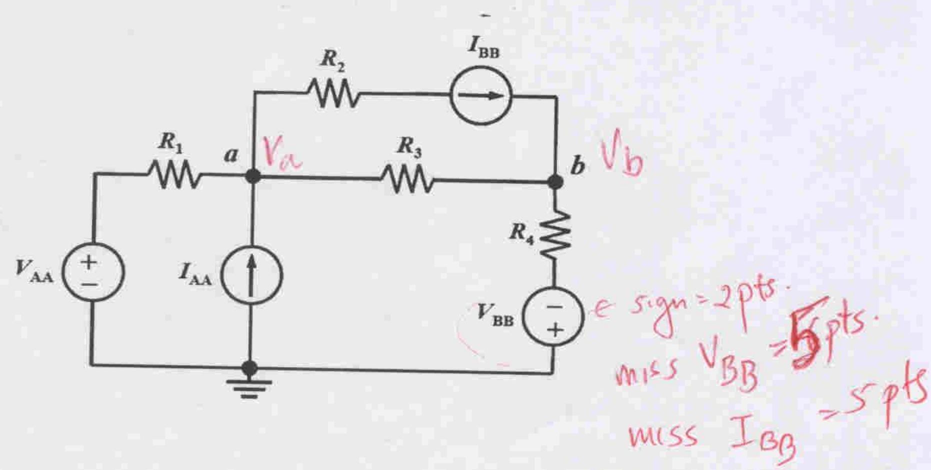
EE100 Summer 2004 Midterm Solutions

1. (25 points) In the circuit below, use the **NODE VOLTAGE** method to write 2 equations sufficient to solve for V_a and V_b (the voltages at nodes a and b respectively). Your equations will obviously be in terms of the resistances and the independent source values. To receive credit, you must write your answer in the box below. **DO NOT SOLVE THE EQUATIONS!**

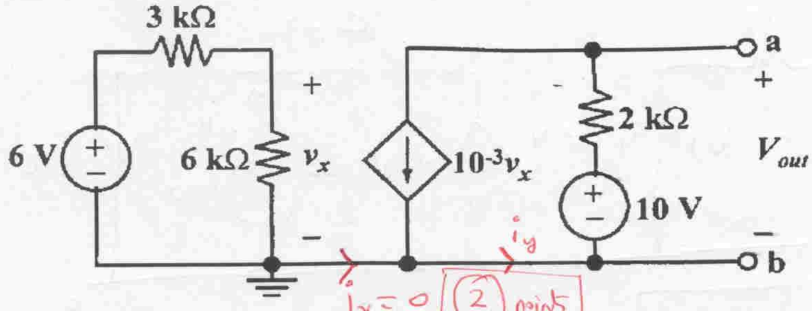


$$\frac{V_a - V_{AA}}{R_1} + \frac{V_a - V_b}{R_3} + I_{BB} = I_{AA}.$$

$$\frac{V_b + V_{BB}}{R_4} + \frac{V_b - V_a}{R_3} = I_{BB}.$$

(1)

2. (25 points). Consider the following circuit:



a. Find V_{out}

$V_x = \left(\frac{6k}{6k+3k}\right) 6\,V$ [voltage divider]

$= 4\,V$ (4) points

(12) point

$i_y = 10^{-3} V_x = 4 \cdot 10^{-3} = 4\,mA$ (2) points

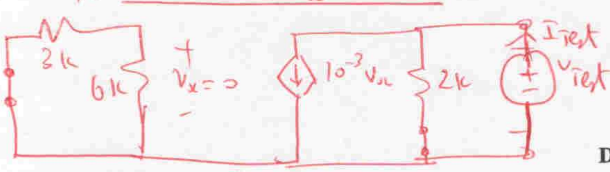
$V_{out} = 10 - (2k)(4\,mA) = 2\,V$ (4) points

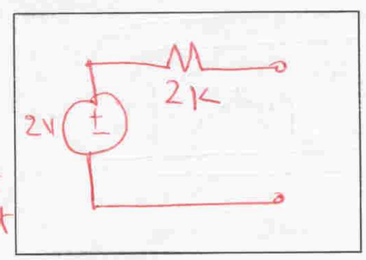
V_{out} = 2 V

b. Draw the Thevenin equivalent with respect to terminals ab

Now, $V_{out} = V_{oc} = 2\,V$

R_{Th}: (1) kill all independent sources:



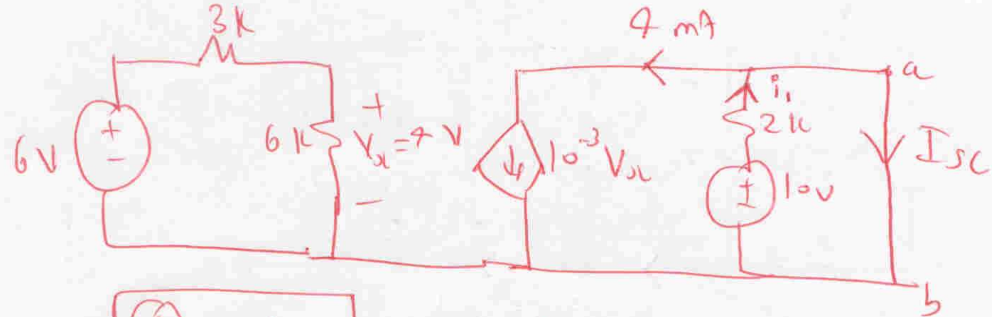


Draw Thevenin equivalent in the box

Apply V_{test} [circuit has only dependent sources 2 resistors] (13) points

Since $V_x = 0 \Rightarrow R_{Th} = 2k$ [P.T.O →]

R_{Th} : (2) Finding I_{SC}



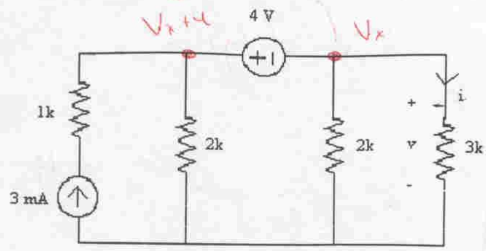
(6) point : correct direction for I_{SC}

(7) point : $i_1 \neq 0$ (6) point

$I_{SC} = i_1 - 4 = \frac{10}{2K} - 4\ mA = 1\ mA$ (1) point

Total : (13) point

3. (25 points). Find v and i in the circuit below.



Nodal

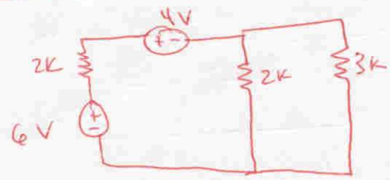
$$\frac{V_x}{3} + \frac{V_x}{2} + \frac{V_x+4}{2} = 3$$

$$2V_x + 3V_x + 3V_x + 12 = 18$$

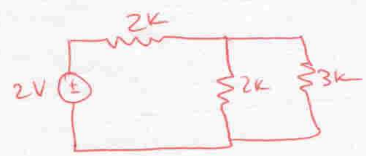
$$8V_x = 6$$

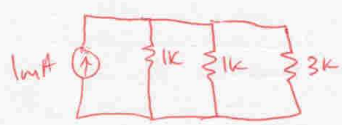
$$V_x = 3/4\ V \Rightarrow i = \frac{\frac{3}{4}V}{3K} \Rightarrow i = 1/4\ mA$$

Source Transform

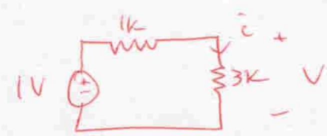


$\Rightarrow$





$\Rightarrow$

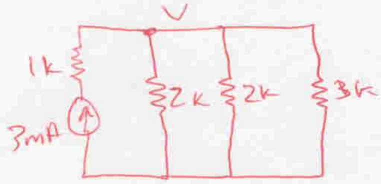


$V = 3/4\ V \quad i = 1/4\ mA$

v = 3/4 V

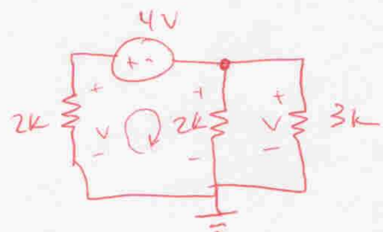
i = 1/4 mA

Superposition



$$3mA = \frac{V}{2} + \frac{V}{2} + \frac{V}{3}$$

$$V = 2.25\ V$$



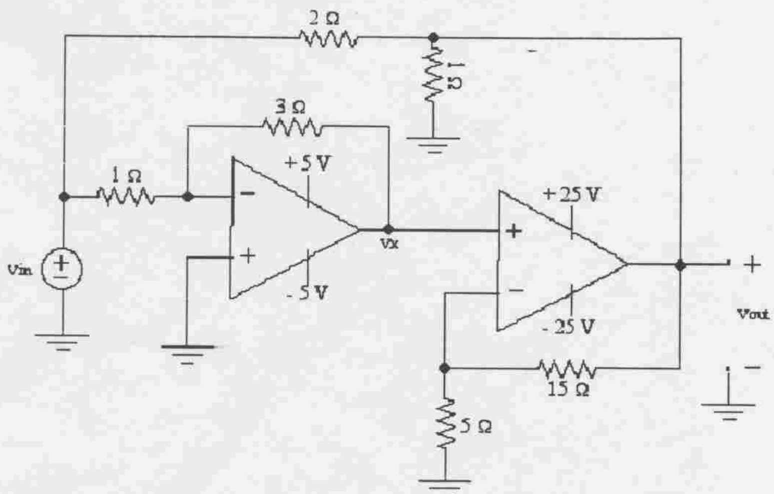
$$\frac{V}{2} + \frac{V}{3} + \frac{V+4}{2} = 0$$

$$V = -1.5\ V$$

$$V_{total} = .75\ V$$

$$\therefore\ i = \frac{V}{R} = .25\ mA$$

4. (22 points) Consider the following dual op-amp circuit. Each op-amp has a separate power supply. Assume the open loop gain for both op-amps is infinite (A = ∞).



a.) Overall, is the above circuit an inverting or non-inverting amplifier?

(1) inverting → non-inverting ⇒ Inverting

Write your answer here: INVERTING

b.) Assuming op-amp 1 is working in the linear region; find the closed loop gain of op-amp 1.

(5) $\frac{vx}{vin} =$ -3

c.) Assuming both op-amps are working in the linear region, find the overall closed loop gain

(6) $\frac{vout}{vin} =$ -12

(4) d.) If Vin = 3 V, find Vout. vout = -20 V

(4) e.) If Vin = -4 V, find Vout. vout = +20 V

(2) f.) If Vin = 1 V, find Vout. vout = -12 V

PROBLEM 4 EXTRA WORKSPACE

B.)

$$\frac{V_{in}-0}{1} = \frac{0-V_x}{3} \Rightarrow V_{in} = -\frac{V_x}{3} \Rightarrow \boxed{\frac{V_x}{V_{in}} = -3}$$

C.)

$$\frac{V_o - V_x}{15} = \frac{V_x}{5} \Rightarrow \frac{V_o}{V_x} = 15\left(\frac{1}{5} + \frac{1}{15}\right) = 3+1 \Rightarrow \frac{V_o}{V_x} = 4$$

$$V_x = -3V_{in} \quad V_o = 4V_x \Rightarrow V_o = 4(-3V_{in}) \Rightarrow \boxed{\frac{V_o}{V_{in}} = -12}$$

D.) Op-Amp 1: $V_{in} = 3V \rightarrow V_x = -9 \Rightarrow V_x = -5V$
RAIL

OP-AMP 2: $V_x = -5 \Rightarrow \boxed{V_o = -20V}$

E.) OP-AMP 1: $V_{in} = -4V \rightarrow V_x = 12 \Rightarrow V_x = 5V$
RAIL

OP-AMP 2: $V_x = 5V$ $\boxed{V_o = 20V}$

F.) $\frac{V_{out}}{V_{in}} = -12 \rightarrow V_{OUT} = -12(1V) \rightarrow \boxed{V_{out} = -12V}$