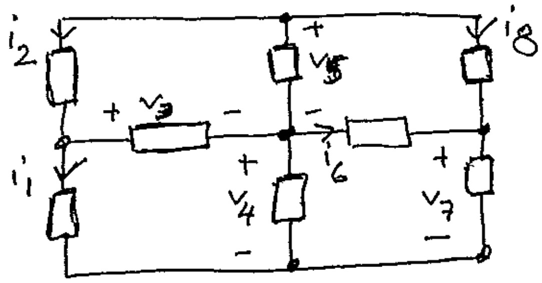
Ömer Morgül $\overline{NAME}$ $\overline{FAMILYNAME}$ $\overline{SECTION}$

EEE 202 CIRCUIT THEORY
First Midterm, Spring 2012-13

No credits will be given for unjustified answers.

Prob. 1 : (20 pt.s)

For part **i** and **ii**, consider the circuit shown in the following figure. Here, boxes represent arbitrary circuit elements. Some voltage and current reference directions are shown in the figure. For other voltage/current reference directions, use passivity sign convention.



i : (4 pt.s) Consider the circuit given above. We have $i_1 = 4\ A$, $i_2 = 5\ A$, $i_6 = 3\ A$, $i_8 = 2\ A$. Find as many remaining currents as you can.

$-i_2 + i_1 + i_3 = 0 \Rightarrow i_3 = i_2 - i_1$, $i_3 = 1A$. (01)

$-i_1 - i_4 - i_7 = 0 \Rightarrow i_4 = -i_1 - i_7$, $i_4 = -9A$. (01)

$-i_6 - i_8 + i_7 = 0 \Rightarrow i_7 = i_6 + i_8$, $i_7 = 5A$. (01)

$-i_3 - i_5 + i_4 + i_6 = 0 \Rightarrow i_5 = -i_3 + i_4 + i_6$, $i_5 = -7A$ (01)

ii : (4 pt.s) Consider the circuit given above. We have $v_3 = 5\ V$, $v_4 = 4\ V$, $v_5 = 3\ V$, $v_7 = 2\ V$. Find as many remaining voltages as you can.

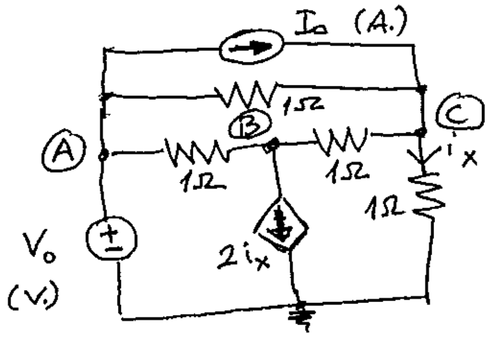
$-V_1 + V_3 + V_4 = 0 \Rightarrow V_1 = V_3 + V_4$, $V_1 = 9V$. (01)

$V_6 + V_7 - V_4 = 0 \Rightarrow V_6 = V_4 - V_7$, $V_6 = 2V$. (01)

$V_5 - V_3 - V_2 = 0 \Rightarrow V_2 = V_5 - V_3$, $V_2 = -2V$. (01)

$V_8 - V_6 - V_5 = 0 \Rightarrow V_8 = V_5 + V_6$, $V_8 = 5V$. (01)

iii : (6 pt.s) Consider the following circuit. Let v_A, v_B, v_C represent the node voltages of nodes A,B,C. Write the **node** equations. Simplify these equations so that only **node voltages** remain as unknowns. (You may write the equations by inspection. You don't have to solve these equations).



(1) $V_A = V_o$

(2) $-V_A + 2V_B - V_C = -2i_x$

(3) $-V_A - V_B + 3V_C = I_o$

$i_x = V_C$

04

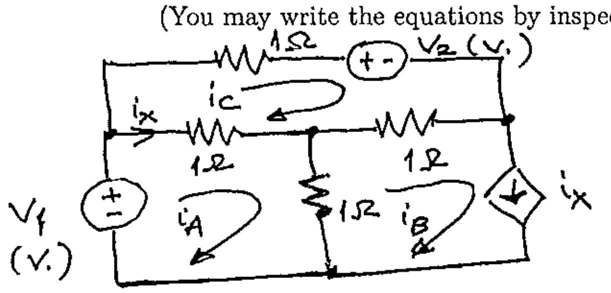
$\boxed{V_A = V_o}$

$\boxed{-V_A + 2V_B + V_C = 0}$

$\boxed{-V_A - V_B + 3V_C = I_o}$

02

v : (6 pt.s) Consider the following circuit. Write the **mesh** equations by using the mesh currents indicated in the figure. Simplify these equations so that only **mesh currents** remain as unknowns. (You may write the equations by inspection. You don't have to solve these equations).



(1) $2i_A - i_B - i_C = V_1$

(2) $i_B = i_x$

(3) $-i_A - i_B + 3i_C = -V_2.$

$i_x = i_A - i_C$

04

$\boxed{2i_A - i_B - i_C = V_1}$

$\boxed{-i_A + i_B + i_C = 0}$

$\boxed{-i_A - i_B + 3i_C = -V_2}$

02

Prob. 2 : (25 pt.s)

i : (12 pt.s) Consider the circuit shown in Figure 1. Let v_A , v_B, v_C represent the node voltages of nodes A,B,C. Use **node** analysis and find the voltages v_o and v_x.

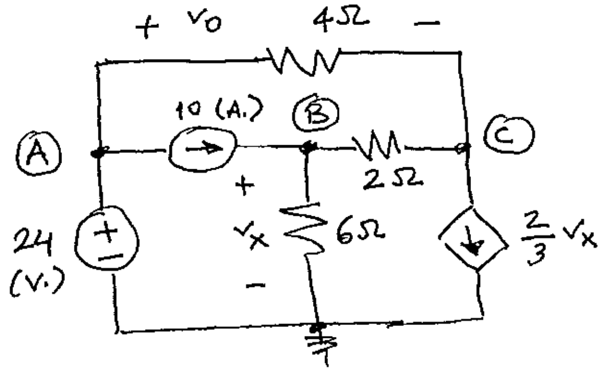


Fig.1

$V_A = 24$

$\left(\frac{1}{6}+\frac{1}{2}\right) V_B - \frac{1}{2} V_C = 10$

$-\frac{1}{4} V_A - \frac{1}{2} V_B + \left(\frac{1}{2}+\frac{1}{4}\right) V_C = -\frac{2}{3} V_x$

$V_x = V_B$

(04)

$\frac{2}{3} V_B - \frac{1}{2} V_C = 10$

$\left(\frac{2}{3}-\frac{1}{2}\right) V_B + \frac{3}{4} V_C = 6$

$\Downarrow$

$\boxed{\frac{2}{3} V_B - \frac{1}{2} V_C = 10 \quad \frac{1}{6} V_B + \frac{3}{4} V_C = 6}$ (04)

$\Downarrow$

$\boxed{V_C = 4\text{ V.} \quad V_B = 18\text{ V.}}$

$\Leftarrow$ $\boxed{V_x = V_B = 18\text{ V}}$ (02)

$V_o = V_A - V_C$

$\boxed{V_o = 20\text{ V}}$ (02)

ii : (13 pt.s) Consider the circuit shown in Figure 2. Let i_A , i_B, i_C represent the mesh currents as indicated in the Figure 2. Use **mesh** analysis and find v_x and v_o.

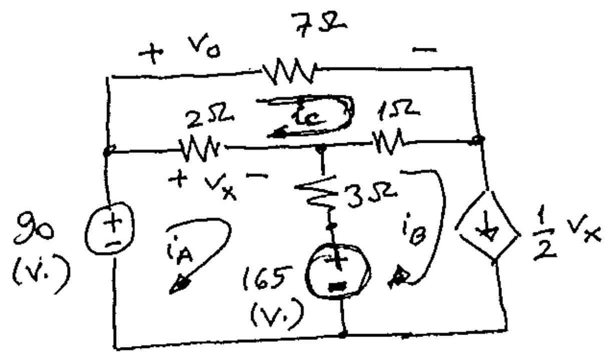


Fig.2

$5 i_A - 3 i_B - 2 i_C = -75$

$i_B = \frac{1}{2} V_x$

$-2 i_A - i_B + 10 i_C = 0$

$V_x = 2(i_A - i_C)$

(03)

$\boxed{5 i_A - 3 i_B - 2 i_C = -75 \quad i_B = i_A - i_C \quad -2 i_A - i_B + 10 i_C = 0}$

$\Downarrow$

$\boxed{2 i_A + i_C = -75 \quad -3 i_A + 11 i_C = 0}$ (04)

$\boxed{i_C = -9\text{ A.}}$ (01)

$\boxed{i_A = -33\text{ A.}}$ (01)

$V_x = 2(i_A - i_C)$

$\boxed{V_x = -48\text{ V.}}$ (02)

$V_o = 7 i_C$

$\boxed{V_o = -63\text{ V.}}$ (02)

Prob. 3 : (30 pt.s)

i : (10 pt.s) Consider the circuit shown in Figure 1. Here the load represents an arbitrary circuit. Find the Thévenin equivalent circuit seen by the load.

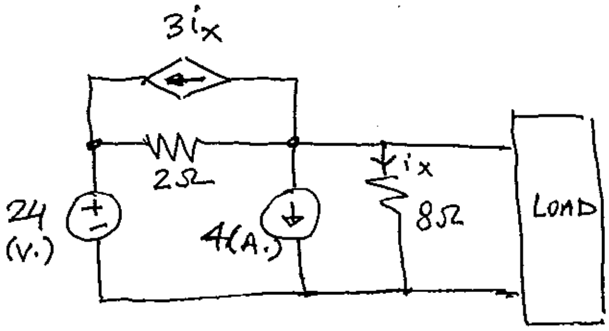
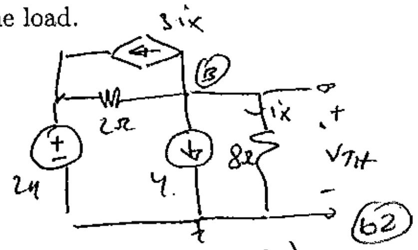


Fig.1



$V_A = 24$

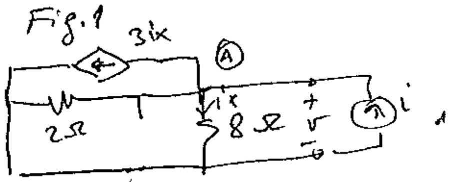
$V_B = V_{TH}$

$i_x = \frac{V_{TH}}{8}$

(B) $-\frac{24}{2} + \left(\frac{1}{2}+\frac{1}{8}\right)V_{TH} = 4 - 3i_x$

$\Rightarrow \underbrace{\left(\frac{1}{2}+\frac{1}{8}+\frac{3}{8}\right)}_{1} V_{TH} = -4+12 = 8$

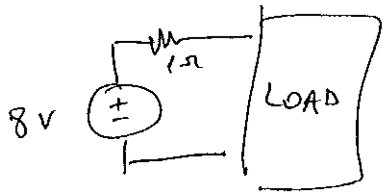
$\Rightarrow \boxed{V_{TH} = 8V}$ (03)



$V_A = v$ (02) $\Rightarrow \left(\frac{1}{8}+\frac{1}{2}\right)v = i - 3i_x \quad i_x = \frac{v}{8}$

$\Rightarrow \left(\frac{1}{8}+\frac{1}{2}+\frac{3}{8}\right)v = i \Rightarrow v = i$ (03)

$\Rightarrow \boxed{R_T = \frac{v}{i} = 1\ \Omega}$



ii : (10 pt.s) Consider the circuit shown in Figure 2. Here the load represents an arbitrary circuit. Find the Norton equivalent circuit seen by the load.

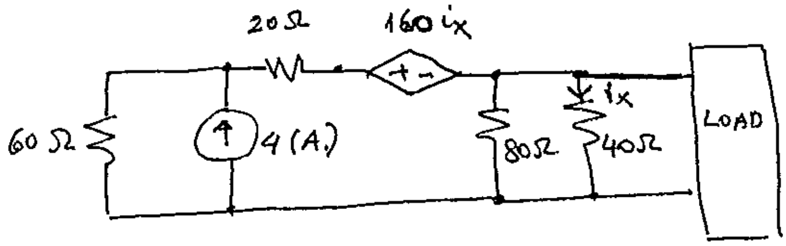
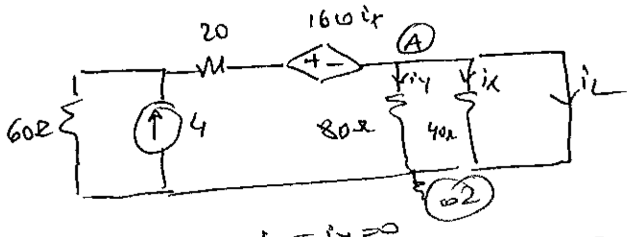
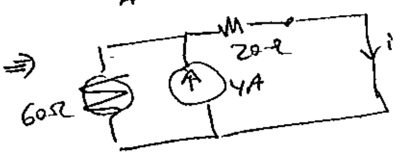


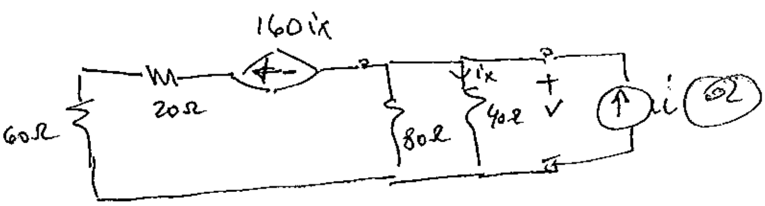
Fig.2

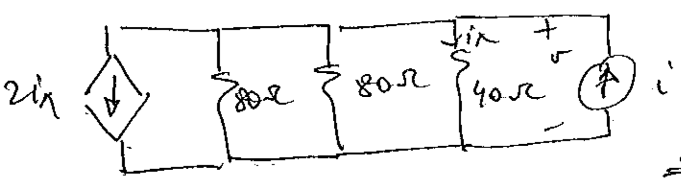


$V_A = 0 \Rightarrow i_x = i_y = 0$



$\boxed{i_N = \frac{60}{80}\cdot 4 = 3A}$ (03)

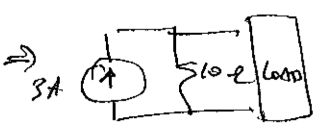




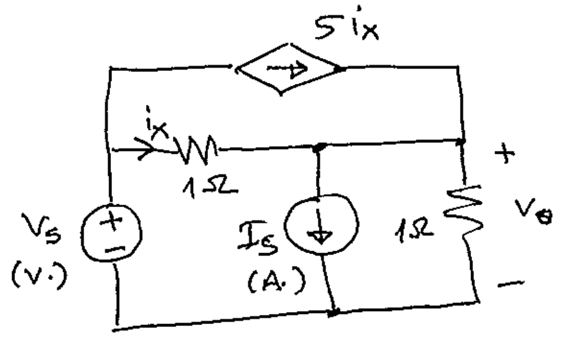
$i_x = \frac{v}{40}, \quad \left(\frac{1}{40}+\frac{1}{80}+\frac{1}{80}\right)v = i - 2i_x$

$\Rightarrow \left(\frac{1}{40}+\frac{1}{80}+\frac{1}{80}+\frac{2}{40}\right)v = i$ (03)

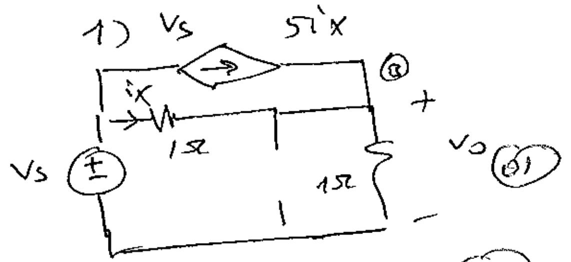
$\frac{1}{10}v = i \Rightarrow \boxed{R_N = \frac{v}{i} = 10\Omega}$



iii : (10 pt.s) Consider the circuit shown below. By using **superposition**, find v_0.



1) Vs

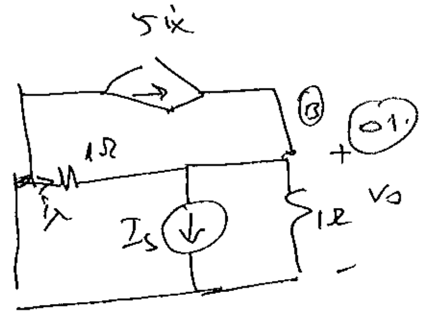


$i_x = \frac{V_S - V_O}{1} = V_S - V_O$ 01

Node at (B) → $-\frac{V_S}{1} + 2V_O = 5i_x = 5(V_S - V_O)$

→ $7V_O = 6V_S$ → $\boxed{V_O = \frac{6}{7}V_S}$ 02

2) is



$\boxed{i_x = -V_O}$ 01

(B) → $2V_O = 5i_x - I_S = -5V_O - I_S$

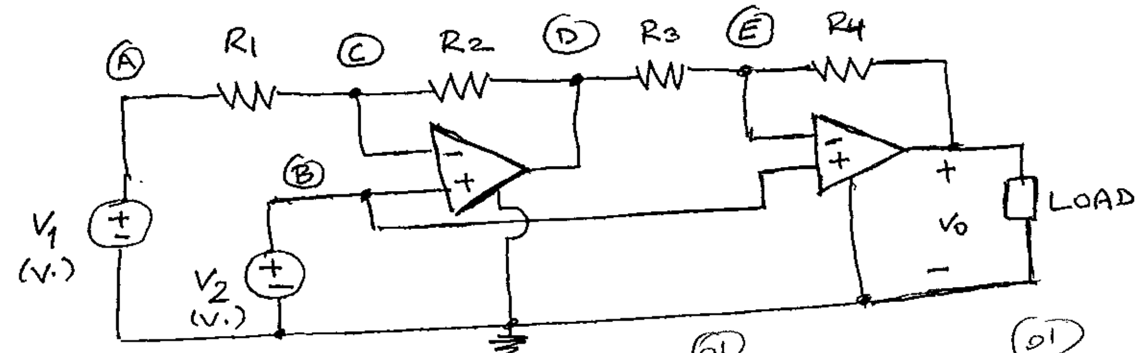
$7V_O = -I_S$ → $\boxed{V_O = -\frac{1}{7}I_S}$ 02

$$\boxed{V_O = \frac{6}{7}V_S - \frac{1}{7}I_S}$$ 02

Prob. 4 : (25 pt.s) Consider the following circuit. Here the op-amps are linear and operate in their linear regions; the load represents an arbitrary circuit. Note that in case you use node analysis, use the notation indicated in the Figure.

i : Find v_o in terms of v_1, v_2 and the resistances.

ii : Assume that the saturation voltage E_{sat} is $E_{sat} = 15\ V$ for both op-amps. Let $R_1 = R_2 = R_3 = R_4 = 1\ \Omega$ and $v_2 = 1\ V$. Find the range of v_1 so that both op-amps operate in the linear region.



i) 17/17

01 $\boxed{V_A = V_1}$ 01 $\boxed{V_B = V_2}$ 01 $\boxed{V_C = V_B = V_2}$ 01 $\boxed{V_E = V_2}$

(C) $-\frac{1}{R_1} V_A + \left(\frac{1}{R_1} + \frac{1}{R_2}\right) V_C - \frac{1}{R_2} V_D = 0$ 02 $\Rightarrow \boxed{V_D = \left(1 + \frac{R_2}{R_1}\right) V_2 - \frac{R_2}{R_1} V_1}$ 02

(E) $-\frac{1}{R_3} V_D + \left(\frac{1}{R_3} + \frac{1}{R_4}\right) V_E - \frac{1}{R_4} V_o = 0$ 02 $\Rightarrow \boxed{V_o = \left(1 + \frac{R_4}{R_3}\right) V_2 - \frac{R_4}{R_3} V_D}$ 02

$$V_o = \left(1 + \frac{R_4}{R_3}\right) V_2 - \frac{R_4}{R_3}\left(1 + \frac{R_2}{R_1}\right) V_2 + \frac{R_4}{R_3} \cdot \frac{R_2}{R_1} V_1 = \left[1 - \frac{R_4 R_2}{R_3 R_1}\right] V_2 + \frac{R_4 R_2}{R_3 R_1} V_1$$ 03

$$\rightarrow \boxed{V_o = \frac{R_1 R_3 - R_4 R_2}{R_3 R_1} V_2 + \frac{R_4 R_2}{R_3 R_1} V_1}$$ 02

ii) 08/08

$V_D = 2V_2 - V_1 = 2 - V_1$ 01 $\Rightarrow -15 < 2 - V_1 < 15 \Rightarrow \boxed{-13 < V_1 < 17}$ 02

$V_o = V_1$ 01 $\Rightarrow \boxed{-15 < V_1 < 15}$ 02

$\boxed{-13 < V_1 < 15}$ 02