الجامعة السورية الخاصة
SYRIAN PRIVATE UNIVERSITY

كـلـيـــة هندسة الحاسوب والمعلوماتية
Computer and Informatics Engineering Faculty

Electric Circuits I

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DC Circuits Course Outline

1. Basic Concepts
2. Basic Laws
3. Methods of Analysis
4. Circuit Theorems
5. Operational Amplifiers
6. Capacitors and Inductors
7. First-Order Circuits
8. Second-Order Circuits
9. Magnetic Circuits

Assessment

Coursework:	**50%**	
Activity	10%	
2 Tests	20%	(10% each)
Practice	20%	
Examination:	**50%**	

To pass the course, at least 25% of coursework AND examination marks are required.

Book List

Text books

1. **C. K. Alexander and M.N.O. Sadiku. Fundamentals of Electric Circuits. 6-th Ed., McGraw-Hill, 2017.**
2. **Robert L. Boylested, Introductory Circuit Analysis, (7/9/10) 11-th Ed. Prentice Hall, 2007.**

References

1. James W. Nilsson. Electric circuits, 9-th Ed. Prentice Hall, 2011.
2. Allan H. Robbins and Wilhelm C. Miller. Circuit Analysis: Theory and Practice, Fifth Edition. Cengage Learning 2013.

Chapter 1
Basic Concepts

1.1 System of Units

Six basic units

Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	Kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd

The derived units commonly used in electric circuit theory

Quantity	Unit	Symbol
electric charge	coulomb	C
electric potential	volt	V
resistance	ohm	Ω
conductance	siemens	S
inductance	henry	H
capacitance	farad	F
frequency	hertz	Hz
force	newton	N
energy, work	joule	J
power	watt	W
magnetic flux	weber	Wb
magnetic flux density	tesla	T

600,000,000 mm   600,000 m   600 km

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

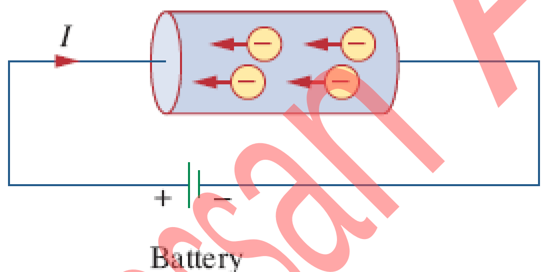
Decimal multiples and submultiples of SI units

1.2 Electric Charges

- Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).
- The charge e on one electron is negative and equal in magnitude to 1.602×10^{-19} C which is called as ***electronic charge***.
- In 1 C of charge, there are $1/(1.602\times10^{-19}) = 6.24\times10^{18}$ electrons.
- The charges that occur in nature are integral multiples of the electronic charge $e = -1.602\times10^{-19}$ C .

1.3 Current

- **Conducting process**: positive charges (+) move in one direction while negative charges (–) move in the opposite direction. This *motion* of charges creates electric current.
- The **current flow** is the *movement* of *positive charges*.

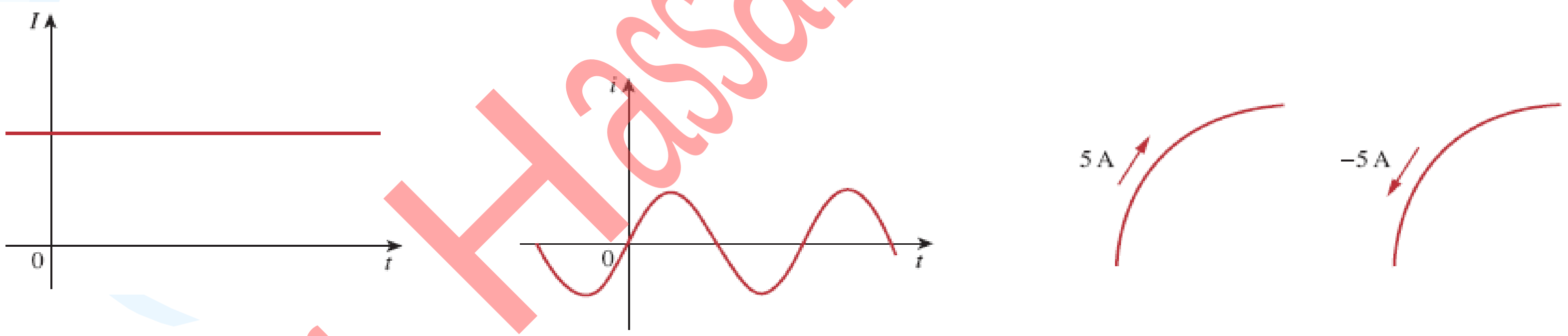


- **Electric current** is the time rate of change of charge, measured in amperes (A).
- Electric current $i = dq/dt$. The unit of ampere can be derived as 1 A = 1C/s.
- The **charge** transferred between time t_0 and t is obtained by

$$Q = \int_{t_0}^{t} i\,dt$$

1.3.1 Types of Current

- A **direct current (dc)** is a current that remains constant with time, Fig. (a).
- An **alternating current (ac)** is a current that varies sinusoidally with time. (reverse direction), Fig. (b).
- A current may be represented positively or negatively, Fig. (c).



(a) (b) (c)

Example 1.1

How much charge is represented by 4,600 electrons?

Solution:

Each electron has -1.602×10^{-19} C . Hence 4,600 electrons will have

$$-1.602\times10^{-19}\ C/\text{electron}\times4600\,\text{electrons} = -7.369\times10^{-16}\ C$$

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Example 1.2

The total charge entering a terminal is given by q = 5t sin(4πt) mC. Calculate the current at t = 0.5 s.

Solution:

$$i=\frac{dq}{dt}=\frac{d}{dt}\big(5t\sin(4\pi t)\big)mC/s=\big(5\sin(4\pi t)+20\pi t\cos(4\pi t)\big)\text{mA}$$

$$t=0.5s\Rightarrow i=5\sin(2\pi)+10\pi\cos(2\pi)=0+10\pi=31.42\,\text{mA}$$

Example 1.3

Determine the total charge entering a terminal between t = 1 s and t = 2 s if the current passing the terminal is $i = (3t^2 - t)$ A.

Solution:

$$Q = \int_{t=1}^{2} i dt = \int_{t=1}^{2} (3t^2 - t) dt = \left(t^3 - \frac{t^2}{2} \right) \Big|_1^2 = (8-2) - (1 - \frac{1}{2}) = 5.5\text{C}$$

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Example 1.4

A conductor has a constant current of 5 A. How many electrons pass a fixed point on the conductor in one minute?

Solution:

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

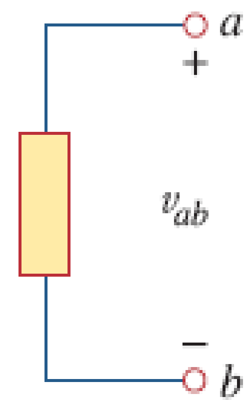
5 A = (5 C/s)(60 s/min) = 300 C/min

Total no. of electronics pass in 1 min is given

$$\frac{300 \text{ C/min}}{1.602 x 10^{-19} \text{ C/electron}} = 1.87 x 10^{21} \text{ electrons/min}$$

1.4 Voltage

- **Voltage** (or potential difference) is the energy required to move a unit charge from a reference point a (−) to another point b (+), measured in volts (V).

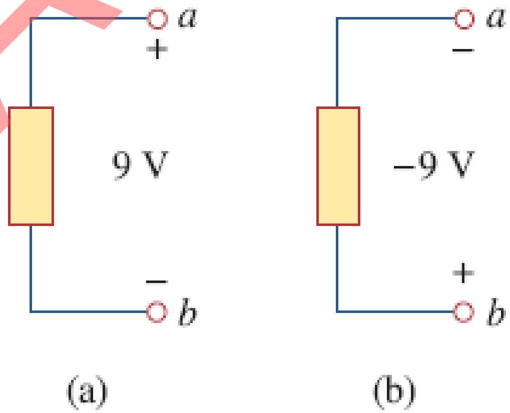


- Mathematically, $$v_{ab} = \frac{dw}{dq}$$ (Volt)

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

- The plus (+) and minus (–) signs are used to define reference voltage polarity.

- **Electric voltage**, v_{ab}, is always across the circuit element or between two points in a circuit.
  - $v_{ab} > 0$ means the potential of *a* is higher than potential of *b*.
  - $v_{ab} < 0$ means the potential of *a* is lower than potential of *b*.



(a) (b)

For example,

- In Fig.(a), point *a* is +9V above point *b*;
- In Fig.(b), point *b* is –9V above point *a*.
- We may say that in Fig.(a), there is a 9-V *voltage drop* from *a* to *b* or equivalently a 9-V *voltage rise* from *b* to *a*.

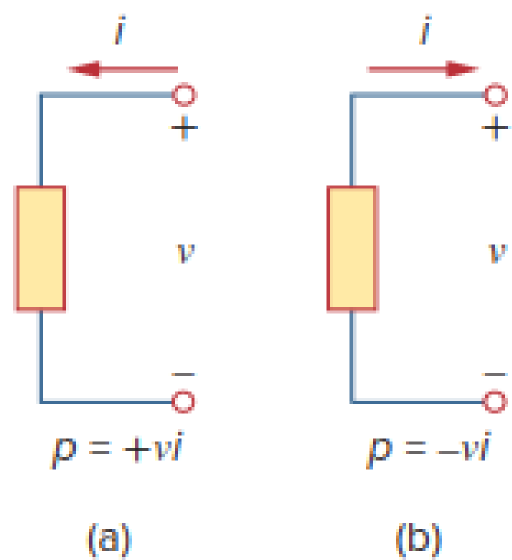
1.5 Power and Energy

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

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

- The power p is a time-varying quantity and is called the instantaneous power.
- **Passive sign convention**:
  - Fig. (*a*): the element is absorbing power.
  - Fig. (*b*): the element is supplying power.

$+$Power absorbed $= -$Power supplied



- The **law of conservation of energy**:

$$\sum p = 0 \quad \text{at any time}$$

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

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

- The **electric power** utility companies measure energy in watt-hours (Wh), where

$$1 \text{ Wh} = 3600 \text{ J}$$

Example 1.5

An energy source forces a constant current of 2 A for 10 s to flow through a light bulb. If 2.3 kJ is given off in the form of light and heat energy, calculate the voltage drop across the bulb.

Solution:

- The total charge is $\Delta q = i\Delta t = 2\times 10 = 20\ \text{C}$

- The voltage drop is $v = \dfrac{\Delta w}{\Delta q} = \dfrac{2.3\times 10^3}{20} = 115\ \text{V}$

Example 1.6

Find the power delivered to an element at t = 3 ms if the current entering its positive terminal is $i = 5\cos(60\pi t)$ A, and the voltage is:

$$a)\quad v = 3i; \quad b)\quad v = 3\,di/dt$$

Solution:

a) The voltage is v = 3i = 15 cos 60πt; hence, the power is

$$p = vi = 75\cos^2(60\pi t)\ \text{W}$$

At t=3 ➔ $$p = 75\cos^2(60\pi\times 3\times 10^{-3}) = 53.48\ \text{W}$$

b) We find the voltage and the power as

$$v = 3\frac{di}{dt} = 3(-60\pi)5\sin 60\pi t = -900\pi\sin 60\pi t\ \text{V}$$

$$p = vi = -4500\pi\sin 60\pi t\cos 60\pi t\ W$$

- At t=3 ➔

$$p = -4500\pi\sin 0.18\pi\cos 0.18\pi\ W$$

$$= -14137.167\sin 32.4^\circ\cos 32.4^\circ = -6.396\ \text{kW}$$

Example 1.7

How much energy does a 100-W electric bulb consume in two hours?

Solution:

$$w = pt = 100(\text{W}) \times 2(\text{h}) \times 60(\text{min/ h}) \times 60(\text{s/ min})$$

$$720000\ \text{J} = 720\ \text{kJ}$$

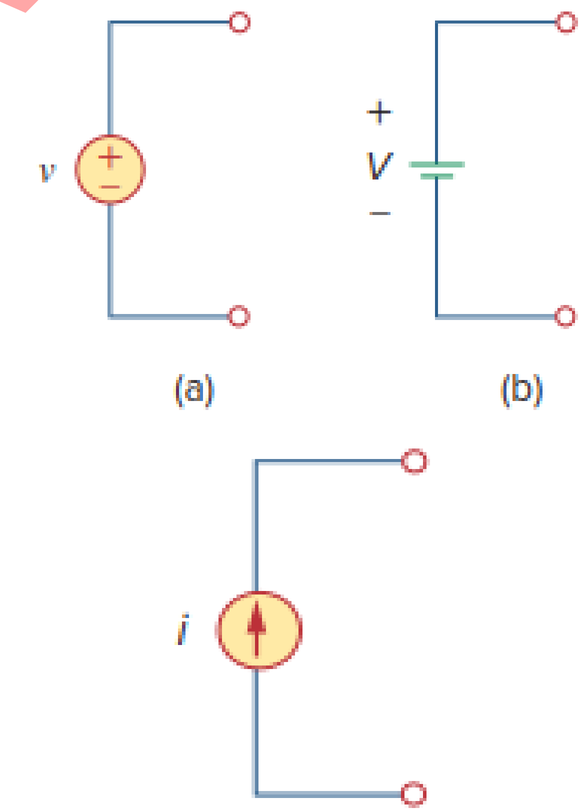
This is the same as $w = pt = 100\,\text{W} \times 2\,\text{h} = 200\,\text{Wh}$

1.6 Circuit Elements

- There are two types of elements:
  - An **active** element is capable of generating energy.
  - A **passive** is not capable of generating energy.
- Examples of passive elements are resistors, capacitors, and inductors.
- Examples of active elements include generators, batteries, and operational amplifiers.
- The most important active elements are **voltage or current sources** that generally deliver power to the circuit connected to them.

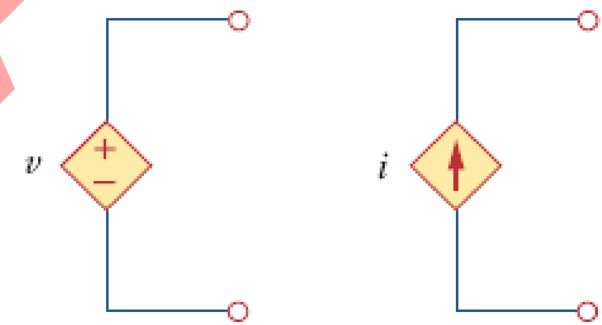
1.6.1 Kinds of sources

1. **Ideal independent source** is an active element that provides a specified voltage or current that is completely independent of other circuit elements.
   - Physical sources such as batteries and generators.
   - Symbols for independent voltage sources:
     - Fig.(a), used for constant or time-varying voltage,
     - Fig.(b), used for constant voltage (dc).
   - Symbol for independent current source, Fig. (c), where the arrow indicates the direction of current *i*.



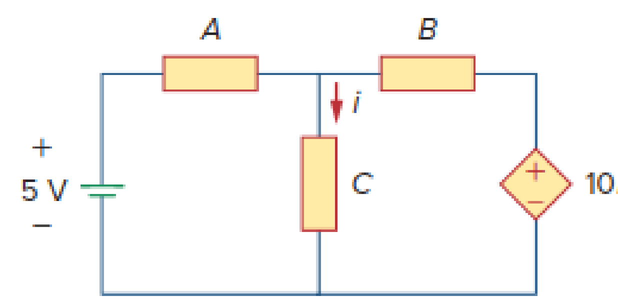
2. **Ideal dependent (or controlled) source** is an active element in which the source quantity is controlled by another voltage or current.

- Dependent sources are usually designated by **diamond-shaped symbols**:
  - Fig.(a) dependent voltage source,
  - Fig. (b) dependent curent source.



(a) (b)

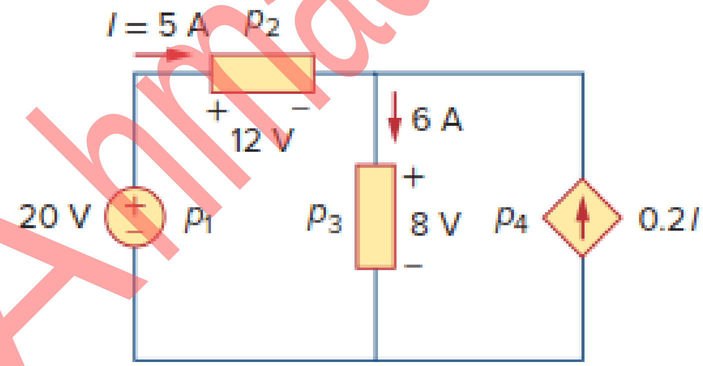
- There are four possible types of dependent sources
  1. A voltage-controlled voltage source (VCVS).
  2. A current-controlled voltage source (CCVS).
  3. A voltage-controlled current source (VCCS).
  4. A current-controlled current source (CCCS).



Example 1.8

Calculate the power supplied or absorbed by each element in Fig.

Solution



We apply the sign convention for power.

For p_1, the 5-A current is out of the positive terminal (or into the negative terminal);

hence, $$p_1 = 20(-5) = -100\,\text{W} \ \ (\text{Supplied power})$$

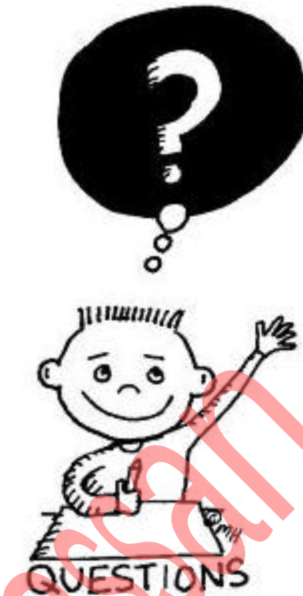
For p_2 and p_3, the current flows into the positive terminal of the element in each case.

$$p_2 = 12(5) = 60\,\text{W} \ \ (\text{Absorbed power}); \quad p_3 = 8(6) = 48\,\text{W} \ \ (\text{Absorbed power})$$

For p_4, we should note that the voltage is 8 V (positive at the top), the same as the voltage for p_3 since both the passive element and the dependent source are connected to the same terminals. (Remember that v oltage is always measured across an element in a circuit.) Since the current flows out of the positive terminal,

$$p_4 = 8(-0.2I) = 8(-0.2 \times 5) = -8\,\text{W} \ \ (\text{Supplied power})$$

$$\sum p_i = p_1 + p_2 + p_3 + p_4 = -100 + 60 + 48 - 8 = 0$$



The end of chapter 1