Lecture 1

Units and Scales, Charge, Current, Voltage

Course Outcome/s:

1. Identify the different dc and ac circuit parameters and components.
2. Relate the laws and principles applied in DC and AC circuits in real-life situations.

Objectives:

1. Define the basic concepts of electric circuits.
2. Solve problems involving the basic concepts of electric circuits

International System of Units (SI)

- Adopted by the General Conference on Weights and Measures in 1960
- Based on six defined quantities

Table 1. The SI Six Basic Quantities

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

Table 2. The SI Prefixes

SI PREFIXES		
Multiple or Submultiple	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^{2}	hecto	h
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	mu
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Example: Which of the three currents $Ia = 0.03\ mA$, $Ib = 45\mu A$, and $Ic = 25\ x\ 10^{-4}\ A$ is the largest?

Solution:

First, express all currents with the same unit.

$Ia = 0.03\ mA$,

$Ib = 45\mu A = 0.045\ mA$,

$Ic = 25\ x\ 10^{-4}\ A = 2.5mA$

Therefore, the largest of the three currents is $\boldsymbol{Ic = 2.5mA}$

DC CIRCUITS

Electric circuit – interconnection of electrical elements

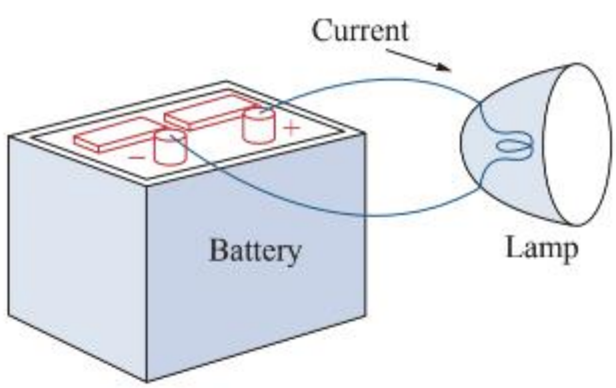


Figure 1. Simple Electric Circuit

Charge

Charge (Q or q) – is an electrical property of the atomic particles of matter, measured in coulombs (C)

$$q = \int_{t0}^{t} idt$$

$$q_T = q(t) - q(t_0)$$

When this charge starts to move around the loop created by the interconnection of electrical elements, power is dissipated in another form of energy – light energy in this case.

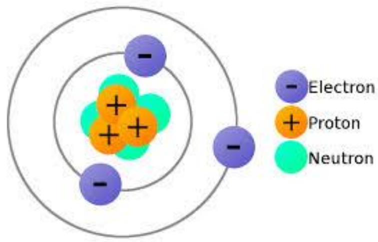


Figure 1. An atom is made up of subatomic charged
(proton and electron) and uncharged (neutron) particles. (toppr.com)

Electric Charge Fundamentals

1. There are $6.24\ x\ 10^{18}$ electrons in 1 C of charge.
2. $1\ e\ =\ -1.602\ x\ 10^{-19}$ C
3. The law of conservation of charge states that charge can neither be created nor destroyed, it can only be transferred.

Current

Electric Current (I or i) – is the rate of flow of charges, measured in amperes (A).

$$1A\ =\ 1\frac{Coulomb}{second} = 1\frac{C}{s}$$

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

Andre-Marie Ampere – French mathematician who defined the electric current and developed a way to measure it in 1820s.

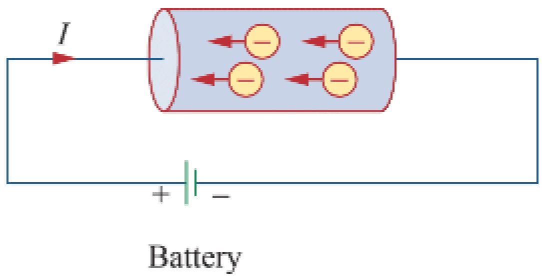
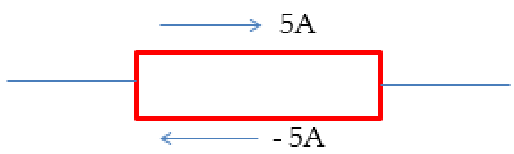


Figure 3. Electric Current due to Flow of Electronic Charge in a Conductor



Note: a negative current of -5A flowing in one direction is the same as a current of +5A flowing in the opposite direction

Direct Current (DC) – current that remains constant with time

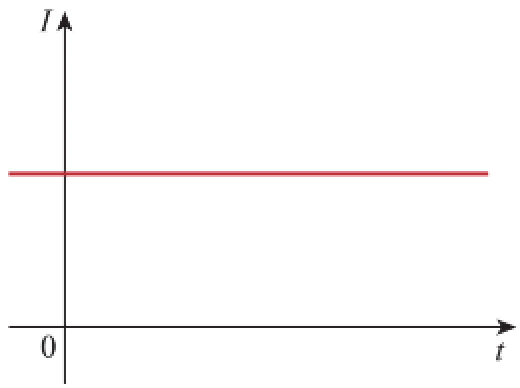


Figure 4. Direct Current

Alternating Current (AC) – current that varies sinusoidally with time

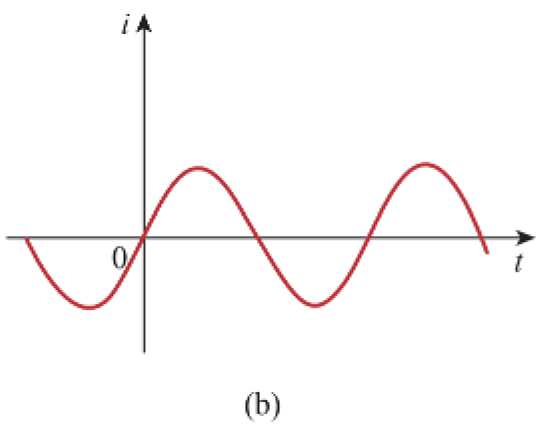


Figure 5. Alternating Current

Electromotive Force (EMF) or Voltage (V) or potential difference - is the energy required to move a unit charge through an element, measured in volts (V).

$$1V \;=\; 1\,Joule/Coulomb = 1\,J/C = 1\,\frac{newton - meter}{coulomb}$$

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

Alessandro Antonio Volta – Italian physicist who invented the electric battery, which provided the first continuous flow of electricity

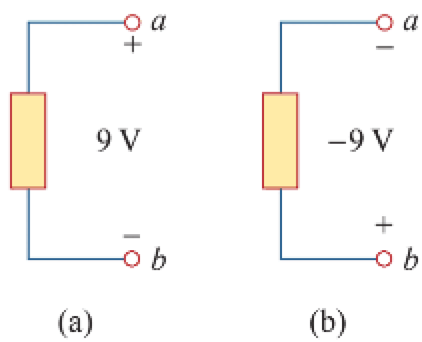


Figure 6. Two Equivalent Representations of the Same Voltage

Examples:

1. How much charge is represented by 4600 electrons?
2. The total charge entering a terminal of an element is given by $q = (4t^3 – 5t)$ mC. Find the current i at $t = 0$ and $t = 2$ sec.
3. If in Problem 2, $q = 5t \sin 4\pi t \ mC$, calculate the current at $t = 0.5$ s.
4. Determine the total charge entering a terminal between t=1s and t=2s if the current passing the terminal is $i(t) = (3t^2 - t)A$.
5. Find the charge flowing through a device if the current is:
$$i(t) = (2t + 5)mA, q(0) = 0$$

Solutions:

1. Note that in 1 electron, there are $-1.602x10^{-19}\ C$ of charge.

   Therefore,

$$4600\ electrons\ x\ \frac{-1.602x10^{-19}\ C}{1\ electron} = \boldsymbol{-7.369x10^{-16}C}$$

2. Note:

$$i = \frac{dq}{dt} = \frac{d(4t^3 - 5t)mC}{dt}$$

$$i = [4(3)t^2 - 5]mA$$

$$i = (12t^2 - 5)mA$$

   At $t = 0\ second$:

$$i = (12(0)^2 - 5)mA$$

$$\boldsymbol{i = -5\ mA}$$

   At $t = 2\ seconds$:

$$i = (12(2)^2 - 5)mA$$

$$\boldsymbol{i = 43\ mA}$$

3. Note:

$$i = \frac{dq}{dt} = \frac{d(5t\sin(4\pi t))mC}{dt}$$

$$i = [5t(\cos 4\pi t)(4\pi) + 5sin4\pi t]\ mA$$

$$i = [20\pi t\cos 4\pi t + \ 5sin4\pi t]mA$$

At $t = 0.5\ seconds$:

$$i = [20\pi(0.5)(\cos 4\pi(0.5)) + 5\sin(4\pi(0.5))]mA$$

$$\boldsymbol{i = 10\pi\ mA\ or\ 31.42\ mA}$$

4. Note:

$$q = \int idt = \int_{t=1\,sec}^{t=2\,sec} (3t^2 - t)dt$$

$$q = \left[\frac{3t^3}{3} - \frac{t^2}{2}\right]$$

$$q = \left[(2)^3 - \frac{2^2}{2}\right] - \left[(1)^3 - \frac{1^2}{2}\right]$$

$$\boldsymbol{q = 5.5\ C}$$

5. Note:

$$q = \int idt = \int (2t + 5)dt$$

$$q = \left[\frac{2t^2}{2} + 5t\right]mC$$

$$\boldsymbol{q = (t^2 + 5t)mC}$$

Textbook:

Alexander, C. K. & Sadiku, M. N. (2017). *Fundamentals of Electric Circuits (6th ed.)*. New York: McGraw-Hill Education

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