Department of Metallurgical and Materials Engineering
NIT Raipur

5th Semester Syllabus

Sl. No.	Subject	Subject Code	Category
5.1 5.2 5.3	Materials Characterization Metals Joining Physics of Materials	MM105101MM MM105102MM MM105103MM	Core
5.4.	5.4.1 Special steels and Alloys 5.4.2 Light Metals and Alloys	MM105201MM MM105202MM	Program Elective (PE)
5.5.	5.5.1 Non-Destructive Testing 5.5.2 Powder Metallurgy	MM105301MM MM105302MM	Open Elective (OE)
5.6 5.7	Materials Characterization Lab Metal Joining Lab	MM105401MM MM105402MM	Laboratory
5.8	Summer Internship-1	MM105701MM	Internship

Department of Metallurgical and Materials Engineering
NIT Raipur

5.1 Materials Characterization

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	Materials Characterization
3.	L-T-P Structure	3-1-0
4.	Credits / # of period	4 / 40
5.	Course number(Code)	MM105101MM
6.	Status (Core/Elective) / Category	Core
7.	Pre-requisites (course no./title)	None
8.	Course Objectives (CO) : 1. To study the principles and methods of characterizing the structure and other aspects of materials. 2. Motivate the choice of analytical methods based on the capabilities of the method and the relevance of the results to address a specific problem 3. To apply advanced spectroscopy techniques for getting structural and elemental analysis of Material. 4. To understand thermal analysis techniques to study high temperature behaviour of materials.	
9.	Course Syllabus: **Unit-1** Fundamentals of optics, Optical microscope and its instrumental details, Variants in optical microscopes and image formation, Phase contrast, Polarised light, Differential interference contrast, Fluorescence microscopy, Sample preparation and applications of optical microscopes, elements of quantitative metallography and image processing. **Unit-2** Fundamentals of X-ray generation and scattering, properties and applications of X-rays, absorption of X-rays and filters, Bragg's law, X-Ray diffraction and applications, working principles of diffractometer, diffraction methods, diffraction intensities, factors affecting intensity, 'structure factor' calculations, Indexing of XRD patterns. **Unit-3** Introduction to electron microscope and applications, introduction to Scanning electron microscopy (SEM), Instrumental details and image formation of SEM, Various imaging techniques, Sample preparation and applications of	

	SEM, Introduction to transmission electron microscopy (TEM), Diffraction and image formation, Various imaging techniques, Sample preparation and applications of TEM. **Unit-4** SPM: STM, AFM, Nanoindentation, Spectroscopic Techniques: Fundamentals, EDS, WDS, EPMA, XPS, AES, SIMS, RBS, EELS, UV-VIS, FTIR, Thermal analysis technique: DTA, DSC, TGA, DMTA, Dilatometry.
10.	Text Books:- 1. Microstructural Characterization of Materials–D. Brandon and W.D. Kaplan, John Wiley and Sons. 2. Materials Characterization Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press. 3. Materials Science and Engineering – W.D. Callister, Jr. Wiley India (P) Ltd. 4. Materials Science and Engineering, G.S. Upadhyaya and Anish Upadhyaya. 5. Fundamentals of Materials Science - the microstructure property relationship using metals as model systems, E.J. Mittemeijer, Springer
11.	1. Reference Books 2. Crystals and Crystal structures, R.J.D. Tilley, John Wiley and Sons, 3. Science of Microscopy, P.W. Hawkes and J.C.H. Spence, Springer 4. Scanning Electron Microscopy & X-Ray Microanalysis, J.Goldstein et.al, Springer 5. Transmission Electron Microscopy – B.D.Williams& C. B. Carter, Springer 6. Surface Analysis Methods in Materials Science, Editors: D.J.O Connor, B.A. Sextton, R. St. C. Smart, Springer 7. Fundamentals of Light Microscopy and Electronic Imaging, D.B.Murphy, John Wiley and Sons Inc. 8. Characterization of Materials Volume 1and 2, E.N. Kaufmann, John Wiley and Sons 9. Handbook of Analytical Methods for Materials, Materials Evaluation and Engineering Inc. 10. Electron Microscopy and analysis, 3rd edition, P. J. Goodhew, J. Humphreys and R. Beanland, Taylor and Francis 11. Characterization of Materials (Materials Science and Technology:A Comprehensive Treatment,Vol 2A & 2B, VCH.

5.2 Metals Joining

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Metals Joining**
3.	L-T-P Structure	3-1-1
4.	Credits / # of period	4/ 40
5.	Course number(Code)	MM105103MM
6.	Status (Core/Elective) / Category	Core
7.	Pre-requisites (course no./title)	Physical Metallurgy, Heat Treatment and Phase Transformation
8.	Course Objectives(CO) : 1. Understanding of metallurgical fundamentals of welding with regard to heat flow, and phase transformations during welding. 2. To study Welding of ferrous and non-ferrous metals and alloys. 3. To gain a knowledge about quality control methods in welded joints.	
9.	Course Syllabus: **Unit-1** Introduction to various manufacturing processes. Importance of metal joining process over other manufacturing processes, Fusion and solid state welding processes, Process involved in joining: Solidification, solidification of single phase and multiphase metals and alloys, Denderitic and cellular structure, segregation, brittleness, heat transfer, temperature distribution, cooling rate and its effect on structure and properties of weld. **Unit-2** Joint geometry, Heat input and diffusion, materials properties affecting welding characteristics: Heat requirement for melting, heat capacity, thermal conductivity, thermal expansion, oxidation tendency, chemical composition, hardenability, process parameters affecting welding characteristics: Voltage, current and welding speed, Gas welding & arc welding, types of arc welding, MIG, TIG, Submerge arc welding, plasma arc welding, stud welding, resistant welding, electron beam welding. atomic hydrogen	

	welding, friction and friction stir welding, induction welding, flash welding, laser welding, thermit welding, explosive welding, ultrasonic welding. **Unit-3** Welding defects, phase transformations during welding, CCT diagrams, preheating and post heating, weldability of low alloy steels, carbon equivalent, welding of cast irons, stainless steels, Schaffler diagrams, Welding of non ferrous metals and alloys. **Unit-4** Welding of dissimilar materials, welding defects: cause and its remedy, shrinkage, Weld Residual Stresses, Distortion, solidification cracking, hot cracking, cold cracking, lamellar tearing, reheat cracking different weld zones, Fusion Zone, Partially Melted Zone, Heat Affected Zone. Weld inspection and testing, corrective measures.
10.	Text Books 1. Welding Metallurgy – Sindo Kou, 2nd edition, published by Wiley 2. Normal Bailey, Weldability of Ferritic Steels, Jaico Publishing house, 1997 3. S P Tiwari, Advanced Welding Technology,S K Kataria& sons 4. Linnert G. E., Welding Metallurgy, Volume I and II, 4th Edition, AWS, 1994
11.	Reference Books 1. Granjon H., Fundamentals of Welding Metallurgy, Jaico Publishing House, 1994 2. Kenneth Easterling, Introduction to Physical Metallurgy of Welding, 2nd Edition, Butterworth Heinmann, 1992 3. Saferian D., 'The Metallurgy of Welding', Chapman and Hall, 1985 4. Jackson M. D., 'Welding Methods and Metallurgy', Griffin, London, 1967 5. Mishra. R.S and Mahoney. M.W, Friction Stir Welding and Processing, ASM, 2007

Department of Metallurgical and Materials Engineering
NIT Raipur

5.3 Physics of Materials

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Physics of Materials**
3.	L-T-P Structure	3-1-0
4.	Credits / # of period	4 / 40
5.	Course number(Code)	MM105103MM
6.	Status (Core/Elective) / Category	Core
7.	Pre-requisites (course no./title)	None
8.	Course Objectives(CO) : 1. The course deals with crystalline solids and is intended to provide students with basic physical concepts and mathematical tools used to describe solids. 2. The objective of this course is to study the underlying physics of a group of materials, as in the periodic table, in terms of their structure, electronic, optical and thermal properties. 3. This course helps students in providing an in-depth knowledge to understand the elementary classical and quantum theory of free electrons and nearly free electrons in metals, periodic structures, and semiconductors.	
9.	Course Syllabus: **Unit-1** Introduction and Approach, Properties of materials and some important relationships, Free electron theory of metals, Drude model Electronic Conductivity, Thermal Conductivity - Ratio the Wiedemann Franz Law. Maxwell Boltzmann Statistics, Limitations of the Drude model. **Unit-2** Elementary quantum mechanics: History and Significant concepts, The Drude Sommerfeld model, Fermi Dirac statistics, Density of states, Fermi Energy and Fermi Surface, Improvements over Drude model, remaining limitations. **Unit-3** Specific heat, phonons, Real space Vs Reciprocal space, Diffraction condition and its significance for electron energy, Wigner Seitz cells, Brillouin zones, Band Theory, Density of occupied states, the origin of anisotropy.	

	Unit-4 Electrons and Holes, Classification of semiconductors, Direct Band gap, indirect Band gap, opto-electronic materials, Magnetic properties, superconductivity, Meissner effect, Bose-Einstein Statistics, BCS theory, High temperature superconductors, physics of nano-scale materials. Semiconductors, Intrinsic and extrinsic Properties, Optical Properties, Doping, p-n Junctions.
10.	Text Books 1. Solid State Physics, by N.W. Ashcroft and N.D. Mermin
11.	Reference Books 1. Introduction to Solid State Physics by C. Kittel (Wiley, 7th Ed., 1996)

5.4.1 Special steels and Alloys

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Special steels and Alloys**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM105201MM
6.	Status (Core/Elective) / Category	Program Elective
7.	Pre-requisites (course no./title)	Iron and Steel Making, Physical Metallurgy
8.	Course Objectives (CO) : 1. Understand principles of microalloying and problem associated with developing high strength steels. 2. Selection of advanced and ultra-high strength steels for specific engineering applications 3. Choose the suitable tool steel for specific applications based on the property requirements 4. Select proper alloying and heat treatment procedure to obtain required properties in cast iron.	
9.	Course Syllabus: **Unit-1** Definition of high strength steels, problems in developing high strength steels;; HSLA steels: principle of microalloying and thermomechanical processing; importance of fine grained steels, TRIP steels: Introduction, Manufacturing of TRIP Steels, and Phase Transformations during Heat Treatment to Produce TRIP Steels, Microstructure, and Mechanical Properties of TRIP Steels. **Unit-2** Maraging steels: Different types of Maraging steels and applications, heat treatment of Maraging Steels, Ultrafine-grained steels: Refinement of Austenitic Microstructure and Its Influence on $\gamma \rightarrow \alpha$ Transformation, Deformation Induced Ferrite Transformation, Microstructure Refining and Strengthening of Low- carbon Bainitic Steel, Martensitic	

	Steel, Carbide-free Bainite/Martensite (CFB/M) Duplex Phase Steel. Extra Low Sulfur and Non-metallic Inclusions Control for Ultra-Fine Grain High Strength Steels. **Unit-3** Stainless steels (ferritic, martensitic, austenitic), high nitrogen stainless steels manufacture and applications, sensitization of stainless steels, Heat and oxidation resistant steels Dual phase steels: Yield Strength of Dual-Phase Steels, Strain Hardening of Dual-Phase Steels, The Ductile Properties of Dual-Phase Steels. Tool steels; classification, composition, and application, constitution diagram of high-speed steels, special problems in heat treatment of tool steels. **Unit-4** Types of cast irons - grey, SG, white, malleable; austempered ductile iron; alloy cast irons, Ni hard, high, silicon cast irons, heat resistant cast irons- high chrome cast iron- structure, property and engineering applications.
10.	Text Books 1. W.C. Leslie, Physical Metallurgy of Steels, Tech Books, 1991. 2. ASM Hanbook, Vol 1. Properties and Selection: Irons, Steels, and High-Performance Alloys, 1990. 3. Pickering P. B., 'Physical Metallurgy and the Design of Steels', Applied Science Publishers, 1983. 4. Pereloma and V. E. David, Phase Transformations in Steels Diffusion less Transformations, High Strength Steels, Modelling and Advanced Analytical Techniques Volume 2, Wood head Publishing Series, 2017. 5. S. Mahadev and T. Muralidhar ,Welding and Joining of Advanced High Strength Steels (AHSS), Woodhead Publishing Series, 2017.
11.	Reference Books 1. George Adam Roberts, Richard Kennedy, G. Krauss: Tool Steels, 5th Ed., ASM, 1998 2. Albert M. Hall: Introduction to Today's Ultrahigh-strength Structural Steels, ASTM Special Technical Publication, 1973 3. R.F. Decker: Source Book on Maraging Steels, ASM, 1979

5.4.2 Light Metals and Alloy

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Light Metals and Alloy**
3.	L-T-P Structure	3-1-0
4.	Credits / # of period	3 / 30
5.	Course number(Code)	MM105202MM
6.	Status (Core/Elective) / Category	Program Elective
7.	Pre-requisites (course no./title)	Physical Metallurgy
8.	Course Objectives(CO) : 1. To study the important production light metals: aluminium, magnesium and titanium 2. Understanding the nomenclature, processing and applications of various light metal alloys. 3. Importance of strengthening mechanisms applicable in the light metal alloys.	
9.	Course Syllabus: **Unit-1** Introduction to Light Metals & Alloys, Importance of Strength to weight ratio and its application. General principles of production of aluminium, magnesium and titanium. Application of light metals in industrial sectors. **Unit-2** Introduction to aluminium alloys, classification into aluminium series, Properties and physical metallurgy of Al-Cu, Al-Mg, Al-Zn, Al-Mn,Al-Cu-Mg, Al-Si-Mg, Al-Zn-Mg and Al-Si alloys. Understanding the important phase diagrams of aluminium alloys. Importance of age hardening in aluminium alloys. Applications of wrought and cast Al alloys. Nomenclature and temper designation for Al alloys. Development of new alloys for advanced applications. **Unit-3** Introduction to magnesium alloys, production of the alloys and classification into magnesium series. Important alloying elements and their effects on the microstructure and mechanical properties. Grain refinement and precipitation hardening applicable in	

	magnesium alloys. Mg-Al-Zn, Mg-Li, Mg-Zr and Mg-rare earth metal alloys. Corrosion resistance of Mg-alloys. **Unit-4** Introduction to titanium alloys, commercially Pure Titanium and its properties and its applications. Importance of the interstitial solid solutions of Titanium and the strengthening mechanisms applicable in the Ti-alloys. Classification of titanium alloys into Alpha Ti alloys, Beta Ti-alloys, Alpha plus Beta Ti alloys. Important titanium alloys with their applications, Ti-6Al-4V, Ti-8Al-1Mo-1V, Ti-13V-11Cr-3Al alloys. Shape memory and other strategic applications of Ti-alloys.
10.	Text Books 1. Heat treatment, structure and properties of Nonferrous alloys- Charlie Brooks, ASM Metals Park, Ohio, USA. 2. Light alloys: Metallurgy of the light metals by I. J. Polmear. 3. Introduction to Physical Metallurgy – S.H. Avner.
11.	Reference Books 1. Engineering Physical Metallurgy – Lakhtin. 2. ASM Metals Handbook Vol-1 & 2. 3. Metallurgical abstracts on light metals and alloysKeikinzokuShōgakukai, Light Metal Educational Foundation., 1999.

5.5.1 Non Destructive Testing

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Non Destructive Testing**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3 / 30
5.	Course number(Code)	MM105301MM
6.	Status (Core/Elective) / Category	Open Elective
7.	Pre-requisites (course no./title)	Testing of Materials
8.	Course Objectives(CO) : 1. In-depth coverage of the applications of Non-Destructive Testing's for materials characterization. 2. Various methods and principles of testing involved in the study of materials. 3. Important instrumentation of the processes relevant to the testing.	
9.	Course Syllabus: **Unit-1** Basic Concepts and Surface Inspection: Concepts of Non-Destructive testing, relative merits and limitations. Types of defects, Visual inspection, Liquid penetrant inspection-principles, practice, applications, advantages and limitations. Principles, applications and instrumentation of thermal inspection, Infrared Thermography. **Unit-2** Radiography: X-rays and Gamma rays. Properties of X-rays relevant to NDE. Absorption of rays, scattering, types and use of filters. Gamma ray sources, characteristics of Gamma rays, Radiography of pipes, welds and castings. Safety with X-rays and Gamma rays. **Unit-3** Ultrasonics: Types of ultrasonic waves, principles of wave propagation, characteristics of ultrasonic waves, attenuation, Production of ultrasonic waves, Ultrasonic probes, couplants. Inspection methods-Pulse echo, Transmission and Resonance techniques. Types of scanning. Immersion testing, thickness measurement. Test block. IIW Standard and reference blocks, calibration in UT. Ultrasonic testing of welds and castings.	

	Unit-4 Magnetic Particle Inspection: Principles, applications, Magnetization methods, magnetic particles. Dry technique and wet technique, demagnetization. Eddy current testing – principles, impedance diagrams, test coils and probes, inspection methods and applications. Other Techniques: Holography and Acoustic emission technique. Pressure and leak testing. Brief overview of Non-Destructive testing standards - ASTM, ISO.
10.	Text Books 1. Barry Hull and Vernon John, Non-Destructive Testing, ELBS/Macmillan,UK, 1988. 2. Baldev Raj, Jaya kumar T. Thavasimuthu M, Practical Non-Destructive Testing, Narosa Publishing House, New Delhi, 1997. 3. McGonnagle, W.T, Non-Destructive Testing, McGraw-Hill Book Co, USA, 1988.
11.	Reference Books 1. ASM Metals Hand Book, Non-Destructive Evaluation and Quality Control, American Society of Metals, Metals Park ,Ohio, USA, 1989. 2. Louis Cartz, Non-Destructive Testing, ASM International, Metals Park Ohio, USA, 1995.

5.5.2 Powder Metallurgy

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Powder Metallurgy**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM105302MM
6.	Status (Core/Elective) / Category	Open Elective
7.	Pre-requisites (course no./title)	None
8.	Course Objectives (CO) : 1. To understand history, importance, and applications of powder metallurgy. 2. Acquaint with the knowledge powder characteristics, production methods, powder characterization techniques and methods of powder compaction. 3. Acquire knowledge on the types of sintering and mechanism of sintering. 4. Understand causes of defects in powder metallurgy processed materials and methods to minimize defects.	
9.	Course Syllabus: **Unit-1** Introduction: Historical and modern developments in Powder Metallurgy. Advantages, limitations and applications of Powder Metallurgy. Basic Steps for Powder Metallurgy. Characteristics of metal powder: Chemical composition, Particle size, shape and size distribution, Characteristics of powder mass such as apparent density, tap density, flow rate, friction index. Powder treatment and handling, Properties of green compacts and sintered compacts. **Unit-2** Metal powder production methods: Atomization, Reduction from oxide, Electrolysis, Crushing, Milling, Condensation of metal vapour, Hydride and carbonyl processes, Mechanical Alloying, New developments. Powder Characterization: Powder conditioning, fundamentals of powder compaction, density distribution in green compacts, compressibility, green strength, pyrophorocity and toxicity. **Unit-3**	

	Powder Compaction Methods: Basic aspects, types of compaction presses, compaction tooling and role of lubricants, Single and double die compaction, isostatic pressing, hot pressing, defects. Powder Forming: Powder rolling, powder forging, powder extrusion and explosive forming technique. **Unit-4** Sintering: Definition, stages, effect of variables, sintering atmospheres and furnaces, Mechanism, liquid-phase sintering, Secondary operations. Sintered Products: Study of sintered bearings, cutting tools, metallic filters, friction and antifriction parts and electrical contact materials. Defects in Powder metallurgy processed materials and their processing to minimize defects etc.
10.	Text Books 1. Powder Metallurgy Science by R.M German. 2. Powder Metallurgy: Science, Technology, and Materials byAnishUpadhyaya, Gopal Shankar Upadhyaya. 3. Powder Metallurgy by A.K. Sinha. 4. Powder Metallurgy: Science, Technology and Applications by PC Angelo and R. Subramanyam.
11.	Reference Books 1. Introduction to Powder Metallurgy by J.S. Hirshhorn. 2. Treatise on Powder Metallurgy: Technology of Metal Powders and Their Products by C. GoetzelVol 1& II. 3. Powder Metallurgy: Principles and Applications by F.V. Lenel. 4. Powder Metallurgy Practice and Applications by R.L. Sands & C.R. Shakespeare. 5. ASM W.D.Kingery, Introduction to Ceramic Material, Volume 18, Wiley 1960. 6. Barsaum - Fundamentals of Ceramics- 2003.

Department of Metallurgical and Materials Engineering
NIT Raipur

5.6 Material Characterization Laboratory

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	Material Characterization Laboratory
3.	L-T-P Structure	0-0-2
4.	Credits / # of period	1/ 20
5.	Course number(Code)	MM105401MM
6.	Status (Core/Elective) / Category	Laboratory
7.	Pre-requisites (course no./title)	Material Characterization (Theory)
8.	Course Objectives (CO) : 1. The students will be able to perform basic materials characterization and analysis using optical microscope, SEM, EDS, XRD, DSC etc. 2. Sample preparation for various characterization processes. 3. Understanding and evaluation of the results obtained.	
9.	List of Experiments 1. To prepare metal specimen for microscopy and XRD characterization. 2. Quantitative and qualitative analysis of microstructure using optical microscopy. 3. Sputter coat and SEM-EDS analysis of specimen. 4. Qualitative analysis of crystalline materials by X-Ray Diffraction. 5. Thermal analysis of specimen using DSC.	
10.	Text Book 1. Characterization of Materials Volume 1and 2, E.N. Kaufmann, John Wiley and Sons, 2003.	
11.	Reference Books Handbook of Analytical Methods for Materials, Materials Evaluation and Engineering Inc. 2001.	

5.7 Metal Joining Laboratory

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Metal Joining Laboratory**
3.	L-T-P Structure	0-0-2
4.	Credits / # of period	1/ 20
5.	Course number(Code)	MM105402MM
6.	Status (Core/Elective) / Category	Laboratory
7.	Pre-requisites (course no./title)	Metal Joining Theory
8.	Course Objectives(CO) : 1. Preparation of samples for various types of joint. 2. Hands on experience of various joining techniques. 3. Mechanical and Microstructural characterization of welded joints. 4. Determination of weakest zone in the welded sample and understand fracture behavior.	
9.	**List of Experiments** 1. Metallic sample preparation for welding 2. Study of Electric Arc Welding Unit 3. Study of Metal Inert Gas Unit 4. Study of Tunguston Inert Gas Unit 5. Welding of prepared similar steel work pieces in arc welding unit 6. Welding of prepared similar Aluminum work pieces in TIG welding unit 7. Macro and micro-structural studies of weldments 8. Study hardness variation across different weld zones 9. Tensile test of the welded structure-Comparision between tensile strength of base metal and weldment 10. Fractographic study of the fractured specimen	
10.	Text Book 1. Welding Metallurgy – Sindo Kou, 2nd edition, published by Wiley.	
11.	Reference Books	

	1. Granjon H., Fundamentals of Welding Metallurgy, Jaico Publishing House, 1994. 2. Kenneth Easterling, Introduction to Physical Metallurgy of Welding, 2nd Edition, Butterworth Heinmann, 1992.

5.8 Summer Internship – I

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	Summer Internship – I
3.	L-T-P Structure	
4.	Credits	1
5.	Course number(Code)	MM105701MM
6.	Status (Core/Elective)	Internship
7.	Pre-requisites (course no./title)	

Department of Metallurgical and Materials Engineering
NIT Raipur

6th Semester Syllabus

Sl. No.	Subject	Subject Code	Category
6.1	Corrosion Engineering	MM106101MM	Core
6.2	Polymer, Ceramic and Composite Materials	MM106102MM	
6.3	Metal Forming Processes	MM106103MM	
6.4.	**6.4.1** Artificial Intelligence in Materials Engineering	MM106201MM	Program Elective (PE)
	6.4.2 Liquid Metal Engineering	MM106202MM	
6.5	**6.5.1** Fracture Mechanics and Failure Analysis	MM106301MM	Open Elective (OE)
	6.5.2 Tribology of Materials	MM106302MM	
6.6	Corrosion Engineering Lab	MM106401MM	Laboratory
6.7	Academic Writing and Seminar	MM106601MM	Seminar

6.1 Corrosion Engineering

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Corrosion Engineering**
3.	L-T-P Structure	3-1-0
4.	Credits / # of period	4 / 40
5.	Course number (Code)	MM106101MM
6.	Status (Core/Elective) / Category	Core
7.	Pre-requisites (course no./title)	Metallurgical Thermodynamics & Kinetics
8.	Course Objectives (CO) : 1. To introduce the concept of interaction of surfaces from surrounding. 2. Application of Kinetics and Thermodynamics in Materials Degradation. 3. Introducing concept of wet and dry (high temperature) corrosion. 4. Introduction of various electrochemical characterization techniques.	
9.	Course Syllabus: **Unit-1** Charged Interfaces, The Electrical Double Layer, The Gouy-Chapman Model of the Electrical Double Layer, Electrode Potentials, Electrochemical Cells and Galvanic Corrosion, Electrochemical Cells, Electrochemical Cells on the Same Surface, Galvanic Corrosion, Differential Concentration Cells , Metal Ion Concentration Cells. **Unit-2** Pourbaix Diagrams, Applications of Pourbaix Diagrams to Corrosion, Limitations of Pourbaix Diagrams, Units for Corrosion Rates, Methods of Determining Corrosion Rates, Electrochemical Polarization, Anodic and Cathodic Polarization, Electrode Kinetics for Activation Polarization, Absolute Reaction Rate Theory, Electrode Kinetics for Non-Corroding Metals, The Tafel Equation, Mixed Potential Theory, Electrode Kinetic Parameters. **Unit-3** Applications of Mixed Potential Theory, Metals in Acid Solutions, Tafel Extrapolation, Linear Polarization Method, Applications of the Linear Polarization Technique, Small-Amplitude Cyclic Voltammetry, Concentration Polarization and Diffusion, Solubility and Diffusion, Electrode Kinetics for Concentration Polarization, Concentration Profile	

	Near an Electrode Surface, Limiting Diffusion Current Density, Diffusion Layer vs. The Diffuse Layer, Current–Potential Relationship for Concentration Polarization, Linear Polarization, Concentration Polarization in Acid Solutions, Theories of Passivity, Properties of Passive Oxide Films, Passivity in Stainless Steels, Composition of Passive Films on Stainless Steels, Passivity by Alloying with Noble Metals, Anodic Protection, Crevice Corrosion, Crevice Corrosion Testing, Critical Pitting Potential, Differences Between Pitting and Crevice Corrosion, Detection of Corrosion Pits, Mechanically Assisted Corrosion, Stress-Corrosion Cracking, Types of Inhibitors, Crevice Corrosion, Stress-Corrosion Cracking and Corrosion Fatigue, Vapor-Phase Inhibitors, Corrosion Under Organic Coatings, Paints and Organic Coatings, Underfilm Corrosion. **Unit-4** AC Impedance, Relaxation Processes, Experimental Setup, Complex Numbers and AC Circuit Analysis, Additional Methods of Plotting Impedance Data, Multiple Time Constants and the Effect of Diffusion, Kramers–Kronig Transforms, Theory of High-Temperature Oxidation, Effect of Temperature on the Oxidation Rate, Defect Nature of Oxides, Semiconductor Nature of Oxides, Hauffe Rules for Oxidation, Effect of Oxygen Pressure on Parabolic Rate Constants, Non-uniformity of Oxide Films, Protective vs. Non-protective Oxides, Pilling–Bedworth Ratio, Properties of Protective High-Temperature Oxides, Biocorrosion, mechanisms and microbiological aspects. Corrosion under sub-soil and sea water conditions- Marine biofouling and biocorrosion with respect to industrial conditions. Methods of abatement.
10.	Text Books:- 1. Introduction to Corrosion Science: E. McCafferty, Springer, ISBN: 978-1-4419-0454-6. 2. M.G. Fontana: Corrosion Engineering, 3rd Edition, McGraw-Hill, N.Y., 1978.
11.	Reference Books/ **Online Course Materials** 1. Revie, W.R. and Uhlig, H.H., *Corrosion and Corrosion Control*, 4th edition, Wiley, 2008. 2. Natarajan, K.A., *Advances in Corrosion Engineering,* NPTEL Course Material, Indian Institute of Science Bangalore, http://nptel.ac.in/courses/113108051/ 3. NPTEL lectures by Prof. Kallol Mondal.

Department of Metallurgical and Materials Engineering
NIT Raipur

6.2 Polymer, Ceramic and Composite Materials

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Polymer, Ceramic and Composite Materials**
3.	L-T-P Structure	3-1-0
4.	Credits / # of period	4 / 40
5.	Course number (Code)	MM106102MM
6.	Status (Core/Elective) / Category	Core
7.	Pre-requisites (course no./title)	Mechanical Behavior of Materials
8.	Course Objectives (CO) : 1. To develop understanding of the structure of polymer, ceramics and composite materials on multiple length scales. 2. To describe key processing techniques for producing polymer, ceramics and composites. 3. To develop knowledge of use of polymer, ceramics and composite materials for different applications. 4. To demonstrate the relationship among synthesis, processing, and properties in polymer, ceramics and composite materials.	
9.	Course Syllabus: **Unit-1** Polymers: Classification of polymerization reaction, semi-crystalline and amorphous polymers, Elastomers, Additives, Fillers, Viscoelasticity, Molecular theory for viscoelasticity, Glass and rubbery states, Glass transition temperature, Crystallinity, Deformation, Mechanical response, High temperature specialty polymers, Polymer liquid crystals. **Unit-2** Ceramics: Definition & scope, classification of ceramic materials – conventional and advanced, Area of applications, Beneficiation process, Forming processes, Drying processes, Shaping, Surface finishing, Glazing, Firing, Defects, Applications. **Unit-3**	

	Composites: Introduction, Reinforcement and Matrix materials: types, properties and application, Classification of Composite, Role of interfaces: wettability, bonding, interactions and tests for measuring Interfacial strength, Advantages and disadvantages of different composites. **Unit-4** Polymer Matrix Composites, Ceramic Matrix Composites, Metal Matrix Composites, Processing, and Applications, Hybrid and Green composites, Mechanics, Fracture, Toughening Mechanisms.
10.	Text Books:- 1. Composite Materials – Science & Engineering, K.K. Chawla, Springer-Verlag, New York, 1987. 2. An Introduction to Composite Materials, Hull, Cambridge, 2nd Edt 3. Young and Lovell, Introduction to Polymers, Nelson Thomes. 4. Introduction to Ceramics – W.D.Kingery 5. Fundamentals of Ceramics by Michel Barsoum, Mcgraw Hill
11.	Reference Books: 1. Composites, Engineered Materials Handbook, Vol.1, ASM International, Ohio, 1988. 2. Structure and Properties of Composites, Materials Science and Technology, Vol. 13, VCH, Weinheim, Germany, 1993 3. Composite Materials: Engineering and Science, F.L. Matthews and R.D. Rawlings, Chapman & Hall, London, 1994 4. S. Kumar: Hand book of ceramics ; Vol – I & II

6.3 Metal Forming Processes

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Metal Forming Processes**
3.	L-T-P Structure	3-1-0
4.	Credits / # of period	4 / 40
5.	Course number (Code)	MM106103MM
6.	Status (Core/Elective) / Category	Core
7.	Pre-requisites (course no./title)	Mechanical Behavior of Materials
8.	Course Objectives(CO) : 1. Gain an understanding of fundamentals of metal working. 2. Analyze the behavior of metals during plastic deformation. 3. Obtain a working knowledge of forging, rolling, extrusion, wire drawing etc.	
9.	Course Syllabus: **Unit-1** Fundamentals of Metal Working: Classification of forming processes, Mechanics of metal working for slab method and Deformation zone geometry. Cold working, Recovery, Recrystallization and grain growth, hot working, Strain-Rate effects, Work done in plastic deformation processes, Yield criterion and its significance in metal working. **Unit-2** Forging: Classification of forging processes, forging equipment. Forging in plane strain. Open-die forging, closed-die forging, Forging pressure & load calculation, Forging defects. **Unit-3** Rolling of Metals: Classification of rolling processes, rolling mills. Hot rolling, cold rolling, geometrical relationships in rolling, Simplified analysis of rolling load, rolling variables. Concept of Roll separating force, power required in rolling, effects of front & back tensions, friction hill curve and factors affecting it. Maximum reduction of sheet. problems and defects in rolled products. **Unit-4**	

	Extrusion: Classification of extrusion processes, extrusion equipment. Hot extrusion. Deformation and defects in extrusion. Analysis of extrusion process. Cold extrusion. Extrusion of tubing and production of seamless pipe and tubing. Rod and wire drawing, tube drawing processes, residual stresses in rod, wire and tubes. Sheet metal forming processes, Equipment.
10.	Text Books 1. Mechanical Metallurgy by G.E. Dieter (3rd edition) 2. Mechanical working of metals - A. Avitzur.
11.	Reference Books 1. Engineering Metallurgy – Part-II – Higgins

6.4.1 Artificial Intelligence in Materials Engineering (Program Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Artificial Intelligence in Materials Engineering**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number (Code)	MM106201MM
6.	Status (Core/Elective) / Category	Program Elective
7.	Pre-requisites (course no./title)	Physical Metallurgy, Iron and steel making, Math-I, Math- II and Mathematics- III
8.	Course Objectives (CO): 1. To understand what AI is, scope of its applications in materials and metallurgical engineering cases. 2. To expose the students to the technology like Machine Learning, Deep Learning, Neural Networks, and Genetic Algorithms. 3. To build the knowledge to describe several metallurgical and materials problems in context of industry and research and development surrounding AI. 4. To Articulate the current trends and future of materials and metallurgical industries progression of AI technology	
9.	**Unit 1** Introduction to artificial intelligence and machine learning, History, Philosophy, and Definitions of AI, The Foundation of AI, correlation between materials structure, properties, phenomena, and process. Scope of solving industrial and research-based materials problem using AI. Role of AI in solving materials science problems. Accelerating Materials Development and Deployment. **Unit 2** Fundamental of Artificial neural network, basic elements and principles, types, etc. Supervise unsupervised and reinforcement learning. Back propagation algorithm, hyper parameters loss function transfer function and optimization algorithms, recent development, and deep learning. Applications and examples of solving materials	

	problem, structure properties linking, process property linking, creating computer vision of microstructure. **Unit 3** Framing a material problem as optimization search problem, classical and heuristic search. local and global search, Genetic Algorithms as AI based search tool, single and multi-criteria search, constraints etc. Example study with solving the blast furnace operation-based problem / design of steel and other alloys / glass and ceramic. **Unit 4** Reasoning and Association rule mining for solving materials problem, decision trees, fuzzy logic and reasoning, fuzzy set, fuzziness in materials systems, a fuzzy variable with metallurgical examples, fuzzy inference system case example of fuzzy modelling materials problem solving. Rough set theory and its applications in alloy design. Hybrid system and their application in materials with examples of more complex problems.
10.	Textbooks 1. Dan W. Patterson, Introduction to AI & Expert System, PHI, First Edition, 2015. 2. Russel & Norvig, Artificial Intelligence: A Modern Approach, Pearson Education, by Stuart Russell and Peter Norvig. Cahn, Fourth edition, 2019 3. Artificial Intelligence: Elaine Rich, Kevin Knight, Mc-Graw Hill, 2nd Edition 1991. 4. Rajalingappa Shanmugamani, Deep learning for Computer Vision, Packt Publication, Mumbai India, First Edition, 2018.
11.	Reference Books 1. Neuro-Fuzzy and Soft Computing: A computational approach to learning and machine intelligence, Indian Edition, Prentice Hall, USA 1997. 2. David E. Goldberg, Genetic Algorithms in search of optimization and machine Learning, Pearson Education Inc. Fifth Indian Reprint, 2002 3. Luger Artificial Intelligence, Pearson Education India; 5th edition, 2008. 4. S. Rajasekaran, G.A.V. Pai: Neural networks, Fuzzy Logic and Genetic Algorithms Synthesis and Applications, Prentice-Hall of India.

6.4.2 Liquid Metal Engineering (Program Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Liquid Metal Engineering**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number (Code)	MM106202MM
6.	Status (Core/Elective) / Category	Program Electives
7.	Pre-requisites (course no./title)	Physical Metallurgy
8.	Course Objectives (CO): 1. To understand the limitation and challenges of the present casting and metal processing technologies of industries. 2. To understand and develop knowledge of various force convection technologies used for melt conditioning. 3. To understand the effect of force convection on liquid metal to alter microstructure and mechanical properties.	
9.	Course Syllabus: **Unit-1** Limitations of metal forming and heat treatment processes, Economics of metal processing and its impact, introduction to reo-casting and its limitations, introduction to the concept of liquid metal engineering. **Unit-2** Solidification of metal under various conditions, effects of introducing grain refiners and modifiers on castings, limitations of grain refiners and modifiers, effect of forced convection on solidification mechanism in pure metal and alloy systems, tools of forced convection, nucleation under force convection, effect of forced convections on growth. **Unit-3** Various force convection technologies, Principles of ultrasonic treatment of liquid metal, low frequency vibrations and ultrasound, propagation of acoustic waves in the melt, acoustic cavitations in liquid metal, mechanical force on liquid metal and its effects, types of mechanical stirrers and their effects, stirrer materials, effect of electromagnetic forces	

	on liquid metal, static magnetic field, pulsed electric field, electromagnetic oscillation field. **Unit-4** Effect of introducing force convection during solidification on the microstructure and mechanical properties of metals and alloys, designing new caster for introducing external fields into liquid metal during casting.
10.	Text Books: 1.Solidification processing of metallic alloys under external fields, Dmitry G. Eskin, JiaweiMi, Springer 2018
11.	Reference Books: 1. Ultrasonic Treatment of Light Alloy Melts, By Georgy I. Eskin and Dmitry G. Eskin, 2017 by CRC Press.

6.5.1 Fracture Mechanics and Failure Analysis (Open Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Fracture Mechanics and Failure Analysis**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number (Code)	MM106301MM
6.	Status (Core/Elective) / Category	Open Elective
7.	Pre-requisites (course no./title)	Physical Metallurgy, Mechanical Behaviour of Materials
8.	Course Objectives(CO) : 1. To introduce the concept fracture toughness of materials in presence of crack. 2. Effect of crack size and shape on crack propagation behaviour. 3. Learn the various factors affecting/causing failures. 4. Design new materials that can withstand failures, based on the environmental considerations and application.	
9.	Course Syllabus: **Unit-1** Cohesive strength of metals, relationship between cohesive strength and actual strength of metals, concept of whiskers, Linear Elastic Fracture Mechanics, Griffiths analysis, concept of energy release rate and fracture energy, critical stress intensity factor, plasticity at the crack tip, plastic zone shape and size, effect of constraint, plane stress, plane strain, thickness, EPFM, CTOD, J integral. **Unit-2** Stages of failure analysis, classification and identification of various types of fracture. Overview of fracture mechanics, characteristics of ductile and brittle fracture. General concepts, fracture characteristics revealed by microscopy, factors affecting fatigue life Creep, stress rupture, elevated temperature fatigue, metallurgical instabilities, environmental induced failure. Some case studies failures. **Unit-3**	

	Analysis of wear failure. Corrosion failures- factors influencing corrosion and wear failures, Procedure for analyzing wear and corrosion failures, various types of hydrogen damage failures. Causes of failure in forming, failure of iron and steel castings, improper heat treatment, stress concentration and service conditions. Failure of weldments-reasons for failure procedure for weld failure analysis. **Unit-4** Reliability concept and hazard function, life prediction, condition monitoring, application of Poisson, exponential and Weibull distribution for reliability, bath tub curve, parallel and series system, mean time between failures and life testing.
10.	Text Books 1. G.E. Dieter: Mechanical Metallurgy, McGraw Hill, 1988 2. T.L. Anderson: Fracture Mechanics- Fundamentals and Applications, 3rd Ed., CRC Press, 2011 3. R.W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, 4th Ed., John Wiley & Sons, 1995
11.	Reference Books 1. ASM Metals Handbook, Failure Analysis and Prevention, ASM Metals Park. Ohio, Vol.10, 10th Edition, 1995 2. Colangelo.V.J. and Heiser.F.A., Analysis of Metallurgical Failures, John Wiley and Sons Inc. New York, USA, 1974

6.5.2 Tribology of Materials (Open Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Tribology of Materials**
3.	L-T-P Structure	3-1-0
4.	Credits / # of period	3 / 30
5.	Course number (Code)	MM106302MM
6.	Status (Core/Elective) / Category	Open Elective
7.	Pre-requisites (course no./title)	None
8.	Course Objectives(CO) : 1. Understanding the friction, wear and lubrication in materials and their industrial importance. 2. Optimization of process parameters and material properties to improve tribological properties of materials. 3. Understanding the techniques for improvement in tribological performance of materials in various applications.	
9.	Course Syllabus: **Unit-1** Introduction to Tribology, History and industrial importance of tribology, Surface properties and measurements, Nature of metallic surface, surface geometry, measurement of surface topography, quantifying surface roughness, contact between surfaces; **Unit-2** Friction, the laws of friction, measurement of friction, origin of friction, theories of friction; adhesion- theory, lubricant types, composition and their properties, selection of lubricants. Wear: Types of wear, adhesive wear, Archard's law, abrasive wear, erosion wear, factors affecting corrosive wear. **Unit-3** Wear map, various wear testing methods- pin on disc, pin on drum, slurry wear, air jet and water jet erosion as per ASTM standards. Worn out surface and wear mechanisms. Effects of various mechanical properties and microstructures on Tribological behaviour of materials, effect of temperature. **Unit-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, various applications.
10.	Text Books 1. Harish Hirani, Fundamentals of Engineering Tribology with applications, Cambridge University press, 2016. 2. PrashantaSahu, Engineering Tribology, PHI, 2018. 3. I M Htchings, Tribology: Friction and wear of Engineering Materials, Butterworth-Heinemann, 2001.
11.	Reference Books / Online learning resources 1. Williums, Engineering Tribology. New York : Cambridge University Press, 2006. 488 p. ISBN 0-521-60988-7. 2. P Blaškovitš, M Dzimko, J Balla, Tribológia. Bratislava: Alfa, 1990. ISBN 80-05-00633-0. 3. https://nptel.ac.in/courses/112102015/1

6.6 Corrosion Engineering Laboratory

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Corrosion Engineering Laboratory**
3.	L-T-P Structure	0-0-2
4.	Credits / # of period	1 / 20
5.	Course number (Code)	MM106401MM
6.	Status (Core/Elective) / Category	Laboratory
7.	Pre-requisites (course no./title)	None
8.	Course Objectives(CO) : 1. To introduce the experimental aspects of weight loss test. 2. Introduction to direct current characterization techniques. 3. Introduction to alternating current characterization techniques. 4. Introduction to high temperature oxidation and rate measurement.	
9.	**List of Experiments** 1. Measurement of Open Circuit Potential 2. Corrosion Rate of Measurement by Tafel's extrapolation 3. Corrosion Rate of Measurement by Linear Polarization 4. Electrochemical Impedance Characterization of an system: Bode's plot 5. Corrosion Rate measurement by Weight Loss method 6. Effect of cold working on Corrosion Rate 7. Experiments on Galvanic Corrosion 8. Effect of Stirring and Temperature on Corrosion Rate 9. Determination of Scaling Temperature of Mild Steel	
10.	Text Books 1. Introduction to Corrosion Science: E. McCafferty, Springer, ISBN: 978-1-4419-0454-6 2. M.G. Fontana: Corrosion Engineering, 3rd Edition, McGraw-Hill, N.Y., 1978	
11.	Reference Books 1. ASM Handbook on Corrosion Engineering	

6.7 Academic writing and seminar

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Academic Writing and Seminar**
3.	L-T-P Structure	0-0-2
4.	Credits / # of period	1 / 20
5.	Course number (Code)	MM106601MM
6.	Status (Core/Elective) / Category	seminar
7.	Pre-requisites (course no./title)	None
8.	Course Objectives(CO) : 1. To introduce the academic writing and develop the technical writing skills 2. To familiarize the students with different word processors including MS-Word, Lyx and LaTeX 3. Improvising the presentation skills	
9.	Course Content: 1. Advanced Features of MS-word for thesis writing 2. Introduction to Lyx 3. Introduction to LaTeX 4. Introduction to Mendeley 5. Introduction to Academic Writing: Style, Tone, Flow, Sequence, General to Specific and Specific to General Writing, Data commentary 6. Presentation Skills	
10.	Text Book 1. Academic Writing: Essential Tasks and Skills- Freaks and Swales 2. Using Microsoft Word for writing a Thesis: Hints and Tips by Prof. Martin Fahey	
11.	Reference Books :- 1. Writing Your Thesis: Paul Oliver	

Department of Metallurgical and Materials Engineering
NIT Raipur

7th Semester Syllabus

Sl. No.	Subject	Subject Code	Category
7.1	Materials Data Science and Informatics	MM107101MM	Core
7.2	7.2.1 Introduction to Electrical, Magnetic and Optical Materials	MM107201MM	Program Elective (PE)
	7.2.2 Energy Materials and Technologies	MM107202MM	
7.3	7.3.1 Additive Manufacturing of Materials	MM107203MM	Program Elective (PE)
	7.3.2 Biomaterials	MM107204MM	
7.4.	7.4. 1 X-Ray Diffraction and TEM	MM107301MM	Open Elective (OE)
	7.4.2 Materials Selection in Mechanical Design	MM107302MM	
7.5	Materials Data Science and Informatics Lab	MM107401MM	Laboratory
7.6	Project work	MM107501MM	Project
7.7	Summer Internship -II	MM107701MM	Internship

Department of Metallurgical and Materials Engineering
NIT Raipur

7.1 Materials Data Science and Informatics

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Materials Data Science and Informatics**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number (Code)	MM107101MM
6.	Status (Core/Elective) / Category	Core
7.	Pre-requisites (course no./title)	Basic programming, Maths, Physical Metallurgy
8.	Course Objectives(CO): 1. To understand the history and current trends in materials discovery and development. 2. To introduce the wide variety of topics under the umbrella of exploratory data analysis. 3. To learn how to explore new materials data sets, implement a comprehensive set of machine learning algorithms from scratch and mines the new knowledge for accelerating the materials development activity. 4. To learn how to solve materials and metallurgical problem through data analytics and data science.	
9.	Course Syllabus: **Unit 1** Introduction to data science, types of data, variables and their types, scale of measurement, Examples with materials data. Materials data science and its needs in industry and materials research perspective. Concept of materials informatics, Material Discovery and Development, History of Materials Development Cycles, Need for accelerated materials development and deployment. Materials Innovation and Ecosystem. Big Data. **Unit 2** Data Science approach: Terminology and Components of Data Science, Getting and Cleaning Data, Data Statistics, Descriptive and Inferential Statistics, Event Space, Probability, Distributions and Hypothesis Testing Summarizing and Visualizing Data: Example with a material and metallurgical data. **Unit 3**	

	Univariate and Multivariate Exploratory Data Analysis. Feature extraction and feature selection. Simple example with materials data. Model development using data, learning algorithms: supervise, unsupervised and reinforcement learning, tools, and techniques. Functional mapping, Classification, and pattern recognition, rule base model etc. **Unit 4** Data Pre-processing, Model Evaluation and Ensembles. stages of data science approach of problem solving, Descriptive, diagnostic, predictive and prescriptive analytics of materials data. Example with industrial and laboratory data. Structure-Property Linkages using a Data Science Approach, exploring new materials space using data science informatics.
10.	Textbooks 5. Joel Grus, Data science from scratch, O'Reilly Media, USA, First edition, 2015 6. Krishna Rajan (Ed), Elsevier, Informatics for Materials Science and Engineering. Data-driven Discovery for Accelerated Experimentation and Application, Elsevier, First Edition, 2013. 7. Zacharias Voulgaris, Yunus E. Bulut, AI for Data Science, Prentice Hall Inc, New Jersey, USA, 1995 8. Trevor Hastie, Robert Tibshirani, and Jerome Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer, Second Edition, 2017.
11.	Reference Books 1. Web resource: https://www.coursera.org/learn/material-informatics 2. Amit Konar, Computational Intelligence: principles, techniques and application, Springer, NY, First Edition 2007.

Department of Metallurgical and Materials Engineering
NIT Raipur

7.2.1 Introduction to Electrical, Magnetic and Optical Materials (Program Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Introduction to Electrical, Magnetic and Optical Materials**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3 / 30
5.	Course number (Code)	MM107201MM
6.	Status (Core/Elective) / Category	Program Elective
7.	Pre-requisites (course no./title)	None
8.	Course Objectives(CO) : 1. The objective of this course is to provide students a fundamental understanding of electrical, magnetic and optical properties of materials. 2. To apply fundamentals for selecting materials for different engineering applications. 3. To understand development of new materials for different engineering applications.	
9.	Course Syllabus: **Unit-1** Electrical and Dielectric Materials: Review of electrical conduction - resistivity and dielectric phenomena-concept of polarization - effects of composition, frequency and temperature on these properties-discussion on specific materials used as conductors (OFHC Copper, Al alloys, Fe-Si alloys, amorphous metals)-discussion on specific materials used as dielectrics (ceramics and polymers)-dielectric loss, dielectric breakdown - ferroelectricitypiezo and pyro electricity. **Unit-2** Magnetic Materials: Introduction to dia, para, ferri and ferro magnetism - hard and soft magnetic materials - iron- silicon alloys – iron, nickel alloys - ferrites and garnets - (Ag - Mn - Al) alloys-(Cu - Ni- Co) alloy - fine particle magnets - applications of hard and soft magnetic materials-Giant magneto resistance- Nanomaterials. **Unit-3**	

	Semiconducting and Superconducting Materials: Review of semiconducting materials - concept of doping-simple and compound semi-conductors - amorphous silicon, oxide semiconductors; amorphous semiconductors - FER, MOSFET and CMOS - Concept of supercondcutivity Production of Electronic Materials: Review of electronic materials - methods of crystal growth for bulk single crystals - zone melting-refining, leveling - synthesis of epitaxial films by VPE, PVD, MBE and MOCVD techniques - lithography; production of silicon - starting applications. **Unit-4** Optical Properties of Materials: Introduction to electromagnetic radiation, atomic and electronic interactions with electromagnetic radiation, optical properties of metals, optical properties of nonmetals, opacity and translucency in insulators, color of materials, applications of optical phenomena-luminescence, photoconductivity, lasers, optical fibers in communications.
10.	Text Books:- 1. Pradeep Fulay, Electrical, magnetic, and Optical Materials, 1st edition, CRC press, 2010 2. C. Kittel, Introduction to Solid State Physics, 6th Edition, Wiley Eastern, New International Publishers, 1997
11.	Reference Books 1. Raghavan V, Materials Science and Engineering, 4th Edition, Prentice Hall of India, 1998. 2. A. J. Dekker, Solid State Physics, MacMillan India, 1995

7.2.2 Energy Materials and Technologies (Program Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Energy Materials and Technologies**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM107202MM
6.	Status (Core/Elective) / Category	Program Elective
7.	Pre-requisites (course no./title)	Physics of Metals
8.	Course Objectives(CO) : 1. To provide the fundamental knowledge for understanding concepts of different technologies based on electronic devices. 2. To understand various manufacturing techniques for different energy materials. 3. Understand materials selection for different applications as energy materials.	
9.	Course Syllabus: **Unit-1** Relevance of renewable energy generation, conservation and harvesting vis-à-vis environmental concerns (Energy requirement of society and depleting fossil fuels; Break-up of various renewable energy sources and consumption patterns), Solar cell device physics, LED device physics, Solar energy: amount of energy available area wise. **Unit-2** Available solar energy technologies, PV technologies, materials, processes and issues, First generation technologies–Si based, Thin film (a-Si, CdTe, CIGS): Solar concentrators, Third generation (high efficiency and low cost)–Organic and dye solar cells, multi-junction, quantum dots: Present Status and future outlook and Indian Scenario. **Unit-3** Energy Efficient Lighting: Introduction, Energy efficient buildings, role of sensors *etc,* Comparison of LEDs with conventional technologies, Principles of light emission; Optical processes and materials, Light Emitting Diodes (LEDs): Introduction to p-n junction, hetero-junctions, recombination processes, semiconductor materials (III-V,	

	II-VI, SiC, ternary and quaternary alloys) for LEDs, metallurgical considerations (crystal defects, lattice mismatch, optical losses, degradation), and fabrication technology, OLED for lighting, Characterization Energy Conversion Devices: Description of Operation, Configurations, Cell Components, Materials Requirements, Manufacturing Techniques, Losses, Efficiency. **Unit-4** Solid Oxide Fuel Cells, Solid Oxide Electrolyzer Cells, Batteries, Capacitors, Energy Harvesting Materials and Technologies: Working principles and case studies of with emphasis on materials, their selection vis-à-vis their characteristics: Piezoelectric Sensors, Actuators, Transducers and MEMS, Thermoelectrics, Applications: Ultrasound Imaging, Pyroelectric Sensors IR imaging.
10.	Text Books 1. Handbook of Photovoltaics Science and Technology, By Antonio Luque and Steven Hegedus. **2.** Physics of Solar Cells, By Jenny Nelson. 3. Physics of solar cells: from basic principles to advanced concepts, By Peter Würfel and UliWürfel.
11.	Reference Books 1. Organic photovoltaics: materials, device physics, and manufacturing technologies, By Christoph J. Brabec, Vladimir Dyakonov, UllrichScherf. 2. Principles of Solar Cells, LEDs and Diodes: The Role of the PN Junction, By Adrian Kitai. 3. Electroceramics: materials, properties, applications by A.J. Moulson and J.M. Herbert Electroceramics-based MEMS: fabrication-technology and applications, By Nava Setter.

7.3.1 Additive Manufacturing of Materials (Program Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Additive Manufacturing of Materials**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM107203MM
6.	Status (Core/Elective) / Category	Program Elective
7.	Pre-requisites (course no./title)	Polymer Ceramic and Composite material
8.	Course Objectives (CO) : 1. To understand the different Additive Manufacturing processes 2. To enable selection of a suitable AM process and materials for a particular application 3. To learn the Additive Manufacturing defect and how to control them. 4. To understand the process-structure-property correlation of additively manufactured product	
9.	Course Syllabus: **Unit 1** Additive Manufacturing (3D Printing): Introduction, Process, Classifications, Advantages, Additive v/s Conventional Manufacturing processes, Applications, CAD for Additive Manufacturing: CAD Data formats, Data translation, Data loss, STL format. **Unit2** Materials: Polymers, Metals, Non-Metals, Ceramics, Composites etc, Raw material Preparation and their desired properties, Support Materials; Additive Manufacturing Equipment and tooling; Process: Process parameter, Process Selection for various applications. Various forms of raw material- Liquid, Solid, Wire, Powder **Unit3** Additive Manufacturing Techniques: Stereo- Lithography, LOM, FDM, SLS, SLM, Binder Jet technology. Process, Process parameter, Process Selection for various applications	

	Unit 4 Post Processing: Requirement and Techniques; Defects, Product Quality, Application Domains: Aerospace, Electronics, Health Care, Defence, Automotive, Construction, Food Processing, etc.
10.	Text Books 1. Additive Manufacturing Technologies by by Ian Gibson, David Rosen, Brent Stucker, Mahyar Khorasani, Springer, 3rd ed. 2021
11.	Reference Books 1. Additive Manufacturing: Foundation Knowledge For The Beginners by Sunpreet Singh, Chander Prakash, Seeram Ramakrishna,World Scientific, 2020 2. Additive Manufacturing Applications for Metals and Composites, by K.R. Balasubramanian (Editor), V. Senthilkumar (Editor), Engineering Science Reference, 2020 3. Fabricated: The New World of 3D Printing by Hod Lipson and Melba Kurman, Design and Modeling for 3D Printing by Matthew Griffin

7.3.2 Biomaterials (Program Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Biomaterials**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM107204MM
6.	Status (Core/Elective) / Category	Program Elective
7.	Pre-requisites (course no./title)	Polymer, Ceramic and Composite Materials
8.	Course Objectives(CO) : 1. Understand the concept and significance of Biomaterials. 2. Understand selection of biomaterials for a particular application. 3. Understand mechanical properties of biomaterials. 4. Understand biocompatibility of the materials for the intended application.	
9.	Course Syllabus: **Unit-1** Definition and requirements of biomaterials, properties of some standard biomaterials. Importance of Biomaterials. Interactions of materials with the human body. Classification of Biomaterials, Metallic implant materials: Stainless steel, Co-based alloys, Ti and Ti-based alloys. Composite materials and applications. **Unit-2** Polymeric implant materials: Polyolefin's, polyamides, acrylic polymers, silicone, rubbers, acetyls. (Based on thermo sets, thermoplastics and elastomers). Hydrophilic and hydrophobic surface properties of polymeric biomaterials. Biodegradable polymers for medical purposes, Biopolymers in controlled release systems. Criteria for selection of biomaterials for specific medical applications. **Unit-3** Ceramic implant materials: Definition of bio ceramics. Common types of bio ceramics: Aluminum oxides, Glass ceramics, Carbons. Bio resorbable and bioactive ceramics. Importance of wear resistance and low fracture toughness. Host tissue reactions: importance of interfacial tissue reaction (e.g. ceramic/bone tissue reaction). **Unit-4**	

	Concepts of Biocompatibility, Cell material interaction – types of materials - toxic, inert, bioactive - long term effects of materials within the body and cell response. Corrosion and biodegradation, simulated body fluids and their effect on biodegradation. Engineering biomaterials for tissue engineering. Orthopedic implants, dental materials, vascular grafts, ocular materials, drug delivery carriers, introduction to tissue regeneration scaffolds.
10.	Text Books 1. Biomaterials Science: An Introduction to Materials in Medicine, 3rd Edition, Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, 2013, Academic press, UK. 2. Biomaterials- An Introduction by Park Joon & R.S. Lakes.
11.	Reference Books 1. Fundamentals of Biomaterials by Vasif Hasirci, Nesrin Hasirci,, Springer

7.4.1 X-Ray Diffraction and TEM (Open Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**X-Ray Diffraction and TEM**
3.	L-T-P Structure	3-1-0
4.	Credits / # of period	3 / 30
5.	Course number(Code)	MM107301MM
6.	Status (Core/Elective) / Category	Open Elective
7.	Pre-requisites (course no./title)	Materials Characterization
8.	Course Objectives(CO) : 1. Understand the basic theory of X-ray diffraction for crystal structure determination and its practical application to real problems. 2. Understand diffraction techniques for identification of phases and estimation of their chemical composition, microstructures, and crystal structures. 3. Calculate the residual stress and macro texture of materials 4. Understand working principles of TEM for microstructural and compositional analysis of materials.	
9.	Course Syllabus: **Unit-1** Introduction to crystallography, Symmetry – point group and space group, space group tables etc, Pole figures (Stereographic projection and their applications), Formation of selected area diffraction patterns, reciprocal lattice and Ewald sphere construction, kikuchi lines. **Unit-2** X-ray diffraction and analysis: Production and properties of X-rays, X-rays absorption, filter and detectors. Bragg's law, Diffraction Methods, Structure factor and intensity calculations. **Unit-3** Determination of crystal structure, sources of error in measurements. Chemical Analysis by X-ray techniques, Effect of texture, grain size, plastic deformation, micro strain, residual stresses etc on diffraction lines. **Unit-4**	

	TEM: Principle and operation, sample preparation techniques, detectors and imaging modes, Introduction to HRTEM, diffraction patterns, Indexing of selected area diffraction patterns.
10.	Text Books 1. B.D. Cullity, Elements of X-ray Diffraction by (II edition), Addison-Wesley Publishing Co Inc., Reading, USA, 1978 2. P.J. Goodhew and F.J. Humphreys, Electron Microscopy and Analysis by Taylor and Francis, London, 2001(ISBN-0-7484-0968-8).
11.	Reference Books 1. S.H. Cohen and M.L. Lightbody, Atomic Force Microscopy / Scanning Tunneling Microscopy, (Editors), Plenum Press, New York, 1994. 2. P.J. Haines (Editor), Principles of Thermal Analysis and Calorimetry by Royal Society of Chemistry (RSC), Cambridge, 2002.

7.4.2 Materials Selection in Mechanical Design (Open Elective)

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Materials Selection in Mechanical Design**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number (Code)	MM107302MM
6.	Status (Core/Elective) / Category	Open Elective
7.	Pre-requisites (course no./title)	Physical Metallurgy, Mechanical Behaviour of Materials
8.	Course Objectives(CO) : 1. Develop an understanding of the relationship between design parameters and materials properties. 2. Gain understanding on how properties are influenced by processing, fabrication and service conditions and how to integrate materials selection in a range of modern engineering applications. 3. Selection of materials for Specific engineering applications and processes.	
9.	Course Syllabus: **Unit 1** Introduction Evolution of Engineering materials. Overview: Technologically important properties of materials, Introduction to Material Property Charts Material property charts: Modulus – density, strength-density, fracture toughness-strength, Rationalizing and Critical Assessment of Material Properties, Basics of Design- Design Process and Types, Materials Information for design, oriented Materials Selection. **Unit 2** Selecting Materials and Shape: The Selection strategy, Materials Indices, Selection procedure, –Case studies on Materials selection (Materials for Fly wheel, Spring, heat exchanger etc.) , Shape factors, Microscopic and Micro structural shape factors – limit to shape efficiency, Comparison of structural sections and material indices, Materials Indices that includes shape. **Unit 3**	

	Service, Fabrication and economic requirements for the components – Methodology for selection of materials, Multiple Constraints and Objectives: Introduction, Selection with multiple constraint, conflicting objectives, case studies multiple constraint: Light pressure vessel, connecting rod for high performance engine, Case studies on conflictive objective: Materials for Disk Break calliper. **Unit 4** Process and their effect on Properties: Introduction, classifying processes, the processes: shaping, joining, finishing, Processing for Properties, Systematic Process Selection and cost, Selection charts – Ranking of processes, case studies – Influence of manufacturing aspects and processing route on properties of materials and its influence on selection of materials. process selection: strategy case studies on process selection: Casting an aluminium connecting rod, forming a fan, Joining a Steel Radiator etc.
10.	Text Books 1. M.F. Ashby, Materials Selection in Mechanical Design– Fourth edition, Elsevier Butterworth Heinemann, 2011 2. Materials and Design. The Art and Science of Material Selection in Product Design-Michael F. Ashby and Kara Johnson (Auth.) -Butterworth Heinemann (2014) 3. Gladius Lewis, Selection of Engineering Materials, Prentice Hall Inc, New Jersey, USA, 1995
11.	Reference Books 1. Charles.J.A. and Crane,F.A.A., Selection and Use of Engineering Materials, Butterworths, London, UK, 1989. 2. P. L. Mangonon, The Principles of Materials Selection and Design, Prentice Hall International, Inc. 1999.

7.5 Materials Data Science and Informatics Lab

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	Materials Data Science and Informatics Lab
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	1 / 20
5.	Course number (Code)	MM107401MM
6.	Status (Core/Elective) / Category	Core
7.	Pre-requisites (course no./title)	Materials Data Science and Informatics
8.	Course Objectives (CO): 5. To learn python programming language for data science and visualization. 6. Hand on experience with material data and data science. 7. To how to solve the critical materials/metallurgical problems using data science approach. 8. To expose the students with hand on experience in solving industry problem analysing industrial data	
9.	Laboratory assignments: 1. Computational thinking and data science application with Python programming 2. Study the periodic table as materials data. 3. Diagnostic analysis of sinter plan data/blast furnace operation data/continuous casting data for stabilize the quality of sinters/pig iron/CC steel bar using a sample industrial data set. Or Blast furnace data analysis using AI tool/process structure property corelation study. 4. Prescriptive analysis of an alloying data base to prescribe the rule for alloying. Or Automatic recognition microstructure using deep learning technology. 5. Multivariate analysis of HEA/BMG/perovskite database in search of new materials by material informatics approach. Or Alloy design by analysis of data set using hybrid AI technologies	

10.	Textbooks 1. Laboratory manual 2. Ashok NamdevKamthane and Amit Ashok Kamthane, Programming and problem solving with Python, Second Reprint, McGraw Hill education (India) Private Limited, 2018.
11.	Reference Books 1. Joel Grus, Data science from scratch, O'Reilly Media, USA, First edition, 2015 2. Zacharias Voulgaris, Yunus E. Bulut, AI for Data Science, Prentice Hall Inc, New Jersey, USA, 1995

7.6 Project work

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	Project work
3.	L-T-P Structure	0-0-8
4.	Credits	4
5.	Course number(Code)	MM107501MM
6.	Status (Core/Elective)	Project
7.	Pre-requisites (course no./title)	

7.7 Summer Internship - II

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	Summer Internship – II
3.	L-T-P Structure	
4.	Credits	2
5.	Course number(Code)	MM107701MM
6.	Status (Core/Elective)	Internship
7.	Pre-requisites (course no./title)	

Department of Metallurgical and Materials Engineering
NIT Raipur

8th Semester Syllabus

Sl. No.	Subject	Subject code	Category
8.1	8.1.1 Materials Modeling and Simulation	MM108201MM	Program Elective (PE)
	8.1.2 Nuclear Materials	MM108202MM	
	8.1.3 Grain Boundary Engineering	MM108203MM	
8.2	8.2.1 High Temperature Materials	MM108204MM	Program Elective (PE)
	8.2.2 Metallurgical Waste Management	MM108205MM	
	8.2.3 Furnace Technology	MM108206MM	
8.3	8.3.1 Advanced Materials	MM108301MM	Open Elective (OE)
	8.3.2 Science and Technology of Nano Materials	MM108302MM	
8.4	8.4.1 Automotive Engineering	MM108303MM	Open Elective (OE)
	8.4.2 Engineering Economics	MM108304MM	

Scheme (Eighth Semester for Students undergoing Major Internship)

Sl. No.	Course Title	L	T	P	Credits
1.	Open Elective (0XX4)	3	0	0	3
2.	Open Elective (0XX5)	3	0	0	3
3.	Major Internship				6 (4^+2^^)
	Total Credits				12

^*Mid-semester evaluation report and field evaluation report to be submitted by industry*

^^*Report submission and presentation in the department*

8.1.1 Materials Modelling and Simulation

1.	Department proposing the course	Metallurgical and Materials Engineering
2.	Course Title	**Materials Modelling and Simulation**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number (Code)	MM108201MM
6.	Status (Core/Elective)	Program Elective
7.	Pre-requisites (course no./title)	Engineering Maths I,II and III, Physical Metallurgy, Heat Treatment and Phase Transformation.
8.	Course Objectives (CO): 1. To gains knowledge about fundamentals of Modelling techniques. 2. To gains Knowledge about Simulation methods. 3. To apply the knowledge of modelling and simulation to various structural materials.	
9.	Course Syllabus: **Unit 1** General introduction to materials modelling, Role of materials modelling in connection to experiment and theory, Concept of length and time scale, Classification of materials modelling, General aspects of materials modelling, steps in construction of a model. **Unit 2** Concept of Inter atomic potentials, the cohesive energy, pair potentials, ionic materials, metals, covalent solids, Introduction to molecular dynamics, equation of motion, algorithm, initialization, connection to thermodynamics, reliability of simulations, application in material research and examples. **Unit 3** Metropolis Monte-Carlo algorithm, Ising model, Q-state Potts Model for mesoscale applications, Application of Monte-Carlo for simulation of grain growth, re-crystallization etc. Basics of Cellular automata, example in two-dimension, application of cellular automata in materials research, Phase field modelling, basic principles, one	

	dimension phase filled transformation, application and example of phase field modelling in grain growth and microstructure simulation in polycrystalline materials. Basics of FEM modelling and its application in heat flow problem, mass flow problem with metallurgical application. **Unit 4** Concept of physical and empirical mathematical modelling, modelling of phase diagram, solidification fonts, phenomenological/constitutive modelling microstructure to properties, data driven modelling, Engineering optimization and its applications in materials modelling and simulation. of material processes, properties and phenomena.
10.	Textbooks 1. Richard Lesar, Introduction to Computational Materials Science MRS, Cambridge University Press, UK, Reprint 2014. 2. Dierk Raabe, Computational Materials Science, Wiley VCH Verlag GmbH, 1998 3. Introduction to materials Modelling, Edited by Zoe. H. Barber, Maney Publishing for the Institute of Materials, Minerals and mining, London 2005. 4. K. Dev, Optimization for Engineering Design, algorithms and examples, PHI, Sixth Edition, 1995.
11.	Reference Books 1. Z. Xiao Guo (Ed.), Multiscale Materials Modelling: Fundamental and Applications. Woodhead Publishing Limited, Cambridge, 2007 2. J. S. Szekely, J.W. Evans and J.K. Brimakombe: The Mathematical and Physical Modelling of Primary Metals Processing Operations, Wiley. 3. D. Mazumdar and J.W. Evans: Modelling of Steel Making Processes, CRC.

8.1.2 **Nuclear Materials**

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Nuclear Materials**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM108202MM
6.	Status (Core/Elective)	Program Elective
7.	Pre-requisites (course no./title)	None
8.	Course Objectives(CO) : 1. To explain the basics of Nuclear technology 2. To understand relevance of metallurgy to nuclear reactors. 3. To gain a working knowledge of extraction of nuclear metals like Uranium, Thorium, and Beryllium.	
9.	Course Syllabus: **Unit-1** Elementary Nuclear Physics and Chemistry: Structures of nucleus, radioactivity, bending energy: nuclear interaction; fission and fusion: nuclear reaction; energy release and chain reactions; neutron cross-section; multiplication and criticality concepts and factors. Mechanisms of moderation, radiation detection, radiation effects on fissile and non-fissile materials; radiation damage and radiation growth; thermal cycling; protection against radiations. **Unit-2** Types of reactors and classification. Considerations in selection and properties of common materials used as fuels, their physical and chemical properties; canning materials; coolants; control rods; reflectors and shielding materials. **Unit-3** Occurrence and general characteristics of nuclear minerals. Flow sheets of processing of nuclear minerals for the production of nuclear grade uranium, thorium, beryllium and zirconium with emphasis on basic scientific principles involved. Production and enrichment of uranium, Fabrication fuel elements. Irradiated fuel processing for recovery of Plutonium. Nuclear power production in India and its economics. **Unit-4**	

	Uranium: Acid and alkali processes for digestion of uranium ores, purification of crude salt, production of reactor grade UO_2 and uranium. Thorium: Flow sheets, Acid and alkali processes for digestion of thorium ores, purification and production. Zirconium: Flow sheets, Acid and alkali processes for digestion of zirconium ores, purification and production.
10.	Text Books 1. Metallurgy in Nuclear Power Technology: Wright JC, Iliffe Book Ltd., 1962 2. Nuclear Reactor Metallurgy: Wilkinson WD and Murphy WF, Van Nostrand, 1958 3. Symposium on Rare Materials: Indian Institute of Metals. 4. Principles of Nuclear Reactor Engineering: Glasstone S and Snesonske A Macmillan, London.
11.	Reference Books 1. Uranium and Thorium: Grainger L; George Newnes Ltd., London. 2. Nulcears Fuels: Gurinsky DH and Dienes JL; Macmillan. 3. Reactor Hand book Material; US Atomic Energy Commission, McGraw Hill Book Co. 1955 4. Proceedings of the symposium on Nuclear Science and Engineering – Bhabha Atomic Research Centre, Bombay.

8.1.3 Grain Boundary Engineering

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Grain Boundary Engineering**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM108203MM
6.	Status (Core/Elective)	Program Elective
7.	Pre-requisites (course no./title)	Physical Metallurgy, Mechanical Behavior of Materials
8.	Course Objectives(CO) : 1. To understand the effect of grain boundary on material properties. 2. Knowledge of interface representation and analysis . 3. Application of existing knowledge to tailor interface in new material. 4. Idea of grain boundary structure and its implication in engineering properties.	
9.	Course Syllabus: **Unit-1** Introduction to interfaces: basic classification and definitions, Basics of energetics: definitions and relations to physical properties, Solid-Vapour interfaces, Solid-Liquid Interfaces, Solid-Solid Interfaces **Unit-2** Grain boundary structure and energy, Types of grain boundaries and dislocation models, Stacking Fault and Twin Boundaries, Grain Boundary Segregation, Grain boundary and twin boundary equilibria, CSL boundary (Coincidence site lattice, like sigma 3 , sigma 5 etc). **Unit-3** Hetero-phase Interfaces, Interphase boundaries, Coherent and semi coherent interphase boundaries, Roughening and Phase transformations on interphase boundaries, Interfaces between differences materials and structures, Role of interfaces in conduction in metals and ceramics	

	Unit-4 Effect of interfaces in mechanical properties, High temperature behaviour, sliding and migration, Fracture of metals/alloys: surface embrittlement, grain boundary embrittlement, interface strengthening, Interfaces and Functional Behaviour: Case Studies
10.	Text Books 1. Interfaces in Materials: Atomic Structure, Thermodynamics and Kinetics of Solid-Vapor, Solid-Liquid and Solid-Solid Interfaces, James M. Howe, Wiley-Inter science. 2. The Role of the Coincidence Site Lattice in Grain Boundary Engineering, Valerie Randle. 3. Physics and chemistry of interfaces By Hans-Jürgen Butt, Karlheinz Graf, Michael Kappl, Wiley-VCH. 4. Physics of surfaces and interfaces, H. Ibach, Springer.
11.	Reference Books 1. Solid surfaces, interfaces and thin films, Hans Lüth, Springer. 2. Physical Chemistry of Surfaces, Arthur W. Adamson, Wiley-Interscience 3. Grain Boundary Migration in Metals: Thermodynamics, Kinetics, Applications, Second Edition, Günter Gottstein and Lasar S. Shvindlerman 4. Recrystallization and Related Annealing Phenomena by F.J. Humphreys , M. Hatherly

8.2.1 High Temperature Materials

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**High Temperature Materials**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM108204MM
6.	Status (Core/Elective)	Program Elective
7.	Pre-requisites (course no./title)	Corrosion Engineering
8.	Course Objectives (CO) : 1. To learn and design material's microstructure for high temperature applications. 2. To learn scientific issues related to high temperature such as creep, oxidation and materials degradation. 3. To understand fracture behavior at high temperature.	
9.	Course Syllabus: **Unit-1** Oxidation, high temperature corrosion, erosion, Super alloys, Ceramics and polymers for high temperature applications, Intermetallics, Usage of spring steels, evaluation of property data extrapolation. Factors influencing functional life of components at elevated temperatures, definition of creep curve, various stages of creep, metallurgical factors influencing various stages, effect of stress, temperature and strain rate. **Unit-2** Design of transient creep, time hardening, strain hardening, expressions for rupture life for creep, ductile and brittle materials, Monkman - Grant relationship Various types of fracture, brittle to ductile transition, cleavage, ductile fracture, fracture maps for different alloys and oxides. **Unit-3** Oxidation, Pilling-Bedworth ratio, kinetic laws of oxidation - defect structure and control of oxidation by alloy additions - sulphation, hot gas corrosion deposit, modified hot gas corrosion, effect of alloying elements on hot corrosion. **Unit-4**	

	Iron base, nickel base and cobalt base superalloys, composition control, solid solution strengthening, precipitation hardening by gamma prime, grain boundary strengthening, TCP phase - embrittlement.
10.	Text Book 1. J.R. Davis, ASM Specialty Handbook: Heat- resistant materials, ASM, 1997
11.	Reference Book 1. Evans, R.W and Wilshire, B. Creep of metals and alloys. Institute of metals, 1985, London.

8.2.2 Metallurgical Waste Management

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Metallurgical Waste Management**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM108205MM
6.	Status (Core/Elective)	Program Elective
7.	Pre-requisites (course no./title)	None
8.	Course Objectives (CO) : 1. Identify the various kinds of wastes produced during mining, beneficiation, manufacturing, finishing operations and e-wastes. 2. Classify the wastes produced from iron making, steel making, plasma processing, hydrometallurgical processing etc. 3. Utilization of waste produced during mining and mineral beneficiation. Select a suitable methods to recycle the wastes produced during extraction of non-ferrous metals. 4. Provide a solution for waste management through process integration and intensification.	
9.	Course Syllabus: **Unit-1** Environmental and health impacts of Mining and Metallurgical waste. Various kind of wastes: Mining and Beneficiation waste production. Ferrous metal waste production. Ferroalloys waste production. Hydrometallurgical waste production. Metal manufacturing and finishing waste production. Postconsumer Waste production. E-waste and recovery of metals and useful things from e-waste. **Unit-2** Utilization of mine overburden and waste rock. Potential utilization of mineral beneficiation tailings. Prevention and mitigation of acid mine drainage. Recycling and reuse of blast furnace ironmaking slags, steel making dusts and sludges. Utilization of steel making dusts – Plasma based processing, hydrometallurgical processing, solidification and stabilization.	

	Unit-3 Recycling and reuse of steelmaking slags Utilization of Jarosite, goethite produced during extraction of zinc, Utilization of red mud produced in Bayer process: metallurgical utilization through metal recovery, utilization in building and construction, Glass-ceramics and Pigments. Recycling and utilization of surface oxide scale produced during metal forming operation. Metal recovery from pickling and plating sludges. **Unit-4** Waste management and utilization options: zero waste process approach, synergy between residue produces and residue end users. Process integration to mineral waste utilization. Process intensification.
10.	Text Book 1. Ndlovu, S., G.S. Simate and E. Matinde, Waste production and utilization in the Metal Extraction Industry, CRC Press, 2017.
11.	Reference Book 1. Ramachandra Rao, Resource recovery and recycling from metallurgical wastes, Elsevier, 2006. 2. K. Hieronymi, R. Kahhat, E. Williams, E-waste Management: From waste to resource, Routledge, New York,2013.

8.2.3 Furnace Technology

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	Furnace Technology
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM108206MM
6.	Status (Core/Elective)	Program Elective
7.	Pre-requisites (course no./title)	None
8.	Course Objectives (CO) : 1. To apply various methods of heat transfer and solve problems. 2. To apply /select a suitable pyrometer for high temperature measurements under various conditions. 3. To have knowledge about various furnaces and their applications.	
9.	Course Syllabus: **Unit- 1** Steady State Heat Transfer: Importance of heat transfer, conduction through plane, cylindrical, spherical and compound walls, shape factor and effect of variable thermal conductivity. Unsteady state conduction: Thermal diffusivity equation for uni-directional heat flow. Sudden change of surface temperature of a thick plane wall, cylinder and sphere. Graphical Solutions. **Unit - 2** Furnaces: Blast furnace Characteristic features of vertical shaft furnaces, reverberatory furnaces, Electric Arc and Induction furnaces. Tube and muffle type resistance furnaces, continuous furnaces. Sources of heat losses in furnaces and heat balance.Acid, basic and neutral refractories, their composition and properties; Methods of production of fire clay, silica, magnesite, chrome- magnesite, dolomite and insulation bricks; special refractories;. Testing of Refractories, Factors deciding the choice of refractory for a particular furnace and its parts. **Unit - 3** Pyrometry: Thermo electric pyrometer- Peltier and Thomas e.m.fs. Thermo-electric power of thermocouples. Required properties of thermocouples. Noble and base metal	

	thermocouples. Thermopile. Measurement of e.m.f by Milli-voltmeters and potentiometers. Cold junction correction. Resistance thermometers – Calendars correction. Principle, construction of resistance thermometers. Measurement of resistance compensation for connection wires. **Unit -4** Fuels for furnace: Metallurgical coke, manufacture, specifications, testing and properties; Coking and Non-coking coals; Coke Oven Gas, Blast Furnace Gas and natural Gas. Factors affecting the choice of fuels.
10.	Text Book 1. Elements of heat transfer- Jakob and Hawikns. 2. Pyrometry – W.P. wood and J. M. Corck 3. Metallurgical furnaces- Krivadin and Markov. 4. Rashid Chesti, Refractories. Prenticae- Hall of India private ltd.
11.	Reference Book 1. Furnaces-J. D. Gilchrist, First edition, Published by Pergamon press. 2. Elements of thermodynamicsand heat transfer- Obert and Young. 3. Control systems and Instrumentation – S. Bhasker. 4. Norton, Fo H. Refractories, McGraw- Hill, N.Y. 1958 5. Butt A Metallurgical problems McGraw-Hill, Book Company London 194Efficient use of fuels, HMSO London 1953

8.3.1 Advanced Materials

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Advanced Materials**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3 / 30
5.	Course number(Code)	MM108301MM
6.	Status (Core/Elective)	Open Elective
7.	Pre-requisites (course no./title)	Mechanical Behaviour of Materials, Physics of Materials
8.	Course Objectives(CO) : 1. Introducing recent developments in Engineering materials. 2. Realize how material structure is engineered for specific application. 3. Select appropriate materials for specific engineering applications.	
9.	Course Syllabus: **Unit 1** Piezoelectric materials (PZT): Piezoelectric effect, Dielectric hysteresis, piezoelectric constants, PZT transducers, piezoelectric materials and manufacturing techniques (stability, poling and depolarisation) etc, Multiferroic materials. **Unit 2** Shape memory alloys (SMA): Shape memory effect and the metallurgical phenomenon of SMA, Temperature assisted shape memory effect, visco-elastic behaviour, magnetic shape memory effect. Micro-electro-mechanical (MEMS) systems: Introduction, silicon wafers and other materials for MEMS applications, manufacturing techniques. **Unit 3** Mechanically alloyed oxide dispersion strengthened superalloys, Functionally Gradient Material (FGM), Thermal barrier coating for aero engines and gas turbines.	

	Unit 4 Cellular materials (metals, ceramic, polymers, lattice), Metamaterials, Quasicrystalline alloys and their composites, Bulk Metallic glasses, High Entropy Alloys.
10.	Text Books:- 1. An Introduction to Materials Science and Engineering, W. D. Callister, John Wiley & Sons (2007) 2. Materials Science and Engineering, V. Raghavan, PHI, 2004. 3. Functional Materials Editors: S. Banerjee A.K. Tyagi, Elsevier, 2011
11.	Reference Books :- 1. Cellular Solids: Structure and Properties, Gibson, L., & Ashby, M.Cambridge University Press. doi:10.1017/CBO9781139878326 2. Bulk Metallic Glasses, by C. Suryanarayana and A. Inoue, second edition, CRC Press. 3. High-Entropy Alloys, by B. S. Murty, Jien-Wei Yeh, S. Ranganathan, Butterworth-Heinemann; 1st edition . 4. Superalloys-II edited by C.T. SIMS, N.S. Stoloff and W.C.Hagel A Wiley-Interscience publication John wiley and sons, New York, 1972. 5. Functional Materials: Properties, Performance and Evaluation by EwaKlodzinska(Editor), CRC Press.

Department of Metallurgical and Materials Engineering
NIT Raipur

8.3.2 Science and Technology of Nano Materials

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Science and Technology of Nano Materials**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3 / 30
5.	Course number(Code)	MM108302MM
6.	Status (Core/Elective)	Open Elective
7.	Pre-requisites (course no./title)	
8.	Course Objectives(CO) : 1. To Introduce concepts of nano science and technology for improvement in various propertied of materials. 2. This course intends to introduce synthesis of nano materials by different techniques. 3. To understand various characterization techniques for nano-materials and its engineering application.	
9.	Course Syllabus: **Unit-1** Basics of Nano science - Introduction to nano science and technology, history, definition, classification of nanomaterials based on origin, dimension - Unique properties of nanomaterials - mechanical, magnetic, thermal, optical and electrical properties **Unit-2** Introduction and preparation of thin film: Difference between thin and thick film. Thin film Growth mechanism. Deposition technology: Thermal and ultrasound decomposition methods. Reduction methods. Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductor nanoparticles. High energy ball milling and mechanical attrition. Thermal evaporation. Sputtering. Laser ablation. Chemical vapor deposition. Molecular beam epitaxy. Thermal spraying. Electro and electroless deposition., vacuum technology: Vacuum pumps & pressure gauges. Defects in thin film: General concepts, nature of defect, microscopic defect, and dislocation. Boundary defects. Defect and energy states - donor acceptor levels, trap and recombination centers, excitons, phonons. **Unit-3**	

	Structural studies: GIXRD and electron diffraction. Surface studies: electron microscopy studies (FESEM, HRTEM), Scanning probe microscopy (STM, AFM), X-ray photoelectron spectroscopy (XPS), Rutherford Back Scattering spectroscopy (RBS) and Secondary Ion Mass Spectroscopy (SIMS). Properties of thin film: Optical behaviors: transmission, reflection, refractive index, photoconductivity, and photoluminescence (PL spectra). **Unit-4** Electrical behaviors: sheet resistivity, electron mobility and concentration, Hall effect. Mechanical behaviors: stress, adhesion, hardness, stiffness. Applications of thin films in various fields: Antireflection coating, FET, TFT, resistor, thermistor, capacitor, solar cell, and MEMs fabrication of silicon wafer: Introduction. preparation of the silicon wafer media, silicon wafer processing steps.
10.	Text Books:- 1. Introduction to Nanoscience And Nanotechnology by K. K. Chattopadhyay, A. N. Banerjee.
11.	Reference Books :- 1. Materials Science of Thin Films by Milton Ohring. 2. Thin Film Materials: Stress, Defect Formation and Surface Evolution by L. B. Freund, S. Suresh. 3. Thin-Film Deposition: Principles and Practice by Donald Smith. 4. Nanomaterials and Nanochemistry by Editors: C. Bréchignac, P. Houdy, M. Lahmani, (Eds.)

8.4.1 Automotive Materials

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Automotive Materials**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM108303MM
6.	Status (Core/Elective)	Open Elective
7.	Pre-requisites (course no./title)	None
8.	Course Objectives(CO) : 1. To impart the knowledge in automobile materials and to equip the students to meet the demands of automobile engineering. 2. Understand the fundamentals of automobile engineering and different components in automobile 3. Describe the importance and reasons for using different types of material used in automobiles 4. Understand future challenges and expectations in automobile engineering.	
9.	Course Syllabus: **Unit-1** Introduction to major systems, assemblies and components of an automobile and their Functions; Materials Used in the Automotive Industry an Overview. Engine and Its Components; Drive transmission and steering, Clutch assembly, Gear box assembly (Transmission case assembly), Suspension and brake; Body and chassis. **Unit-2** Engine cylinder: Structure and functions, types, cylinder blocks materials and manufacturing processes, improving engine components with surface modifications, Piston: Structures and functions, types, piston materials, piston manufacturing processes Structure. **Unit-3**	

	Function and materials for piston rings, camshaft, valves and valve seats, valve springs, connecting rod, crankshaft, front axle and steering system, drive line, propeller shaft, universal joints, wheels and suspension system. **Unit-4** Wheel, Different types of wheel rim, Tyre; Desirable Properties of a Tyre, Functions of Tyre, Types of Tyre and Brake; Requirements of A good Braking System, Types of Brake, Materials used in Brakes, friction and wear consideration in breaking system.Introducing New Materials in the Automotive Industry Advances in manufacturing and joining techniques.
10.	Text Books 1. Hiroshi Yamagata, The Science and Technology of Materials in Automotive Engines, Woodhead Publishing in Materials, 2005 2. Ganesan.V, Internal Combustion Engines, Tata-McGraw Hill Publishing Co., New Delhi, 1994
11.	Reference Books 1. Kamaraju Ramakrishna, Automobile Engineering, PHI, 2014

8.4.2 Engineering Economics

1.	Department proposing the course	Metallurgical Engineering
2.	Course Title	**Engineering Economics**
3.	L-T-P Structure	3-0-0
4.	Credits / # of period	3/ 30
5.	Course number(Code)	MM108304MM
6.	Status (Core/Elective)	Open Elective
7.	Pre-requisites (course no./title)	None
8.	Course Objectives(CO) : 1. To introduce the basic concept of Demand and Supply. 2. To introduce the basic concept of Forms of Business Organization, Money, Banking, Foreign Trade. 3. To introduce the basic concept of Taxation, Depreciation, Trade Cycle. 4. Introduction to Accounting Principles.	
9.	Course Syllabus: **Unit-1** An idea of fundamental concepts of economics, its relationship with engineering and technology. Factors of Production: Characteristics and importance of Demand and Supply analysis, elasticity of demand, Price determination, Laws of returns, monopoly. G.N.P. and National income: Importance, distribution, Direct and indirect taxes, taxes and industrial development, elementary idea of theory of employment. **Unit-2** Meaning and function of money and bank, value of money and its fluctuations, Quantity theory of money, Gresham's law, Devaluation of money, foreign trade. Industrialization: Factory system of production, its advantages, limitations and problems, small scale industries, problems of small scale industries in India, Comparative merits and demerits of small and large scale industries. **Unit-3** Partnership, joint stock company cooperative societies, limited and unlimited liabilities. Financing by Banks and specialized institutions, stock exchange and money market, credit instruments, shares, debentures and bonds. Depreciation, Depreciation accounting Methods of calculating depreciation.	

	Unit-4 Book keeping and accounting:Importance of accounting for engineers, engineer as a controller of finances, elements of double entry system of book-keeping, preparation of journal and ledger accounts, Interest and profit analysis, Trial balance, Manufacturing and profit and loss accounts, Balance sheet. Elements of cost, components of cost, cost accounting, procedure of costing, costing methods, cost control.
10.	Text Books:- 1. Engineering Economics – By Tarachand. 2. Industrial Organisation and Engineering Economics, By T.R. Banga and S.C. Sharma.
11.	Reference Books :- 1. Industrial engineering and Management system, Dalela, Dr.Mansoor Ali. 2. Engineering Economics, Accounts and Management By S. Prasad. 3. Industrial Engineering & Management By O.P. Khanna.