Lec. 1

Fundamentals of Electrical Engineering

أساسيات الهندسة الكهربائية :

Introductory Circuit Analysis, 5th Edition
By: Boylestad , 10th Edition

Systems of Units:

In the past, the systems of units most commonly used were the English and metric, as indicated in the table below.

English	Metric		SI
	MKS	CGS	
Length: Yard (yd)	Meter (m)	Centimeter (cm)	Meter (m)
Mass: Slug	Kilogram (kg)	Gram (g)	Kilogram (kg)

« See Table 1.1 Page 10 »

From this table, we can see that:

- The English system is based on a single standard,
- The metric system is subdivided into:
  a) MKS (Meters, Kilograms, Seconds).
  b) CGS (Centimeters, Grams, Seconds).

In order to avoid the confusion, a standard set of units was adopted, which was called:
- SI (International System of Units).
Therefore, it is important that they be used whenever applicable to insure universal understanding.

Scientific Notation:

In the study of sciences, we often use various units of measurement, and hence, very large and very small numbers will frequently be encountered.
To ease the difficulty of mathematical operations, scientific notation is usually employed:

$1 = 10^{0}$ $\qquad 1/10 = 0.1 = 10^{-1}$

$10 = 10^{1}$ $\qquad 1/100 = 0.01 = 10^{-2}$

$100 = 10^{2}$ $\qquad 1/1000 = 0.001 = 10^{-3}$

$1000 = 10^{3}$ $\qquad 1/10{,}000 = 0.0001 = 10^{-4}$

A quick method to find the power of 10 is to place a mark to the right of (1), then count until the decimal point:

ex] $1\underbrace{0{,}000.}_{1\ 2\ 3\ 4}0 = 10^{+4}$ (right → +ve power)

$0.\underbrace{00001}_{5\ 4\ 3\ 2\ 1} = 10^{-5}$ (left → -ve power)

The written form of abbreviation was adopted for some of the widely used powers of 10:

Multiplication Factor	Power of 10	Prefix	Abbreviation
1 000 000 000 000 000	10^{15}	Peta	P
1 000 000 000 000	10^{12}	Tera	T
1 000 000 000	10^{9}	Giga	G
1 000 000	10^{6}	Mega	M
1 000	10^{3}	Kilo	k
0.001	10^{-3}	Milli	m
0.000 001	10^{-6}	Micro	μ
0.000 000 001	10^{-9}	Nano	n
0.000 000 000 001	10^{-12}	Pico	p
0.000 000 000 000 001	10^{-15}	Femto	f

Examples:

$1{,}000{,}000$ ohms $= 1 \times 10^{6}$ ohms
$= 1\ M\Omega$ (don't use 10^{6} here)

$100{,}000$ meters $= 100 \times 10^{3}$ meters $= 100$ km

0.0001 seconds $= 0.1 \times 10^{-3}$ seconds $= 0.1$ ms

0.000001 farad $= 1 \times 10^{-6}$ farad $= 1\ \mu F$

Convert 9×10^{13} femto farads to milli farads

sol.) $9 \times 10^{13} \times 10^{-15} = 9 \times 10^{-2} = 9 \times \left(\frac{10}{10}\right) \times 10^{-2} = 90 \times 10^{-3}$ farad
$= 90$ mFarad

Some important mathematical relationships applying to powers of 10:

$$\frac{1}{10^{n}} = 10^{-n} \qquad \frac{1}{10^{-n}} = 10^{n}$$

$$10^{\pm n} * 10^{\pm m} = 10^{\pm n + (\pm m)}$$ عند الضرب تُجمع الأُسس

$$\frac{10^{\pm n}}{10^{\pm m}} = 10^{\pm n - (\pm m)}$$ عند القسمة تُطرح الأُسس

$$\left(10^{n}\right)^{m} = 10^{n * m}$$ عند الرفع تُضرب الأُسس

ex)

$$\frac{1}{1000} = \frac{1}{10^{+3}} = 10^{-3}$$

$$\frac{1}{0.00001} = \frac{1}{10^{-5}} = 10^{+5}$$

$$(1000)(10{,}000) = (10^{3})(10^{4}) = 10^{7}$$

$$(0.00001)(100) = (10^{-5})(10^{2}) = 10^{-3}$$

$$\frac{1000}{0.0001} = \frac{10^{3}}{10^{-4}} = 10^{3-(-4)} = 10^{7}$$

$$(100)^{4} = (10^{2})^{4} = 10^{8}$$

$$(0.01)^{-3} = (10^{-2})^{-3} = 10^{6}$$

Example :- The time constant of an electric circuit is defined as the product $\tau = RC$. Find τ, if $R = 6500\ \Omega$ & $C = 0.000\,000\,052\ F$, using scientific notation.

Sol.] $\tau = RC = 65 * 10^2 * 52 * 10^{-9} = 3{,}380 * 10^{-7}$ sec.

$= 338 * 10 * 10^{-7} = 338 * 10^{-6}$ sec.

$= 338\ \mu s.$

Conversion within and between Systems of Units:

Example :- Convert 6.8 min to seconds.

Sol.

$$6.8\ \cancel{min}\left(\frac{60\ s}{1\ \cancel{min}}\right) = 408\ s$$

Example :- Convert 0.24 m to cm.

$$0.24\ \cancel{m}\left(\frac{100\ cm}{1\ \cancel{m}}\right) = 24\ cm$$

Example :- Determine the number of minutes in half a day

$$0.5\ \cancel{day}\left(\frac{24\ \cancel{h}}{1\ \cancel{day}}\right)\left(\frac{60\ min}{1\ \cancel{h}}\right) = (0.5)(24)(60) = 720\ min$$

Example:- How many foot-pounds (English system) of energy are associated with 1000 J (SI)?

Sol. From Appendix A: (P-842)

$\because 1\,J = 0.7376$ foot-pound

$\therefore$ energy in SI $= 1000\,\cancel{J}\left(\dfrac{0.7376 \text{ foot-pounds}}{1\,\cancel{J}}\right)$
$= 737.6$ ft.Lb

Example:- A man weighs 160 Lb on earth. Calculate:

a) His weight in newtons, ($1N = 0.2248$ Lb)

b) His mass in Kilograms. (1 Kg $= 2.205$ Lb)

Sol.

a) $160\,\cancel{Lb}\left(\dfrac{1\,N}{0.2248\,\cancel{Lb}}\right) = 711.7\,N$

b) $160\,\cancel{Lb}\left(\dfrac{1\,kg}{2.205\,\cancel{Lb}}\right) = 72.56\,Kg$

Symbols:-

Symbol	Meaning	Example
$\neq$	Not equal to	$6.12 \neq 6.13$
$>$	Greater than	$4.78 > 4.20$
$\gg$	Much greater than	$840 \gg 16$
$<$	Less than	$430 < 540$
$\ll$	Much less than	$0.002 \ll 46$
$\geqslant$	Greater than or equal to	$x \geqslant y$ if $y=3$ & $x>3$ or $x=3$
$\leqslant$	Less than or equal to	$x \leqslant y$, if $y=3$ & $x<3$ or $x=3$
$\cong$	Approximately equal to	$3.14159 \cong 3.14$
Σ	Sum of	$\Sigma(4+6+8)=18$
$\|\ \|$	Absolute magnitude	$\|a\|=4$, where $a=\pm 4$
$\therefore$	Therefore	$x=\sqrt{4}$ $\therefore x=\pm 2$

H.W.

1- If a microprocessor can perform 4 million instructions per second, how many nanoseconds are required to excute an operation requiring three instructions? Ans: 750 nSec.

2- Current is defined as the rate of charge flow. If a charge of 0.0065 colombs passes a given point in a conductor in 100 millisesonds, calculate the:

a) Current in amperes (Hint: $I = \frac{Q}{t}$)

b) Current in milliamperes.

Ans: a) 0.065 A
b) 65 mA

3- A car travels 200 Km in 4 h. Calculate its velocity in:

a) kilometers per hour — Ans: 50 km/h

b) kilometers per second — Ans: $1.38 * 10^{-2}$ km/s

c) meters per second — Ans: 13.8 m/s

d) Centimeters per second — Ans: 1388 cm/s

e) miles per hour — Ans: 31.07 mile/h

4- Express the answer in scientific notation:

a) $(31 \times 10^{2}) * (650 * 10^{3})$ — Ans: $2.015 * 10^{9}$

b) $0.000078 * 0.00065$ — Ans: $5.07 * 10^{-8}$

c) $95000 \div 0.0000375$ — Ans: $2.53 * 10^{9}$

d) $(2 * 10^{-2})^{2} \times (4 * 10^{3})^{3}$ — Ans: $2.56 * 10^{7}$

5- perform the following using scientific notation:

a) $6300 + 75000$ — Ans: $81.3 * 10^{3}$

b) $0.00047 / 0.002$ — Ans: $23.5 * 10^{-2}$

c) $(300)^{2} * 100 / (10^{4})$ — Ans: $9 * 10^{2}$

Lec.2 Current and Voltage

Current:

If 6.242×10^{18} electrons drift at uniform velocity through the circular cross section of a conductor, in 1 second, the flow of charge, or current, is said to be 1 ampere (A).

A coulomb (C) of charge is defined as the total charge associated with 6.242×10^{18} electrons. Then, the charge associated with one electron is given by:

$$\text{Charge/electron} = Q_e = \frac{1C}{6.242 \times 10^{18}} = 1.6 \times 10^{-19} C$$

The current (I) in amperes can now be calculated by:

$$I = \frac{Q}{t}$$

I = amperes (A)
Q = coulombs (C)
t = seconds (s)

$$\therefore 1\,A = \frac{1C}{1\,s} = \frac{\text{charge of } (6.242 \times 10^{18}\, e)}{1\,s} = \frac{1.6 * 10^{-19} * 6.242 * 10^{18}}{1\,s}$$

Example: The charge flowing through the cross section of a conductor is 0.16 C every 64 ms. Determine the current in amperes.

Sol.)

$$\because I = \frac{Q}{t} = \frac{0.16}{64 \times 10^{-3}} = \frac{160 \times 10^{-3}}{64 \times 10^{-3}} = 2.5\,A$$

Example:- How many electrons pass through a conductor in 1 min, if the current is 1 A?

Sol:)

$$\because I = \frac{Q}{t} \Rightarrow 1 = \frac{Q}{1\,\cancel{min}\left(\frac{60\ s}{1\ \cancel{min}}\right)} \Rightarrow Q = 60\ C$$

$\because 1\ C = 6.242 * 10^{18}\ e$

$\therefore$ The number of electrons in $60\ C = 60 * 6.242 * 10^{18}$

$60\ \cancel{C}\left(\frac{6.242 * 10^{18}\ e}{1\ \cancel{C}}\right)$ $= 374.52 * 10^{18}\ e$

Example:- If $21.847 * 10^{18}$ electrons pass through a wire in 7 sec., find the current.

Sol:)

$\because Q = Q_e * \text{no. of electrons} = 1.6 * 10^{-19} * 21.847 * 10^{18}$

OR $21.847 * \cancel{10^{18}}\ \cancel{e}\left(\frac{1C}{6.242 * \cancel{10^{18}}\ \cancel{e}}\right)$ $= 3.4955\ C$

$$\therefore I = \frac{Q}{t} = \frac{3.4955}{7} = 0.499\ A$$

Example:- Determine the time required for 4×10^{16} electrons to pass through the cross section of a conductor if the current is 5mA.

Sol.)

$$4 \times 10^{16}\ \cancel{electrons}\left(\frac{1\ C}{6.242 \times 10^{18}\ \cancel{electrons}}\right) = 0.641 * 10^{-2}\ C$$
$$= 6.41\ mC$$

$$\because I = \frac{Q}{t} \Rightarrow t = \frac{Q}{I} = \frac{6.41 * 10^{-3}}{5 * 10^{-3}} = 1.282\ s$$

Voltage:

A potential difference of 1 volt (V) exists between two points if 1 joule (J) of energy is exchanged in moving 1 collomb (C) of charge between the two points.

In other words, potential difference is defined as the work done to carry a given charge Q from one point in a circuit to another point, measured in joules per coulomb or volt.

In general, the potential difference between two points is determined by:

$$V = \frac{W}{Q} \text{ volts}$$

; where V (volts) = voltage or potential difference
W (Joule) = Energy
Q (Coulomb) = Charge.

In summary, the applied potential difference (in volts) of a voltage source in an electric circuit is the "pressure" to set the system in motion and "cause" the flow of charge or current through the electrical system. A mechanical analogy of the applied voltage is the pressure applied to the water in a main. The resulting flow of water is similar to the flow of charge through the circuits.

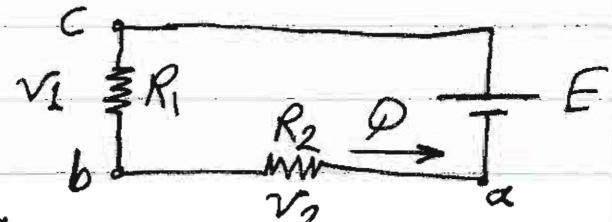
Note :-

To distinguish between sources of voltages (batteries, ... etc) and losses of potential across elements, the following notation will be used:

E for voltage sources (volts)

V for voltage drops (volts)

Consider the following circuit:



$$V_{ba} = V_b - V_a = V_2 = \frac{W_b - W_a}{Q}$$

$$V_{cb} = V_c - V_b = V_1 = \frac{W_c - W_b}{Q}$$

Example:- An energy of 20 J is used to move a charge of 2C to point a. An energy of 30 J is required to bring the same charge to point b. Find the

1) potential of point a,

2) " " " b,

3) " difference between b and a.

Sol:) $V_a = \frac{W_a}{Q} = \frac{20}{2} = 10\ J/C = 10\ V$

$$V_b = \frac{W_b}{Q} = \frac{30}{2} = 15\ J/C = 15\ V$$

$$V_{ba} = V_b - V_a = 15 - 10 = 5V$$

Example :- Charges are flowing through a conductor at a rate of 420 C/min. If 742 J of electrical energy are converted to heat in 30 Sec. What is the potential drop across the conductor?

Sol.) $\because V = \frac{W}{Q}$

$\because I = \frac{Q}{t} \Rightarrow Q = It = 420 \frac{C}{\cancel{min}} \left(\frac{\cancel{min}}{60\,\cancel{s}}\right) 30\,\cancel{s}$

$\therefore Q = 210\, C$

$\therefore V = \frac{742}{210} = 3.533\ V.$

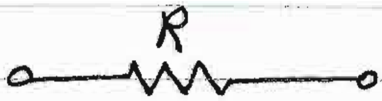
Resistance :-

The flow of charge through any material encounters an opposing force similar to mechanical friction.

This opposition, due to the collisions between electrons and between electrons and other atoms in the material, which converts electrical energy into heat, is called the resistance of the material.

Resistance is measured by ohm (Ω).

The symbol for resistance is :



The resistance of any material with a uniform cross-sectional area is determined by the following four factors:

1- <u>Material</u>:

a- Conductors: have low resistance.

b- Insulators: " high "

2- <u>Length</u>:

The longer the path the charge must pass through, the higher the resistance level.

3- <u>Cross-sectional area</u>:

The larger the area (and thus the available room), the lower the resistance.

4- <u>Temperature</u>:

As the temperature of most conductors and resistive elements increases, the increased motion of the particles within the molecular structure makes it increasingly difficult for the "free" carriers to pass through, and the resistance level increases.

At a fixed temperature of 20°C (room temperature), the resistance is related to the other three factors by:

$$\boxed{R = \rho \frac{l}{A}} \quad (\text{ohms}, \Omega)$$

Where ρ is the resistivity
l is the length
A is the cross-sectional area

To derive the unit for ρ in SI system of units:

A: is measured in cm^2

l: " " " cm

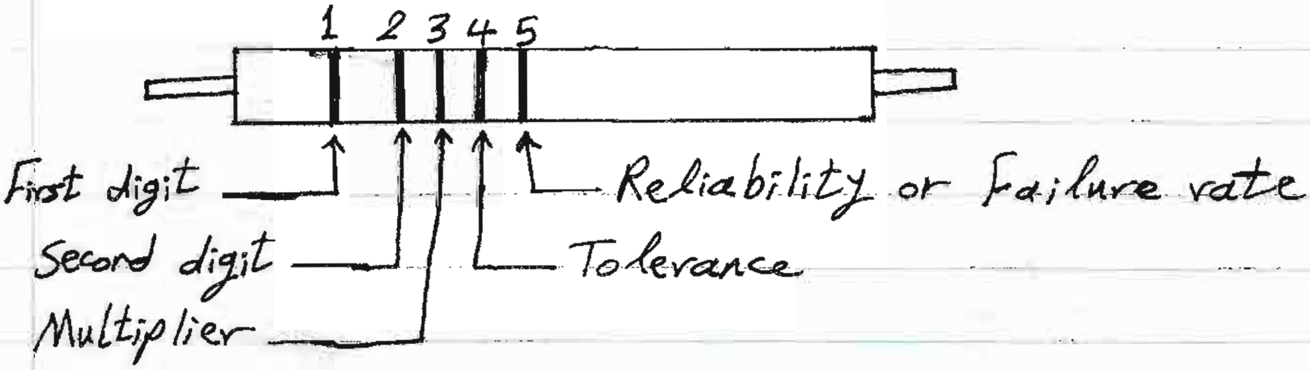
R: " " " Ω

$$\therefore R = \rho \frac{l}{A} \Rightarrow \rho = \frac{RA}{l} = \frac{\Omega \cdot cm^{\cancel{2}}}{\cancel{cm}} = \Omega \cdot cm$$

Lec.3

Color Coding and Standard Resistor Values:

Due to the small size of some resistors, it is difficult to print the resistance value in ohms on their casing. Therefore, a system of color coding is used.
For the fixed molded composition resistor, four or five color bands are printed on one end of the outer casing as shown in this figure:



The color bands are always read from the end that has the band closest to it.
The fourth band is the manufacturer's tolerance, which is an indication of the precision by which the resistor was made. If the fourth band is omitted, the tolerance is assumed to be ± 20%. The fifth band is a reliability factor which gives the percentage of failure per 1000 hours of use. For example, a 1% failure rate would reveal that one out of every 100 will fail to fall within the tolerance range after 1000 hours of use.

Color	Band 1 & Band 2	Multiplier (Power of 10) Band 3	Tolerance ($\pm$ %) Band 4	Reliability or Failure rate (%) Band 5 (optional)
Black	0	$10^0 = 1$	—	—
Brown	1	$10^1 = 10$	1	1
Red	2	$10^2 = 100$	2	0.1
Orange	3	$10^3 = 1000$	—	0.01
Yellow	4	10^4	—	0.001
Green	5	10^5	0.5	
Blue	6	10^6	0.25	
Violet	7	10^7	0.1	
Gray	8	10^8	0.05	
White	9	10^9	—	
Gold	—	10^{-1}	5	
Silver	—	10^{-2}	10	
None	—	—	20	

Example: A resistor is color-coded as: Yellow-violet-Gold-Gold-yellow. Find:

a) It's nominal value, tolerance, and reliability.

b) The extreme upper and lower values possible expressed as a range.

Sol:

a) $47 * 10^{-1} \pm 5\%$; 0.001% failure rate per 1000 h of operation.

$\therefore R = 4.7\,\Omega \pm 5\%$

b) Lower limit $= 4.7\,\Omega - \frac{5}{100} * 4.7\,\Omega = 4.7 - 0.235 = 4.465\,\Omega$

Upper limit $= 4.7\,\Omega + \frac{5}{100} * 4.7\,\Omega = 4.7 + 0.235 = 4.935\,\Omega$

$\therefore$ Range $= 4.465\,\Omega$ & $4.935\,\Omega$ (i.e. The resistor should lie somewhere between $4.465\,\Omega$ and $4.935\,\Omega$).

Example: A resistor is color-coded as:
Red - Red - Orange - Silver - Brown
a) Find its nominal value, tolerance, and reliability.
b) The upper and lower resistance ranges.

Sol:

a) $22 * 10^3\,\Omega$ $(22\,k\Omega)$; $\pm 10\%$; 1% per 1000 hour failure rate.

b) Lower limit $= 22\,k - 0.1 * 22\,k = 19.8\,k\Omega$
Upper limit $= 22\,k + 0.1 * 22\,k = 24.2\,k\Omega$
$\therefore$ Range $= 19.8\,k\Omega$ & $24.2\,k\Omega$

Conductance:

It is the reciprocal of the resistance of a material, and it has the symbol (G), and it is measured in siemens (S).

$$\therefore \; G = \frac{1}{R} \qquad (S)$$

$$\therefore \; G = \frac{A}{\rho l} \qquad (S)$$

Temperature Effects:

For most conductors, the resistance increases with increase in temperature, due to the increased molecular movement within the conductor which hinders the flow of charge.