Electrical Circuits for Engineers (EC1000)

Course Overview

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Dept. of Electronics & Communication Engineering

Course Information

Classes: 2023 CSE Batch

Day	CSE-B1 Batch (Venue: H-01)	CSE-B2 Batch (Venue: H-41)
Monday	8 a.m-8.50 a.m	10 a.m-10.50 a.m
Tues Day	1 p.m-1.50 p.m	
Wednesday	9 a.m-9.50 a.m	11 a.m-11.50 a.m
Thurs Day		8 a.m-8.50 a.m
Friday	10 a.m-10.50 a.m	1 p.m-1.50 p.m

Text Book:

Hughes Electrical and electronic technology, Edward Hughes, Ian McKenzie Smith, John Hiley, Keith Brown, Tenth edition, Pearson, 2010

References:

1. Charles Alexander and Matthew Sadiku 'Fundamentals of Electric Circuits' 7th Edition, McGraw Hill,2021
2. C. H. Roth, Jr., "Fundamentals of Logic Design," 7th Edition, Cengage Learning, 2013.
3. Millmans, 'Electronic Devices and Circuits' (SIE) 4th Edition, 2015
4. A.E. Fitzgerald, C. Kingsley, Jr., (S.D. Umans), Electric Machinery, McGraw-Hill, 6th ed. 2002.

Module Overview

- **Target Students:**
  - ❖ B.Tech (All UG students offered by Dept. of Electronics & Communication Engineering.
- **Education Aims:**
- This course aims to equip the students with a basic understanding of electrical circuits and machines for specific types of applications.
- This course also equips students with an ability to understand basics of analog and digital electronics.

Learning Outcomes

By the end of this module, students should be able to:

- The students shall develop an intuitive understanding of the circuit analysis, basic concepts of electrical machines, and electronic devices and circuits and be able to apply them in product design and development.

Grading Weights

Category	Grading Weight
Assignment	10%
Mid Sem	40%
End Sem	50%

Marks Distribution for Grading

Grade	Marks
S	≥ 90
A	[80-89)
B	[70-79)
C	[60-69)
D	[50-59)
U	< 50

I- Incomplete
W- Due to lack of attendance

Course Contents

- Elements in an electrical circuits : R, L, C, voltage and current sources, Ohm's law, Kirchoff's Law **(4 hours)**
- Network analysis: Nodal and mesh analysis only with independent sources **(4 hours)**
- Network theorems: Superposition, Thevenin's & Norton's, Maximum power transfer theorems **(4 hours)**
- DC circuits: Response of RC, RL and RLC circuits **(6 hours)**
- AC circuits: AC signal measures, Phasor analysis of single phase AC circuits, Three phase AC circuits **(6 hours)**
- Machines: Transformers, DC generator, DC motor, AC induction machines **(8 hours)**
- Diodes: V-I characteristics, applications -rectifiers, clippers, clampers **(2 hours)**
- Op-amps: gain, feedback, applications - inverting/non-inverting amplifiers, sum and difference amplifier, comparators **(4 hours)**
- Logic gates and combinational circuits – Basic gates, Karnaugh maps, Full adder, half adder **(4 hours)**

Introduction and Motivation

Electrical Engineering:

Engineering of systems involving electrical *energy or power*. These systems do *work.*

Examples: for heating, lighting, motors for trains, moving things in industry, pumping water to homes, amplification of audio signals to move loudspeaker, to activate powerful radar, antennas etc.

Electronic Engineering:

Engineering of systems to manipulate *information.* Information is represented in (small!) electrical signals

Examples: circuits for conditioning/processing signals, coding, microprocessors, computers.

What are Power and Energy?

- Many definitions (see google!)

- Energy – the capacity to do work (Watt hours)
  - This is what you buy (look at your electricity bill)
- Power – work done per unit time (Watts)
  - Instantaneous consumption – rating of equipment

Consider buying 7 kWh of electricity

Electrical Engineering is still extremely important.
A few examples:

Society needs energy. Distributed to industry and homes in controlled and efficient way.

Industry needs energy for moving and processing things, pumping liquids and gases, conveyors.

Homes need energy – electrical engineering surrounds you in homes as much as electronic information.

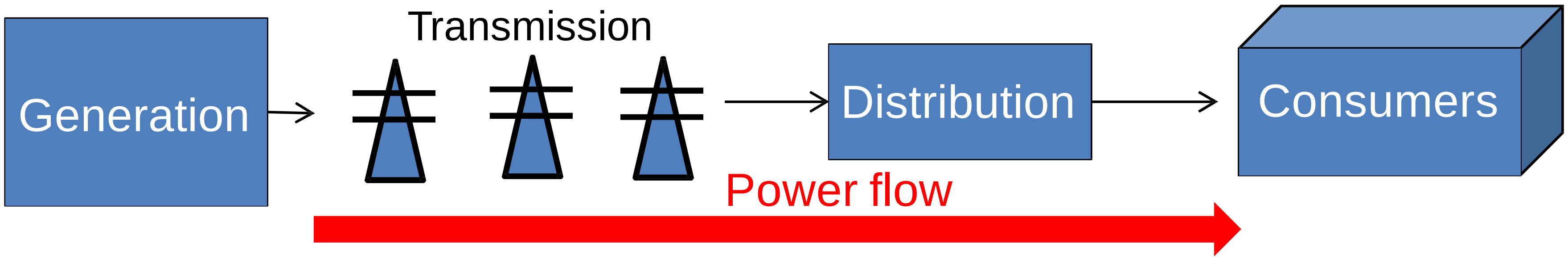
Transportation needs energy -Aircraft need electrical power for actuating surfaces, pumping fuel, air-conditioning, radar etc. then ships, cars, trains etc.

Brief History of Electricity

- Static electricity discovered about 600 BC by Thales
- **Electromagnetism** studied systematically by William Gilbert, 1600.
- The first **battery** discovered by Allessandro Volta, 1800.
- Andre Ampere discovered the **relationship between current and magnetic field**, 1825.
- George Ohm discovered the **relationship between voltage and current** through a conductor, Ohm's law, 1827.
- Faraday's law, (**Electromagnetic induction**) discovered by Michael Faraday, 1831.
- James Clerk Maxwell, **Maxwell's Equations**, 1864.
- Thomas Edison discovered the **Incandescent Lamp**, 1879.
- **First power station** in Manhattan found by Thomas Ediston, 1882.
- **DC motor** produced by Frank Sprague, 1884.
- **Transformer** discovered by William Stanley, 1886.
- **Polyphase AC system**, and **Induction motors** by Nicola Tesla, 1888.
- First transmission line found in US, Oregon, 1889.
- Over 3000 power stations By 1900.

A Conventional Electrical System

- The conventional electrical T&D system has four main parts:-



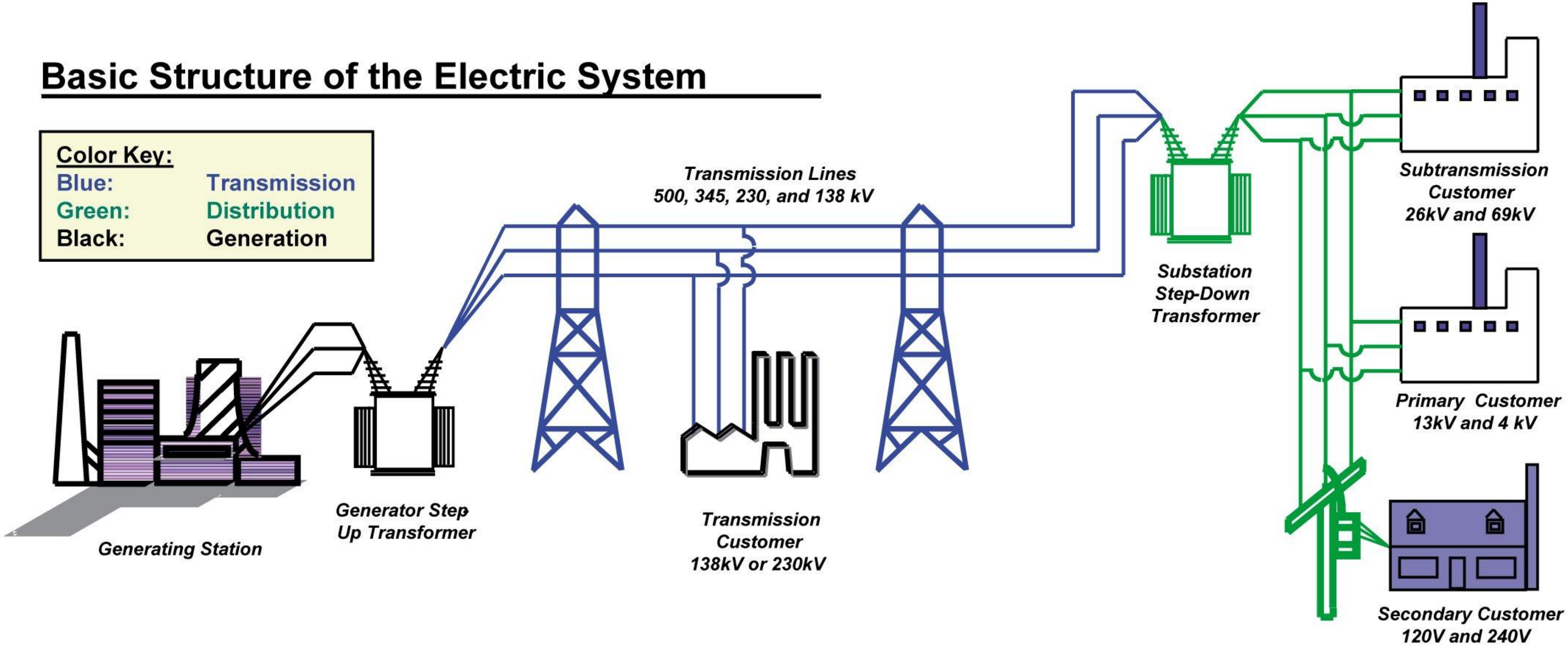
❖ Bulk Generation : provide energy to the system

❖ Transmission system: transfer of bulk energy using high voltage alternating current (HVAC) - very efficient

❖ Distribution System: delivers energy to individual users (low voltage for convenience and safety)

❖ The Consumers : adsorb the energy supplied (homes, factories, schools)

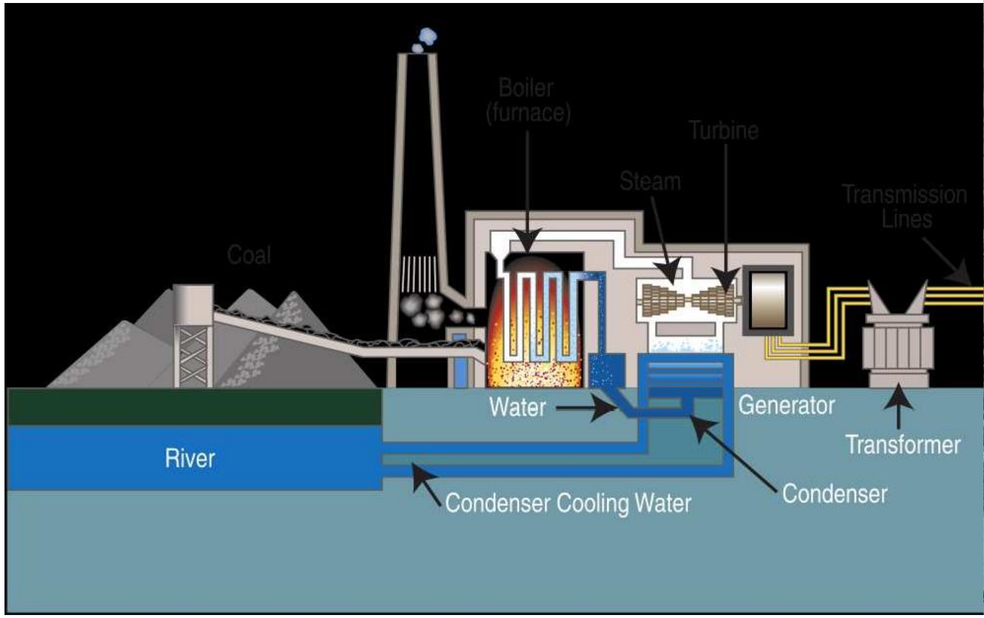
ELECTRICAL POWER SYSTEM



1. Electrical Power Generation
2. Power Transmission
3. Electricity Distribution
4. Electrical Energy Consumption

Electrical System Equipment

- Conventional generation:-



- ❖ Generated “centrally” using fossil fuels to convert water into steam, which then powers steam turbines. Turbines drive generators – “dispatchable”;
- ❖ Power flow in one direction – straightforward management protection schemes;

Electrical System Equipment

- Transmission System:-

❖ Pylons support HVAC (400kV, 275kV @ 50Hz) cables which transmit high power over longer distances

❖ Switchgear – connect and disconnect under normal and fault conditions (circuit breakers);

Electrical System Equipment

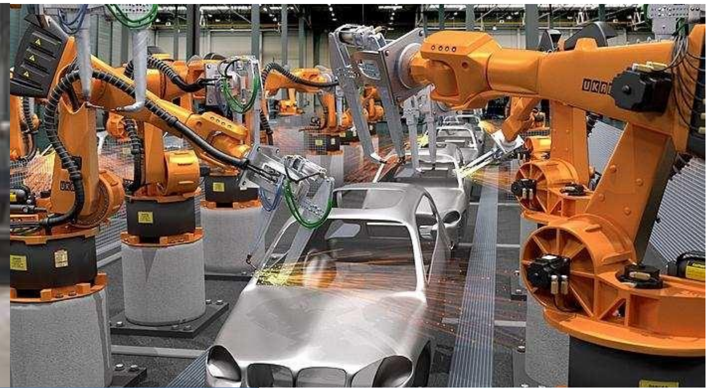
- Distribution System:-

❖ Transformers convert HV to lower voltages which can be used locally

❖ Substations contain transformers and low voltage switchgear (circuit breakers)

Electrical System Equipment

- Loads:-


❖ Electric motors use 60% of all electricity generated

❖ Industrial – fans, pumps, compressors, lifts, hoists, machine tools, robots

❖ Transport – trains, trams

Summary

- To introduce you to basic concepts (volts, amps, power, energy) and general circuit analysis techniques;
- To apply these concepts to analyzing power and energy flow in power systems (and the constraints imposed by real world characteristics – R, L, C);
- To understand the operation of transformers and motors;

•To understand the basic characteristics of Diodes and their applications.

To understand the Ideal characteristics of Op-Amps and their applications.

Lecture-01

Basics of Electricity

Overview

✓Electricity fundamentals

✓Law of conservation of energy

✓Circuit Elements

✓Sources

✓Problems

Introduction

- Electricity is the physical phenomena associated with the presence and motion of electric charge.
- Every matter contains atom and atom contains particles of electricity *viz*. protons and electrons.
- The positive charge on a proton is equal to the negative charge on an electron.
- Whether a given body exhibits electricity or not depends upon the relative number of these particles of electricity.

Introduction

- If the number of protons is equal to the number of electrons in a body, the resultant charge is zero and the body will be electrically neutral.
- If from a neutral body, some electrons are removed, there occurs a deficit of electrons in the body. Consequently, the body attains a *positive charge*.
- If a neutral body is supplied with electrons, there occurs an excess of electrons. Consequently, the body attains a *negative charge*.
- The unit of charge is coulomb.
- The charge on one electron is given by 1.6×10^{-19} C.

Introduction

Conductor, Insulator, Semi conductor

- Based on electrical conductivity, materials are generally classified into *conductors*, *insulators* and *semi-conductors*.
- When the valence electrons of an atom is weakly bonded - Conductor.

  E.g, Copper and Aluminium.
- When the valence electrons of an atom is strongly bonded- Insulator.

  E.g., Glass, Ceramic.
- When the valence electrons of an atom is moderately bonded - Semi-conductor.

  E.g., Silicon and Germanium.

Introduction

Electric Potential

The ability of the charged body to do work is called electric potential.

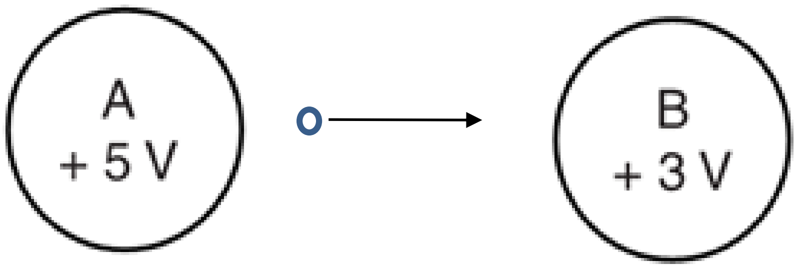
$$\text{Electric potential,} \quad V = \frac{\text{Work done}}{\text{Charge}} = \frac{dw}{dq} \quad \text{joule/coulomb or Volt}$$

- When we say an electric potential of 5V, it means that 5 joules of work has been done to charge the body to 1 coulomb.
- In other words, every coulomb of charge possesses an energy of 5 joules.

Introduction

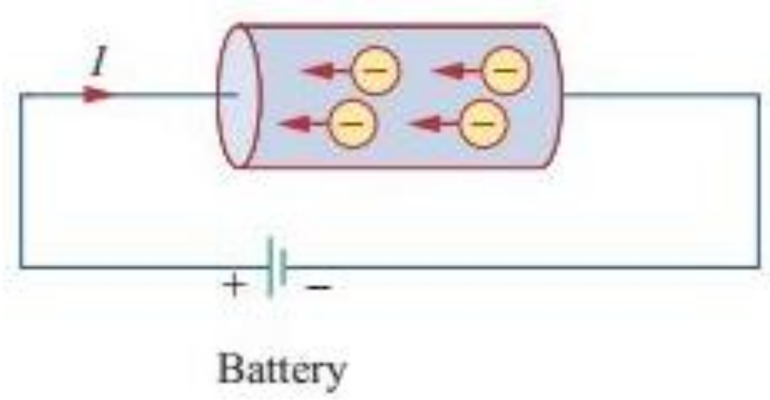
Electromotive force (EMF)

The difference in the potentials of two charged bodies is called **potential difference.**



A device that maintains potential difference between two points is said to develop electromotive force (e.m.f.).

Introduction



Electric current

The directed flow of free charge is called electric current.

$$I = \frac{dq}{dt} \; Coloumb/\sec \; or \; Ampere$$

- The actual direction of current (electrons) is from negative terminal to the positive terminal through the circuit.
- However, prior to Electron theory, it was assumed that current flowed from positive terminal to the negative terminal
- This convention is so firmly established that it is still in use. This assumed direction of current is now called conventional current.

Introduction

Energy

The total work done in an electric circuit is called electrical energy

$$V = \frac{\text{Work}}{Q}$$

$$\text{Energy} = \text{Work} = VQ = VIt \quad \text{Joules or Watt-hour}$$

Power

The rate at which work is done in an electric circuit is called electric power

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

$$P = \frac{\text{Work}}{t} = \frac{VIt}{t} = VI \quad \text{joules/sec or watts}$$

Introduction

Law of conservation of energy

Energy can neither be created nor be destroyed
One form of energy can be converted into another form

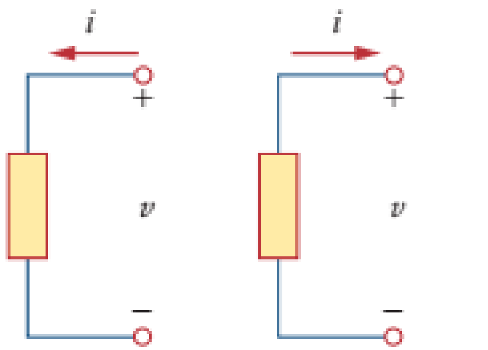
Mechanical to Electrical
Thermal to Electrical
Chemical to Electrical

Electrical to Mechanical
Electrical to Thermal

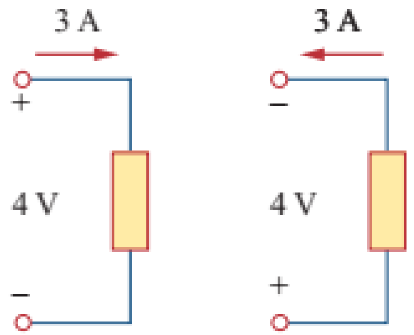
Introduction

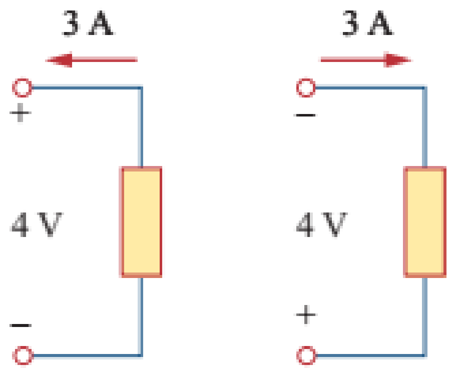
Law of conservation of energy must be obeyed in any electric circuit.

$$\sum E = 0 \quad \sum P = 0$$



Power absorbed (Load) Power delivered (Source)





Introduction

Active element

Active elements generate energy.

Active components control the charge flow in electronic circuits.

E.g., Generator, Battery, Amplifiers

Passive element

Receive energy.

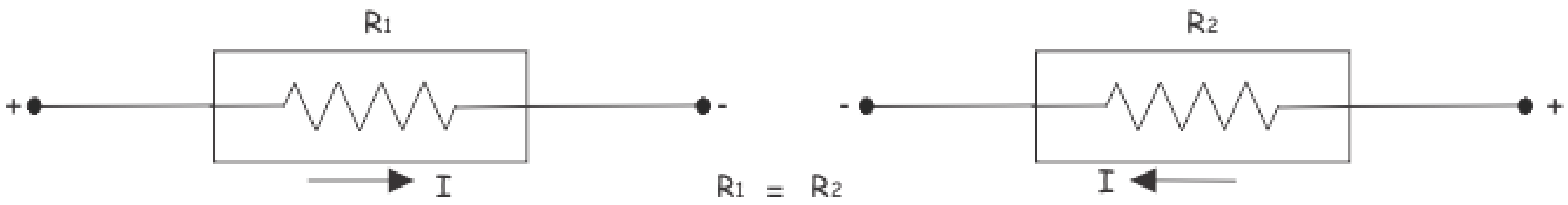
Absorb or dissipate energy

E.g., Resistor, Capacitor, Inductor

Introduction

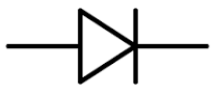
Bilateral Elements

Conduction of current in both directions in a circuit element with same magnitude is termed as a bilateral circuit element.



Unilateral element

Conduction of current in both directions in a circuit element with same magnitude is termed as a bilateral circuit element.



Introduction

sistance

The opposition offered by a substance to the flow of electric current is called its **resistance**.

$$R = \rho \frac{l}{a}$$

Where ρ is the resistivity or specific resistance of the material.
The unit of resistance is Ohms (Ω).

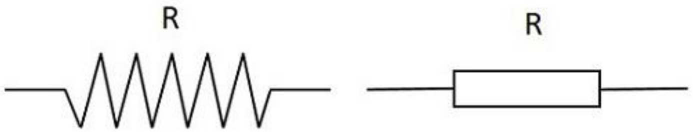
Conductance

The reciprocal of resistance of a conductor is called its **conductance** (G).
If a conductor has resistance R, then its conductance G is given by ;

$$G = 1/R$$

Siemens (S) is the unit of conductance. Also Mho (℧) can be used as unit of conductance

Introduction



Symbol for a fixed resistor

Symbol for Variable resistor

Different Types of Resistor

Introduction

Electric Sources

Dependent source

Independent source

Voltage source Current source

Current dependent Current source

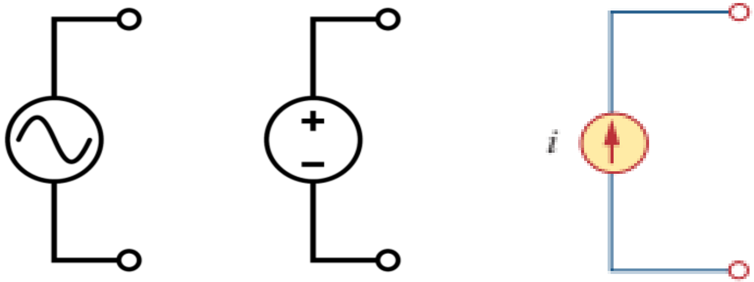
Voltage dependent Voltage source

Voltage dependent Current source

Current dependent Voltage source

Introduction

An independent source is an active element that provides a specified voltage or current, completely independent of other circuit elements.

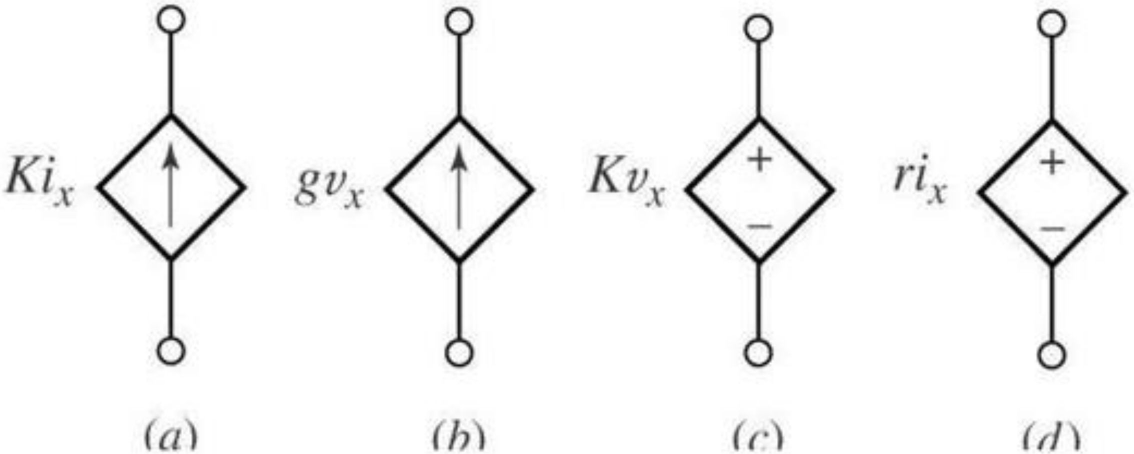


(a) (b) (C)

(a) Time-varying (AC) voltage, (b) Constant voltage (DC), (c) Current source

Introduction

Dependent or controlled source is an active element whose voltage or current is controlled by other circuit elements.



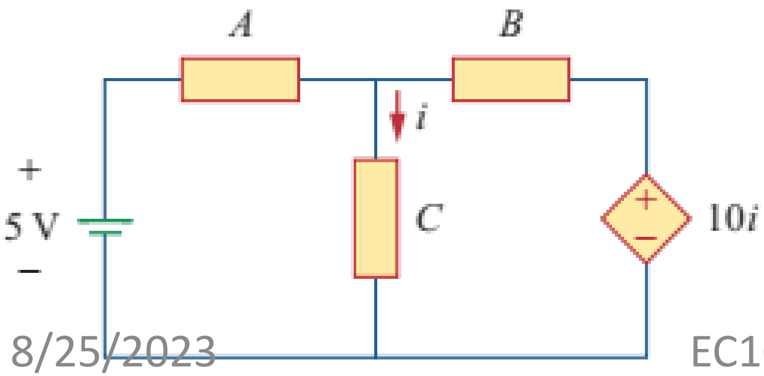
Symbol for dependent sources:

(a) Current dependent current source

(b) Voltage dependent current source

(c) Voltage dependent voltage source

(d) Current dependent voltage source



Problems

Example:1

An energy source forces a constant current of 2 A for 10 s to flow through a lightbulb. If 2.3 kJ is given off in the form of light and heat energy, calculate the voltage drop across the bulb.

The total charge is

$$\Delta q = i\,\Delta t = 2 \times 10 = 20\ \text{C}$$

The voltage drop is

$$v = \frac{\Delta w}{\Delta q} = \frac{2.3 \times 10^3}{20} = 115\ \text{V}$$

Problems

Example:2

How much energy does a 100-W electric bulb consume in two hours?

$$w = pt = 100\ (\text{W}) \times 2\ (\text{h}) \times 60\ (\text{min/h}) \times 60\ (\text{s/min})$$
$$= 720{,}000\ \text{J} = 720\ \text{kJ}$$

This is the same as

$$w = pt = 100\ \text{W} \times 2\ \text{h} = 200\ \text{Wh}$$

Problems

Example: 3

A 100 V lamp has a hot resistance of 250 Ω. Find the current taken by the lamp and its power rating in watts. Calculate also the energy it will consume in 24 hours.

Current taken by lamp, $I = V/R = 100/250 = \mathbf{0.4\ A}$

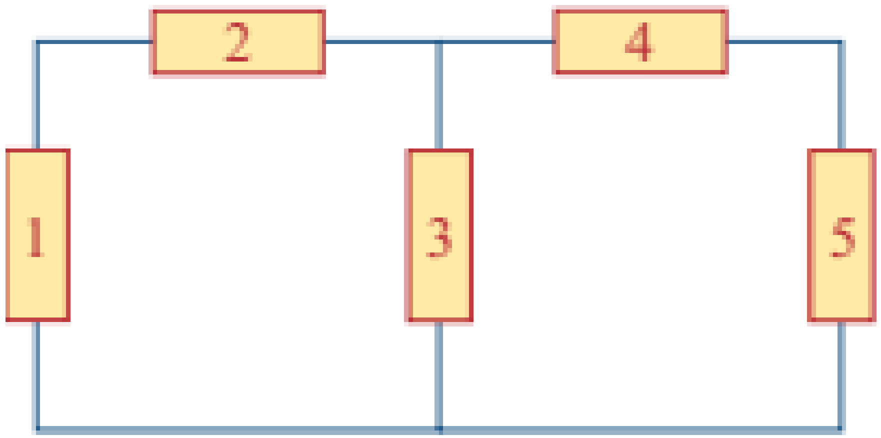
Power rating of lamp, $P = VI = 100 \times 0.4 = \mathbf{40\ W}$

Energy consumption in 24 hrs. $=$ Power $\times$ time $= 40 \times 24 =$ **960 watt-hours**

Problems

Example: 4

Figure shows a circuit with five elements. If P_1= -205W, P_2= 45W, P_4 = 45W, P_5= 30W, calculate the power P_3 received or delivered by element 3.



Soln:

$\Sigma P = 0$

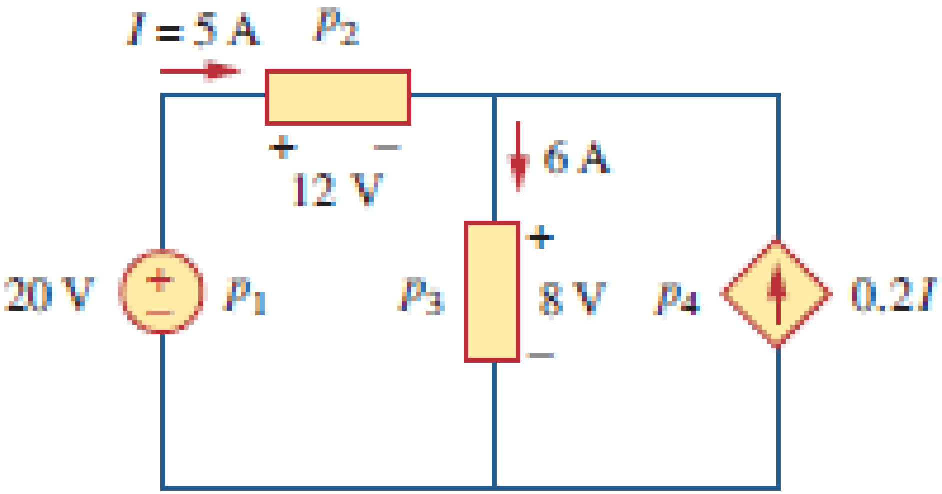
$P_1+P_2+P_3+P_4+P_5 = 0$

$P_3 = -(P_1+P_2+P_4+P_5)$

$P_3 = -(-205+45+45+30) = 85$ W

Problems

Calculate the power absorbed or supplied by each element.



$P_1+P_4 = 100 + 8 = 108$ W
$P_2+ P_3 = 60 + 48 = 108$ W
$\Sigma P = 0$

Power supplied by the 20V source $P_1=(20 \times 5) = 100$ W

Power absorbed by the element $P_2 = 12 \times 5 = 60$ W

Power absorbed by the element $P_3 = 8 \times 6 = 48$W

Power supplied by the source $P_4 = (0.2 \times 5) \times 8 = 8$ W

Problems

Example: 5

A coil consists of 2000 turns of copper wire having a cross-sectional area of 0.8 mm^2. The mean length per turn is 80 cm and the resistivity of copper is 0.02 μΩm. Find the resistance of the coil.

Soln:

Length of coil, l = 0.8 × 2000 = 1600 m

Cross-sectional area of coil, a = 0.8 mm^2 = 0.8 × 10^{-6} m^2

Resistivity of copper, ρ = 0.02 × 10^{-6} Ωm

$$R = \rho \frac{l}{a}$$

R=40 Ω

Practice Problems

1 A 60-W incandescent lamp is connected to a 120-V source and is left burning continuously in an otherwise dark staircase. Determine:

(a) the current through the lamp.

2 A flashlight battery has a rating of 0.8 ampere-hours (Ah) and a lifetime of 10 hours.

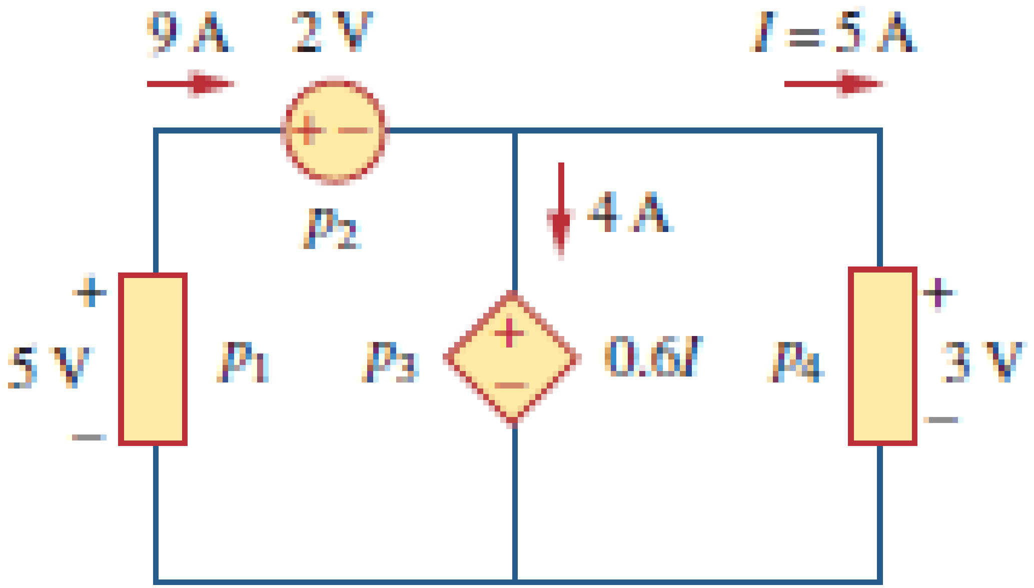
(a) How much current can it deliver?

(b) How much power can it give if its terminal voltage is 6 V?

(c) How much energy is stored in the battery in Wh?

Practice Problems

Find the power absorbed or supplied by each component



Thank You