ACADEMIC AFFAIRS OFFICE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

No. Acd./1248/IAPC-109 Dated: August 26 , 2021

Head, Department of Metallurgical and Materials Engineering

The IAPC in its 109th meeting held on 21.08.2021 vide Item No. 109.2.9 considered and approved the following proposals of Department of Metallurgical and Materials Engineering: **(Appendix-A)**

1. **New PECs for B.Tech. (MT):**

   (i) **MTN-316: Materials Informatics**
   (ii) **MTN-317: Introduction to Nanomaterials**
   (iii) **MTN-318: Additive Manufacturing**
   (iv) **MTN-319: Metal Recovery and Recycling**

2. **Revision in the course title and syllabus of the following courses:**

Existing Courses	Approved Revised Courses
MTN-502: Modelling, Simulation and Computer Applications	MTN-506: Materials Modelling and Simulation
MTN-530: Nanomaterials and Applications	MTN-560: Nanotechnology: Materials & Devices
MTN-555: Advanced and Stainless Steels	MTN-562: Advanced Steel Technology

3. **Revision of the syllabus of the following courses:**

   (i) **MTN-315: Metallurgy of Joining**
   (ii) **MTN-531: X-ray Diffraction Techniques**
   (iii) **MTN-533: Electron Microscopy**
   (iv) **MTN-542: Biomaterials**
   (v) **MTN-554: Crystallographic Texture**

Reeti
Assistant Registrar (Curriculum)

Encl: as above

Copy to (through e mail):-

1. All faculty
2. Head of all Departments / Centres
3. Dean, Academic Affairs
4. Associate Dean of Academic Affairs (Curriculum)
5. Channel i/ Acad portal/ Academic webpage of iitr.ac.in

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-316 **Course Title:** Materials Informatics
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Both 7. **Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** The course will introduce concepts of Big Data handling and analysis for Materials Science applications.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction to Materials Informatics:** History of materials development and need for concept materials design, Multiscale materials modelling, need for data driven modelling, accelerated materials discovery and development, Quantitative structure-processing-property-performance relationships, knowledge discovery workflow for materials informatics, materials data science – structured and unstructured data, data mining, crystallography database, Materials Genome, different sets of descriptors, nuts and bolts of materials informatics.	8
2.	**Optimization & Calibration:** gradient based optimization, non-gradient based optimization, multi-objective genetic algorithms (MOGA), Optimization of a multivariate model, applications to materials synthesis, processing, and transport phenomena	9
3.	**Predictive Modelling:** supervised learning, regression methods, classification methods, surrogate based optimization, prediction of material properties such as fatigue life, creep life	9
4.	**Descriptive Modelling:** Unsupervised learning, clustering analysis, clustering algorithms. Case studies: Estimation of microstrain, residual stress from diffraction, classification of materials based on physical properties	6
5.	**Limitations and Remedies:** Problem of small datasets in materials science, Data dimensionality reduction – principal component analysis, applications to 4D diffraction, spectroscopic data sets, high-throughput computational modelling of materials	6
6.	**Materials Selection for Engineering Design:** Systematic selection methods, trade-off analysis, vectors for materials development	4
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Informatics for Materials Science and Engineering, Edited by Krishna Rajan, 1st edition, Butterworth-Heinemann, ISBN: 978-0-123-94399-6	2013
2.	Materials Informatics: Methods, Tools, and Applications, Edited by Olexandr Isayev, Alexander Tropsha and Stefano Curtarolo, 1st edition, Willey, ISBN: 978-3-527-34121-4	2019
3.	S.R. Kalidindi, Hierarchical Materials Informatics, 1st edition, Butterworth-Heinemann, ISBN: 978-0-124-10394-8	2015
4.	Nanoinformatics, Edited by Isao Tonaka, 1st edition, Springer Nature, ISBN: 978-9-811-07616-9 (Open access eBook)	2018
5.	Information Science for Materials Discovery and Design, Edited by Turab Lookman, Francis Alexander and Krishna Rajan, 1st edition, Springer, ISBN: 978-3-319-23870-8	2016

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-317 **Course Title:** Introduction to Nanomaterials
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the fundamentals of nanomaterials, their synthesis, properties and various applications.

10. Details of the Course

S.No.	Contents	Contact hours
1.	**Introduction:** Nanotechnology and Nanomaterials, possible fields of applications, Challenges and opportunities	3
2.	**Surface Science of Nanomaterials:** Atomic bonding, band structure, band structure in nanomaterials, Crystal structure, Surfaces of closed packed structures, Surface energy – Crystallographically preferred surfaces, Surface reconfiguration	10
3.	**Synthesis/Fabrication of Nanostructures:** Zero-Dimensional Nanostructure, One-Dimensional Nanostructure, Two-Dimensional Nanostructure, Principles of Lithography, Bulk Nanostructured Materials	13
4.	**Properties of Nanomaterials:** Electrical Properties, Mechanical Properties, Optical Properties, Magnetic Properties, Thermal Properties, Physical Properties	8
5.	**Unique Nanostructures:** Quantum dots, fullerene, core-shell nanoparticles, carbon nanotubes, boron nitride nanotubes, graphene and related materials, Chalcogenides	8
	Total	**42**

11. List of experiments:

1. Synthesis of carbon dots and observation of fluorescence
2. Synthesis of carbon nanotubes by CVD, observation of their morphology/structure by SEM, TEM and Raman spectroscopy
3. Synthesis of metallic nano-powder by ball milling, observation of their morphology/structure by XRD, SEM, TEM and comparison with starting structure
4. Spark plasma sintering of nano- and bulk- powder, comparison of their mechanical properties by nano-indentation
5. Synthesis of polymeric fibres by electro-spinning and their characterization

12. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Poole C.P., Owens F.J., Introduction to Nanotechnology, Wiley India	2012
2.	Guo Z., Tan L., Fundamentals and Applications of Nanomaterials, Artech House	2009
3.	Cao G., Nanostructures and Nanomaterials, Imperial College Press	2006
4.	Vollath D., Nanomaterials – An introduction to synthesis, properties and applications, Wiley-VCH	2008
5.	Pradeep T., Nano: The Essentials – Understanding Nanoscience and Nanotechnology, McGraw-Hill	2016
6.	Zehetbauer M.J. and Zhu Y.T., Bulk Nanostructured Materials, Wiley	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-318 **Course Title:** Additive Manufacturing
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To familiarize the students with the possibilities and materials aspects of additive manufacturing techniques.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction:** Transition from rapid prototyping to additive manufacturing, Advantages and limitations of additive manufacturing, role of CAD and CAM, various AM processes and relevant science, designing of components for AM	6
2.	**Metals and alloys**: Powder-bed fusion and direct energy deposition processes, powder vs wire deposition processes, laser vs electron beam, selection of AM process, requirement of metal and pre-alloyed powders, role of process parameters including rapid solidification on microstructure, phase transformation, residual stress and other defects, distortion control, post processing: heat treatments, shot peening, hot isostatic pressing	10
3.	**Polymers and Ceramics:** Photopolymerization, Stereolithography, selective laser sintering and laser chemical vapor deposition, manufacturing of various composites with micro and nano additives, bio-polymers and bio-ceramics	6
4.	**Process monitoring, modeling and control:** In-situ measurement of temperature, mass flow, and component shape, role of heat and mass transfer on composition, microstructure and residual stress and related mathematical models, thermal management: use of pre-heated base plates, cooling system, control of process parameters, Challenges in reuse of powders.	7
5.	**Applications of AM**: Aerospace: Superalloys, titanium alloys, aluminum alloys, shape memory alloys, coatings, AM on demand; Nuclear: stainless steel, Ni based alloys, oxide dispersion strengthened steels; Bio-medical: prosthetics, bio-implants, tissue engineering; Other applications: art, fashion and jewellery	8
6.	**Case studies**: Control of residual stress in ceramics, material requirement in personalized surgery, pattern making and rapid prototyping for automobile industry, 3D printing of electronics, challenges in commercialization and mass production.	5
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Gibson, I., Rosen, D.W., Stucker, B., Additive Manufacturing Technologies, Springer	2014
2.	J.D. Majumdar and I. Manna, Laser-assisted fabrication of materials, Springer Series in Material Science	2012
3.	Zhang, J. Jung, Y.-G., Additive Manufacturing: Materials, Processes and applications, Elsevier	2018
4.	Brandt, M., Laser Additive Manufacturing; Materials, Design, Technologies and applications, Elsevier	2020

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NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-319 **Course Title:** Metal Recovery and Recycling
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Both 7. **Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To understand fundamental principles and practices involved in metal recovery and recycling processes.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Fundamentals on primary and secondary production of raw materials (steel, aluminum, phosphorous, copper, precious metals, rare metals) Use and demand of metals and minerals in industry and society, collection systems and concepts, efficiency, sorting technologies, mechanical pretreatment, other treatment options	6
2.	Hydrometallurgy and its applications in metals production (base metals and Rare earths): an overview. Metal resources for hydrometallurgical extraction and recycling Leaching (atmospheric-, pressure-, bio-, organic lixiviants). Separation and solution purification: precipitation method; solvent extraction and ion exchange.	7
3.	Metals recovery: cementation and hydrogen reduction; recovery and refining: electrowinning and electro-refining. Thermodynamical Assessment, Eh-pH diagram	6
4.	Sampling and materials characterization, Chemical analysis of Critical Materials in post-consumer products, Analytical tools in Resource Management (Material Flow Analysis, Recycling Performance Indicators, Criticality Assessment, statistical analysis of uncertainties). Waste to Energy concept consisting of Thermal Process (incinerator, combustion); energy , emissions	6
5.	Critical factors for sustainable waste valorization. Linear and circular economy, lifecycle analysis market value calculations from end of life products and value additions.	5
6.	Case studies of batteries, printed circuit boards, display screens (CRT LED CFL), solar panels and industrial waste (Red mud; iron and steel slag, aluminum dross). Laboratory demonstration.	6
7.	Sustainability environmental challenges and remediations, national international scenario, societal impact energy consumption an environmental footprint. Industrial processes, flowsheet development	6
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	M. Kaya, Electronic Waste and Printed Circuit Board Recycling Technologies, ISBN 978-3-030-26592-2, Springer International	2016
2.	G. Chauhan, P.J. Kaur, K.K. Pant, K.D.P. Nigam, Sustainable Metal Extraction from Waste Streams, Wiley publishers, ISBN: 978-3-527-34755-1,	2020
3.	Recycling of Metals and Engineered Materials, Editor(s): D.L. Stewart Jr. J.C. Daley R.L. Stephens, ISBN:9781118820469	2000

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NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-506 **Course Title:** Materials Modeling and Simulation
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce various approaches used for modeling and simulation of materials.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction:** Need for modelling and simulation. Concepts of length and time scales in different materials phenomena, and choosing the appropriate modelling schemes to tackle them.	2
2.	**Brief review of classical and statistical mechanics:** Concepts of Lagrangian, Hamiltonian, and equations of motion from classical mechanics. Statistical mechanical concepts of Microstates, Phase space, Ensembles and the Ergodic hypothesis.	5
3.	**Interatomic potentials and Boundary Conditions:** Concept of cohesive energy and its formulation using semi-empirical potentials, Pair potentials like Lennard-Jones, Morse and Born-Mayer, Limitations of Pair Potentials, Embedded atom model potentials (EAM) for metals and alloys. Stillinger-Weber (SW) potential for covalent solids, Modeling Coulomb interactions in ionic materials and challenges, Transferability of semi-empirical potentials, Boundary conditions: periodic and free, cut-off distances for potentials.	7
4.	**Molecular statics (MS) and dynamics (MD):** Fundamentals of MS, Energy minimization algorithms like Steepest Descent and Conjugate Gradient, Applications of MS in calculating defect energies, Fundamental concepts of MD, Numerical algorithms for time integration of equations of motion, Properties of MD simulations, Analyzing MD simulations using spatial and time correlation functions, MD in different ensembles, Applications of MD, Limitations of MD.	10
5.	**Monte-Carlo simulations (MC):** Metropolis algorithm and its application to study the Ising model, Monte-Carlo in the mesoscopic scale: Q-state Potts Model, MC across different ensembles, Concept of time in MC, Analyzing MC simulations, Applications and Limitations of MC.	8
6.	**Phase-field modeling**: The diffuse interface and its advantages, Concepts of conserved and non-conserved order parameters to describe microstructure, Allen-Cahn and Cahn-Hilliard equations for microstructure evolution, Concepts of interfacial energy and width, Numerical algorithms and analysis of simulation results, Ways to construct free energy functions.	10
	Total	**42**

11. List of Practicals:

1. Defect energy calculation using Molecular Statics
2. Molecular Dynamics simulation of melting
3. Simulations of deformation using Molecular Dynamics
4. Metropolis Monte-Carlo study of the Ising model
5. Employing Q-state Potts model to simulate grain growth
6. Phase-field simulation of spinodal decomposition

12. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Lesar R., An introduction to computational material science – Fundamentals to Applications, Cambridge University Press	2013
2.	Landau D. P., and Binder K., A Guide to Monte-Carlo Simulation in Statistical Physics, Cambridge University Press	2014
3.	Frenkel D., and Smit B., Understanding Molecular Simulation, Academic Press	2001
4.	Provatas N., and Elder K., Phase-field methods in Material Science and Engineering, Wiley-VCH	2011

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NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-560 **Course Title:** Nanotechnology: Materials & Devices
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Autumn 7. **Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the fundamentals of nanomaterials, their properties and various applications.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction to nanostructure synthesis:** Importance of surface and its attributes in nanostructures, principles of different physical and chemical methods for nanostructure synthesis	6
2.	**Fabrication of nanostructures and devices:** Principles of lithography, Moore's law, photolithography, U-V lithography, X-ray lithography, e-beam lithography, ion-beam lithography, soft-lithography, nano-imprint lithography, miniaturization and its application	12
3.	**Thin film deposition:** Evaporation – thermodynamics and kinetics, deposition – nucleation and structure development, physical vapor deposition, chemical vapor deposition, epitaxial growth	6
4.	**Characterization of nanomaterials:** Structural characterization- XRD, SAXS, SEM, TEM, SPM/AFM, chemical characterization – optical spectroscopy, electron spectroscopy, ionic spectrometry physical properties – melting point, lattice constant, optical properties, mechanical properties – nanoindentation, nanotribology	12
5.	**Nanocomposites and nano-reinforced composites:** difference between nanocomposites and nano-phase reinforced composites, unique nanocomposites structures, advantages of nano-phase reinforcement in composites and examples	3
6.	**Society and nano:** Implications on society, issues, policies, public perception and involvement	3
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Poole C.P., Owens F.J., Introduction To Nanotechnology, Wiley India	2012
2.	Guo Z., Tan L., Fundamentals and Applications of Nanomaterials, Artech House	2009
3.	Madou MJ., Fundamentals of Microfabrication – The Science of Miniaturization, CRC Press	2002

4.	Smith DL., Thin Film Deposition – Principles and Practice, McGrawHill	1995
5.	Pradeep T, Nano: The Essentials – Understanding Nanoscience and Nanotechnology, McGrawHill	2016
6.	Wang Z.L., Characterization of Nanophase Materials, Wiley.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-562 **Course Title:** Advanced Steel Technology
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Both 7. **Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To understand the fundamentals and applications of different steels in different engineering sectors of importance of today's society.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Indian heritage:** Steel making in early days, Iron pillars of India, Wootz steel, canons of India	6
2.	**Fundamentals of steel:** Fe-C phase diagram, different microstructures of steel, TTT/CCT diagram, basic heat treatment processes, role of alloying elements	8
3.	**Microalloyed / Pipe line steel:** Thermo-mechanical processing, origin of micro-alloyed steel, controlling the grain size, tailoring the precipitation, extent of strengthening	7
4.	**Automotive steels:** Global trends, different types of automotive steels (HS-IF, BH, DP, TRIP, TWIP, bainitic, martensitic, precipitation hardened), design of steel	7
5.	**Power plant steels:** Metallurgy of high temperature steel, steels for super-critical thermal and boiler plants, creep behaviour and its characterisation	6
6.	**Stainless steels:** Types of stainless steel, alloying elements and their effect, relevance of Nickel equivalent and Chromium equivalent, inadequacy of Fe-C diagram, corrosion resistance of stainless steel.	4
7.	**Ship building steels:** Quench and tempering process, global trends, surface treatments, applications of Q&T steels in defense and non-defense sector	4
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Rana, R. "High performance ferrous alloys", 1st edition, Springer,	2021
2.	Bhadeshia, H.K.D.H. and Honeycombe, R. "Steels: Microstructure and Properties", 4th edition, Butterworth-Heinemann	2017
3.	Rana, R. and Singh, S.B. "Automotive Steels: Design, Metallurgy, Processing and Application", Woodhead Publishing	2016
4.	Cola, R. and G.E. Totten, S.B. "Encyclopedia of Iron, Steel and Their Alloys", CRC Press.	2016
5.	Bhadeshia, H.K.D.H. "Theory of transformations in steel", 1st edition, CRC Press	2021

6.	Krauss, G. “Steels: Processing, Structure, and Performance”	2005
7.	Leslie, W.C., “Physical Metallurgy of Steels” McGraw Hill	1991

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-315 **Course Title:** Metallurgy of Joining
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** An understanding of phase transformation and heat treatment.
9. **Objective:** To gain basic understanding of common welding processes and to understand the metallurgical changes that occur during and post welding.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction:** Classification of welding processes, heat and fluid flow in welding.	6
2.	**Solidification after welding:** Weld solidification, modes of grain formation (epitaxial / non-epitaxial), thermal cycle during welding, weld pool shape and size, weld microstructure, phase transformation.	8
3.	**Heat affected zone**: Development of HAZ, recrystallisation and grain growth, effect of welding parameters on the size of HAZ, phase transformation in HAZ, mechanical properties in HAZ.	8
4.	**Residual stress and cracking:** Origin of residual stress, distortion and cracking, means to reduce distortion, different types of cracking and their remedies, hydrogen embrittlement, liquid metal embrittlement.	8
5.	**Heat treatment related to welding:** Importance of heat treatment, pre and post-weld heat treatment.	3
6.	**Weldability of steel:** Weldability, Schaeffler-DeLong diagram**,** Graville diagram, considerations for stainless steel -- weldability of stainless steels, effect of welding on corrosion resistance, welding dissimilar steels, welding of advanced high strength steels.	6
7.	**Quality control in welding:** Non-destructive testing, weld integrity, neutron and synchrotron radiation – stress measurement, phase transformation during and post welding.	3
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	S. Kou, "Welding Metallurgy", 2nd edition, Wiley& Sons.	2002
2.	K. Easterling, "Introduction to the Physical Metallurgy of Welding", 2nd edition, Butterworth-Heinemann.	1992
3.	J. C. Lippold, "Welding Metallurgy and Weldability", 1st ed., Wiley& Sons.	2015
4.	J. C. Lippold and D. J. Kotecki, "Welding Metallurgy and Weldability of Stainless Steels", 1st edition, Wiley& Sons.	2005

5.	Welding, Brazing and Soldering, ASM Metals Handbook, Vol. 6, ASM International	1993
6.	R.W. Messler, Principles of welding, Wiley-VCH; 1st edition (1999)	2004

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-531 **Course Title:** X-ray Diffraction Techniques
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To impart knowledge on the applications of X-ray diffraction for structural and chemical characterization.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Properties of X-rays, absorption, filters, production and detection	4
2.	Crystal systems, Bravais lattices, Motif/Basis, Point groups and space groups, crystal structures, stereographic projections	6
3.	Laue diffraction conditions, Bragg's Law, Scattering of X-rays by electrons, Elastic-coherent scattering and incoherent inelastic-scattering, Relative intensities of powder diffraction peaks; atomic scattering factor, structure factor, anomalous X-ray scattering, multiplicity factor, Lorentz-Polarization factor, absorption factor, temperature factor.	8
4.	Laue, Rotating crystal and powder diffraction methods, Debye-Scherrer Camera, Diffractometer, Parallel beam and focused beam geometries, Florescence and its effect on quality of diffraction pattern, measurement of peak position and intensity. Integral breadth and Full Width at Half Maximum, 0D, 1D and 2D X-ray detectors, Method of finding instrumental offset.	6
5.	Indexing patterns of cubic and non-cubic crystals, Indexing peaks of different phases of multiphase materials, Determination of phase fractions, crystallite-size and strain broadening, Scherrer equation, Williamson-Hall and Modified Williamson-Hall methods, Determination of stacking fault probability, Rietveld refinement, texture of wire and sheet, effect of distortion, unit cell determination.	8
6.	Diffraction effects from composition gradients in solutions and non-stoichiometric compounds, Diffraction from periodic compositionally modulated specimens, method of determining composition modulation wavelength, Diffraction from nano-multilayers, Small Angle X-ray scattering, Grazing incidence X-ray diffraction for thin films, application of X-ray scattering techniques for amorphous materials	6
7.	Applied stress and residual stress, diffractometer method, parabolic method of peak position determination, strain-free lattice spacing determination, X-ray elastic constants, Voigt, Reuss and Neerfeld-Hill methods of determination of elastic constants, constant-penetration depth stress determination.	2
8.	Synchrotron X-Ray Diffraction: Synchrotron X-ray sources, in-situ time resolved measurements; tensile testing, welding, solving 2D X-ray diffraction patterns for texture and residual stress determination	2
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Cullity, B.D. and Stock, S.R., “Elements of X-ray Diffraction”, 3rd Ed., Prentice Hall.	2001
2.	Suryanarayana, C. and Norton, M.G., “X-ray Diffraction: A Practical Approach”, Springer.	1998
3.	Murphy, B. and Seeck, O.H., “X-ray Diffraction: Modern Experimental Techniques”, Pan Stanford Publishing.	2011
4.	Warren, B.E., “X-ray Diffraction”, Dover Publications.	1990
5.	Guinier, A., “X-ray Diffraction: In Crystals, Imperfect Crystals and Amorphous Bodies”, Dover Publications.	1994
6.	Habbar, K.R., “Basics of X-ray Diffraction and its Applications”, I K International Publishing.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-533 **Course Title:** Electron Microscopy
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Autumn 7. **Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the fundamentals of scanning and transmission electron microscopes.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction**: TEM construction, Emission: Schotky vs cold FEG, low kV imaging; Illumination: Parallel beam, focusing beam, translating and tilting beam; Alignment & stigmation, magnification and diffraction calibration; Detectors: CCD vs direct electron detectors & fast detectors; role of environment on imaging.	6
2.	**Imaging in TEM**: Diffraction contrast: Bright field, dark field, weak-beam dark field imaging, mass-thickness contrast, two-beam condition, role of deviation parameter, thickness & bending effects; Phase contrast: origin of lattice fringe, Scherzer defocus, contrast transfer function, pattern recognition, Moire patterns, contrast from defects, interfaces, surfaces; Scanning TEM: Bright field, annular dark field, high angle annular dark field imaging, lattice fringes and Z-contrast imaging; Defect characterization: imaging strain fields, dislocation- dipole, nodes & loops, vacancy loops, stacking faults, precipitates; aberration corrected TEM & STEM: role of probe corrector, image corrector, monochromator	10
3.	**Diffraction in TEM**: Reciprocal space, characteristic length, amplitude and intensity of diffracted beams, superlattice and forbidden reflections, thin foil effect, diffraction from line, planar defects, Kikuchi diffraction: origin and construction of Kikuchi maps, crystal orientation; CBED: TEM vs STEM, estimation of specimen thickness and strain, ZOLZ & HOLZ patterns; Precession electron diffraction: orientation determination.	10
4.	**SEM**: Working of SEM: Resolution mode, high current mode, depth of focus mode, low voltage surface imaging, variable pressure; Sample-specimen interaction: calculation of interaction volume- role of beam energy, atomic number & tilt, Imaging signals: Distribution of energy, sampling depth and range, BSE: Electron channeling contrast imaging – orientation contrast and defect contrast; SE: Imaging and spectrum; In-lens imaging: combined topographic and compositional contrast, role of stage and detector bias, energy filter.	8
5.	**Analytical electron microscopy**: Inelastic scattering: EDS – detection of low energy vs high energy X-rays, implications on energy and spatial resolution, Qualitative analysis – general requirement, peak identification and deconvolution of overlapping peaks, Quantitative analysis – matrix corrections, ZAF factors, spectrum imaging; WDS – Diffracting crystals, CCD detectors; EELS: Energy	8

	loss spectrum, Omega and GIF filters, monochromators, atomic column EELS, Energy Filtered TEM.	
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Goodhew, P.J., Humphreys, J. and Beanland, R., "Electron Microscopy and Analysis", 3rd Ed., Taylor and Francis.	2000
2.	Thomas, G., "Transmission Electron Microscopy of Materials", Techbooks.	1990
3.	Reimer, L., "Scanning Electron Microscope: Physics of Image Formation and Microanalysis", 2nd Ed., Springer.	1998
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 Ed., Springer.	2003
5.	Carter, C.B. and Williams, D.B., "Transmission Electron Microscopy: A Textbook for Materials Science", 2nd Ed., Springer	2009
6.	Egerton, R., "Physical Principles of Electron Microscopy: An Introduction to TEM, SEM and AEM", Springer.	2010
7.	Fultz B., Howe, J. "Transmission Electron Microscopy and Diffraction of Materials" IV Ed. Springer	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of 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:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To impart knowledge on structure-property relationship in biomaterials and their applications as implants and scaffolds.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction:** Historical background, impact of biomaterials, biocompatibility, classes of biomaterials, evolution of biomaterials and generation of implants, topics integral to biomaterials, ethics and regulations	2
2.	**Properties and Surfaces of Biomaterials:** strength of biomaterials, mechanical properties of different biological tissues and factors influencing them, simulation of mechanical behavior of implants, surfaces of biomaterials and interaction with host tissue, characterization of biomaterial surfaces – different available techniques	5
3.	**Cell Biomaterial Interaction:** Type and structure of cells, cell differentiation, development of tissue, apoptosis, chemical communication, Immunity	8
4.	**Metallic Biomaterials:** Mechanical properties and biocompatibility of metals, Application – pros and cons of implants made of Stainless steels, Co-Cr alloys, Ti-based alloys, Nitinol etc.	4
5.	**Ceramic Biomaterials:** Properties and biocompatibility of ceramics, tissue response, types and applications of bioinert, resorbable and bioactive ceramics, degradable implants	4
6.	**Polymeric Biomaterials:** Basic structure and properties of polymers, various polymers in biomedical application – their properties, pros and cons and fields of application, mechanism of degradation of polymers and the influencing factors, degradable polymers and hydrogels for temporary implants and scaffolds, smart polymers, medical textiles.	6
7.	**Biological Evaluation of Biomaterials:** in-vitro assays and in-vivo evaluations	3
8.	**Biomaterials for Dental Application:** structure of human tooth and requirement of implants, types of dental implants, biomaterials in user for dental implants, root canal (endodontic) treatment, materials for dentures	3
9.	**Biomaterials for Orthopedic implants and Scaffolds:** Materials Selection and types of commercially used implants, coatings on implants and bone cements, stress shielding, new materials for orthopedic application, drug releasing orthopedic implants, cartilage regenerating scaffolds	3
10.	**Tissue Engineering scaffolds and soft tissue regeneration**: Tissue engineering scaffolds, requirements of an ideal regenerative scaffold, neural system and nerve repair strategies, scaffolds (conduits) for nerve regeneration, architecture-	4

	chemistry and biology of skin tissue, scaffolds for different types of wound healing	
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Rattner B.D., Hoffman A.S, Schoen F.J., Lemons J.E., Biomaterials Science: An Introduction to Materials in Medicine, Third Edition, Academic Press	2013
2.	Basu B., Biomaterials Science and Tissue Engineering, Principles and Methods, Cambridge IISc Series	2017
3.	Park J.B. and Bronzino J.D., Biomaterials: Principals and Applications, CRC Press	2003
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/CENTRE: Department of Metallurgical and Materials Engineering

1. **Subject Code:** MTN-554 **Course Title:** Crystallographic Texture
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To impart knowledge on crystallographic texture and the evolution of texture during materials processing and their applications.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction**: Crystallographic texture- preferred orientation of crystals in a polycrystalline material, effect on different properties of material	3
2.	**Representation of texture:** Introduction to stereographic projection, pole figure, inverse pole figure, representation of orientation in Miller indices, matrix, axis-angle relation, Euler angles, Rodrigues-Frank space and conversion between them, orientation distribution function (ODF), grain boundary characteristics – coincidence site lattice boundaries.	10
3.	**Measurement and analysis of texture:** X-ray, synchrotron and neutron diffraction techniques, electron backscattered diffraction (EBSD), precession electron diffraction (PED), High throughput texture using ultrasonic and polarized microscopy	6
4.	**Origin and evolution of texture:** Phase transformation: solidification and solid to solid transformation, orientation relationships; Deformation: role of single and poly-slip, twinning, deformation bands, shear bands, role of SFE, Schmid and Taylor factors; Annealing: effects of recovery and recrystallization on the formation of cube texture, Goss texture, abnormal grain growth; coating processes, thin film deposition.	10
5.	**Effect of texture:** On mechanical properties – Formability, elastic and plastic anisotropy, yield locus and strain hardening, electrical and magnetic properties	6
6.	**Case studies:** Sheet metal forming of Al, automotive steels, electrical steels, pilgering of zirconium, superplastic forming, role of grain boundaries on crack propagation and corrosion, simulation of stress-strain curves.	7
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Suwas, S., Ray, R.K., Crystallographic texture of materials, Springer-Verlag	2014
2.	Randle V., Engler O., Texture Analysis: Macrotexture, Microtexture and Orientation Mapping, Gordon & Breach	2000

3.	Bunge H.-J., Texture Analysis in Materials Science, London-Butterworths	1982
4.	Kocks U.F., Tomé C., Wenk H.-R., Texture and Anisotropy, Cambridge University Press	1998