Introduction to Electrical Circuits

Mid Term
Lecture – 5

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Reference Book:

Introductory Circuit Analysis

Robert L. Boylestad, 11th Edition

Week No.	Class No.	Chapter No.	Article No., Name and Contents	Example No.	Exercise No.
W3	MC5	Chapter 8	8.7 MESH ANALYSIS (Either General or Format Approach)	See the circuits given	21(a), 22(I, II)

Current Source

A *current source* determines the *current in the branch* in which it is located and the magnitude and polarity of the voltage across a current source are a function of the network to which it is applied.

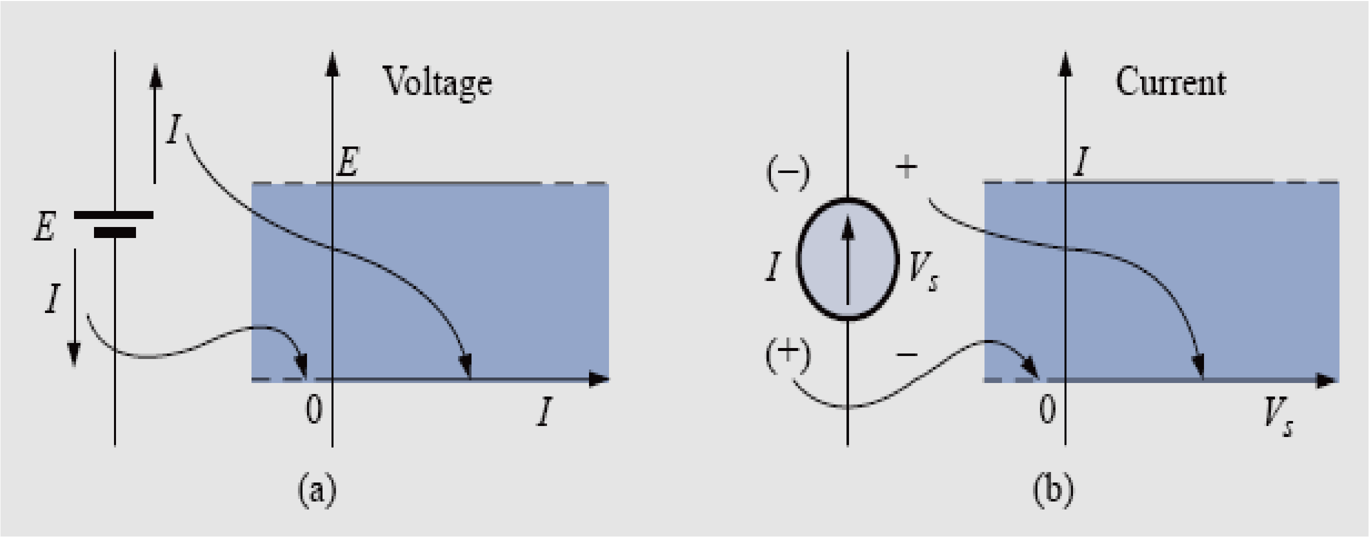


FIG. 1 *Comparing the characteristics of an ideal voltage and current source.*

Source Conversion

Source conversions are equivalent only at their external terminals.

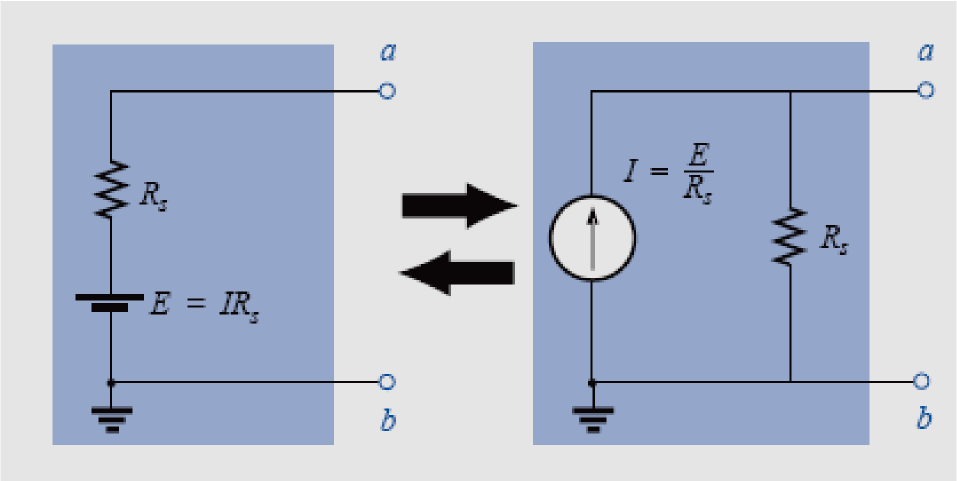


FIG. 2 *Source conversion.*

For the voltage source, if ***R_s = 0 Ω*** *or is so small compared to any series resistor that it* can be ignored, then we have an *"ideal" voltage source*.

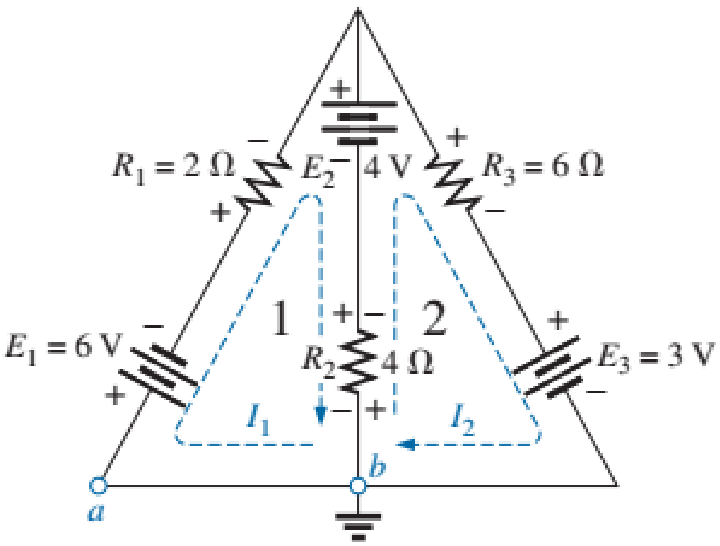
For the current source, if ***R_s = ∞ Ω*** *or is large enough compared to other parallel elements* that it can be ignored, then we have an *"ideal" current source*.

Mesh Analysis (Format Approach)

1. Assign a distinct current in the clockwise direction to each independent, closed loop of the network.
2. Indicate the polarities within each loop for each resistor as determined by the assumed direction of loop current for that loop.
3. Current entering the positive polarity of resister and leaving from the negative polarity denotes a negative sign in the KVL equation and vice versa. Voltage source is polarity is independent of the direction of current.
4. Add resistances of a designated assigned current loop and multiply it with loop current.
5. Form simultaneous equations based on KVL where the right side of equation will have the value for voltage source based on designated current loop.
6. Solve equation using determinant method.

EXAMPLE 8.13 Find the branch currents of the networks in Fig. 8.32.

Solution:



Steps 1 and 2: These are as indicated in the circuit.

Step 3: Kirchhoff's voltage law is applied around each closed loop:

loop 1: $-E_1 - I_1R_1 - E_2 - V_2 = 0$ (clockwise from point a)
$-6\text{ V} - (2\ \Omega)I_1 - 4\text{ V} - (4\ \Omega)(I_1 - I_2) = 0$

loop 2: $-V_2 + E_2 - V_3 - E_3 = 0$ (clockwise from point b)
$-(4\ \Omega)(I_2 - I_1) + 4\text{ V} - (6\ \Omega)(I_2) - 3\text{ V} = 0$

which are rewritten as

$$\left.\begin{aligned} -10 - 4I_1 - 2I_1 + 4I_2 &= 0 \\ +1 + 4I_1 + 4I_2 - 6I_2 &= 0 \end{aligned}\right\} \begin{aligned} -6I_1 + 4I_2 &= +10 \\ +4I_1 - 10I_2 &= -1 \end{aligned}$$

or, by multiplying the top equation by -1, we obtain

$$\begin{aligned} 6I_1 - 4I_2 &= -10 \\ 4I_1 - 10I_2 &= -1 \end{aligned}$$

Step 4:
$$I_1 = \frac{\begin{vmatrix} -10 & -4 \\ -1 & -10 \end{vmatrix}}{\begin{vmatrix} 6 & -4 \\ 4 & -10 \end{vmatrix}} = \frac{100 - 4}{-60 + 16} = \frac{96}{-44} = \mathbf{-2.18\ A}$$

$$I_2 = \frac{\begin{vmatrix} 6 & -10 \\ 4 & -1 \end{vmatrix}}{-44} = \frac{-6 + 40}{-44} = \frac{34}{-44} = \mathbf{-0.77\ A}$$

The current in the 4 Ω resistor and 4 V source for loop 1 is

$$\begin{aligned} I_1 - I_2 &= -2.18\text{ A} - (-0.77\text{ A}) \\ &= -2.18\text{ A} + 0.77\text{ A} \\ &= \mathbf{-1.41\ A} \end{aligned}$$

revealing that it is 1.41 A in a direction opposite (due to the minus sign) to I_1 in loop 1.

Chosen Circuit:

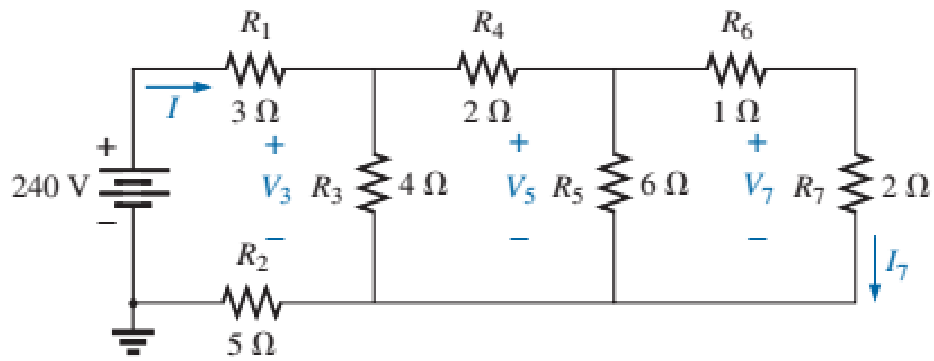
For the ladder network in Fig. 7.85:

a. Find the current I.

b. Find the current I_7.

c. Determine the voltages V_3, V_5, and V_7.

d. Calculate the power delivered to R_7, and compare it to the power delivered by the 240 V supply.



Do the Math in the class using either General Approach or Format Approach

Answers are:

I= 24A

I_7= 8A

V_3= 48V

V_7= 16V

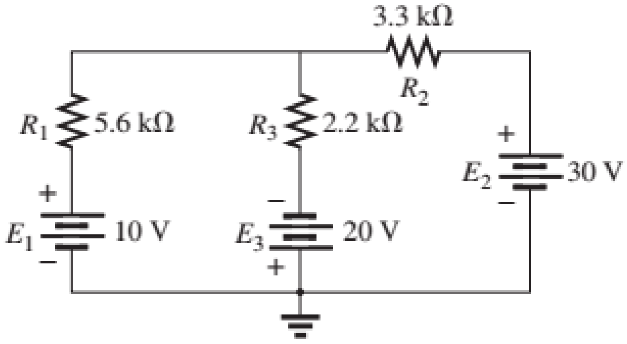
P_{R7}= 128W

$P_E = 5760W$

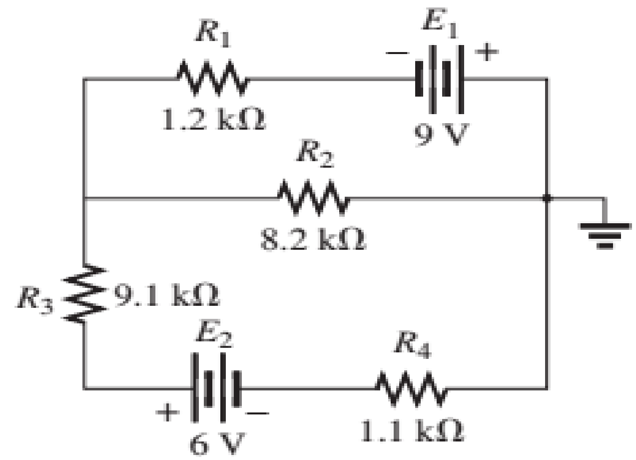
V_5= 24V

Exercise Problems

21. Find the current through each resistor for the networks in Fig. 8.117.



(I)



(II)

Solution:

(I): $I_1 \curvearrowright$ $I_2 \curvearrowright$

$$10 - I_1(5.6\text{ k}\Omega) - 2.2\text{ k}\Omega(I_1 - I_2) + 20 = 0$$
$$-20 - 2.2\text{ k}\Omega(I_2 - I_1) - I_2\, 3.3\text{ k}\Omega - 30 = 0$$

$I_1 = \mathbf{1.45\text{ mA}}$, $I_2 = \mathbf{8.51\text{ mA}}$

$I_{R_1} = I_1 = \mathbf{1.45\text{ mA}}$, $I_{R_2} = I_2 = \mathbf{8.51\text{ mA}}$

$I_{R_3} = I_2 - I_1 = \mathbf{7.06\text{ mA}}$ (direction of I_2)

(II): $I_1 \curvearrowright$ $I_2 \curvearrowright$

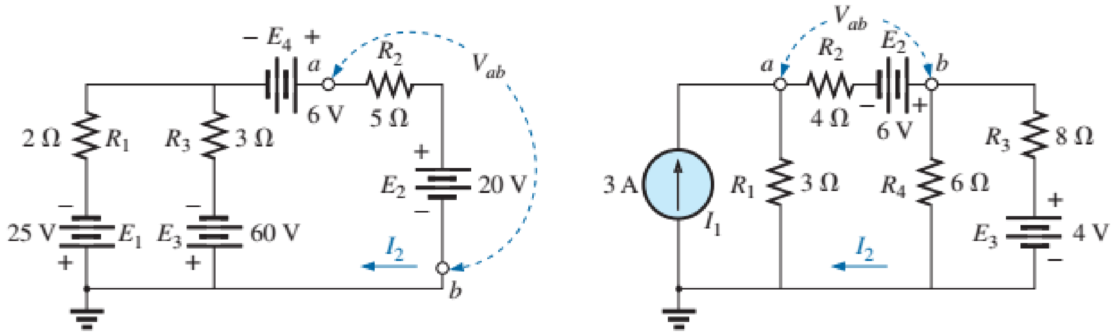
$$-I_1(1.2\text{ k}\Omega) + 9 - 8.2\text{ k}\Omega(I_1 - I_2) = 0$$
$$-I_2(1.1\text{ k}\Omega) + 6 - I_2(9.1\text{ k}\Omega) - 8.2\text{ k}\Omega(I_2 - I_1) = 0$$

$I_1 = \mathbf{2.03\text{ mA}}$, $I_2 = \mathbf{1.23\text{ mA}}$

$I_{R_1} = I_1 = \mathbf{2.03\text{ mA}}$, $I_{R_3} = I_{R_4} = I_2 = \mathbf{1.23\text{ mA}}$

$I_{R_2} = I_1 - I_2 = 2.03\text{ mA} - 1.23\text{ mA} = \mathbf{0.80\text{ mA}}$ (direction of I_1)

22. Find the mesh currents and the voltage V_{ab} for each network in Fig. 8.118. Use clockwise mesh currents.



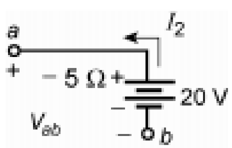
(I) (II)

Solution:

(I): $\overset{\curvearrowright}{I_1}\ \overset{\curvearrowright}{I_2}$

$$-25 - 2I_1 - 3(I_1 - I_2) + 60 = 0$$
$$-60 - 3(I_2 - I_1) + 6 - 5I_2 - 20 = 0$$

$I_1 = \mathbf{1.87\ A}$, $I_2 = \mathbf{-8.55\ A}$



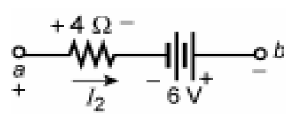
$$\underset{+-}{V_{ab}} = 20 - I_2 5 = 20 - (8.55\ \text{A})(5) = 20\ \text{V} - 42.75\ \text{V}$$
$$= \mathbf{-22.75\ V}$$

(II): Source conversion: $E = 9\ \text{V}$, $R = 3\ \Omega$

$\overset{\curvearrowright}{I_2}\ \overset{\curvearrowright}{I_3}$

$$9 - 3I_2 - 4I_2 + 6 - 6(I_2 - I_3) = 0$$
$$-6(I_3 - I_2) - 8I_3 - 4 = 0$$

$I_2 = \mathbf{1.27\ A}$, $I_3 = \mathbf{0.26\ A}$



$$\underset{+-}{V_{ab}} = I_2 4 - 6 = (1.27\ \text{A})(4\ \Omega) - 6\ \text{V}$$
$$= 5.08\ \text{V} - 6\ \text{V}$$
$$= \mathbf{-0.92\ V}$$


END