EE2003 Circuit Theory

Chapter 2
Basic Laws

Basic Laws - Chapter 2

2.1 Ohm's Law.

2.2 Nodes, Branches, and Loops.

2.3 Kirchhoff's Laws.

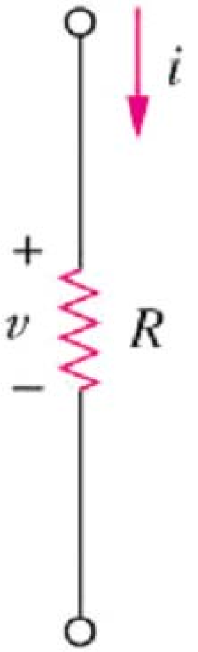
2.4 Series Resistors and Voltage Division.

2.5 Parallel Resistors and Current Division.

2.6 Wye-Delta Transformations.

2.1 Ohms Law (1)

- Ohm's law states that the voltage across a resistor is directly proportional to the current I flowing through the resistor.



- Mathematical expression for Ohm's Law is as follows:

$$v = iR$$

- Two extreme possible values of R: **0 (zero) and ∞ (infinite)** are related with two basic circuit concepts: short circuit and open circuit.

2.1 Ohms Law (2)

- *Conductance* is the ability of an element to conduct electric current; it is the reciprocal of resistance R and is measured in mhos or siemens.

$$G = \frac{1}{R} = \frac{i}{v}$$

- The power dissipated by a resistor:

$$p = vi = i^2 R = \frac{v^2}{R}$$

2.2 Nodes, Branches and Loops (1)

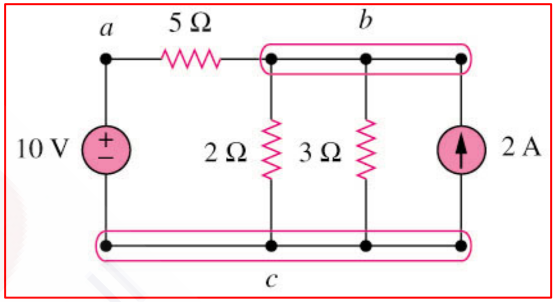
- A branch represents a single element such as a voltage source or a resistor.
- A node is the point of connection between two or more branches.
- A loop is any closed path in a circuit.

- A network with b branches, n nodes, and l independent loops will satisfy the fundamental theorem of network topology:

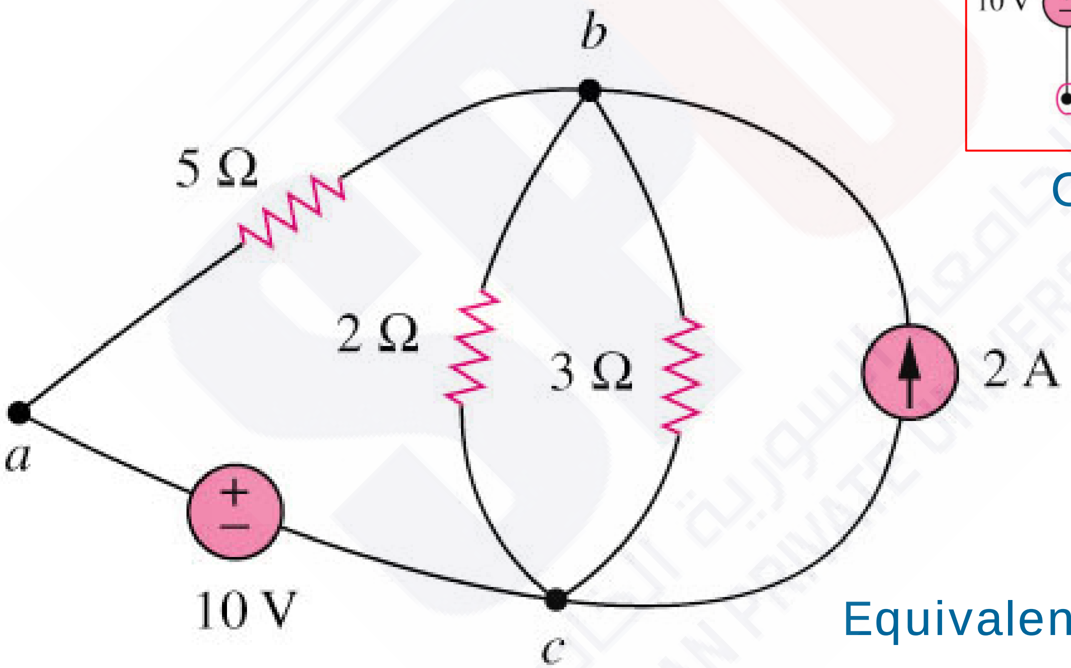
$$b = l + n - 1$$

2.2 Nodes, Branches and Loops (2)

Example 1



Original circuit



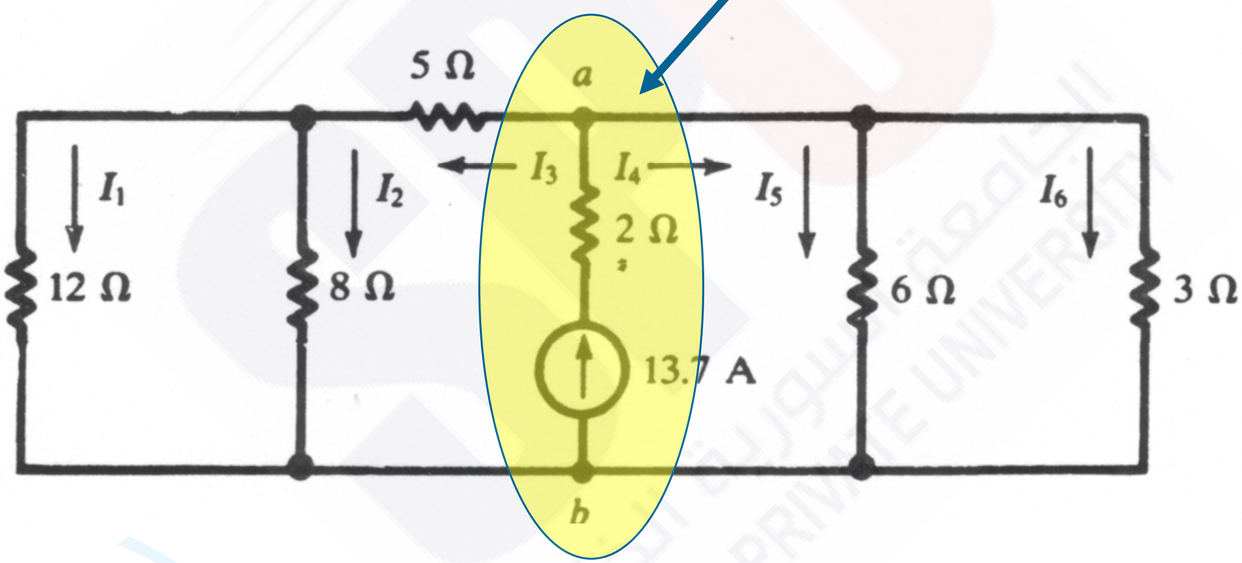
Equivalent circuit

How many branches, nodes and loops are there?

2.2 Nodes, Branches and Loops (3)

Example 2

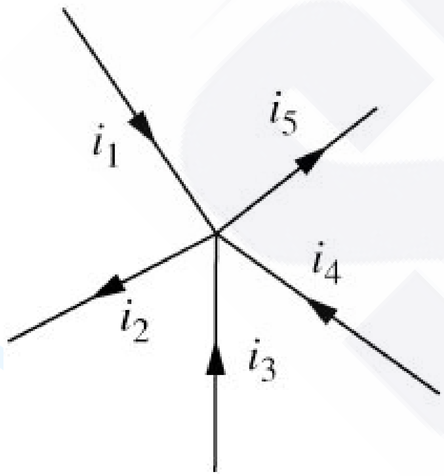
Should we consider it as one branch or two branches?

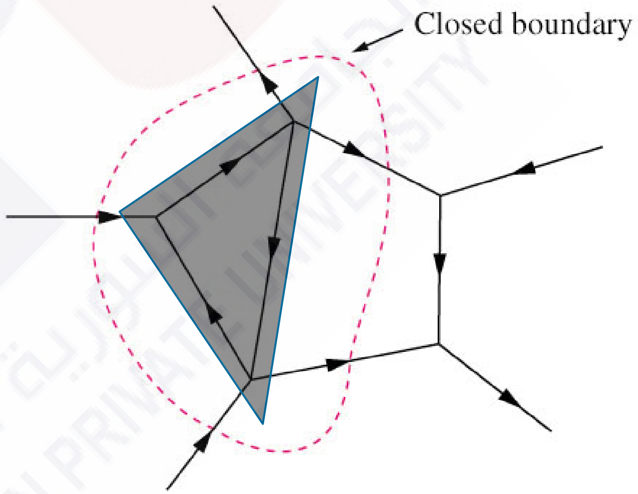


How many branches, nodes and loops are there?

2.3 Kirchhoff's Laws (1)

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



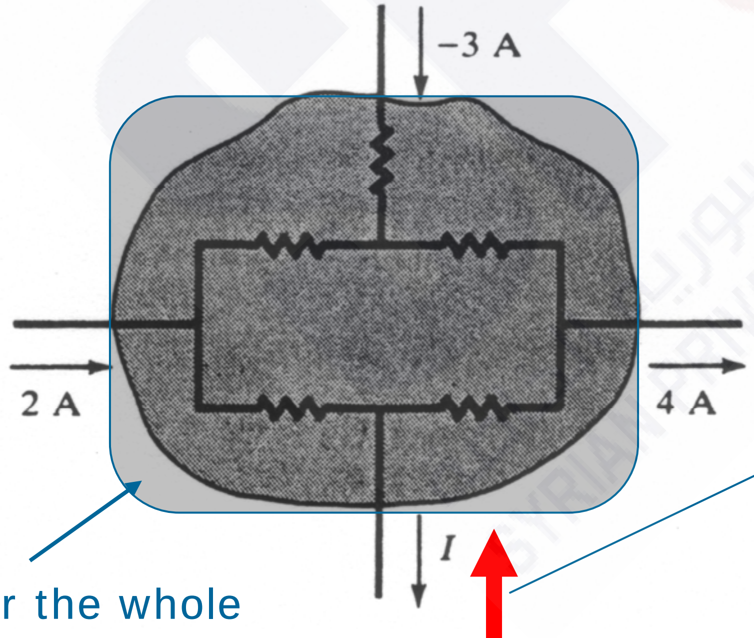


Mathematically, $$\sum_{n=1}^{N} i_n = 0$$

2.3 Kirchhoff's Laws (2)

Example 4

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



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

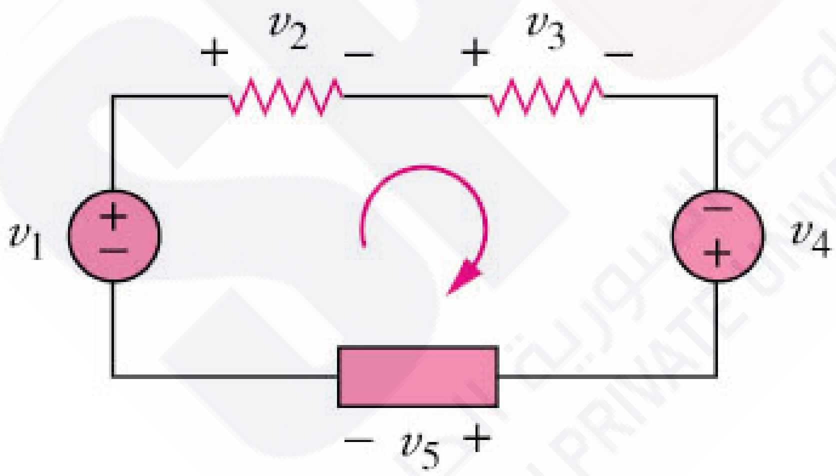
$\Rightarrow I = -5A$

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

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

2.3 Kirchhoff's Laws (3)

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

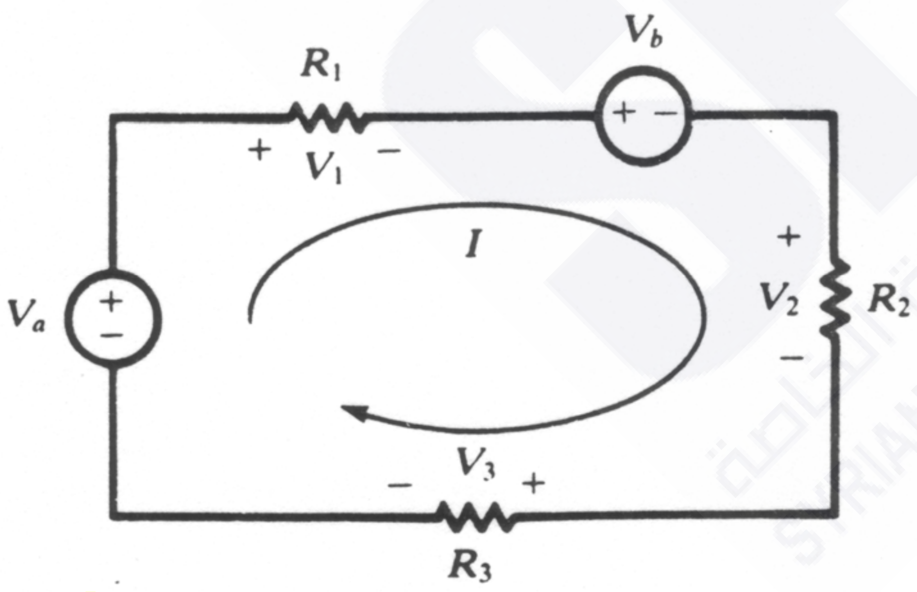


Mathematically, $$\sum_{m=1}^{M} v_n = 0$$

2.3 Kirchhoff’s Laws (4)

Example 5

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



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

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

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

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

2.4 Series Resistors and Voltage Division (1)

- 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.

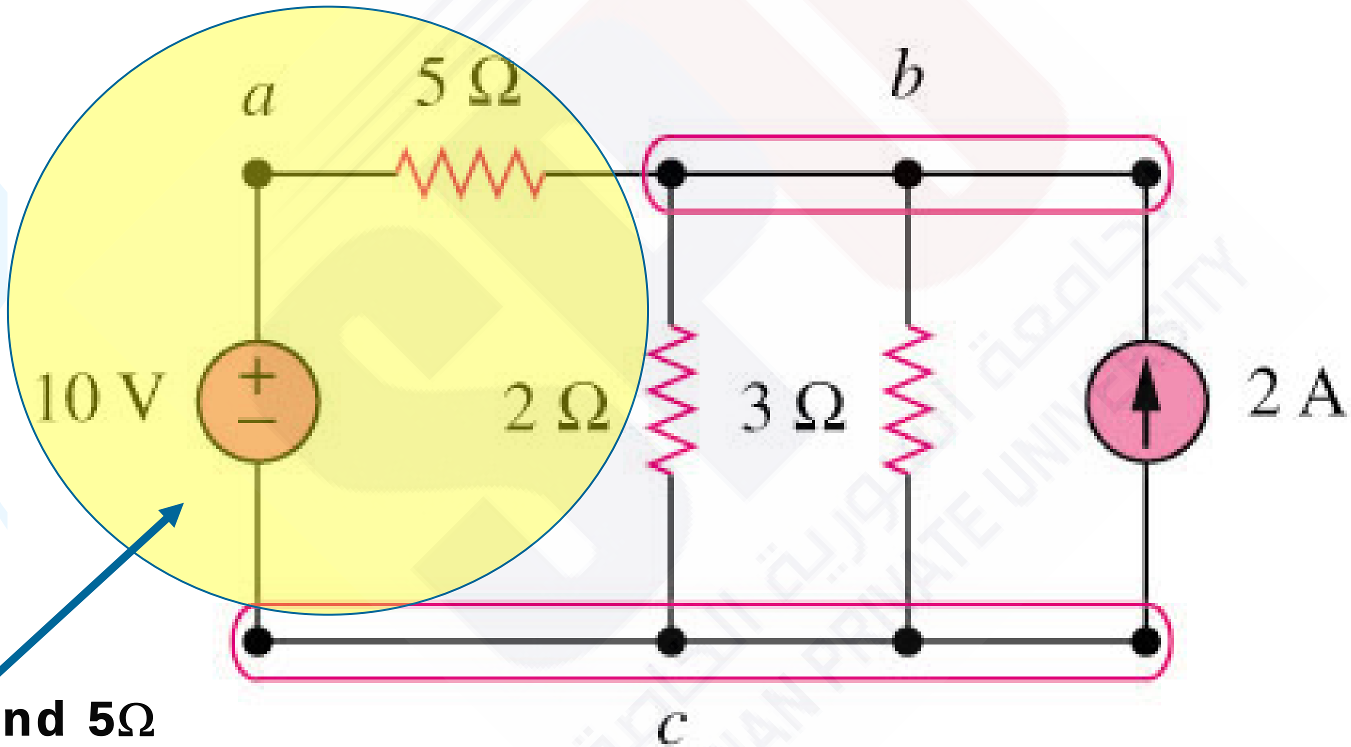
$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

- The voltage divider can be expressed as

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

2.4 Series Resistors and Voltage Division (1)

Example 3



10V and 5Ω are in series

2.5 Parallel Resistors and Current Division (1)

- 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:

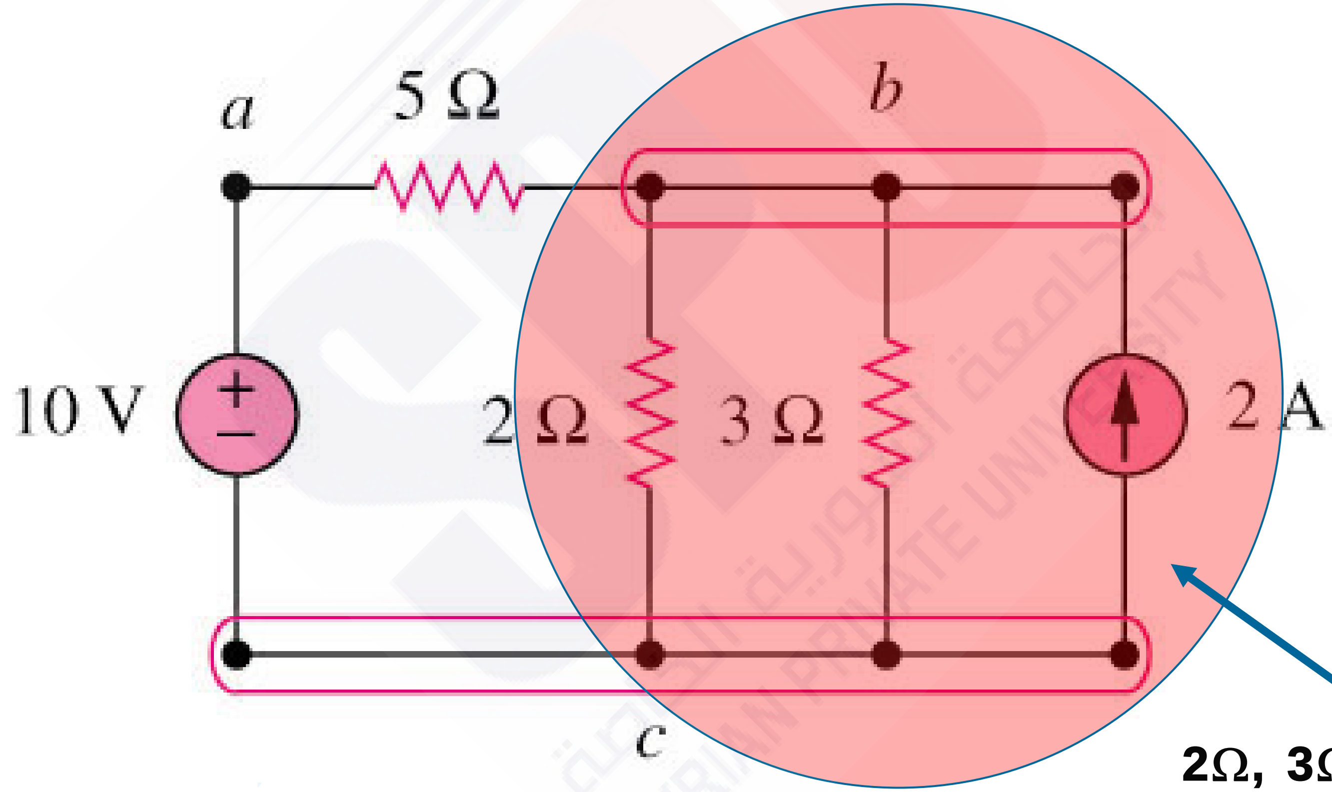
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$$

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

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

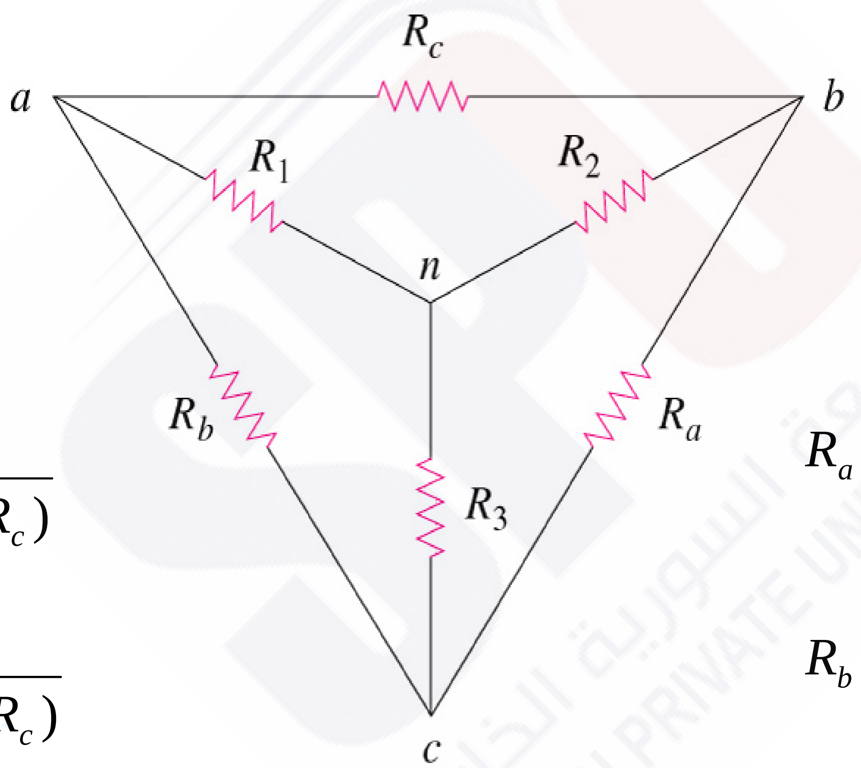
2.5 Parallel Resistors and Current Division (1)

Example 4



2Ω, 3Ω and 2A are in parallel

2.6 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

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

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

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