ELECTRICAL SCIENCE-II
(15B11EC211)

UNIT 1
LECTURE 1

COURSE OUTCOMES		COGNITIVE LEVELS
C203.1	Study and analyze the complete response of the first order and second order circuits with energy storage and/or non-storage elements.	Analysing Level (C4)
C203.2	Understand two-port network parameters and study operational amplifier, first-order&second-orderfilters.	Understanding Level (C2)
C203.3	Study the properties of different types of semiconductors, PN junction diode, zener diode and analyze diode applications.	Analyzing Level (C4)
C203.4	Study the characteristics, operation of bipolar junction transistor (BJT) and its biasing, stability aspects.	Understanding Level (C2)

Course Description

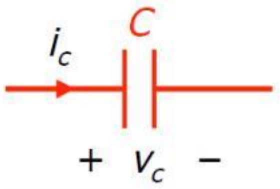
Module No.	Title of the Module	Topics in the Module	No. of Lectures for the module
1	Transient Analysis	First order network analysis, sequential switching, Differential equation approach for DC and Non constant source, second order network analysis using differential equation approach for DC and non-constant source	8
2	Two Port Network Parameters	Definition of Z, Y, h and transmission parameters and their conversions	7
3	Introduction to filters	First order and Second order (Low pass, High pass, Band pass and Band Stop) RLC Filters	4
4	Introduction to Semiconductor	Semiconductor Physics - Energy Band Model, Carrier Statistics, Intrinsic Semiconductors, Extrinsic Semiconductors, Fermi Level, Charge densities in a semiconductor Carrier Mobility and Drift Current, Hall Effect, Recombination of charges, diffusion and conductivity equation.	5
5	Diodes & Applications	PN Junction, Biasing the PN Junction, Current–Voltage Characteristics of a PN Junction, PN Junction Diodes, Half Wave Rectifier & Full Wave Rectifier, Clipper & Clamping Circuits, Zener Diodes and applications, Line and load regulations	9
6	Bipolar Junction Transistor	Transistor Construction and Basic Transistor Operation, Transistor Characteristics (CE, CB, CC), Transistor Biasing & Stability,	9

Evaluation Criteria and Recommended Books

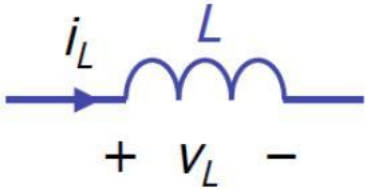
Components	Maximum Marks
T1	20
T2	20
End Semester Examination	35
TA	25
Total	100

Recommended Reading material: (Books/Journals/Reports/Websites etc.: Author(s), Title, Edition, Publisher, Year of Publication etc. in IEEE format)	
1.	R.C. Dorf and James A. Svoboda, "Introduction to Electric Circuits", 9^{th} ed, John Wiley & Sons, 2013.
2.	Charles K. Alexander (Author), Matthew N.O Sadiku, "Fundamentals of Electric Circuits", 6^{th} ed, Tata Mc Graw Hill, 2019.
3.	Oppenheim, A.V., Willsky, A.S. and Nawab, S.H., Signals and Systems. Prentice-Hall.
4.	Abhijit Chakrabarti, Circuit Theory Analysis and Synthesis, 7th ed, Dhanpat Rai & Co. 2018.
5.	Robert L. Boylestad, Louis Nashelsky, "Electronic Devices and Circuit Theory", 11^{th} ed, Prentice Hall of India, 2014.
5.	Jacob Millman, Millman's Electronic Devices and Circuits (SIE), 4th ed, McGraw Hill Education, 2015.

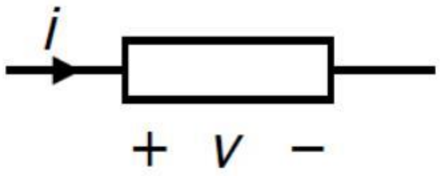
constitutive relation of C,L, R



$$i_C = C\frac{dv_C}{dt}$$



$$v_L = L\frac{di_L}{dt}$$



$$v = i\,R$$

- If a circuit has one C or L then ***circuit becomes dynamic*** **means**
  - Its behaviour is a function of time.
    - Its behaviour is described by a (set of) differential equation(s).
    - It has a transient response as well as a steady state.
- Resistive circuits have no transient
  - When the switch is turned on, the voltage across R becomes V **immediately (in zero time).**

RL and RC circuits are called first-order circuits

Steady State and Transient Response Content

- The Simple *RL* Circuit.
    - Concept of Time Constant.
    - Meaning of Time Constant.
    - Growth of Current in Series *RL* Circuit.
    - The Simple *RC* Circuit.
    - Discharging of a Capacitor.
    - Charging of a Capacitor.
- Comparison between *RC* and *RL* Circuits.

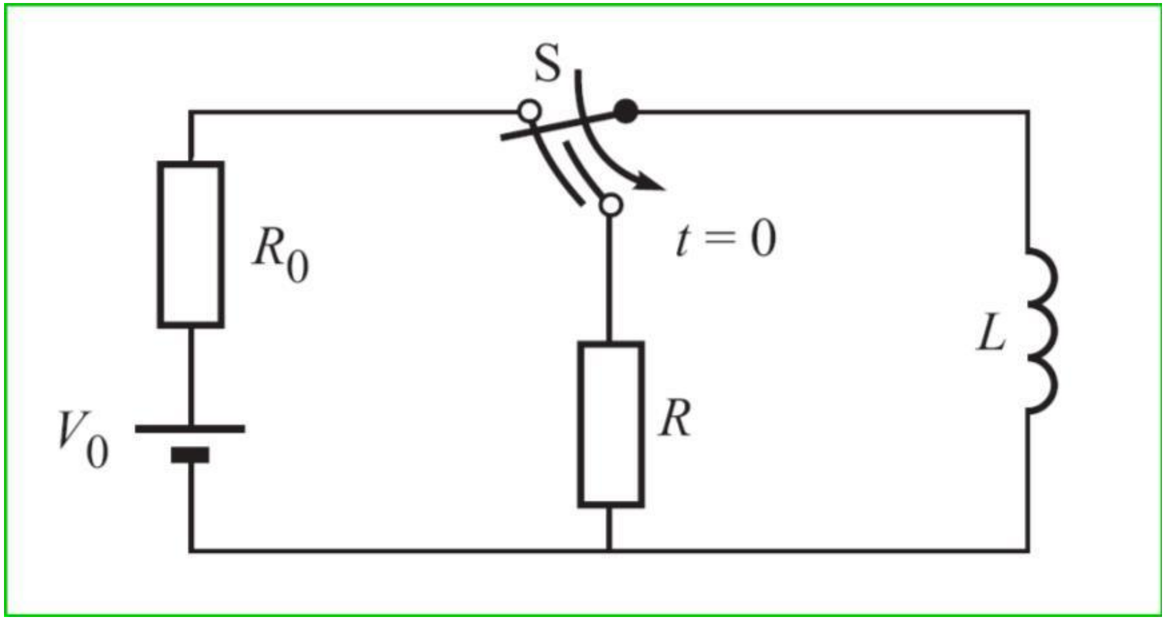
Steady State

- Both the inductance and capacitance are energy-storing elements.
- When connected to a dc source, energy starts flowing to these elements.
- Initially the rate of flow of energy is high, but as more and more energy is stored, the rate of flow decreases.
  - When maximum possible energy has been stored, the flow of energy stops altogether. We say that the circuit has reached its 'steady state'.

Transient Response

- If we switch off the source, or switch over the network to another source, the circuit starts attaining another ‘steady state’.
- The time taken by the circuit to change over from one steady-state condition to another steady-state condition is called *transient time*.
- The response of the circuit during this time is known as *transient response*.

The Simple RL Circuit



At t = 0-, a steady current that has been flowing in the circuit,

$$I_0 = \frac{V_0}{R_0}$$

For $t > 0+$, applying KVL,

$$v_R + v_L = 0 \quad \text{or} \quad Ri + L\frac{di}{dt} = 0 \quad \text{or} \quad \frac{di}{dt} + \frac{R}{L}i = 0$$

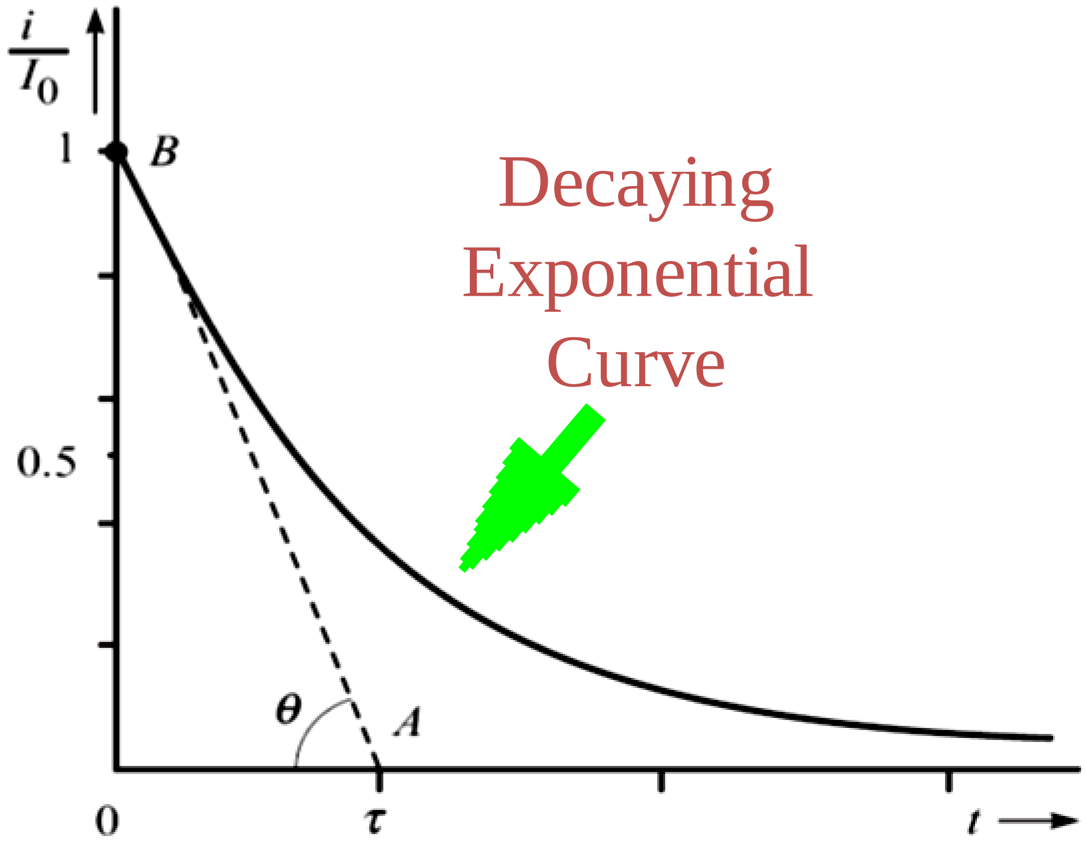
Re-writing the equation to separate variables and then integrating,

$$\frac{di}{i} = -\frac{R}{L}dt$$

$$\int_{I_0}^{i(t)} \frac{1}{i}\,di = \int_0^t \left(-\frac{R}{L}\right)dt \quad \text{or} \quad \ln i\Big|_{I_0}^{i} = -\frac{R}{L}t\Big|_0^t$$

$$\text{or} \quad \ln i - \ln I_0 = -\frac{R}{L}(t-0)$$

or $$i(t) = I_0 e^{-Rt/L}$$



At $t = 0+$, the current is I_0. As time increases, the current decreases and approaches zero.

Concept of Time Constant

- From equation, we see that with larger L/R ratio, the current takes longer to decay.
  - By doubling L/R, the "width" of the curve also doubles.
  - The "width" is proportional to L/R.
  - Instead of "width", we use the concept of "time constant (τ).
  - *It is the time that would be required for the current to drop to zero if it continued to drop at its initial rate.*

Meaning of Time Constant

Determining the value of $i(t)/I_0$ at $t = \tau$, we have

$$\frac{i(\tau)}{I_0} = e^{-1} = 0.368 \qquad \text{or} \qquad i(\tau) = 0.368 I_0$$

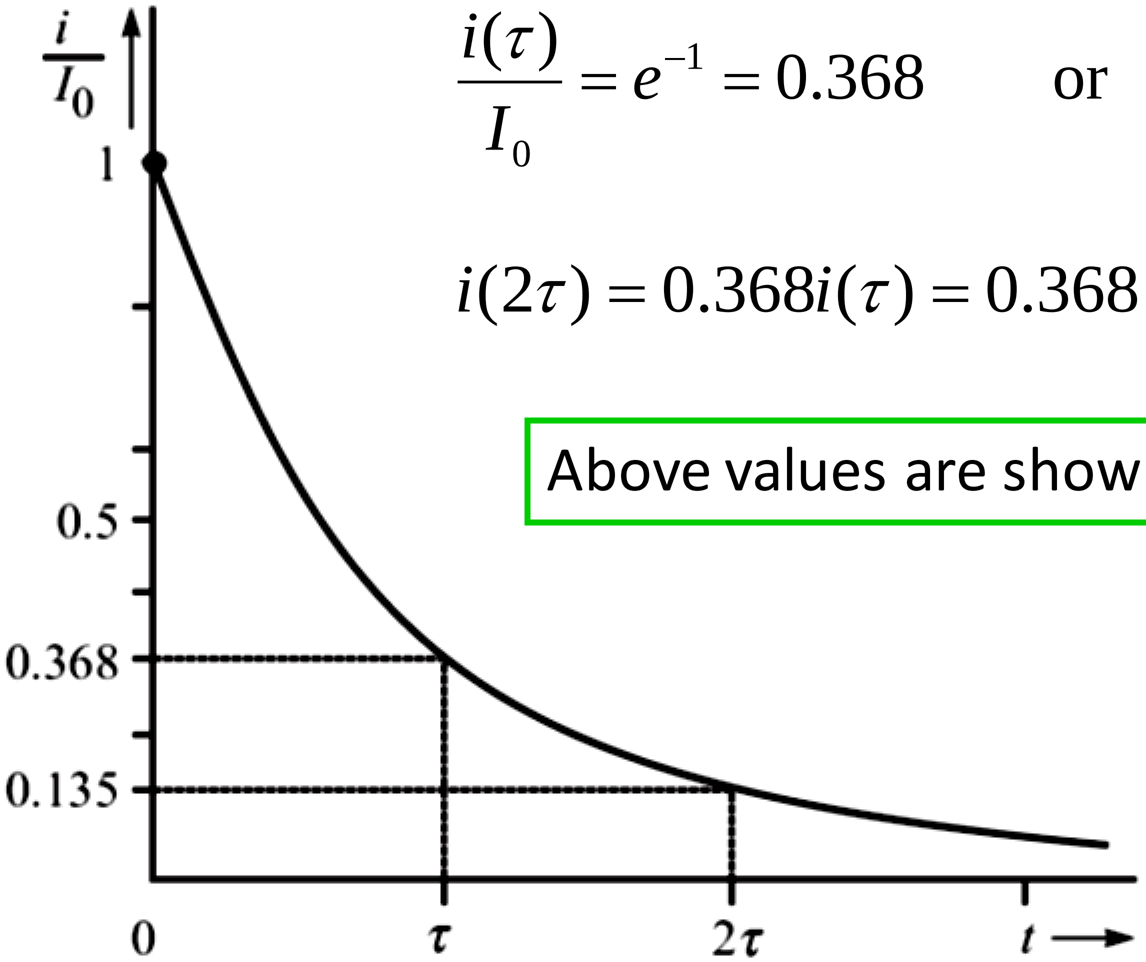
Thus, in one time constant the response drops to 36.8 % of its initial value.

Hence,

$$i(2\tau) = 0.368 i(\tau) = 0.368 \times 0.368 I_0 = 0.1354 I_0$$

How long does it take for the current to decay to zero ?

Ans. : To answer this question, let us calculate



$$\frac{i(\tau)}{I_0} = e^{-1} = 0.368 \qquad \text{or} \qquad i(\tau) = 0.368 I_0$$

$$i(2\tau) = 0.368 i(\tau) = 0.368 \times 0.368 I_0 = 0.1354 I_0$$

Above values are shown on the graph.

$$i(3\tau) = 0.0498I_0,$$
$$i(4\tau) = 0.0183I_0,$$
$$i(5\tau) = 0.0067I_0,$$
$$\cdots \qquad \cdots \qquad \cdots$$

- It takes about **five time constants** for the current to decay to zero.
- At the end of this time interval, the current is less than one percent of its original value.

References

1. R.C.Dorf and James A. Svoboda, “Introduction to Electric Circuits”,9thed, John Wiley & Sons, 2013.
2. Charles K. Alexander, Matthew N.O. Sadiku,“FundamentalsofElectricCircuits”, 6th Edition,Tata McGrawHill,2019.