Electrical Circuits for Engineers (EC1000)

Lecture-2 (a) (Chapter-2)
Basic Laws

Overview

- Ohm's law
- Kirchoff's law
- Network topology
- Series and Parallel connection
- Verification of Ohm's law and Kirchoff's law
- Practice problems

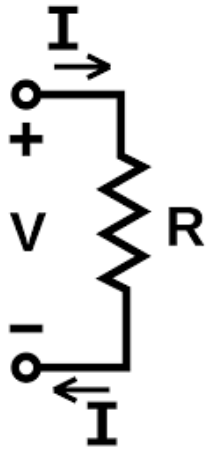
Basic Laws

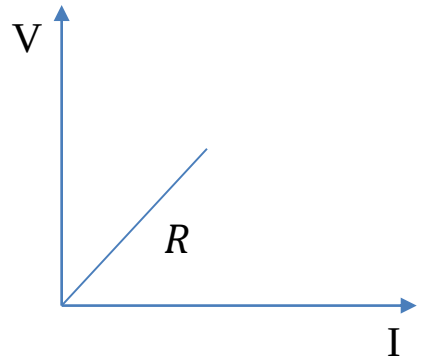
Ohm's law

Ohm's law states that "T***he voltage 'V' across a resistor is directly proportional to the current 'I' flowing through the resistor***".

$$V \propto I$$

$$V = I\,R$$





Some expressions for power

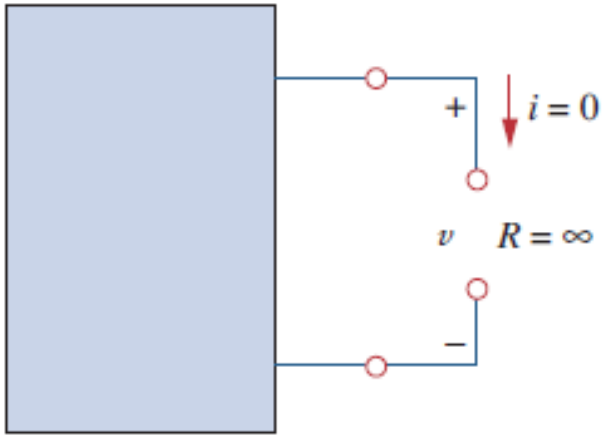
$$P = \frac{V^2}{R}$$

$$P = I^2 R$$

$$P = VI$$

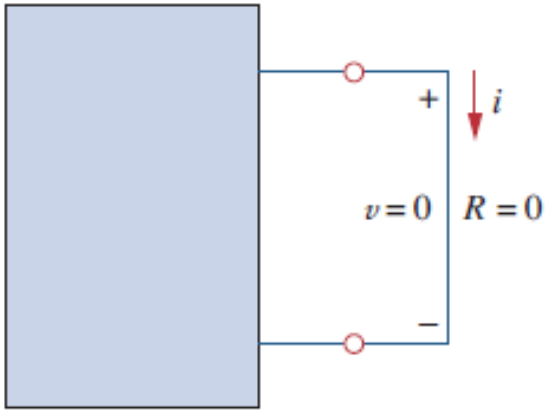
Basic Laws

Open circuit



An open circuit is a circuit element with resistance approaching infinity.

Short circuit



A short circuit is a circuit element with resistance approaching zero.

$$R = \frac{V}{I}$$

Basic Laws

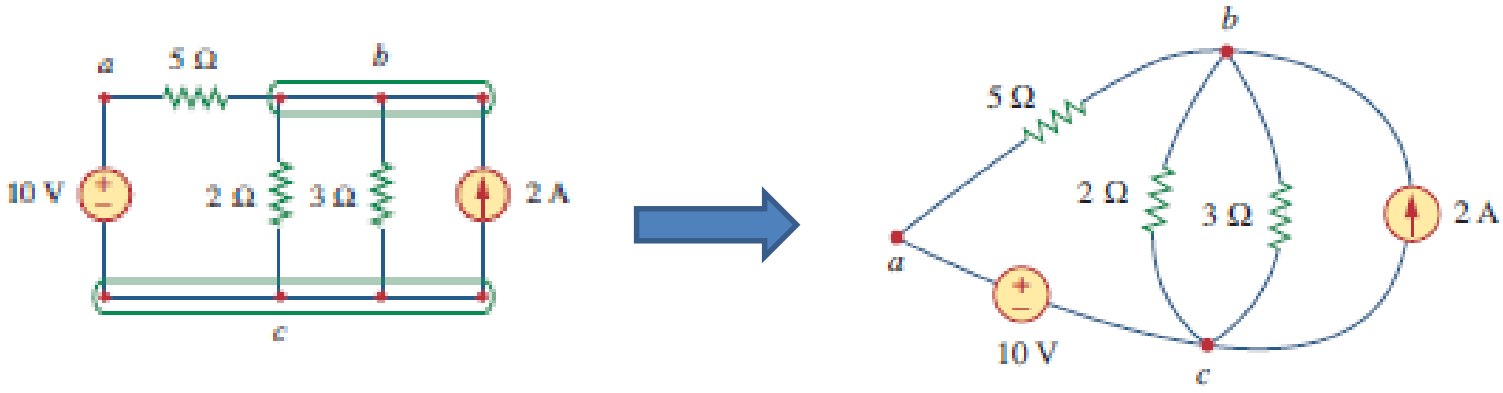
Network topology

Node

A node is the point of connection between two or more branches.

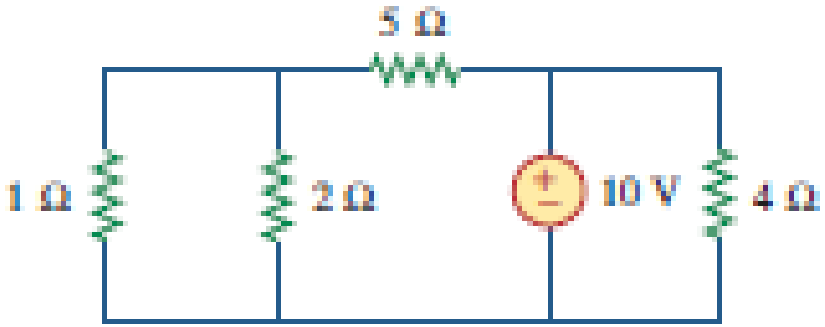
Branch

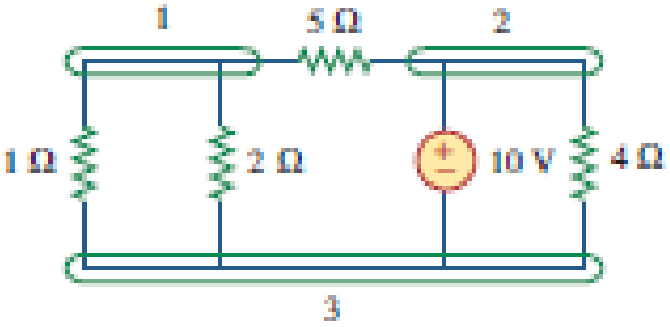
A branch represents a single element such as a voltage source or a resistor.



Basic Laws

1. How many nodes and branches does the below circuit have?





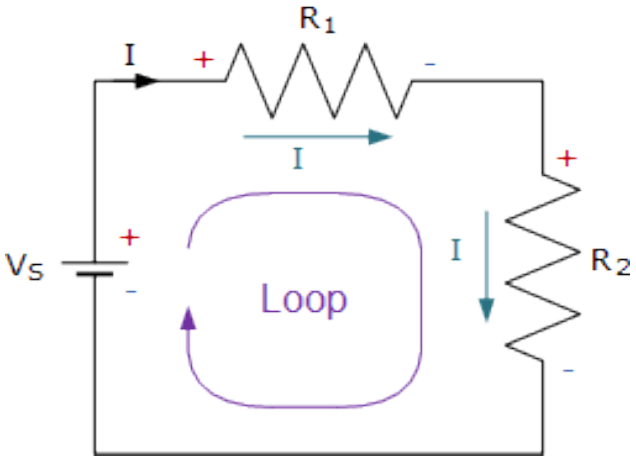
Basic Laws

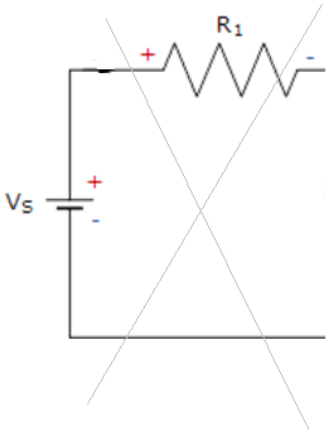
Loop

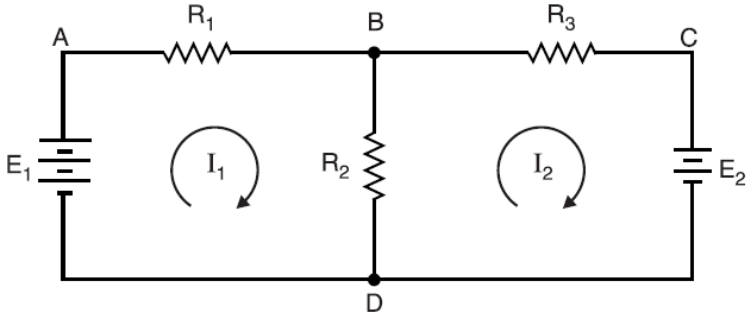
A loop is any closed path in a circuit.

Mesh

A mesh is the most elementary form of a loop and cannot be further divided into other loops.





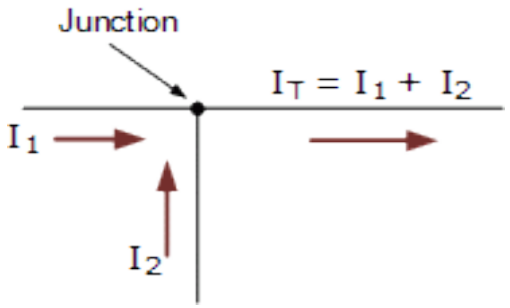


Basic Laws

Kirchhoff's current law (KCL)

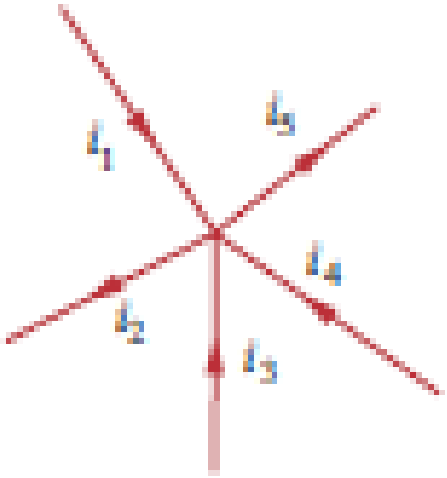
Current law states that the "*Algebraic sum of currents entering a node (a closed bath) is zero*".

i.e Total current entering a node is exactly equal to the total current leaving the same node.



$$\Sigma I_{in} = \Sigma I_{out}$$

$$\Sigma I = 0$$



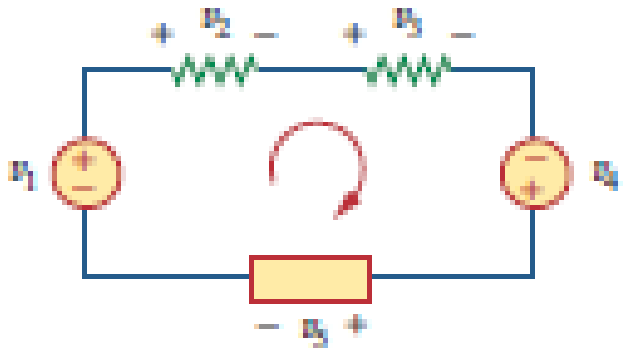
$$i_1+i_3+i_4=i_2+i_5$$

Basic Laws

Kirchoff voltage law

It states that the "Algebraic sum of all voltages around a closed path (loop) is zero".

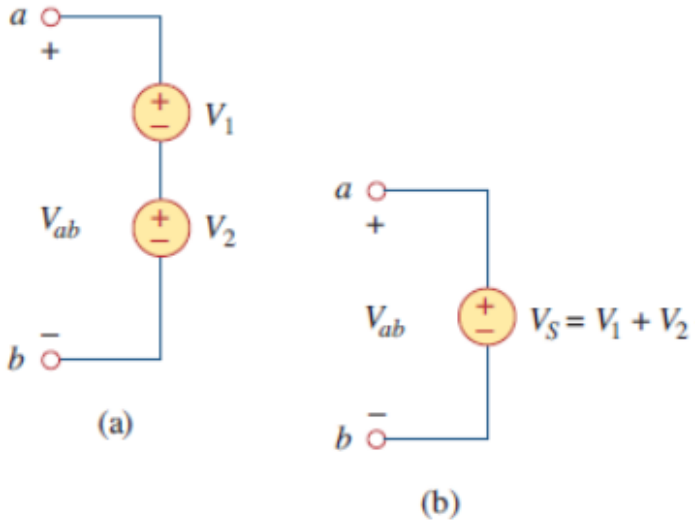
$$\Sigma v = 0$$



$$-v1+v2+v3-v_4+v_5=0$$

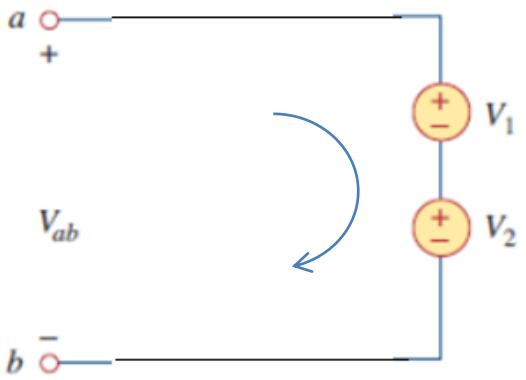
i.e. Sum of voltage drops=Sum of voltages rises

Basic Laws

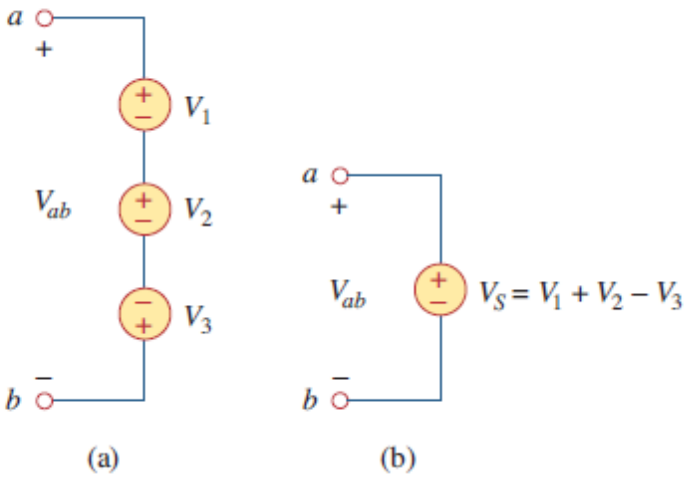


$$-V_{ab} + V_1 + V_2 = 0$$

$$V_{ab} = V_1 + V_2$$



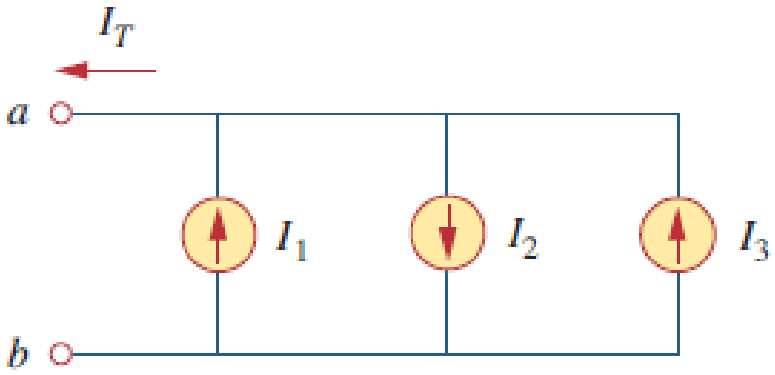
Basic Laws

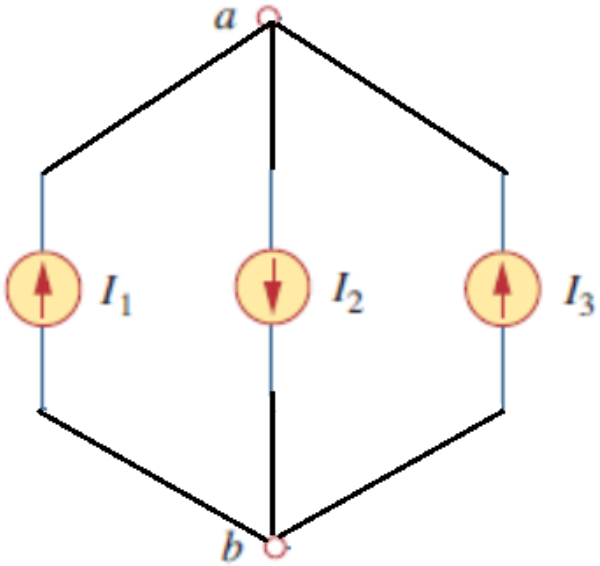


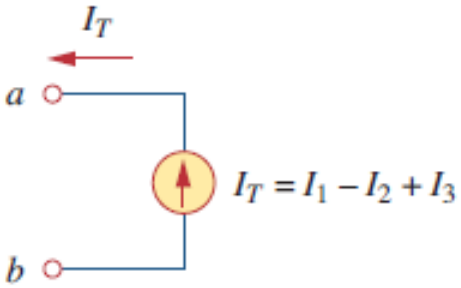
$$-V_{ab} + V_1 + V_2 - V_3 = 0$$

$$V_{ab} = V_1 + V_2 - V_3$$

Basic Laws



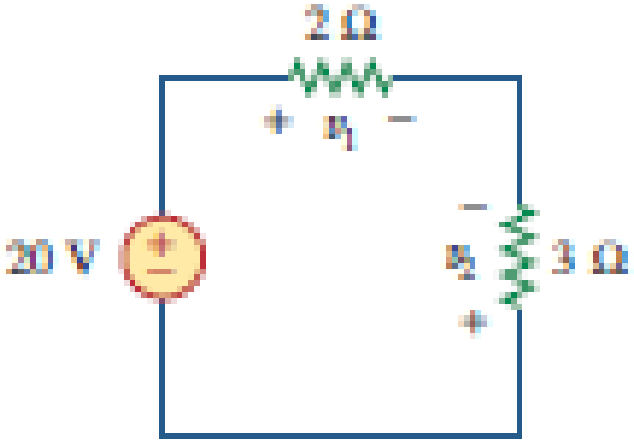


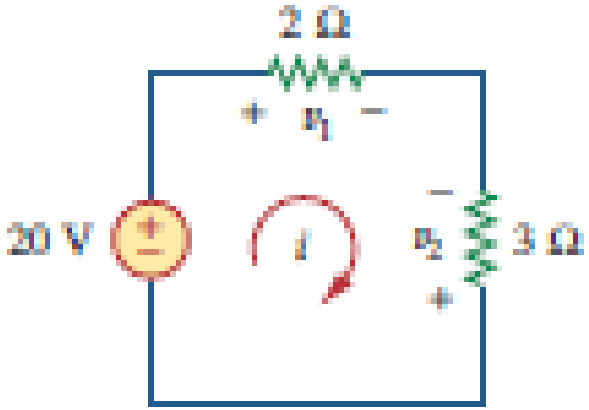


$$I_T = I_1 - I_2 + I_3$$

Problems

Find voltages v_1 and v_2 using KVL



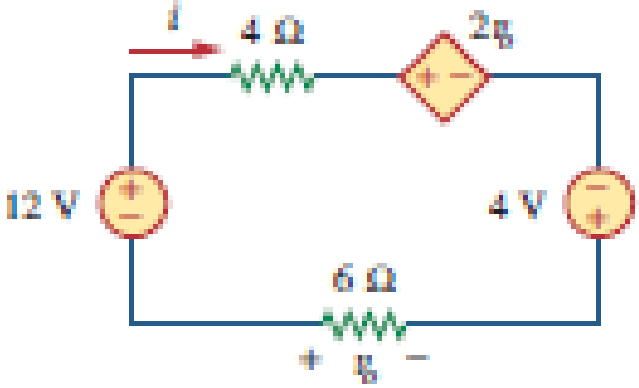


$$v_1 = 2i, \qquad v_2 = -3i$$

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

Ans: v_1=8 V, v_2=-12 V

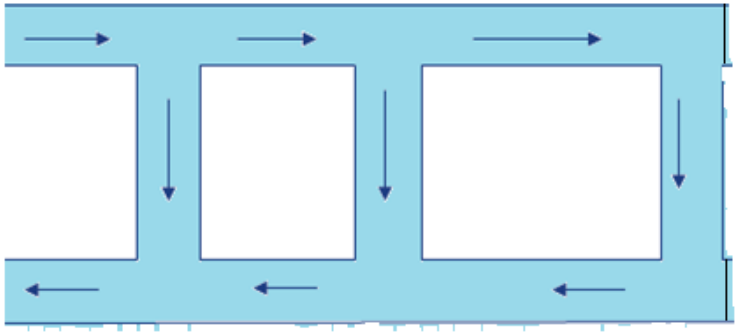
Find V_0 for the below circuit

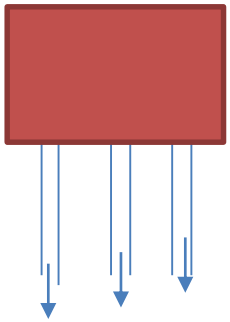


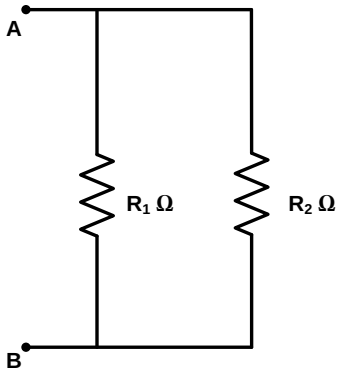
Ans: v_0=48 V

Basic Laws

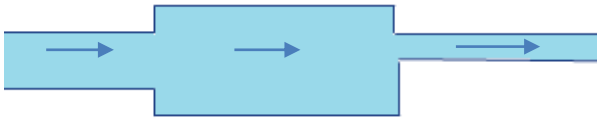
Parallel connection

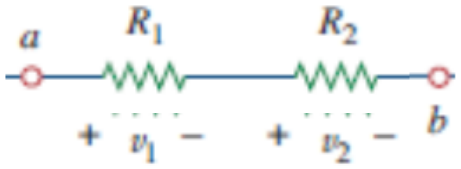






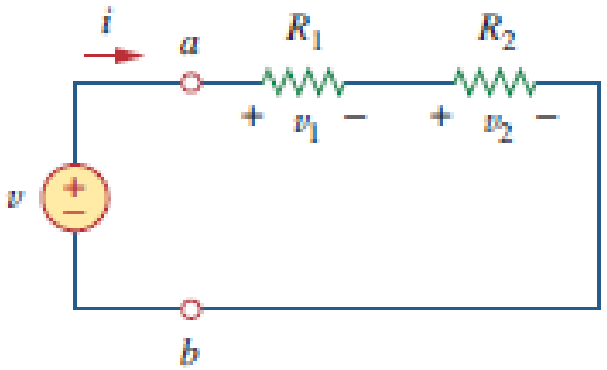
Series connection





Basic Laws

Resistance in Series



$$v_1 = iR_1, \qquad v_2 = iR_2$$

$$-v + v_1 + v_2 = 0$$

$$v = v_1 + v_2 = i(R_1 + R_2)$$

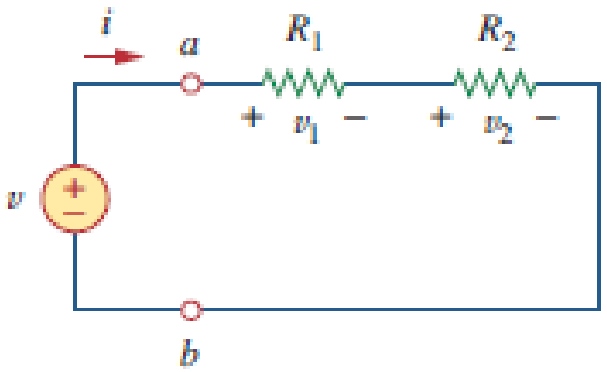
$$i = \frac{v}{R_1 + R_2}$$

$$\frac{i}{v} = \frac{1}{R_1 + R_2}$$

$$\frac{1}{R} = \frac{1}{R_1 + R_2}$$

$$R_{eq} = R_1 + R_2$$

Voltage division rule

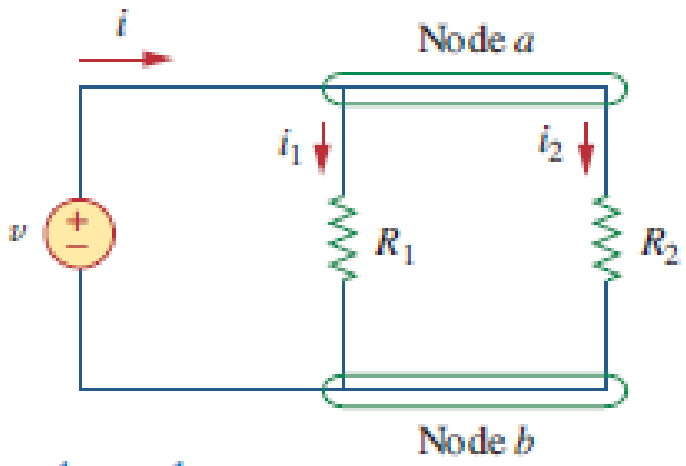


$$i = \frac{v}{R_1 + R_2}$$

$v_1 = iR_1$, $V_1 = \frac{R_1}{R_1 + R_2} V$

$v_2 = iR_2$ $V_2 = \frac{R_2}{R_1 + R_2} V$

Parallel Connection & Current Division



$$v = i_1 R_1 = i_2 R_2$$

$$i_1 = \frac{v}{R_1}, \qquad i_2 = \frac{v}{R_2}$$

Applying KCL at node a gives the total current i as

$$i = i_1 + i_2$$

$$i = \frac{v}{R_1} + \frac{v}{R_2} = v\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{v}{R_{eq}}$$

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

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

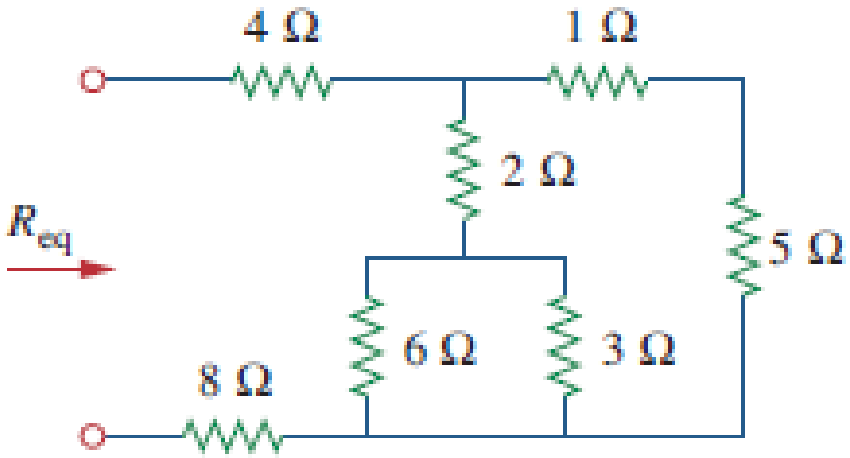
$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

$$i_1 = \frac{R_2\, i}{R_1 + R_2}, \qquad i_2 = \frac{R_1\, i}{R_1 + R_2}$$

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

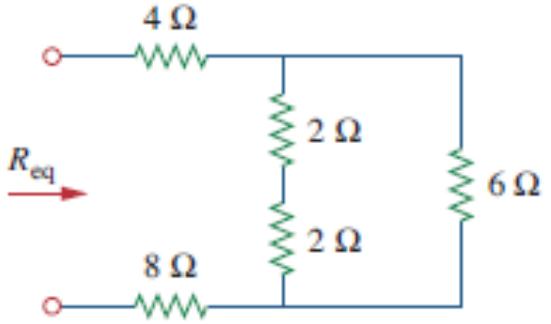
Problems

Find R_{eq}

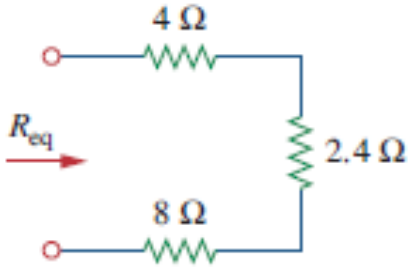


$$6\,\Omega \parallel 3\Omega = \frac{6 \times 3}{6 + 3} = 2\,\Omega$$

$$1\,\Omega + 5\,\Omega = 6\,\Omega$$



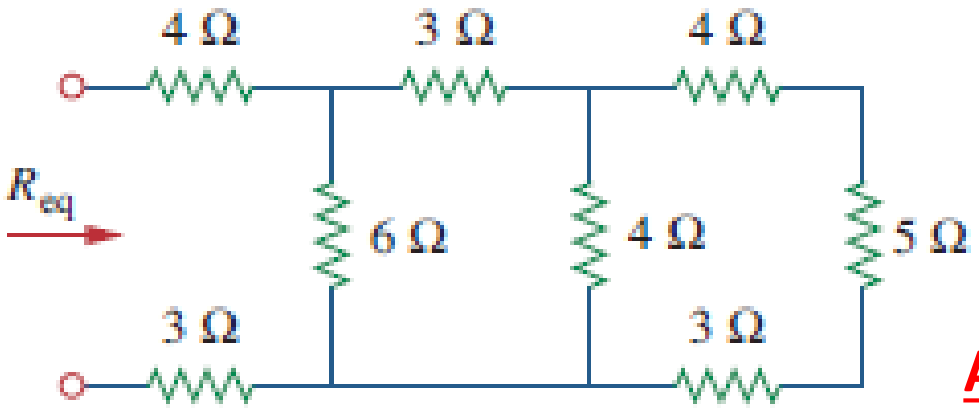
(a)



$$R_{eq} = 4\,\Omega + 2.4\,\Omega + 8\,\Omega = 14.4\,\Omega$$

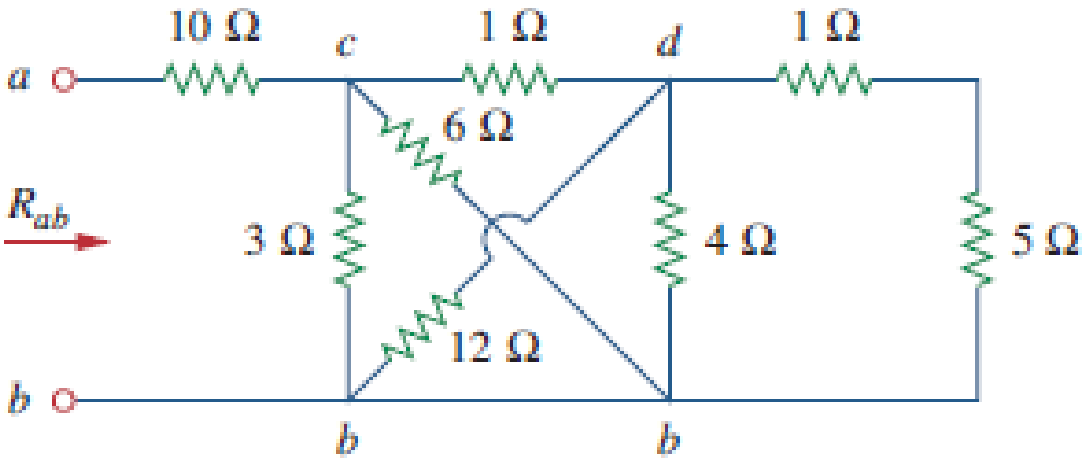
Problems

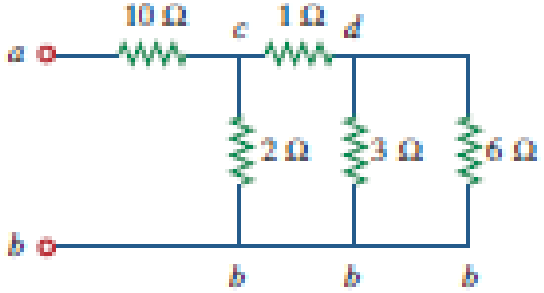
1. Find R_{eq}



Ans: 10 Ω

2. Find R_{eq}

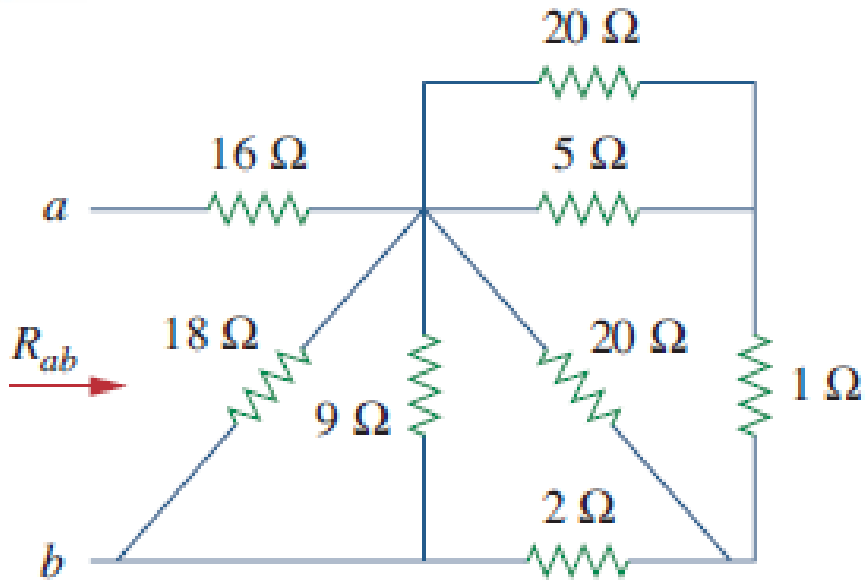




Ans: 11.2 Ω

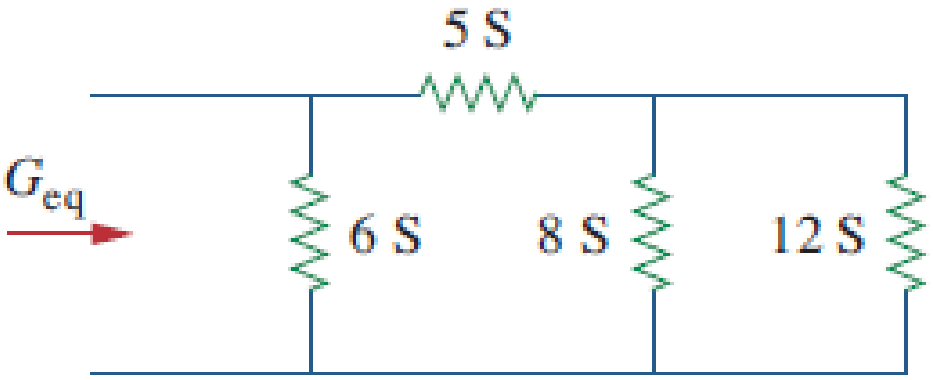
Problems

3. Find R_{ab}



Ans: 10 Ω

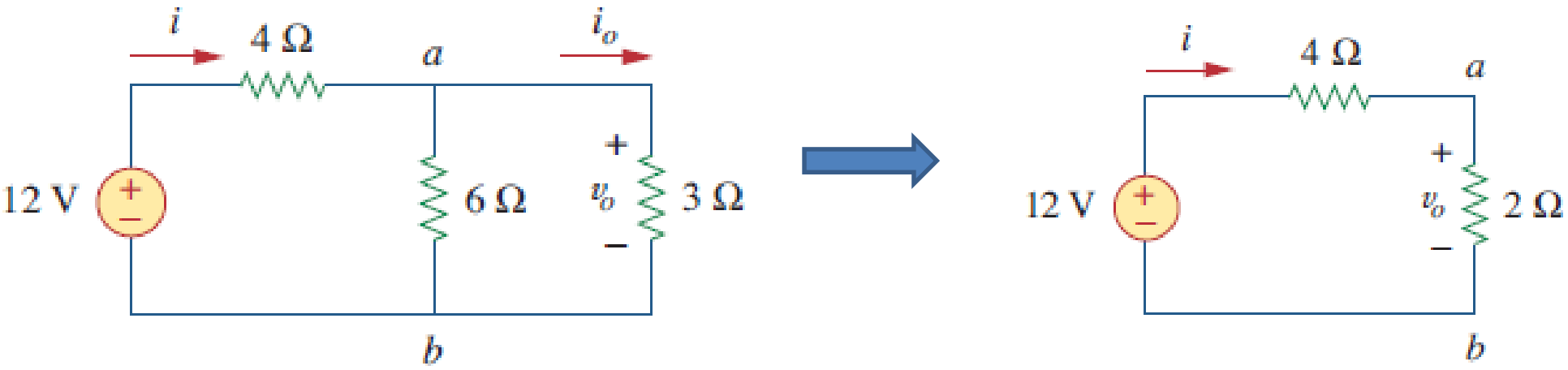
4. Find G_{eq}



Ans: 10 S

Problems

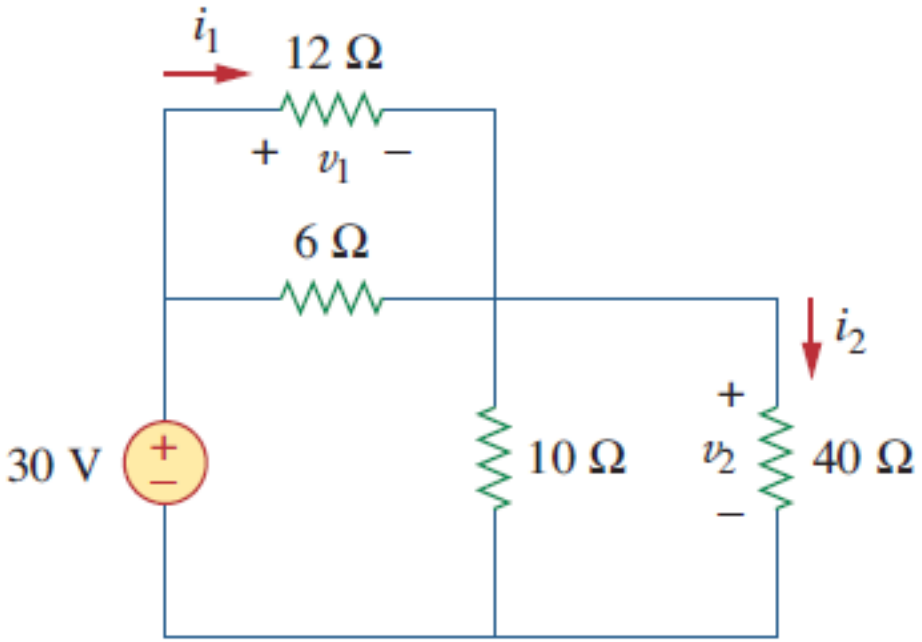
Find i_0 and v_0 in the circuit shown here. Calculate the power dissipated in the 3 Ω resistor.



Ans: 4/3 A, 4 V, and 5.33 W

Problems

Find v_1 and v_2 in the circuit shown here. Also calculate i_1 and i_2, and power dissipated in12 Ω and 40 Ω resistors.

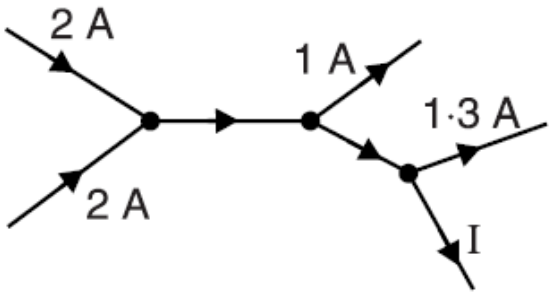


Answer: $v_1 = 10$ V, $i_1 = 833.3$ mA, $p_1 = 8.333$ W, $v_2 = 20$ V, $i_2 = 500$ mA, $p_2 = 10$ W.

Practical Problems

Find the voltage V_{AB}

Find the current I



Thank You