CIRCUITS & NETWORKS

INTRODUCTION

Electronics and Communication Engineering Department
Indus Institute of Technology and Engineering

SYLLABUS

Unit No.	Topic
1	**Introduction** Electromotive force, potential, voltage, current, Resistor, capacitor, inductor, Voltage and current sources, Dependent sources, Dot conventions , current directions
2	**Network Equations** Nodal analysis, Mesh analysis, Source transformation, Analysis of circuit containing dependent sources, Superposition theorem, Substitution Theorem, Compensation theorem, Thevenin's and Norton's theorem, Maximum power transfer theorem

SYLLABUS

Unit No.	Topic
3	**Time domain response of linear circuits** Mathematical preliminaries, DC response of first order and second order circuits, Initial conditions in the network, Charging and discharging of capacitor, Charging and discharging of inductor, Solution of circuit equations by using Initial Conditions
4	**Laplace transform analysis** : **Circuit Applications** Manipulation of impedance and admittance, Equivalent Laplace transform of circuit elements, RLC circuit analysis using Laplace transform, Switching in RLC

SYLLABUS

Unit No.	Topic
5	**Two Port Network** Y- Parameter, z-Parameter, h-parameter, ABCD-parameter, Relation between two port parameters, Parallel connection of two network

BOOKS

1. Electric Circuits and Networks :- By K. S. Suresh Kumar – Pearson Education
2. Linear Circuits Analysis 2nd edition :-By DeCarlo/ Lin – Oxford University Press , (Indian edition)
3. Network Analysis :- By M.E Van Valkenburg PHI Publication
4. Engineering Circuit Analysis : - By W H Hayt, J E Kemmerly, S M Durbin 6th Edition TMH Publication
5. Network Analysis & Synthesis By Franklin S. KUO, Wiley Publication

CHAPTER 1

Introduction

PREPARED BY:
HARDIK PRAJAPATI

OUTLINES COVERED IN CHAPTER

- Electric Charge
- Current, Voltage, Power and Energy
- Circuit Elements
- Nodes, Branches, and Loops
- Kirchhoff’s Laws
- Series Resistors and Voltage Division
- Parallel Resistors and Current Division
- Dot Convention

ELECTRIC CHARGES

- Electric charge is a physical property of matter that causes it to experience a force when near other electrically charged matter , measured in coulombs (C).
- Electric charge comes in two types, called positive and negative.
- The charge e on one electron is negative and equal in magnitude to $1.602 \quad 10^{-19}$ C which is called as electronic charge. The charges that occur in nature are integral multiples of the electronic charge.

CURRENT

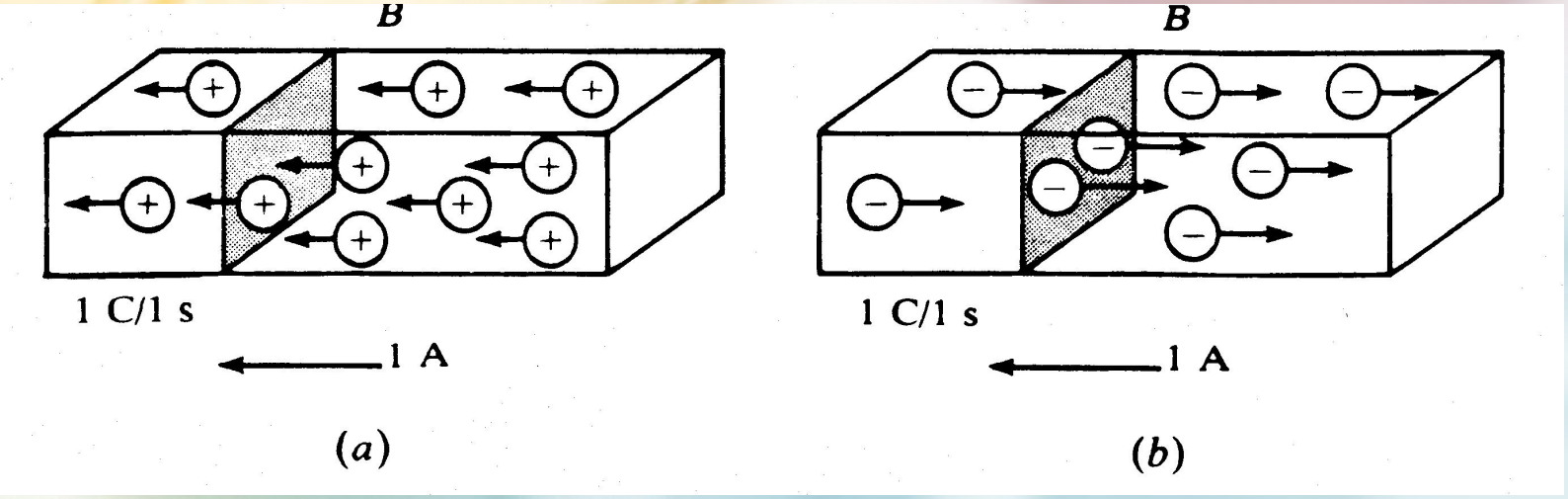
- Electrical current is a measure of the amount of electrical charge transferred per unit time.

$$i = dq/dt$$

- The unit of ampere can be derived as $1\ A = 1 C/s$.
- A direct current (dc) is a current that remains constant with time.
- An alternating current (ac) is a current that varies sinusoidally with time. (reverse direction)

CURRENT

- The direction of current flow



Positive ions

Negative ions

CURRENT

Example 1

A conductor has a constant current of 5 A.

How many electrons pass a fixed point on the conductor in one minute?

CURRENT

Solution

Total no. of charges pass in 1 min is given by

$$5\ \text{A} = (5\ \text{C/s})(60\ \text{s/min}) = 300\ \text{C/min}$$

Total no. of electronics pass in 1 min is given

$$\frac{300\ \text{C/min}}{1.602x10^{-19}\ \text{C/electron}} = 1.87x10^{21}\ \text{electrons/min}$$

VOLTAGE

- Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).
- Mathematically,

$$v_{ab} = dw / dq$$

  - *w* is energy in joules (J) and *q* is charge in coulomb (C).

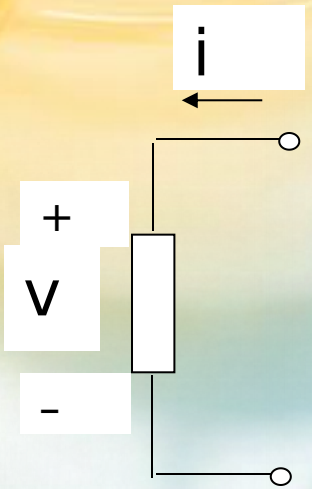
- Electric voltage, $v_{ab,}$ is always across the circuit element or between two points in a circuit.

  - $v_{ab} \; l \; 0$ means the potential of a is higher than potential of b

POWER AND ENERGY

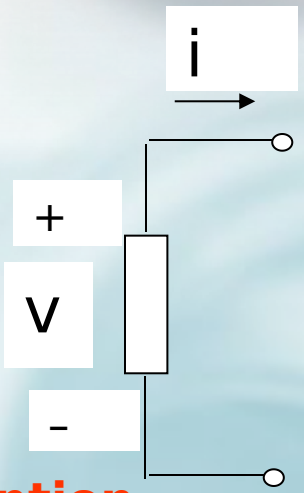
- Power is the time rate of expending or absorbing energy, measured in watts (W).

$$p = \frac{dw}{dt} = \frac{dw}{dq} \times \frac{dq}{dt} = vi$$



P = +vi
absorbing power

Passive sign convention



p = –vi
supplying power

POWER AND ENERGY

- The law of conservation of energy

$$\gg p = 0$$

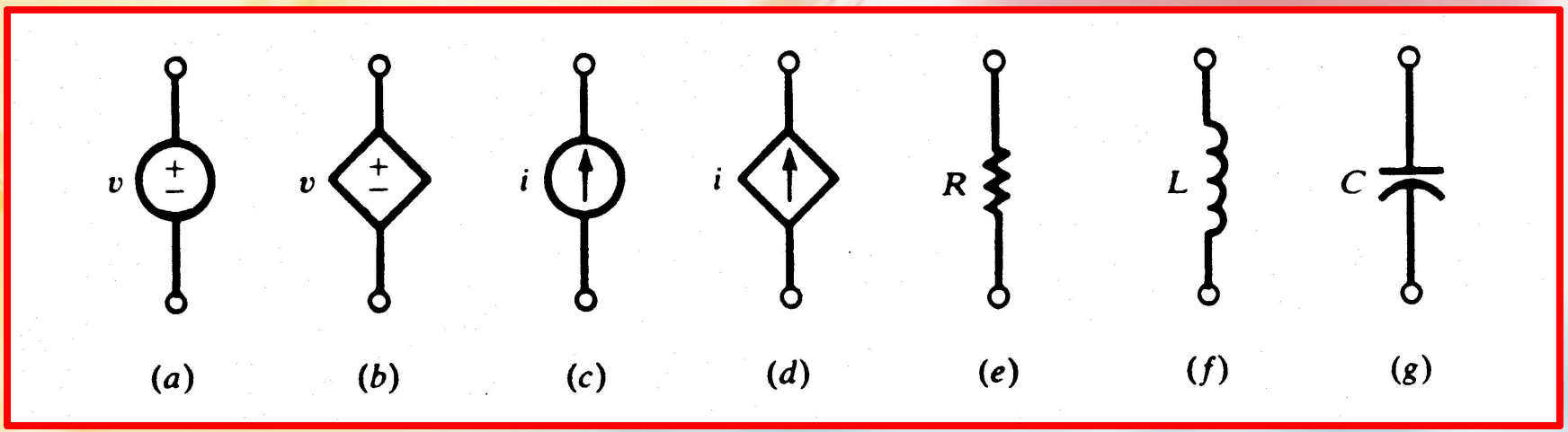
- Energy is the capacity to do work, measured in joules (J).

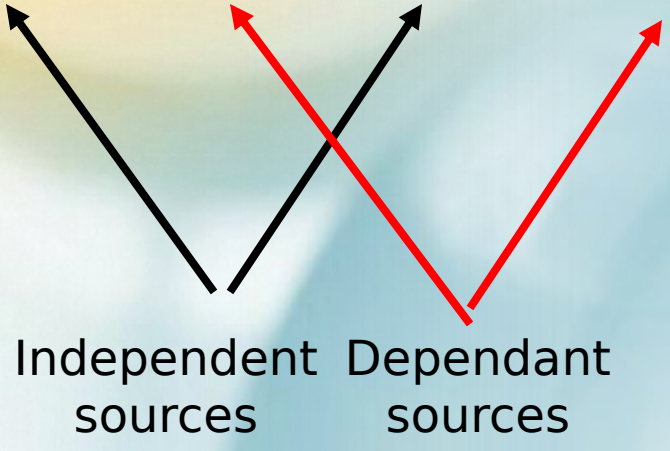
- Mathematical expression

$$w = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} vi\,dt$$

CIRCUIT ELEMENTS

Active Elements | **Passive Elements**





Independent sources

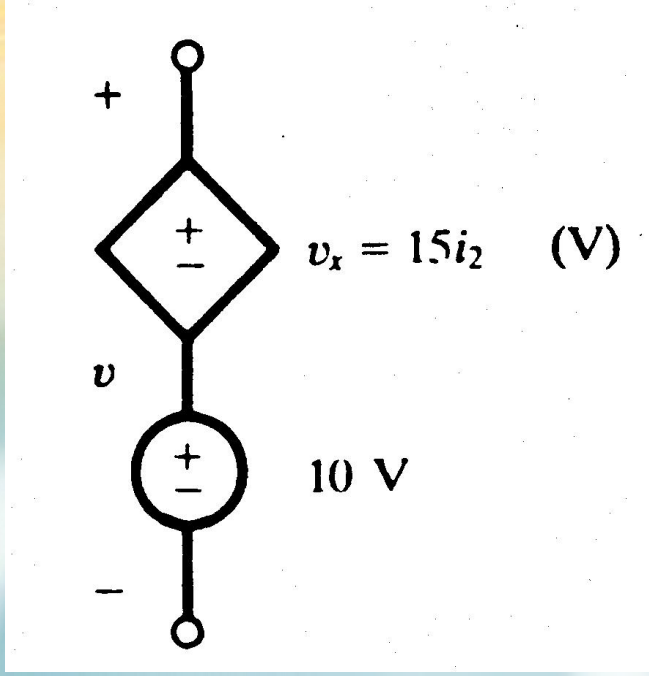
Dependant sources

- **A dependent source is an active element in which the source quantity is controlled by another voltage or current.**
- **They have four different types: VCVS, CCVS, VCCS, CCCS. Keep in minds the signs of dependent sources.**

CIRCUIT ELEMENTS

Example 2

Obtain the voltage v in the branch shown in Figure $2.1.1$P for $i_2 = 1$A.



CIRCUIT ELEMENTS

Solution

Voltage v is the sum of the current-independent 10-V source and the current-dependent voltage source v_x.

Note that the factor 15 multiplying the control current carries the units Ω.

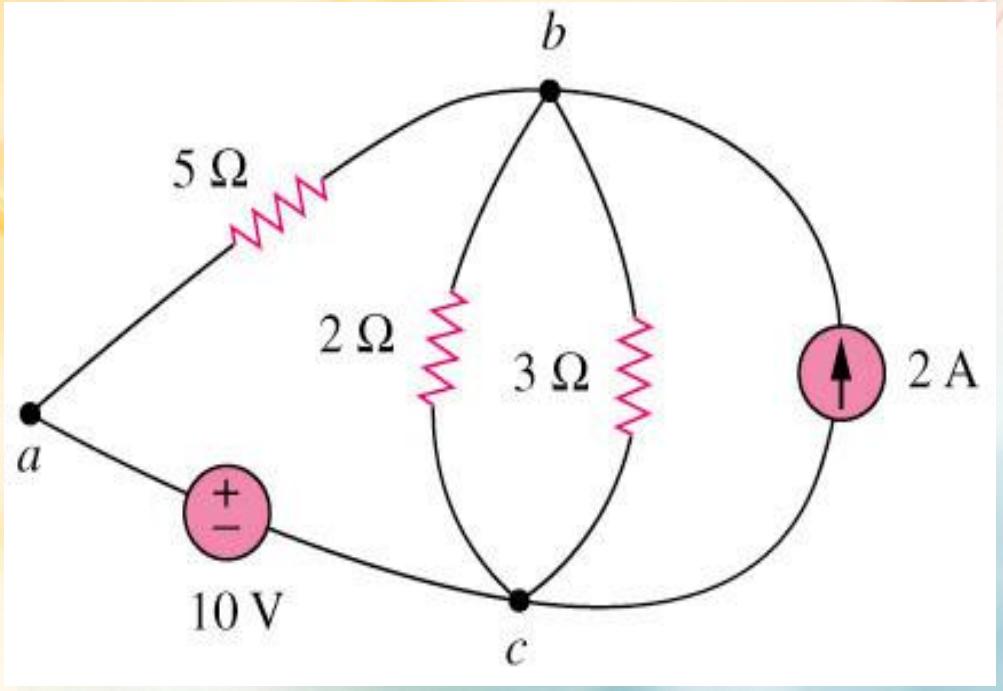
Therefore, $v = 10 + v_x = 10 + 15(1) = 25$ V

NODES, BRANCHES AND LOOPS

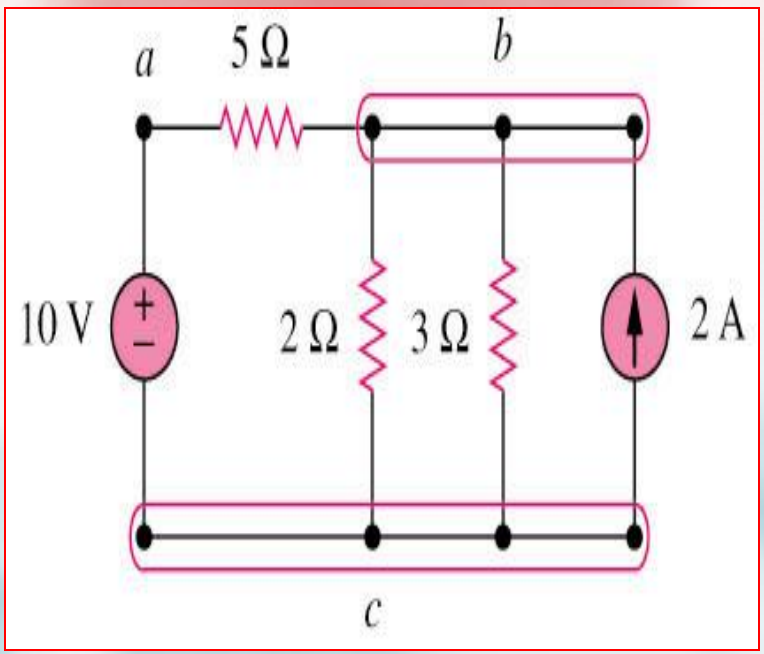
- A branch represents a single element such as a voltage source or a resistor.
- A node is the point of connection between two or more branches.
- A loop is any closed path in a circuit.
- A network with b branches, n nodes, and l independent loops will satisfy the fundamental theorem of network topology: $b = l + n - 1$

NODES, BRANCHES AND LOOPS

Example 1



Equivalent circuit



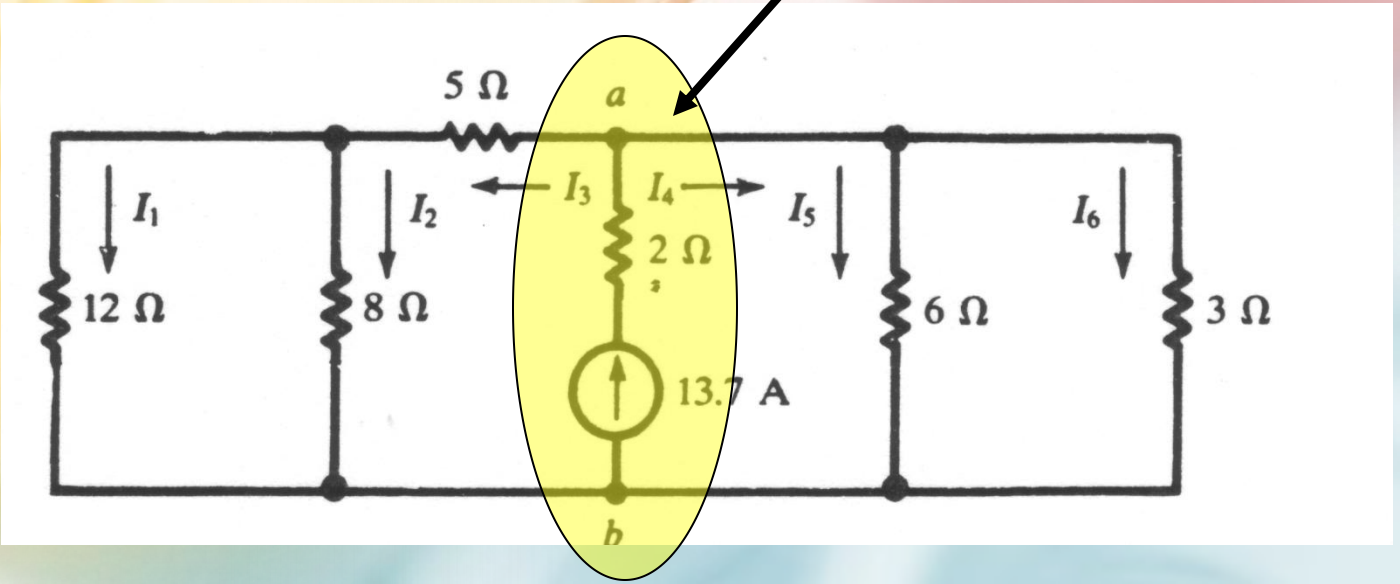
Original circuit

How many branches, nodes and loops are there?

NODES, BRANCHES AND LOOPS

Example 2

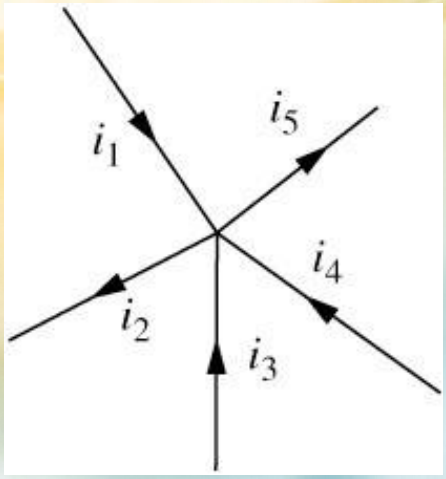
Should we consider it as one branch or two branches?

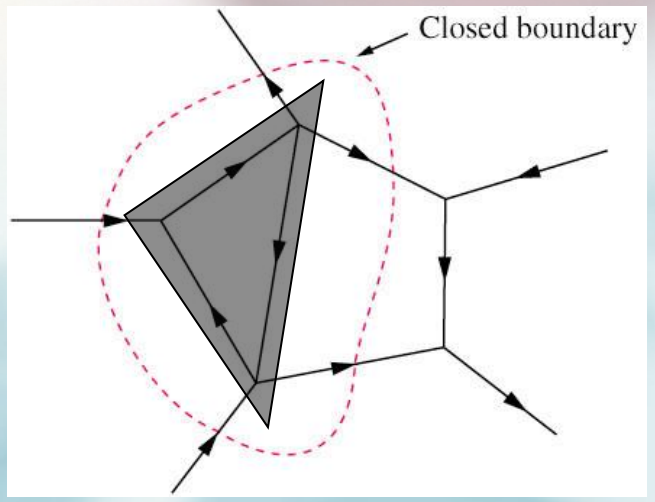


How many branches, nodes and loops are there?

KIRCHHOFF'S LAWS

- Kirchhoff's current law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero.



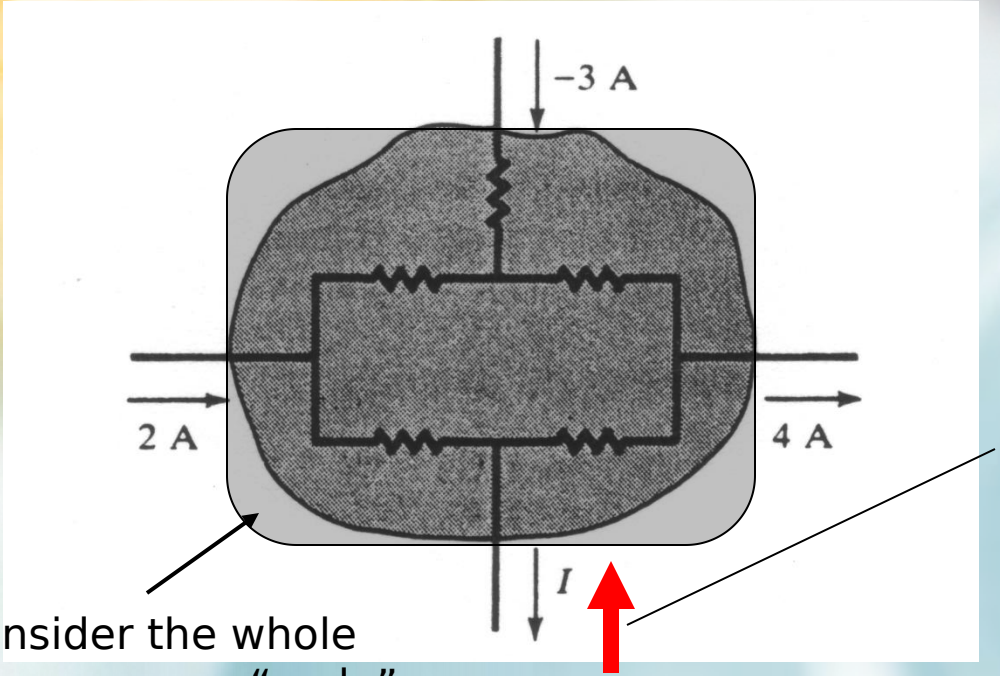


Mathematically, $\sum_{n=1}^{N} i_n = 0$

KIRCHHOFF'S LAWS

Example 4

- Determine the current I for the circuit shown in the figure below.



We can consider the whole enclosed area as one "node".

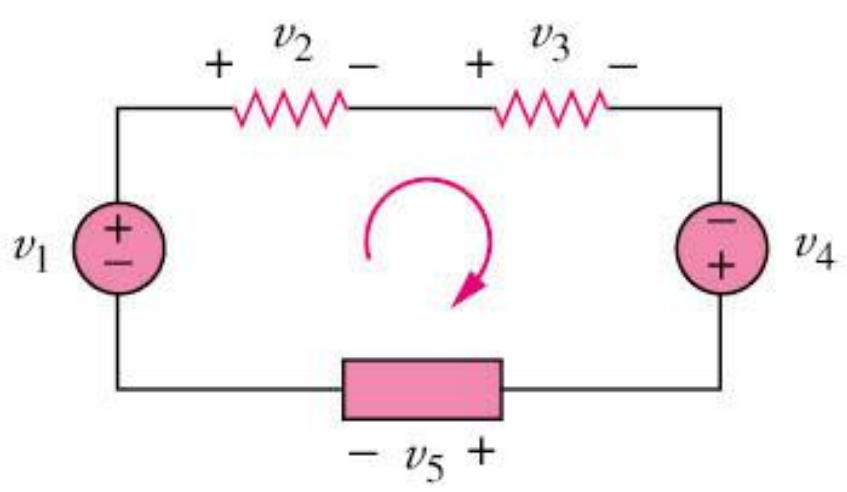
I + 4-(-3)-2 = 0

I = -5A

This indicates that the actual current for I is flowing in the opposite direction.

KIRCHHOFF'S LAWS

- Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

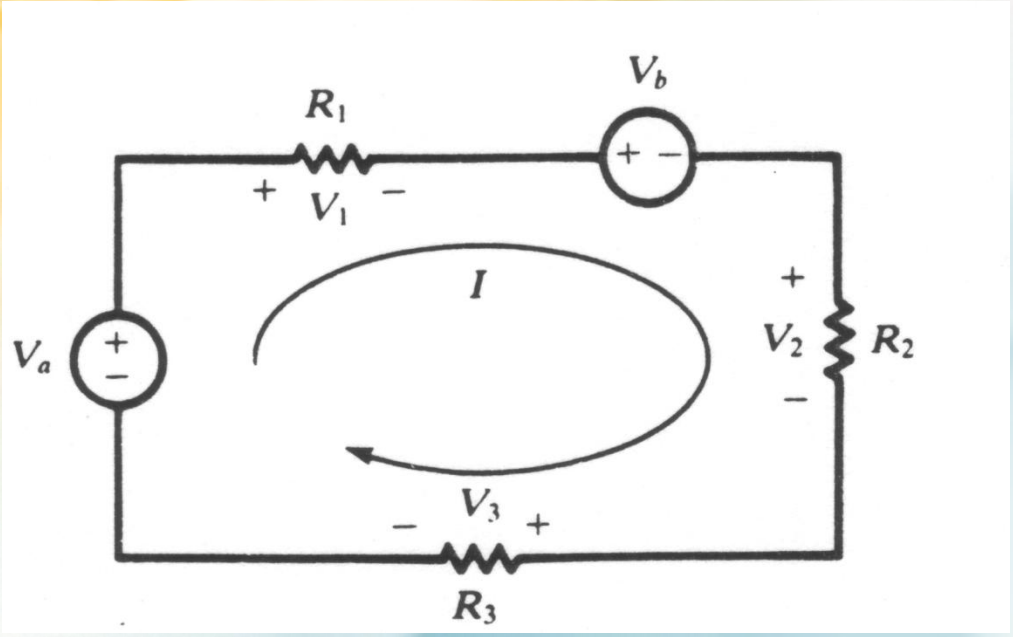


Mathematically, $\sum_{m=1}^{M} v_n = 0$

KIRCHHOFF'S LAWS

Example *5*

- Applying the KVL equation for the circuit of the figure below. Find I.



$$v_a - v_1 - v_b - v_2 - v_3 = 0$$

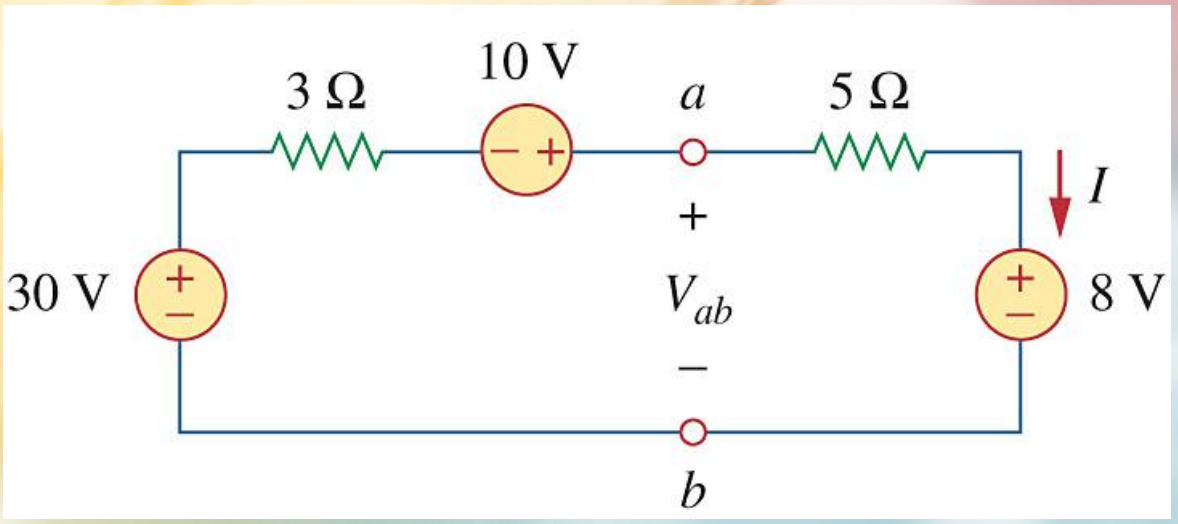
$$V_1 = IR_1 \quad v_2 = IR_2 \quad v_3 = IR_3$$

$$v_a - v_b = I(R_1 + R_2 + R_3)$$

$$I = \frac{v_a - v_b}{R_1 + R_2 + R_3}$$

KIRCHHOFF'S LAWS

- Find I and V_{ab} in the circuit.



HW2_Ch2: 7, 9, 11, 17, 21

SERIES RESISTORS AND VOLTAGE DIVISION

- Series: Two or more elements are in series if they are cascaded or connected sequentially and consequently carry the same current.
- The equivalent resistance of any number of resistors connected in a series is the sum of the individual resistances.

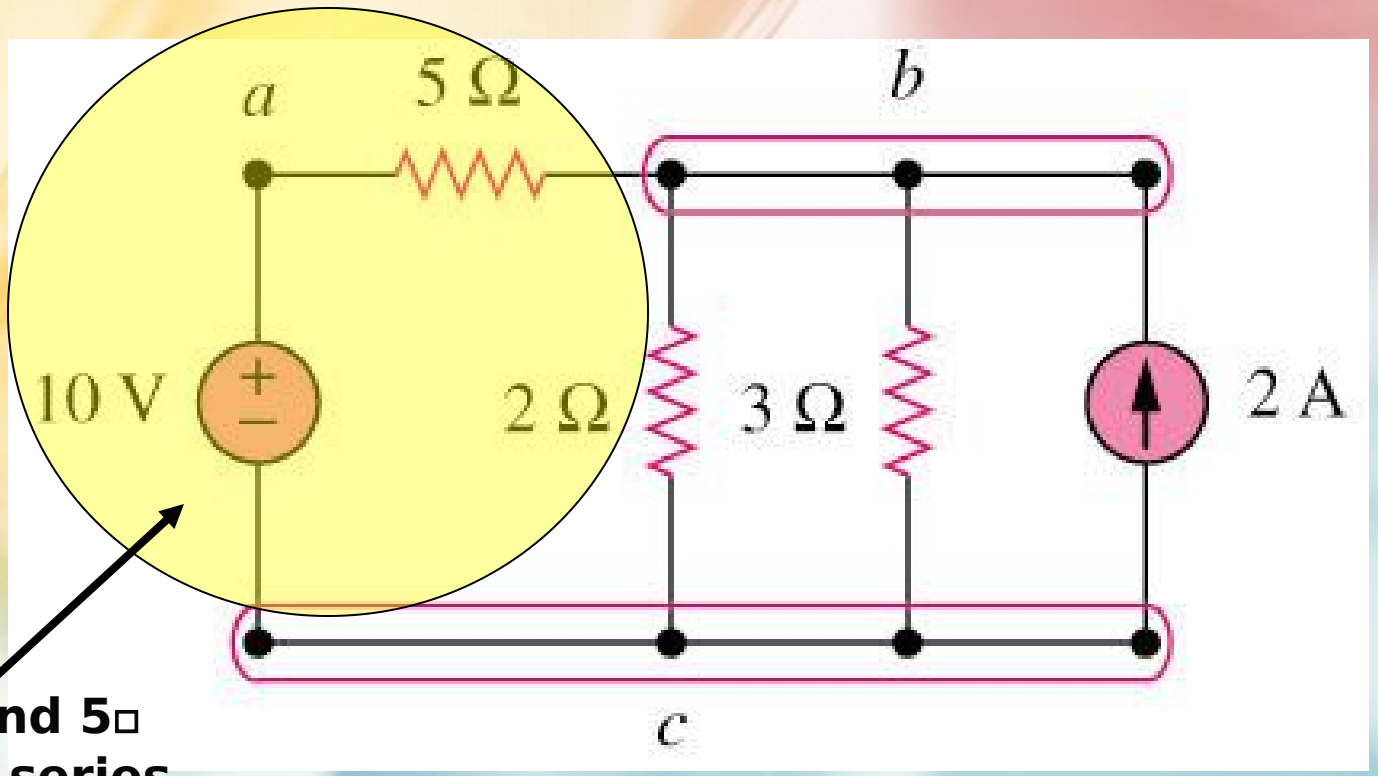
$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

- The voltage divider can be expressed as

$$v_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} v$$

Series Resistors and Voltage Division

Example 3



10V and 5□ are in series

PARALLEL RESISTORS AND CURRENT DIVISION

- Parallel: Two or more elements are in parallel if they are connected to the same two nodes and consequently have the same voltage across them.
- The equivalent resistance of a circuit with N resistors in parallel is:

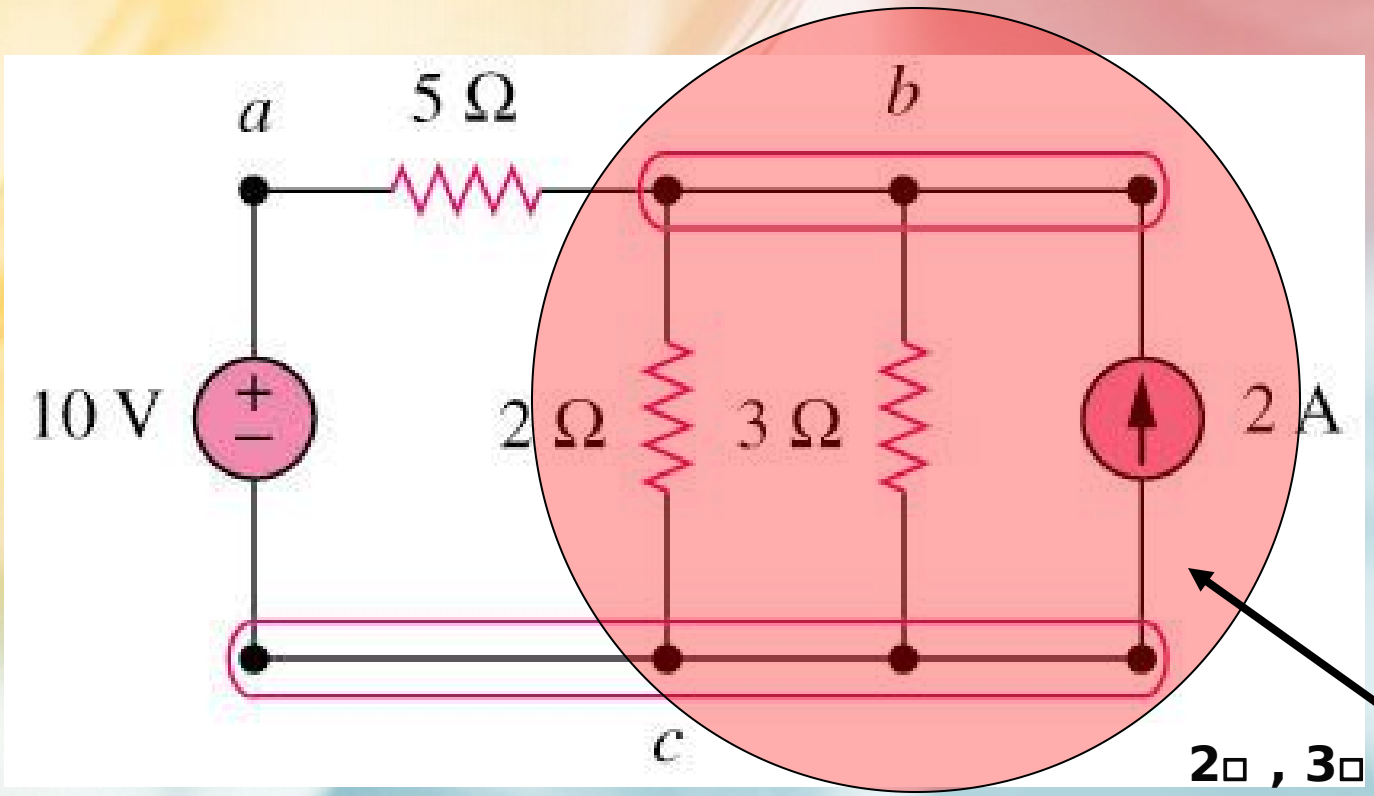
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$$

- The total current i is shared by the resistors in inverse proportion to their resistances. The current divider can be expressed as:

$$i_n = \frac{v}{R_n} = \frac{iR_{eq}}{R_n}$$

Parallel Resistors and Current Division

Example 4



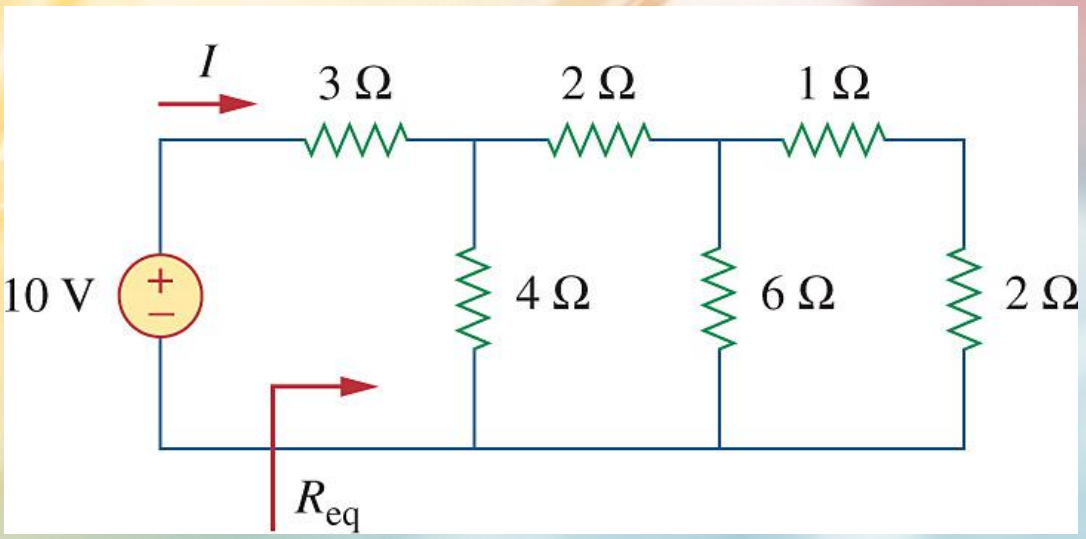
2□ , 3□ and 2A are in parallel

Parallel Resistors and Current Division

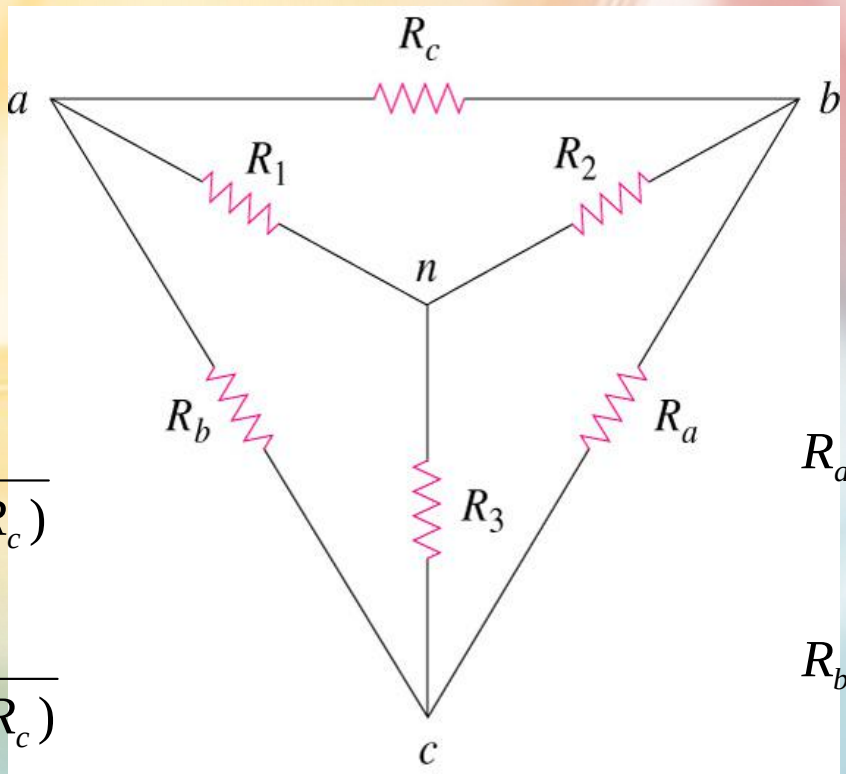
- For the circuit below, $i_o = 2$ A. Calculate i_x and the total power dissipated by the circuit.

Parallel Resistors and Current Division

- For the ladder network below, find I and R_{eq}.



WYE–DELTA TRANSFORMATIONS



Delta -> Star

$$R_1 = \frac{R_b R_c}{(R_a + R_b + R_c)}$$

$$R_2 = \frac{R_c R_a}{(R_a + R_b + R_c)}$$

$$R_3 = \frac{R_a R_b}{(R_a + R_b + R_c)}$$

Star -> Delta

$$R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$$

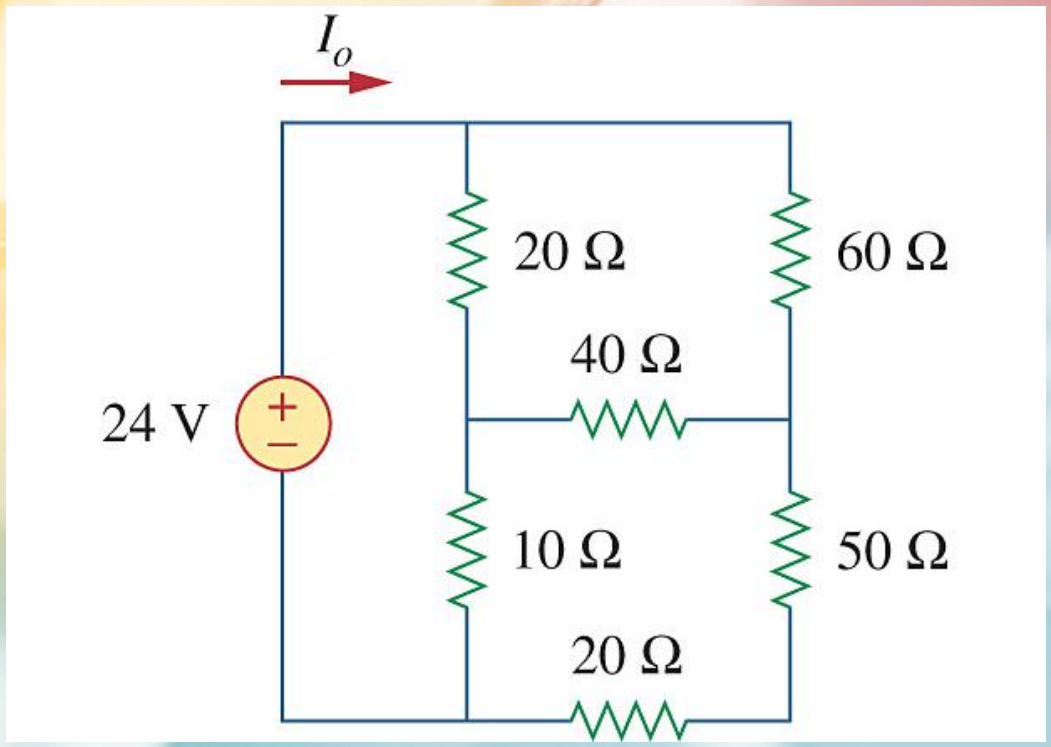
$$R_b = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$$

$$R_c = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$$

HW3_Ch2: 35, 39, 61, 83

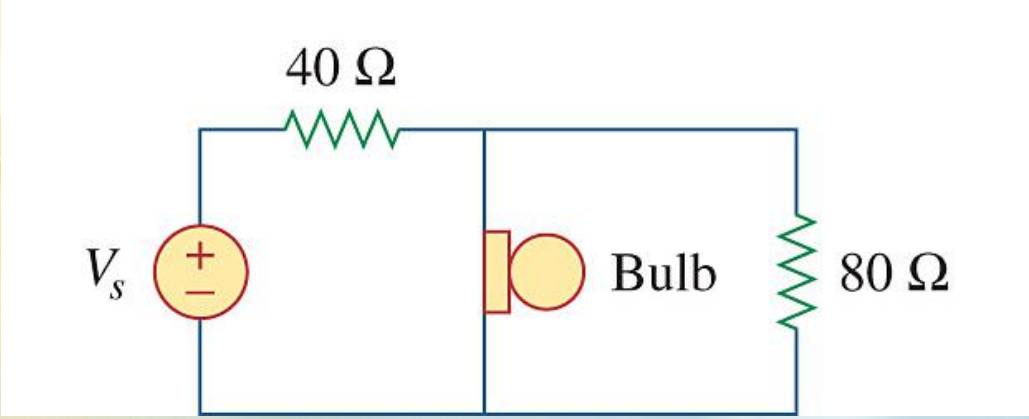
WYE-DELTA TRANSFORMATIONS

- Calculate I_o in the circuit



APPLICATION PROBLEM

- The light bulb is rated 120 V, 0.75 A. Calculate V_s to make the light bulb operate at the rated conditions.



DOT CONVENTION

- In circuit analysis, the **dot convention** is a convention used to denote the polarity of two mutually inductive components, such as windings on a transformer.