THEORY

FUNDAMENTALS OF ELECTRICAL AND ELECTRONICS LAB (25EE01I)

I & II SEM (for all branches)

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WEEK-1

1a. Meaning of Electrical Safety

Electrical safety means **protecting people and machines** from the harmful effects of electricity. It involves **using equipment properly**, **following safe work procedures**, and **maintaining systems** to avoid accidents caused by electric current.it also includes

1. Secure against connection. ...
2. Verify that the installation is dead. ...
3. Carry out earthing
4. Provide protection against live parts.
5. Prevent electrical equipment from contacting wet wires
6. Ensure safe when unplugging

1b. Safety precautions in electrical working place

To ensure electrical safety in the workplace, several precautions should be taken, including using personal protective equipment (PPE), de-energizing equipment before maintenance, and ensuring proper grounding and insulation.

1. Personal Protective Equipment (PPE):

1. **Insulated Gloves:** Essential for working with live circuits to prevent shock.
2. **Protective Clothing:** Wear non-conductive clothing and shoes with insulated soles to minimize the risk of contact with electricity.
3. **Hard Hats:** Protect against falling objects and potential electrical hazards.

2. De-energizing Equipment:

1. **Lockout Procedures:** Ensure equipment is de-energized and locked out before any maintenance or repair work.
2. **Switch Off and Unplug:** Before cleaning or adjusting electrical equipment, switch it off and unplug it.
3. **Proper Isolation:** Isolate the circuit and properly ground it before working on it.

3. Grounding and Insulation:

1. **Proper Grounding:** Ensure all electrical equipment is properly grounded to provide a safe path for electricity in case of a fault.
2. **Insulated Tools and Equipment:** Use tools with non-conductive handles and ensure electrical equipment is properly insulated.

4. General Safety Practices:

1. **Avoid Water and Wet Conditions:** Electricity and water are a dangerous combination. Keep electrical equipment away from water and damp areas.
2. **Report Faulty Equipment:** Immediately report any damaged or faulty electrical equipment, cords, or outlets.

3. **Regular Inspections:** Conduct routine inspections of electrical equipment and systems to identify potential hazards.
4. **Avoid Working Alone:** If possible, avoid working alone on electrical equipment, especially if it involves potential hazards.
5. **Never Touch a Person in Contact with Electricity:** If someone is in contact with electricity, do not touch them. First, turn off the power source or use a non-conductive object to separate the person from the electrical source.

1c.Electrocution (Electric shock) and How to free a person from electrocution.

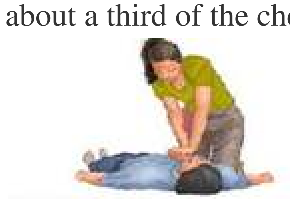
1. Don't touch the person: Do not go near or touch the person until you are sure the electrical supply has been switched off.

2. Be careful in areas that are wet such as bathrooms, pool areas, and wet grounds. Water is an electrical conductor and you may get electrocuted. If you're uncertain about wet grounds, make sure the main electricity supply of the house or building is turned off

.

3. Separate the Person from Current's Source: To turn off power: Unplug an appliance or shut off power via circuit breaker, fuse box, or outside switch. If you can't turn off power, stand on something dry and non-conductive, such as dry newspapers or wooden board and then try to separate the person.

4. If the person is unconscious and has stopped breathing, begin cardiopulmonary resuscitation (CPR). Position your hand in the center part of the chest, about a couple of inches above the end of the breastbone. Push hard and fast to about a third of the chest diameter. Give 30 compressions.



5. If the person is conscious and breathing is normal, and if burns are present, cover with ordinary cling wrap or other non-adhesive dressing, but no ointment or lotion

6. As soon as the victim has been freed from the electrical source, call for an ambulance or medical help if you are alone with the patient.

1d).First aid in Electrical injury and methods

First aid for electrical injuries involves ensuring safety, checking for responsiveness, breathing, and providing appropriate care for burns or other injuries. Do not touch the victim with bare hands if they are still in contact with the electricity.

1. **Ensure Safety:** Prioritize your own safety and the safety of others. Disconnect the power source if possible or use a non-conductive object to move the source away from the victim.
2. **Check for Responsiveness and Breathing:** If the victim is unresponsive and not breathing, begin CPR immediately.
3. **Control Bleeding:** Apply pressure to any bleeding wounds.
4. **Treat Burns:** Cool the burn with cool running water for at least 10 minutes, and then cover it with a sterile, non-adhesive dressing.
5. **Monitor Vital Signs:** Continuously monitor the victim's breathing and responsiveness while waiting for emergency medical services.
6. **Call for Help:** If the injury is severe or the source of electricity is high voltage, call emergency services immediately.
7. **Keep Warm:** Electric shock can cause hypothermia. Help the victim maintain body temperature by covering them with a blanket or clothing.
8. **Avoid Movement:** Unless there is immediate danger, avoid moving the victim, as this could worsen potential spinal injuries.

1e).Electrical fire, causes and preventions, Fire extinguishers and types

An **electrical fire** is a fire caused by a malfunction or failure in electrical components such as wiring, outlets, appliances, or circuit breakers. These fires start due to heat generated from electrical energy.

Causes of Electrical Fires:

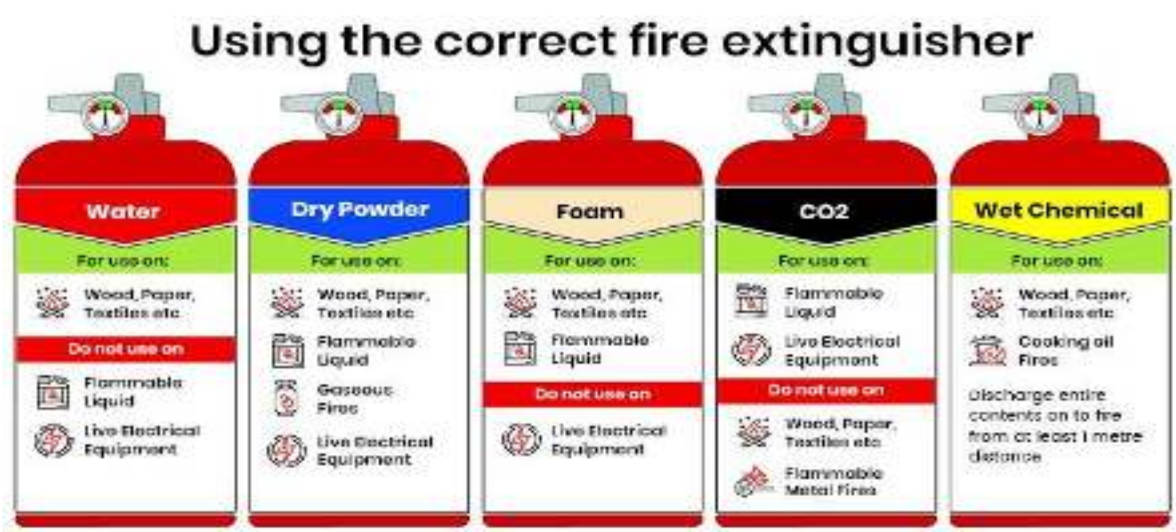
1. **Faulty wiring:** Old, damaged, or improperly installed wiring can overheat and ignite nearby materials.
2. **Overloaded circuits:** Plugging too many high-wattage appliances into a single circuit can cause it to overheat and spark.
3. **Malfunctioning appliances:** Appliances with faulty heating elements, cords, or plugs can overheat and cause fires.
4. **Damaged cords and plugs:** damaged cords and plugs can expose wires and create a fire hazard.
5. **Loose electrical connections:** Loose connections can generate heat and lead to arcing, which can ignite nearby materials.

Prevention of Electrical Fires:

1. **Regular electrical inspections:** electrician has to inspect the electrical system regularly to identify potential problems.
2. **Proper wiring:** Ensure that all wiring is properly installed and meets safety standards.
3. **Avoid overloading circuits:** Distribute electrical loads evenly across circuits and avoid plugging too many high-wattage appliances into one outlet.
4. **Use appliances safely:** Follow manufacturer's instructions for using appliances and avoid overloading them.
5. **Replace damaged cords and plugs:** Replace any damaged cords or plugs immediately.
6. **Keep electrical equipment clean and dry:** Dust and moisture can create a fire hazard.
7. **Use surge protectors:** Protect electronics from power surges with a surge protector.
8. **Work done by professionals:** Do not attempt to repair electrical wiring or equipment yourself
9. **Electrical Safety Plan:** Create a plan for how to handle electrical emergencies.

Types of fire extinguishers

Class of Fire	**Description**
Class A Fires	Ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics. – fire extinguisher -water ,foam
Class B Fires	Fires in flammable liquids, combustible liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases. fire extinguisher -Foam ,co2,dry powder
Class C Fires	Fires that involve energized electrical equipment. fire extinguisher --Co2
Class D Fires	Fires in combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium. fire extinguisher -Chemical powder
Class K Fires	Fires in cooking appliances that involve combustible cooking media (vegetable or animal oils and fats). fire extinguisher -wet chemical powder



1f).Types of Electrician Tools and their functions

Electricians use a wide variety of tools to safely install, maintain, and repair electrical systems. These tools are essential for working with wires, circuits, and devices.

HAND TOOL

1. **Pliers:** for gripping, bending, twisting, and cutting wires. Different types include lineman's pliers, needle-nose pliers.
2. **Screwdrivers:** Used for tightening and loosening screws on electrical components and fixtures. Common types include flathead and specialized insulated screwdrivers for safety.
3. **Wire Strippers:** Designed to remove insulation from wires without damaging the conductor. Some have adjustable jaws for different wire gauges.
4. **Electrical Tape:** Used for insulating and protecting wires and connections.
5. **Hacksaw:** Used for cutting metal conduits or other materials.
6. **Utility Knife:** Used for cutting various materials, including wire insulation, and sometimes for stripping wires in a pinch.
7. **Crimping Tool:** Used to secure connectors to wires, creating a strong and reliable connection.
8. **Fish Tape:** Used to pull wires through walls, conduits, and other tight spaces.
9. **Tape Measure:** Used for accurate measurement of wire lengths, distances for mounting and other critical dimensions.
10. **Level:** Used to ensure that electrical boxes, conduits, and other components are installed level.

POWER TOOLS:

1. **Drills:** Used to create holes for mounting electrical boxes, running wires, and installing various components.
2. **Hole Saw:** Used to cut larger diameter holes in various materials.
3. **Knockout Punch Set:** Used to create holes in electrical boxes or panels for conduit entry.

MEASURING & TESTING EQUIPMENT:

1. **Multimeter:** An instrument used to measure voltage, current, and resistance in electrical circuits.
2. **Voltage Tester:** Used to detect the presence of voltage in a circuit, ensuring safety before working on electrical components.
3. **Circuit Tester:** Similar to a voltage tester, but may offer additional features like indicating the presence of a short circuit.

ADDITIONAL TOOLS & ACCESSORIES:

1. **Gloves (Insulated):** Essential for protecting electricians from electrical shock.
2. **Conduit Bender:** Used to bend electrical conduit to the desired angle.
3. **Flashlight:** Essential for working in dimly lit areas.
4. **Tool Bag or Belt:** Used to organize and carry tools efficiently

1g).Earthing; Definition, necessity and types Advantages of Earthing

Earthing (or grounding) is the process of connecting the non-current-carrying parts of electrical equipment (like metal frames) to the **ground (earth)**.This ensures that any **fault current** is safely discharged into the ground, preventing electric shocks and equipment damage.

Necessity of Earthing:

1. **Safety of Human Life :** Prevents electric shock in case of insulation failure.
2. **Protection of Equipment:** Diverts fault currents safely to the ground.
3. **Voltage Stabilization:** Maintains a consistent voltage level in the system.
4. **Fire Prevention:** Prevents sparks and overheating caused by leakage currents.
5. **Protection from Lightning:** Provides a safe path for lightning discharge.

Types of Earthing:

1. Plate Earthing:	A copper or GI plate is buried in the ground with charcoal and salt to improve conductivity.
2. Pipe Earthing:	A GI pipe is used vertically in the ground; suitable for high soil resistance.
3. Rod Earthing:	Copper or GI rods are driven into the earth; economical and effective.
4.Strip or Wire Earthing;	Copper/GI strips are buried horizontally; used in rocky soils or large installations.

Advantages of Earthing:

1. **Prevents Electric Shock ;** Ensures user safety during fault conditions.
2. **Protects Equipment :** Saves appliances from overvoltage or faults.
3. **Reduces Risk of Fire :** Prevents overheating and arcing.
4. **Improves Voltage Stability:** Maintains system reliability.
5. **Provides Safe Fault Path:** Fault currents are safely discharged to earth.

WEEK-2

2a).Sources of Electricity- Conventional and Non-conventional sources

Definition: Conventional sources of electricity are traditional methods of generating power that are **widely used, non-renewable**, and mostly based on **fossil fuels** or **natural resources** that take millions of years to form.

Conventional Sources of Electricity:

1. Thermal Power:	Generated by burning **coal, oil, or natural gas** to produce steam, which drives turbines.
2. Hydroelectric Power;	Produced by using **water flow** (from dams) to spin turbines.
3. Nuclear Power:	Electricity generated through **nuclear fission** (usually uranium), which produces heat to generate steam.
4. Diesel Power:	Small-scale generation using **diesel engines**, often used in backup systems.
5. Natural Gas power:	Similar to thermal power, but uses **natural gas** which is cleaner than coal or oil.

Sources of Electricity – Non-Conventional Sources

Definition: Non-conventional sources of electricity also known as **renewable energy sources** are **eco-friendly, sustainable**, and **naturally replenished** sources used to generate electricity. They help reduce pollution and dependence on fossil fuels.

Non-Conventional Sources of Electricity:

1. Solar Energy :	Electricity is produced using **solar panels (photovoltaic cells)** that convert sunlight into electrical energy.
2. Wind Energy:	**Wind turbines** convert the kinetic energy of wind into electricity.
3. Biomass Energy:	Organic materials (like wood, crop waste, animal dung) are burned or converted into gas to produce power.
4. Tidal Energy ;	Electricity is generated by the **movement of ocean tides** through turbines.
5. Geothermal Energy:	Heat from beneath the Earth's surface is used to produce steam that runs turbines.
6. Ocean Wave Energy :	Uses the up-and-down movement of sea waves to drive electric generators.
7. Hydrogen Fuel Cells ;	Hydrogen reacts with oxygen to produce electricity, with water as the only by-product.

2b).Advantages of electrical energy

Electrical energy is one of the most widely used and essential forms of energy in modern life. It is versatile, clean at the point of use, and easy to control.

Major Advantages of Electrical Energy:

1. **Easy to Use;** Can be easily switched on/off, controlled, and distributed.
2. **Highly Versatile:** Can power homes, industries, transport, lighting, communication, and more.
3. **Clean;** Produces **no smoke or pollutants** during use (e.g., fans, lights).
4. **Easily Transmitted;** Can be transmitted over long distances with minimal loss using high-voltage lines
5. **Instant Availability:** Ready to use instantly - no need for preparation like fuel.

6. **Can Be Generated from Renewables:** Can be produced from solar, wind, hydro, and other eco-friendly sources.
7. **Economic:** Cost-effective when generated and distributed at large scale.
8. **Safe and Reliable:** Safe if proper insulation and protective devices are used.

2c). Effects of electric current and its applications

Electric current, the flow of electric charge, has several key effects: heating, magnetic, and chemical. These effects are utilized in a wide range of applications, from everyday appliances to industrial processes.

1. Heating Effect: When electric current flows through a conductor, it generates heat due to the resistance of the material.

Applications:

a. **Electric Heaters:** Electric heaters utilize the heating effect to warm rooms.
b. **Electric Irons:** Irons use the heating effect to remove wrinkles from clothes.
c. **Toasters:** Toasters heat bread using the heating effect of current.
d. **Bulbs:** Incandescent bulbs produce light by heating a filament until it glows.
e. **Fuses:** Fuses are safety devices that melt and break the circuit when excessive current flows, preventing damage.

2. Magnetic Effect: Electric current creates a magnetic field around the conductor.

Applications:

a. **Electric Motors:** Motors convert electrical energy into mechanical energy using the magnetic effect.
b. **Electric Bells:** Electric bells use electromagnets to produce sound.
c. **Generators:** Generators convert mechanical energy into electrical energy using the magnetic effect.
d. **Transformers:** Transformers use the magnetic effect to step up or step down voltage.
e. **Lifting Magnets:** Powerful electromagnets used for lifting heavy metallic objects.
f. **Magnetic Resonance Imaging (MRI):** MRI machines use strong magnetic fields generated by electric currents to create detailed images of the human body.

3. Chemical Effect: When electric current flows through a solution (electrolyte), it can cause chemical reactions.

Applications:

a. **Electroplating:** Electroplating deposits a thin layer of one metal onto another using electric current.
b. **Batteries:** Batteries use chemical reactions to produce electric current.
c. **Electrolysis:** Electrolysis uses electric current to decompose compounds.
d. **Purification of Metals:** Electrolysis can be used to purify certain metals.
e. **Production of Chemicals:** Electric current can drive chemical reactions to produce various chemicals.

2d).Definition, units and meters; Electric Current, Voltage, Resistance, Potential Difference, EMF

An electric current is a flow of electrons flowing through wires and components. It is the rate of flow of charge. The SI Unit of electric current is the Ampere. It is represented by 'A'.SI Unit: Ampere (A), Measuring Instrument: Ammeter (connected in series)

Voltage is the pressure from an electrical circuit's power source that pushes charged electrons (current) through a conducting loop, enabling them to do work such as illuminating a light.**SI Unit: Volt (V), Measuring Instrument: Voltmeter** (connected in parallel)

EMF; EMF is the force which makes current continuously flows through a conductor. EMF is measured in unit called VOLT.**SI Unit: Volt (V), Measuring Instrument: Voltmeter** or **EMF meter**

Potential difference: the difference between two point of higher potential and lower potential is called potential difference.**SI Unit: Volt (V)** (same as voltage), **Measuring Instrument: Voltmeter**

Resistance: The property of a conductor by virtue of which it opposes the flow of electric current through it is called resistance. Resistance is measured in ohms and it is represented by the letter ohms (Ω).SI Unit: Ohm (Ω), Measuring Instrument: Ohmmeter **or** Multimeter

2e).Ohm's Law; Statement, explanation, Applications and limitations.

Ohm's Law states that the current flowing through a conductor is directly proportional to the voltage across it; provided the temperature and physical conditions remain constant. This is called Ohm's Law.

$V \propto I$

VI=Constant=R (Resistance)

$V \propto I$

$V = IR$

R is called the resistance of the conductor.

S.I Unit of R - Ohm

Explanation:

Ohm's Law explains the relationship between **voltage, current, and resistance** in an electric circuit:

Direct Proportionality between Voltage and Current: If increase the voltage in a circuit while keeping the resistance constant, the current will increase proportionally. For example, if double the voltage, the current will also double.

Inverse Proportionality between Current and Resistance: If increase the resistance in a circuit while keeping the voltage constant, the current will decrease proportionally. For example, if double the resistance, the current will be halved.

Key Components:

- **Voltage (V):** The electrical potential difference that drives the current, measured in volts.
- **Current (I):** The flow of electrical charge, measured in amperes (amps).
- **Resistance (R):** The opposition to the flow of current, measured in ohms.

Applications of Ohm's Law

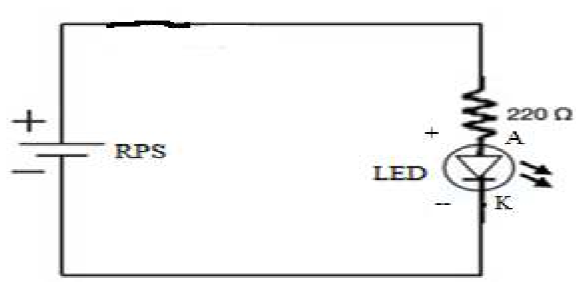
Application	Use
1. **Design of Electrical Circuits**	Used to calculate current, voltage, and resistance.
2. **Household Wiring**	Ensures safe current flow through appliances.
3. **Battery and Charger Testing**	Helps check if components operate within rated limits.
4. **Troubleshooting Circuits**	Used with multimeters to detect faults in resistors or wires.
5. **Electric Power Calculation**	Power $P=VI=I^2R$ = V^2/R depends on Ohm's Law.

Limitations of Ohm's Law

1. **Not Valid for Non-Ohmic Materials**	Does not apply to semiconductors like diodes and transistors.
2. **Temperature Dependence**	Resistance may change with temperature, affecting accuracy.
3. **Not Suitable for AC Circuits**	Pure Ohm's Law applies to DC; AC involves reactance/impedance.
4. **Applies Only to Linear Circuits**	Not valid if the V-I relationship is non-linear.

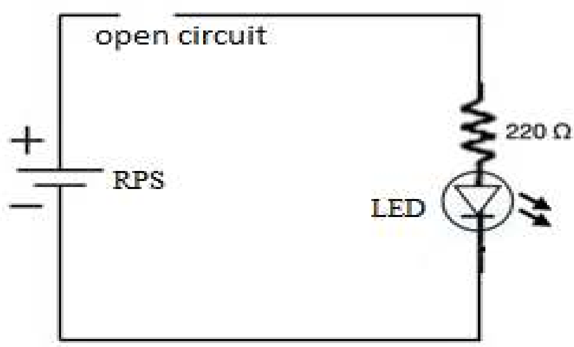
2f).Circuit conditions- open, close, and short circuit

Closed Circuit:A closed circuit is a complete and continuous path for electrical current to flow from a power source (like a battery) to a load (like a bulb) and back to the source. Current flows through all components in the circuit. A closed circuit is the normal operating condition for most electrical devices.



Open Circuit: An open circuit is a break in the electrical path, preventing the flow of current. This break can be caused by a switch being open, a wire or a component failing.

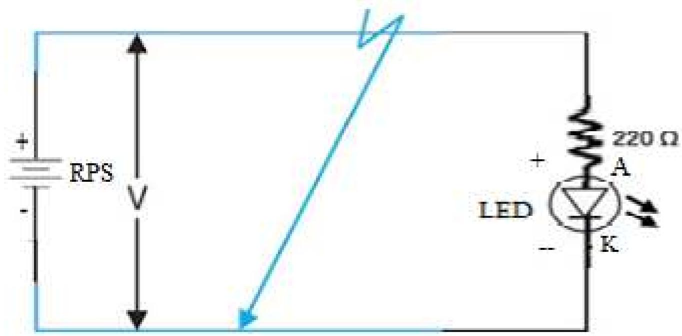
a. In an open circuit, the load (e.g., a bulb) will not light up because current cannot reach it.
b. A fuse blowing is an example of an intentional open circuit, designed to protect the circuit.



Short Circuit: A short circuit occurs between two points in a circuit that should have a voltage difference. This path bypasses the intended load, causing a large surge of current.

a. Short circuits can be dangerous, potentially leading to overheating, fires, or damage to components.

b. They can be caused by faulty wiring, damaged insulation, or accidental contact between wires.



WEEK-3

3a).Features of Series and Parallel circuits

Features of a Series Circuit:

1. Single Path for Current: Current flows through one continuous path. If the path is broken, the entire circuit stops working.

2. **Same Current:** The **same amount of current** flows through **all components**.

$I_{total} = I_1 = I_2 = I_3$

3. Voltage is divided: The total voltage is **shared** across each component:

Drop across each component:

$V_1 = IR_1$, $V_2 = IR_2$, etc

$V_{Total} = V_1 + V_2 + V_3 + \ldots$

4. Resistance Adds Up: total resistance is the **sum of individual resistances**:

$R_{total} = R_1 + R_2 + R_3 + \ldots$

5. One Component Affects All: If **one component fails**, the **entire circuit stops** working.

6. Simple Design:. Easier to design and build with fewer wires.

7. Not Suitable for Home Use: Not ideal for circuits where devices need to work independently.

Features of a Parallel Circuit

A **parallel circuit** is one where electrical components are connected **side by side**, forming **multiple paths** for current to flow.

1. **Multiple Paths for Current:** Each component has its **own independent path**. If one path is broken, **others still work**.
2. **Voltage is the same across All Components:** Each branch gets the **full supply voltage**. Vtotal=V1=V2=V3…
3. **Current is divided;** Total current is **split among the branches**, based on their resistance. I1=V/R1 , I2=V/R2 , I3=V/R3

   Itotal=I1+I2+I3+…

4. **Total Resistance:** Total resistance **decreases** as more branches are added: 1Rtotal=1R1+1R2+…

5. **Independent Operation;** Devices work **independently** — turning one off doesn't affect the others.

6. **Used in Homes and Buildings:** Common in household wiring — fans, lights, sockets operate separately.

7.**More Complex Wiring;** Needs more wires than a series circuit but offers better control and safety

3b).Simple problems on Series circuit

Example Problem 1: A circuit has a 12V battery and three resistors with values 10Ω, 20Ω, and 30Ω connected in series. **Calculate the total resistance:**

Total resistance (R_T) = $R_1 + R_2 + R_3$

R_T = 10Ω + 20Ω + 30Ω = 60Ω

Calculate the current (I):

Using Ohm's Law (V = IR), I = V / R

I = 12V / 60Ω = 0.2A

Calculate the voltage drop across the 20Ω resistor:

Voltage drop (V_{20}) = I * R_2

V_{20} = 0.2A * 20Ω = 4V

Example Problem 2:A series circuit has a total voltage of 24V and a total resistance of 12Ω. If one resistor is 4Ω, calculate the voltage drop across it. **Calculate the current (I):**

I = V / R

I = 24V / 12Ω = 2A

Calculate the voltage drop across the 4Ω resistor:

V_4 = I * R

V_4 = 2A * 4Ω = 8V

3. Find Total Resistance in a Series Circuit: Three resistors are connected in series:

R1=5 Ω,
R2=10 Ω,
R3=15 Ω
Rtotal=R1+R2+R3=5+10+15=30 Ω

4. Find the Current Using Ohm's Law: A 12V battery is connected to a series circuit with total resistance of 6 Ω6. Find the current.

Solution:
I=V/R
=12 V/6 Ω=2 A

5. Voltage Drop across Each Resistor: In a series circuit with a 24V supply and resistors:

R1=2 Ω
R2=4 Ω
R3=6 Ω
Find the voltage drop across each resistor.

Step 1: Total Resistance
Rtotal=2+4+6=12 Ω

Step 2: Find Total Current
I=V/R=24/12=2 A

Step 3: Voltage Drops (V = I × R)
V1=2×2=4 V
V2=2×4=8 V
V3=2×6=12 V
Total: 4+8+12=24 V

Simple problems Parallel circuit.

1. Two Resistors in Parallel; given = 10 Ω, R_2 = 5 Ω, Find the total resistance (R).

Solution:
1/Rt=1/10+1/5
=0.1+0.2 =0.3
Rt= 1/Rt
=1/0.3 = 3.33 ohms

2: find Current in Each Resistor; Given: Voltage = 12V,R_1 = 6 Ω, R_2 = 3 Ω (in parallel)

Solution:
Use Ohm's Law I1=V/R1,I2=V/R2
I1=12/6=2 A
I2=12/3=4 A

Problem 3: Three Resistors in Parallel: Given$_1$ = 4 Ω, R_2 = 6 Ω, R_3 = 12 Find total resistance.

Solution:
1/Rt=1/4+1/6+1/12

=0 .25+0.16+0.08 =0.49

Rt =1/Rt = 1/0.49

= 2.04 ohms

Problem 4: Find Total Current: Given = 18V,R_1 = 9 Ω, R_2 = 3 Ω (parallel)

Step 1:
1/Rt=1/9+1/3
=0.11+0.33 =0.44
Rt=1/Rt
=1/0.44 = 2.27 ohms
Step 2:
I=V/Rt=18/2.27=8 A

5. A parallel circuit with two resistors: R1 = 10 ohms and R2 = 5 ohms. A 12V battery is connected to this circuit. Find total current.

Calculations:
Total Resistance (R_total):
1/R_total = 1/R1 + 1/R2
1/R_total = 1/10 + 1/5
1/R_total = 3/10
R_total = 10/3 ohms ≈ 3.33 ohms
Current through R1 (I1)
I1 = V / R1
I1 = 12V / 10 ohms
I1 = 1.2 Amps
Current through R2 (I2)
I2 = V / R2
I2 = 12V / 5 ohms
I2 = 2.4 Amps
Total Current (I_total)
I_total = I1 + I2
I_total = 1.2A + 2.4A
I_total = 3.6 Amps

WEEK-4

4a).Definitions, units and meters; Electrical work, power and energy

Definition of Electrical Work: Electrical work is done when electric current flows through a circuit under the influence of voltage for a specific time. **Formula:** W=V×I×t

Where:

- W = Electrical work (Joules)
- V = Voltage (Volts)
- I = Current (Amperes)
- t = Time (Seconds)

SI Unit: Joule (J) ,(1 Joule = 1 Volt × 1 Ampere × 1 Second)
Measuring Instrument: It's calculated from current, voltage, and time (using a **voltmeter**, **ammeter**, and **stopwatch** or **time recorder**).

Definition of Electrical Power: Electrical power is the rate at which electrical work is done.
Formula: Power (P) = Voltage (V) * Current (I) ,**Unit:** Watt (W)*Measuring Instrument:* **Wattmeter**

Definition of Electrical Energy; Electrical energy is the total amount of work done by the electric current over time.**Formula:**E=P×t=V×I×t .**SI Unit: Joule (J),** (1 Joule = 1 Watt × 1 Second)

Commercial Unit: Kilowatt-hour (kWh),1 kWh = 1000 Watts × 3600 seconds = **3.6×10^6 Joules**
Measuring Instrument: Energy Meter (also called kilowatt-hour meter)

4b).Simple problems on Electrical energy consumption (Unit/ KWh)

Problem 1: A 1000 W electric heater is used for 5 hours daily. Calculate the energy consumed in 1 day and in 30 days.

Solution:
Power = 1000 W = 1 kW
Time per day = 5 hours
Energy/day=1×5=5 kWh
Energy in 30 days=5×30x1=150 kWh

Problem 2: A 60 W fan runs for 10 hours a day. Find the energy consumed in 10 days.

Solution:
Power = 60 W = 0.06 kW
Time/day = 10 hours
Energy/day=0.06×10=0.6 kWh
Energy in 10 days=0.6×10=6 kWh

Problem 3: Find the total energy consumed by the following appliances used for 2 hours:

- 1.5 kW geyser
- 100 W bulb
- 250 W refrigerator

Solution:

Total Power = 1500 + 100 + 250 = 1850 W = 1.85 kW

Time = 2 hours

Energy=1.85×2=3.7 kWh

Problem 4: A household uses 250 units (kWh) of electricity in a month. If the cost per unit is Rs 6.50, find the total bill.

Solution:

Cost=250×6.50=1625

Problem 5:A 200 W computer runs for 8 hours per day for a week. Calculate the energy consumption.

Solution:

Power = 200 W = 0.2 kW

Time/day = 8 hours

Total time = 8 × 7 = 56 hours

Energy=0.2×56=11.2 kWh

4c).AC Fundamentals: Sinusoidal voltage, current, definitions of amplitude, cycle, time-period, frequency

A **sinusoidal voltage or current** varies with time in the shape of a sine wave. This is the most common form of alternating current (AC).**General Equation for Voltage** (t)=Vmsin(ωt+ϕ)

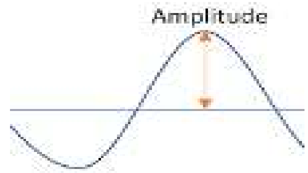
Current: i(t)=Imsin(ωt+ϕ)

Where:

- Vm, Im: Maximum value (Amplitude)
- ω: Angular frequency (rad/s) = 2πf
- t: Time (seconds)
- ϕ: Phase angle (degrees or radians)

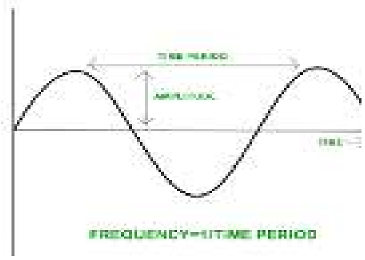
Amplitude: The **maximum value** of voltage or current from its average (zero) value.

Symbol: Vm for voltage, Im for current . **Unit**: Volts (V) or Amperes (A). A full sine wave from 0→+Vm→0→−Vm→0 is **one cycle**.



Time Period (T): The **time taken** to complete one full cycle of the waveform is called time period

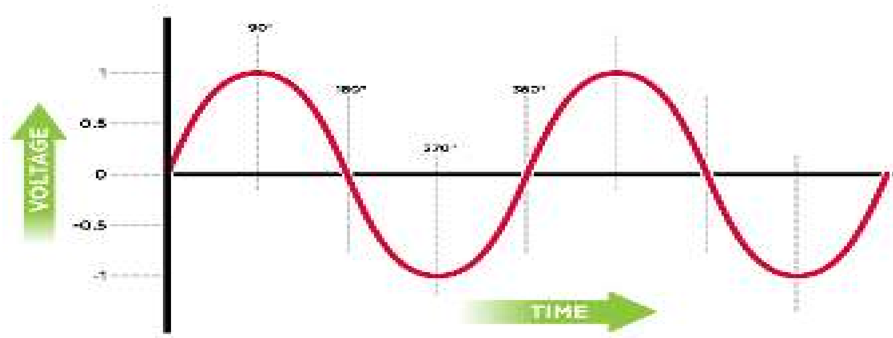
- Symbol: T,**Unit**: Seconds (s)Formula:T=1/f



Frequency (f): Frequency is the number of cycles of the waveform that occur in one second. It's the reciprocal of the time period (f = 1/T).Frequency is measured in Hertz (Hz)

4d).Single phase and Three phase electrical power supplies

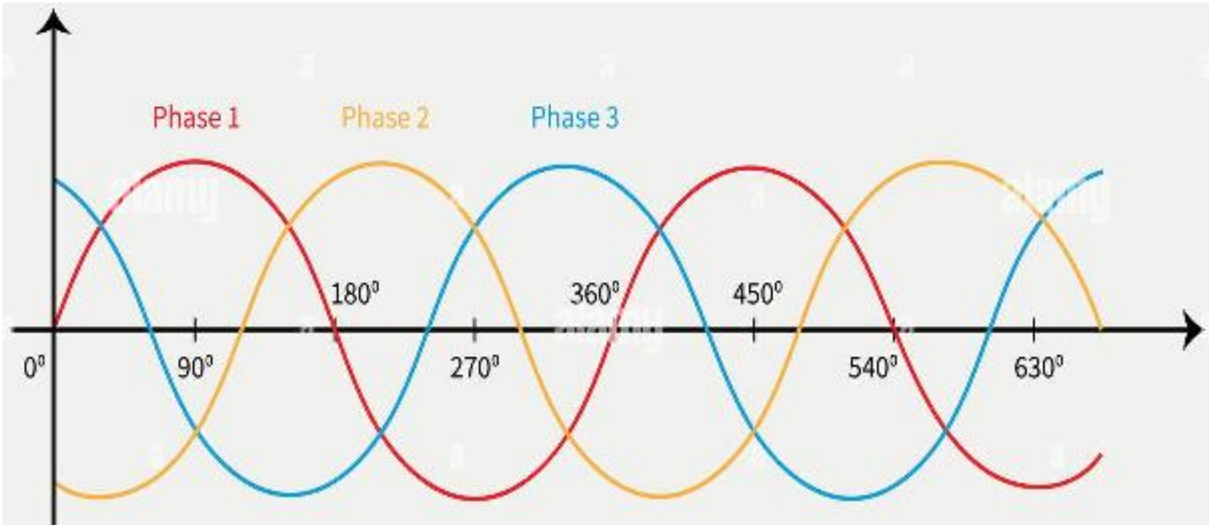
Single Phase Supply: Single-phase supply is an electrical distribution system where power is transmitted using only one alternating current (AC) waveform. It involves a single voltage sinusoidal waveform. The rating of single phase voltage is 230v, 50Hz.



Characteristics:
1. Commonly found in residential settings.
2. Consists of two wires – one live (hot) wire and one neutral wire.
3. Voltage fluctuates between positive and negative in a sinusoidal manner.

Uses: Typically used for powering small appliances, lighting, and other domestic applications.

Three Phase Supply: Three-phase supply is an electrical distribution system where power is transmitted using three alternating current waveforms, usually 120 degrees out of phase with each other It consists of three live (phase) wires. This involves three waveforms of alternating current (AC), each 120 degrees out of phase with the others



Characteristics

1. Common in industrial and commercial settings.
2. Involves three live (hot) wires and one neutral wire.
3. provides a more constant and balanced power flow.

Uses: Widely used in industrial machinery, motors, large-scale HVAC systems, and other heavy-duty

4e).Applications of single-phase and three-phase power

Single-Phase Power Applications:

1. Residential Use:

- Homes and apartments
- Lighting, fans, TVs, refrigerators, washing machines

2. Small Commercial Buildings:

- Small offices, shops, clinics
- Computers, printers, small air conditioners

3. Portable Equipment:

- Drills, grinders, welding machines
- Small motors (up to ~2 HP)

4. Rural or Remote Areas:

- Areas with low power demand
- Agriculture pumps (small scale)

5. Household Appliances:

- Microwave ovens, induction cooktops
- Water heaters and geysers

Three-Phase Power Applications:

1. Industrial and Manufacturing:
- Factories, mills, large production units
- Heavy-duty motors, pumps, compressors

2. Large Commercial Establishments:
- Hospitals, malls, multiplexes, hotels
- Central air conditioning, lifts, escalators

3. Power Transmission and Distribution:
- Used by power utilities for efficient transmission
- Reduces copper losses and voltage drop

4. Data Centers and IT Parks:
- High load equipment like servers, HVAC systems

5. Electric Vehicles and Charging Stations:
- Fast-charging EV stations
- Industrial automation setups

4f).Merits of three phase system over single phase system.

1. To transmit a specific power over a specific distance at a given rated voltage, a three phase system needs less conductor material as compared to the single phase system.
2. In a three phase power supply system, the less voltage drop occurs from source to the load points,
3. A three phase supply produces uniform rotating magnetic field therefore, three phase motors are simpler in construction, small in size and can be started automatically with smooth operation.
4. A three phase system can transmit more power as compared to a single phase system.
5. The efficiency of three phase operated devices and appliances is higher than the single phase operated machines.
6. A three phase system provides constant power while a single phase system provides pulsating power .
7. The output rating of machines can be increased by increasing the number of phases in a system.
8. A single phase supply can be obtained from three phase supply to run the 1-phase machines. A three phase machine can’t be operated on single phase supply voltage.
9. If a fault occurs on a single phase line, the whole system will have to shut down. In case of three phase single line fault, the other two lines provide the power supply to other single phase load points connected to them.
10. A three phase motor provides uniform torque while single phase motors (expect commutator motors) provides pulsating torque.
11. Three phase motors are self-started while single phase motors can’t be started automatically.
12. A three phase alternator can be easily paired and run in parallel operation as compared to single phase alternators having the pulsating armature reaction.
13. Three phase motors have better power factor as compared to single phase motors.

WEEK-5

5a).Protective Devices: Protective devices **are electrical components used to** protect electrical circuits, equipment, and people **from** damage or danger **caused by electrical faults like** overcurrent, short circuits, earth faults, or voltage surges**.**

Purpose:

- To **prevent electrical fires**
- To **protect appliances and machinery**
- To **ensure safety of human life**

5b).Necessity of protective devices

Protective devices are essential for ensuring safety in electrical systems by preventing damage to equipment and safeguarding individuals from electrical hazards. They achieve this by detecting abnormal conditions like overcurrent, short circuits, and overvoltage, and then automatically disconnecting the power supply.

1. Protecting Equipment:

1. Preventing Damage: Protective devices, such as fuses and circuit breakers, are designed to interrupt the flow of excessive current that can damage electrical equipment, motors, and other components.

2. Limiting Fault Currents: They limit the magnitude and duration of fault currents (e.g., short circuits), minimizing the potential for overheating, arcing, and fire hazards.

3. Maintaining System Stability: By isolating faulty sections of a circuit, protective devices help prevent cascading failures and maintain the overall stability of the electrical system.

2. Protecting People:

1. Preventing Electric Shock: Protective devices like Residual Current Circuit Breakers (RCCBs) detect leakage currents to ground and quickly disconnect the power, preventing electric shock and electrocution.

2. Reducing Fire Hazards: By preventing overheating and arcing, protective devices help reduce the risk of electrical fires.

3. Providing Safety in Faulty Situations: In the event of a fault, protective devices act as a "fail-safe" mechanism, quickly interrupting the circuit and preventing further harm.

5c).Functions and Applications of Rewireable Fuse

A rewireable fuse (also known as a kit-kat fuse) is a protective device used in electrical circuits to protect against overcurrent. It contains a fuse wire that melts when excessive current flows, thereby breaking the circuit.

Functions of a Rewireable Fuse:

1. Overcurrent Protection: It disconnects the circuit when the current exceeds the safe limit.
2. Short Circuit Protection: It melts instantly during a short circuit to avoid damage to the system.
3. Isolation: By blowing, it isolates the faulty circuit from the rest of the system.
4. Resettable: The fuse can be rewired easily with a new wire after it blows — making it reusable.
5. Simple Operation: No mechanical parts, operates on the principle of thermal melting of fuse wire.

Applications of a Rewireable Fuse:

Homes	:Used in old household distribution boards
Small Commercial Buildings	:Light-duty circuits like lighting and fans
Workshops	:Protection of low-power tools and machines
Laboratories	:Used for circuit protection in basic setups
Rural Areas	:Still widely used due to **low cost** and **easy maintenance**

5d).Functions and Applications of Glass cartridge fuse

Glass cartridge fuses are primarily used to protect electrical circuits from overcurrent and short circuits. Its transparent glass body allows for easy visual inspection to identify blown fuses. They are widely used in various applications, including household appliances, automotive circuits, and industrial equipment.

Functions:

1. **Overcurrent Protection:** Glass cartridge fuses are designed to interrupt the flow of current when it exceeds the limits
2. **Short Circuit Protection:** They also safeguard circuits from short circuits, where a low-resistance path is created, causing a large surge of current.
3. **Visual Indication:** The transparent glass body allows for quick visual inspection to determine if the fuse has blown, making troubleshooting easier.
4. **Circuit Isolation:** When a fuse blows, it isolates the faulty section of the circuit

Applications: Household Appliances:

They are commonly found in various appliances like refrigerators, air conditioners, and washing machines, protecting their internal circuits.

1. **Automotive Circuits:** Glass cartridge fuses are used in automotive electrical systems to protect various circuits like lighting, power windows, and audio systems.
2. **Industrial Equipment:** They are utilized in industrial machinery and power distribution systems to protect motors, transformers, and other sensitive components.

3. **Electronic Devices:** Miniature glass cartridge fuses are used in electronic devices and circuit boards to protect components.
4. **General Purpose Protection:** They are also used in a wide range of applications where a overcurrent and short circuit protection solution is needed.

5e).Functions and Applications of HRC fuse

HRC (High Rupturing Capacity) fuses are primarily used to protect electrical circuits from overcurrent, including short circuits and overloads. They are designed to interrupt high fault currents safely and reliably, preventing damage to equipment and preventing electrical fires.

Functions of HRC Fuses:

1. **Overcurrent Protection:** HRC fuses are designed to interrupt fault currents that exceed a specified limit, preventing damage to circuits and connected equipment.
2. **Short Circuit Protection:** They effectively handle short circuit currents, which are high-magnitude currents that can cause significant damage.
3. **Overload Protection:** HRC fuses can also protect against overloads, which are currents that are higher than the normal operating current but not as high as a short circuit current.
4. **Arc Extinction:** in HRC fuses the filling powder within the ceramic body, helps to extinguish the arc
5. **Industrial Control Circuits:** They are integrated into motor control centers, switchgear, and control panels to protect equipment from overcurrents and short circuits.
6. **Power Distribution Systems:** HRC fuses are used in power distribution networks to protect transformers, feeder lines, and other critical components.

Industrial Applications:

1. **Protection of Cables and Bus-bars:** HRC fuses are crucial for safeguarding cables and bus-bars, which are conductors that carry large currents, in industrial settings.
2. **Motor Protection:** They are used to protect motors from overloads and short circuits.
3. **Transformer Protection:** HRC fuses are vital for protecting transformers from damage caused by overcurrent and short circuits.
4. **Switchgear and Control Panels:** They are integrated into switchgear and control panels to protect associated equipment from overcurrent and short circuits.
5. **Industrial Distribution Systems:** HRC fuses are used in industrial distribution systems to isolate faulty circuits and prevent system instability.

Other Applications:

1. **Automotive Industry:** HRC fuses are sometimes used in automotive electrical systems for protection.
2. **Residential Use:** HRC fuses can be found in residential electrical circuits for overcurrent protection.

3. **Renewable Energy Systems:** HRC fuses are used in solar and wind power generation to protect against overcurrent.
4. **Transportation:** HRC fuses are also used in trains and other transportation systems.

5f).functions and applications of Kit-kat fuse

Kit-Kat fuses, also known as rewirable fuses, are designed to protect electrical circuits from overcurrents and short circuits. They function by interrupting the flow of electricity when the current exceeds a safe level, preventing damage to equipment and potential fire hazards.

Functions:

1. **Overcurrent Protection:** Kit-Kat fuses contain a fuse element (typically a wire) that melts and breaks the circuit when the current exceeds the fuse's rated capacity.
2. **Short Circuit Protection:** They effectively interrupt the circuit during short circuit events, where a large surge of current flows due to a fault.
3. **Safety Mechanism:** The primary function is to safeguard electrical equipment and prevent potential fire hazards.

Applications:

1. **Residential Wiring:** Used in homes for protecting appliances and general lighting circuits.
2. **Commercial Buildings:** Applied in various circuits within commercial establishments.
3. **Low-Voltage Systems:** Suitable for systems where the fault currents are relatively low.
4. **Overcurrent Protection:** Kit Kat fuses are designed to melt and break the circuit when the current flowing through them exceeds their rated capacity.
5. **Short Circuit Protection:** They also protect against short circuits.
6. **Industrial and Commercial:** They are widely used in various industrial and commercial applications.

5g). Functions and applications of MCB

An MCB (Miniature Circuit Breaker) is an electromechanical device that protects electrical circuits from overcurrent and short circuits by automatically interrupting the flow of electricity. It acts as a safety device, preventing damage to circuits and connected equipment due to excessive current.

Functions of an MCB:

1. **Overload Protection:** MCB detects when a circuit is carrying more current than it's designed for (overload) and automatically trip to disconnect the power, preventing overheating and potential fires.
2. **Short Circuit Protection:** When a short circuit occurs the MCB trips instantaneously to prevent damage from the high current flow.
3. **Overcurrent Protection:** MCB is designed to protect against both overload and short circuit situations.
4. **Automatic Disconnection:** Unlike fuses, MCBs can be reset and reused after they trip, providing a more convenient and durable solution.

Applications of MCBs:

1. **Residential:** MCBs are commonly found in homes to protect lighting circuits, power outlets, and other appliances.
2. **Commercial:** They are used in offices, shops, and other commercial buildings to safeguard various electrical circuits.
3. **Industrial:** MCBs are essential in industrial settings for protecting machinery, motors, and other electrical equipment from overcurrent and short circuits.
4. **Replacement of Fuses:** MCBs are often used as a safer and more reliable alternative to traditional rewireable fuses.

5h).Functions and applications of ELCB

An ELCB (Earth Leakage Circuit Breaker) is a safety device that protects against electrical shocks and fires by detecting earth leakage currents. It works by monitoring the current flow in the live and neutral wires. If an imbalance is detected, indicating a leakage current, the ELCB trips the circuit, cutting off the power supply.

Functions of an ELCB:

1. **Detects Earth Leakage:** ELCBs primarily detect earth leakage currents, which occur when electricity flows to the ground due to a fault in the electrical system.
2. **Protects against Electric Shock;** ELCBs prevent electric shocks and minimize the risk of injury or death.
3. **Prevents Electrical Fires:** ELCBs can prevent electrical fires by detecting and interrupting fault currents before they can cause overheating or arcing.
4. **Provides Additional Safety:** ELCBs are an additional layer of protection to other safety devices like MCB, offering electrical safety.

Applications of ELCB:

1. **Residential Buildings:** ELCBs are installed in homes to protect personal from electric shocks in areas like bathrooms, kitchens and outdoor areas where there is a risk of moisture.
2. **Commercial Establishments:** ELCBs are used in offices, shops, and other commercial spaces to ensure the safety of employees and customers.
3. **Industries:** ELCBs are vital in industrial environments, protecting machinery, equipment, and workers from electrical hazards, especially in areas with high moisture levels.
4. **Construction Sites:** ELCBs are temporary electrical installations on construction sites to protect workers from electric shock and prevent accidents.
5. **Areas with High Moisture:** ELCBs are important in areas with high moisture content or where water is present, as they can detect leakage currents caused by dampness or water ingress.

5i).Types of wiring systems and accessories

Electrical wiring systems can be broadly categorized into several types. Common electrical accessories include switches, outlets, fuses, circuit breakers, and junction boxes.

Types of Wiring Systems:

1.**Cleat Wiring:**This is a temporary wiring method using insulated wires secured by porcelain or plastic cleats. It's inexpensive and easy to install but not suitable for permanent or heavy-duty applications.

2.**Casing and Capping Wiring:**This system uses wooden or plastic enclosures (casing) to house and protect the wires, with a capping strip to cover the casing. It's more durable than cleat wiring but can be affected by moisture and termites.

Use Cases:
1. Suitable for surface wiring where a more finished appearance is desired.
2. Provides protection to wires and allows for easy maintenance.

3.**Batten Wiring:**This method involves fixing cables on a wooden batten (a strip of wood) and covering them with a waterproof tape. It's a relatively durable and economical option.

uses

1. Temporary installations:
2. Workshops and garages:
3. Indoor applications:
4. Homes and offices:

4.**Conduit Wiring:**This is a widely used and safer method where wires are run through either metal or PVC pipes (conduits).types of conduit are given below

Surface Conduit Wiring: Conduits are mounted on the surface of walls or ceilings.

Use Cases:1. Common in areas where aesthetics are less critical.
2. Often used in industrial settings and for temporary installations.

Concealed Conduit Wiring: Conduits are embedded within walls or under floors.

Use Cases:
1. Preferred in residential and commercial buildings.
2. Reduces the risk of physical damage to wires.

5.**Lead Sheathed Wiring:**Wires are protected by a lead sheath, offering good protection against moisture and mechanical damage. This method is less common now.

Lead sheathed wiring is used particularly in damp or corrosive environments. It's known for moisture resistance, mechanical protection, and corrosion resistance, making it suitable for underground and industrial applications

6.**CTS/TRS/PVC Sheath Wiring:**This method uses wires with a tough outer sheath (either braided cotton, tough rubber, or PVC) for added protection.

CTS wiring, also known as Tough Rubber Sheathed (TRS) wiring, is used for its durability and resistance to moisture and chemicals, making it suitable for damp environments and low-voltage lighting installations. It's often used in open wiring systems, where the cables are clipped onto walls or ceilings.

Common Electrical Accessories:

Switches	: Used to control the flow of electricity by opening or closing the circuit.
Sockets (Outlets)	: Provides connection points for electrical appliances to draw power.
Plugs	: used to Connect appliances to sockets for power supply.
Lamp Holders	: used to Hold and connect electric bulbs or lamps to the supply.
Ceiling Rose	: It acts as a junction box for connecting lighting fixtures, especially hanging ones.
MCBs	: It Provides automatic protection by tripping the circuit during overcurrent.
Fuses	: It Provides overcurrent protection by melting and breaking the circuit when current is too high.
Junction Boxes	: It Enclose and protect wiring connections; used for branching wires.
Conduits and Trunking	: Used to protect and route electrical wiring.
Busbars	: Distributes power to multiple circuits; commonly used in distribution boards.
Grommets	: Protects wires from sharp edges where they pass through metal/plastic enclosures.
Clips and Saddles	: Secure wires and conduits neatly to walls or surfaces.
Distribution Boards (DBs)	: House circuit breakers and distribute electricity to various circuits.

Cable Lugs : Provides a secure connection between cables and terminals.

WEEK-6

6a).Electromagnetic Induction: Definition, Faraday’s laws, statically and dynamically induced EMF generation.

Electromagnetic induction is the process where a voltage (electromotive force or EMF) is induced in a conductor when it's exposed to a changing magnetic field or when a conductor moves through a stationary magnetic field. Here's a more detailed explanation:

1. Electromagnetic Induction: Electromagnetic induction is a fundamental concept where a voltage (EMF) is induced in a circuit or conductor when the magnetic field around it changes.

This change can be caused by either moving a magnet near a conductor, changing the current in a nearby conductor (creating a changing magnetic field), or moving the conductor through a magnetic field. Faraday’s law describes the relationship between changing magnetic fields and induced EMF.

1. Faraday's Laws of Electromagnetic Induction:

Faraday's First Law: Whenever the magnetic flux through a circuit changes, an EMF is induced in the circuit. This change in magnetic flux can be caused by a changing magnetic field, a moving circuit in a static magnetic field, or a change in the orientation of the circuit relative to the magnetic field.

Faraday's Second Law (or Faraday's Law of Induction): The magnitude of the induced EMF is directly proportional to the rate of change of magnetic flux through the circuit.

This can be expressed mathematically as: EMF = $-Nd\Phi/dt$, where EMF is the induced electromotive force, Φ is the magnetic flux, and t is time. The negative sign indicates that the induced EMF opposes the change in magnetic flux, a concept described by Lenz's law.

Where:

- e = induced EMF (in volts),
- N = number of turns in the coil,
- $d\phi/dt$ = rate of change of magnetic flux (in Weber/second),
- The **negative sign** indicates the direction of EMF as per **Lenz's Law**.

3. Statically Induced EMF: it occurs when the conductor and magnetic field are stationary relative to each other, but the magnetic field is changing over time. A common example is a transformer, where an alternating current in the primary coil creates a changing magnetic field that induces a voltage in the secondary coil. No mechanical motion is involved in the induction process.

4. Dynamically Induced EMF: it occurs when there is relative motion between the conductor and the magnetic field. This can be due to a conductor moving through a stationary magnetic field, or a magnetic field moving past a stationary conductor.
Examples: electric generators, where a coil rotates within a magnetic field, and motors, where a current-carrying conductor experiences a force within a magnetic field. The motion of the conductor or the magnetic field creates a change in magnetic flux, inducing an EMF.
Expression=$B \cdot l \cdot v \cdot \sin(\theta)$
Where:

- B = magnetic flux density (Tesla),
- l = length of conductor (meters),
- v = velocity of conductor (m/s),
- θ = angle between conductor and magnetic field direction.

6b).Self and mutual induced EMF.

Statically Induced EMF: Definition: Induced when there is a change in magnetic field with respect to time, but **no relative motion** between the conductor and the magnetic field.

Types
Self-Induced EMF: Produced in the same coil due to a change in its own current (e.g., in inductors).
Mutually Induced EMF: Produced in a nearby coil due to change in current in the first coil (e.g., transformers).
Self-Induced EMF: Definition: Self-induced EMF is the EMF generated in a **coil or circuit** when the **current flowing through it changes**, causing a change in its **own magnetic flux**.
Principle: When current in a coil changes, the magnetic field linked with the coil also changes, which induces an EMF **in the same coil**.
Formula: $e = -L\,di/dt$

Where:

- e = self-induced EMF (volts),
- L = self-inductance of the coil (Henries),
- di/dt = rate of change of current,
- Negative sign indicates opposition to change (Lenz's Law).

Example: In an **inductor** or **choke coil**, when you suddenly switch off the current, a self-induced EMF appears that tries to keep the current flowing.

2. Mutually Induced EMF :Definition: Mutually induced EMF is the EMF generated in one **coil (secondary)** due to a change of current in a **nearby coil (primary)**, which causes a change in the magnetic field linking the second coil.

Principle: Based on **mutual inductance** between two coils placed close to each other. Changing current in the primary coil creates a varying magnetic field that cuts the secondary coil, inducing EMF in it.

Formula: $e = -M \, di/dt$

Where:

- e= mutually induced EMF (volts),
- M = mutual inductance between the coils (Henries),
- di/dt = rate of change of current in the primary coil.

Example: In a **transformer**, when AC current flows in the primary winding, it induces EMF in the secondary winding via mutual induction.

6c).Transformers: Function, working, video demonstration on construction of transformer

Function of Transformer: A **transformer** is a static electrical device used to **transfer electrical energy** between two or more circuits through **electromagnetic induction**. It is mainly used to **step up (increase)** or **step down (decrease) AC voltage** levels without changing the frequency.

Construction of Transformer:

1. Core: Made of laminated **silicon steel** to reduce eddy current loss. Provides a low reluctance path for magnetic flux.

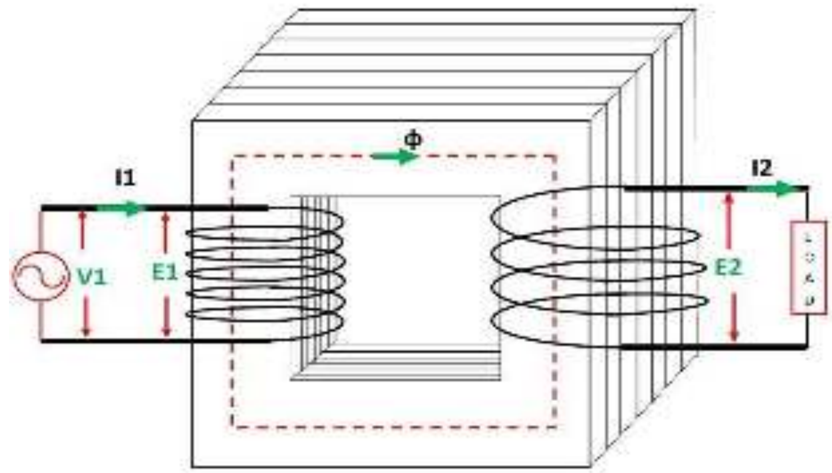
2. Windings: Primary winding: Connected to input voltage.

- **Secondary winding**: Connected to output load. Both windings are made of copper or aluminum.

3. Insulation: Separates windings and core to avoid short circuits.

4. Tank & Cooling (in power transformers): Filled with insulating oil or air for cooling.
May have radiators and fans for heat dissipation.

Working Principle of Transformer: The working is based on **Faraday's Law of Electromagnetic Induction**, which states:*" A change in magnetic flux through a coil induces an EMF (voltage) in the coil."*



The winding to which AC supply is connected is called primary winding and to which load is connected is called secondary winding as shown in the figure below. It works on the **alternating current only** because an alternating flux is required for mutual induction between the two windings.

When the AC supply is given to the primary winding with a voltage of V_1, an alternating flux ϕ sets up in the core of the transformer, which links with the secondary winding and as a result of it, an emf is induced in it called **Mutually Induced emf.**therefore the electrical power is transferred from the primary circuit to the secondary circuit through mutual inductance.

6d).Classification and applications, Transformation ratio.

Classification of Transformers:

Transformers can be classified based on various criteria:

1. Based on Voltage Levels:
- **Step-Up Transformer**: Increases voltage from primary to secondary.
- **Step-Down Transformer**: Decreases voltage from primary to secondary.

2. Based on Construction:
- **Core Type Transformer**: Windings surround the core limbs.
- **Shell Type Transformer**: Core surrounds the windings.

3. Based on Supply Type:
- **Single-Phase Transformer**
- **Three-Phase Transformer**

4. Based on Use:
- **Power Transformer** – For transmission (high voltage, used in substations).
- **Distribution Transformer** – For local distribution (low voltage).
- **Instrument Transformer** – For measurement:
  - **Current Transformer (CT)**
  - **Potential Transformer (PT)**

5. Based on Cooling Method:
- **Air-Cooled**
- **Oil-Cooled**

Applications of Transformers:

Power Generation & Grid :Stepping up voltage for transmission (Power Transformers)
Residential Areas ;Stepping down voltage for homes (Distribution Transformers)
Electronics ;In adapters, chargers, audio systems
Measurement Systems ;Using CT and PT for safe voltage and current readings
Welding Machines :Special welding transformers
Industrial Machinery ;Voltage regulation and isolation
Medical Equipment ;Isolation transformers for patient safety

Transformation Ratio (Turns Ratio)

The **Transformation Ratio (K)** is the ratio of the number of turns in the **secondary winding (Ns)** to the **primary winding (Np)**.

$K=Ns/Np=Vs/Vp=Ip/Is$

Where:

- Np = No. of turns in primary
- Ns = No. of turns in secondary
- Vp = Primary voltage
- Vs = Secondary voltage
- Ip = Primary current
- Is = Secondary current

If $K>1$ → Step-Up Transformer
If $K<1$ → Step-Down Transformer
If $K=1$ → Isolation Transformer

WEEK-7

7a).Generators: DC and AC Generators- definition, types and applications

Definition of Generator: A generator is an electrical machine that converts mechanical energy into electrical energy, based on the principle of electromagnetic induction.

Types of Generators: Generators are broadly classified into:
1. DC Generators (Direct Current Generators)

Definition: DC generators convert mechanical energy into direct electrical energy.
Principle: They also rely on electromagnetic induction, but employ a commutator and brushes to rectify the alternating current generated in the coil into direct current. Produce **unidirectional (DC)** current.

Types of DC Generators (based on field excitation):

1. **Separately Excited DC Generator**
   - Field winding is powered by an external DC source.
2. **Self-Excited DC Generator**
   - Field winding is powered by the generator itself. Sub-types:
   - **Series Wound Generator** – Field winding in series with armature.
   - **Shunt Wound Generator** – Field winding in parallel with armature.
   - **Compound Wound Generator** – Combination of series and shunt windings (can be short or long compound).

Applications: DC generators were historically used for powering arc lamps, and in some specialized applications like boosters and certain industrial processes.

3. AC Generators (Alternating Current Generators)

Definition: AC generators, also known as alternators, convert mechanical energy into alternating electrical energy.
Principle: They utilize the principle of electromagnetic induction, where a rotating coil within a magnetic field induces an alternating current in the coil. Produce alternating current (AC).
Applications: AC generators are widely used in power stations, industries, and as backup power sources for homes and businesses
Types of AC Generators:

1. **Single-phase AC Generator**
   - Produces single-phase AC.
   - Used in small power applications.
2. **Three-phase AC Generator (Alternator)**
   - Produces three-phase AC.
   - Common in power stations and industrial applications.

7b).DC Motors: Definition, types and applications.

Definition: A **DC motor** (Direct Current motor) is an electrical machine that converts **direct current electrical energy** into **mechanical energy**. It operates on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force (Lorentz force).

Types of DC Motors:DC motors are classified based on the connection between the **field winding** and the **armature**:
1. Permanent Magnet DC Motor (PMDC):

- Uses permanent magnets to produce the magnetic field.
- No field winding needed.

Features: Compact, lightweight, low cost.
Applications: Toys, small fans, wipers, and robotics.

2. Separately Excited DC Motor: Field winding is powered from an independent external source.

Features:

- Independent control of field and armature.
- Suitable for wide speed range control.

Applications: Research labs, industrial drives requiring precise speed control.

3. Self-Excited DC Motors: Field winding gets supply from the same source as the armature.

a) DC Series Motor: Field winding connected in series with the armature.

Features:

- High starting torque.
- Speed decreases with load.

Applications: Cranes, hoists, electric trains, elevators.

b) DC Shunt Motor: Field winding connected in parallel (shunt) with the armature.

Features:

- Nearly constant speed.
- Moderate starting torque.

Applications: Lathes, fans, blowers, conveyors.

c) DC Compound Motor: Has both series and shunt field windings.

Types:

- Cumulative Compound (series + shunt aid each other)
- Differential Compound (series opposes shunt)

Features: Combines benefits of both series and shunt motors.

Applications: Presses, elevators, rolling mills.

Applications of DC Motors:

PMDC Motor	:Toys, portable devices, battery-operated tools
DC Series Motor	:Electric traction, cranes, lifts, trolley cars
DC Shunt Motor	;Fans, pumps, machine tools, blowers
DC Compound Motor	;Presses, elevators, conveyors requiring variable load speed
Separately Excited	;Industrial automation, testing equipment, research setups

7c).BLDC motor applications

Brushless DC (BLDC) Motor: A BLDC motor is a type of DC motor where the commutation is done electronically instead of using brushes. It is known for high efficiency, long life, and low maintenance.

Applications of BLDC Motors:

1. Automotive Applications:

- Electric vehicles (EVs) and hybrid vehicles
- Power steering systems
- Cooling fans and blowers
- Fuel and water pumps

2. Household Appliances:
- Refrigerators
- Air conditioners (compressor motors)
- Washing machines
- Ceiling and exhaust fans
- Vacuum cleaners

3. Industrial Applications:
- CNC machines
- Robotics and automation
- Textile machinery
- Printing machines
- Actuators

4. Aerospace and Defense:
- Drones (UAVs)
- Gyroscopes
- Missile guidance systems

5. Consumer Electronics:
- Hard disk drives (HDDs)
- DVD players
- Cooling fans for laptops and desktops

6. Medical Equipment:
- CPAP machines
- Infusion pumps
- Portable ventilators
- Electric wheelchairs

7d).AC Motors: Definition, Types & Applications

Definition: An AC motor is an electric motor that runs on alternating current (AC). It converts AC electrical energy into mechanical energy using the interaction between a magnetic field and current-carrying conductors.

Types of AC Motors:

AC motors are broadly classified into two main types:

1. Synchronous Motor
- The rotor rotates at the **same speed** as the stator's rotating magnetic field (synchronous speed).
- Requires **external DC supply** for excitation.

Types:
- **Non-excited type** (permanent magnet, reluctance)
- **DC-excited type**

Applications:

- Power factor correction
- Constant-speed industrial applications
- Electric clocks, synchronous timers

2. Asynchronous (Induction) Motor

- The rotor rotates at a **slower speed** than the magnetic field (asynchronous).
- Most commonly used motor type.

Types: a) Single-phase Induction Motor:

- Used in small appliances and household devices.

Applications: Ceiling fans, washing machines, pumps, compressors

b) Three-phase Induction Motor: Used in industrial and heavy-duty applications.
Applications: Elevators, conveyors, cranes, air compressors, machine tools

7e).Necessity of starters for AC motors, Types and applications.

Necessity of Starters for AC Motors

1. **To Limit High Inrush Current:** When an AC motor starts, it draws a very high **starting current** (6 to 8 times the full load current).This surge can **damage the motor windings** and **stress the power system**.
2. **To Provide Smooth Acceleration:** Starters help motors **gradually reach full speed**, preventing mechanical stress and damage to connected loads.
3. **To Provide Overload Protection:** Starters usually include protection devices like **overload relays** or **circuit breakers** to prevent overheating.
4. **To Control Starting Torque:** Sudden full voltage can result in **excessive torque**, damaging mechanical components. Starters help regulate this.

Types of Starters for AC Motors

1. Direct-On-Line (DOL) Starter

- **Working**: Applies full line voltage directly to the motor.
- **Used For**: Small motors (<5 HP)
- Simple, low cost, High starting current, high torque

2. Star-Delta Starter

- **Working**: Motor starts in star connection (low voltage), then switches to delta (full voltage).
- **Used For**: Motors >5 HP
- Reduces starting current (by 1/3), Slight torque reduction during start

3. Auto-Transformer Starter

- **Working**: Reduces voltage using a transformer during start, then switches to full voltage.
- **Used For**: Large motors (industrial use)
- Adjustable voltage and current levels, Expensive and bulky

4. Soft Starter

- **Working**: Uses electronics (thyristors) to gradually increase voltage.
- **Used For**: Pumps, fans, compressors

- Smooth start, adjustable acceleration, Higher cost, less torque than DOL

5. Variable Frequency Drive (VFD)

- **Working**: Varies the frequency and voltage supplied to the motor.
- **Used For**: Applications needing speed control (e.g., HVAC, conveyors)
- Excellent speed and torque control, energy efficient, Expensive, complex

Applications of Starters

DOL Starter	:Small pumps, compressors, conveyors
Star-Delta Starter	:Large fans, blowers, crushers
Auto-Transformer	:Large industrial machines, elevators
Soft Starter	:Pumps, HVAC systems, centrifugal loads
VFD	:Conveyor belts, escalators, fans, variable loads

WEEK-8

8a).Cells and Batteries: Definition, symbol, types, comparison and applications

Definition

- **Cell**: A device that converts **chemical energy into electrical energy**. It is a single electrochemical unit that provides a voltage when connected in a circuit.
- **Battery**: A group of **two or more cells connected together** to increase voltage or current to power electrical devices.

Symbols

Component	Symbol	Description
Cell		One long and one short line (positive and negative terminals)
Battery		Two or more cells in series (multiple long and short lines)

Types of Cells and Batteries

1. Primary Cells *(Non-rechargeable)*

- Used once and then discarded.
- Chemical reaction is **not reversible**.

a.Dry Cell	Zinc-Carbon	1.5V	Flashlights, toys
b.Alkaline Cell	Alkaline Battery	1.5V	Clocks, remotes
c.Coin Cell	Lithium Cell	3V	Watches, calculators

2. Secondary Cells *(Rechargeable):* Can be recharged by reversing the chemical reaction using external electrical energy.

a.Lead-Acid Cell	Car Battery	2V per cell	Automobiles, UPS
b.Nickel-Cadmium	NiCd Battery	1.2V	Cordless tools, emergency lights
c.Lithium-Ion	Li-ion Battery	3.6V	Mobile phones, laptops
d.Nickel-Metal Hydride	NiMH Battery	1.2V	Cameras, toys

Comparison: Primary vs Secondary Cells

Feature	Primary Cell	Secondary Cell
Rechargeability	Not rechargeable	Rechargeable
Cost per Unit	Lower	Higher
Life Cycle	One-time use	Multiple cycles
Internal Resistance	Usually higher	Lower (in many cases)
Applications	Remotes, clocks	Laptops, vehicles

Applications

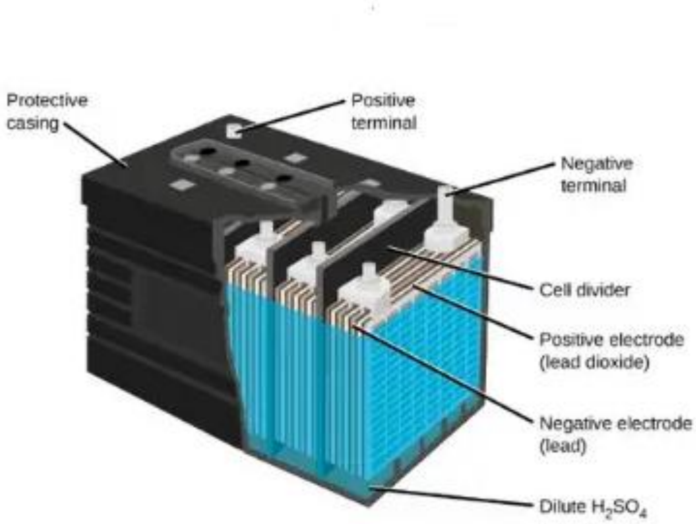
Application Area	Example Devices
Household	Clocks, remotes, flashlights
Automotive	Car ignition, lighting (lead-acid)
Electronics	Phones, laptops (Li-ion)
Industrial	Backup power (UPS, inverter systems)
Medical Devices	Pacemakers, hearing aids
Renewable Energy	Solar power storage systems

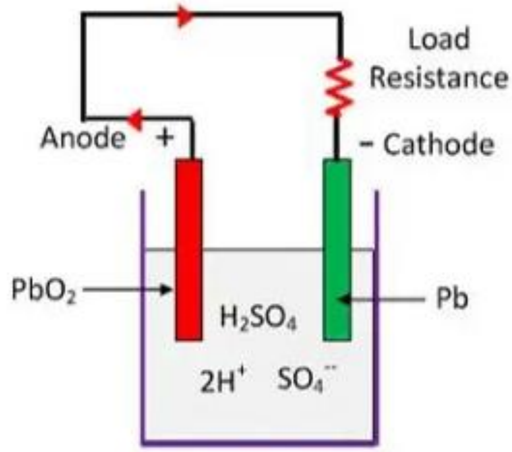
8b).Lead Acid battery and its maintenance

Definition: A lead-acid battery is a rechargeable electrochemical battery that uses lead dioxide (PbO_2) as the positive plate, sponge lead (Pb) as the negative plate, and dilute sulfuric acid (H_2SO_4) as the electrolyte.

Construction

- **Positive Plate**: Lead dioxide (PbO_2)
- **Negative Plate**: Sponge lead (Pb)
- **Electrolyte**: Dilute sulfuric acid (H_2SO_4)
- **Separator**: Insulating material (prevents short circuit between plates)
- **Container**: Hard rubber, plastic, or other acid-resistant material
- **Terminals**: Positive (+) and Negative (−) terminals for external connection





Working Principle

- During **discharging**:
  - $PbO_2 + Pb + H_2SO_4 \rightarrow PbSO_4 + H_2O$ (chemical energy → electrical energy)
- During **charging** (by applying external DC supply):
  - $PbSO_4 + H_2O \rightarrow PbO_2 + Pb + H_2SO_4$ (electrical energy → chemical energy)

Applications

- Automobiles (starting, lighting, ignition)
- UPS systems
- Inverter systems
- Solar energy storage
- Electric vehicles (low-speed types)
- Industrial forklifts and emergency lighting

Maintenance of Lead-Acid Battery

Proper maintenance extends battery life and ensures safety and performance.

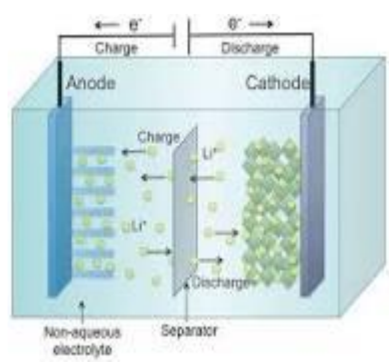
Routine Maintenance Tips:

1. **Check Electrolyte Level**:
   - Should cover the plates.
   - Top up with **distilled water only** (not tap water).
2. **Charge Regularly**:
   - Do not let battery fully discharge.
   - Use proper charger for full charging cycles.
3. **Clean Terminals**:
   - Remove any corrosion (white/green powder).
   - Use baking soda solution and a brush.
   - Apply petroleum jelly or terminal grease.
4. **Check for Sulfation**:
   - White deposits on plates indicate sulfation.
   - Regular charging helps prevent it.

5. **Avoid Overcharging**:
   - Overcharging leads to excessive gassing and water loss.
   - Use charger with auto-cutoff if possible.
6. **Check Battery Voltage**:
   - Use a multimeter: full charge is ~12.6V to 12.8V.
   - Below 11.8V indicates undercharged battery.
7. **Ensure Proper Ventilation**:
   - During charging, hydrogen gas is emitted.
   - Keep in well-ventilated area to avoid explosion risks.
8. **Inspect Battery Case**:
   - Look for cracks, leaks, or bulges.
   - Replace damaged batteries immediately.

8c).Lithium-Ion battery and its applications

Definition; A **Lithium-Ion (Li-ion) battery** is a **rechargeable battery** in which **lithium ions** move from the **negative electrode (anode)** to the **positive electrode (cathode)** during discharge, and back when charging. It is widely used due to its **high energy density**, **lightweight** and **long cycle life**.



Construction and Working

- **Anode**: Typically graphite
- **Cathode**: Lithium metal oxide (like $LiCoO_2$, $LiFePO_4$)
- **Electrolyte**: Lithium salt in organic solvent
- **Separator**: Prevents direct contact between anode and cathode

During discharge:

- **Lithium ions move** from anode to cathode through the electrolyte
- **Electrons flow** through external circuit, powering devices

Advantages

- High energy density
- Low self-discharge
- No memory effect

- Long cycle life
- Lightweight and compact

Applications of Lithium-Ion Battery

Sector	Applications
Consumer Electronics	:Smartphones, laptops, tablets, smart watches, cameras
Electric Vehicles (EVs)	:Electric cars, e-bikes, e-scooters, hybrid vehicles
RenewableEnergy Storage	:Solar power storage systems, home energy storage units
Medical Devices	:Pacemakers, hearing aids, portable diagnostic equipment
Industrial Equipment	:Power tools, robotics, backup power systems
Aerospace & Defense	:Satellites, drones, unmanned aerial vehicles (UAVs)

WEEK-9

9a).Battery-Ampere-Hour Capacity, Selection criteria of batteries

Definition: The **Ampere-Hour (Ah)** rating of a battery indicates the amount of **electric charge** the battery can deliver over time.

1 Ah = the battery can deliver **1 Ampere of current for 1 hour**

Formula: Battery Capacity (Ah)=Current (A)×Time (hours)

Example:

- A **100Ah** battery can deliver:
  - 10A for 10 hours
  - 5A for 20 hours
  - 100A for 1 hour (ideal case)

Selection Criteria of Batteries

When selecting a battery for a specific application, several factors must be considered:

1. Voltage Rating: Match the required **system voltage** (e.g., 12V, 24V, 48V).

2. Ampere-Hour (Ah) Capacity: Choose based on **load current** and **backup time** needed.

- Higher Ah = longer operation time.

3. Discharge Rate (C-Rate):

- Indicates how quickly the battery can be discharged.
- C1 = full discharge in 1 hour, C10 = in 10 hours.

4. Battery Type:

- **Lead-Acid:** Low cost, bulky, needs maintenance.
- **Lithium-Ion:** Lightweight, long life, fast charging.
- **Nickel-Cadmium (Ni-Cd):** Durable, but expensive and memory effect.

5. Cycle Life: Number of **charge-discharge cycles** a battery can perform before capacity drops.

6. Temperature Tolerance: Ensure the battery works well in expected temperature conditions.

7. Maintenance Requirements: Maintenance-Free (Sealed) vs **Vented (Flooded)** batteries.

8. Physical Size and Weight: Important for **portable** or **space-limited** applications.

9. Cost and Availability: Initial cost and **total cost should be less** (including maintenance and life).

10. Safety and Environmental Impact: Check for **protection features** (overcharge, overheat, short-circuit) and **disposability/recycling** options.

9b).UPS: Meaning, types and applications

A **UPS (Uninterruptible Power Supply)** is an electrical device that provides **backup power** to connected equipment when the main power supply fails or fluctuates beyond acceptable limits. It ensures continuous operation and protects devices from power disturbances like surges, sags, and outages.

Types of UPS:

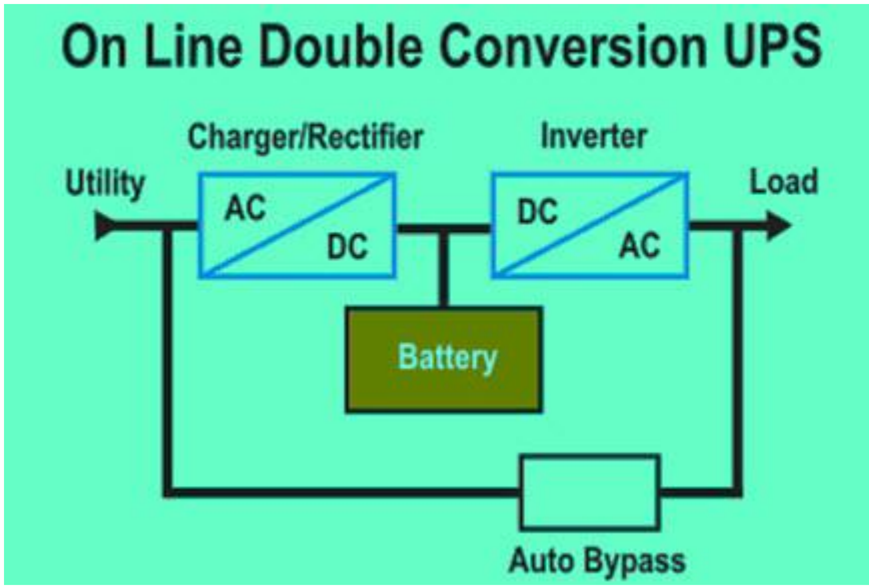
1. **Offline/Standby UPS:**
   - **Working:** Normally, the load is powered directly by the main supply. When a power failure occurs, the UPS switches to battery backup.
   - **Switching Time:** 2–10 milliseconds.
   - **Usage:** Home PCs, small office equipment.
2. **Line-Interactive UPS:**
   - **Working:** Uses automatic voltage regulation (AVR) to correct minor power fluctuations without switching to battery.
   - **Switching Time:** 2–4 milliseconds.
   - **Usage:** Small business networks, servers, point-of-sale systems.
3. **Online/Double-Conversion UPS:**
   - **Working:** Converts AC to DC and then back to AC continuously, providing a stable and clean power supply without switching time.
   - **Switching Time:** Zero (no delay).
   - **Usage:** Critical systems like data centers, medical equipment, large servers.

Applications of UPS

- **Computers and IT Equipment:** Prevents data loss during power outages.
- **Medical Equipment:** Ensures continuous power to life-saving devices.
- **Industrial Automation:** Keeps control systems running during power interruptions.
- **Telecommunication Systems:** Maintains signal and communication during blackouts.
- **Home Electronics:** Protects TVs, routers, and appliances from power surges.

9c).Block diagram of online UPS system.

Online UPS: Constantly powers devices from the inverter, providing the highest level of protection. Applications: Critical data centers, medical equipment.The online UPS is also called as double conversion online uninterruptible power supply. This is the most commonly used UPS and the block diagram of this UPS is shown below. The designing of this UPS is similar to the Standby UPS, excluding that the primary power source is the inverter instead of the AC main. In this UPS design, damage of the i/p AC does not cause triggering of the transfer switch, because the i/p AC is charging the backup battery source which delivers power to the o/p inverter. So, during failure of an i/p AC power, this UPS operation results in no transfer time.



WEEK-10

10a).Introduction of Alternate Energy Sources and Applications

Introduction: Alternate energy sources, also known as **renewable energy sources**, are forms of energy that are naturally replenished and are more environmentally friendly compared to fossil fuels. These sources help reduce greenhouse gas emissions, minimize pollution, and ensure long-term energy sustainability.

Major Alternate Energy Sources:

1. Solar Energy:

- **Source:** Sunlight
- **Conversion:** Solar panels (photovoltaic cells) convert sunlight into electricity.
- **Applications:**
  - Home and street lighting
  - Solar water heaters
  - Solar power plants
  - Solar cookers

2. Wind Energy

- **Source:** Wind movement
- **Conversion:** Wind turbines convert kinetic energy of wind into electricity.
- **Applications:**
  - Electricity generation in wind farms
  - Water pumping (windmills)
  - Remote area power supply

3. **Hydropower (Hydroelectric Energy)**
   - **Source:** Flowing or falling water
   - **Conversion:** Turbines in dams convert water movement into electricity.
   - **Applications:**
     - Electricity production in dams
     - Irrigation support systems
4. **Biomass Energy**
   - **Source:** Organic matter (wood, crop waste, animal dung)
   - **Conversion:** Burned or converted into biogas or biofuels.
   - **Applications:**
     - Cooking and heating (rural areas)
     - Electricity generation in biomass plants
     - Production of biofuels (ethanol, biodiesel)
5. **Geothermal Energy**
   - **Source:** Heat from within the Earth
   - **Conversion:** Used to heat water or generate electricity through steam turbines.
   - **Applications:**
     - Geothermal power plants
     - Space heating in homes and buildings
6. **Tidal and Wave Energy**
   - **Source:** Ocean tides and waves
   - **Conversion:** Turbines placed underwater convert water movement into power.
   - **Applications:**
     - Coastal power generation
     - Experimental marine energy projects

10b).Evolution of Electric Vehicles, Batteries used for EVs

Evolution of Electric Vehicles (EVs)

1. Early Development (1800s - Early 1900s)

- **1830s-1880s:** First concepts of electric propulsion using primitive batteries and motors.
- **1890s-1900s:** Electric cars gained popularity due to their quiet operation and ease of use compared to steam or gasoline cars.
  - Example: Baker Electric, Detroit Electric (popular among urban users).

2. Decline Period (1920s - 1970s)

- **Internal combustion engine (ICE) cars dominated** due to:
  - Mass production (e.g., Ford Model T),
  - Lower fuel prices,
  - Longer driving range.

- EVs almost vanished during this period.

3. Re-emergence (1970s - 1990s)

- Triggered by:
  - **Oil crisis (1973 & 1979),**
  - Growing environmental concerns.
- Governments and companies experimented with EV prototypes, but limited success due to poor battery technology and high costs.

4. Modern Era (2000s - Present)

- **2008:** Tesla Roadster revolutionized the EV industry—first long-range lithium-ion powered EV.
- **2010s onwards:** Rapid development in EV technology, charging infrastructure, and policy support.
  - Popular models: Tesla Model S, Nissan Leaf, Chevy Bolt, etc.
- **Present trends:** EVs are widely adopted with government incentives, improved range, faster charging, and lower battery costs.

Batteries Used in Electric Vehicles

1. Lead-Acid Batteries (Early Use)

- First used in early EVs due to availability and low cost.
- **Drawbacks:**
  - Heavy weight,
  - Short life span,
  - Low energy density.

2. Nickel-Metal Hydride (NiMH) Batteries

- Used in hybrid vehicles (e.g., Toyota Prius).
- **Advantages:** Better energy density than lead-acid, safer.
- **Disadvantages:** Memory effect, expensive, lower efficiency than lithium-ion.

3. Lithium-Ion (Li-ion) Batteries (Current Standard)

- Dominant in modern EVs due to:
  - **High energy density,**
  - **Long cycle life,**
  - **Lightweight and compact.**
- Types include:
  - **Lithium Iron Phosphate ($LiFePO_4$):** Safer, lower energy density, widely used in buses and some cars (e.g., BYD).
  - **Nickel Cobalt Manganese (NCM) / Nickel Cobalt Aluminum (NCA):** Higher energy density, used in Tesla, Hyundai, etc.

4. Solid-State Batteries (Future Tech); Still under development.

- Potential benefits:
  - Higher energy density,
  - Faster charging,
  - Improved safety,

- Longer lifespan.

10c).Electric Motors used in EVs

Electric Vehicles (EVs) use electric motors to convert electrical energy from batteries into mechanical energy to drive the wheels. The most commonly used motors in EVs are:

1. DC Series Motor

- **Features**: High starting torque, Simple speed control
- **Used in**: Early electric cars and some industrial EV applications
- **Disadvantages**:
  - Brushes and commutator need maintenance
  - Not efficient at higher speeds

2. Brushless DC Motor (BLDC)

- **Features**: High efficiency and reliability, No brushes → low maintenance
- Compact and lightweight
- **Used in**: Electric scooters, bikes, and low to mid-power EVs
- **Advantages**:
  - Precise speed control
  - Less noise and better thermal performance

3. Permanent Magnet Synchronous Motor (PMSM)

- **Features**: High efficiency (over 90%),Compact with excellent torque-to-weight ratio
- Operates with high power density
- **Used in**: High-end EVs (like Tesla Model 3 rear motor)
- **Advantages**:
  - Suitable for high-performance EVs
  - Smooth and quiet operation

4. Induction Motor (Asynchronous Motor)

- **Features**: No permanent magnets, Rugged and durable
- **Used in**: Tesla Model S and X
- **Advantages**:
  - Inexpensive compared to PMSM
  - Can handle overloads better
  - Good performance across a range of speeds

5. Switched Reluctance Motor (SRM)

- **Features**: Simple and robust design, No permanent magnets or rotor windings
- **Used in**: Emerging technology, some commercial EVs
- **Advantages**:
  - Low cost
  - High temperature tolerance
- **Disadvantages**:
  - Torque ripple
  - More complex control system required

10d).Battery and UPS ratings for Solar powered Street lighting

When designing a solar-powered street lighting system, proper sizing of the **battery** and **UPS (or Inverter)** is critical to ensure reliability, efficiency, and cost-effectiveness.

Battery Rating for Solar Street Light

Purpose: To store solar energy during the day and supply power to the streetlight at night.

1. Key Parameters to Calculate Battery Size:

- **Load Power (W):** Wattage of the LED lamp (e.g., 12W, 24W, 30W).
- **Lighting Hours:** Usually 10–12 hours per night.
- **Autonomy Days:** Number of days the battery should supply power without sun (typically 2–3 days).

- **System Voltage:** Usually 12V or 24V DC.

2. Battery Capacity Calculation (Ah):

$$\text{Battery Capacity (Ah)} = \frac{\text{Load (W)} \times \text{Hours per night} \times \text{Autonomy days}}{\text{System Voltage} \times \text{DOD (Depth of Discharge)}}$$

Assume:

- LED Load: 30W
- Hours per Night: 12
- Autonomy: 2 days
- Voltage: 12V
- DOD: 0.8 (for Li-ion or $LiFePO_4$), 0.5 for Lead-acid

$$\text{Battery Capacity} = \frac{30 \times 12 \times 2}{12 \times 0.8} = 75\text{Ah}$$

So, a **12V, 75Ah Li-ion** battery is suitable for a 30W light.

Inverter Rating for Solar Street Light

Note: In standalone solar street lights, a traditional UPS may not be required. But if an AC light or grid backup is used, an inverter becomes necessary.

1. Inverter Sizing:

- Must handle **peak load** (e.g., 30W light)
- Add 25–30% buffer for safety

$$\text{Required VA Rating} = \frac{\text{Total Load (W)}}{\text{Power Factor}} \quad \text{(Power factor } 0.8)$$

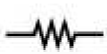
$$\text{VA} = \frac{30}{0.8} = 37.5 \rightarrow \text{Use 50VA or higher inverter}$$

Usually, a **100VA to 200VA inverter** is sufficient for a single solar street light system.

WEEK-11

11a).Electronic Components: Resistors, Capacitors and Inductors - Definition, Unit, Types, and Applications.

1. Resistors; A **resistor** is a passive electrical component that opposes or limits the flow of electric current in a circuit by converting electrical energy into heat. **Unit: Ohm (Ω)Symbol:**

 Resistor

Types of Resistors:

1. **Fixed Resistors**
   - Carbon Composition
   - Metal Film
   - Wire-Wound
2. **Variable Resistors**
   - Potentiometer
   - Rheostat
   - Trimmer
3. **Special Resistors**
   - Thermistor (temperature dependent)
   - LDR (Light Dependent Resistor)
   - Varistor (voltage dependent)

Applications:

- Current limiting
- Voltage division
- Pull-up/pull-down circuits in microcontrollers
- Biasing of transistors
- Heating elements

2. Capacitors;A **capacitor** is a passive electrical component that stores electrical energy in an electric field between two conductive plates separated by an insulator (dielectric).**Unit: Farad (F)„Symbol:** Two parallel lines (one curved for polarized capacitors) 

Types of Capacitors:

1. **Fixed Capacitors**
   - Ceramic
   - Electrolytic
   - Film
   - Tantalum
2. **Variable Capacitors**
   - Air-gap
   - Trimmer capacitors

Applications:

- Energy storage
- Power factor correction
- Signal filtering
- Timing circuits
- Coupling and decoupling AC signals

3. Inductors: An **inductor** is a passive component that stores energy in a magnetic field when electric current flows through it.**Unit:Henry (H),Symbol:** Coiled wire symbol

Types of Inductors:

1. **Air Core Inductors**
2. **Iron Core Inductors**
3. **Ferrite Core Inductors**
4. **Toroidal Inductors**
5. **Choke Coils**

Applications:

- Filters in power supplies
- Transformers
- Tuning circuits in radios
- Energy storage in switching regulators
- Inductive sensors

11b).Definitions of conductors, insulators and semiconductors with examples

Conductors: Materials that readily allow electric current to pass through them.

- **Characteristics:** Possess a large number of free electrons that can move and carry an electrical charge when a voltage is applied.
- **Examples:** Metals like copper, silver, and aluminum are excellent conductors. Other examples include the human body, saltwater, and graphite (a non-metal).

Insulators: Materials that impede the flow of electric current.

- **Characteristics:** Have few free electrons, making it difficult for electricity to flow.
- **Examples:** Common insulators include rubber, plastic, glass, wood, and ceramics.

Semiconductors: Materials with conductivity between that of conductors and insulators.

- **Characteristics:** Their conductivity can be altered by external factors like temperature, light, or the addition of impurities (doping).
- **Examples:** Silicon and germanium are the most common examples. Other examples include gallium arsenide and cadmium selenide.

11c).Difference between Conductor, Semiconductor and Insulator

Parameter	Conductor	Semiconductor	Insulator
1.Definition	A material that allows electric current to pass through it very easily.	A material that has conductivity in between conductors and insulators.	Materials that do not allow the electric current to pass through them.
2.Forbidden Energy Gap	No energy gap i.e. the conduction band overlap the valance band.	Small energy gap (approx. 1 eV).	Very large energy gap (approx. 15 eV).
3.Conductivity	High Conductivity (of the order of 10^{-7} mho/m).	Intermediate conductivity (ranging from 10^{-7} mho/m to 10^{-13} mho/m).	Very low conductivity(of the order of 10^{-13} mho/m).
4.Conduction	Due to free electrons.	Due to movement of both electrons and holes (positive charge carriers).	No conduction.
5.Resistivity	Low (of the order of $10^{-5}\Omega$/m).	Intermediate (from $10^{-5}\Omega$/m to 10^{5} Ω/m).	Very high (of the order of 10^{5} Ω/m).
6.Temperature Coefficient of Resistivity	Positive	Negative	Negative
7.Examples	Metals like silver, gold, copper, aluminium etc.	Silicon, Germanium, Gallium, Arsenide etc.	Air, Mica, Glass, Paper, Porcelain, Wood etc.
8.Application	In the manufacturing of conducting wires and cables.	In the manufacturing of solid state electronic devices like ICs, diodes, transistors etc.	Used for providing insulation electrical and electronic devices, for preventing electric shock etc

11d).Semiconductor Diode; Definitions of P and N type semiconductors,

Semiconductor Diode: A **semiconductor diode** is a two-terminal electronic component that allows current to flow in one direction only. It is made by joining a **P-type** and an **N-type** semiconductor, forming a **PN junction**.

P-type Semiconductor: A P-type semiconductor is created by **doping** a pure semiconductor (like Silicon or Germanium) with a **trivalent element** (e.g., Boron, Gallium).

- **Charge Carriers:** Majority carriers are **holes** (positive charge carriers).
- **Minority carriers:** Electrons.
- **Doping Element:** Trivalent (3 valence electrons).

Example: Doping Silicon with Boron creates a P-type material.

N-type Semiconductor: An N-type semiconductor is made by doping a pure semiconductor with a **pentavalent element** (e.g., Phosphorus, Arsenic).

- **Charge Carriers:** Majority carriers are **electrons** (negative charge carriers).
- **Minority carriers:** Holes.
- **Doping Element:** Pentavalent (5 valence electrons).

Example: Doping Silicon with Phosphorus creates an N-type material.

11e). Diode and its Symbol

A **diode** is a two-terminal electronic device that **allows current to flow in one direction only**. It is made by combining a **P-type** and **N-type** semiconductor material, forming a **PN junction**.

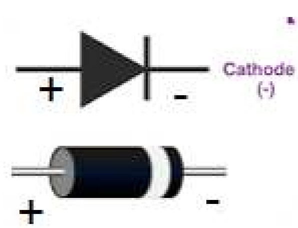
Key Functions of a Diode:

- **Rectification:** Converts AC to DC.
- **Protection:** Used in circuits to block reverse current.
- **Switching:** Used in digital logic circuits.

Basic Operation:

- **Forward Bias:** Diode conducts current (P connected to +, N to -).
- **Reverse Bias:** Diode blocks current (P connected to -, N to +).

Symbol of Diode:



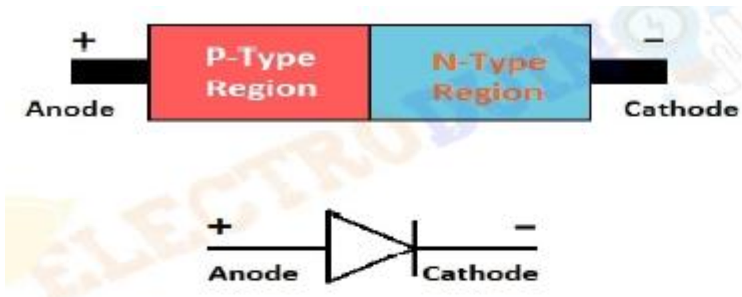
A = Anode (P-type)
K = Cathode (N-type)

- **Anode (A):** Connected to the **P-type** material.
- **Cathode (K):** Connected to the **N-type** material.

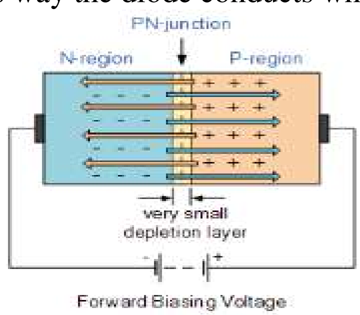
- **Arrow direction:** Indicates the **direction of conventional current** (from P to N) when forward biased.

11f). Working of Diode in forward and reverse bias

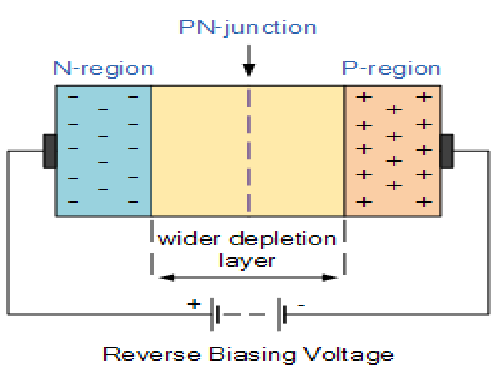
PN Junction Diode: A diode is a electronic device that allows flow of current in only one direction and this device formed by joining a p-type semiconductor and an n-type semiconductor.
Symbol:



FORWARD BIAS:A P-N junction diode is said to be forward biased when the positive terminal of a cell or battery is connected to the p-side of the junction and the negative terminal to the n side. When diode is forward-biased the depletion region narrows and consequently, the potential barrier is lowered. This causes the majority charge carriers of each region to cross into the other region. The electrons travel from the n-side to the p-side and go to the positive terminal of the battery. The holes that travel from the p-side to the n-side combine with the electrons injected into the n-region from the negative terminal of the battery. This way the diode conducts when forward-biased.



REVERSE BIAS:A pn-junction diode is said to be reverse biased when the positive terminal of a cell or battery is connected to the n-side of the junction and the negative terminal to the p-side. When reverse biased. The holes in the p-region from the electrons injected into the p-region from the negative terminal of the battery. The electrons in the n-region go to the positive terminal of the battery. This way, the majority charge carrier concentration in each region decreases against the equilibrium values and the reverse biased junction diode has a high resistance. Thus, the diffusion current across the junction becomes zero. Thus, the diode does not conduct when reverse biased and is said to be in a quiescent or non-conducting state i.e., it acts as an open switch.



11g).Types of diodes and ratings and Applications

1. PN Junction Diode: Basic diode formed by joining P-type and N-type semiconductors.

Ratings: Voltage: 50V to 1000V, Current: Few mA to several Amps

Applications:

- Rectifiers (AC to DC conversion)
- Clipping and clamping circuits

2. Zener Diode: Designed to operate in reverse breakdown region.

Ratings: Voltage: 3V to 200V, Current: 1 mA to 50 A

Applications:

- Voltage regulation
- Overvoltage protection

3. Light Emitting Diode (LED); Emits light when forward biased.

Ratings: Forward Voltage: 1.8V to 3.3V,, Current: 10 mA to 30 mA

Applications:

- Display indicators
- Lighting systems

4. Schottky Diode; Fast-switching diode with low forward voltage drop.

Ratings: Voltage: 20V to 100V, Current: 1 A to 100 A

Applications:

- High-speed switching circuits
- Power supplies

5. Photodiode: Converts light into electrical current.

Ratings: Voltage: 5V to 100V, Response Time: Very fast (Nano to microseconds)

Applications:

- Light sensors
- Solar panels

6. Varactor Diode (Varicap): Acts as a variable capacitor under reverse bias.

Ratings: Capacitance Range: 1–100 PF,Voltage: 5V to 30V

Applications:

- RF tuning circuits
- Voltage-controlled oscillators

7. Tunnel Diode: Has negative resistance region, used in high-frequency applications.

Ratings: Voltage: <1V, Current: Up to 100 mA

Applications:

- Oscillators
- Microwave amplifiers

WEEK-12

12a).Rectifier:• Definition, types, working of Bridge rectifier

Definition of Rectifier: A **rectifier** is an electrical device that **converts alternating current (AC) into direct current (DC)**. It is used in power supplies for electronic devices.

Types of Rectifiers:

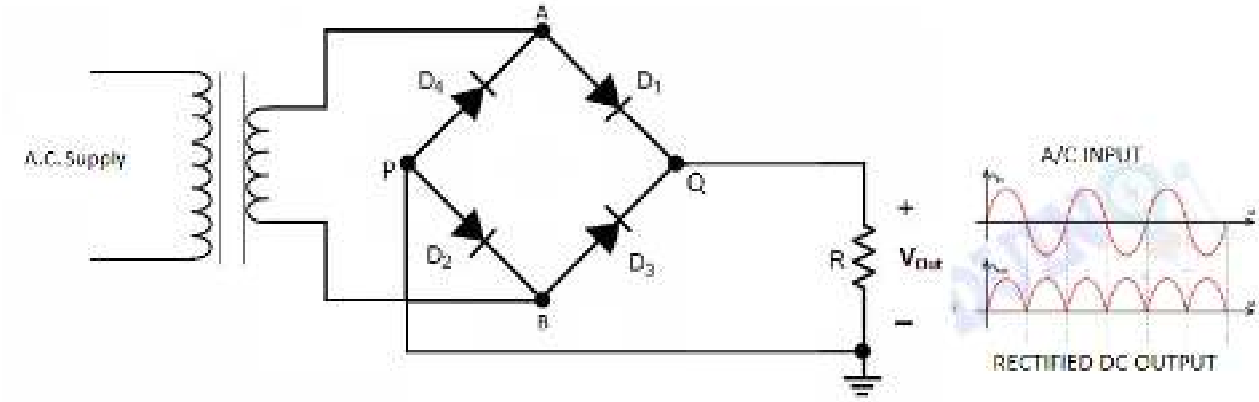
1. **Half-Wave Rectifier**
   - Uses a single diode
   - Conducts only one half-cycle of AC
   - Output: Pulsating DC (only positive or negative half)
2. **Full-Wave Rectifier (Center-Tap)**
   - Uses two diodes and a center-tap transformer
   - Conducts both half-cycles
   - Output: Full-wave pulsating DC
3. **Bridge Rectifier**
   - Uses four diodes
   - No center-tap required
   - Conducts both half-cycles
   - Most commonly used in power supply units

12b).Working of a Bridge Rectifier:

1. Positive Half-cycle: During the positive half-cycle of the AC input, diodes D1 and D3 are forward-biased and conduct, while diodes D2 and D4 are reverse-biased and block current flow. Current flows from the AC input, through D1, through the load resistor, through D3, and back to the AC input, producing a positive voltage across the load.

2. Negative Half-cycle: During the negative half-cycle, diodes D2 and D4 are forward-biased and conduct, while diodes D1 and D3 are reverse-biased. Current flows from the AC input, through D2, through the load resistor, through D4, and back to the AC input, again producing a positive voltage across the load.

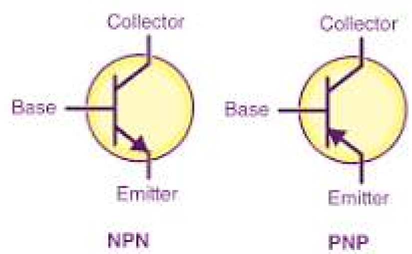
3. Result: Because current flows through the load resistor in the same direction during both the positive and negative half-cycles, the output voltage across the load is always positive, resulting in a pulsating DC output. This pulsating DC can be smoothed by using a filter capacitor to produce a more stable DC voltage.



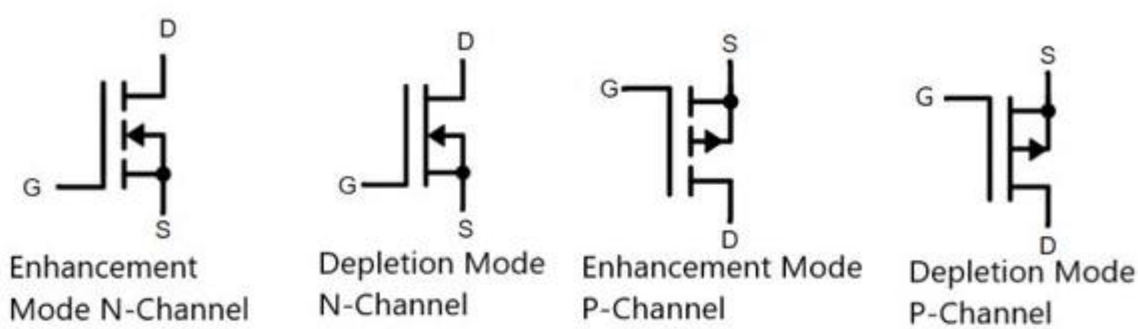
12c).Transistor: Definition and Types

A transistor is a semiconductor device with three terminals that controls the flow of current between two of the terminals by applying a voltage to the third terminal (base in BJTs, gate in FETs).

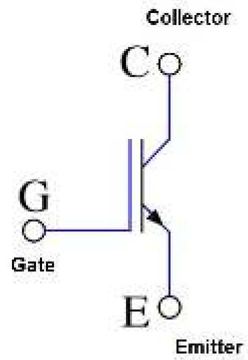
Bipolar Junction Transistors (BJTs): These transistors use both majority and minority carriers to conduct current and have three terminals: emitter, base, and collector.



Field-Effect Transistors (FETs): These transistors control the current flow by varying an electric field at the gate terminal.



Insulated-Gate Bipolar Transistors (IGBTs): These transistors combine the characteristics of both MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) and BJTs, offering high input impedance and high current/voltage handling capabilities.



Applications of Transistors

1. **Switching** in electronic circuits
2. **Amplification** of audio, radio, or other signals
3. Used in **logic gates** and **digital electronics**
4. Found in **oscillators** and **modulators**
5. Key component in **microprocessors** and **microcontrollers**
6. Used in **power control** (SMPS, motor drivers)

12d).Digital fundamentals

Definition: An Integrated Circuit (IC), also known as a microchip, is a miniaturized electronic circuit containing numerous interconnected components like transistors, resistors, and capacitors, all fabricated on a single semiconductor material, typically silicon.

Advantages:

1. **Miniaturization:** ICs reduce the size of electronic circuits compared to using discrete components.
2. **Increased Reliability:** Since all components and connections are integrated on the chip, there are fewer solder joints, leading to higher reliability and fewer failures.
3. **Lower Power Consumption:** ICs consume less power due to the small size and close proximity of components.
4. **Cost Reduction:** Mass production of ICs makes them relatively inexpensive compared to assembling circuits with individual components.
5. **Higher Speed:** The close proximity of components in an IC allows for faster signal processing and higher operating speeds.

Applications:

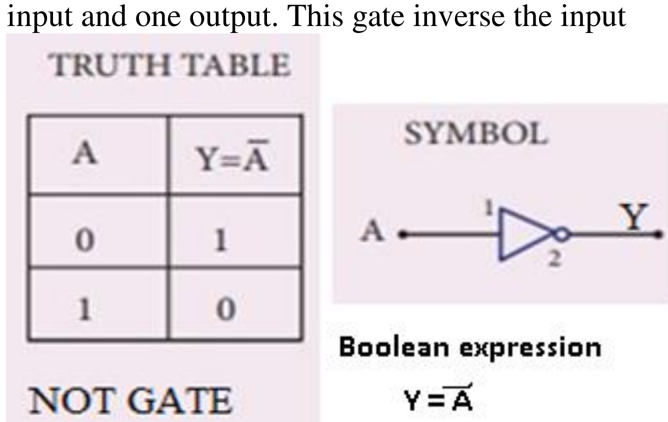
1. **Computers:** ICs are the core components of processors, memory, and other essential parts of computers and laptops.

2. **Smartphones:** They power the processing, memory, and communication systems in mobile phones.
3. **Automobiles:** ICs are used in engine control units, anti-lock braking systems, and other electronic systems in vehicles.
4. **Medical Devices:** ICs are crucial in various medical equipment, including diagnostic tools and monitoring systems.
5. **Consumer Electronics:** televisions and audio systems to gaming consoles and appliances, ICs are ubiquitous in consumer electronics.
6. **Industrial Automation:** ICs are used in control systems, sensors, and other electronic components in industrial automation and robotics.

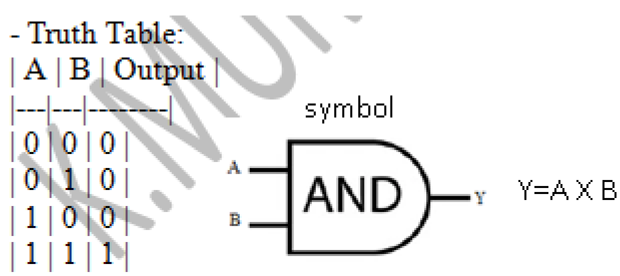
12e).Logic Gates- Symbol, Boolean expression and truth table of AND, OR, NOT, NAND, NOR, EX- OR gates

Logic gates are the basic building blocks of any digital system. it is an electronics circuit having one or more input and only one output. There are seven logic gates named as NOT, OR, NOR, EX-OR, EX-NOR, AND, NAND.

1. NOT Gate: it has one input and one output. This gate inverse the input



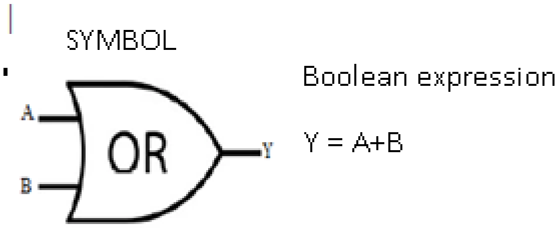
2. AND Gate: Outputs true (1) only when both inputs are true (1).



3. OR Gate: Outputs true (1) when at least one input is true (1).

- Truth Table:

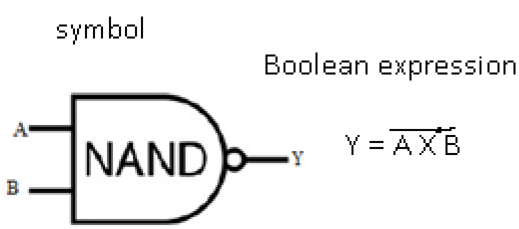
A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1



4. NAND Gate: Outputs false (0) only when both inputs are true (1); otherwise, it outputs true (1).

- Truth Table:

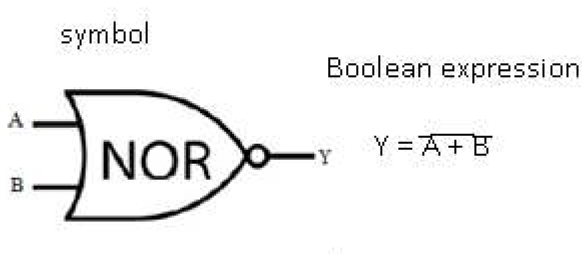
A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0



5. NOR Gate: Outputs false (0) when at least one input is true (1); otherwise, it outputs true (1).

- Truth Table:

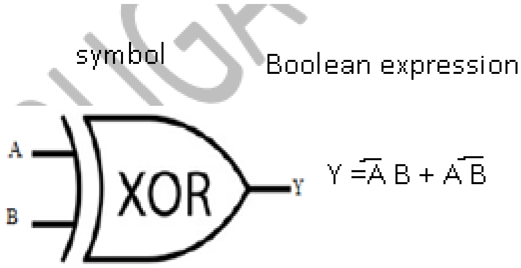
A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0



6. XOR Gate (Exclusive OR): Outputs true (1) when the number of true inputs is odd.

- Truth Table:

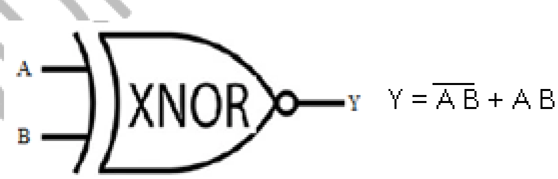
A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0



7. X-NOR Gate (Exclusive NOR): Outputs true (1) when the number of true inputs is even.

- Truth Table:

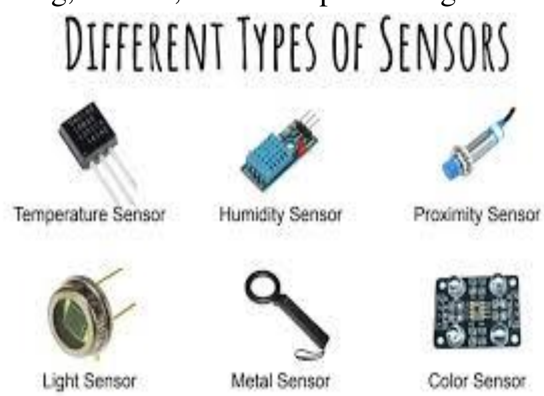
A	B	Output
0	0	1
0	1	0
1	0	0
1	1	1



WEEK-13

13a).Sensors; Definition, Types and Applications of sensors

Definition; sensors are devices that convert physical quantities (such as temperature, light, pressure, or magnetic fields) into electrical signals. These signals can then be interpreted or utilized in electronic systems for monitoring, control, or further processing.



Types and Applications of Sensors:

i. Temperature Sensors: Measures temperature changes and are commonly used in climate control systems, industrial processes.

ii. Light Sensors (Photocells or Photodiodes): Detects variations in light intensity, in automatic lighting systems, cameras, and solar panels.

iii. Pressure Sensors: Monitor changes in pressure like automotive systems, and industrial processes.

iv. Proximity Sensors: Detects the presence or absence of an object without physical contact, commonly used in industries, robotics, and security systems.

v. Motion Sensors: Respond to movement and are found in applications like gaming consoles, security systems, and automatic doors.

vi. Magnetic Sensors: Measure magnetic fields and are used in compasses, navigation systems, and certain medical devices.

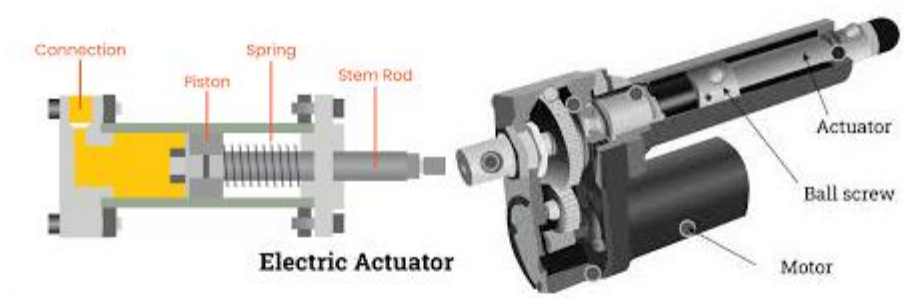
vii. Gas Sensors: Detect the presence of gases in the air is crucial in environmental monitoring, industrial safety, and gas leak detection.

viii. Humidity Sensors: Measure the moisture content in the air and are employed in weather stations, industrial processes.

ACTUATORS

Actuators: Actuators are devices that convert electrical signals into physical action. They are responsible for initiating a mechanical movement or controlling a process based on the input received.

Actuators convert energy into mechanical motion. They can be broadly classified by the type of energy they use (e.g., electric, hydraulic, pneumatic, mechanical) or by the type of motion they produce (e.g., linear, rotary).



Types of actuator

1. Based on Energy Source:

1. **Electric Actuators:** These use electric motors, solenoids to generate motion.
2. **Hydraulic Actuators:** Hydraulic actuators utilize pressurized fluid (often oil) to generate force, often in cylinders
3. **Pneumatic Actuators:** These actuators use compressed air to produce motion, typically with cylinders or rotary actuators.
4. **Mechanical Actuators:** These use mechanical linkages and components like gears, screws, or cams to convert motion
5. **Magnetic Actuators:** These use magnetic forces, such as from magnets or solenoids, to create movement.
6. **Thermal Actuators:** These actuators use heat to cause a material to change shape or volume, resulting in motion.

2. Based on Motion

a. **Linear Actuators:** Produce movement in a straight line, like pushing or pulling.
b. **Rotary Actuators:** Produce rotational or turning motion.
c. **Oscillating Actuators:** Produce back-and-forth motion.

3. Other Notable Actuators:

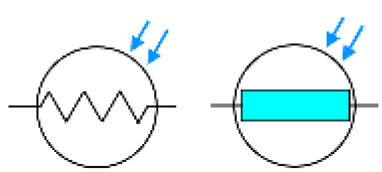
a. **Piezoelectric Actuators:** Utilize the piezoelectric effect to create precise, small movements.
b. **Electrohydraulic Actuators:** Combine electrical and hydraulic components for precise control of hydraulic force.
c. **Stepper Motor Actuators:** These electric motors move in discrete steps, providing precise positioning.

Applications of Actuators

1. **Industrial Automation:** Actuators are used in manufacturing for tasks like assembly, material handling, and packaging.
2. **Robotics:** Actuators are used as muscle of robots, providing the necessary movement for tasks like welding, painting, and exploration.
3. **Automotive:** Actuators are used to control various vehicle systems, including power windows, door locks, steering, and engine control.
4. **Medical:** Actuators are used in medical devices like MRI and CT scanners, as well as in prosthetics and surgical equipment.
5. **Aerospace:** Actuators are used to control aircraft components like wing flaps and landing gear, ensuring smooth and safe flight operations.
6. **Entertainment:** Actuators are used for stage movements.
7. **Agriculture:** Actuators can be used in farming equipment, such as automated irrigation systems and harvesting machinery.
8. **Food Processing:** Actuators are used in food processing equipment for tasks like cutting, mixing, and packaging food products.

13c).LDR,PHOTODIODE,PHOTORESISTER,SOLOR CELL

A Light Dependent Resistor (LDR), also known as a photo resistor, is a passive electronic component whose resistance varies with the intensity of light it detects. Its resistance decreases as light intensity increases, and vice versa



LDR - Light Dependent Resistor

Types of LDR

1. Based on applications

a. Photoconductive LDRs
b. Photo resistive LDRs

2. Based on Light Sensitivity

a. Ultraviolet LDRs: These are highly responsive to UV light
b. Infrared LDRs: infrared LDRs are essential in high-tech applications like missile guidance, geographic exploration.
c. Visible Light LDRs: They control everything from street lights to automated industrial processes.

3. Based on Material-Based

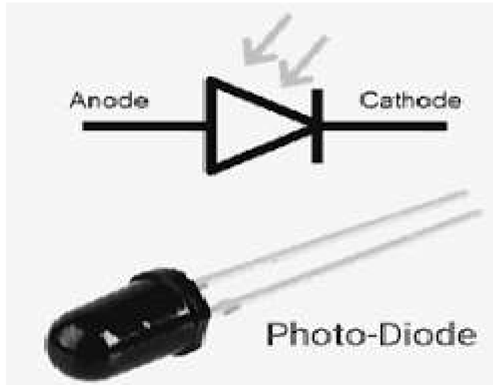
a. Intrinsic Photo resistors:
b. Extrinsic Photo resistors

Applications of LDR

1. **Automatic Lighting:** LDRs are widely used in automatic streetlights, garden lamps, and indoor lighting systems to switch lights on or off based on ambient light levels.
2. **Security Systems:** in burglar alarms, where they detect changes in light levels, indicating potential intrusions.
3. **Camera Shutter Control:** LDRs can be used to measure light intensity in cameras and adjust the shutter speed accordingly.
4. **Clock Radios:** Many alarm clocks utilize LDRs to automatically turn on a light when it gets dark.
5. **Smoke Detectors:** Simple smoke detectors can incorporate LDRs to detect changes in light caused by smoke particles.
6. **Solar Tracking Systems:** LDRs are used in solar tracking systems to orient solar panels towards the sun for optimal energy capture.
7. **Object Counting:** They can be used in conveyor belts to count objects by detecting the light blocked by them.
8. **Light Meters:** in light meters to measure light intensity in various environments.

PHOTODIODE

A photodiode is a PN-junction diode that consumes light energy to produce an electric current. Sometimes it is also called a photo-detector, a light detector, and photo-sensor. These diodes are particularly designed to work in reverse bias conditions, it means that the P-side of the photodiode is associated with the negative terminal of the battery, and the n-side is connected to the positive terminal of the battery.



Types of Photodiode

The types of photodiodes can be classified based on their construction and functions as follows.

1. PN Photodiode
2. Schottky Photo Diode
3. PIN Photodiode
4. Avalanche Photodiode

Applications of Photodiode

1. These diodes are used in smoke detectors, compact disc players, televisions and remote controls in VCRs.
2. Used in clock radios, camera light meters, and street lights.
3. Photodiodes are frequently used for exact measurement of the intensity of light in science & industry.
4. Photodiodes are also widely used in medical applications like instruments to analyze samples, detectors for computed tomography, and also used in blood gas monitors.
5. These diodes are much faster hence frequently used for lighting regulation and in optical communications.

PHOTOTRANSISTER

A phototransistor is a light-sensitive transistor that converts light energy into electrical current. It acts as a light-controlled switch and can also amplify the current generated by incident light, making it more sensitive than a photodiode.

Types of Phototransistors:

1.**Bipolar Junction Transistor (BJT) Phototransistors:**These are the most common type and are essentially BJTs with a light-sensitive base region. They can be either NPN or PNP.

2.**Field Effect Transistor (FET) Phototransistors:**These operate on the principle of the photoelectric effect, with a conducting channel between the drain and source, and a gate (base) region that is not light-sensitive.

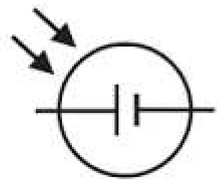
3.**Heterojunction Phototransistors:**These use different semiconductor materials for the emitter, base, and collector, offering better control over carrier flow and improved light responsiveness.

Applications of Phototransistors:

1. **Light Detection and Control:** Used to detect the presence or intensity of light and control electronic circuits accordingly.
2. **Optical Switches:** Act as light-activated switches, turning circuits on or off based on light levels.
3. **Counting Systems:** counts objects or events based on light interruption, such as in punch card readers.
4. **Alarm Systems:** Used in security systems to detect unauthorized light or movement.
5. **Level Indicators:** Indicate the level of a substance by detecting the amount of light reflected or transmitted by it.
6. **Proximity Detectors:** Detect the presence of nearby objects by sensing changes in reflected light.
7. **Encoders:** Used in encoders to generate digital signals based on light and position.
8. **Light Meters:** Used in light meters to measure the intensity of light.
9. **Smoke Detectors:** Used to detect smoke particles that scatter light.
10. **Infrared Receivers:** Detect infrared light, used in remote controls and other applications.
11. **Solar Power Generation:** In some cases, used in solar power systems to detect and respond to sunlight.

SOLOR CELL

A solar cell, also known as a photovoltaic (PV) cell, is a device that converts light energy into electrical energy. It works on the photovoltaic effect, where light striking the cell causes electrons to flow, generating an electrical current. Solar cells are primarily made of semiconductor materials, most commonly silicon.



Solar Cell

Types of Solar Cells

1.**Monocrystalline:**Made from a single, continuous crystal of silicon, offering high efficiency but higher cost.

2. Polycrystalline: Made from many silicon crystals, less efficient than monocrystalline but more affordable.

3. Thin-film: Various materials like amorphous silicon, CdTe, or CIGS are deposited in thin layers. Lower cost but typically lower efficiency.

4.**Concentrated Photovoltaic (CPV):**Use lenses or mirrors to focus sunlight onto smaller, high-efficiency solar cells.

5.**Perovskite solar cells:** A newer technology using perovskite materials, known for rapid efficiency improvements, but still under development for long-term stability.

Applications of Solar Cells

1. **Residential and Commercial Power:** Rooftop solar panels for homes to generate electricity
2. **Spacecraft:** Providing power for satellites and other spacecraft.
3. **Transportation:** Solar-powered vehicles, including cars, boats, and other electric vehicles.
4. **Portable Electronics:** Calculators, watches, and other small devices powered by solar cells.
5. **Remote Power:** Powering off-grid locations, such as remote villages or research stations.
6. **Water heating and Pumping:** solar energy to heat water for various applications.
7. **Solar Lighting:** Streetlights and other outdoor lighting systems powered by solar energy.
8. **Agricultural Applications:** Solar dryers, water pumps, and other tools for farming.
9. **Industrial Processes:** Solar thermal power plants generate electricity by concentrating sunlight to heat fluids.

THANK YOU