Solution

ECE101F19 Midterm Examination, Oct. 29, 2019

Name________________ Student ID____________________

You are allowed to use one page of formulas. No calculator is allowed.

Please show all of your work to obtain full credits.

Problem 1 (20 points) ____________________

Problem 2 (20 points) ____________________

Problem 3 (20 points) ____________________

Problem 4 (20 points) ____________________

Problem 5 (20 points) ____________________

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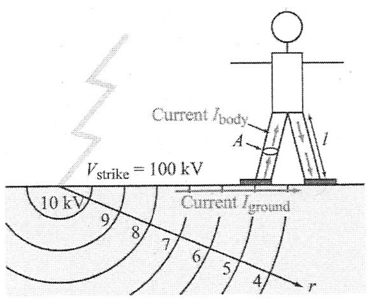
Total (100 points) ____________________

[1]. (20 points) This problem tests your understanding of circuit modeling.

A person who was on a golf course was exposed to a thunder strike V_{strike} = 100 KV on a rainy day. His right foot was 10 meters away from the strike point and his left foot 11 meters from the strike point. It is estimated that the resistance between the bottoms of the right and left shoe is R_{R-L} = 2 KΩ.



$$\text{Voltage} = \frac{V_{strike}}{\frac{1}{2}\left(\frac{4}{3}\pi r^3\right)}$$

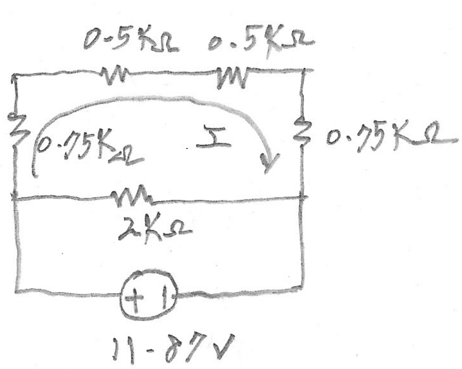
Each shoe provides some degree of protection with a series resistance of 750 Ω, and each leg has a series resistance of 500 Ω.

(10 points) Draw an equivalent circuit that models this accident using a voltage source V_{source} which can be calculated by $V_{source} = V_{r1} - V_{r2}$, and R_{R-L}, R_{shoe} for each side, and R_{leg} for each side. Note that V_r = 100 KV/(1/2 x 4/3π x r^3) = (47.75)/ r^3 [KV].

First find V_{source} = 11.87×10^{-3} **KV**

$V_{source} = 47.75\,KV\left(\frac{1}{10^3} - \frac{1}{11^3}\right) = 47.75\,KV \frac{1331-1000}{1000 \times 1331} = 47.75 \frac{331}{1331}$
$= 11.87\,V$

Draw the circuit diagram (hint: voltage source is in parallel with R_{R-L} which in turn is in parallel with the resistances in the shoe-leg path starting from the left shoe touiching the ground to the right shoe touching the ground.)



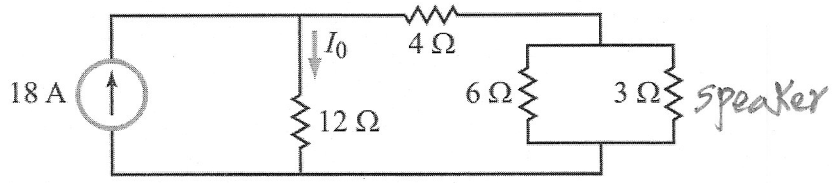
(10 points) Calculate the current through both legs in this unfortunate situation as

I = 4.75 [mA].

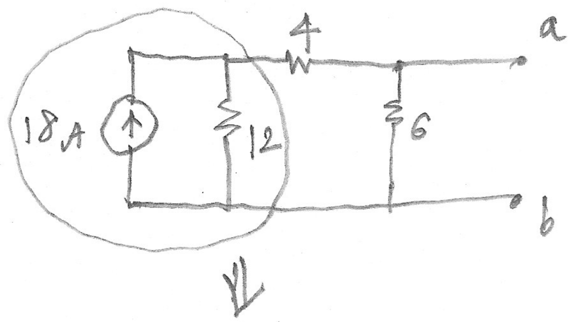
$$I = \frac{11.87\ V}{(0.75+0.5+0.5+0.75)\ K\Omega} = \frac{11.87\ V}{2.5\ K\Omega} \fallingdotseq 4.75\ mA$$

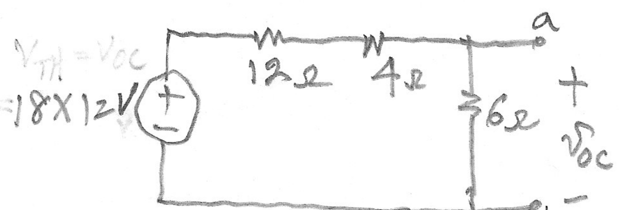
[2]. (20 points) This problem tests your understanding of Thevenin's and Norton's equivalent circuits.

In the circuit below, the rightmost 3Ω resistor represents a speaker.



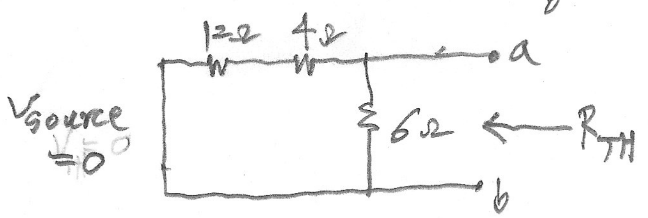
Part 1 (10 points) Draw a Thevinin's equivalent circuit connected to the speaker





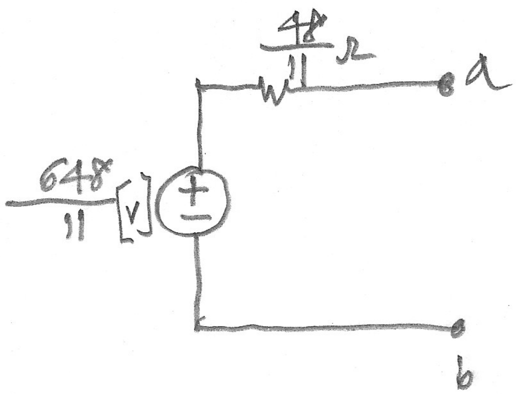
$$v_{oc} = \cancel{18}^{9} \times 12 \times \frac{6}{\underbrace{12+4+6}_{=\cancel{22}\ 11}}$$

$$= 108 \times \frac{6}{11} = \frac{648}{11} \approx 58.91\ [V]$$



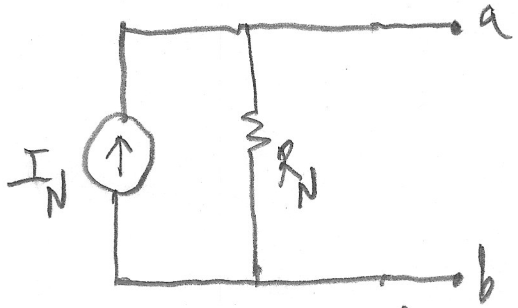
$$R_{TH} = 6 \parallel (12+4) = \frac{6 \times 16}{6+16} = \frac{96}{22}\ \Omega$$

$$= \frac{48}{11}\ \Omega$$



Thevin's equivalent circuit

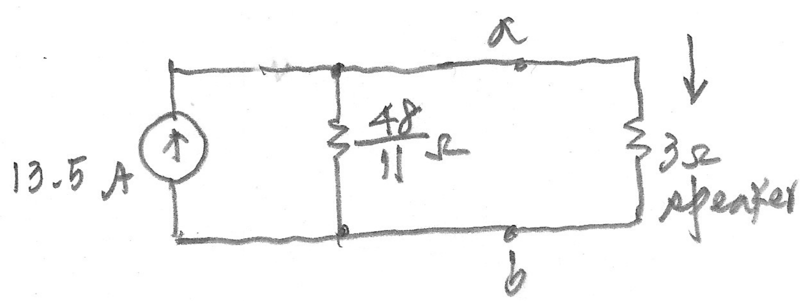
Part 2 (10 points) Draw a Norton's equivalent circuit connected to the speaker and calculate the power delivered to the speaker..



Norton's equivalent circuit

$$I_N = \frac{\frac{648}{11}}{\frac{48}{11}} = \frac{648}{48} = \frac{81}{6}$$

$$= 13.5 \, [A]$$



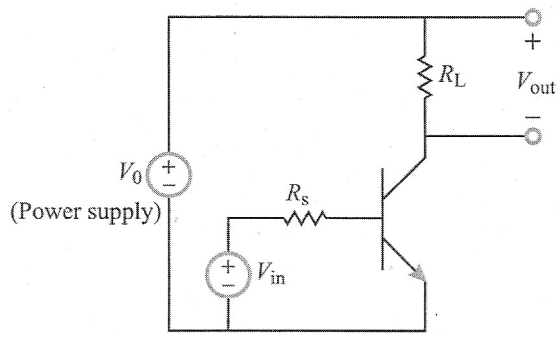
$$\text{Current through } 3\Omega = I_{3\Omega} = 13.5 \times \frac{\frac{48}{11}}{\frac{48}{11} + 3}$$

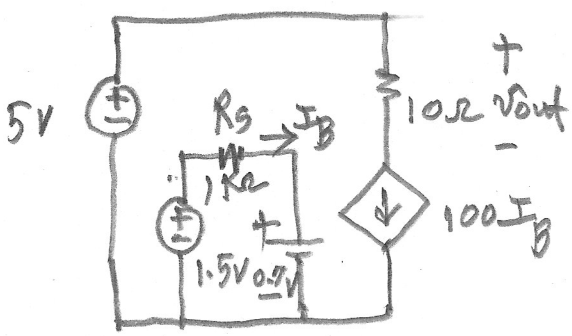
$$= 13.5 \times \frac{\frac{48}{11}}{\frac{48 + 3 \times 11}{11}} = 13.5 \times \frac{48}{81} \, [A]$$

$$P_{3\Omega} = I_{3\Omega}^2 \times 3 = \left(13.5 \times \frac{48}{81}\right)^2 \times 3$$

$$= (8)^2 \times 3 = 64 \times 3 = \underline{0.192} \, [Kw]$$

[3]. (20 points) This problem tests your ability to analyze bipolar junction transistor (BJT) circuit where power supply voltage V_o is 5 V, input voltage V_{in} is 1.5 V, R_S = 1 KΩ, , R_L = 10 Ω, V_{BE}= 0.7 V, and β=100. **Calculate V_{out}** 0.8 [V].



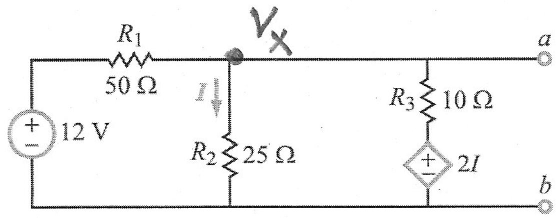


$$I_B = \frac{1.5 - 0.7}{1\,K\Omega} = 0.8\ mA$$

$$I_C = \beta I_B = 100\,(0.8\,mA) = 80\ mA$$

$$V_{out} = 10\,\Omega \times 80\ mA = 800\ mV = \underline{0.8\ [V]}$$

[4]. (20 points) This problem tests your ability for circuit analysis, i.e. finding currents, voltages, power consumptions, generations, etc.



Part 1. (10 points) Find current I through the 25 Ω resistor.

I = $\frac{6}{95}$ [A],

$I = \frac{V_X}{25}$, $V_X = 25I$

KCL at V_X node :

$$\frac{12 - V_X}{50} = \frac{V_X}{25} + \frac{V_X - 2\left(\frac{V_X}{25}\right)}{10}$$

Multiply both sides by 50 ⇒

$$12 - V_X = 2V_X + 5V_X - 10\left(\frac{V_X}{25}\right)$$

$V_X = 25I$ ⇒

$$12 - 25I = 2(25I) + 5(25I) - 10\left(\frac{25I}{25}\right)$$

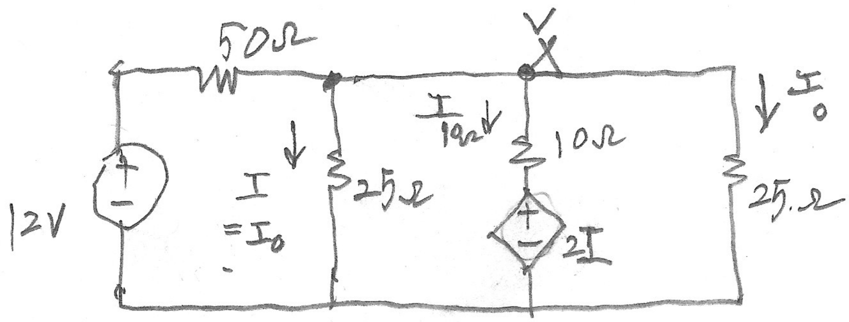
$$= 50I + 125I - 10I$$

$$12 = 25I + 50I + 125I - 10I = 190I$$

$$I = \frac{12}{190} = \frac{6}{95} [A]$$

Part 2. (10 points) Find power consumed in another 25 Ω resistor (load) when it is connected across terminals a and b.

P = 0.0625 [W]



$$P_{25\Omega} = \left(I_{25\Omega}\right)^2 \times 25$$

$$V_X = 25 I_o$$

$$I_{10\Omega} = \frac{V_X - 2I}{10} = \frac{25 I_o - 2 I_o}{10} = 2.3 I_o$$

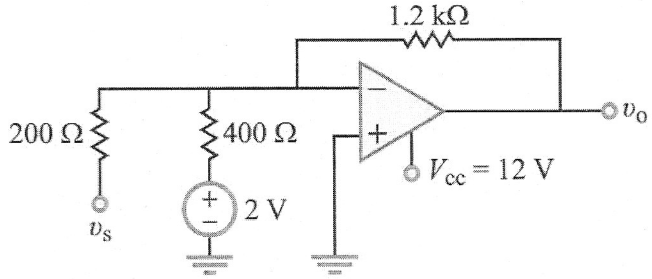
$$\frac{12 - \overset{25 I_o}{V_X}}{50} = I_o + \overset{I_{10\Omega}}{2.3 I_o} + I_o = 4.3 I_o$$

$$12 - 25 I_o = 50 \times 4.3 I_o = 215 I_o$$

$$12 = (25 + 215) I_o = 240 I_o \Rightarrow I_o = \frac{12}{240} = \underline{0.05\ [A]}$$

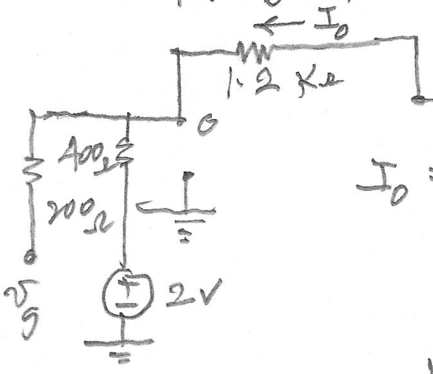
$$P_{25\Omega} = (0.05)^2 \times 25 = 0.0025 \times 25 = \underline{0.0625} = \underline{62.5\ mW}$$

[5].(20 points) This problems tests your ability to analyze OP amp circuits. In the circuit below, although not shown, there is a -12V power supply,



Part 1 (10 points) Find v_S when v_o = 12V and -12V.

For $v_o = +12V$



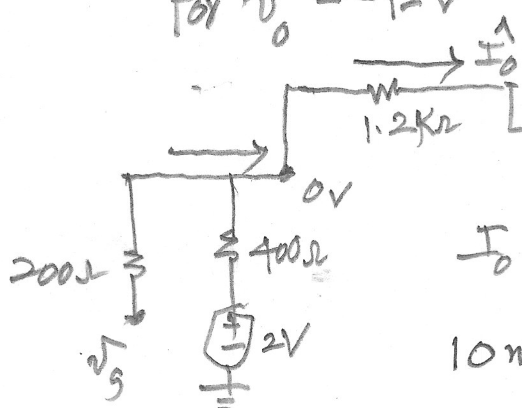
$$I_o = \frac{12V}{1.2K\Omega} = 10\ mA$$

$$I_o = 10\ mA = \frac{0 - v_S}{\underset{0.2K}{200}} + \frac{0-2}{\underset{0.4K}{400}}$$

$$= \frac{-v_S}{0.2K} - 5\ mA$$

$$15\ mA \times 0.2K\Omega = -v_S \Rightarrow \underline{v_S = -3\ V}$$

For $v_o = -12V$



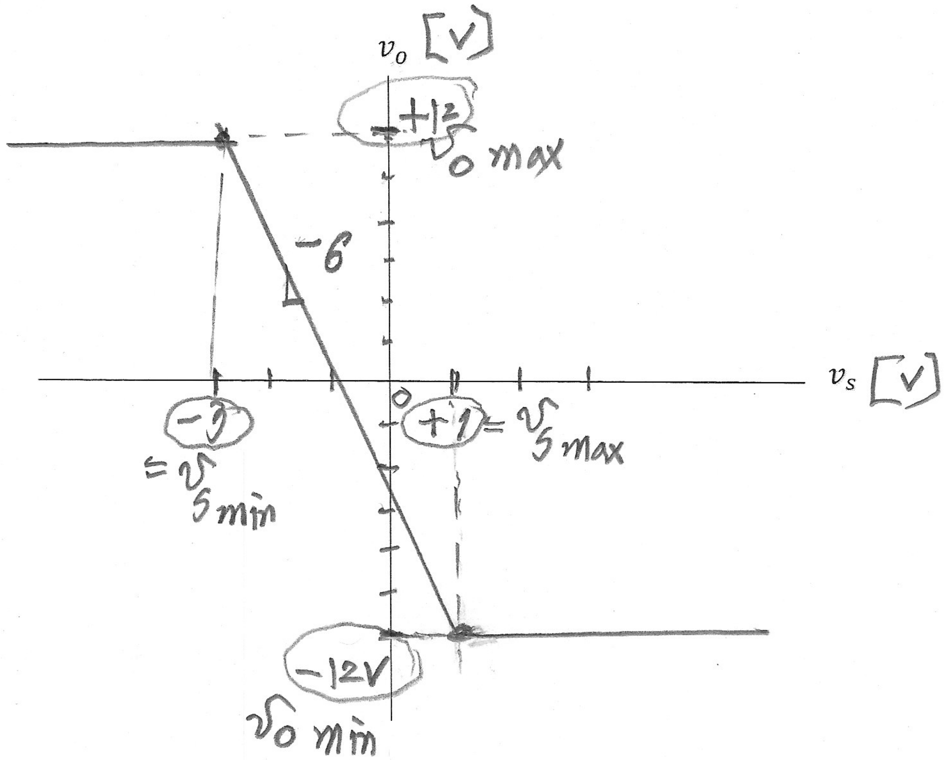
$$I_o = \frac{0-(-12)}{1.2K} = 10\ mA$$

$$I_o = \frac{v_S}{0.2K} + \frac{2}{0.4K}$$

$$10\ mA = \frac{v_S}{0.2K} + 5\ mA \Rightarrow v_S = (10-5)\ mA \times 0.2K$$

$$\underline{= 1\ V}$$

Part 2 (10 points) Plot the v_o- v_s curve to show saturation effects and also the linear region. Mark important values such as the max and min values of v_o and those of v_s, and also the circuit gain slope G.



$$G = \frac{-12-(+12)}{+1-(-3)} = \frac{-24}{4} = \underline{-6}$$