UNIT – IV:

Radiation Sensors

1. INTRODUCTION TO RADIATION SENSORS

Definition

Radiation sensors are devices used to detect electromagnetic radiation or nuclear radiation and convert it into electrical signals.

Purpose

- Detection of light
- Detection of X-rays
- Detection of gamma rays
- Measurement of radiation intensity

Applications

- Medical imaging
- Nuclear power plants
- Space research
- Communication systems
- Industrial inspection

2. BASIC CHARACTERISTICS OF RADIATION SENSORS

Sensitivity

Ability to detect weak radiation.

Spectral Response

Response over different wavelengths.

Response Time

Time taken to react to radiation.

Resolution

Ability to distinguish small radiation changes.

Noise Level

Unwanted electrical signals.

Stability

Ability to maintain accuracy over time.

3. TYPES OF PHOTORESISTORS / PHOTODETECTORS

A. PHOTORESISTOR (LDR)

Definition

Light Dependent Resistor (LDR) changes resistance according to light intensity.

Principle

Resistance decreases as light intensity increases.

Characteristics

- High resistance in darkness
- Low resistance in bright light

Applications

- Street lights
- Camera exposure meters
- Light sensing circuits

B. PHOTODIODE

Principle

Uses photoelectric effect.

Working

Light generates electron-hole pairs producing current.

Advantages

- Fast response
- High sensitivity

Applications

- Optical communication
- Light measurement

C. PHOTOTRANSISTOR

Principle

Operates like a photodiode with transistor amplification.

Advantages

- Higher output current
- Better sensitivity

Applications

- Optical switches
- Light detectors

D. SOLAR CELL

Principle

Converts sunlight directly into electrical energy.

Applications

- Solar power systems
- Satellites
- Calculators

4. X-RAY SENSORS

Definition

Sensors used for detection of X-ray radiation.

Principle

X-rays ionize matter and generate electrical signals.

Types

- Scintillation detectors
- Semiconductor detectors
- Ionization chambers

Applications

- Medical diagnostics
- Airport security
- Industrial inspection

5. NUCLEAR RADIATION SENSORS

Definition

Detect alpha, beta, gamma, and neutron radiation.

Types

Geiger-Muller Counter

Detects ionizing radiation.

Scintillation Detector

Converts radiation into light pulses.

Semiconductor Detector

Converts radiation directly into electrical signals.

Applications

- Nuclear reactors
- Radiation monitoring
- Medical imaging

6. FIBRE OPTIC SENSORS

Definition

Sensors that use optical fibers to detect physical parameters.

Principle

Physical changes affect light transmission through fiber.

Characteristics

- Immune to EMI
- Lightweight
- High sensitivity

Types

Intrinsic Sensors

Measurement occurs inside fiber.

Extrinsic Sensors

Measurement occurs outside fiber.

Applications

- Structural health monitoring
- Temperature sensing
- Pressure sensing
- Biomedical systems

ECTRO-ANALYTICAL SENSORS

7. ELECTROCHEMICAL CELL

Definition

A device that converts chemical energy into electrical energy.

Components

- Anode
- Cathode
- Electrolyte

Working

Chemical reactions produce electrical potential.

Types

- Galvanic Cell
- Electrolytic Cell

Applications

- Batteries
- Electrochemical sensors

- pH measurement

8. CELL POTENTIAL (EMF)

Definition

Voltage difference between two electrodes of an electrochemical cell.

Cell EMF

$$E_{cell} = E_{cathode} - E_{anode}$$

Factors Affecting EMF

- Temperature
- Concentration
- Electrode material

Applications

- Chemical analysis
- Sensor calibration

9. STANDARD HYDROGEN ELECTRODE (SHE)

Definition

Primary reference electrode used for measuring electrode potentials.

Construction

- Platinum electrode
- Hydrogen gas at 1 atm
- H^+ ions concentration = 1 M

Standard Potential

$$E^0 = 0\ V$$

Advantages

- Universal reference standard

Applications

- Electrochemical measurements

- Calibration of electrodes

10. LIQUID JUNCTION POTENTIAL

Definition

Potential difference formed at the boundary of two electrolyte solutions.

Cause

Different ion diffusion rates.

Effects

- Measurement errors
- Reduced accuracy

Reduction Methods

- Salt bridges
- Junction compensation

11. OTHER POTENTIALS

Membrane Potential

Develops across selective membranes.

Diffusion Potential

Produced by unequal ion movement.

Electrode Potential

Potential difference between electrode and electrolyte.

Importance

Affects sensor accuracy and calibration.

12. POLARIZATION

Definition

Deviation of electrode potential from equilibrium value due to current flow.

Causes

- Chemical reactions
- Gas accumulation
- Ion depletion

Effects

- Reduced accuracy
- Slower sensor response

13. CONCENTRATION POLARIZATION

Definition

Occurs when concentration of ions near electrode changes during operation.

Cause

Slow diffusion of ions.

Effects

- Voltage drop
- Reduced sensor efficiency

Prevention

- Stirring electrolyte
- Increasing diffusion rate

14. REFERENCE ELECTRODES

Definition

Electrodes with stable and known potential.

Characteristics

- Constant potential

- Reproducible response

Types

Standard Hydrogen Electrode (SHE)

Saturated Calomel Electrode (SCE)

Silver/Silver Chloride Electrode

Applications

- pH meters
- Electrochemical analysis

15. SENSOR ELECTRODES

Definition

Electrodes used to detect specific ions or chemicals.

Types

Metal Electrodes

Detect metal ions.

Ion Selective Electrodes (ISE)

Detect specific ions.

Glass Electrodes

Used for pH measurement.

Applications

- Water analysis
- Medical diagnostics
- Chemical industries

16. ELECTROCERAMICS IN GAS MEDIA

Definition

Ceramic materials used as gas sensors.

Principle

Gas interaction changes electrical properties.

Common Materials

- Zirconia (ZrO_2)
- Tin Oxide (SnO_2)
- Titanium Oxide (TiO_2)

Characteristics

- High temperature operation
- Good chemical stability

Applications

- Oxygen sensors
- Pollution monitoring
- Industrial gas detection

IMPORTANT FORMULAS

Cell Potential

$$E_{cell} = E_{cathode} - E_{anode}$$

Standard Hydrogen Electrode

$$E^0 = 0\ V$$

SHORT EXAM POINTS

Radiation Sensors

✓ LDR → Resistance changes with light

✓ Photodiode → Light produces current

✓ Phototransistor → Amplified photodiode

✓ Solar Cell → Converts sunlight to electricity

✓ X-ray Sensor → Detects X-radiation

✓ Nuclear Sensor → Detects alpha, beta, gamma radiation

✓ Fibre Optic Sensor → Uses light in optical fibers

Electro-Analytical Sensors

✓ Electrochemical Cell → Chemical energy to electrical energy

✓ SHE → Standard reference electrode (0 V)

✓ Polarization → Change in electrode potential due to current

✓ Concentration Polarization → Ion concentration changes near electrode

✓ Reference Electrode → Stable known potential

✓ Sensor Electrode → Detects specific ions

✓ Electroceramic Sensor → Gas sensing using ceramic materials

FREQUENTLY ASKED 5-MARK QUESTIONS

1. LDR and Photodiode
2. Fibre Optic Sensors
3. X-ray Sensors
4. Standard Hydrogen Electrode
5. Reference Electrodes
6. Sensor Electrodes
7. Electroceramics in Gas Media

FREQUENTLY ASKED 10-MARK QUESTIONS

1. Types of Photodetectors
2. Nuclear Radiation Sensors
3. Fibre Optic Sensors – Construction and Working
4. Electrochemical Cell and Cell Potential
5. Standard Hydrogen Electrode (SHE)
6. Polarization and Concentration Polarization
7. Reference Electrodes and Sensor Electrodes
8. Electroceramics in Gas Media and Applications

ONE-LINE REVISION

- LDR → Light changes resistance.

- Photodiode → Light generates current.
- Fibre Optic Sensor → Uses light transmission.
- SHE → Standard reference electrode (0 V).

- Polarization → Electrode potential shift.
- Reference Electrode → Stable potential.
- Electroceramics → Gas sensing materials.
- Nuclear Sensors → Detect ionizing radiation