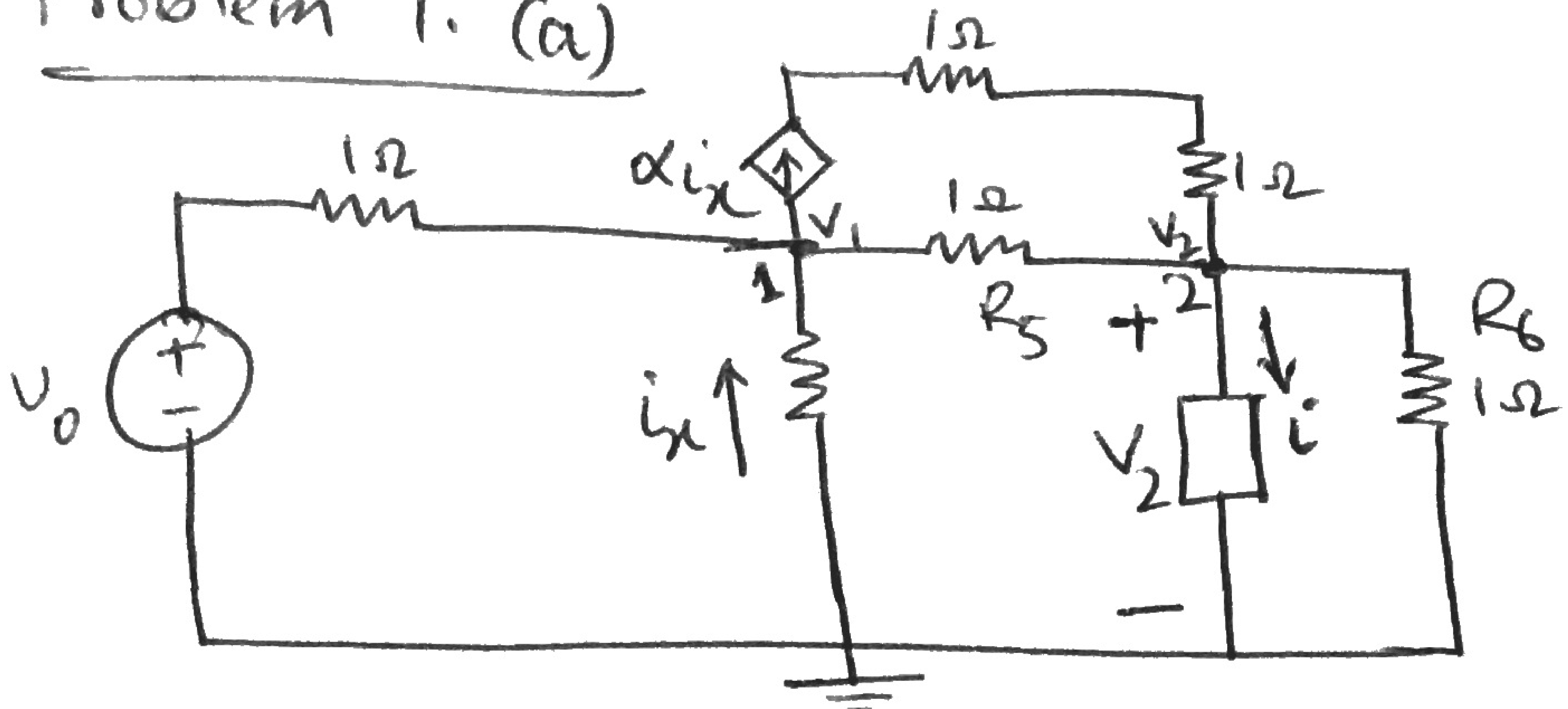
Problem 1. (a)



To Find i_x and hence i, we can any of the given V_0 conditions, for simple calculation.

I am using $V_0 = 2V$ condition, ($V_0 = 1$ condition will give same result).

So, $V_1 = -1V$, $V_2 = 5V$

$\therefore \; i_x = \frac{0-(-1)}{1} = 1A$

Now, KCL at node 2,

$$\frac{V_2 - V_1}{R_5} + \frac{V_2}{R_6} - \alpha i_x + i = 0$$

$$\Rightarrow 2V_2 - V_1 - \alpha i_x + i = 0$$

$$\Rightarrow i = \alpha i_x - 2V_2 + V_1$$

$$= 10 - 10 - 1$$

$$= -1A$$

Let's find the element inside the box:

Current is going from negative to the positive potential. So, it must be an active

Source and not a passive element (e.g. resistors).

Can it be an independent voltage source?

- NO. V_2 varies with V_o.

Can it be a dependent voltage source?

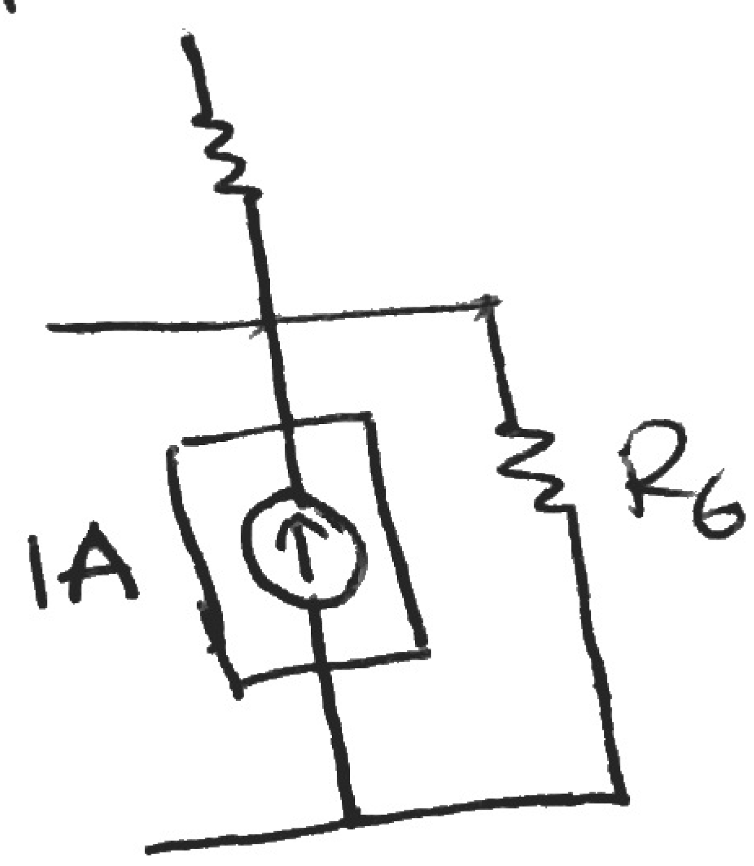
- NO.

say, the element is a VCVS, V_{box}.
~~then, for, V_o ...~~ so, $V_{box} = \beta V_o$.
If $V_o = 1$, $\beta = \frac{16}{5}$
If $V_o = 2$, $\beta = 2.5$
which is not consistent.
So, element inside the box can not be a VCVS.

(*) Can it be an independent current source?

- YES!

No, problem with this.

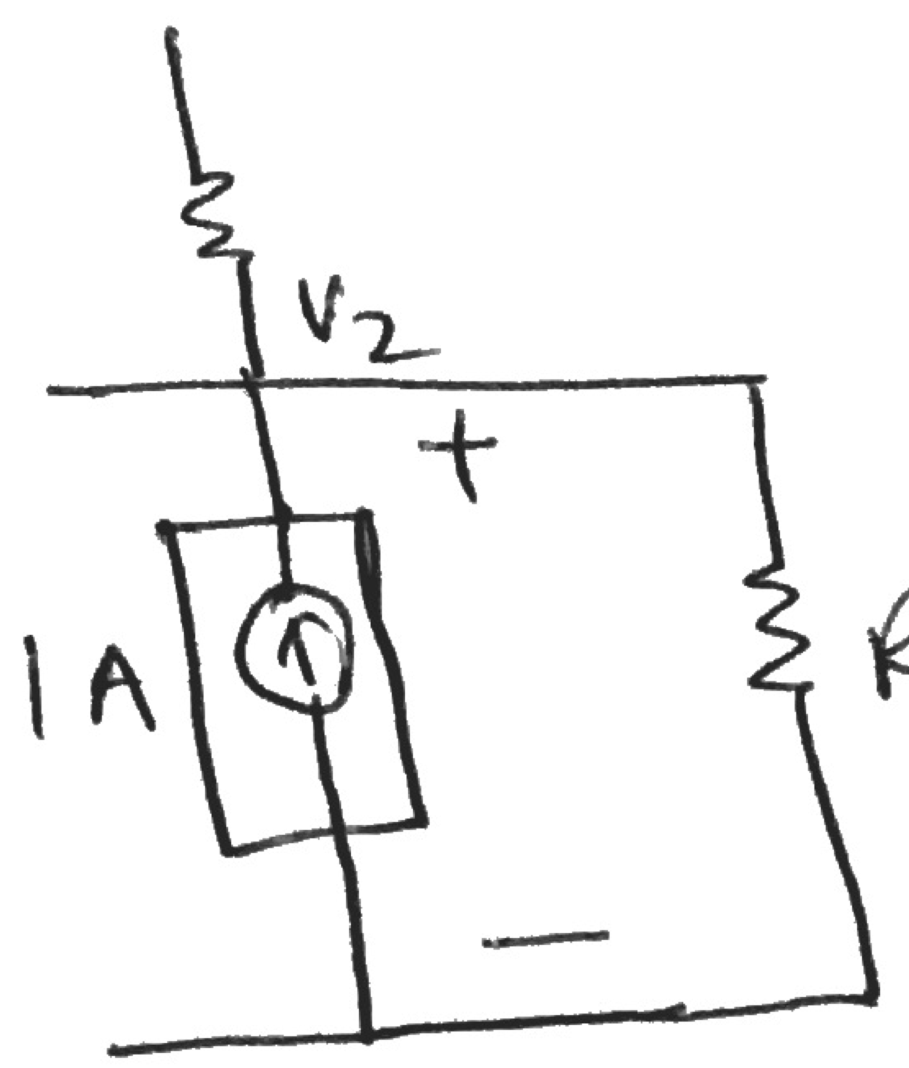


Can it be a dependent current source?

- NO. The current in the branch consisting the box has a constant value which does not vary with any other current or voltage.

Problem 1(b)

From part (a)



V_2 is positive. Now, According to passive sign convention.

Power, $P = V_2 \cdot i$

$= 5 \times -1$

$= -5W$

$P < 0$, so power is producing.

Alternatively, positive current is flowing from negative to positive potential.

So, power is producing.

Rubrics for Problems 1 (a), (b)

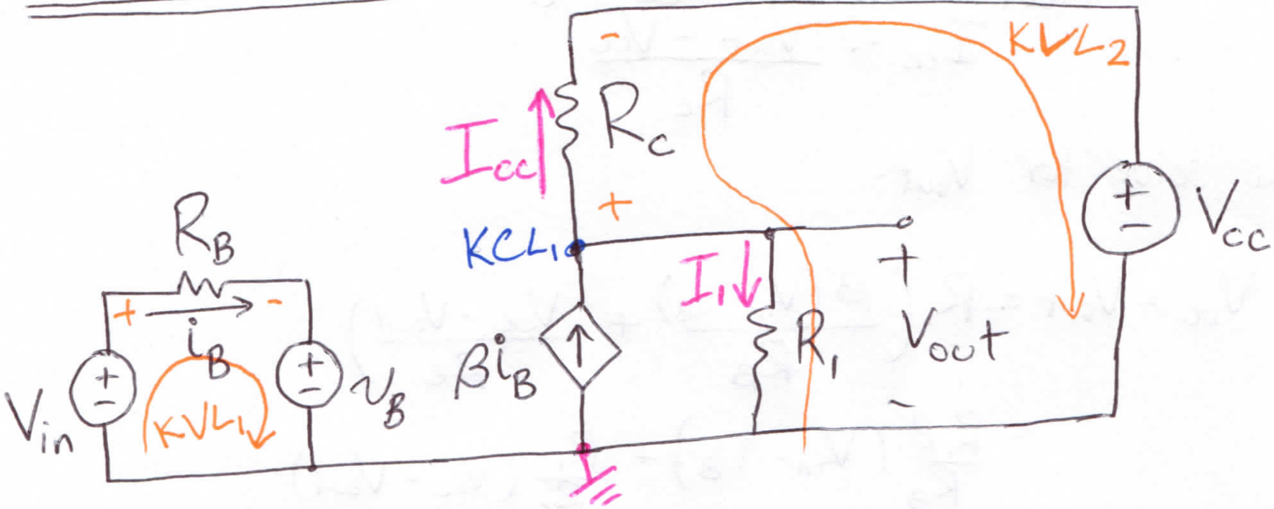
Problem 1 (a) - Total points: 10, negative scoring system used

Mistake	Penalty
Wrong value of the element in the box	4
Wrong circuit analysis (wrong current through the box element) and wrong element in the box	7
Right current through the box element but wrong element in the box	3
Right current through the box element but wrong or no symbol of the element in the box	1
Wrong polarity (arrow direction)/value combination of the current source in the box	1
No Work or Nothing is right	10

Problem 1 (b) - Total points: 5, negative scoring system used

Mistake	Penalty
If you did part a correct then this answer would be 'producing'. But blindly giving answer will not give you any point. We are judging your concept of power 'consuming' and 'producing' based on the current and voltage polarity of the element in the box that you found on part a. $P=VI$. $P>0$ is Consuming, $P<0$ is Producing. V and I polarity should be consistent.	3
Incorrect answer	5

PROBLEM 1 (c):



How to approach this problem:

The question asks for V_{TH} when seen across the V_{out} terminals. This means $V_{oc} = V_{out} = V_{TH}$ = voltage across R_1. To get this voltage, we need to find the current through R_1. There are two sources that contribute to this current: V_{cc} and βi_B. So the first step would be to find i_B, then use the circuit techniques we learned in class (KVL, KCL, mesh, nodal, V=IR, etc..) to find V_{oc}.

Solution

KVL_1 around left loop to find i_B.

$$-V_{in} + R_B i_B + v_B = 0$$

$$i_B = \frac{V_{in} - v_B}{R_B}$$

KCL - for convenience, gnd is chosen at the bottom node.

$$\beta i_B = I_{cc} + I_1 = I_{cc} + \frac{V_{out}}{R_1}$$

Solve for V_{out}:

$$V_{out} = R_1(\beta i_B - I_{cc})$$

$$= R_1\left(\beta\left(\frac{V_{in} - v_B}{R_B}\right) - I_{cc}\right)$$

KVL_2 around right loop to get an expression for I_{cc}.

$$-V_{out} + I_{cc}R_c + V_{cc} = 0$$

$$I_{cc} = \frac{V_{out} - V_{cc}}{R_c}$$

Now solve for V_{out}:

$$V_{oc} = V_{out} = R_1\left(\frac{\beta(V_{in} - v_B)}{R_B} + \frac{V_{cc} - V_{out}}{R_c}\right)$$

$$= \frac{R_1\beta}{R_B}(V_{in} - v_B) + \frac{R_1}{R_c}(V_{cc} - V_{out})$$

$$= \frac{R_1\beta}{R_B}(V_{in} - v_B) + \frac{R_1V_{cc}}{R_c} - \frac{R_1V_{out}}{R_c}$$

$$\therefore V_{out}\left(1 + \frac{R_1}{R_c}\right) = \frac{R_1\beta}{R_B}(V_{in} - v_B) + \frac{R_1V_{cc}}{R_c}$$

$$\rightarrow V_{out} = \boxed{V_{oc} = \left(\frac{R_cR_1}{R_c + R_1}\right)\left[\frac{\beta}{R_B}(V_{in} - v_B) + \frac{V_{cc}}{R_c}\right]}$$

PROBLEM 1(d):

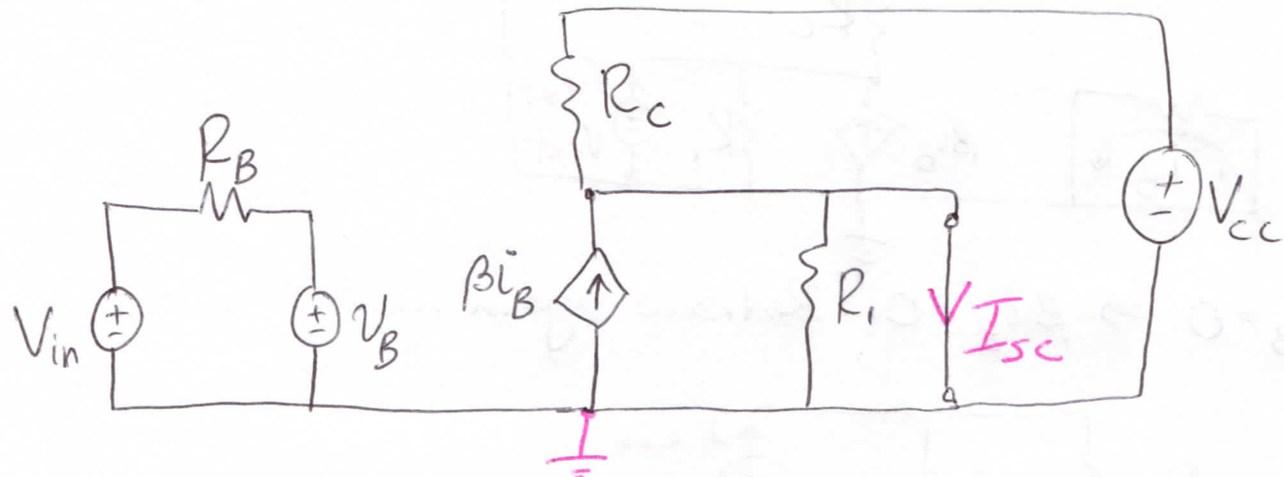
How to approach this problem:

There are a couple of ways to find R_{TH}.

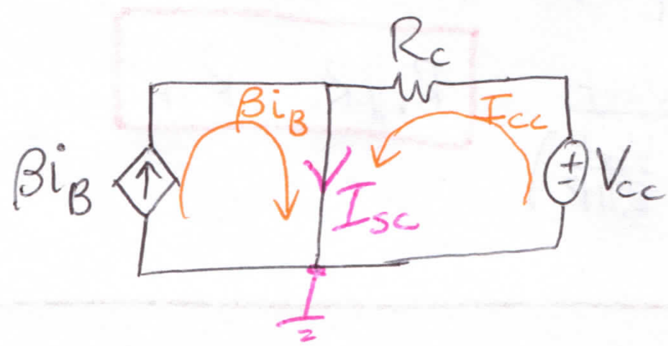
① We can find I_{sc} and the R_{TH} will equal V_{oc}/I_{sc}, OR

② apply an external test voltage (while turning off INDEPENDENT sources), measure the resulting current I_{ex}, and R_{TH} will equal V_{ex}/I_{ex}.

Method ① - Redraw the circuit shorting V_{out}.



R_1 is shorted out, so no current goes through it. Redrawing again, we get:

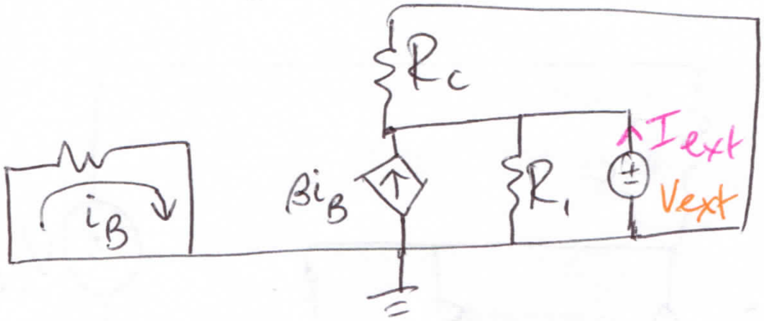


$$I_{sc} = \beta i_B + I_{cc} = \beta i_B + \frac{V_{cc}}{R_c}$$

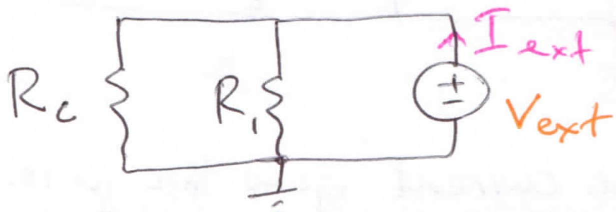
AND, $i_B = \dfrac{V_{in} - v_B}{R_B}$.

$$R_{TH} = \frac{V_{oc}}{I_{sc}} = \left(\frac{R_c R_1}{R_c + R_1}\right) \frac{\beta i_B + V_{cc}/R_c}{\beta i_B + V_{cc}/R_c} \Rightarrow \boxed{R_{TH} = \frac{R_c R_1}{R_c + R_1} = R_1 || R_c}$$

Method ② - Redraw circuit while turning off INDEPENDENT sources.



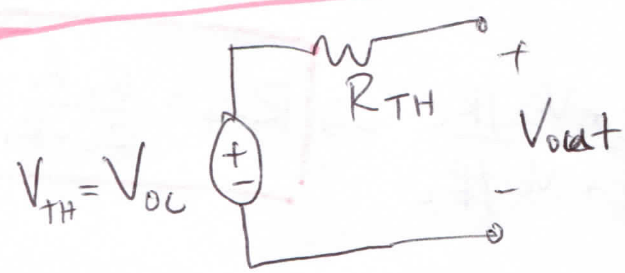
$i_B = 0 \Rightarrow \beta i_B = 0$, Redraw again...



$I_{ext} = \frac{V_{ext}}{R_1 \| R_c}$ {Combined resistors and used V=IR here}

$\Rightarrow R_{TH} = \frac{V_{ext}}{I_{ext}} = \frac{V_{ext}}{\left(\frac{V_{ext}}{R_1 \| R_c}\right)} = \boxed{R_1 \| R_c = R_{TH}}$

PROBLEM 1 (e):



PROBLEMS 1 c-e Solutions by Divya Kashyap

Rubrics for Problems 1 (c), (d), (e)

Problem 1 (c) - Total points: 5, negative scoring system used

Mistake	Penalty
Didn't have KVL to find expression for i_B	1
Didn't have correct expression for i_B	1
Flaws in the method used for getting V_{oc}	2
Incorrect answer for V_{out}	1
Arithmetic error	0.5

Problem 1 (d) - Total points: 5, negative scoring system used

Mistake	Penalty
Wrong answer, didn't show work, or not clear how student got the answer	5
Fundamental mistake: Wrong circuit, didn't calculate I_{sc}, or didn't know V = IR	5
Shorted the dependent source	2.5
Correct circuit, but calculated I_{sc} and/or R_{th} wrong	2.5
Didn't calculate I_{sc} correctly (wrong circuit or correct circuit, but wrong KVL/KCL, etc.,), but demonstrated that they know $R_{th} = V_{oc}/I_{sc}$, or using a test source, $R_{th} = V_{ext}/I_{ext}$	4
Calculated I_{sc} correctly, but had wrong V_{th} in part (c) so got wrong R_{th}	1
Arithmetic error	0.5

Problem 1 (e) – Total points: 5, negative scoring system used. Here, if you got the wrong answers to Vth and Rth, you were already penalized in parts (c) and (d), so I just looked to see if you had placed the circuit elements and labeled them correctly.

Mistake	Penalty
Wrong circuit, or blank	5
Correct circuit, but didn't label V_{th} (or labeled with a value that didn't match answer for part (c)), or made it a current source	2.5
Correct circuit, but didn't label R_{th} (or labeled with a value that didn't match answer for part (d)), or placed it on the other side	2.5
Arithmetic error	0.5

Problem 2

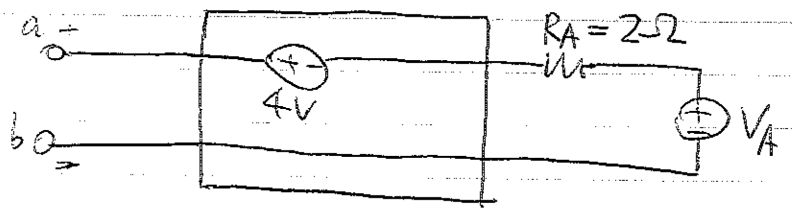
1) $V_1 = 10$
2) $V_1 - V_2 = -20$
3) Form node 3:
$$\frac{V_2 - V_3}{R_7} = \frac{V_3 - V_1}{R_3} + \frac{V_3}{R_8} + \frac{V_3 - V_5}{R_9}$$
$V_1 + V_2 - 4V_3 + V_5 = 0$
4) Form node 4:
$$\frac{V_2 - V_4}{R_5} = \frac{V_4}{R_4} + \frac{V_4 - V_5}{R_6}$$
$V_2 - 3V_4 + V_5 = 0$
5) Form node 2 & 5:
$$\frac{V_4 - V_2}{R_5} + \frac{V_3 - V_2}{R_7} = i_x = \frac{V_5 - V_4}{R_6} + \frac{V_5 - V_3}{R_9}$$
$V_2 - V_3 - V_4 + V_5 = 0$

*each equation for 5 points

EE40 Fall 2014. Midterm 1

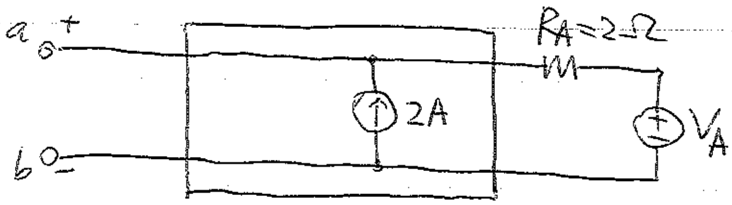
Problem 3

Sol:



Need to say 4V & $R_A = 2\Omega$ to get full points.

OR



Need to say 2A & $R_A = 2\Omega$ to get full points.

OR, if you put more than 1 element into the box, you will receive ~~no~~ full points as long as your solution fulfills all three requirements as follows:

(a) The open circuit voltage across terminals a, b is 5 V.

(b) The short circuit current from terminals a to b is 2.5 A

(c) A correct value of RA that goes with your circuit.

EE 40 Fall 2014 Midterm 1
Problem 4.

Mesh 1: $I_1 R_2 + R_3(I_1 - I_2) + R_4(I_1 - I_3) + R_1 I_1 = 0$ — (a). (5pts)

OR

$I_1 + I_1 - 1 + 10(I_1 - I_3) + 10 I_1 = 0$

From Loop 2: $I_2 = I_A = 1$ — (b) — (4pts)

Supermesh 3 & 4: $V_0 = R_4(I_3 - I_1) + V_1 + R_6 I_4$ — (c) — (5pts)

OR

$0.5 = 10(I_3 - I_1) + 0.5 + 10 I_4$

$I_4 - I_3 = I_B = 1$ — (d) — (5pts)

$I_1 = -\frac{4}{17}$ — (1pts)

$I_5 = 0$ — (5pts)

If you list 5 equations, including I_5, and those equations are correct/similar to equ (a)–(d), you will get points accordingly. Also, if your 5 equations are correct but your solved $I_5 \neq 0$, for (b), you will get 4pts.

For example:

① $R_1(I_1-I_5)+R_2(I_1-I_5)+R_3(I_1-I_2)+R_4(I_1-I_3)=0$

② $-V_1+R_3(I_2-I_1)+R_2(I_5-I_1)+R_1(I_5-I_1)+V_0$
$+I_5(R_7+R_8+R_9+R_{10}+R_{11}+R_{12}+R_{13}+R_{14})+R_6(I_5-I_4)=0$

③ $I_2-I_5=I_A$

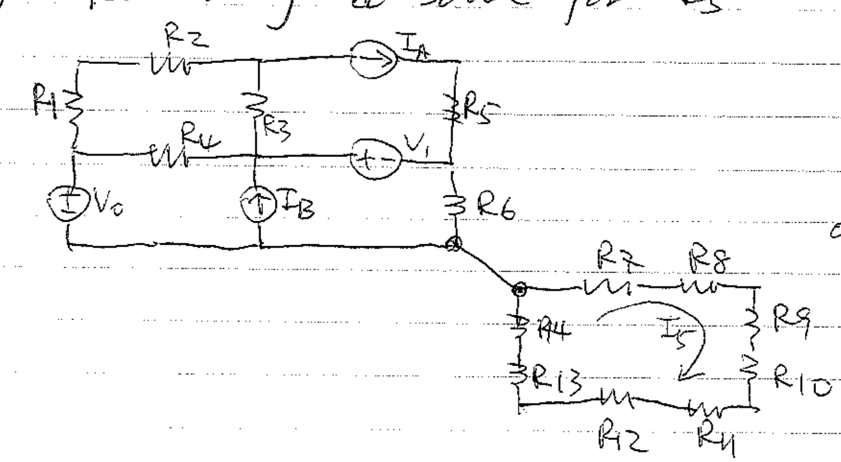
④ $-V_0+R_4(I_3-I_1)+V_1+R_6(I_4-I_5)=0$

⑤ $I_4-I_3=I_B$

$$\Longrightarrow \begin{bmatrix} 22 & -1 & -10 & 0 & -11 \\ -12 & 1 & 0 & -10 & 29 \\ 0 & 1 & 0 & 0 & -1 \\ -1 & 0 & 1 & 1 & -1 \\ 0 & 0 & -1 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 1 \end{bmatrix}$$

If you give above ~~equation~~ equations ① – ⑤ OR give the above matrix correctly, you will get 19 points for part(a) & 4 points for part (b) without numerically ~~solved~~ solving I_1 & I_5.

- A quicker way to solve for I_5 —



open circuit, $I_5=0$.