

|           |                                |          |   |   |   |   |        |                         |
|-----------|--------------------------------|----------|---|---|---|---|--------|-------------------------|
| 25UEET413 | ELECTRICAL<br>MATERIAL SCIENCE | Category | L | T | P | R | Credit | Year of<br>Introduction |
|           |                                | PEC      | 3 | 0 | 0 | 0 | 3      | 2025                    |

**Preamble:** By integrating theoretical knowledge with practical applications, this course enables students to select appropriate materials for electrical and electronic components, design reliable devices, and understand the limitations and performance of materials under different operating conditions.

**Prerequisite:** IEE 104 Introduction to Electrical and Electronics Engineering

**Course Outcomes:** After the completion of the course, the student will be able to:

| CO  | Course Outcomes                                                                                                                                                      | Knowledge Level |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| CO1 | Apply the properties of conducting and semiconductor materials to select suitable materials for electrical and electronic applications.                              | K3<br>Apply     |
| CO2 | Apply the principles of dielectric and insulating materials to evaluate their performance in electrical engineering applications.                                    | K3<br>Apply     |
| CO3 | Apply knowledge of dielectric breakdown mechanisms to analyze insulation failure in gases, liquids, solids, and vacuum systems                                       | K3<br>Apply     |
| CO4 | Apply the properties of magnetic, superconducting, and solar energy materials, and use material characterization techniques to assess their engineering applications | K3<br>Apply     |

**Mapping of course outcomes with program outcomes and program specific outcomes**

|     | PO1 | PO2 | PO3 | PO4  | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PSO1 | PSO2 |
|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|------|------|------|------|
| CO1 | 3   | 2   | 1   | 1    | -   | -   | -   | -   | -   | -    | 1    | 3    | 2    |
| CO2 | 3   | 3   | 1   | 1    | -   | -   | -   | -   | -   | -    | 1    | 3    | 2    |
| CO3 | 3   | 3   | 2   | 2    | -   | -   | -   | -   | -   | -    | 1    | 3    | 2    |
| CO4 | 3   | 2   | 2   | 1    | -   | -   | -   | -   | -   | -    | 1    | 2    | 3    |
| Avg | 3   | 2.5 | 1.5 | 1.25 | -   | -   | -   | -   | -   | -    | 1.3  | 2.75 | 2.25 |

**Mapping of course outcomes with Knowledge and Attitude Profile (WK)**

|     | WK1 | WK2 | WK3 | WK4 | WK5 | WK6 | WK7 | WK8 | WK9 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| CO1 | *   | *   | *   | *   | *   | -   | -   | *   | -   |
| CO2 | *   | *   | *   | *   | *   | -   | -   | *   | -   |
| CO3 | *   | *   | *   | *   | *   | -   | -   | *   | -   |
| CO4 | *   | *   | *   | *   | *   | -   | -   | *   | -   |

**Wks Mapped with the course**

| WK1 | WK2 | WK3 | WK4 | WK5 | WK6 | WK7 | WK8 | WK9 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| *   | *   | *   | *   | *   | -   | -   | *   | -   |

**Mark Distribution:**

| Total Marks | CIE Marks | ESE Marks | ESE Duration |
|-------------|-----------|-----------|--------------|
| 100         | 40        | 60        | 2.5 Hours    |

**Continuous Internal Evaluation Pattern:**

|                                  |            |
|----------------------------------|------------|
| Attendance                       | : 5 marks  |
| Continuous Assessment Test       | : 20 marks |
| Continuous Assessment Assignment | : 15 marks |

**SYLLABUS****Module 1 (10 Hours)**

Conducting Materials-Electrical conductivity – factors affecting conductivity-Dependence of conductivity on:-Temperature-Composition and impurities-Materials for electrical applications:-Low resistivity materials-High resistivity materials-Materials used in electrical machines-Resistance materials-Contact materials-Solder materials. Semiconductor Materials-Intrinsic and extrinsic semiconductors-Semiconductor materials and properties-Silicon-Germanium. Advanced Semiconductor Materials- Compound semiconductors: Gallium Arsenide (GaAs)-Cadmium Sulphide (CdS)

**Module 2 (11 Hours)**

Dielectric Materials-.Dielectric polarization mechanisms: Electronic polarization-Ionic polarization-Orientation polarization-Space charge polarization-Classification of dielectric materials-Clausius-Mosotti relation. Insulating Materials- Classification of insulating materials. Properties of insulating

materials: Electrical properties-Thermal properties-Mechanical properties-Chemical properties. Common Insulating Materials-Solid insulating materials: Inorganic insulators (ceramics, mica, glass)-Organic insulators (paper, rubber, plastics)-Liquid insulators: Transformer oil-Gaseous insulators:-Air-SF<sub>6</sub> gas.

### Module 3 (10 Hours)

Dielectric Breakdown in Gases-Townsend breakdown mechanism-Streamer mechanism. Breakdown in Liquid Dielectrics-Suspended particle theory-Cavitation theory. Breakdown in Solid Dielectrics-Intrinsic breakdown-Electro-mechanical breakdown-Thermal breakdown. Ageing and Failure of Insulators-Factors influencing ageing: Electrical stress-Thermal stress-Environmental conditions. Transformer Oil Testing and Treatment: Importance of transformer oil-Basic testing methods-Oil treatment methods

### Module 4 (11 Hours)

Magnetic Materials for Electrical Applications: Soft magnetic materials: Silicon steel-Ferrites-Hard magnetic materials: Permanent Magnets-Applications in: Electrical machines-Transformers-Relays-Instruments. Superconducting Materials: Basic concept of superconductivity-Types of superconductors:-Type I-Type II-Characteristics:-Critical temperature-Critical field-Applications Solar Energy Materials: Photo-thermal conversion-Solar selective coatings-Photovoltaic conversion-Solar cell materials:-Silicon-Cadmium sulphide-Gallium arsenide-Organic solar cells.Emerging and Next-Generation Battery Materials- Sodium-ion battery materials: Sodium Iron Phosphate ,Prussian Blue compounds. Nano-materials: Graphene, Carbon Nanotubes (CNT), MXenes. Thermal management materials: Phase Change Materials (PCM), ceramic insulation materials. Introduction to solid-state battery and lithium-metal battery materials.

### Text Books

1. Dekker, A. J. (2014). *Electrical engineering materials*. Prentice Hall of India / Pearson Education.
2. Solymar, L., Walsh, D., & Syms, R. R. A. (2018). *Electrical properties of materials*. Oxford University Press.
3. Bhattacharya, S. K. (2022). *Electrical engineering materials*. S. K. Kataria & Sons.

### Reference Books

1. Hummel, R. E. (2000). *Electronic properties of materials*. Springer.
2. Fulay, P., & Lee, J.-K. (2016). *Electronic, magnetic, and optical materials*. CRC Press.
3. Martinez-Vega, J. (2010). *Dielectric materials for electrical engineering*. Wiley.
4. Kittel, C. (2019). *Introduction to solid state physics*. Wiley India.
5. Ashcroft, N. W., & Mermin, N. D. (2003). *Solid state physics*. Cengage Learning.

## END SEMESTER EXAMINATION – MODEL QUESTION PAPER (STC 2025 SCHEME)

|                |                             |
|----------------|-----------------------------|
| Course Code    | 25UEET413                   |
| Course Name    | ELECTRICAL MATERIAL SCIENCE |
| Max. Marks: 60 | Duration: 2.5 Hours         |

| <b>Part A</b><br><i>(Answer all questions. Each question carries 3 marks)</i>               |                                                                                                                                                                 |              |           |           |
|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-----------|-----------|
| <b>Qn No.</b>                                                                               | <b>Question</b>                                                                                                                                                 | <b>Marks</b> | <b>CO</b> | <b>BL</b> |
| 1                                                                                           | Explain the effect of temperature on the electrical conductivity of conducting materials.                                                                       | 3            | 1         | L2        |
| 2                                                                                           | Differentiate intrinsic and extrinsic semiconductors with suitable examples.                                                                                    | 3            | 1         | L2        |
| 3                                                                                           | Describe the various dielectric polarization mechanisms.                                                                                                        | 3            | 2         | L2        |
| 4                                                                                           | Classify insulating materials with suitable examples.                                                                                                           | 3            | 2         | L2        |
| 5                                                                                           | Explain the Townsend breakdown mechanism in gases.                                                                                                              | 3            | 3         | L2        |
| 6                                                                                           | Explain the factors influencing ageing of insulating materials.                                                                                                 | 3            | 3         | L2        |
| 7                                                                                           | Compare soft magnetic materials and hard magnetic materials.                                                                                                    | 3            | 4         | L2        |
| 8                                                                                           | Explain the significance of critical temperature in superconductors                                                                                             | 3            | 4         | L2        |
| <b>Part B</b><br><i>(Answer any one full question from each Module. Each carry 9 marks)</i> |                                                                                                                                                                 |              |           |           |
| <b>Module I</b>                                                                             |                                                                                                                                                                 |              |           |           |
| <b>Qn No.</b>                                                                               | <b>Question</b>                                                                                                                                                 | <b>Marks</b> | <b>CO</b> | <b>BL</b> |
| 9.a                                                                                         | Compare low resistivity materials and high resistivity materials used in electrical engineering applications with respect to their properties and applications. | 6            | 1         | L2        |
| 9.b                                                                                         | Explain the properties and applications of Gallium Arsenide (GaAs) and Cadmium Sulphide (CdS).                                                                  | 3            | 1         | L2        |
| <b>OR</b>                                                                                   |                                                                                                                                                                 |              |           |           |
| 10.a                                                                                        | Summarize the effect of composition and impurities on the conductivity of conducting materials with suitable examples.                                          | 6            | 1         | L2        |
| 10.b                                                                                        |                                                                                                                                                                 | 3            | 1         | L2        |

|                   |                                                                                                                                                                       |              |           |           |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-----------|-----------|
|                   | Describe the properties of Silicon and Germanium as semiconductor materials.                                                                                          |              |           |           |
| <b>Module II</b>  |                                                                                                                                                                       |              |           |           |
| <b>Qn No.</b>     | <b>Question</b>                                                                                                                                                       | <b>Marks</b> | <b>CO</b> | <b>BL</b> |
| 11.a              | Explain the Clausius–Mosotti relation and describe the relationship between dielectric constant and molecular polarizability.                                         | 5            | 2         | L2        |
| 11.b              | Explain the electrical and thermal properties of insulating materials.                                                                                                | 4            | 2         | L2        |
| <b>OR</b>         |                                                                                                                                                                       |              |           |           |
| 12.a              | Describe the various dielectric polarization mechanisms with suitable illustrations.                                                                                  | 5            | 2         | L2        |
| 12.b              | Describe the properties and applications of transformer oil as a liquid insulating material.                                                                          | 4            | 2         | L2        |
| <b>Module III</b> |                                                                                                                                                                       |              |           |           |
| <b>Qn No.</b>     | <b>Question</b>                                                                                                                                                       | <b>Marks</b> | <b>CO</b> | <b>BL</b> |
| 13. a             | Demonstrate the breakdown mechanisms in gaseous, liquid, and solid dielectrics.                                                                                       | 5            | 3         | L3        |
| 13. b             | Explain the importance of transformer oil testing and treatment methods.                                                                                              | 4            | 3         | L2        |
| <b>OR</b>         |                                                                                                                                                                       |              |           |           |
| 14. a             | Apply the suspended particle theory and cavitation theory to determine the causes of breakdown in liquid dielectrics.                                                 | 5            | 3         | L3        |
| 14. b             | Describe the effects of electrical stress and thermal stress on the ageing of insulators.                                                                             | 4            | 3         | L2        |
| <b>Module IV</b>  |                                                                                                                                                                       |              |           |           |
| <b>Qn No.</b>     | <b>Question</b>                                                                                                                                                       | <b>Marks</b> | <b>CO</b> | <b>BL</b> |
| 15. a             | Determine the type of superconductor suitable for MRI magnets and power transmission applications based on the characteristics of Type I and Type II superconductors. | 6            | 4         | L3        |
| 15. b             | Explain the applications of soft magnetic materials and hard magnetic materials in electrical machines, transformers, relays, and measuring instruments.              | 3            | 4         | L2        |
| <b>OR</b>         |                                                                                                                                                                       |              |           |           |
| 16. a             | A satellite manufacturer needs a high-efficiency solar cell.                                                                                                          | 6            | 4         | L3        |

|       |                                                                                                            |   |   |    |
|-------|------------------------------------------------------------------------------------------------------------|---|---|----|
|       | Determine the most suitable solar cell material for the application, with stating its reason.              |   |   |    |
| 16. b | Describe the importance of nanomaterials and biomaterials in emerging electrical engineering applications. | 3 | 4 | L2 |

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