Phys. 103

Lecture 1

Electric Circuits and Alternating Current

Definitions and Circuit Parameters

BY

Dr. Mahdy M. Elmahdy

Associate Professor at Physics Department, Mansoura University, Mansoura, Egypt

First year students for Mathematics and Statistics

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الخريطة الزمنية للدراسة والامتحانات
خلال العام الجامعي 2016-2017 م

الفصل الدراسى الأول	الفصل الدراسى الثانى
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بداية امتحانات الفصل الدراسى الأول من السبت٧/١/٢٠١٧ حتى الخميس ٢٦/١/٢٠١٧م ولمدة ٣ اسابيع	بداية امتحانات الفصل الدراسى الثانى من السبت 27/05/2017 حتى الخميس 22/06/2017 ولمدة ٤ اسابيع
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Course Materials

- **Course:** Electric Circuits and Alternating Current
- **Grade:** First year students for Mathematics and Statistics
- **Class room:** Class room 24
- **Time:** 11 AM – 2 PM
- **Day:** Sunday
- **Required textbooks:**
  Electric Circuits and Alternating Current Book, Physics Department, Faculty of Science, Mansoura University, 2017.

Recommended Literatures

- Mahmood Nahvi, Joseph Edminister-Schaum's Outline of Electric Circuits-McGraw-Hill Education (2013)
- Mahmood Nahvi, Joseph Edminister-Schaum's Outline of Theory and Problems of Electric Circuits-McGraw-Hill (2002)

Course Information

- **Course has several components:**
  - **Lecture:** **(me talking, demos and Active learning).**
  - **Homework Sets:** **problems from the book.**
  - **Tests:** **one midterm and a final.**
    - **Questions on tests will look like those we do in the rest of the class; in homework and during lectures.**
    - **No surprises**
  - **Office hours:** **to answer additional questions**
  - **Labs:** **(group exploration of physical phenomena).**

How to do well in the course ?

- **Final grade will be made of :**
  - **Midterm** **10%**
  - **Final Exam** **60%**
  - **Oral exam** **10%**
  - **Labs** **20%**

Chapter 1

Contents

Definitions and Circuit Parameters

Electrical Quantities and SI Units

Table 1-1

Quantity	Symbol	SI Unit	Abbreviation
length	L, l	meter	m
mass	M, m	kilogram	kg
time	T, t	second	s
current	I, i	ampere	A

Table 1-2

Quantity	Symbol	SI Unit	Abbreviation
electric charge	Q, q	coulomb	C
electric potential	V, v	volt	V
resistance	R	ohm	Ω
conductance	G	siemens	S
inductance	L	henry	H
capacitance	C	farad	F
frequency	f	hertz	Hz
force	F, f	newton	N
energy, work	W, w	joule	J
power	P, p	watt	W
magnetic flux	ϕ	weber	Wb
magnetic flux density	$\mathbf{B}$	tesla	T

Table 1-3

Prefix	Factor	Symbol
pico	10^{-12}	p
nano	10^{-9}	n
micro	10^{-6}	μ
milli	10^{-3}	m
centi	10^{-2}	c
deci	10^{-1}	d
kilo	10^{3}	k
mega	10^{6}	M
giga	10^{9}	G
tera	10^{12}	T

Force, Work, and Power

Force (Newton) = mass (kilogram) x acceleration (m/sec^2)

The *Newton* (N) is defined as the unbalanced force which will produce an acceleration of 1m/sec^2 in a mass of 1 kg. Thus, 1N = 1 Kg . m/s^2

- **Work results when a force acts over a distance.**

Work = Force x distance

1 joule = newton x meter

1 J = 1N m

- **Work and energy have the same units.**
- **Power is the rate at which work is done or the rate at which energy is changed from one form to another.**
- **The unit of power, the watt (W), is one joule per second (J/s).**

1 newton . Meter = 1 joule

1 joule/sec = 1 watt

Coulomb's law

➢ **When the surrounding medium is vacuum:**

The force *F* between two point charges *q* and *q'* varies directly as the magnitude of each charge and inversely as the square of the distance *r* between them

$$F = k\frac{qq'}{r^2}$$

$$k = \frac{1}{4\pi\varepsilon_0} = 9\times10^9\,\frac{N.m^2}{coul^2}$$

$$\varepsilon_0 = 8.85\times10^{-12}\ \mathrm{m^{-3}kg^{-1}S^4A^2}$$

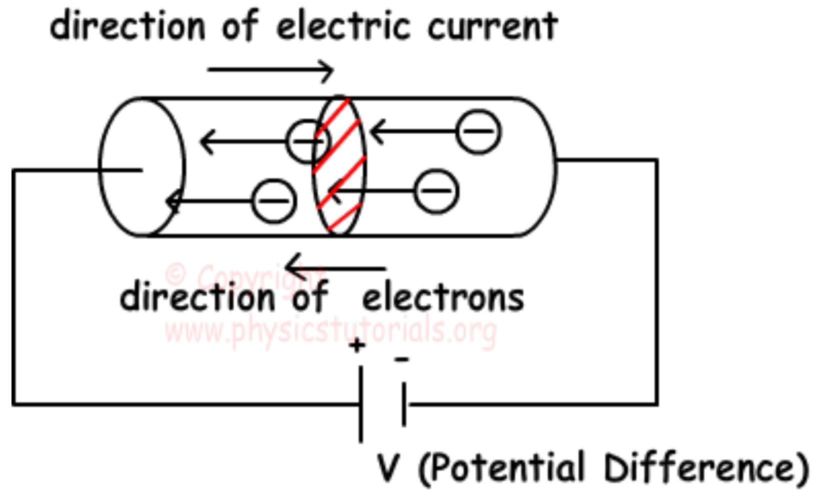
ε_0: permittivity of free space
k: is a (dimensional) proportionality constant which depends on the units for charge, distance and force.

$$F = \frac{1}{4\pi\varepsilon_0}\frac{qq'}{r^2}$$

Potential Difference (v)

- The potential difference (v) between two points is measured by the work required to transfer unit charge from one point to the other
- Volt: is the potential difference (p.d) between two points when 1 joule of work is required to transfer 1 coulomb of charge from one point to the other: 1 volt=1joule/coulomb
- If two points of an external circuit have a potential difference v, then a charge q in passing between the two circuit points does an work qv as it moves from the higher to the lower potential point.

Current (I)



- A material containing free electrons capable of moving from one atom to the next is a conductor
- The application of a potential difference causes these electrons to move
- An electric current exist in a conductor whenever charge q is being transferred from one point to another in that conductor
- If charge transferred at the uniform rate of 1 coulomb/sec, then the constant current existing in the conductor is 1 ampere
- Positive current direction is, by convection, opposite to the direction in which the electrons move.

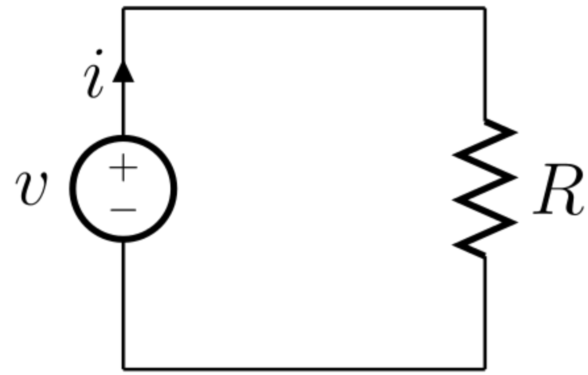
$$I\,(Amper) = \frac{dq\,(coulomb)}{dt\,(sec)}$$

$$1\,Amper = \frac{1\,coulomb}{sec}$$

Power (P)

- Electrical power ***P*** is the product of impressed voltage ***v*** and resulting current ***i***

$$P\ (watts) = \mathbf{v}\ (volt) \times i\ (amperes)$$



- Positive current, by definition, is in the direction of the arrow on the voltage source
- When P has a positive value the source transfers energy to the circuit.
- If power is a periodic function of time t with period T, then the

Average power $P = \frac{1}{T}\int_0^T p\,dT$

Energy (W)

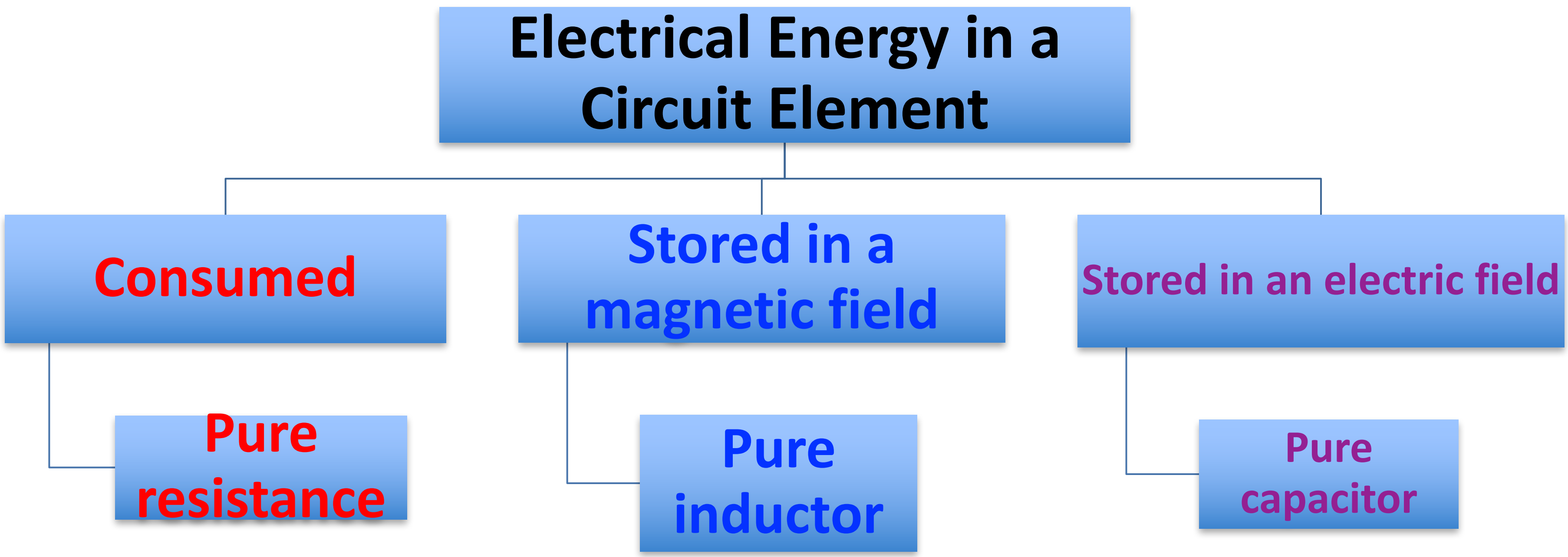
- Since power is the time rate of energy transfer,

$$P = \frac{dW}{dt}$$

$$\therefore W = \int_{t1}^{t2} p dT$$

Where W is the energy transferred during the time interval

Resistor, Inductor, Capacitor



- ✓ A practical circuit device exhibit more than one of the above and perhaps all three at the same time
- ✓ A coil may be designed to have a high inductance, but the wire with which it is wound has some resistance, hence the coil has both properties

Resistance R

- The potential difference v(t) across the terminals of a pure resistor is directly proportional to the current i(t) in it. The constant of proportionality is called the resistance of the resistor and is expressed in volts/amper or ohms

$$\mathbf{v}(t) \propto i(t)$$

$$\mathbf{v}(t) = R\, i(t)$$

$$\therefore i(\mathbf{t}) = \frac{\mathbf{v}(t)}{R}$$

- In DC circuits, v(t) and i(t) are constant with respect to time
- In AC circuits, v(t) and i(t) may be sine or cosine functions
- Lower case letters (v,i,p) indicate general functions of time
- Capital letters (V,I,P) denotes constants quantities
- Peak or maximum values carry a subscript (V_m, I_m, P_m)

Inductance L

- When the current in a circuit is changing, the magnetic flux linking the same circuit changes. This change in flux causes an emf v to be induced in the circuit
- The induced emf v is proportional to the time rate of change of current if the permeability is constant. The constant of proportionality is called the self-inductance or inductance of the circuit

$$\mathbf{v}(t) \propto \frac{\mathbf{d}i}{dt}$$

$$\mathbf{v}(t) = L\frac{\mathbf{d}i}{dt}$$

$$\therefore i(\mathbf{t}) = \frac{1}{L}\int \mathbf{v}dt$$

- When v is volt, d*i*/dt is amperes/sec, L is in volt.sec/ampere or Henries.
- The self-inductance of a circuit is 1 henry (1 h) if an emf of 1 volt is induced in it when the current changes at the rate of 1 ampere

Capacitance C

- The potential difference v between the terminals of a capacitor is proportional to the charge q on it.
- The constant of proportionality C is called the capacitance of the capacitor

$$\mathbf{q}(t) \propto \mathbf{v}(t)$$

$$\mathbf{q}(t) = C\,\mathbf{v}(t)$$

$$\therefore\ i(\mathrm{t}) = \frac{dq}{dt} = C\frac{d\mathrm{v}}{dt}$$

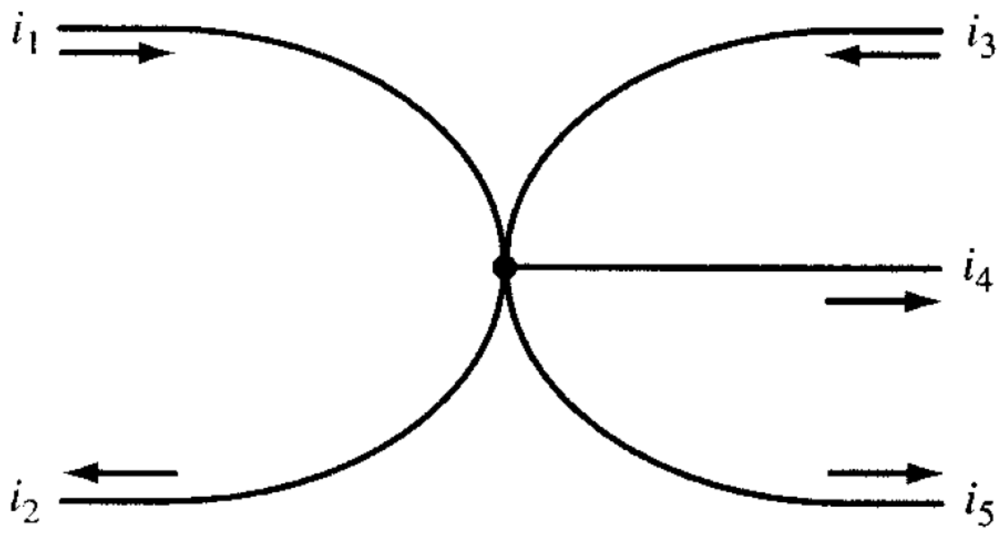
$$\therefore\ \mathrm{v}(\mathrm{t}) = \frac{1}{C}\int i(\mathrm{t})\,dt$$

- When q is in coulombs and v is in volts, C is in coulombs/volt or Farad
- A capacitor has capacitance 1 Farad (1 F) if it requires 1 coulomb of charge per volt of potential difference between its conductors.
- Convenient submultiples of the Farafd are

1μF = 1 microfarafd = 10^{-6} F and 1$\mu\mu$ Farad = 10^{-12} F

Kirchhoff's Laws

- **KIRCHHOFF'S CURRENT LAW: The The sum of the currents entering a junction is equal to the sum of the currents leaving the junction. If the currents toward a junction are considered positive and those away from the junction negative, then this law states that the algebraic sum of all the currents meeting at a common junction is zero.**



$$\sum currents\ entering = \sum current\ leaving$$

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

$$\text{Or } i_1 + i_3 + i_2 + i_4 + i_5 = 0$$

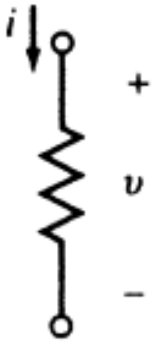
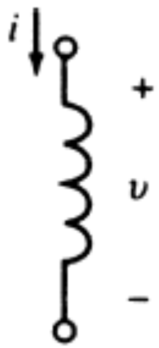
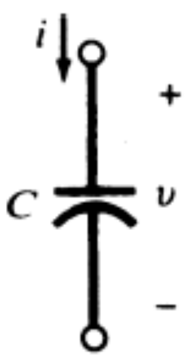
Kirchhoff's Laws

- KIRCHHOFF'S POTENTIAL LAW: The sum of the rises of potential around any closed circuit equals the sum of the drops of potential in that circuit. In other words, the algebraic sum of the potential difference around a closed circuit is zero.
- With more than one source when the directions do not agree, the voltage of the source is taken as positive if it is in the direction of the assumed current

$$\sum potential\,rises = \sum potential\,drops$$

$$\mathbf{v}_A - \mathbf{v}_B = Ri + L\left(\frac{di}{dt}\right)$$

Or $\mathbf{v}_A - \mathbf{v}_B - Ri - L\left(\frac{di}{dt}\right) = 0$

Circuit element	Units	Voltage	Current	Power
 **Resistance**	ohms (Ω)	$\upsilon = Ri$ **(Ohm's law)**	$i = \dfrac{\upsilon}{R}$	$p = \upsilon i = i^2 R$
 **Inductance**	henries (H)	$\upsilon = L\dfrac{di}{dt}$	$i = \dfrac{1}{L}\displaystyle\int \upsilon\, dt + k_1$	$p = \upsilon i = Li\dfrac{di}{dt}$
 **Capacitance**	farads (F)	$\upsilon = \dfrac{1}{C}\displaystyle\int i\, dt + k_2$	$i = C\dfrac{d\upsilon}{dt}$	$p = \upsilon i = C\upsilon\dfrac{d\upsilon}{dt}$