Lecture 01 – Introduction to Network Analysis

COURSE DETAILS

- Course Duration – 80 hrs
- Detailed Theory – Handwritten + Typed
- Large no. of Numerical – Basic to Advanced
- Weekly Quiz
- 3 Hours Daily (Mon - Sat) 6 am – 9:30 am

SYLLABUS

- BASIC OF NETWORK ANALYSIS ← class XII
- DC NETWORK THEOREMS
- TRANSIENT ANALYSIS
- STEADY STATE AC ANALYSIS

$\left.\begin{array}{l}\text{TRANSIENT ANALYSIS}\\ \text{STEADY STATE AC ANALYSIS}\end{array}\right\}$ Time response

- 2 - PORT NETWORK
- ECE
- MAGNETICALLY COUPLED CIRCUITS
- GRAPH THEORY
- THREE PHASE CIRCUITS

only EE

STRATEGY

- attend live class daily
- download class PDF → revise class notes & make short notes
- Solve assignment
- ask doubts
- Be prepared for weekly quiz

solve workbook on Sundays

last 10 years PYQ : end of chapter

SHOULD I MAKE HANDWRITTEN NOTES?

NO

Running notes : Skip something while hearing

later : time for practice ↓

No. of question ↓

problem solving ability ↓

GATE Syllabus: EE (Electrical Engineering)

Electric Circuits:

Electric circuits Network Elements: ideal voltage and current sources, dependent sources, R, L, C, M elements; Network solution methods: KCL, KVL, Node and Mesh analysis; Network Theorems: Thevenin's, Norton's, Superposition and Maximum Power Transfer theorem; Transient response of dc and ac networks, sinusoidal steady-state analysis, resonance, two port networks, balanced three phase circuits, star-delta transformation, complex power and power factor in ac circuits.

basic

ac analysis

GATE Syllabus: ECE (Electronics & Communication Engineering)

Networks:

Node and mesh analysis, superposition, Thevenin's theorem, Norton's theorem, reciprocity. Sinusoidal steady state analysis: phasors, complex power, maximum power transfer. Time and frequency domain analysis of linear circuits: RL, RC and RLC circuits, solution of network equations using Laplace transform. Linear 2-port network parameters, wye-delta transformation.

basic

Syllabus: IN (Instrumentation Engineering)

Electric Circuits:

Electrical Circuits voltage and current sources: independent, dependent, ideal and practical, v-i relationships of resistor, inductor, mutual inductance and capacitor; transient analysis of RLC circuits with dc excitation. Kirchoff's laws, mesh and nodal analysis, superposition, Thevenin, Norton, maximum power transfer and reciprocity theorems.

Peak, average and rms values of ac quantities; apparent, active and reactive powers, phasor analysis, impedance and admittance, series and parallel resonance, locus diagrams, realization of basic filters with R, L and C elements, transient analysis of RLC circuits with ac excitation. One-port and two-port networks, driving point impedance and admittance, open-, and short circuit parameters.

Marks Distribution of Network Theory in Previous Year GATE Papers. (EE)

Exam Year	1 Mark	2 Marks	Total marks
2003	3	6	15
2004	1	7	15
2005	4	7	18
2006	2	6	14
2007	-	7	14
2008	2	6	14
2009	2	6	14
2010	3	4	11
2011	3	5	13
2012	5	6	17
2013	2	3	8

Exam Year	1 Mark	2 Marks	Total marks
2014 set 1	2	2	6
2014 set 2	3	2	7
2014 set 3	3	3	9
2015 set 1	4	3	10
2015 set 2	3	3	9
2016 se 1	4	5	14
2016 set 2	5	4	13
2017 set 1	2	3	8
2017 set 2	2	2	6
2018	3	4	11
2019	1	3	7

Exam Year	1 Mark	2 Marks	Total marks
2020	2	2	6
2021	3	5	13
2022	3	2	5
2023	2	3	8

average: 8-10 marks

Marks Distribution of Network Theory in Previous Year GATE Papers. (ECE)

Exam Year	1 Mark	2 Marks	Total marks
2003	4	8	20
2004	5	5	15
2005	5	6	17
2006	6	-	6
2007	2	4	10
2008	2	7	16
2009	3	4	11
2010	2	4	10
2011	3	3	9
2012	4	4	12
2013	3	6	15

Exam Year	1 Mark	2 Marks	Total marks
2014 set 1	2	4	10
2014 set 2	2	2	6
2014 set 3	2	4	10
2014 set 4	2	4	10
2015 set 1	4	3	10
2015 set 2	3	3	9
2015 set 3	3	2	7
2016 set 1	1	2	5
2016 set 2	4	3	10
2016 set 3	1	3	7
2017 set 1	1	2	5
2017 set 2	2	2	6
2018	1	3	7

Exam Year	1 Mark	2 Marks	Total marks
2019	1	2	5
2020	3	2	7
2021	2	4	10
2022	2	3	5
2023	2	4	10

average: 8-10 marks

LAST 5 YEAR TOPIC WISE ANALYSIS OF NETWORK ANALYSIS (EE)

NETWORK BASICS	2018	2019	2020	2021	2022	2023	TOTAL
NETWORK ELEMENTS (pre req)			1M				1M
KIRCHHOFF'S LAWS	2M						2M
NODAL AND MESH ANALYSIS		1M		1M	2M	1M	5M
POWER AND ENERGY CALCULATION							
DUALITY							

NETWORK THEOREMS (DC CIRCUITS)	2018	2019	2020	2021	2022	2023	TOTAL
THEVENIN AND NORTON THEOREM (other subjects) eg analog			1M	1M			2M
MAXIMUM POWER TRANSFER THEOREM			2M				2M
MILLMAN'S THEOREM		2M					2M
OTHER THEOREMS							

TRANSIENT ANALYSIS	2018	2019	2020	2021	2022	2023	TOTAL
INITIAL AND FINAL CONDITIONS		1M	2M	2M	1M	1M	7M
FIRST ORDER CIRCUITS				1M		2M	3M
SECOND ORDER CIRCUITS							
LAPLACE TRANSFORM METHOD				2M			2M
FILTER				1M			1M

Sinusoidal Steady State Analysis	2018	2019	2020	2021	2022	2023	TOTAL
PHASOR ANALYSIS				1M			1M
MAXIMUM POWER TRANSFER THEOREM	2M			2M			4M
OTHER THEOREMS						2M	2M
POWER IN AC CIRCUITS (more imp. for EE)	1M						1M
MISCELLANEOUS							
RESONANCE	2+2=4M				1+1 =2M		6M

TWO PORT NETWORK	2018	2019	2020	2021	2022	2023	TOTAL
TWO PORT NETWORK	1M					2M	3M
GRAPH THEORY							
GRAPH THEORY (not in syllabus)	1M						1M
MAGNETICALLY COUPLED CIRCUITS (EE + IN)							
MAGNETICALLY COUPLED CIRCUITS				2M			2M
THREE PHASE CIRCUITS		2M			1M	2M	5M

LAST 5 YEAR TOPIC WISE ANALYSIS OF NETWORK ANALYSIS (ECE)

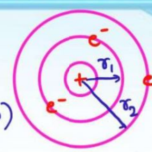
Chapter	2018			2019			2020			2021			2022			2023		
	1M	2M	TOTAL	1M	2M	TOTAL	1M	2M	TOTAL	1M	2M	TOTAL	1M	2M	TOTAL	1M	2M	TOTAL
NETWORK ELEMENTS	0	1	2	0	0	0	0	0	0	2	0	2	2	0	2	1	0	0
NETWORK THEOREMS	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0
TRANSIENT RESPONSE	0	1	2	0	1	2	0	0	0	0	3	6	0	0	0	1	1	0
SSS ANALYSIS	0	1	2	0	1	2	1	1	3	0	0	0	0	2	4	1	0	0
NETWORK FUNCTION	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TWO PORT NETWORKS	1	0	1	0	0	0	1	1	3	0	1	2	0	1	2	1	1	0
GRAPH THEORY AND STATE EQUATION	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1	6	7	1	4	5	3	4	7	2	8	10	2	6	8	4	4	8

Introduction To Network Analysis

Basic Definitions

Charge

(SI unit : coulomb)



nucleus : proton + neutron
orbit : electron
neutral atom
protons = e^- net charge = 0

- It is an inherent property of matter by virtue of loss or gain of electrons.

  Charge on an e^- = 1.6×10^{-19} C

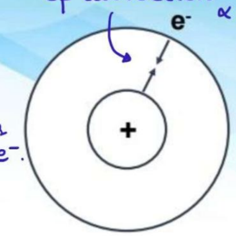
- Loss of e^- : +ve charge
  Gain of e^- : -ve charge

Charge on any body is quantized
$q = ne$; $e = 1.6 \times 10^{-19}$ C
n = number of e^- lost or gained
(+ve integer)

→ Charge transfer is always associated with mass transfer
$m_e = 9.1 \times 10^{-31}$ Kg

mass transferred = $n m_e$

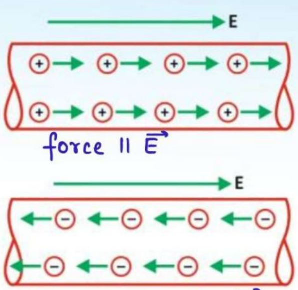
Free and bound charge



electrostatic force of attraction $\propto 1/r^2$

- When e^- revolves around the nucleus in fixed orbit, then it is bound to nucleus by electrostatic forces is called as Bound Charge.
  Inner e^- are more tightly bound than outer e^-.
- When we apply higher force than electrostatic force on e^- or provide energy more than Ionization energy then e^- comes out of atom and can take part in current conduction.
- Such charges are called as free charges.
  freed from outer most orbit (least force & least energy reqd)

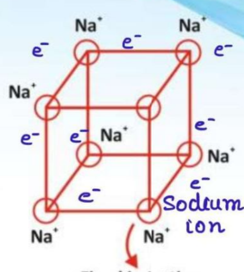
- Free charges are responsible for current flow.



force ∥ $\vec{E}$

force is opp. to $\vec{E}$

when e^- move current flows.



Sodium crystal

metal → cation
$Na \rightarrow Na^+ + 1e^-$

- Na releases one e^- to attain stable electronic configuration and becomes positive ion.
- Na^+ ion remains fixed inside lattice while e^- is free to flow.

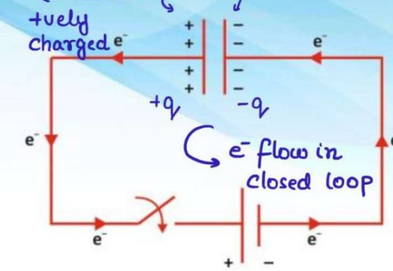
When E-field is applied then e^- experience force opposite to $\vec{E}$
$\vec{F} = q\vec{E}$
Charge on $e^- < 0$
$\vec{F}$ opposite to $\vec{E}$

Conservation of Charge

- Charge can neither be created nor be destroyed but can only be transferred from one body to another.

- When battery charges a capacitor it delivers electrons to one plate and absorbs e^- from other plate due to which equal and opposite charges appear on 2 plates.

Net charge = 0



Before connecting battery
charge = 0 & 0
total 0

after battery
charge = q & -q
total = 0

Current

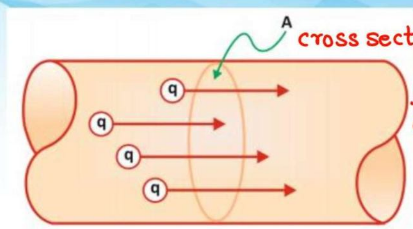
- When electric field is applied across a condition, e^- flow opposite to $\vec{E}$

** SN

- Rate of flow of charges per unit time through a CSA is called as current.

  $i = {}^{dq}/_{dt}$ SI unit : ampere

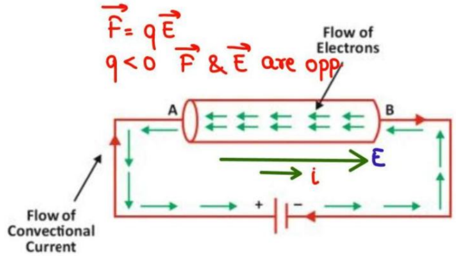
- Direction of conventional current $\parallel \vec{E}$ in same direction as flow of +ve charges in opposite direction to flow of e^-.



cross sectional area ⊥ to charge flow

$\vec{F} = q\vec{E}$

$q < 0$ $\vec{F}$ & $\vec{E}$ are opp



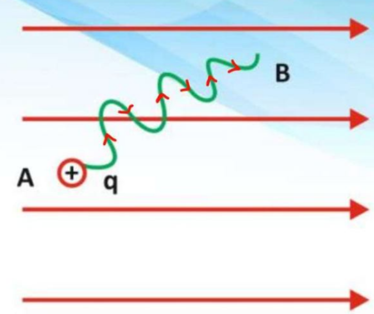
Voltage

- Also called as potential difference.
- When a charge is moved under the influence of electric field then work done per unit charge is potential difference.

  $V_B - V_A = \frac{W_{A\to B}}{q} = -\int_A^B \vec{E}.\vec{dl}$ (B → final, A → initial)

  $\vec{E}\cdot\vec{dl} = E\,dl\cos\theta$

  θ : angle b/w $\vec{E}$ & $\vec{dl}$ → disp.



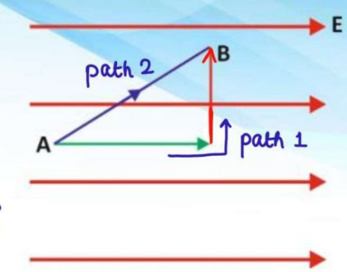
If we move in same direction as $\vec{E}$ i.e. $\vec{dl} \parallel \vec{E}$ then pd<0 or potential reduces. → $\theta = 0$ $V_B < V_A$

- Generally, electric field is conservative i.e. work done is independent of path.

$\therefore$ pd depends on initial and final position and not on path taken to go from initial to final position.

$$V_B - V_A = -\int_{path\ 1} \vec{E}\cdot\vec{dl} = -\int_{path\ 2} \vec{E}\cdot\vec{dl}$$

indep. of path



EMF AND POTENTIAL DIFFERENCE

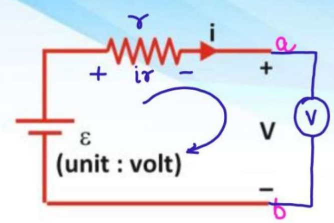
EMF : (electromotive force) → resposible for movement of charge

Potential difference between 2 electrodes of a battery responsible for the flow of current inside a circuit.

- Due to finite resistance of voltmeter a current flows while meas. voltage using voltmeter.

$V = \varepsilon - ir$; r : internal resistance

pd across terminal < emf



If $i = 0$ $V = \varepsilon$

→ Can be measured via potentiometer

QUESTION-01

A current of 0.5 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through the circuit .

$i = dq/dt$

$q = \int i\,dt$

if i = constant

$q = i\int dt = i \times t$

$= 0.5 \times \underbrace{(10 \times 60)}_{sec} = 300\ C$

QUESTION-02

For $t \geq 0, q = (4.0 \times 10^{-4})(1 - e^{-250t})(C)$. Obtain the current at at t = 3 ms .

$i = dq/dt = 4 \times 10^{-4}\ d/dt\ (1 - e^{-250t})$

$= 4 \times 10^{-4}\ (0 + 250 e^{-250t}) = 0.1 e^{-250t}$

at 3 ms

$i = 0.1 e^{-250 \times 3/1000} = 0.1 e^{-0.75}$

$= 0.047\ A$

$= 47.2\ mA$

QUESTION-03

In an electric circuit an energy of 9.25 μJ is required to transport 0.5 μC from point a to point b. What electric potential difference exists between the two points?

Work done = energy

$pd = \frac{WD_{A \to B}}{q} = \frac{9.25\ \mu J}{0.5\ \mu C} = 18.5\ V$

QUESTION-04

In an electrical circuit an energy of $9.25\mu J$ is required to transport $0.5\mu C$ from point a to point b than electric potential difference exists between the two points will be

~~(a)~~ 18.5V

(b) 9.30V

(c) 4.6V

(d) 9.20V

same as Q-3

QUESTION-05

The current flowing through an element is

$$i=\begin{cases} 2A, 0 < t < 1 \\ 2t^2 A, t > 1 \end{cases}$$

Then calculate the charge entering the element from t = 0 to t = 2 s.

$$q = \int_0^2 i\,dt = \int_0^1 (2)\,dt + \int_1^2 (2t^2)\,dt$$

$$= 2(1-0) + 2\left(\frac{t^3}{3}\right)_1^2$$

$$= 2 + \frac{2}{3}(8-1) = \frac{20}{3}$$

$$= 6.67\ C$$

Power

- rate of flow of energy wrt time is called as power.
- energy = work done
  $= q \times V$ V: potential diff. through which charge moves
- power. $P = \frac{dU}{dt} = \frac{d}{dt}(qV)$

  $P = V\frac{dq}{dt} = Vi$

SI unit: Watt

INSTANTANEOUS POWER

- power at an instant of time is called as Instantaneous Power.
  or power as a function of time.

**SN

- $p(t) = v(t) \cdot i(t)$ Watts

  obtained by product of v & i at any time.

Work Done

Work done = charge × potential diff

**SN

∴ energy supplied by battery = charge supplied × emf of battery

$$WD = \int i\,dt \times V = \int Vi\,dt$$

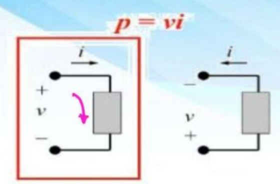
$$WD = \int p(t)\,dt$$

Sign convention for power calculation

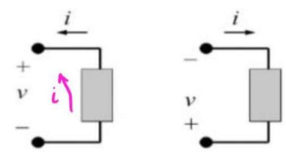
**SN

- Whenever current enters +ve terminal of any element or leaves -ve terminal then element is said to be absorbing power.

  power = vi → >0 : absorb; <0 : deliver



$p = vi$



- When current leaves +ve terminal of any element or enters -ve terminal then element is said to be delivering power.

  power delivered = vi → >0 : deliver; <0 : absorb

Energy

- energy absorbed or delivered by an element = WD

  energy = q × pd

  $= \int p\, dt$

  ↳ Instantaneous power

  SI unit : joules

- absorption or delivery of energy follows same sign convention as power.

Law of Conservation of Energy

- Energy can neither be created nor be destroyed but transformed from one form to other.

  Battery : chemical to electrical

  generator : mechanical to electrical

  motor : electrical to mechanical

  R : electrical to heat

  lamp : electrical to heat & light

QUESTION-06

absorbed by element

power absorbed

Find the power $\boxed{\text{delivered to an element}}$ at t=3ms if the current entering its positive terminals is $i=5\cos 60\pi t$ A and the voltage is :

(a) $v=3i$

(b) $v=3\frac{di}{dt}$

(a) at 3 ms

$i = 5\cos 60\pi t = 5\cos(60\pi \times 3/1000) = 4.221\,A$

$v = 3i = 12.665\,V$

$p = vi = 53.4586\,W$

(b) $v = 3\,di/dt = -3\,[5 \times 60\pi \sin 60\pi t]$

at 3 ms $i = 4.221\,A$

$v = -15 \times 60\pi \sin(60\pi \times 3/1000)$

$= -7575.07\,V$

$p = vi = -31.794\,KW$