INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-501 **Course Title**: Structure of Materials

2. Contact Hours: L: 3 T: 1 P: 0

3. Examination Duration (Hrs): **Theory:** 3 **Practical**: 0

4. Relative Weight **: CWS:** 25 **PRS:** 0 **MTE:** 25 **ETE:** 50 **PRE:** 0

5. Credits: 4 **6. Semester:** Autumn

7. Pre-requisite: NIL **8. Subject Area:** PCC

9. Objective: To provide knowledge of structure property correlations of different materials.

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1.	**Nature of Geometry of Crystals:** Atomic arrangements in solids, space lattices, coordination number and effective number of atoms for common crystalline structures: FCC, BCC and HCP, indexing of crystallographic planes and directions.	4
2.	**Structure of Ceramics and Polymers:** Atomic arrangements in ceramics and polymers, their influence on mechanical properties.	3
3.	**Principles of Alloy Formation:** Primary and intermediate phases their formation, solid solutions, Hume Rothery rules, electron compounds, normal valency compounds and interstitial compounds.	4
4.	**Solidification:** Solidification of metals and alloys- equiaxed, dendritic and columnar grains; Coring.	3
5.	**Phase Diagrams:** Binary equilibrium diagrams involving isomorphous, eutectic, peritectic and monotectic systems, phase rule, lever rule effect of non-equilibrium cooling on structure and distribution of phases.	8
6.	**Solid State Transformations:** Phase equilibria involving eutectoid and peritectoid transformations, TTT and CCT diagrams, harenability,Heat Treatment of Ferrous and Non Ferrous Alloys viz., annealing, normalizing, quenching, tempering and precipitation hardening.	8
7.	**Diffusion in Solids:** Fick's laws of diffusion, Darken's equation, Kirkendall effect and mechanism of diffusion.	4
8.	**Important Binary Systems:** Cu-Ni, Al-Si, Al-Cu, Pb-Sn, Cu-Zn, Cu-Sn and Fe-C systems, effect of non equilibrium cooling and important alloys belonging to these systems.	8
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Book/ Publisher	Year of Publication/ Reprint
1.	Avner, S.H., "Introduction to Physical Metallurgy", McGraw Hill	2005
2.	Callister W.D., Materials Science and Engineering, 7th Ed., Wiley India (P) Ltd.	2010
3.	Hansen, P. Mordike, B.L., "Physical Metallurgy", 3rd Ed. Cambridge University Press	1996
4.	Hosford. W.F, "Physical Metallurgy", 2nd Ed., CRC Press	2011
5.	Smallman, R.E., Ngan, A.H.W., Modern Physical Metallurgy, 8th Ed. Butterworth-Heinemann.	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-502 **Course Title**: Modeling, Simulation, and Computer Applications

2. Contact Hours: L: 3 T: 0 P: 2

3. Examination Duration (Hrs): Theory: 3 **Practical**: 0

4. Relative Weight : CWS: 15 **PRS:** 25 **MTE**: 20 **ETE:** 40 **PRE:** 0

5. Credits: 4 **6. Semester:** Spring

7. Pre-requisite: NIL **8. Subject Area:** PCC

9. Objective : To impart knowledge on modeling with emphasis on metallurgical systems.

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1.	**Introduction :** System, environment, input and output variables; State variables and their transition; Hierarchy of knowledge about a system; System identification – structure and parameter identification; Deterministic and stochastic systems; Static and Dynamic Systems; Objectives of modelling and simulation	4
2.	**Physical Modelling:** Dimension analysis, Dimensionless grouping of input and output variables to find empirical relations, similarity criteria and their application to physical models.	5
3.	**Modelling of Systems with Known Structure:** Review of conservation laws and the governing equation for heat, mass and momentum transfer, Deterministic models – (a) distributed parameter models in terms of partial differential equations and their solutions and (b) lumped parameter models in terms of differential and difference equations, state space models, transfer functions, block diagrams and subsystems, stability of transfer functions, modelling for control, Stochastic models	10
4.	**Neural Network Modelling of Systems only with Input-output Database:** Neurons, architecture of neural network, knowledge representation, learning algorithm, Multilayer feed forward network and its back propagation learning algorithm, Application to metallurgical systems.	6
5.	**Fuzzy logic modelling of systems only with broad expert knowledge:** Fuzzy sets, membership functions, fuzzy linguistic variables, 'IF-THEN' rules, Fuzzy Inference systems (FIS) – (i) Mamdani type and (ii) Sugeno (TSK) type, Application to metallurgical systems.	5
6.	**Neuro-fuzzy Modelling of Systems with Limited Database:**	4

	Adaptive neuro-fuzzy inference system (ANFIS), hybrid learning algorithm using MATLAB®; Co-active neuro-fuzzy system (CANFIS)	
7.	**Optimization and Design of Systems:** Summary of gradient based techniques; Nontraditional optimization techniques – (i) Genetic Algorithm (GA) – coding, GA operators, elitism, application using MATLAB; (ii) Simulated Annealing	4
8.	**Simulation of Metallurgical Systems:** Monte-Carlo simulation, simulation of solidification and casting, simulation of melt stream disintegration by fluid flow	4
	Total	**42**

List of Practicals:

1. Introduction to programming with MATLAB
2. Find the response of a lumped variable model expressed in terms of transfer function using MATLAB for inputs of (i) unit step function, (ii) unit impact function and (iii) unit ramp function
3. Use of Simulink in MATLAB® for metallurgical problems
4. Use of Neural Network in MATLAB for metallurgical problems
5. Use of FIS and ANFIS in MATLAB for metallurgical problems
6. Develop a computer program to determine the temperature of ingot during its solidification.
7. Develop a computer program to determine the temperature of metal slab during its hot rolling.
8. Develop a computer program for Monte Carlo simulation for grain growth.

11. Suggested Books:

Sl. No.	Name of Authors/ Book/ Publisher	Year of Publication/ Reprint
1.	Zeigler, B.P., Praehofer, H. and Kim T.G., "Theory of Modelling and Simulation", 2nd Edition, Academic Press	2000
2.	Szekely, J.S. and Ray, W.H., "Process optimization with applications metallurgy and chemical engineering", Wiley-Interscience	1973
3.	Ogata, K., "Modern Control Engineering", 3rd Edition, Prentice Hall of India	2001
4.	Jang, J.S.R., Sun C.T. and Mizutani E., "Neuro-Fuzzy and Soft Computing", 3rd Edition, Prentice Hall of India	2002
5.	Kuang-O,Y., "Modeling for casting and solidification processing", Marcel Dekker	2002
6.	Irving, W.R., "Continuous casting of steel", Institute of Materials	1993
7.	Pratab, R., "Getting Started with MATLAB", Oxford University Press	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Metallurgical and Materials Engineering

1. **Subject Code**: MTN-503 **Course Title**: Characterization of Materials

2. Contact Hours: L: 3 T: 0 P: 2

3. Examination Duration (Hrs): **Theory:** 3 **Practical**: 0

4. Relative Weight **: CWS**: 15 **PRS:** 25 **MTE:** 20 **ETE:** 40 **PRE:** 0

5. Credits: 4 **6. Semester:** Autumn

7. Pre-requisite: NIL **8. Subject Area:** PCC

9. Objective: To familiarize the students with the basic principles related to materials characterization methods.

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1.	**X-ray Diffraction and Diffractometry:** Stereographic projection, Laue's equation, Bragg's condition of diffraction, structure factor rules, single phase analysis, multi-phase analysis, estimation of particle size and strain, orientation and texture, residual stress.	10
2.	**Light Microscopy:** Basic principles, estimation of grain size, grain boundary area, volume fraction of second phase.	5
3.	**Transmission Electron Microscopy (TEM):** Reciprocal space and lattice, Ewald sphere, diffraction from finite crystal, bright and dark field imaging, selected area diffraction, indexing of diffraction patterns, contrast from precipitates, dislocations, and stacking faults.	10
4.	**Scanning Electron Microscopy (SEM):** Basic principles of scanning electron microscopy, energy dispersive spectroscopy (EDS), wavelength dispersive spectroscopy (WDS), electron backscattered diffraction (EBSD).	6
5.	**Thermal analyses techniques:** Principles of differential scanning calorimetry (DSC), differential thermal analysis (DTA), Dilatometry, Thermogravimetric analysis (TGA).	6
6.	**Spectroscopy Methods:** Emission spectroscopy, Atomic Absorption Spectroscopy(AAS), Inductively Coupled Plasma – Mass Spectroscopy (ICP-MS).	5
	Total	**42**

List of Practicals:

1. Sample preparation for optical microscopy: estimation of grain size and volume fraction of second phases in brass.
2. Demonstration of X-ray diffraction equipment.
3. Indexing of the powder pattern obtained by XRD.
4. Demonstration of Transmission Electron Microscope.
5. Indexing of the Selected Area Diffraction (SAD) patterns.
6. Demonstration of Scanning Electron Microscope and EDS.
7. Demonstration of DSC technique.

11. Suggested Books

Sl. No.	Name of Authors/ Book/ Publisher	Year of Publication/ Reprint
1.	Goodhew, P.J., Humphreys, J. and Beanland, R., "Electron Microscopy and Analysis", 3rd Edition, Taylor and Francis	2001
2.	Cullity, B.D. and Stock, S.R., "Elements of X-Ray Diffraction", 3rd Edition, Printice Hall	2001
3.	Williams, D. B. and Carter, C. B., "Transmission Electron Microscopy: A Textbook for Materials Science", 2nd Edition, Springer	2009
4.	Goldstein, J., Newbury, D.E., Joy, D.C., Lyman, C.E., Echlin, P., Lifshin, E., Sawyer, L. and Michael, J.R., "Scanning Electron Microscopy and X-ray Microanalysis", 3rd Edition, Springer	2003
5.	Speyer, R., "Thermal Analysis of Materials", CRC Press	1993
6.	Dehoff, R.T. and Rhines, F.N., "Quantitaive Microscopy", McGraw Hill	1968

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-504 **Course Title**: Phase Transformation

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Spring

7. Pre-requisite: Nil **8. Subject Area:** PCC

9. Objective: To introduce the fundamentals of phase transformations in metal and alloys.

10. **Details of the Course**:

Sl. No.	Contents	Contact Hours
1.	**Introduction :** Types and classification of phase transformations, thermodynamic basis of phase transformation, introduction to concept of Gibbs free energy, entropy and enthalpy	2
2	**Thermodynamics and phase diagram:** Equilibrium in a closed system, effect of temperature and composition, order of transformation, fluctuations, stable unstable and metastable state, single component systems, binary solutions and binary phase diagrams	5
3	**Structural defects:** Surface free energy, interfaces in solids; boundaries in single phase solids, coherent, semicoherent and incoherent interfaces and interface migration	5
4	**Empirical transformations kinetics:** Atomic mechanism of diffusion, rate of atomic processes, empirical rate equation, determination of activation energy	5
5	**Liquid solid transformation:** Introduction, nucleation, rate of nucleation, growth, eutectic solidification, crystallization, cellular and dendritic solidification	9
6	**Diffusional transformations in solids:** Polymorphic transformations, massive transformations, order-disorder transformations, recrystallisation, precipitation, pearlitic reaction, cellular transformation, particle coarsening	9
7	**Spinodal decompositions:** Points of inflexion, solubility differences	2
8	**Martensitic transformations:** Thermodynamic of martensitic transformation, phenomenological theory of martensite crystallography (PTMC), effect of composition and temperature	5
	Total	**42**

11. Suggested Books:

Sl. No.	Authors/Name of Books/ Publisher	Year of Publications
1	Porter D.A. and Easterling K.E., Phase Transformations in Metals and Alloys, 3rd Ed., CRC Press.	2009
2	Jena A.K. and Chaturvedi M.C., Phase Transformations in Materials, Prentice Hall.	1992
3	Burke J., The Kinetics of Phase Transformations in Metals, Pergamon Press.	1996
4	Phase Transformation in Materials, Editor G. Kostoz, Wiley-VCH Verlag.	2001
5	Shewmon, P., Diffusion in Solids, 2nd Ed. Wiley.	1991

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-505 **Course Title**: Non Destructive Testing

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): Theory: 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS**: 0 0 **MTE**: 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester**: Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart the importance of non-destructive testing in assuring quality control in engineering components.

10. Details of the Course:

Sl.No.	Contents	Contact Hours
1	**Introduction:** Non destructive testing and its comparison with destructive testing, role of NDT in quality control.	5
2	**Liquid penetrant inspection:** its principles, equipment, advantages, limitations and applications.	6
3	**Magnetic particle inspection:** its principles, equipment, advantages, limitations and applications.	6
4	**Ultrasonic inspection:** its principles, equipment, advantages, limitations and applications.	6
5	**Eddy current inspection:** its principles, equipment, advantages, limitations and applications.	6
6	**X-ray radiography:** its principles, equipment, advantages, limitations and applications.	5
7	**Quality control:** Statistical quality control, control charts, control chart attribute and variables and acceptance sampling; Quality assurance and ISO 9000:2000	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Author/Book/ Publisher	Year of Publication/ Reprint
1	"Non Destructive Evaluation and Quality Control", Metals Handbook, Vol. 17, 9th Ed., ASM.	1989
2	Baldev Raj, Jayakumar T, Thavasimuthu M, Practical Non-Destructive Testing, 3rd Ed., Narosa.	2009
3	Srivastava, K.C., "Handbook of Magnetic Particle Testing", Oscar Publications.	1998
4	Grant, E.L. and Larenwork, R.S., "Statistical Quality Control", Tata McGraw-Hill.	2000
5	Hull, B., "Non Destructive Testing", Springer.	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Metallurgical and Materials Engineering

1. **Subject Code**: MTN-507 **Course Title**: Casting and solidification

2. Contact Hours: L: 3; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6 Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** DEC

9. Objective: To understand fundamentals of metal casting & solidification related to the foundry industry and quality control of the cast product.

10. **Details of the Course**:

Sl. No.	Contents	Contact Hours
1	**Introduction:** Metal casting as a manufacturing process, foundry industry in India, challenges for foundry industry in India, important industrial sectors using casting.	2
2	**Moulding processes, equipments and mechanization:** Different types of moulds, moulding materials and moulding processes, pattern and other mould making equipments, forces acting on moulds, mould factors in metal flow, moulding factors in casting design. ; different types of binders and their use in mould and core-making.	6
3	**Melting of metals and alloys for casting:** Brief mention of various melting units, melting and post melting treatments, melting practices as adopted for a few metals and alloys such as Al, Cu, steel, cast irons.	7
4	**Solidification of metals and alloys:** Nucleation, growth, role of alloy constitution, thermal conditions and inherent nucleation and growth conditions in the liquid melt, significance and practical control of cast structure.	9
5	**Principles of gating and risering:** Feeding characteristics of alloys, types of gates and risers, time of solidification and Chvorinov rule, Wlodawer system for feeder head calculations, gating ratio, concept of directionality in solidification, yield of casting and prescription for its augmentation.	7
6	**Special casting Methods:** Investment casting, die casting, centrifugal casting, full mould casting, vacuum sealed casting.	6
7	**Casting Defects & quality control:** A detailed analysis of casting defects, their causes and prescription of remedial measures.	5
	Total	**42**

11. Suggested Books:

Sl. No.	Authors/Name of Books/ Publisher	Year of Publications/ Reprint
1	Beeley, P. R., Foundry Technology, Newnes-Buttterworths.	2001
2	Jain, P. L., Principles of Foundry Technology, Tata McGraw-Hill Edu.	2003
3	Ramana Rao, T. V., Metal Casting, Principles and Practice, New Age International (P) Ltd.	2003
4	Webster, P. D., Fundamentals of Foundry Technology, Portwillis press, Red Hill.	1980
5	Mukherjee, P. C., Fundamentals of Metal Casting Technology, Oxford IBH.	1980
6	Hein, R. W., Loper, C.R. and Rosenthal, P.C., Principles of Metal Casting, Tata-Mc Graw Hill.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Metallurgical and Materials Engineering

1. **Subject Code**: MTN-511 **Course Title**: Thin Film Technology

2. Contact Hours: L: 3; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart knowledge on the processing and characterization of thin films for device applications

10. **Details of the Course**:

Sl. No.	Contents	Contact Hours
1	**Introduction**: Applications of thin films, process steps.	2
2	**Gas kinetics**: Maxwell-Boltzmann distribution, molecular impingement flux, Knudsen equation, mean free path, transport properties.	6
3	**Evaporation**: thermodynamics of evaporation, evaporation rate, alloys, compounds, sources, deposition monitoring techniques.	5
4	**Deposition**: adsorption, surface diffusion, nucleation, structure development, interfaces, stress, adhesion.	6
5	**Epitaxy**: symmetry, applications, disruption, growth monitoring, composition control, lattice mismatch, surface morphology.	6
6	**Chemical Vapor Deposition**: Gas supply and convection, reaction equilibrium and surface processes, diffusion limited deposition and reactor models.	6
7	**Film Analysis**: structure-thickness, topography, inhomogeneity, crystallography, bonding, point defects, composition, and optical, electrical and mechanical behavior of thin films.	6
8	**Applications:** Technology of polysilicon thin-film transistors, thin film transistors in active-matrix liquid crystal displays, organic based thin film transistors, vacuum deposited organic thin film transistos based on small molecules	5
	Total	**42**

11. Suggested Books:

Sl. No.	Authors/Name of Books/ Publisher	Year of Publications/ Reprint
1	Ohring, M., "Materials Science of Thin Films", 2nd Ed., Academic Press.	2001
2	Smith D.L., "Thin-Film Deposition: Principles and Practice", McGraw-Hill Professional.	1995
3	Kagan, C.R., Andry, P., "Thin Film Transistors", Marcel Dekker.	2003
4	Eishabini-Riad, A., Barlow, F. D., "Thin Film Technology Handbook", 1st Ed., McGraw-Hill Professional.	1997
5	Siddal, G. (Ed.), "Thin Films Science and Technology", Elsevier.	1984

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-512 **Course Title**: Joining of Materials

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart the knowledge of joining different metallic and non-metallic materials

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1	**Introduction:** Arc welding, electrical resistance welding, solid state welding, welding consumables, brazing and soldering, mechanical joining, adhesive joining	6
2	**Thermal and mechanical effects of joining**: Isotherm and thermal cycle, fusion and solidification, heat affected zone, microstructure, fastening, riveting, clinching, distortion and residual stresses in different joints	7
3	**Joining of ferrous and non ferrous metals**: Plain carbon structural steels, high strength low alloy steels, alloy steels, cast iron, stainless steels, aluminium alloys, copper alloys, titanium alloys, nickel alloys, characterization, defects and remedial measures	10
5	**Joining of non metallic materials**: Structural polymers, structural ceramics, composites, defects and remedial measures	5
6	**Joining of dissimilar materials**: Structural steel-stainless steel, aluminium-copper, metal-polymer, metal-ceramic, microstructure, defects and remedial measures	6
7	**Quality assessment of joint**: Inspection, mechanical testing, non-destructive testing, standards and codes for joint testing and qualification of joints	8
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publisher	Year of Publications/ Reprint
1	Larry J., Welding Principles and Applications, 4th Ed., Delmar Publishers	1999
2	Cornu J., Advanced Welding Systems: Consumable Electrode Processes, IFS Publications	1988
3	Koichi M., Analysis of Welded Structures, Pergamon Press.	1980
4	DeGarmo P.E., Black J.T. and Kohser R.A., Materials and Processes in Manufacturing, 8th Ed., Prentice-Hall India	2000
5	Parmer R.S., Welding Engineering and Technology, Khanna Publishers	1997
6	Mittal K.L. and Pizzi A., Adhesion Promotion Techniques, Marcel Dekker	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-513 **Course Title**: Engineering Ceramics

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semesters:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart knowledge on ceramic materials, their properties, processing and engineering applications.

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1	**Introductory overview**: General characteristics of ceramics, ceramic microstructures, ceramic crystal structures.	3
2	**Ceramic powder preparation and characterization**: Powder synthesis by mechanical methods and chemical methods; Powder characterization: (1) Physical characterization relating particle shape, size, size distribution, surface area, porosity; (2) chemical characterization relating to chemical compositions, phase composition	7
3	**Colloidal Processing**: Types of colloids; Electrostatic stabilization: charges on particles in a liquid, origins of electrical double layer, repulsion between two double layers; Polymeric stabilization: Steric stabilization, stability and sterically stabilized suspensions; Rheology of colloidal suspensions: rheological properties, viscosity of colloidal suspensions; Industrial application of colloidal methods.	6
4	**Powder consolidation and shape forming processes**: Dry and semidry pressing methods: die compaction, isostatic pressing; Casting methods: slip casting, pressure casting, tape casting; Additives in forming process, plastic forming methods: extrusion and injection moulding.	6
5	**Sintering of ceramics**: Defects and defect chemistry; Solid state sintering, atomic mechanisms, coarsening, densification, sintering kinetics: sintering stages, coarsening and grain growth kinetics; Liquid phase sintering: introduction, the different stages, controlling kinetics and thermodynamic factors; Problems of sintering.	8
6	**Ceramic phase diagrams**: Binary systems: complete solid solubility, eutectic diagrams with partials solid solubility and no intermediate	4

	compounds, partial solid solubility with formation of intermediate compounds; Ternary systems.	
7	**Mechanical behavior of ceramics**: Theory of brittle fracture; cracking; strength variability; properties: Hardness, compressive strength, flexural strength, elastic modulus, fracture toughness; toughening mechanisms.	4
8	**Glasses**: Glass formation : kinetics and criteria for glass formation; glass structure; glass properties: glass transition temperature, thermodynamic considerations; Glass-ceramics: processing, properties and industrial applications.	4
	Total	**42**

11. Suggested Books:

S. No.	Name of Authors /Books/ Publisher	Year of Publication/ Reprint
1.	Barsoum M. W., Fundamentals of Ceramics, The McGraw-Hill Companies, Inc.	1997
2.	Kingery W.D., Bowen H.K. and Uhlmann D.R., Introduction to Ceramics, 2nd Ed., John Wiley	1991
3.	Richerson, D.W., "Modern Ceramic Engineering – Properties, Processing and use in Design", Marcel Dekker, Inc.	1992
4.	Rahaman, M. N., "Ceramic Processing and Sintering", Marcel Dekker Inc.	1995
5.	Carter C.B. and Norton M.G., Ceramic Materials: Science and Engineering., 2nd Ed. Springer	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-514 **Course Title**: Powder Metallurgy

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semesters:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To introduce the concepts of powder metallurgy with special reference to recent development of powder metallurgy products

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1	**Introduction:** Scope, limitations in making components, application of powder metallurgy	3
2	**Powder production:** Production methods like physical, chemical, mechanical methods; Single fluid atomization like rotating electrode atomization, roller atomization, rotating disc atomization; Two fluid atomization like gas atomization, water atomization, oil atomization etc. Reduction methods, carbonyl process, hydride-dehydride process, electrolytic method	8
3	**Powder characterization:** Particle size and Size distribution using sieving, sedimentation method, Andreasen pipette method, size distribution functions like normal distribution, log-normal distribution, Rosin-Rammler distribution, particle shape, shape factors, specific surface area of powder, flow rate, tap density, apparent density, compressibility, pyrophoricity, explosivity, toxicity of powder	8
4	**Powder compaction:** Die compaction, isostatic pressing, single level and multi level part compaction, repressing, plane strain compression, powder forging, powder roll compaction, powder extrusion	8
5	**Sintering:** Theory of sintering, sintering practice, furnaces and atmosphere control, activated sintering techniques, after sintering treatments; industrial sintering practice for various and non-ferrous products	8
6	**Applications of powder metallurgy:** Self-lubricating bearing, magnetic materials, tungsten carbide tool bits, bearing materials, dispersion strengthen materials for high temperature applications and manufacture of diamond based cutting tools, break pads	7
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/Authors/Publisher	Year of Publication/ Reprint
1	German R.M., Powder Metallurgy and Particulate Materials Processing, MPIF.	2005
2	Masuda H., Powder Technology Handbook, Taylor & Francis	2006
3	Sands R.L. and Shakespeare C.R., Powder Metallurgy Practice and Applications, Newness Publication	1970
4	Powder Metal Technologies and Applications, Metals Handbook, Vol.7, 9^{th} edition, ASM	1989
5	Upadhyaya G.S., Powder Metallurgy Technology, Cambridge Press	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN- 516 **Course Title**: Principles of Materials Selection

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semesters:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To introduce the salient materials selection criteria for various engineering applications

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1	**Introduction :** Selection criteria, service requirement, design fabricability, functionability, structure-property relationship reappraisal of the role of microstructure; Crystal structure and defect structure vis-à-vis properties; Materials and their applications, compositions, codes and properties	6
2	**Ferrous materials:** Applications of important ferrous materials like stainless steels, maraging steels, tool and die steels, high speed steels, and alloyed cast irons: their composition, heat treatment and properties	8
3	**Non-ferrous materials:** Applications of important non ferrous metals like Cu base, Al base, Ti base and Mg base alloys- their compositions, heat treatment, and properties	5
4	**Composites:** Some important composites like metal-matrix and composite, ceramic matrix composites- their composition, preparation, properties and their applications, some important structural ceramics	6
5	**Polymers:** Thermoplastic, thermo-setting polymers and elastomers, structures, properties and specific applications	6
6	**Wear and corrosion resistant materials:** Important wear resistant alloys for hydro and thermal power stations, low and high temperature materials	7
7	**Case studies:** Case studies highlighting selection of materials for specific applications	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/Authors/Publisher	Year of Publication/ Reprint
1	Ashby M.F., Materials Selection in Mechanical Design, 4th Ed., Butterworth-Heinemann	2010
2	Budinski K.G and Budinski M.K., Engineering Materials: Properties and selection, 9th Ed., Prentice Hall	2009
3	Ashby M.F. and Johnson K., Materials and Design: The art and science of materials selection in product design, 3rd Ed., Butterworth-Heinemann	2014
4	Martin J., Materials for Engineering, 2nd Ed., Woodhead Publishing	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Metallurgical and Materials Engineering

1. **Subject Code**: MTN-517 **Course Title**: High Temperature Materials

2. Contact Hours: L: 3; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart knowledge on requirements for materials for high temperature use and the behavior of materials at high temperatures.

10. **Details of the Course**:

Sl. No.	Contents	Contact Hours
1	**Introduction:** Need for high temperature materials, historical development of high temperature materials, equipment for material testing at high temperatures, requirements of high temperature materials (mechanical properties and preferred microstructure, environmental resistance, erosion and wear).	5
2	**Principles for high temperature strengthening:** Metallic materials (solid solution strengthening, precipitation strengthening, dispersion strengthening grain size and grain boundary effects) Ceramic materials (phase control, defect tolerance, thermal shock resistance) composite materials.	7
3	**Creep and stress rupture:** Creep test, stress rupture test, structural changes during creep, mechanism of creep deformation, fracture at elevated temperatures.	6
4	**Creep- fatigue interaction**: Modes of high temperature fracture and fatigue fracture, creep-fatigue interaction (creep accelerated by fatigue), fatigue-creep interaction (fatigue accelerated by creep), micro-mechanism of damage, fracture criterion for creep fatigue, creep-fatigue failure mapping, creep-fatigue testing, influence of environment.	7
5	**Materials for high temperature:** Metals / alloys, superalloys, steels, titanium and its alloys, ceramics (Alumina, Zirconia, Silicon carbide, Silicon nitride, Glass ceramics) composites (Metal matrix composites, ceramic matrix composites) carbon – carbon composites.	7

6	**Coatings for protection against high temperature corrosion and erosion:** Corrosion / oxidation resistant coatings (metallic, ceramic, rare and reactive metal reinforced coatings), high temperature erosion and wear, thermal barrier coats.	6
7	**Case studies:** Applications in industry, aerospace, defense and nuclear industry.	4
	Total	**42**

11. Suggested Books:

Sl. No.	Authors/Name of Books/ Publisher	Year of Publications/ Reprint
1	Meetham, G. W., Van de Voorde, M. H., "Materials for High Temperature Engineering Applications (Engineering Materials)", 1st Ed., Springer.	2000
2	Chan R. W., "High temperature structural materials", Chapman & Hall.	1996
3	Reed R. C., "The Super-alloys: Fundamentals and Applications", Cambridge University Press.	2008
4	Birks, N., Meier, G. H., and Pettit, F. S., "Introduction to the High Temperature Oxidation of Metals", Cambridge University Press.	2009
5	Bose, S., "High Temperature Coatings", Butterworth-Heinemann.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-518 **Course Title**: Theory of Metal Forming

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight **: CWS:** 2 5 **PRS :** 00 **MTE:** 25 **ETE:** 50 **PRE:** 00

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: MT-501 **8. Subject Area:** PEC

9. Objective: To impart knowledge on fundamentals of various metal forming processes.

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1.	**Stress tensor and yield criteria:** Single crystal versus polycrystal**,** state of stress, representing stress as tensor, principal stresses, stress deviator, yield criteria, comparison of yield criteria, octahedral shear stress and shear strain	8
2	**Fundamentals of metal forming:** Classification of forming processes, mechanics of metal working, flow stress determination, effect of temperature, strain rate and metallurgical structure on metal working, friction and lubrication; Deformation zone geometry, workability, residual stresses, strain rate sensitivity, superplasticity	10
3	**Forging and rolling:** Classification, calculation of forging loads, forging defects- causes and remedies, residual stresses in forging; Rolling- Classification of rolling processes, forces and geometrical relationship in rolling, analysis of rolling load, torque and power, rolling defects	8
4	**Extrusion and drawing:** Direct and indirect extrusion, variables affecting extrusion, deformation pattern, simple analysis of extrusion	8
5	**Sheet metal forming and other processes:** Forming methods - shearing, blanking, bending, stretch forming, deep drawing defects in formed part, sheet metal formability, formability limit diagram	8
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publisher	Year of Publication/ Reprint
1	Dieter G.E., Mechanical Metallurgy, McGraw-Hill	1995
2	Hosford, W.F. Caddell, R.M., Metal Forming – Mechanics and Metallurgy, Cambridge University Press	2011
3	Avitzur A., Metal Forming - Processes and Analysis, Tata McGraw-Hill	1977
4	Juneja B.L., Fundamentals of Metal Forming Processes, New Age International	2010
5	Taylor A., Soo-Oh I.K. and Gegel H.L., Metal Forming: Fundamentals and Applications, ASM	1983
6	Rowe G.W., Sturgess C.E.N., Hartley P. and Pillinger I., Finite-Element Plasticity and Metal Forming Analysis, Cambridge University Press	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-522 **Course Title**: Composite Materials

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To provide an in-depth knowledge on the constituents that make-up a composite materials and its various applications

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1	**Introduction:** Definition, classification, distribution and topology of constituents and interfacial bonding of matrix and reinforcing components	4
2	**Composite materials:** Metal matrix composites, polymer matrix composites and ceramic matrix composites	5
3	**Performance analysis of composites:** Combination effects-summation, complementation and interaction; Quantitative analysis-black box approach and analytical approach - thermoelasticity, plasticity and creep; Composites models- Law of mixtures, shear lag model, laminated plate model and Eshelby's model, others models	6
4	**Strengthening of composites:** Strengthening of matrix, role of matrix in continuous fibre composite, stress distribution in fibre and matrix, critical length of fibre for full strengthening, analysis of uniaxial tensile stress-strain curve of unidirectional continuous and short fibre composite, estimation of minimum and critical amount of fibre to gain a composite strength, analysis of strength during angular loading fibre composite, particle strengthening of matrix	6
5	**Fabrication:** Selection of components, wetting of components, chemical reactivity of components, incorporation of reinforcing components in matrix; Metal matrix, polymer matrix and ceramic matrix composites, in-situ composites and inorganic nano filler polymer composites	8
6	**Fracture and safety of composites:** Griffith theory of brittle fracture and modification for structural materials, basic fracture mechanics of composite- fracture toughness, COD and J-integral approaches, fatigue crack growth rate; Fracture mechanics of brittle matrix fibre composite, fracture mechanics of metal matrix fibre	6

	composite, experimental evaluation- fibre composite; Elementary reliability analysis	
7	**Joining of composites:** Welding, brazing, adhesive joining, weld bonding and mechanical fastening	4
8	**Application of Composite Materials:** Civil constructions of structures/pannels, aerospace industries, automobile and other surface transport industries, packaging industries, house hold and sports components	3
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publisher	Year of Publication/ Reprint
1	Hull D. and Clyne T.W., An Introduction to Composite Materials, 2nd Ed., Cambridge University Press	2013
2	Chawla K.K., Composite Materials: Science and Engineering 3rd Ed., Springer	2012
3	Chawla K.K., Ceramic Matrix Composites, 2nd Ed., Springer	2003
4	Chawla N. Chawla K.K., Metal Matrix Composites, 2nd Ed. Springer	2013
5	Shojiro O., Mechanical Properties of Metallic Composites, Marcel Dekker	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-526 **Course Title**: Failure Analysis

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart knowledge on the analysis of the probability of failure under various service conditions and methods to ensure safety

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1	**Sources of failure:** Material problems including chemical composition, microstructure, faulty selection, faulty heat treatment, corrosion susceptibility and defects; Mechanical irregularities including faulty design, mismatch and notch effects; Wrong welding fabrication and abnormal service conditions	4
2	**Failure analysis**: First hand documentation, planning of steps of analysis, collection of back ground data and samples, selection, cleaning and preservation of fracture surface	4
3	**Failure analysis methodology:** Use of advanced instruments, macroscopic and microscopic examinations of fracture surface, selective application of non-destructive testing, mechanical testing and stress analysis, metallographic examination and analysis; Bulk and micro chemical analysis	12
4	**Fracture:** Mechanisms and models of fracture, ductile flat-face and shear-face tensile fractures, brittle inter-granular and trans-granular fractures, embrittlement failure- Strain-age, quench-age, temper, hydrogen, sigma-phase and neutron embrittlement and blue brittleness; Factors influencing different types of fracture	6
5	**Fracture mechanics (FM):** Applications of FM under static and dynamic loading, application of NDT for defect assessment and monitoring, analysis of failure mechanism, safety and residual life estimation	6
6	**Failure mechanism:** Fatigue, corrosion, stress corrosion cracking and elevated or cryogenic temperature failure- Metallurgical and mechanical factors affecting these failures, loading condition and stages of fracture, macroscopic and microscopic salient features of	6

	failure	
7	**Result analysis and reporting**: Correlations of observations and evidences, documentation, logical conclusions and remedial measures	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publisher	Year of Publication/ Reprint
1	Shipley R.J. and Becker W.T., Failure Analysis and Prevention, ASM handbook, Vol. 11, ASM International	2002
2	Colangelo V.J. and Heiser F.A., Analysis of Metallurgical Failure, 2nd edition, Wiley-Interscience	1987
3	Powell G.W. and Mahmoud S.E., Failure Analysis and Prevention, Metals Handbook, Vol. 11, 9th edition, ASM International	1986
4	Cooper T.D., Prevention of structural failure-the role of quantitative nondestructive evaluation, ASM International	1975
5	Sachs N.W., Practical Plant Failure Analysis: A guide to understanding machinery deterioration and improving equipment reliability, Dekker Mechanical Engineering, CRC press	2006
6	Gulati R. and Smith R., Maintenance and Reliability Best Practices, Industrial Press	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-528 **Course Title**: Tribology of Engineering Materials

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS**: 0 0 **MTE**: 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: The impart knowledge on friction and methods to minimize wear of engineering components

10. Details of Course:

Sl. No.	Contents	Contact Hours
1	**Surface properties and surfaces in contact:** Nature of metallic surface, surface geometry, measurement of surface topography, quantifying surface roughness, contact between surfaces; Friction, the laws of friction, measurement of friction, origin of friction, theories of friction adhesion- theory, extension of the adhesion theory	8
2	**Wear:** Types of wear, adhesive wear, Archard's law, abrasive wear, erosion wear, factors affecting corrosive wear, wear map, various wear testing methods- pin on disc, pin on drum, slurry wear, air jet and water jet erosion as per ASTM standards	12
3	**Tribological properties of solid materials:** Hardness, strength, ductility and work hardening rate, effect of crystal structure, effect of microstructure, mutual solubility of rubbing pairs and effect of temperature	11
4	**Surface treatments to reduce wear:** Surface treatments with or without change of composition, surface coating- welding, flame, spraying, plasma spraying, electroplating and electroless coating, chemical vapour deposition (CVD) and physical vapour deposition (PVD), super hard coatings	11
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publisher	Year of Publication/ Reprint
1	Hutchings I.M., Tribology – Friction and wear of engineering Materials, Edward Arnold	1992
2	Arnold R.D., Davies P.B., Halling J. and Whomes T.L., Tribology – Principles and Design Applications, Springer Verlag	1991
3	Bhushan B., Introduction to Tribology, John Wiley	2002
4	Bhushan B., Principles and Applications of Tribology, John Wiley	1999
5	Stachowiak G and Batchelor A.W., Engineering Tribology, 4th Ed. Elsevier Butterworth-Heinemann	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-530 **Course Title**: Nanomaterials and Applications

2. Contact Hours: L: 3 T: 1 P: 0

3. Examination Duration (Hrs): **Theory:** 3 **Practical**: 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: MT-501 **8. Subject Area:** PEC

9. Objective: To impart knowledge on the synthesis and properties of nanostructured materials and their importance as advanced materials

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1	**Nanomaterials:** Introduction, Classification: 0D, 1D, 2D, 3D nanomaterials and nano-composites, their mechanical, electrical, optical, magnetic properties; Nanomaterials versus bulk materials	5
2	**Thermodynamics and kinetics of nanostructured materials:** Size and interface/interphase effects, interfacial thermodynamics, phase diagrams, diffusivity, grain growth, and thermal stability of nanomaterials	8
3	**Processing:** Bottom-up and top-down approaches for the synthesis of nanomaterials, mechanical alloying, chemical routes, severe plastic deformation, and electrical wire explosion technique	8
4	**Structural characteristics**: Principles of emerging nanoscale X-ray techniques such as small angle X-ray scattering and X-ray absorption fine structure (XAFS), electron and neutron diffraction techniques and their application to nanomaterials; Grain size, phase formation, texture, stress analysis	8
5	**Deformation Behavior:** Elastic and plastic deformation, mechanisms of plastic deformation- lattice dislocation motion, evolution of grain boundary defect structures, comparison between deformation mechanisms and effect of grain size distribution, grain boundary sliding and triple junction migration, triple junction diffusion, abnormal Hall-Petch effect dependence, localization of plastic flow and rotational plastic deformation in nanostructured materials. Nanoindentation techniques- principles and measurement of elastic and plastic properties of nanomaterials	9
6	**Case studies:** Design issues and applications of nanomaterials in various industries	4

	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publisher	Year of Publication/ Reprint
1	Poole C.P, and Owens F.J., Introduction to Nanotechnology, John Wiley	2003
2	Nalwa H.S., Encyclopedia of Nanoscience and Nanotechnology, American Scientific Publishers	2004
3	Koch C.C., Nanostructured Materials: Processing, Properties and Applications, William Andrew	2006
4	Zehetbauer M.J. and Zhu Y.T., Bulk Nanostructured Materials, Wiley	2008
5	Wang Z.L., Characterization of Nanophase Materials, Wiley	2000
6	Gutkin Y., Ovid'ko I.A. and Gutkin M., Plastic Deformation in Nanocrystalline Materials, Springer	2004
7	Fischer A.C., Nanoindentation, Springer	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Department of Metallurgical and Materials Engineering

1. **Subject Code**: MTN-531 **Course Title**: Electronic Materials

2. Contact Hours: L: 3; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6 Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To introduce fundamental principles of electronic materials, their properties and applications.

10. **Details of the Course**:

Sl. No.	Contents	Contact Hours
1.	**Electrical and thermal conduction:** Kinetic molecular theory of matter and its application to conduction, Drude Model of electrical conduction, temperature dependence of resistivity, Matthiessen's rule, Nordheim's rule, resistivity of mixtures, Hall effect, thermal and electrical conduction, electrical conductivity of semiconductors and ionic crystals,	9
2	**Modern theory of solids:** Hydrogen molecule, band theory of solids, semiconductors, density of states in an energy band, Boltzmann statistics, Fermi-Dirac statistics, Quantum theory of metals, Fermi energy significance, Contact potential, Seebeck effect, thermionic emission, field emission, Brillouin zones and origin of band gap, conductors, semiconductors and insulators	9
3	**Semiconductors:** Intrinsic and extrinsic semiconductors, temperature dependence of conductivity, Direct and indirect semiconductors, recombination and minority carrier injection, optical absorption, peizorestivity, Schottky junction, Ohmic contacts and thermo-eleciric coolers	9
4	**Dielectric materials**: Polarization and relative permittivity, electronic polarization, polarization mechanisms, dielectric constant and dielectric loss, dielectric breakdown, capacitor dielectric materials, piezoelectricity, ferroelectricity and pyroelectricity	7
5	**Magnetic properties:** Magnetization of matter, magnetic materials classification – diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism, origin of ferromagnetism and exchange interaction, saturation magnetization, Curie temperature, magnetic domains, soft and hard magnetic materials; Superconductivity, Meissner effect, Josephson's effect, superconducting solenoids, AMR and GMR and their applications	8

	Total	**42**

11. Suggested Books:

Sl. No.	Authors/Name of Books/ Publisher	Year of Publications
1.	Kasap S.O., Principles of Electronic Materials and Devices, 3rd Ed., McGraw-Hill	2009
2.	Hummel R.E., Electronic Properties of Materials, 4th Ed., Springer	2011
3.	Streetman B. and Bannerjee S., Solid State Electronic Devices, 6th Ed., Printice Hall	2005
4.	Callister W.D., Materials Science and Engineering, 7th Ed., Wiley India (P) Ltd.	2010
5.	Raghavan V., Materials Science and Engineering, 5th Ed., PHI	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-532 **Course Title**: Corrosion Protection Methods

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart knowledge on the principles related to protection of materials against corrosion.

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1.	**Introduction:** Importance and economics of corrosion, principles of corrosion	4
2	**Forms of corrosion:** Classification of different forms of corrosion- general corrosion, selective corrosion including pitting corrosion, crevice corrosion, intergranular corrosion, filiform corrosion, stress corrosion cracking, corrosion fatigue, fretting corrosion, cavitation corrosion, dezincification, dealuminization, graphitization, erosion-corrosion	8
3	**Principle behind protection of materials against corrosion:** Protection against corrosion by modifying physical, chemical and/or mechanical aspects of materials- coating, alloying, heat treatment	8
4	**Protection by modifying the environmental parameters:** Concentration, pH, temperature, velocity, oxidizing agents, suspended particles, use of inhibitors	9
5	**Protection against corrosion by modification of external circuit:** By anodic and cathodic protection, problems encountered, study of mechanisms involved, some case studies	9
6	**Systematic approach for protection:** protection with respect to various corrosive environments under different parametric conditions	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publisher	Year of Publication/ Reprint
1.	Fontana M.G., Corrosion Engineering, 3rd Ed., McGraw Hill	2005
2.	Plendek R.V., Design and Corrosion Control, The Macmillan Press	1977
3.	Annual book of ASTM standards, ASTM	1978
4.	Roberge P.R., Handbook of Corrosion Engineering, McGraw Hill	2000
5.	Revie W.R. and Uhlig H.H., Corrosion and Corrosion Control, 4th Ed., Willey	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-542 **Course Title**: Biomaterials

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart knowledge on structure-property relationship in biomaterials and their applications as implants.

10. **Details of Course**:

Sl. No	Contents	Contact Hours
1	**Introduction:** Historical background, construction materials, impact of biomaterials, strength of biological tissues, performance of implants, tissue response to implants, interfacial phenomena, safety and efficacy testing	4
2	**Metallic and Ceramic materials:** Stainless steels, Co-Cr alloys, Ti-based alloys, Nitinol, biological tolerance of implant metals, ceramic implant materials, alumina, yittria stabilized zirconia, hydroxyapatite glass ceramics carbons, restorable ceramics, composites	6
3	**Polymeric implant materials:** Polymers in biomedical use, polyethylene, polypropylene, acrylic polymer, hydrogels, polyurethans, polyamides, biogradable synthetic polymers, silicon rubber, micro-organisms in polymeric implants, polymer sterilization	6
4	**Dental Materials:** Tooth composition and mechanical properties, impression materials, bones, liners, and varnishes for cavities, filling and restorative materials, oral implants, use of collagen in dentistry	4
5	**Cardiovascular and Orthopedic implants:** Artificial heart, aorta and valves, geometry of circulation, vascular implants, cardiac pace makers, bone composition and properties, fracture healing, joint replacement, knee joint repair, bone regeneration with restorable materials	6
6	**Tissue Engineering Materials and Regeneration**: Substrate scaffolds materials, cellular aspects, viability, stem cells, bladder regeneration, cartilage regeneration, skin regeneration, regeneration in cardiovascular system	6
7	**Tissue response to implants:** Normal wound healing process, body response to implants, blood compatibility, carcinogenicity	3
8	**Degradation of Materials in the biological environment:** Chemical	4

	and biochemical degradation of polymers, degradation effects on metals and ceramics, pathological classification of biomaterials	
9	**Case studies:** Selection and design of biomaterials, implant and device failures	3
	Total	**42**

10. Suggested Books:

Sl. No.	**Name of Authors/Books/Publisher**	**Year of Publication/ Reprint**
1	Park J.B. and Bronzino J.D., Biomaterials: Principals and Applications, CRC Press	2003
2	Park J.B., Biomaterials Science and Engineering, Springer Press	1984
3	Rattner B.D., Hoffman A.S, Schoen F.J., Lemons J.E., Biomaterials Science: An Introduction to Materials in Medicine, Academic Press	2004
4	Park J.B. and Lakes R.S., Biomaterials: An Introduction, 3rd edition, Springer press	2007
5	Bhat, S.V., Biomaterials, 2nd edition, Narosa Publishing	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT : Metallurgical and Materials Engineering

1. **Subject Code**: MTN-558 **Course Title**: Energy Storage Materials

2. Contact Hours: L: 3 ; T: 1; P: 0

3. Examination Duration (Hrs): **Theory:** 0 3 **Practical**: 0 0

4. Relative Weight : CWS: 2 5 **PRS:** 0 0 **MTE:** 2 5 **ETE:** 5 0 **PRE:** 0 0

5. Credits: 0 4 **6. Semester:** Autumn/Spring

7. Pre-requisite: Nil **8. Subject Area:** PEC

9. Objective: To impart knowledge on different types of energy storage materials, their functions and applications

10. **Details of Course**:

Sl. No.	Contents	Contact Hours
1	**Introduction**: Basics of solid state chemistry, defect structure of solids, surface and interface analysis	6
2	**Materials for energy storage:** Fuel cells, different types, materials used, mechanism of operation, applications; Solar cells – introduction on photovoltaics, materials used, principle of operation, applications; Storage batteries – battery technology, assembly, electrochemical tests; Supercapacitors – theory, high power super capacitor from carbon nanotubes; Hydrogen storage materials – mechanism of hydrogen storage	12
3	**Material Analysis:** Thermal, structural and morphological analysis of the energy storage materials, different experimental techniques used	6
4	**Rechargable lithium ion battery:** Intercalation compounds, anodes and composite anodes, cathode materials, polymeric electrolyte, currents trends of lithium ion batteries for consumer applications	8
5	**Nanoscale materials:** Nano crystalline materials, nanocomposites, nanotubes, energy storage capacity of the nanostructured materials	6
6.	**Magnetocaloric materials**: Different types of materials, application of the magnetocaloric effect	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors/ Books/ Publisher	Year of Publication/ Reprint
1	Nazri G.A., Pistoia G., Lithium Batteries: Science and Technology, Kluwer Academic Publishers	2004
2	Kumta P.K., Supercapacitors: Fundamentals, Systems, Applications, Emerging trends, Wiley-VCH Verlag	2009
3	Markvart T. and Castaner L., Solar cells: Materials, Manufacture and Application, Elsevier	2003
4	Walker G., Solid State Hydrogen Storage: Materials and Chemistry, Woodhead Publishing	2008
5.	Tishin A.M. and Spichkin, Y.I., The Magnetocaloric Effect and its Applications, IOP publishing	2003