اسس كهرباء

قسم هندسة تقنيات التبريد والتكييف

المرحلة الاولى

المحاضرة الاولى

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1 Basic Concepts & Basic Laws

1.1 Basic Concepts

1.1.1 System of Units

The basic SI 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 SI prefixes

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Examples

$10\ MHz \Rightarrow 10 \times 10^{6}\ Hz$

$2\ mA = 2 \times 10^{-3} = 0.002\ A$

$5\ \mu s = 5 \times 10^{-6}\ s$

1.1.4 Charge and Current

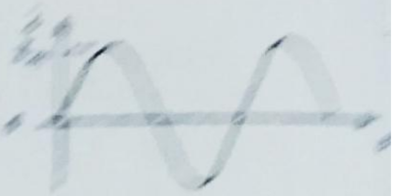
The electric charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C). The charge of an electron is -1.602×10^{-19} C.

Electric Current: is the time rate of change of charge, measured in amperes (A). The current (i) is related mathematically as

$$i = \frac{dq}{dt}$$

D.C current

$$\therefore q = \int_{t_1}^{t_2} i \, dt$$



A.C current

* A direct current (DC) is current that remains constant with time. The symbol (I) is mostly used to represent such a constant current.

* An alternating current (AC) is a current that varies sinusoidally with time. A time varying current is represented by the symbol (i).

Example: 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:

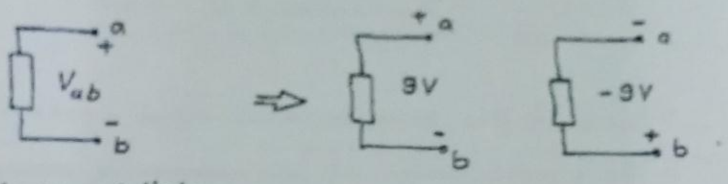
$$q = \int_{t_1}^{t_2} i \, dt$$

$$= \int_1^2 (3t^2 - t) \, dt = \left(t^3 - \frac{t^2}{2}\right)\Big|_1^2$$

$$= (8 - 2) - \left(1 - \frac{1}{2}\right) = \underline{5.5 \text{ C}}$$

1.1.3 Voltage

: The voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).



Polarity of Voltage V_{ab}

* For the voltage V_{ab} ⇒ This means that the potential of point a is higher then that of point b

$$\boxed{V_{ab} = V_a - V_b}$$

1.1.4 Power and Energy :

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

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

where p is the power in watts (W), w is the energy in joules (J), and t is the time in seconds (s)

We have; $p = \dfrac{dw}{dt} \quad \Rightarrow \quad p = \dfrac{dw}{dt} \cdot \dfrac{dq}{dq}$

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

$$\boxed{\therefore \; p = vi}$$

* The energy absorbed or supplied by an element

from time t_0 to time t is :

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

Energy is the capacity to do work, measured in joules (J)

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

$$1\ Wh = 3,600\ J$$

Example: How much energy does a 100 W electric bulb consume in 2 hours ?

Solution:

$$w = pt = 100 \times 2 = 200\ Wh$$

or

$$w = pt = (100\ W)(2 \times 60 \times 60) = 720000\ J = 720\ kJ$$

which is the same result (if you convert from joules to watts or vice-versa).

1.1.5 Circuit Elements

: An electric circuit is an interconnection of electrical elements.

* Circuit analysis is the process of determining voltages across (or the currents through) the elements of the circuit.

Circuit Elements
- Passive Elements (can not generate energy) ⇒ Resistors, capacitors and inductors
- Active Elements (can generate energy) ⇒ Generators, batteries, operational amplifiers

* The most important active elements are voltage or current sources that generally deliver power to the circuit connected to them. [EG1]

Voltage (or current) sources < Independent sources / Dependent sources

* An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit variables.

* Dependent sources (or controlled sources) are active elements in which the source quantity is controlled by another voltage or current. (It will be discussed later).

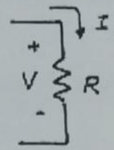
1.2 Basic Laws :

1.2.1 Ohm's Law (1826) :

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

$$V \propto I$$

$$\Rightarrow \boxed{V = IR}$$ قانون أوم

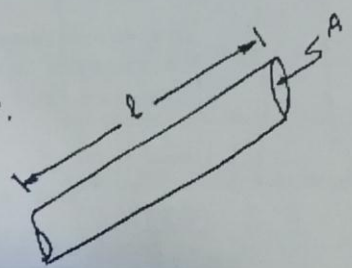


where R is the resistance. The resistance R denotes the ability of an element to resist the flow of electric current, it is measured in ohms (Ω).

For any material, the resistance R depends on its physical dimensions as follows :

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

where ρ is the resistivity of the material.



⇒ Good conductors have low resistivities (such copper, aluminum, etc..)

⇒ Insulators have high resistivities (such as mica, paper, etc...)

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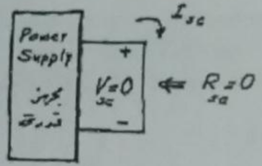
Resistivities of Common Materials

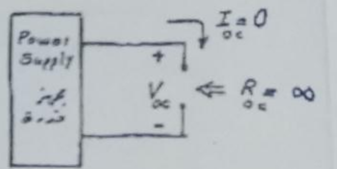
Material	Resistivity ($\Omega . m$)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	"
Aluminum	2.80×10^{-8}	"
Gold	2.45×10^{-8}	"
Carbon	4.00×10^{-5}	Semiconductor
Germanium	47.0×10^{-2}	"
Silicon	6.40×10^{-2}	"
Paper	10^{10}	Insulator
Mica	5×10^{11}	"
Glass	10^{12}	"
Teflon	3×10^{12}	"

* The resistance of a short circuit element is approaching zero

* The resistance of an open circuit is approaching infinity.



Short circuit with $R_{sc}=0$
$V_{sc}=0$



Open circuit with $R_{oc}=\infty$
$I_{oc}=0$

* Conductance (G)

A useful quantity in circuit analysis is the reciprocal of resistance (R), is called the conductance (G);

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

The conductance can be explained as the ability of an element to conduct electric current, it is measured in mhos (℧) or in siemens (S).

$$\therefore \ i = Gv$$

and:

$$p = vi = i^2 R = \frac{v^2}{R} \quad \text{watts (W)}$$

OR

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