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Circuit Theory (SKEE 1023)

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Circuit Theory

Topics

- Basic concepts of electrical circuits.
- Basic Laws: Ohm's law; Nodes, Branches and Loops; Kirchhoff's Law; Series-parallel resistors; Voltage and Current Division.
- Methods of Analysis: Nodal and Mesh Analysis.
- Circuit Theorems: Linearity; Superposition; Thevenin & Norton Theorem; Source Transformation.
- Operational Amplifiers.

BASIC ELECTRICAL CIRCUITS (Definations & Laws)

Electric Charge

The unit of electric charge is the coulomb. Ordinary matter is made up of atoms which have positively charged nuclei and negatively charged electrons surrounding them. Charge is quantized as a multiple of the electron or proton charge:

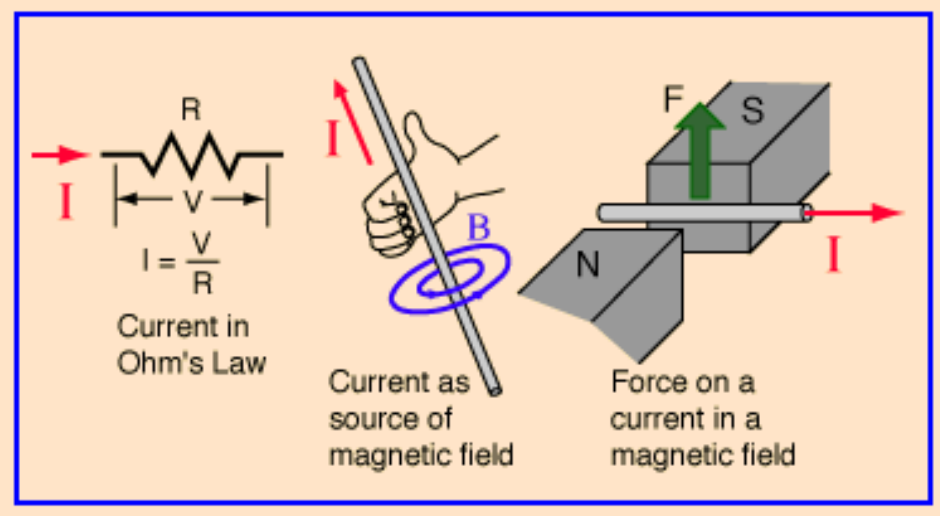
⊕ proton charge $e = 1.602 \times 10^{-19}$ coulombs

⊖ electron charge $-e = -1.602 \times 10^{-19}$ coulombs

- The influence of charges is characterized in terms of the forces between them (Coulomb's law) and the electric field and voltage produced by them.
- The rate of flow of electric charge is called electric current and is measured in amperes.

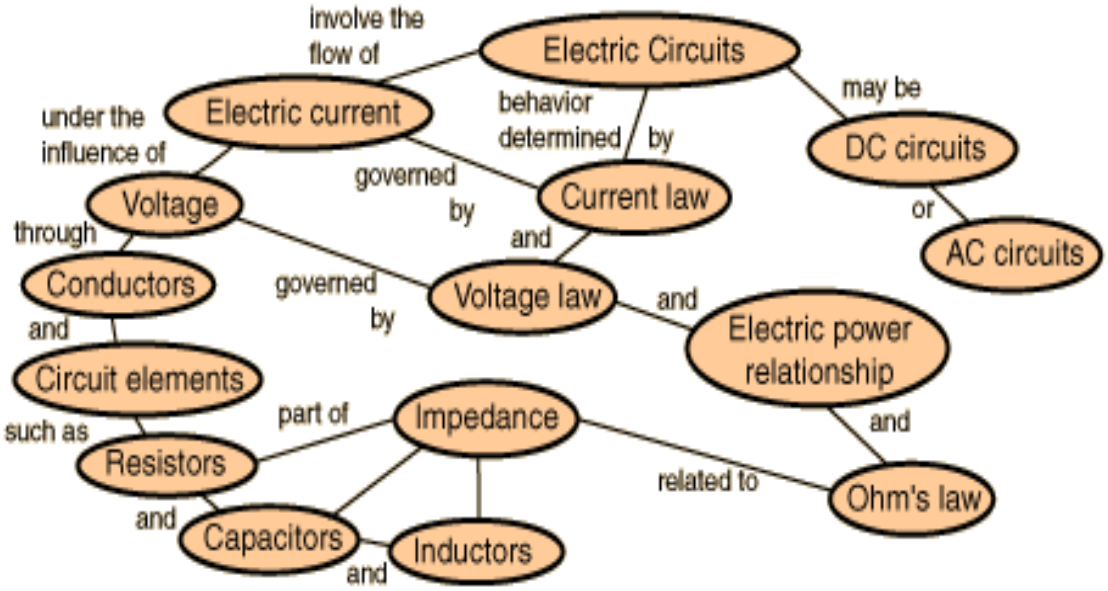
Electric Current

Electric current is the rate of charge flow past a given point in an electric circuit, measured in coulombs/second which is named amperes. In most DC electric circuits, it can be assumed that the resistance to current flow is a constant so that the current in the circuit is related to voltage and resistance by Ohm's law.



Electric Circuits

Most practical applications of electricity involve the flow of electric current in a closed path under the influence of a driving voltage, analogous to the flow in a water circuit under the influence of a driving pressure. A complete path, typically through conductors such as wires and through circuit elements, is called an electric circuit.



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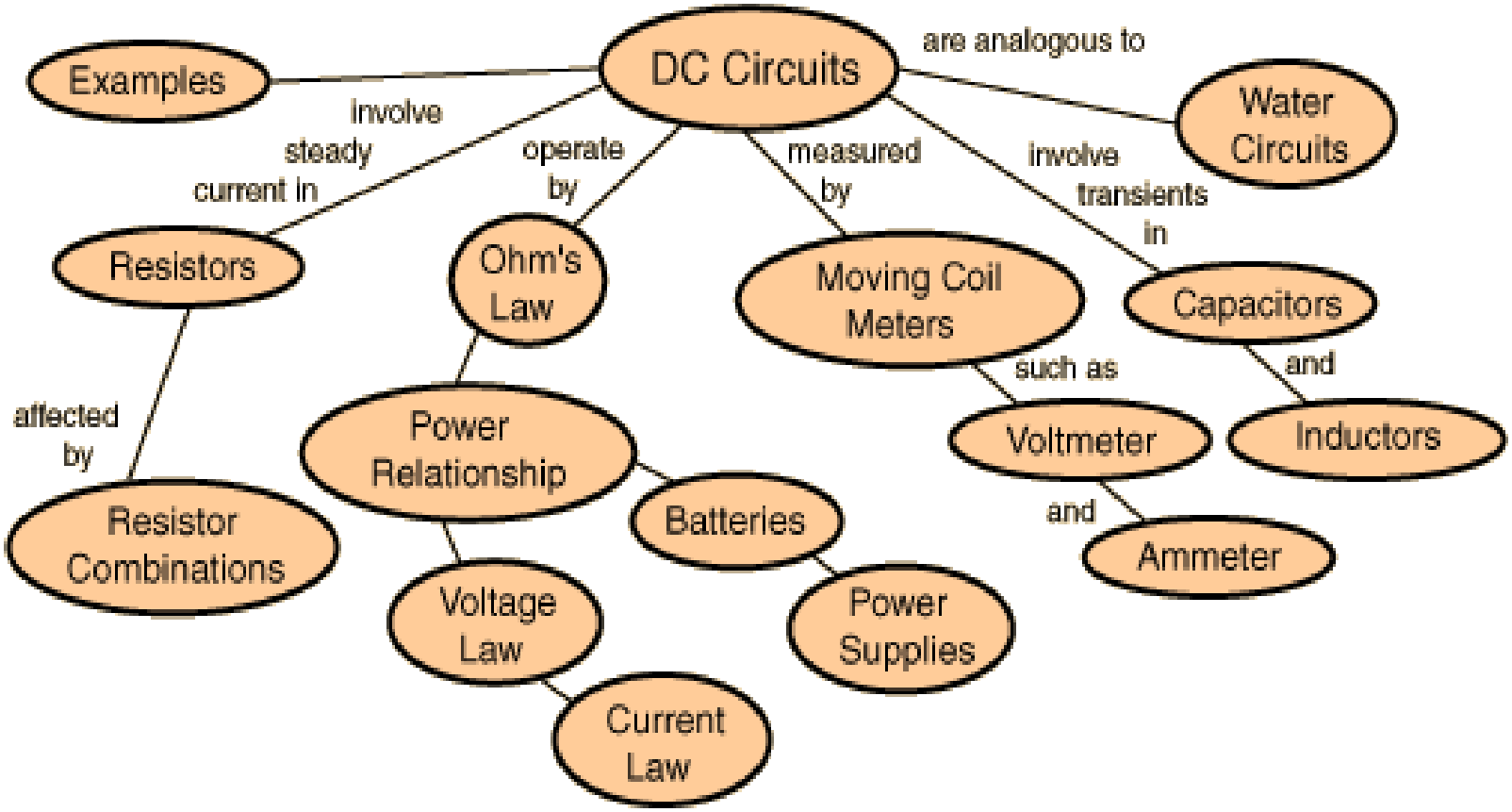

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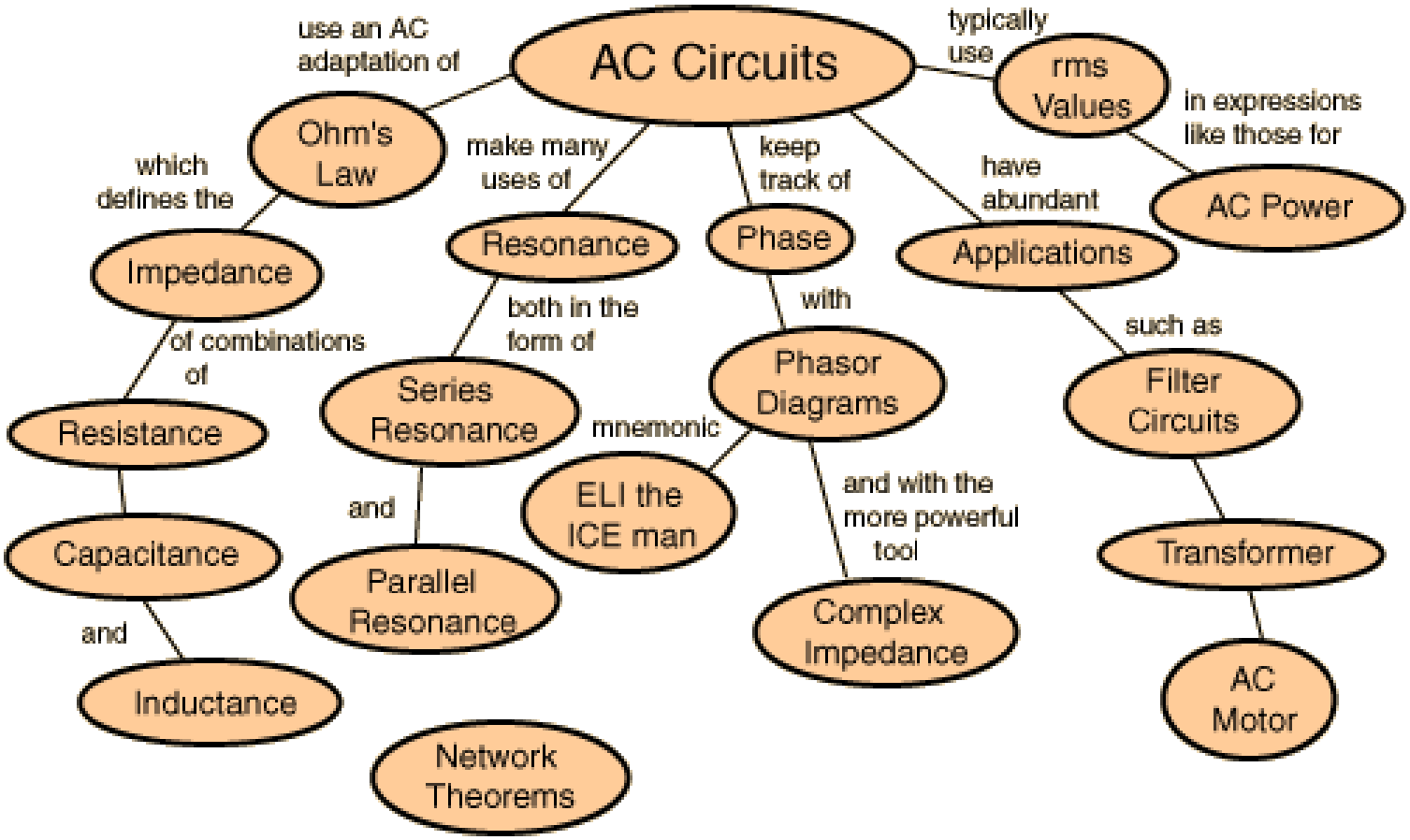
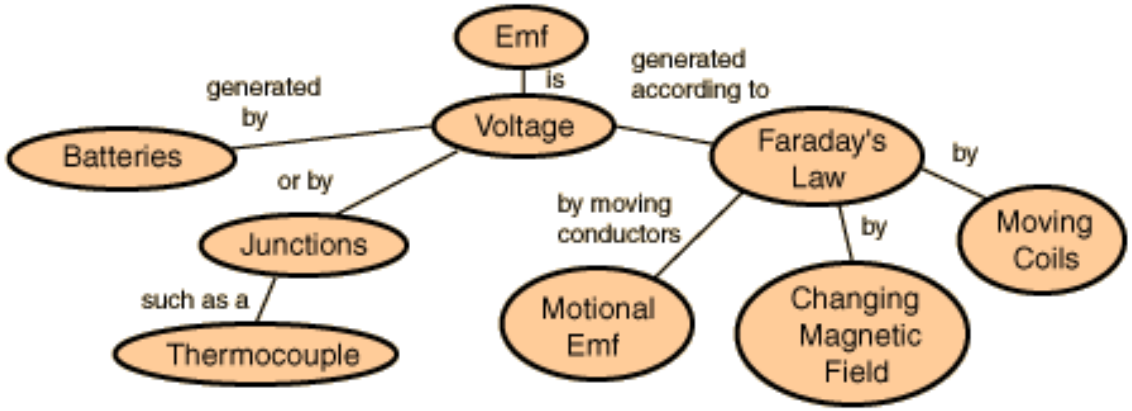


Voltage

Voltage is electric potential energy per unit charge, measured in joules per coulomb (= volts). It is often referred to as "electric potential", which then must be distinguished from electric potential energy by noting that the "potential" is a "per-unit-charge" quantity.



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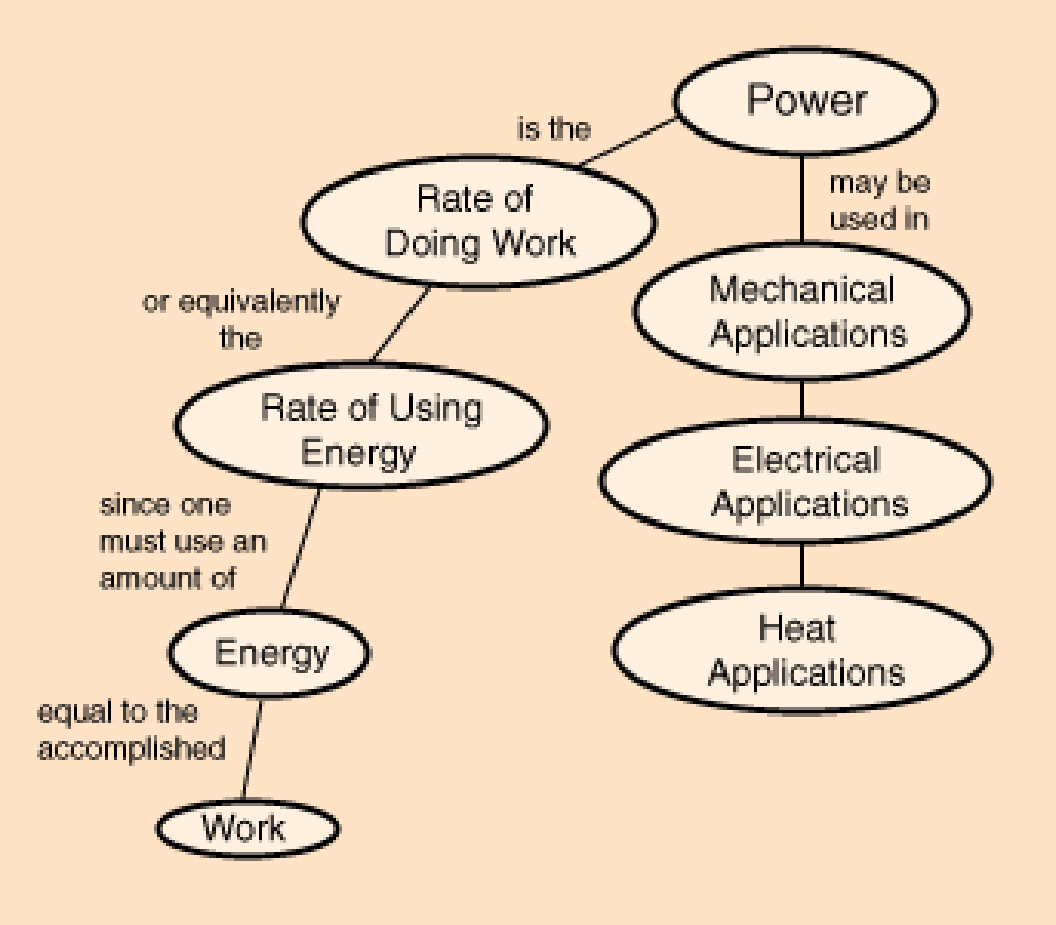

DC Electric Power

The electric power in watts associated with a complete electric circuit or a circuit component represents the rate at which energy is converted from the electrical energy of the moving charges to some other form, e.g., heat, mechanical energy, or energy stored in electric fields or magnetic fields. For a resistor in a D C Circuit the power is given by the product of applied voltage and the electric current:

AC Power

As in the case with DC power, the instantaneous electric power in an AC circuit is given by P = VI, but these quantities are continuously varying. Almost always the desired power in an AC circuit is the average power, which is given by

$$P_{avg} = VI\cos\phi$$

where ϕ is the phase angle between the current and the voltage and where V and I are understood to be the effective or rms values of the voltage and current. The term cos ϕ is called the "power factor" for the circuit.

Circuit Elements

- Active elements – capable of generating energy. Typical active elements include generators, batteries and operational amplifiers.
- Passive elements – resistors, capacitors and inductors.
- The most important active elements are voltage or current sources.
- 2 types of sources, ie;

1. Ideal independent source – is an active element that provides a specified voltage/current that is completely independent of other circuit elements.
2. Ideal dependent (or controlled) source – is an active element in which the source quantity is controlled by another voltage/current. 4 types of dependent sources, ie;

a) Voltage-controlled voltage source (VCVS)
b) Current-controlled voltage source (CCVS)
c) Voltage-controlled current source (VCCS)
d) Current-controlled current source (CCCS)

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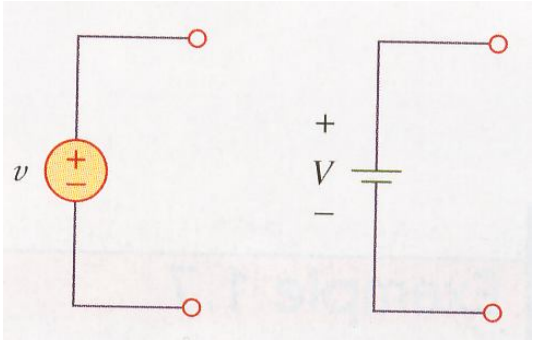
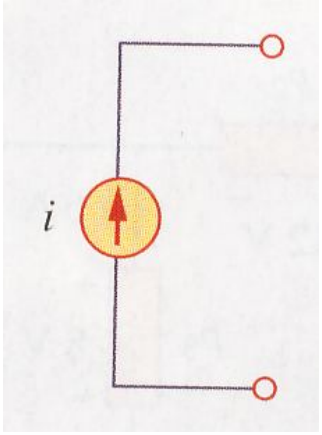
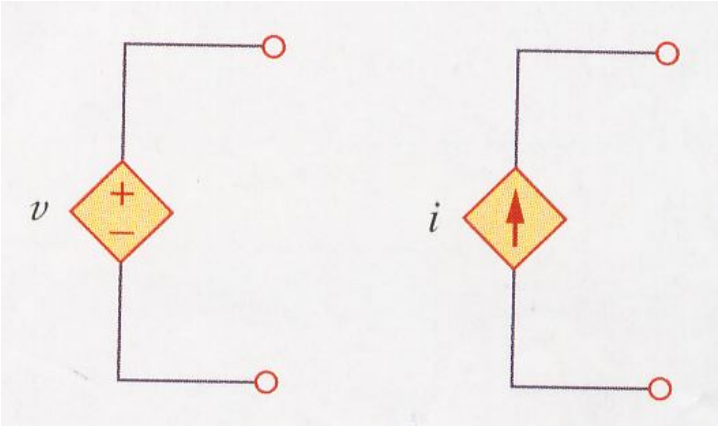
Independent voltage sources



Independent current source



Dependent voltage source



Dependent current source

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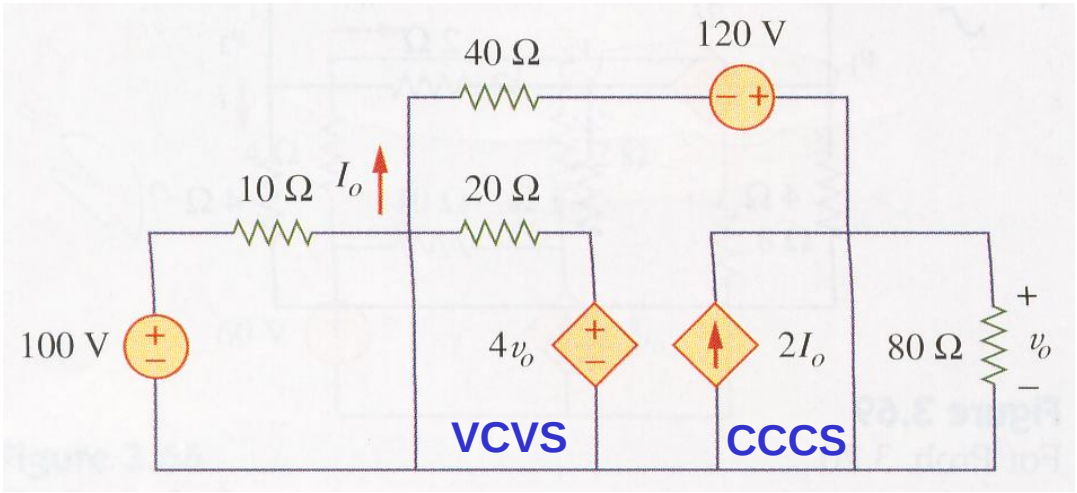

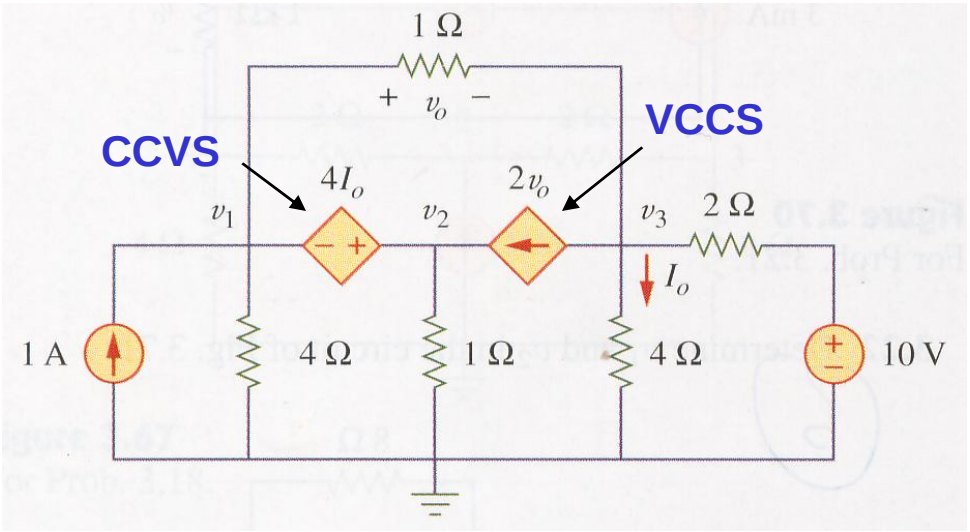

Summary

1. Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

⊕ proton charge $e = 1.602 \times 10^{-19}$ coulombs

⊖ electron charge $-e = -1.602 \times 10^{-19}$ coulombs

1 C of charge = 6.24×10^{18} electrons/protons

2. Electric current is the time rate of charge, measured in amperes (A).

$$i = \frac{dq}{dt}; \quad Q = \int_{t_o}^{t} i \cdot dt$$

3. Voltage is the energy required to move a unit charge through an element, measured in volts (V)

$$v_{ab} = \frac{dw}{dq}$$

Summary

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

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = v \cdot i$$

- Law of conservation of energy : The total power supplied to the circuit must balance the total power absorbed.
- Energy is the capacity to do work, measured in joules (J).
- Passive sign convention : Power assumes a +ve sign when the current enters the +ve polarity of the voltage across an element.

5. Voltage/current sources can be dependent or independent. A dependent source is one whose value depends on some other circuit variable.