Department of Biomedical Engineering

Electrical and Electronic Principles

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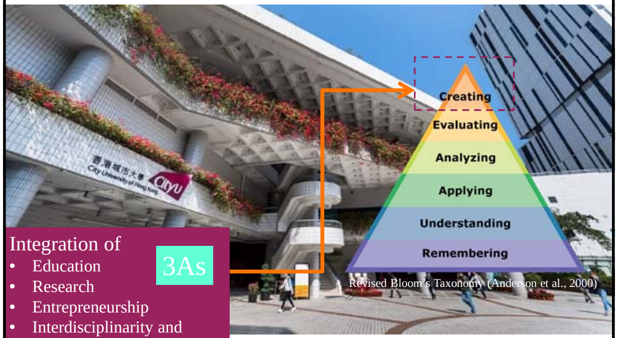
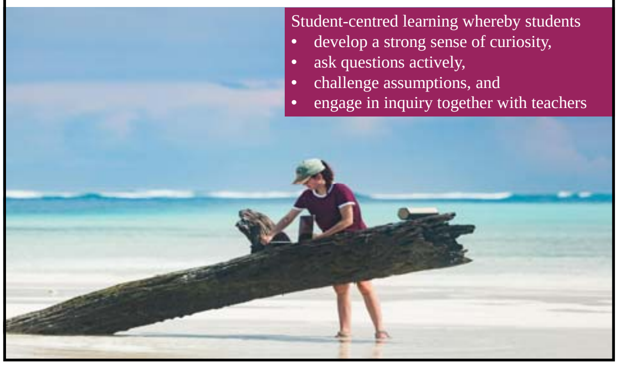
Discovery-Enriched Curriculum (DEC)



Integration of
- Education
- Research
- Entrepreneurship
- Interdisciplinarity and
- Action for the public good

Attitude

Develop an attitude of discovery/innovation/creativity



Student-centred learning whereby students
- develop a strong sense of curiosity,
- ask questions actively,
- challenge assumptions, and
- engage in inquiry together with teachers

Ability

Develop the ability/skill needed to discover/innovate/create

- Development of critical thinking skills to assess ideas
- Acquisition of research skills
- Synthesis of knowledge across disciplines
- Application of academic knowledge to real-life problems

Accomplishments

Demonstrate accomplishments of discovery/innovation/creativity

❖ Oscar award

Demonstration of evidence of original discovery/innovation/creativity through
- creative works/new artefacts
- effective solutions to real-life problems
- new processes

Learning Tips

- Pre-study lecture notes and relevant chapters of the textbook before each lecture

  Identify difficult parts and thus pay more attention to those parts during lecture

  Nurture self-learning capability
- Try to solve as many problems as possible with different approaches
- Try Practice Test from relevant chapters
- Read other reference books if possible

Chapter 1 Introduction

1. Reasons for studying electrical engineering
2. Definitions: current, voltage, and power
3. Circuit elements
4. Basic circuit laws

Overview of Electrical Engineering

Table 1.1 Current and Emerging Electronic/Electrical Applications in Automobiles and Trucks

Safety
- Antiskid brakes
- Inflatable restraints
- Collision warning and avoidance
- Blind-zone vehicle detection (especially for large trucks)
- Infrared night vision systems
- Heads-up displays
- Automatic accident notification
- Rear-view cameras

Communications and entertainment
- AM/FM radio
- Digital audio broadcasting
- CD/DVD player
- Cellular phone
- Computer/e-mail
- Satellite radio

Overview of Electrical Engineering

Table 1.1 Current and Emerging Electronic/Electrical Applications in Automobiles and Trucks

Convenience
- Electronic GPS navigation
- Personalized seat/mirror/radio settings
- Electronic door locks

Emissions, performance, and fuel economy
- Vehicle instrumentation
- Electronic ignition
- Tire inflation sensors
- Computerized performance evaluation and maintenance scheduling
- Adaptable suspension systems

Alternative propulsion systems
- Electric vehicles
- Advanced batteries
- Hybrid vehicles

Biomedical Equipment and Devices

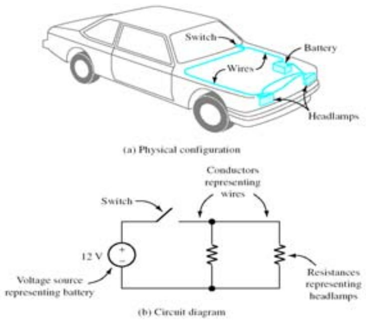
Subdivisions of Electrical Engineering

1. **Communication Systems**
2. **Computers**
3. **Control Systems**
4. **Electromagntics**
5. **Electronics**
6. **Photonics**
7. **Power Systems**
8. **Signal Processing**

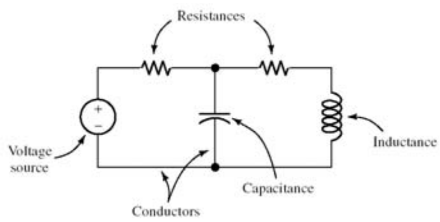
Why Study Electrical Engineering?

- *To pass the Fundamentals of Engineering (FE) Examination as a first step in becoming a Registered Professional Engineer*
- *To have a broad knowledge so that you can lead design projects in your own field*
- *To be able to operate and maintain electrical systems*
- *To communicate with electrical engineering consultants*

Example of Circuit



Electrical Circuit



Basic Concepts

- Charge
- Current
- Voltage
- Power
- Energy

Basic Concepts: Charges

- Charge is an electrical property of the atomic particles which matter consists of, measured in coulombs (C)
- 1C of charge requires 6.24×10^{18} electrons
- ***Law of conservation of charge***: charge cannot be created or destroyed, only transferred

Electric Current

- Electric current is the rate of change of charge, measured in amperes (A)

$$i(t) = \frac{dq(t)}{dt}$$

- 1 A= 1 C/s
- Two main types

  - **Direct current (DC):** Current remains constant

  - **Alternating current (AC):** Current varies sinusoidally with time

Examples: DC and AC Currents

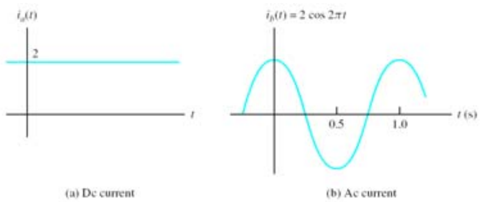


Figure 1.7 Examples of dc and ac currents versus time.

Notes on Current

- *Current is physically realized by movement of electrons*
- *By convention, current direction is defined as flow of positive charges*
- *Positive charge is not flowing physically*
- *Electrons have a negative charge and move in the opposite direction of current*

Safety Considerations

- Even small levels of current through the human body can cause serious, dangerous side effects
- Any current over 10 mA is considered dangerous
- Currents of 50 mA can cause severe shock
- Currents over 100 mA can be fatal
- Treat electricity with respect – not fear

Other Forms of AC Current

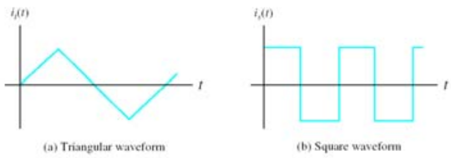


Figure 1.8 Ac currents can have various waveforms.

Reference Directions

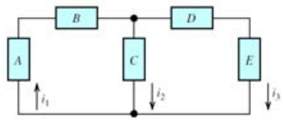


Figure 1.6 In analyzing circuits, we frequently start by assigning current variables i_1, i_2, i_3, and so forth.

Voltage

- Voltage is the **energy** transferred as a unit of charge flows through a circuit element, measured in volts (V), which are equivalent to joules per coulomb (J/C)

$$v = \frac{dw}{dq}$$

- Analogous to pressure in a hydraulic system
- A measure of the potential between two points
- Voltage pushes charges in one direction

Reference Polarities

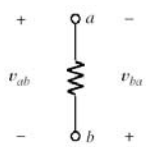


Figure 1.12 The voltage v_{ab} has a reference polarity that is positive at point a and negative at point b.

Power

- *Power:* time rate of expending or absorbing energy (watts)

$$p = \frac{dw}{dt}$$

- *By convention:*

  Circuit elements that *absorb* power have a *positive* value

  Circuit elements that *produce* power have a *negative* value

$$p(t) = \pm v(t)i(t)$$

Energy

- *Energy:* capacity to do work (joules)
- *Laws of conservation of energy:*

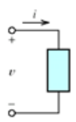
  The net power absorbed by a circuit is equal to 0, or

  The total energy produced in a circuit is equal to the total energy absorbed

$$w = \int_{t_1}^{t_2} p(t)dt \qquad p = \frac{dw}{dt}$$

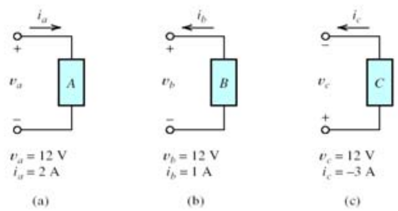
Passive Reference Configuration

- Passive sign convention: Current enters the positive terminal of an element



$$p = vi$$

Example 1.2: Find power



Circuit Laws

- **Kirchhoff's Current Law**
- **Kirchhoff's Voltage Law**
- **Ohm's Law**

Kirchhoff's current law

- A node is a point at which two or more circuit elements are joined together
- *Kirchhoff's Current Law (KCL): The net current entering a node is zero, or*
- *Alternatively, the sum of the currents entering a node equals the sum of the currents leaving a node*

$$\sum_{m=1}^{M} I_m = 0$$

- Based on law of conservation of charge

Series circuits

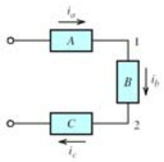
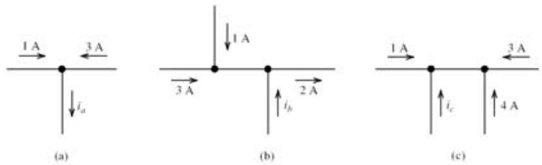
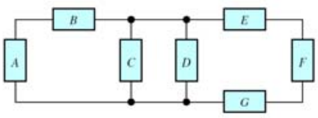


Figure 1.20 Elements A, B, and C are connected in series.

Exercise 1.7: Find currents



Exercise 1.8 – Identify elements in series



Kirchhoff's voltage law

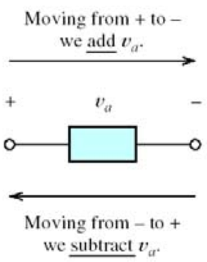
- A loop is a closed path starting at a node and proceeding through circuit elements, eventually returning to the starting node
- ***Kirchhoff's voltage law (KVL)***: *The algebraic sum of the voltages equals zero for any closed path (loop) in an electrical circuit*

$$\sum_{m=1}^{M} V_m = 0$$

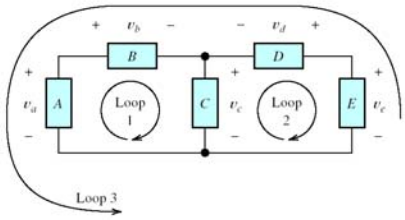
- Based on law of conservation of energy

Reference directions in applying KVL

Figure 1.24 In applying KVL to a loop, voltages are added or subtracted depending on their reference polarities relative to the direction of travel around the loop.



Example



Parallel circuits

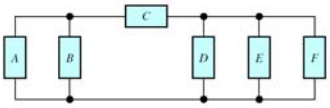
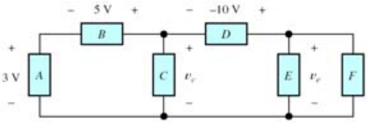


Figure 1.27 In this circuit, elements *A* and *B* are in parallel. Elements *D*, *E*, and *F* form another parallel combination.

Exercise 1.9 and 1.10



$v_c = ?\quad v_e = ?$

Independent voltage sources

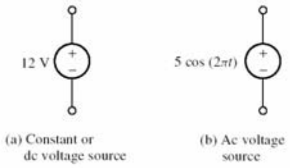


Figure 1.32 Independent voltage sources

Dependent voltage sources

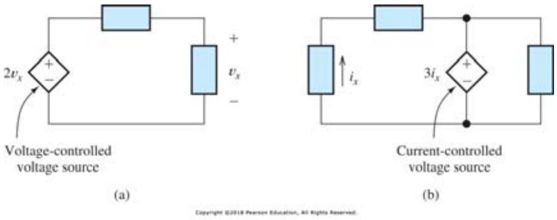


Figure 1.34 Dependent voltage sources (also known as controlled voltage sources) are represented by diamond-shaped symbols. The voltage across a controlled voltage source depends on a current or voltage that appears elsewhere in the circuit.

Independent current sources

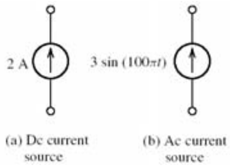


Figure 1.35 Independent current sources

Dependent current sources

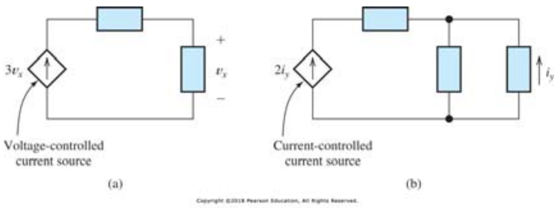


Figure 1.36 Dependent voltage sources. The current through a dependent current source depends on a current or voltage that appears elsewhere in the circuit.

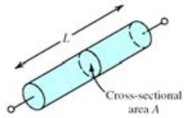
Resistors and Ohm's Law

$$v = iR$$

$$v_{ab} = i_{ab}R$$

- Conductors (e.g. wires) have very low resistance that can be usually neglected
- Insulators (e.g. air) have very large resistance

Resistance Related to Physical Parameters



$$R = \frac{\rho L}{A}$$

Resistance of human body: ?

Other equations derived from Ohm's law

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

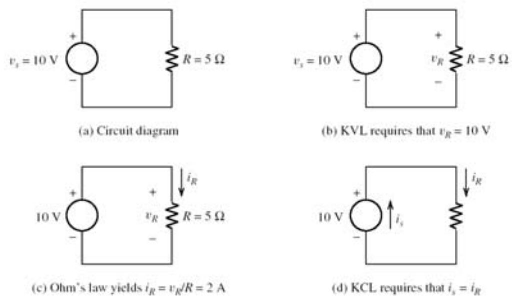
$$R = \frac{v}{i}$$

$$p = vi$$

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

$$p = i^2R$$

Example: Simple circuit



Example: Find current and power

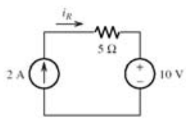
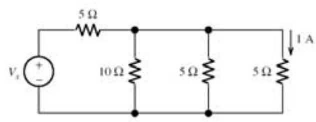


Fig.P1.62

Example: Find voltage



Animation for circuits:
https://www.youtube.com/watch?v=m4jzgqZu-4s