# 4.1

Monday, January 28, 2019 2:59 PM

- Planar Circuit: A circuit that can be drawn on a plane with no crossing branches.

  Branch: A path that connects two nodes.

  Essential branch: A path that connects two essential nodes without passing through an essential node.

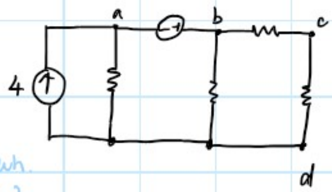
- Node-voltage method is applicable to both planar and non-planar circuits;

  Mesh-current method is only limited to planar circuits.

- 

  $n_e$ essential nodes $\rightarrow$ $n_e - 1$ independent equations (KCL)

  $b_e$ essential branches $\rightarrow$ $b_e$ currents $\rightarrow$ need $b_e - (n_e - 1)$ additional equations (KVL)

  $n_e = 3$. a, b, d

  $b_e = 5$, but 4A current known. So there're 2

  $\Rightarrow$ abda

  bcdb

- Node-Voltage Method
  - Steps:

    I. Identify essential nodes

    II. Select one essential nodes as a reference node.

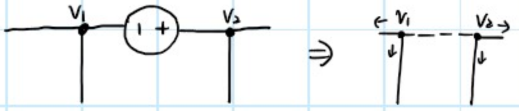
    Normally chose the node with the most branches.

    Define "node voltage" as voltage rise from the reference node to a nonreference node.

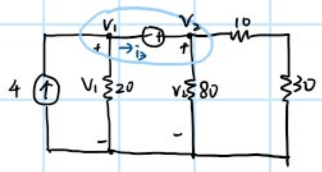
to a nonreference node.

III. Apply KCL at the other essential nodes in terms of node voltage

- Supernodes: When a voltage (or resistor) source is between two essential nodes, we can combine the nodes into a supernode.



They need to share same current.



(Consider the blue circle as a node)

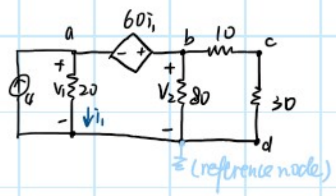
$4 - \frac{V_1}{20} - \frac{V_2}{80} - \frac{V_2}{40} = 0$

Because it's equivalent to using two times KCL

$V_1 + 60 = V_2$

Using supernode can eliminate the unknown $i_3$.

e.g. NV Method with dependent source

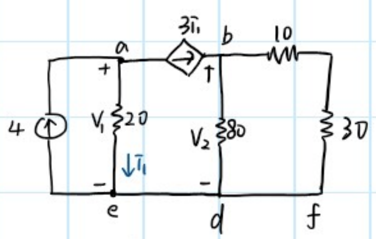


essential nodes: a, b, d.
↓
d as reference node.
↓
super nodes: a-b

$4 - \frac{V_1}{20} - \frac{V_2}{80} - \frac{V_2}{40} = 0$

$V_1 + 60 \cdot \frac{V_1}{20} - V_2 = 0$

Dependent current sources in the Node-Voltage Method



⇒ Can't use supernode

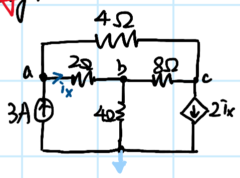
a: $4 - \frac{V_1}{20} - 3\frac{V_1}{20} = 0$

b: $3\frac{V_1}{20} - \frac{V_2}{80} - \frac{V_2}{40} = 0$

def are equivalent nodes.

The dependent current source doesn't provide the information of voltage drop.

e.g.

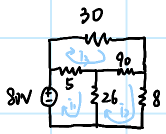



$$
\begin{cases}
a:\ -3 + \dfrac{V_a - V_b}{2} + \dfrac{V_a - V_c}{4} = 0 \\[2ex]
b:\ \dfrac{V_b - V_a}{2} + \dfrac{V_b}{4} + \dfrac{V_b - V_c}{8} = 0 \\[2ex]
c:\ \dfrac{V_c - V_a}{4} + \dfrac{V_c - V_b}{8} + 2i_x = 0 \\[2ex]
i_x = \dfrac{V_a - V_b}{2}
\end{cases}
$$

# 4.5

Wednesday, February 6, 2019 2:33 PM

- Mesh-Current Method
  - Steps:
    - I. Identify meshes (& Supermeshes)
    - II. Applying KVL at each mesh, expressing voltages in terms of mesh currents.
    - III. Solve.
  - e.g. Calculate $i_1, i_2, i_3$.



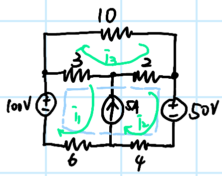
$-80+5(i_1-i_3)+26(i_1-i_2)=0$

$8i_2+26(i_2-i_1)+90(i_2-i_3)=0$

$30i_3+90(i_3-i_2)+5(i_3-i_1)=0$

$i_1=5A$, $i_2=2.5A$, $i_3=2A$

  - Supermesh: shared current source

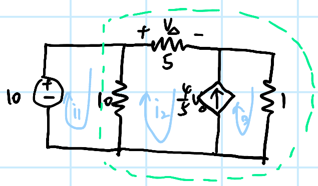


Mesh ac $-100+6i_1+3(i_1-i_3)+2(i_2-i_3)+50+4i_2=0$

5A current source cancelled each other in Mesh 1 & 2.

$i_2-i_1=5$

- Mesh-Current Method with dependent sources



can use supermesh

$-10+10(i_1-i_2)=0$

$V_\Delta=5i_2$

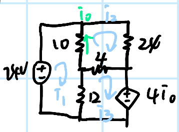
$$\begin{cases} i_3-i_2=\frac{4}{5}V_\Delta \\ V_\Delta=5i_2 \end{cases}$$

Supermesh:

$10(i_2-i_1)+5i_2+i_3=0$

$i_1 = 2A$, $i_2 = 1A$, $i_3 = 5A$, $V_\Delta = 5i_2 = 5V$

e.g.




$$-24 + 10(i_1 - i_2) + 12(i_1 - i_3) = 0$$

$$24i_2 + 4(i_2 - i_3) + 10(i_2 - i_1) = 0$$

$$4i_0 + 12(i_3 - i_1) + 4(i_3 - i_2) = 0$$

$$i_0 = i_2 - i_1$$

# Source Transformations

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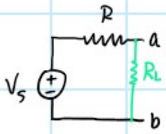
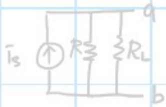
- *Source Transformation*



$i_L = \frac{V_S}{R+R_L}$

o If only consider a-b.



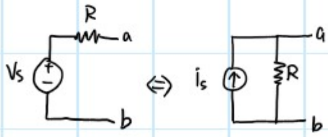
$i_L = \frac{R}{R_L+R} \cdot i_s$

∵ they're equivalent circuit

∴ $i_L = i_L$

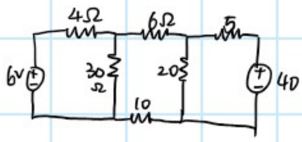
$\frac{V_S}{R+R_L} = \frac{R}{R_L+R} \cdot i_s$

∴ $\frac{V_S}{R} = i_s$





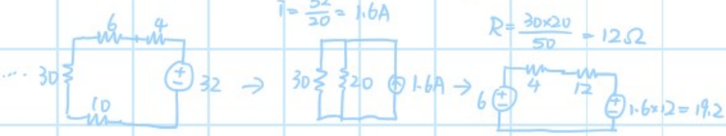
e.g. $P_{4\Omega}$



$\frac{5 \times 20}{25} = 4\Omega$

$i = \frac{32}{20} = 1.6A$

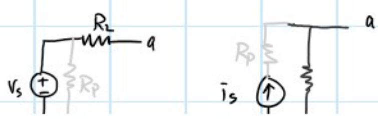
$R = \frac{30 \times 20}{50} = 12\Omega$



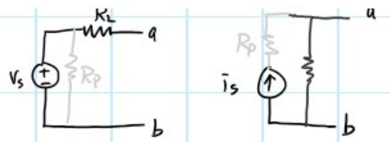
$i = \frac{19.2-6}{16} = 0.825A$

$P_{4\Omega} = i^2 R = 2.7225W$

- If there's $R_p$ in parallel with $V_s$ or in series with $i_s$,



no effect

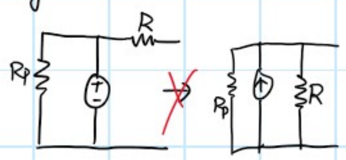



no effect

- Remove them when doing source transformation.

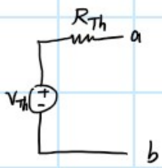
  But the total power will be different.

  e.g.

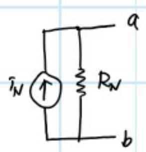



Need to remove $R_P$

- **Thévenin & Norton Equivalent**




Thévenin Equivalent




Norton Equivalent

  - Open Circuit Voltage $V_{oc} = V_{th}$

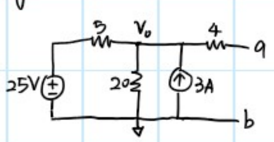
    $R_L \to \infty, \quad V_{R_L} = V_{th}$

  - Short Circuit Current $i_{sc} = \frac{V_{th}}{R_{th}}$

    $R_L = 0, \quad i_{sc} = \frac{V_{th}}{R_{th}}$

  - $i_N = i_{sc}, \quad R_N = R_{Th} = \frac{V_{oc}}{i_{sc}}$

e.g.




Open Circuit:

$$\frac{V_0 - 25}{5} + \frac{V_0}{20} - 3 = 0, \quad V_0 = 32V = V_{th}$$

Short circuit:

$$\frac{V_0 - 25}{5} + \frac{V_0}{20} - 3 + \frac{V_0}{4} = 0 \text{ (different } V_0\text{)}$$

$V_0 = 16V, \quad i_{sc} = \frac{16}{4} = 4A \quad R_{th} = \frac{V_{th}}{i_{sc}} = \frac{32}{4} = 8\,\Omega$

$V_{th} = i_{sc} \cdot R_{th} = 32V$

Method: open circuit & short circuit

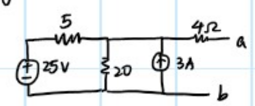
Method: Source Transformation:


- If the circuit only contains independent sources

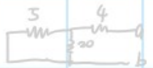
  1° Deactivate all independent source

  replace { current source by an open circuit ; voltage source by a short circuit

  e.g.

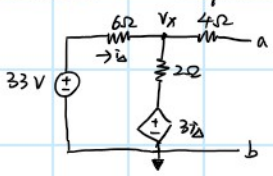



$\Rightarrow R_{eq} = 8\Omega$




$R_{eq}$ is the Thévenin resistor.

- Thévenin & Norton Equivalents with Dependent Sources




- Approach I. open circuit $\rightarrow V_{Th}$

  short circuit $\rightarrow i_{sc} = i_N \rightarrow R_{Th}$

Open-circuit voltage

$$\left.\begin{aligned} &\frac{V_x - 33}{6} + \frac{V_x - 3i_\Delta}{2} = 0 \\ &i_\Delta = \frac{33 - V_x}{6} \end{aligned}\right\} V_x = 15V = V_{Th}$$

Short circuit current

$$\left.\begin{aligned} &\frac{V_x - 33}{6} + \frac{V_x - 3i_\Delta}{2} + \frac{V_x}{4} = 0 \\ &i_\Delta = \frac{33 - V_x}{6} \end{aligned}\right\} \begin{aligned} &V_x = \frac{165}{14} V \\ &i_{sc} = \frac{V_x}{4} = \frac{165}{56} A \end{aligned}$$

$$\therefore R_{Th} = \frac{V_{Th}}{i_{sc}} = \frac{15V}{\frac{165}{56}A} = \frac{56}{11}\Omega$$

- Approach II.
  - Deactivate all independent sources, apply either a

○ Approach II.

- Deactivate all independent sources, apply either a test voltage source or test current source between ab

$$\frac{V_x}{6}+\frac{V_x-3i_\Delta}{2}+\frac{V_x-V_T}{4}=0$$

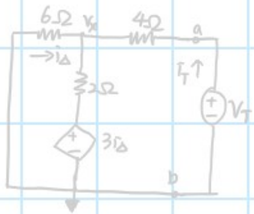
$$i_\Delta=-\frac{V_x}{6}$$

$$i_T=\frac{V_T-V_x}{4}$$

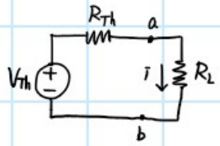
$$V_x=\frac{3}{14}V_T$$

$$i_T=\frac{V_T-\frac{3}{14}V_T}{4}$$

$$R_{Th}=\frac{V_T}{i_T}=\frac{56}{11}\Omega$$




- Maximum Power Transfer.




Maximize $P_{R_L}$

$$P=i^2R_L=\left(\frac{V_{Th}}{R_L+R_{Th}}\right)^2\cdot R_L=\frac{V_{Th}^2\cdot R_L}{(R_L+R_{Th})^2}$$

$$\text{Max: } \frac{dP}{dR_L}=0=V_{Th}^2\cdot\frac{(R_{Th}+R_L)-2R_L}{(R_L+R_{Th})^3}=0$$

$$\therefore R_{Th}+R_L=2R_L,\quad R_{Th}=R_L$$

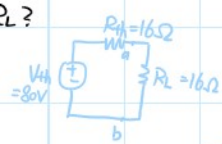
When $\boxed{R_L=R_{Th}}$ the power of $R_L$ is max.

$$P_{max}=\frac{V_{Th}^2}{4R_L}$$

(if $R_{Th}$ complex, $R_L$ is the conjugate)

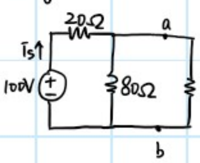
($R_L=R_{Th}$)

- Is 50% power transferred to $R_L$?




No.

e.g.




$$V_{Th}=100\times\frac{80}{20+80}=80V$$

$$V_{ab}=\frac{80V}{2}=40V$$

$$R_{Th}=\frac{20\times80}{100}=16\Omega$$

$$i_s=\frac{100V-40V}{20\Omega}=3A$$

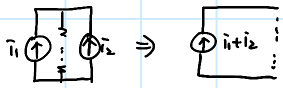
$$P_{max}=\left(\frac{80}{16+16}\right)^2\cdot16=2.5^2\times16=100W$$

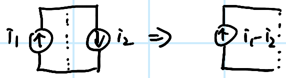
$\therefore P_{voltage\ source}=Vi_s=300W>2\times P_{max}$

⇑

★ Thévenin equivalent circuits cannot be used for calculating the percentage of power delivered to the load!

- Combine parallel current source

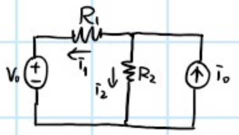




# Superposition

Wednesday, February 20, 2019 2:51 PM

e.g.




$i_1 R_1 + V_0 + R_2(i_1 - i_0) = 0$

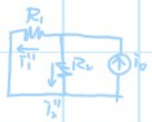
$\Rightarrow i_1 = -\underline{\frac{V_0}{R_1+R_2}} + \underline{\frac{R_2}{R_1+R_2} \cdot i_0}$

$i_2 = i_0 - i_1 = \underline{\frac{V_0}{R_1+R_2}} + \underline{\frac{R_1}{R_1+R_2} i_0}$

Circuit 1


$i_2' = -i_1' = \frac{V_0}{R_1+R_2}$

Circuit 2




$i_1'' = \frac{R_2}{R_1+R_2} i_0$, $i_2'' = \frac{R_1}{R_1+R_2} i_0$

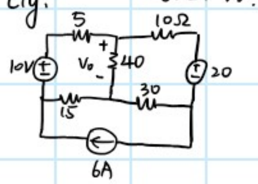
$i_1 = i_1' + i_1''$, $i_2 = i_2' + i_2''$

- Principles of Superposition

  o $\text{Response}(V_1, \ldots, V_n, i_1, \ldots, i_n) = \sum_n V_i + \sum_n i_i$

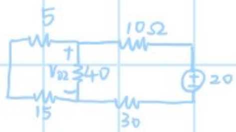
  ( Linear circuit obeys PoS )

e.g. Find $V_o$.

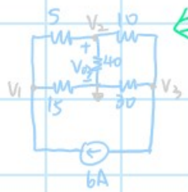




$V_{o1} = 10 \cdot \frac{40 \parallel 40}{5+15+40 \parallel 40} = 5V$




$V_{o2} = 20 \cdot \frac{40 \parallel 20}{10+30+40 \parallel 20} = 5V$




$\Leftarrow$ Use wheatstone bridge $V_{o3} = 0$

$$\begin{cases} \frac{V_1}{15} + \frac{V_1 - V_2}{5} - 6 = 0 \\ \frac{V_2 - V_1}{5} + \frac{V_2}{40} + \frac{V_2 - V_3}{10} = 0 \\ \frac{V_3 - V_2}{10} + \frac{V_3}{30} + 6 = 0 \end{cases}$$

$V_{o3} = 0$

$\therefore V_o = V_{o1} + V_{o2} + V_{o3} = 10V$

- For superposition, it is not required that only one independent source be consider at a time, any number of independent sources may be consider simultaneously.

# EE+215+Lab+2

Wednesday, February 6, 2019 12:43 PM

EE+215+Lab +2



## *EE 215 - Laboratory 2 - Nodal Analysis and Thévenin Equivalents*

### *Authors*

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### *Objectives*

At the end of this lab, you will be able to:

- Construct, analyze and measure multiple-source circuits
- Model transistors as dependent sources, and confirm the model with measurements
- Develop Thévenin equivalent models of real world components (a potato battery!)
- Design an experiment to determine a Thévenin equivalent model (of a diode)

### *Materials and Supplies*

See Laboratory 1 for information on obtaining a laboratory parts kit and multimeter, and for identifying many of the parts used in Laboratory 2.

**Parts for this Lab**

For parts (or, types of parts, like resistors) that you have already used in Lab 1, you should be able to pick the parts out from the circuit diagram and find them in your part kit. This section will discuss parts you have not worked with yet. These are:

- A raw potato (no kidding!)
- Copper and tin (galvanized) nails
- Red Light Emitting Diode (LED)
- Bipolar Junction Transistor (BJT), NPN, 2N3904

The *potato* is NOT supplied in the parts kit, and should be purchased from a grocery store. It provides the electrolyte for a peculiar form of battery. The *copper and tin (galvanized) nails* form the electrodes of the battery. You could buy these from a home improvement store, but for your convenience they are supplied in the parts kit.

*Light Emitting Diodes* or LEDs (Figure 1) are the colored plastic bullet-shaped parts with two parallel leads sticking out the back of the bullet.

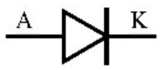



Figure 1 - Types of diodes. The three on the right are Light Emitting Diodes (LEDs). The one on the left is a power diode. To the right is the diode circuit symbol, with A and K on the anode and cathode.

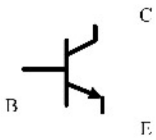



Figure 2 - Types of transistors. The left hand lower one is the one in the lab kit. The large square ones and the large metal cans are power transistors. An NPN transistor circuit symbol, with Collector, Base and Emitter marked C, B and E respectively, is on the right side of the figure.

The *transistor* is the small black plastic part with three leads coming out. The case is shaped like a cylinder with one side shaved flat. If you look closely you can find its model number, 2N3904, printed on the flat side.

## *Laboratory Procedures, Measurements, and Questions*

Record your data and the answers to questions on a separate sheet (or sheets) of paper and hand it in at recitation section when the lab is due. You will also have to bring your breadboard with designated circuits on it to your recitation section the week the lab is due.

**Procedure 1 (25 points) Node and Mesh Analysis, Thévenin Equivalent**

Construct the circuit of Figure P1-1 on your breadboard:

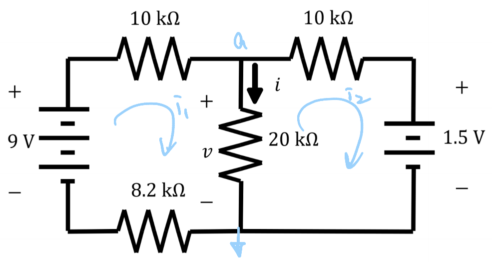


Figure P1-1 procedure 1 circuit

**a** **(5 points)** Calculate the voltage $v$ across the 20 kΩ resistor using node voltage analysis.

**b** **(5 points)** Calculate the current $i$ through the 20 kΩ resistor using mesh current analysis.

**c** **(5 points)** Measure the voltage $v$ across the 20 kΩ resistor. Measure the current $i$ through the 20 kΩ resistor. Are these values consistent with your calculations in parts a and b? Explain any differences. (Remember to return your meter to voltage measurement or off as soon as you have completed the current measurement.)

**d** **(5 points)** Compute the values of the Thévenin equivalent seen by the 20 kΩ resistor using circuit analysis techniques. Draw the equivalent circuit and list the values.

**e** **(5 points)** Remove the 20 kΩ resistor from the circuit you built and measure the open circuit voltage $v$. Replace the 20 kΩ resistor with a short circuit (your multimeter set on current works nicely) and measure the short circuit current $i$. Use these values to compute a Thévenin equivalent. Compare to the Thévenin equivalent from part e.

**Procedure 2 (25 points) Thévenin Equivalents as Models**

Computing Thévenin equivalents is easy when the circuit components have known values. Computing equivalents from measured values is easy when open circuit voltage and short circuit current is available. What about components with unknown quantities, that should not be short circuited? That's what this procedure covers.

Ideal voltage sources have zero internal resistance ($R_{eq} = 0$) but real voltage sources have non-zero internal resistance. For many applications, the non-zero resistance is important. In this procedure you will determine internal resistance by finding Thévenin Equivalent circuits for two real voltage sources, a 1.5V AA battery and a potato. Pay attention to the values of $R_{eq}$!

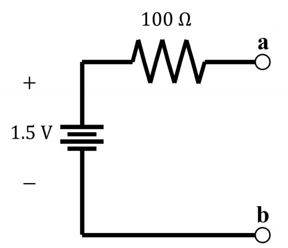
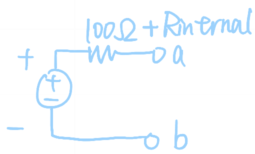


Figure P2-1 - Battery circuit

**a. (5 points)** Connect a 100 Ω resistor and the 1.5 V AA battery as shown in Figure P2-1. Measure the open circuit voltage and the short circuit current at the circuit terminals, marked a and b in Figure P21. Do NOT short circuit the battery all by itself, i.e. always have the 100 Ω resistor in the circuit. If you like, you can find current by measuring the voltage across the resistor and applying Ohm's Law. This is a safer way of measuring current than using an ammeter. If you do this, consider whether you should use the nominal or measured value of the resistance.

**b. (5 points)** Using the measurements made in part a, calculate the Thévenin Equivalent circuit for the battery and series resistor taken together. Then calculate the internal resistance of the battery. Draw the Thévenin Equivalent of the battery, only. Label values.



$$— + \frac{V-9}{10+8.2} + \frac{V-1.5}{10} = 0$$

$(V-9) + 2V - 3 = 0$

$V = 3.1447V.$

$i_2$

$i_1 - 9 + 10\times10^3 i_1 + (i_1 - i_2)20\times10^3 = 0$

$(i_2 - i_1) + 10^4 i_2 + 1.5 = 0$

$i_1 + 3\times10^4 i_2 + 1.5 = 0$

$^4 i_1 - 2\times10^4 i_2 - 9 = 0$

$i_2$

$3.73\times10^4 i_1 = 12$

$i_1 = 3.2172\times10^{-4} A$

$i_2 = 1.6449\times10^{-4} A$

$= i_1 - i_2 = 1.5723\times10^{-4} A$

e $= 3.31V$

e $= 1.7\times10^{-4} A$

re slightly larger than the calculate value,

because the battery of 9V have higher actual value

heortereal value.

re $= 4.40V$

**c. (5 points)** Stick a piece of zinc (the galvanized nail is zinc coated onto iron) into one end of your raw potato and a piece of copper (the copper nail, although a penny will work) into the other end. Connect a 100 Ω resistor in series with the potato. (Alligator clips help here.) Measure the open circuit voltage and short circuit current at the circuit terminals.

**d. (5 points)** Calculate and draw the Thévenin Equivalent circuit for the potato battery without the 100 Ω resistor.

**e. (5 points)** Which is a better battery, and why?

Note: I would not eat the potato after using it in this experiment.

**Procedure 3 (25 points) Dependent Sources**

Unlike resistors or capacitors, you can't buy a dependent source off the shelf. At least, not a cheap one. However, dependent sources are the basis of models for important electronics components, like the Bipolar Junction Transistor (BJT). In this procedure, you will determine the parameters (current gain, $\beta$, and base-to-emitter voltage $v_{BE}$) of a dependent source model for a BJT.

A BJT has three connections, which appear as pins emerging from the transistor package. They are the *collector*, *emitter* and *base*. A simple model of the BJT is that current flow into the base controls the current flow between the collector and emitter. Thus a Current Controlled Current Source (CCCS) can be used as a model. The base is connected to the emitter through a voltage source, $v_{BE}$. Figure P3-1 shows the transistor package pins, the transistor circuit symbol, and the CCCS model.

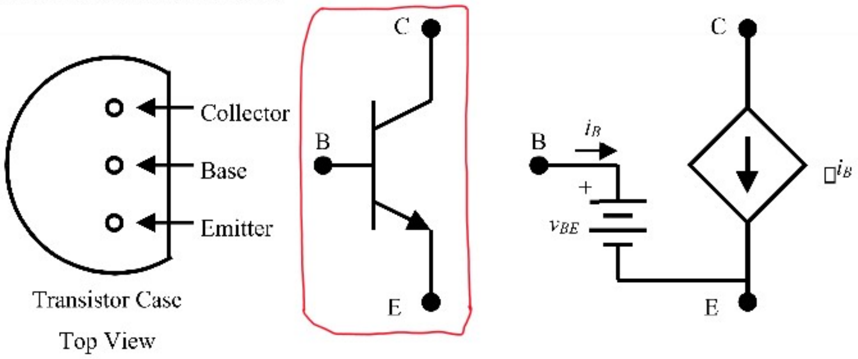



Figure P3-1 - Three different representations of the same NPN Bipolar Junction Transistor (BJT). On the left, the transistor case viewed from the top, with the Collector, Base and Emitter leads identified. In the center, the transistor circuit symbol. On the right, the Current Controlled Current Source (CCCS) model of the transistor.

As with most models, this model is valid over a restricted range of operation. A transistor cannot manufacture current or voltage by itself. If the power supply behind the collector pin cannot supply enough current or voltage to overcome resistance of the circuit on either side of the transistor the model above fails to represent the transistor accurately. If collector-to-emitter voltage $v_{CE} < v_{BE}$, this model is also inaccurate.

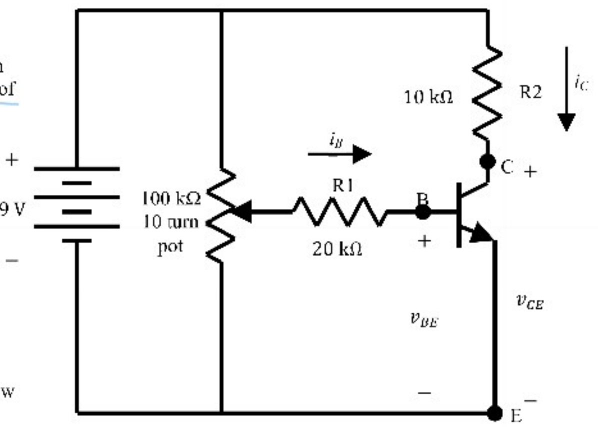



Figure P3-2 Transistor circuit.

**a.** **(5 points)** Construct the circuit of figure P3-2 using the bipolar junction transistor (BJT). Adjust the trim pot to obtain a voltage between the collector and emitter of the transistor, $v_{CE}$, of approximately 5 volts. Measure and record the battery voltage, the voltage across the 20 kΩ resistor R1, the voltage across the 10 kΩ resistor R2, the voltage between the base and emitter of the transistor, $v_{BE}$, and the voltage between the collector and emitter of the transistor, $v_{CE}$. Calculate the currents passing through R1 and R2, $i_B$ and $i_C$, respectively, from the voltages measured in part a, and Ohm's Law.

$V_{ce} = 5.08$ ✓
$V_{R_2} = 4.29V$
$V_{R_1} = 0.024V$
$V_{BE} = 0.58V$
$I_B = 1.2\mu A$
$I_C = 2.4\mu A$

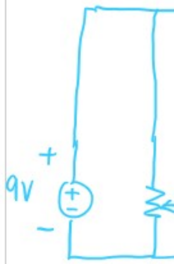
Hint: The 10 turn pot is the long rectangular one. Mount it on the breadboard so the adjustment screw is close to one end of the board.

**b.** **(5 points)** Use the results of part a to compute the parameters of the CCCS model for the transistor, $v_{BE}$ and current gain $\beta$.

$V_{BE} = 5.08 - 0.58 = 4.5V$

$i_e = i_B + i_c = (\beta+1) i_B \quad \therefore \beta = 2$

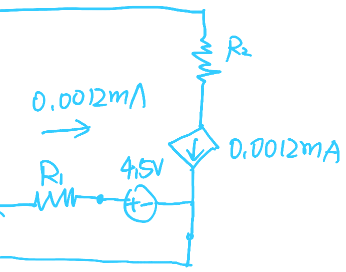
**c.** **(5 points)** Redraw the circuit replacing the transistor with the CCCS model, using the parameters computed in part b. (Don't worry about the potentiometer setting in your drawing.)




**d.** **(5 points)** Assume the potentiometer is set so base current $i_B = 3.50$ μA. Find the voltage across R1 for this base current. Calculate the collector-emitter voltage $v_{CE}$ from the circuit of part c for this base current. In the physical circuit, adjust the potentiometer to obtain the voltage across R1 you just computed. Measure the voltage from the transistor emitter to collector, $v_{CE}$. Compare the computed and measured values. Comment on differences.

$V_{R1} = 0.07V$
$V_{CE}$

**e.** **(5 points)** Look up the data sheet for the 2N3904 transistor by searching for the part number on the Web. Compare your values of $\beta$ and $v_{BE}$ to those in the data sheet. (Note: $\beta$ may appear as $h_{FE}$ in the data sheet.) Comment on differences.


R2
0.0012mA
0.0012mA
R1
4.5V

**Procedure 4 (25 points) Experiment Design**

In this procedure, you get to write and execute an experimental procedure to find a Thévenin equivalent model for a Light Emitting Diode (LED).

The simplest model for a diode is as a switch that is on (short circuit) when current tries to flow in the direction of the arrow in the diode symbol, and off (open circuit) when the current ties to flow in the direction opposite to the arrow. This model doesn't work all that well for an LED because the LED emits more light as the current passing through it increases. The light requires power, and short circuits do not model power dissipation. So we need a model with a resistance and/or source to dissipate the power that goes into the light. A resistance and a voltage source is a Thévenin Equivalent.

**a. (20 points)** Write an experimental procedure to determine a Thévenin equivalent model for an LED that is in the On (light emitting) state. Include a circuit diagram and the steps of your procedure.

**b. (5 points)** Execute your procedure, and determine the parameters of your model. Draw a circuit diagram of your model with the parameters. Check your model against measured values. Check your model when the diode is in the off state. Comment on how good a model you have. Bring the circuit you used to find the model to class and show it to your TA.

NOTE: If you do not show your circuit to your TA, you will get a zero on this Procedure.

A few possibly helpful remarks:

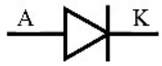



Figure P4-1 Diode circuit symbol

The LED leads are indicated by both the length of the leads and the flat spot on the rim of the diode. The short lead is next to the flat spot, and is the cathode (K), the lead at the head of the arrow, which is also the end of the diode symbol with the bar (Figure P4-1). The long lead, the one further from the flat spot, is the anode (A), the lead at the tail of the arrow of the diode symbol. The diode will allow current to flow from the anode to the cathode.

As the voltage $v_{AK}$ from anode to cathode is slowly increased from 0 to 2.0 V, the LED will glow dimly and then suddenly become much brighter. This sudden transition marks the turn-on point of the diode, called the turn-on voltage. The model you are looking for is for the On state, i.e. for values of $v_{AK}$ greater than the turn-on voltage.

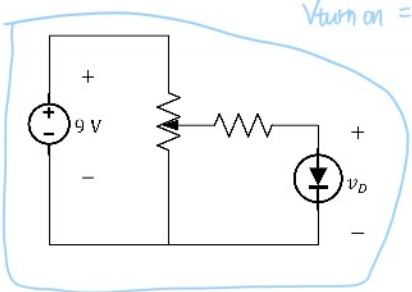
It's a bad idea to have the diode across the battery by itself. It WILL burn out. Keep at least a 1 kΩ resistance in series with the diode.

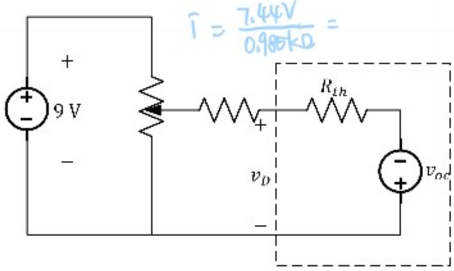
Hint: setup the circuit as following, find the turn-on voltage first. Next is to find $R_{th}$ and $v_{oc}$ from the Thévenin equivalent model for the LED. You need two equations of KVL to solve them.

$V_{turn\ on} = 1.65V$

$V_{oc} = 1.40V + 0.01V = 1.41V$

$I = \frac{7.44V}{0.985k\Omega} =$

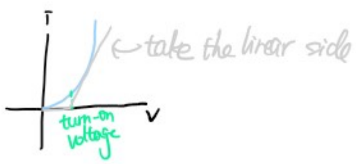


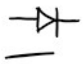



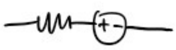



- ideal didode

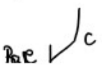
Non-ideal



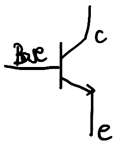





- npn transister



- npn transister




$$i_E = i_B + i_C = (\beta + 1)\, i_B$$

$$i_C = \beta i_B$$

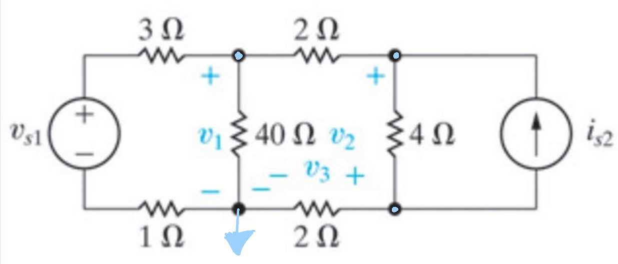
# Prob

Wednesday, February 13, 2019 12:38 PM

## Part A

Use the node-voltage method to find $v_1$ in the circuit in figure if $v_{s1}$ = 40 V and $i_{s2}$ = 28 A .

**Express your answer with the appropriate units.**




$v_1$ = 60.0 V

Submit Previous Answers

✔ Correct

$V_2$ : from 2Ω to 4Ω

$$\begin{cases} \frac{V_1}{40} + \frac{V_1 - V_2}{2} + \frac{V_1 - V_{S1}}{4} = 0 \\ \frac{V_2 - V_1}{2} + \frac{V_2 - V_3}{4} - i_{S2} = 0 \\ \frac{V_3}{2} + \frac{V_3 - V_2}{4} + i_{S2} = 0 \end{cases}$$

$V_1 = 60V$
$V_2 = 73V$
$V_3 = -13V$

## Part D

How much power does the 40 V voltage source deliver to the circuit?

**Express your answer to two significant figures and include the appropriate units.**

$p_g$ = 200 W

Submit Previous Answers

✔ Correct

$$i = \frac{V_1 - V_{S1}}{4} = \frac{20}{4} = 5A$$

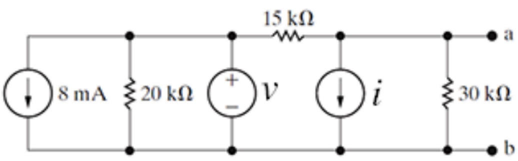
$$P = iV = 5A \times 40V = 200W$$

Review | Constants

Find the Norton equivalent with respect to the terminals a,b in the circuit in (Figure 1) if $i = 15\ \mathrm{mA}$ and $v = 25\ \mathrm{V}$. See (Figure 2) for the positive direction of the current in the equivalent circuit.

## Figure





## Part A

Find the equivalent current.

**Express your answer to three significant figures and include the appropriate units.**

$I_N$ = -13.3 mA

Submit    Previous Answers

✔ Correct

## Part B

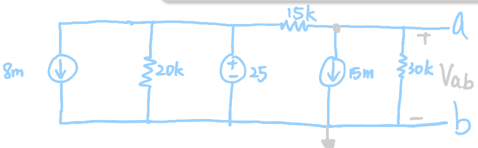
Find the equivalent resistance.

**Express your answer to three significant figures and include the appropriate units.**

$R_N$ = 10.0 kΩ

Submit    Previous Answers

✔ Correct




Part A. $I_N = \frac{V_{th}}{R_{th}}$

use Node-Voltage:

$$\frac{V_{ab}}{30} + 15 + \frac{V_{ab}-25}{15} = 0$$

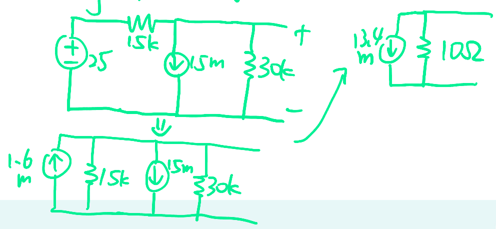
$V_{ab} = -133.3$

Part B. Deactivate


$R_{th} = \frac{30\times15}{30+15} = 10k\Omega$

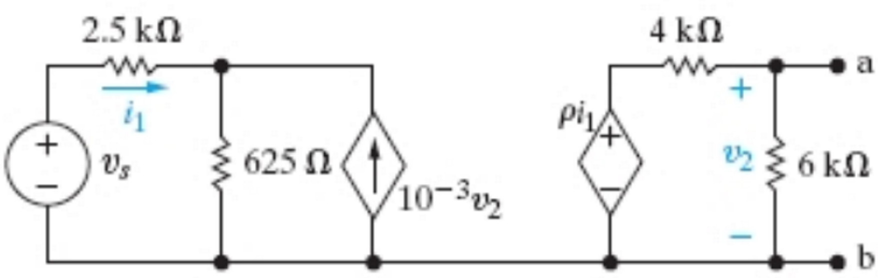
Method II. Source Transformation

left parts are parallel to a voltage source




📖 Review | Constants

Determine the Thevenin equivalent with respect to the terminals a,b for the circuit shown in (Figure 1). Suppose that $v_s$ = 60 V and $\rho$ = 7500.



## Part A

Find $R_{Th}$.

**Express your answer to three significant figures and include the appropriate units.**

$R_{Th} =$ 1.26 $k\Omega$

Submit Previous Answers

Correct

## Part B

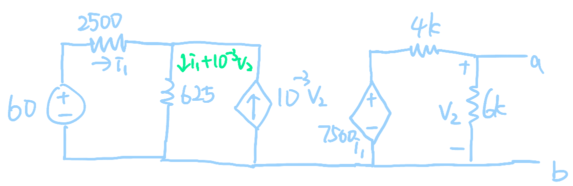
Find $v_{Th}$.

**Express your answer to three significant figures and include the appropriate units.**

$v_{Th} =$ 45.5 $V$

Submit Previous Answers

Correct




Open circuit,

KVL:

$$\begin{cases} -60 + 2500 i_1 + 625(i_1 + 10^{-3} V_2) = 0 \quad \cdots ① \\ V_2 - 7500 i_1 + \frac{V_2}{6}\cdot 4 = 0 \quad \cdots ② \end{cases}$$

① $3125 i_1 + 0.625 V_2 = 60$

② $-7500 i_1 + 1.67 V_2 = 0$

$\Rightarrow i_1 = 0.0101\ A$

$V_2 = 45.4V$

$\boxed{V_{Th} = V_{oc} = V_2 = 45.4V}$

Short circuit:

$i_{sc} = \frac{7500 i_1}{4000}$

$V_2 = 0$

$\therefore i_1 = \frac{60V}{(2500+625)\Omega} = 0.0192A$

$\boxed{\therefore i_{sc} = 0.036A}$

$\therefore R_{th} = \frac{V_{th}}{i_{sc}} = 1.26\ k\Omega$