Al-Anbar University
College of engineering
Electrical Engineering Department

fundamental of Electric Circuit 1
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Stage 1
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LECTURE 03

KIRCHHOFF’S CURRENT LAWS

KIRCHHOFF'S VOLTAGE LAWS-DEPENDENT VOLTAGE SOURCES DEPENDENT CURRENT SOURCES

Topics

- Kirchhoff's Voltage Law
- Fundamental Laws of Electric Circuits
- Dependent Voltage Source
- Dependent Current Source

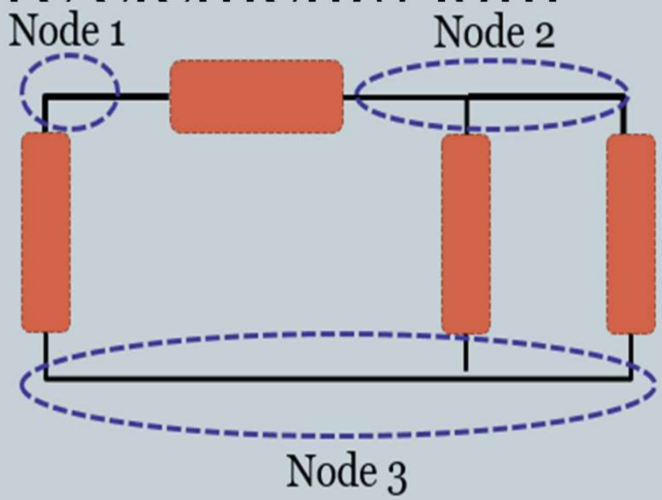
Objectives

- Apply Kirchhoff's voltage law
- Recognize invalid circuits
- Use the fundamental laws to analyze electric circuits
- Recognize the symbol of a dependent source
- Distinguish between the four possible types of dependent sources
- Analyze circuits that contain dependent sources

What is the terms node ?

A nodes is a point where two or more elements join

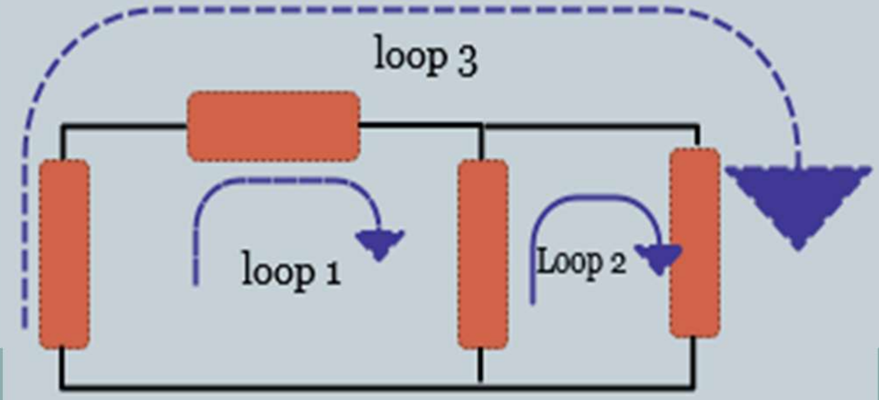
3- nodes shown in the figure



What is the terms loop?

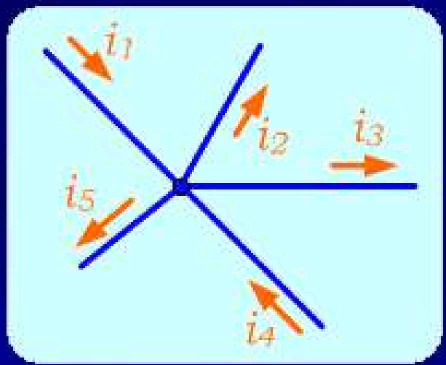
Any closed path in the circuit.

3- loops shown in figure



Kirchhoff's Current Law (KCL)

The sum of currents *entering* a node (interconnection of two or more branches) is equal to the sum of currents *leaving* that node



$$i_1 + i_4 = i_2 + i_3 + i_5$$

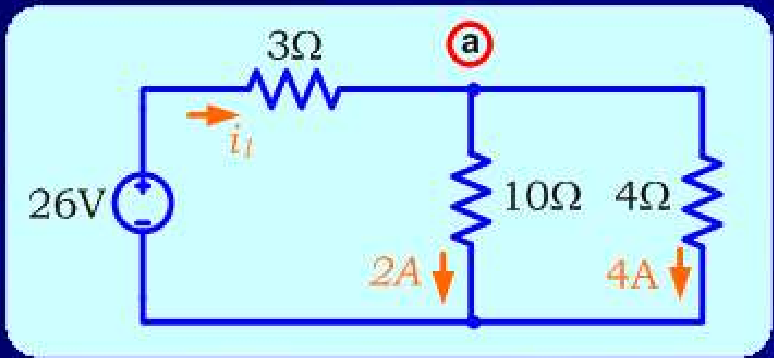
Equivalent Statement of KCL:

The algebraic sum of currents entering a node (currents entering the node is taken as positive) is equal to zero

$$i_1 - i_2 - i_3 + i_4 - i_5 = 0$$

Example 1

Calculate the unknown current in the following circuit

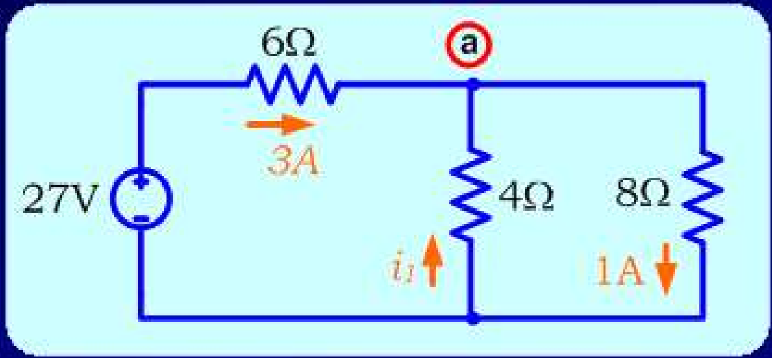


Solution:

KCL at node a $\Rightarrow$ $i_1 = 2 + 4 = 6\,\text{A}$

Example 2

Calculate the unknown current in the following circuit



Solution:

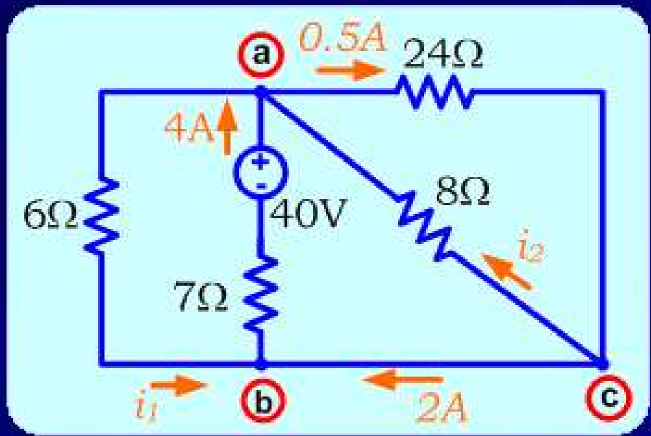
KCL at node a $\Rightarrow 3 + i_1 = 1 \Rightarrow i_1 = -2\,A$

Alternatively,

KCL at node a $\Rightarrow 3 + i_1 - 1 = 0 \Rightarrow i_1 = -2\,A$

Example 3

Calculate the unknown currents in the following circuit



Solution:

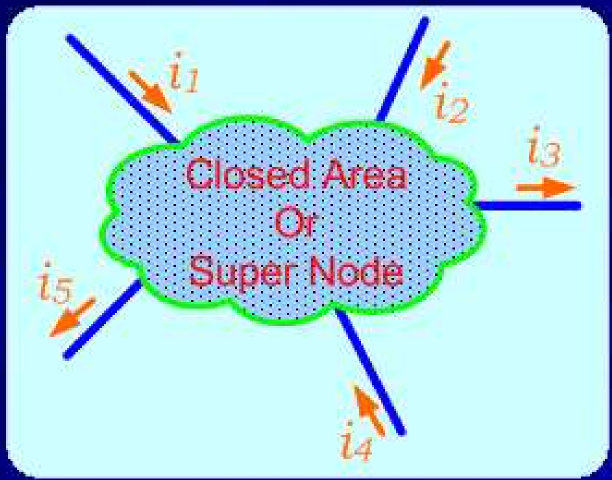
KCL at node b $\Rightarrow i_1 - 4 + 2 = 0 \Rightarrow i_1 = 2A$

KCL at node c $\Rightarrow 0.5 - i_2 - 2 = 0 \Rightarrow i_2 = -1.5A$

Check KCL at node a $\Rightarrow -i_1 + 4 + i_2 - 0.5 = -(2) + 4 + (-1.5) - 0.5 = -4 + 4 = 0$

Supernode

KCL is also applicable to a *closed area* (super node)

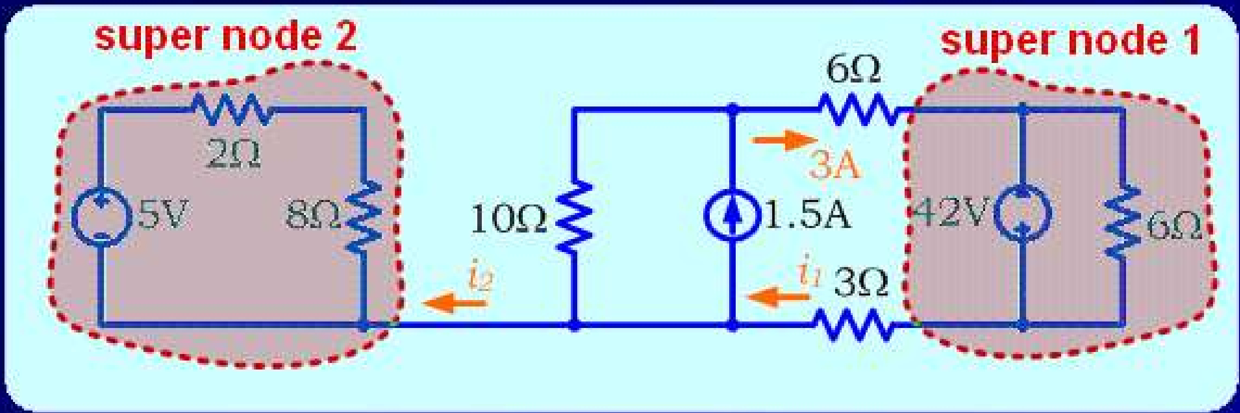


The algebraic sum of currents entering a super node is equal to zero

$$i_1 + i_2 - i_3 + i_4 - i_5 = 0$$

Example 4

Calculate the unknown currents in the circuit shown below



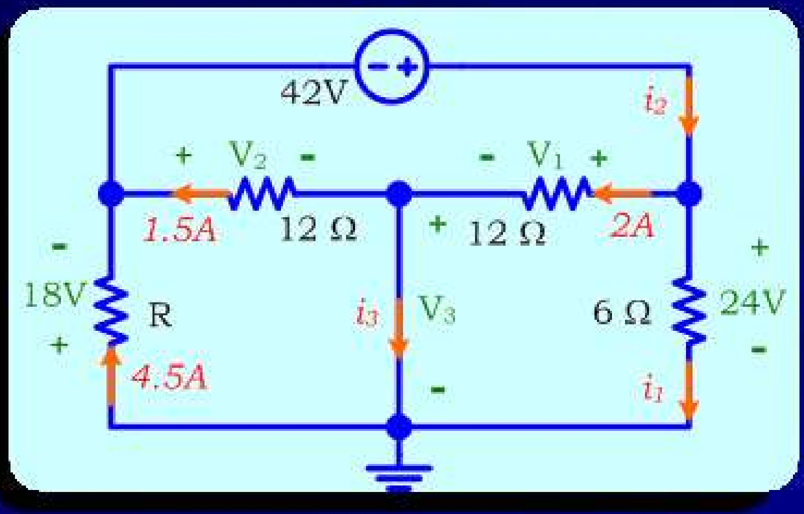
Solution:

KCL at super node 1 $\Rightarrow$ $3 - i_1 = 0$ $\Rightarrow$ $i_1 = 3A$

KCL at super node 2 $\Rightarrow$ $i_2 = 0$ $\Rightarrow$ $i_2 = 0A$

Self Test

In the circuit shown below, calculate:

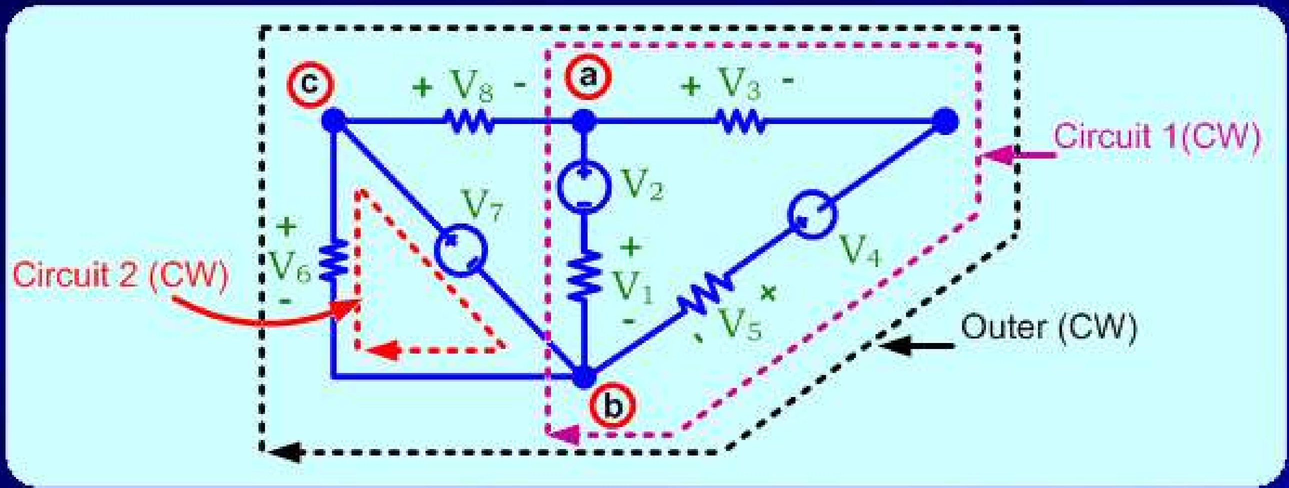


(a) i_1

- **A** $i_1 = 144A$
- **B** $i_1 = -4A$
- **C** $i_1 = 4A$
- **D** $i_1 = 1/4\ A$
- **E** $i_1 = -\ 1/4\ A$

Kirchhoff's Voltage Law (KVL)

The *algebraic* sum of voltages around *any closed* circuit is equal to zero



KVL around circuit 1 (CW) $\Rightarrow$ $-v_1 - v_2 + v_3 - v_4 + v_5 = 0$ ·········(1)

KVL around circuit 1 (CCW) $\Rightarrow$ $-v_5 + v_4 - v_3 + v_2 + v_1 = 0$·········(2) [Same as (1)]

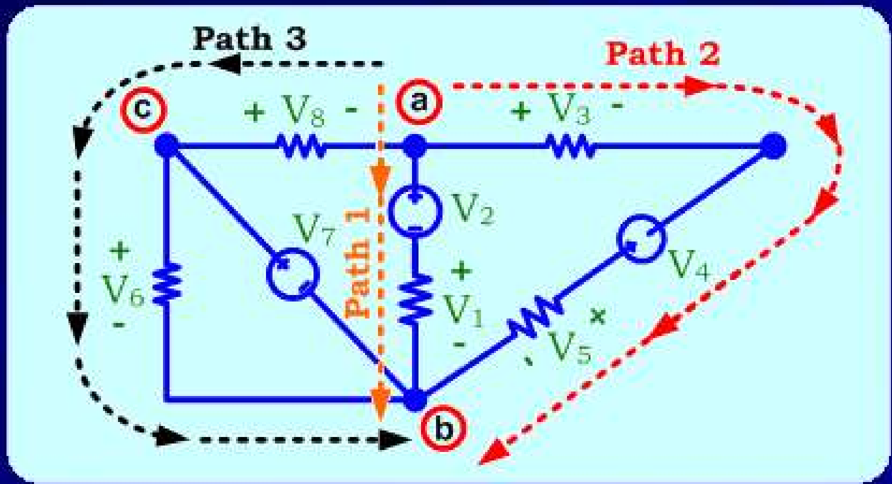
CW = Clockwise direction & CCW = Counter clockwise direction

KVL around outer circuit (CW) $\Rightarrow$ $-v_6 + v_8 + v_3 - v_4 + v_5 = 0$·········(3)

KVL around circuit 2 (CW) $\Rightarrow$ $-v_6 + v_7 = 0$ $\Rightarrow$ $v_6 = v_7$ [Parallel elements]

Alternate statement for KVL

The *algebraic* sum of voltages between two nodes is *independent* of the path taken from the first node to the second node

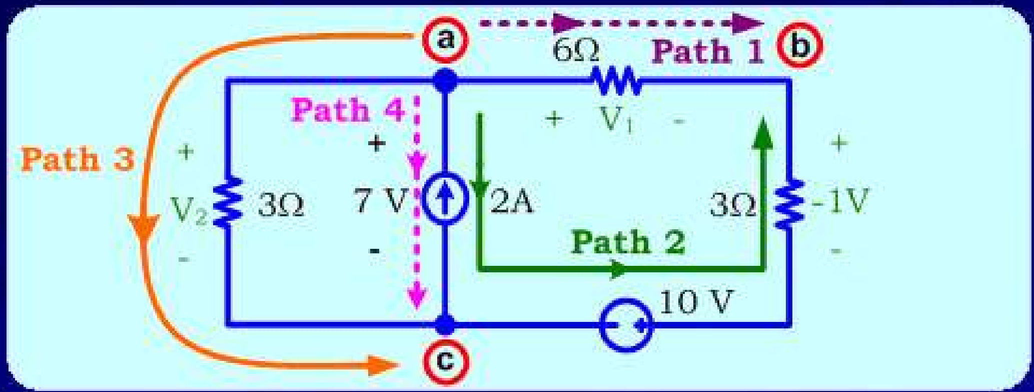


KVL $\mathit{Node\,a} \xrightarrow{path1\&2} \mathit{Node\,b} \Rightarrow +v_2 + v_1 = +v_3 - v_4 + v_5 \cdots\cdots\cdots (4)$ Same as (1) in the previous slide

KVL $\mathit{Node\,a} \xrightarrow{path2\&3} \mathit{Node\,b} \Rightarrow +v_3 - v_4 + v_5 = -v_8 + v_6 \cdots\cdots\cdots (5)$ Same as (3) in the previous slide

Example 1

Calculate the unknown voltages in the given circuit



Solution:

Applying KVL

Right-hand circuit (CW) $\Rightarrow -(7)+v_1+(-1)+10=0 \Rightarrow v_1=-2V$

Right-hand circuit (CCW) $\Rightarrow +(7)-(10)-(-1)-v_1=0 \Rightarrow v_1=-2V$

Node a $\xrightarrow{path1\&2}$ *Node b* $\Rightarrow +v_1=+(7)-(10)-(-1) \Rightarrow v_1=-2V$

Same answer in all cases

Left-hand circuit (CW) $\Rightarrow +(7)-(v_2)=0 \Rightarrow v_2=7V$

Node a $\xrightarrow{path3\&4}$ *Node c* $\Rightarrow +v_2=+7 \Rightarrow v_2=7V$

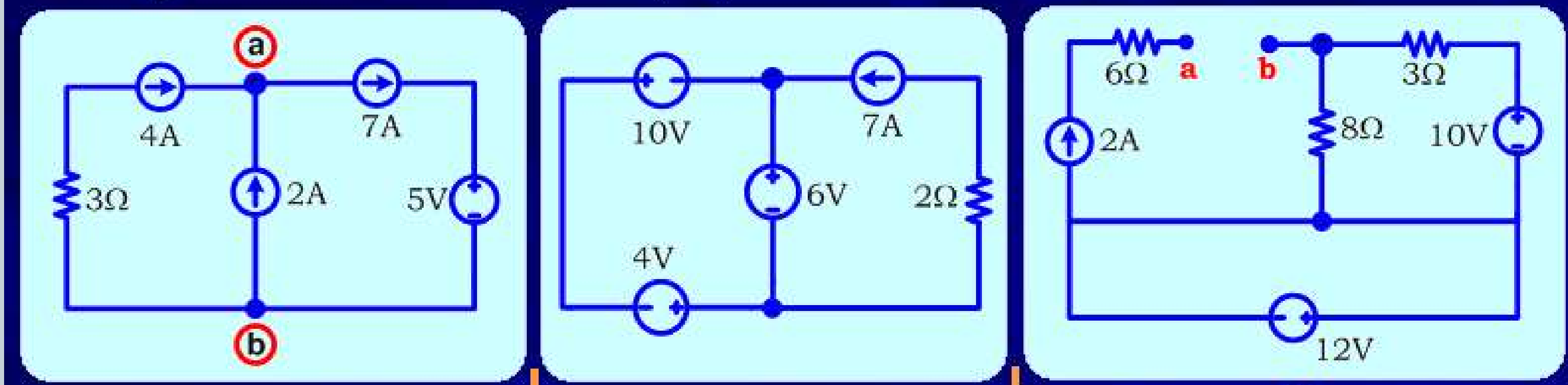
Same answer in both cases

Fundamental Laws of Electric Circuits

1. Ohm's Law, KCL and KVL are the fundamental laws of electric circuits
2. *All* the fundamental laws of electric circuits *must be satisfied*
3. If a given circuit violates *at least one* of the fundamental laws, the circuit is *not valid*

Example 2

All the given circuits below are invalid, why?



(a) (b) (c)

(a) KCL at node a

$\Rightarrow \quad 4+2=7$

$\Rightarrow$ KCL not satisfied

(b) KVL around left hand

$\Rightarrow \quad +10+6+4=0$

$\Rightarrow \quad 20=0$

$\Rightarrow$ KVL not satisfied

(c) KCL at node a

$\Rightarrow \quad 2=0$

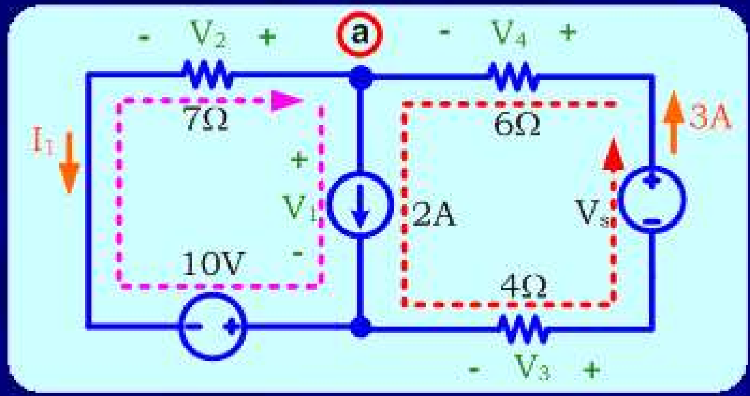
$\Rightarrow$ KCL not satisfied

KVL around lower part of the circuit $\Rightarrow \; 12=0$

$\Rightarrow$ KVL not satisfied

Example 3

In the given circuit calculate the unknown quantities



Solution:

KCL at node a $\Rightarrow 3 = 2 + I_1 \Rightarrow \boxed{I_1 = 1A}$

Ohm's Law $\Rightarrow \boxed{v_2 = +7I_1 = 7\times 1 = 7V}$

KVL around left hand circuit $\Rightarrow v_1 + 10 - v_2 = 0$

$\Rightarrow v_1 + 10 - 7 = 0$

$\Rightarrow \boxed{v_1 = -3V}$

Ohm's Law $\Rightarrow \boxed{v_3 = -3\times 4 = -12V}$

KVL around right hand circuit $\Rightarrow +v_4 + v_1 - v_3 - v_s = 0$

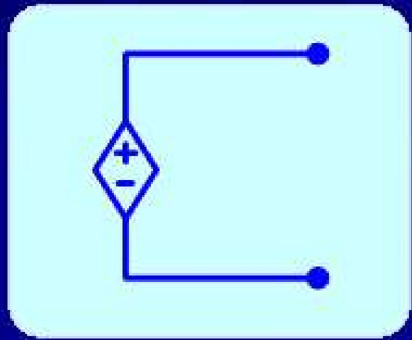
$\Rightarrow +(3\times 6) + v_1 - v_3 - v_s = 0$ (Ohm's Law $\boxed{v_4 = 18V}$)

$\Rightarrow +18 + (-3) - (-12) - v_s = 0$

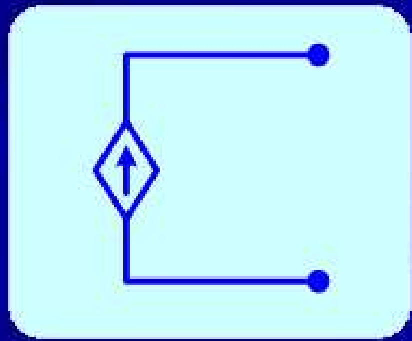
$\Rightarrow \boxed{v_s = 27V}$

Ideal Dependent Sources

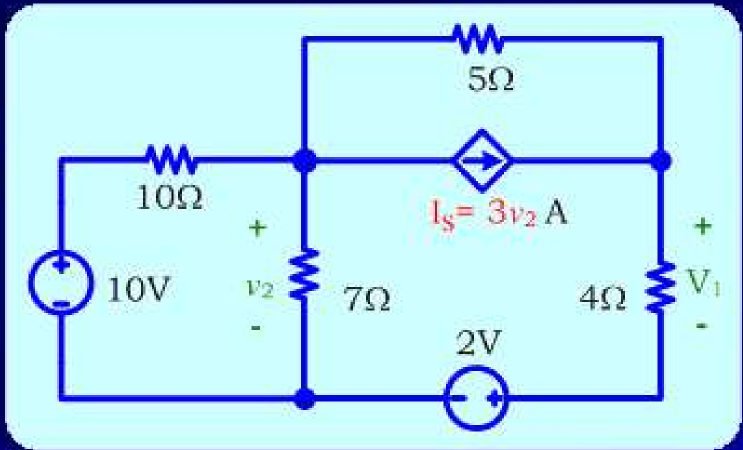
A voltage source whose voltage depends on another voltage or current is called a *dependent voltage source*



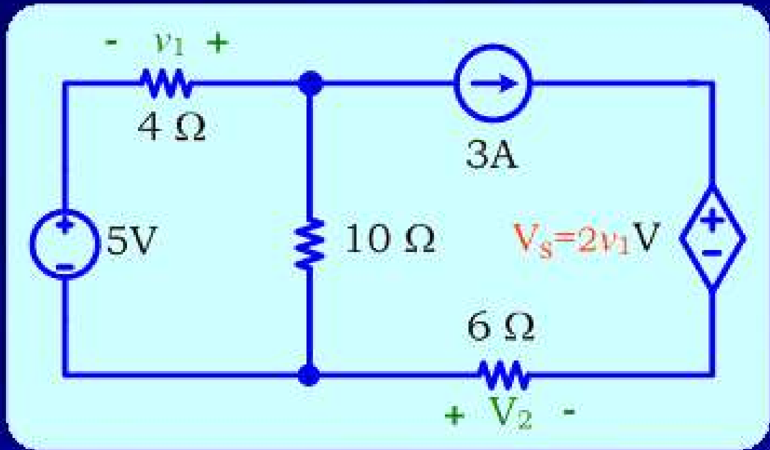
A current source whose current depends on another voltage or current is called a *dependent current source*



Example 4



(a)



(b)

Circuit (a) I_S depends on v_2

$\Rightarrow$ I_S is *voltage dependent* current source

Circuit (b) V_S depends on v_1

$\Rightarrow$ V_S is *voltage dependent* voltage source

Types of Dependent Sources

Four possible types of dependent sources

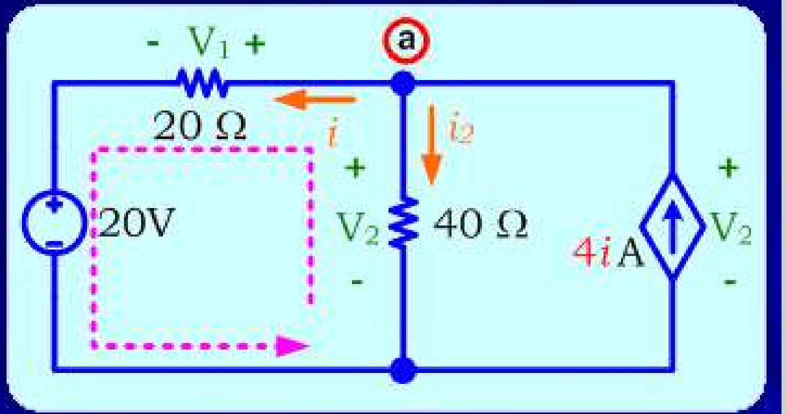
1. Voltage dependent voltage source (it is a *voltage source* that depends on another voltage)
2. Current dependent voltage source (it is a *voltage source* that depends on another current)
3. Voltage dependent current source (it is a *current source* that depends on another voltage)
4. Current dependent current source (it is a *current source* that depends on another current)

Example 5

(a) Calculate the value of the dependent current source

(b) Show that the power generated is equal to the power dissipated

Solution: (a)



KCL at node a

$\Rightarrow -i - i_2 + 4i = 0$

$\Rightarrow i_2 = 3i \qquad (1)$

KVL around left hand circuit

$\Rightarrow -v_2 + v_1 + 20 = 0$

$\Rightarrow -(40 i_2) + (20 i) + 20 = 0$ (Ohm's Law)

$\Rightarrow -(40 \times 3i) + 20i + 20 = 0$ [using (1)]

$\Rightarrow -120i + 20i + 20 = 0$

$\Rightarrow i = \frac{20}{100} = \frac{1}{5}\text{A}$

Value of dependent current source $\Rightarrow 4i = 4 \times \frac{1}{5} = \frac{4}{5}\text{A}$

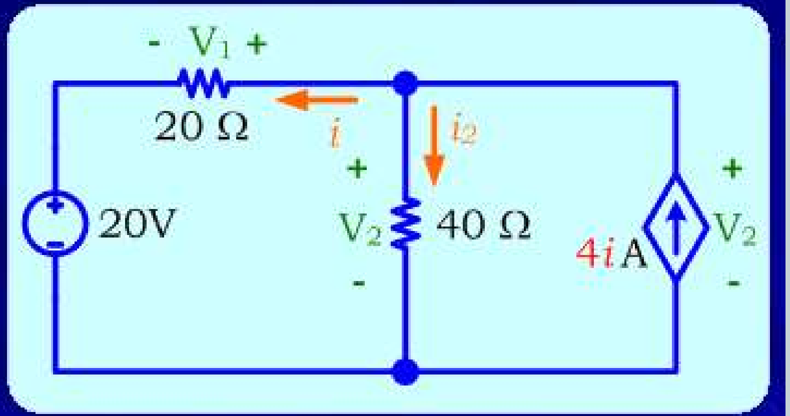
Example 5 (Contd...)

(a) Calculate the value of the dependent current source

(b) Show that the power generated is equal to the power dissipated

Solution: (b)

From previous slide part (a) $\Rightarrow$ $i = \frac{1}{5}\text{A}$



$$p_{20V} = +20i = +20 \times \frac{1}{5} = \frac{20}{5} = 4\,\text{W}$$

$$p_{20\Omega} = +iv_1 = +(\tfrac{1}{5})(20 \times \tfrac{1}{5}) = +(\tfrac{1}{5})(4) = \frac{4}{5}\,\text{W}$$

$$i_2 = 3i = \frac{3}{5}\text{A} \quad \& \quad v_2 = +40i_2 = +40 \times \frac{3}{5} = 24\,\text{V}$$

$$p_{40\Omega} = +i_2 v_2 = +\frac{3}{5} \times 24 = \frac{72}{5}\,\text{W}$$

$$p_{4iA} = -(4i)v_2 = -(\tfrac{4}{5}) \times 24 = -\frac{96}{5} = -19.2\,\text{W}$$

$$\sum p_{dis} = 4 + \frac{4}{5} + \frac{72}{5} = \frac{96}{5} = 19.2\,\text{W}$$

$$\sum p_{gen} = 19.2\,\text{W}$$

$$\therefore \quad \sum p_{dis} = \sum p_{gen} = 19.2\,\text{W}$$