - V_3) + \frac{V_2}{1s} = 0$$

Node 3: $V_3 = -6 \cdot \frac{1}{s}$

Combining

$$\frac{1}{2}V_2 + \frac{1}{2}sV_2 + \frac{1}{s}V_2 = \frac{6}{s} + \left(-3\frac{s}{s}\right)$$

$$\Rightarrow \left(\frac{1}{2}s^2 + \frac{1}{2}s + 1\right)V_2 = 6 - 3s \Rightarrow V_2(s) = \frac{(-3s+6)2}{s^2+s+2}$$

① Converting to table format: $\frac{*}{(s+a)^2+b^2} = \frac{*}{s^2+2as+a^2+b^2} \rightarrow \begin{array}{l} a = 1/2 \\ b = \frac{\sqrt{7}}{2} \end{array}$

$$V_2(s) = A\frac{s+1/2}{(s+1/2)^2 + 7/4} + B\frac{\sqrt{7}/2}{(s+1/2)^2+7/4} \Rightarrow$$

$As + B\sqrt{7}/2 + A/2 = -6s + 12$

$\Rightarrow A = -6$

$B = (12+3)\cdot\frac{2}{\sqrt{7}}$

$$V_2(t) = -6 \cdot e^{-1/2 t}\cos\frac{\sqrt{7}}{2}t + \frac{30}{\sqrt{7}}\cdot e^{-1/2 t}\sin\frac{\sqrt{7}}{2}t \qquad t \geq 0$$

$$\Rightarrow i_1(t) = 6 - \left[\frac{15}{\sqrt{7}}\sin\frac{\sqrt{7}}{2}t - 3\cos\frac{\sqrt{7}}{2}t\right]e^{-1/2 t} \qquad t \geq 0$$

② Alternative Sol'n.: Finding the PFE of $V_2(s) = \frac{-3-5.67j}{s+0.5-1.32j} + \frac{(*)}{s+(*)}$

complex conjug- of 1st term

$$\Rightarrow V_2(t) = (-3-5.67j)e^{(-0.5+1.32j)t} + (*)$$

$$= 2\,\mathrm{Re}\left[(-3-5.67j)(e^{1.32jt})e^{-1/2 t}\right]$$

$$= 2\,\mathrm{Re}\left[(-3-5.67j)(\cos 1.32t + j\sin 1.32t)\right]e^{-1/2 t}$$

$$= 2\left[-3\cos 1.32t + 5.67\sin 1.32t\right]e^{-1/2 t}$$

etc

Pr 14.7

$v(t) = V_2(t) - V_3(t)$, $V(s) = V_2(s) - V_3(s)$

$V_1 = 5 \cdot \frac{1}{s}$

$V_3 = -10 \frac{1}{s}$

$$\frac{V_2 - V_1}{1} + \frac{V_2 - V_3}{2} + \frac{V_2}{(1/s)} = 0$$

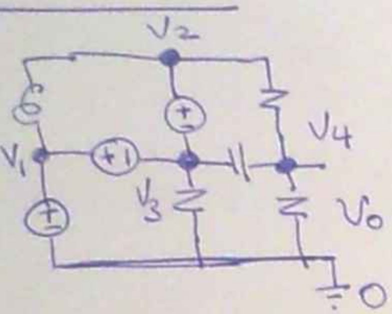
$\Rightarrow V_2 + \frac{1}{2}V_2 + sV_2 = V_1 + \frac{1}{2}V_3$

$(s + 3/2)V_2 = 0$

$\Rightarrow V_2(s) = 0 \rightarrow V_2(t) = 0$

$\therefore v(t) = -V_3(t) = 10\,u(t)$

Pr. 14.11



$V_1 = 6/s$

$V_1 - V_3 = 4/s+1 \quad \Rightarrow V_3 = \frac{6}{s} - \frac{4}{s+1}$

$V_2 - V_3 = 12/s \quad \Rightarrow V_2 = \frac{18}{s} - \frac{4}{s+1}$

$$\frac{V_4 - V_2}{1} + \frac{V_4 - V_3}{1/s} + \frac{V_4 - 0}{1} = 0$$

$V_o = V_4$

$\Rightarrow (s+2)V_4 = V_2 + V_3$

$$\Rightarrow V_o = \frac{1}{s+2} \cdot \left[\frac{24}{s} - \frac{8}{s+1}\right]$$

$$= \frac{24}{s(s+2)} - \frac{8}{(s+1)(s+2)} \overset{PFE}{=} \frac{12}{s} + \frac{-12}{s+2} + \frac{-8}{s+1} + \frac{8}{s+2}$$

$\Rightarrow V_o(t) = 12u(t) - 4e^{-2t}u(t) - 8e^{-t}u(t)$

or $12 - 4e^{-2t} - 8e^{-t} \quad t \geq 0.$

Pr. 12.85 Try the ideal opamp case first: Each stage has transfer functi

$H_i(s) = -\frac{Z_o}{R_i} = -\frac{R/RCs+1}{1k} \Rightarrow$ Total t.f. $H(s) = H_i(s)H_i(s) = \frac{(R/1k)^2}{(RCs+1)^2}$

- For $H_o = 100$, $H(0) = 100 \Rightarrow \frac{R}{1k} = 10 \Rightarrow \boxed{R = 10k}$
- For $f_c = 5kHz$ $\omega_c = 31.4k$ (rad/s), an approximate solution would be to set the corner frequency $1/RC$ equal to ω_c. That would produce a $-6dB$ drop at f_c instead of $-3dB$ because the filter is 2nd order. Instead, we can solve $|H(j\omega_c)| = |H(0)|/\sqrt{2}$

$$\therefore \quad \frac{(R/1k)^2}{(RC)^2\omega_c^2+1} = \frac{(R/1k)^2}{\sqrt{2}} \Rightarrow (RC)^2 = \frac{\sqrt{2}-1}{\omega_c^2} \Rightarrow C = \frac{1}{10k} \cdot \frac{\sqrt{\sqrt{2}-1}}{31.4k}$$

$$\boxed{= 2.05\,nF.}$$

Computing the Bode plot in Matlab we verify that $H(s)$ has the desired properties $H(0) = 40\,dB$, $|H(j\omega)| = (40-3)\,dB$ at $5\,kHz$.

Next, we analyze the effect of a non-ideal op-amp gain, $A = 2e5$

The opamp equations become

$$V_o = A \cdot (V_- - 0)$$

$$\frac{V_o - V_-}{Z} + \frac{V_i - V_-}{R} = 0$$

Substituting, $V_o = -\frac{Z}{1k} V_i \underbrace{\left[\frac{1}{\frac{A-1}{A} - \frac{Z}{A \cdot 1k}}\right]}_{T(s)}$ for each stage

Then, the total T.f. is $V_o = \left(-\frac{Z}{1k}\right)^2 T^2 \cdot V_s = H(s)\, T^2(s)\, V_s$

The deviation of T^2 from one determines the deviation of the transfer function HT^2 from the spec. Forming the Bode plot of $1-T^2$ (e.g. bode(1-T*T)) we find that it is smaller than $-60\,dB$ at all frequencies so the approximate solution is fairly accurate. Any further correction of the R, C values should be justified against the precision of their values.