

Tribhuvan University
Institute of Engineering
Pulchowk, Lalitpur
Course Structure (2026)
MSc in Material Science and Engineering

Year : I**Part I**

Teaching Schedule				Examination Scheme			Total	Remarks
SN	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENSHMS501	Material Science I	4	40	3	60	100	
2	ENSHMS502	Mathematical Methods in Material Science	4	40	3	60	100	
3	ENSHMS503	Quantum Mechanics and Spectroscopy	4	40	3	60	100	
4	ENSHMS504	Research Methods and Scientific Communication	4	40	3	60	100	
Total			16	160	-	240	400	

Year : I**Part II**

Teaching Schedule				Examination Scheme			Total	Remarks
S. N.	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENSHMS551	Material Processing	4	40	3	60	100	
2	ENSHMS552	Material Science II	4	40	3	60	100	
3	ENSHMS56X	Elective-I	4	40	3	60	100	
4	ENSHMS57X	Elective-II	4	40	3	60	100	
Total			16	160	-	240	400	

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Pulchowk, Lalitpur
Course Structure (2026)
MSc in Material Science and Engineering

Year : II**Part I**

Teaching Schedule				Examination Scheme			Total	Remarks
S. N.	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENSHMS61X	Elective -III	4	40	3	60	100	
2	ENSHMS62X	Elective -IV	4	40	3	60	100	
3	ENSHMS601	Project	4	100	-	-	100	
Total			12	180	-	120	300	

Year: II**Part II**

Teaching Schedule				Examination Scheme			Total	Remarks
S. N.	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENSHMS651	Thesis	16	100	-	-	100	

Elective Courses:

Elective courses will be offered as per the availability of resource persons. The lists of electives are as follows:

Elective I:

1. Nanotechnology Equipment and Characterization Techniques [Code: ENSHMS561]
2. Semiconductor Devices and Circuits [Code: ENSHMS562]
3. Continuum Mechanics [Code: ENSHMS563]

Elective II:

1. Advanced Concrete Technology [Code: ENSHMS571]
2. Advanced Materials for Energy Storage [Code: ENSHMS572]
3. Environmental Impact Assessment and Policy [Code: ENSHMS573]
4. Digital System Design [Code: ENSHMS574]

Elective III:

1. Foundation of Data Science [Code: ENSHMS611]
2. Computational Methods for Material Science [Code: ENSHMS612]
3. Photovoltaic Materials and Technology [Code: ENSHMS613]

Elective IV:

1. Advanced Pre-Stressed Concrete [Code: ENSHMS621]
2. Biomaterials and Safety [Code: ENSHMS622]
3. Composite, Ceramic and Polymer Materials [Code: ENSHMS623]

Further Explanation about Project and Thesis works

The project and thesis component theme could be one of the following:

- Industrial/organizational problem assessment (Mainly done at industry/organization)
- Literature based problem assessment (Mainly done at institution)
- Analytical or experimental or prototype based problem assessment (Mainly done at institution)
- Case study based problem assessment (Mainly done at case specific site)
- Field work based problem assessment (Mainly done at specific site)
- Characterization of new material (Mainly done at laboratory)
- Any other relevant and deemed suitable by department
- The project component will be of approximately 3 months (Full - time) duration

Eligibility and Degree Award:

Eligibility: BE/BArch/ BSc Agriculture/MSc for 3-year Bachelor Degree, BSc (4 years) or equivalent

Degree Award: **MSc in Material Science and Engineering**

MATERIAL SCIENCE I
ENSHMS501**Credits: 4****Year: I****Part: I****Course Objectives**

The objective of this course is to provide the advanced knowledge on principles of crystal structure, electrical, thermal and optical properties of their materials. After completion of the course, students will be able to use the knowledge in analysis, design and research works of respective materials.

1. Crystal Structures and Space Group Symmetry [12 hours]

- 1.1 Definition of crystal and amorphous materials, bonding in crystals: Ionic bond, covalent bond, molecular bond, hydrogen bond, metallic bond and Van der Waals bond
- 1.2 Crystalline and non-crystalline materials, Lattice, basis and crystal structure, space lattice, unit cell and lattice parameters, atomic packing factor and coordination number
- 1.3 Crystal systems (7 systems), Bravais lattices (14 types), crystallographic point groups
- 1.4 Symmetry elements: Rotation axes, mirror planes, inversion centers
- 1.5 Vector representation of lattices
- 1.6 Miller indices (Planes and directions)
- 1.7 X-ray crystallography: Bragg's law, inter-planar spacing calculations, measurement of diffraction angles
- 1.8 Crystal defect: Vacancy, interstitial, impurity defect, semiconductor
- 1.9 Reciprocal lattice concept and properties of reciprocal lattice
- 1.10 Brillouin zones (Basic introduction)

2. Material Hybridization and Crystal Field Theory [10 hours]

- 2.1 Hybridization in a complex environment and structure of materials: sp, sp², sp³, sp³d, sp³d², dsp², d-orbital participation in bonding for Hypervalent molecules
- 2.2 Orbital hybridization in materials: sp³ in diamond versus sp² in graphene
- 2.3 Molecular orbitals concept of orbital overlap, bond order, magnetic properties
- 2.4 Band gap concept in metals, non-metal, semiconductors and insulators
- 2.5 Coordination compound, ligands, chelate compounds, Ligand Field Theory (LFT) Valence bond theory (VBT), Crystal Field Theory (CFT), Crystal field stabilization energy (CFSE)
- 2.6 High-spin versus low-spin configurations. Effect of crystal field splitting, construction of MO diagrams for octahedral complexes, Jahn-Teller Effect

3. Thermodynamics of Material and Liquid Crystal [10 hours]

- 3.1 Thermodynamics basic concepts (State variables, the first law, the enthalpy concept, heat capacity) the second law (Reversible and irreversible processes, entropy, Gibbs energy, Helmholtz energy)

- 3.2 Equilibrium conditions (Chemical potential, driving force, the third law, Clausius-Clapeyron equations, thermodynamic application to materials)
- 3.3 Liquid Crystals: Thermotropic and lyotropic liquid crystals, concentration-temperature phase diagram
- 3.4 Emulsions: Microemulsion, Macroemulsion

4. Photo-catalysis and Biosensor [7 hours]

- 4.1 Catalyst materials, positive and negative catalysts, types of catalysis: Homogeneous and heterogeneous catalyst, selection criteria of catalyst
- 4.2 Photo catalysis: Principle involved in photo catalysis, dye degradation photocatalytic water splitting, and application of catalyst in different fields
- 4.3 Photochemistry: Definition and applications of photochemistry in technology
- 4.4 Biosensor: Overview, biosensor classification, biochemical components in biosensor assemblies

5. Density Functional Theory (DFT) [14 hours]

- 5.1 Many-body problem and approximations
- 5.2 Hartree and Hartree-Fock methods
- 5.3 Electron density in DFT
- 5.4 Hohenberg-Kohn theorems
- 5.5 Kohn-Sham approach
- 5.6 Exchange correlation functional (Local density and generalized gradient approximation)
- 5.7 Solving Kohn-Sham equations
- 5.8 Spin Orbit Coupling (SOC)
- 5.9 DFT extensions and limitations
- 5.10 Electronic structure calculations
- 5.11 DFT exercises using software (VASP/FPLO/Wien2k/QE)

6. Synthesis and Processing of Perovskite Ceramics [7 hours]

- 6.1 Solid-state reaction methods, stoichiometry
- 6.2 Wet chemical synthesis: Sol-gel, hydrothermal, and co-precipitation methods
- 6.3 Sintering mechanisms and the critical role of grain size on electrical properties of multiferroics ceramics
- 6.4 The push for environmentally friendly materials: Lead-free perovskite dielectrics and their challenges
- 6.5 Brief overview of organic-inorganic halide perovskites and their disruptive impact on solar cells and LEDs

Assignments/Case Study

1. Determination of wavelength of LASER light source and hence use it to find particle size of given powder samples
2. Study of hall constant, hall voltage, hall mobility and hall resistance with the variation of magnetic field and supplied current of a given semiconductor
3. XRD study of a given crystal/powder sample to determine the wavelength of x-ray
4. Standardize the given potassium permagnet solution and use it to estimate the amount of calcium in limestone
5. Synthesize materials using sol-gel, precipitation sol-gel, redox/electrochemical and hydrothermal methods and characterize their properties
6. Study optical properties of nanoparticles using UV-Visible spectroscopy
7. Determination of amount of copper in alloy (Brass) sample iodometrically
8. Indexing of XRD profile/data of a given sample and determination of lattice parameters of the structure

Evaluation Schemes**a. Internal Evaluation**

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	12	12
2	10	12
3	10	12
4	7	6
5	14	12
6	7	6
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Callister, W. D., Rethwisch, D. G. (2024). Materials science and engineering: An introduction. John Wiley & Sons.
2. Kittel, C. (2005). Introduction to solid state physics. John Wiley & Sons.
3. Dekker, A. J. (1986). Solid state physics (Latest Edition). Macmillan Education.
4. Anderson, J. C., Leaver, K. D., Rawlings, R. D., Leever, P. S. (2003). Materials science for engineers. CRC Press.
5. Smart, L. E., Moore, E. A. (2012). Solid state chemistry: An introduction. CRC Press.
6. Gaskell, D. R., Laughlin, D. E. (2018). Introduction to the thermodynamics of materials. CRC Press.
7. Swalin, R. A. (1972). Thermodynamics of solids (Latest Edition). John Wiley & Sons.
8. Costa, S., Trotta, M. (Eds.). (2023). Comprehensive series in photochemical and photobiological sciences. Springer.

MATHEMATICAL METHODS IN MATERIAL SCIENCE

ENSHMS502

Credits: 4**Year: I****Part: I****Course Objectives**

The objective of this course is to provide a strong mathematical foundation required for the formulation, analysis and solution of physical models arising in materials behavior, transport phenomena, mechanics of solids and computational materials science.

1. Linear Algebra and Vector Calculus [20 hours]

- 1.1 Review of matrices and determinants
- 1.2 Rank and solution of system of equations
- 1.3 Eigen values and eigenvectors, diagonalization
- 1.4 Various co-ordinate systems and their conversions
- 1.5 Scalar and vector fields, vector differential operator
- 1.6 Gradient, divergence and curl and their physical interpretations
- 1.7 Line, surface and volume integrals and transformation theorems

2. Ordinary Differential Equations [10 hours]

- 2.1 First-order differential equations
- 2.2 Systems of linear differential equations
- 2.3 Second order linear differential equation
- 2.4 Hermite Polynomial and equation
- 2.5 Legendre's and Bessel's equation
- 2.6 Modeling through ordinary differential in material sciences

3. Partial Differential Equations [10 hours]

- 3.1 Introduction to partial derivatives and its interpretation
- 3.2 Second order partial differential equations, their classifications, solution by variable separation method second order equations
- 3.3 Solution of PDE: Charpit's method, Lagrange's method and Monge's method
- 3.4 Modeling through PDE in material sciences

4. Probability and Statistics [10 hours]

- 4.1 Random variables and probability distributions
- 4.2 Expectation, variance and moments
- 4.3 Some familiar type of discrete and continuous distributions
- 4.4 Correlation and regression

5. Numerical Methods and Computational Techniques**[10 hours]**

- 5.1 Numerical solution of non-linear equations
- 5.2 Interpolation theory
- 5.3 Numerical differentiation and integration
- 5.4 Finite difference method of solving boundary value problems

Evaluation Schemes**a. Internal Evaluation**

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	20	20
2	10	10
3	10	10
4	10	10
5	10	10
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Harper, C. (2012). Introduction to mathematical physics. Prentice Hall of India.
2. Riley, K. F., Hobson, M. P., Bence, S. J. (2006). Mathematical methods for physics and engineers. Cambridge University Press.
3. Kreyszig, E. (2011). Advanced engineering mathematics. John Wiley & Sons.

QUANTUM MECHANICS AND SPECTROSCOPY

ENSHMS503

Credits: 4**Year: I****Part: I****Course Objectives**

The objective of this course is to acquaint students with the concepts, formalism, and methodologies of quantum mechanics in a logical and systematic manner. The course enables students to understand the limitations of classical mechanics and the application of quantum mechanics in explaining the behavior and unusual properties of microscopic particles. Upon completion of the course, students will be able to apply quantum mechanical principles to the study of atomic, molecular, and other quantum systems.

1. Foundation and Philosophy of Quantum Mechanics [12 hours]

- 1.1 Inadequacy of classical physics and need for a quantum theory
- 1.2 Wave-particle duality, wave packet, phase velocity and group velocity
- 1.3 Heisenberg uncertainty principle, concept of orbit and orbital
- 1.4 Bohr's correspondence principle and principle of superposition
- 1.5 Physical interpretation of the wave function: Probability density and probability current density, orthogonal, normalization and orthonormal wave function, Kronecker delta function
- 1.6 Development of quantum mechanics: Wave mechanics and matrix mechanics
- 1.7 Integral notation and bracket notation, Poisson bracket and commutator bracket
- 1.8 Postulates of quantum mechanics
- 1.9 Schrodinger wave equation (Time-independent and time-dependent), concept of stationary states

2. Operators and Eigen functions [8 hours]

- 2.1 Linear operators in quantum mechanics
- 2.2 Commuting and non-commuting operators
- 2.3 Eigen functions: Eigen operators and eigenvalues
- 2.4 Hermitian operators (Position, momentum, angular momentum and Hamiltonian operators as Hermitian operator)
- 2.5 Degeneracy of energy levels
- 2.6 Expectation value. Eigenvalues and variance of the measurement

3. Quantum basis of Material Science and Applications [8 hours]

- 3.1 Quantum confinement and nanomaterials
- 3.2 Quantum dots: Properties and technological applications
- 3.3 Tunneling effect (Qualitative treatment of quantum mechanical tunneling) and its applications

- 3.4 Quantum mechanical aspect of band theory of solid
- 3.5 Lasers and stimulated emissions
- 3.6 Introduction to quantum materials and nanoscience basis
- 3.7 Computational quantum chemistry

4. Quantum basis of Spectroscopy [16 hours]

- 4.1 Interaction of radiation with matter: Concept of photon, quantum and phonon (Quasi particle)
- 4.2 Quantized molecular orbital energy levels: Rotational levels, vibrational levels and electronic levels, line spectra and band spectra, absorption spectra and emission spectra, continuous spectra and discontinuous spectra
- 4.3 Rotational spectroscopy: Principle of rotational spectroscopy, microwave active molecules, selection rule
- 4.4 Vibrational spectroscopy: Principle of IR spectroscopy, IR active molecules, concept of zero-point energy and its significance, selection rule
- 4.5 Electronic spectroscopy (UV-VIS spectroscopy): Molecular transition selection rule
- 4.6 Raman spectra: Principle of Raman spectroscopy, Raman active molecules, selection rule

5. Stationary States and Energy Spectra [12 hours]

- 5.1 Linear harmonic oscillator and energy eigenvalues (Mathematical detail is not required)
- 5.2 Schrodinger equation for spherically potential (Solving the equation in detail is not required)
- 5.3 Spherical harmonics and eigenvalues of angular momentum operators $\hat{L}^2$ and $\hat{L}_z$
- 5.4 Schrodinger equation for hydrogen atom (Solving the equation in detail is not required)
- 5.5 Significance of quantum numbers n, l and m
- 5.6 Rigid rotator model
- 5.7 Electron energy states in hydrogen atom
- 5.8 Symmetric and antisymmetric wave functions. Bosons and Fermions

6. Addition of Angular Momenta [4 hours]

- 6.1 Postulate of spin of electron
- 6.2 Commutation rules of spin operators
- 6.3 Eigenvalues of $\hat{S}^2$ and $\hat{S}_z$
- 6.4 Introduction to addition of angular momenta
- 6.5 Addition of two spins of electrons

Evaluation Schemes**a. Internal Evaluation**

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	12	12
2	8	9
3	8	9
4	16	15
5	12	12
6	4	3
Total	60	60

*There may be minor deviation in marks distribution.

References

1. McQuarrie, D. A. (2011). Quantum chemistry. Viva Books.
2. Powell, J. L., Crasemann, B. (1995). Quantum mechanics (Latest Edition). Dover Publications.
3. Mathews, P. M., Venkatesan, K. (2010). A textbook of quantum mechanics. McGraw-Hill Education.
4. Griffiths, D. J., Schroeter, D. F. (2018). Introduction to quantum mechanics. Cambridge University Press.
5. Zettili, N. (2009). Quantum mechanics: Concepts and applications. Wiley.
6. Levine, I. N. (2014). Quantum chemistry. Pearson.
7. Agrawal, B. K., Prakash, H. (2019). Quantum mechanics. Pragati Prakashan.

RESEARCH METHODS AND SCIENTIFIC COMMUNICATION

ENSHMS504

Credits: 4**Year: I****Part: I**

Course Objectives

The objective of this course is to emphasize on research methodology, scientific writing, statistical analysis, modeling, simulation, ethical research conduct and modern digital research tools.

1. Fundamental of Research

[12 hours]

1.1 Concept of Research

- 1.1.1 Meaning, objectives and classification of research
- 1.1.2 Research motivation, approaches and significance
- 1.1.3 Research methods versus methodology
- 1.1.4 Research process, criteria of good research

1.2 Research problem, literature review, research design and strategy

- 1.2.1 Problem identification
- 1.2.2 Sources and retrieval
- 1.2.3 Literature review: Scoping review, meta review, narrative review, systematic review
- 1.2.4 Research design and research strategy

2. Scientific Writing and Communication

[10 hours]

- 2.1 Art of scientific writing, importance: various methods of scientific communication
- 2.2 Proposal writing: Types and ingredients of proposal, some standard proposal format
- 2.3 Report and Thesis writing: Types and ingredients of reports, general format of reports
- 2.4 Term paper, seminar, thesis/dissertation, project writing
- 2.5 Scientific communication and dissemination
 - 2.5.1 Common methods of scientific communication and dissemination
 - 2.5.2 Types of presentation: Plenary, keynotes, invited, oral and poster presentation
- 2.6 Citation and referencing
 - 2.6.1 Styles of citations and reference (Specific to at least one)
 - 2.6.2 Tools and software used in referencing (Specific to at least one)

3. Data Collection, Management and Analysis

[9 hours]

- 3.1 Data and sampling techniques
 - 3.1.1 Qualitative and quantitative data: Primary and secondary data, experimental data

- 3.1.2 Sampling Techniques: Population and samples size, methods of sampling, probability sampling (Simple random, stratified, systematic, cluster), non-probability sampling
- 3.2 Methods of data collection: Survey method, interview method, observation method, case study method, experimentation, questions and questionnaires
- 3.3 Data management: Data collection, data visualization, data curation, data validation, data interpretation, big data concepts, common software used for data management.
- 3.4 Error analysis: Types of errors, accuracy and precision, distribution of random errors

4. Statistical analysis in research [9 hours]

- 4.1 Descriptive and inferential statistics in research
 - 4.1.1 Review on: Mean (Geometric mean, arithmetic mean and harmonic mean), mode, median, root mean square, average
 - 4.1.2 Standard deviations, variance, standard errors, least square method
 - 4.1.3 Hypothesis testing: Chi-square test, z-test, t-test, f-test
- 4.2 Regression analysis, ANOVA

5. Research Tools and Techniques [12 hours]

- 5.1 Tools and techniques
 - 5.1.1 Importance of tools and techniques in research,
 - 5.1.2 Research techniques in interdisciplinary and multidisciplinary laboratory
 - 5.1.3 Basic research tools in material science and engineering (Uses, tentative price and applications)
 - 5.1.4 Spectroscopic tools: UV-VIS, FTIR, Raman, NMR, XPS
 - 5.1.5 Microscopic Tools: SEM, TEM, AFM, Optical microscopy
 - 5.1.6 Thermal analysis: TGA, DTA, DSC
 - 5.1.7 Electrochemical Tools: Potentiostat/Galvanostat, impedance analyzer
 - 5.1.8 Analytical Tools: GCMS, HPLC, XRD
 - 5.1.9 Digital and computation tools: SPSS, R, Python, SAS,
 - 5.1.10 Reference manager: Endnote, Zotero, Mendeley
 - 5.1.11 Data analysis and visualization tools: Excel, Origin, MATLAB
 - 5.1.12 Internet Browsing: General concept of internet browsers, file format
- 5.2 Computer programming and simulation tools
 - 5.2.1 Introduction to computation in material science
 - 5.2.2 Molecular modeling and simulation concept (Common software)
 - 5.2.3 Introduction to materials modeling and molecular docking (Common software)

6. Laboratory Management and Ethics in Research**[8 hours]**

- 6.1 Laboratory management
 - 6.1.1 Laboratory engineering, chemicals and equipment management,
 - 6.1.2 Common laboratory accidents and first aid, laboratory safety and risk management,
 - 6.1.3 Laboratory waste management,
 - 6.1.4 Good laboratory practice, laboratory standard and protocols
 - 6.1.5 Quality assurance and accreditation (QAA), Certified laboratory and public service delivery.
- 6.2 Ethics in research
 - 6.2.1 Ethical issues in research, plagiarism, fabrication and falsification,
 - 6.2.2 Rational use of AI in research,
 - 6.2.3 Plagiarism and AI detection software

Assignments

1. Online search of literatures and academic networking platform: Linkedin, science direct, google scholar, google, etc.
2. Search engines and academic data bases (Abstracting, archives of literatures)
3. Uses of AI tools in literature survey
4. Journal matrix and indexing parameter
5. Modes of scientific communication: Online and offline, Conference, workshop, symposium, seminar, webinar
6. Term paper writing and presentation
7. Research proposal writing and presentation
8. Introduction to python and Mathematica

Evaluation Schemes**b. Internal Evaluation**

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	12	12
2	10	9
3	9	9
4	9	9
5	12	12
6	8	9
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Ohno, K., Esfarjani, K., Kawazoe, Y. (1999). Introduction to computational materials science: From ab initio to Monte Carlo methods. Springer.
2. Raabe, D. (1998). Computational materials science: The simulation of materials microstructures and properties. Wiley-VCH.
3. Frenkel, D., Smit, B. (2002). Understanding molecular simulation: From algorithms to applications. Academic Press.
4. Meyer, M., Pontikis, V. (1991). Computer simulation in materials science: Interatomic potentials, simulation techniques and applications. Kluwer Academic Publishers.
5. Allen, M. P., Tildesley, D. J. (2017). Computer simulation of liquids. Oxford University Press.
6. Devadas, R. P. (1976). A handbook of methodology of research. RMM Vidyalaya Press.
7. Taha, H. A. (2017). Operations research: An introduction. Pearson.
8. Rao, S. S. (2019). Engineering optimization: Theory and practice. John Wiley & Sons.
9. Kothari, C. R. (2004). Research methodology: Methods and techniques. New Age International Publishers.

MATERIAL PROCESSING
ENSHMS551**Credits: 4****Year: I****Part: II****Course Objectives**

The objective of this course is to provide the knowledge on principles of materials processing and their applications for materials characterization.

1. Advanced Ceramics and Glass Processing [10 hours]

- 1.1 Ceramics processing and ceramic matrix composites (CMCs): Introduction, powder synthesis, sintering mechanisms (Liquid phase, spark plasma sintering), sol-gel processing. Processing of CMCs (Chemical vapor infiltration, polymer infiltration and pyrolysis)
- 1.2 Ethno-practice in ceramics processing, application of ceramics for advanced materials, high-temperature structural applications
- 1.3 Glass Processing: Classification, glass-melting kinetics, phase separation, controlled crystallization (Glass-ceramics). Glass manufacturing process, advanced forming techniques, optical fiber fabrication and chemical vapor deposition (CVD) for glass coatings, application and recycling of glass

2. Circular Economy, Resource Extraction Processes and Decarbonization [10 hours]

- 2.1 Essential oil: Introduction and sources of essential oil, extraction thermodynamics and kinetics. Extraction methods: Supercritical Fluid Extraction (CO₂), microwave-assisted extraction, steam distillation optimization and commercial applications
- 2.2 Crude oil / Petroleum product processing: Definition, Fractional distillation dynamics, catalytic cracking, hydro processing, refining thermodynamics and upstream versus downstream process modeling. Economics of petroleum products in the context of Nepal
- 2.3 Carbon capture, utilization, and storage (CCUS): Engineering processes for capturing CO₂ from industrial exhaust (Amine scrubbing, MOFs) and converting it into synthetic fuels or building materials.
- 2.4 Biodegradable plastics and polyhydroxyalkanoates (PHA): Introduction, processing of synthetic bioplastics like PLA (Polylactic Acid) and PHA to fully replace petroleum-based single-use plastics.

3. Polymeric and Composite Materials [10 hours]

- 3.1 Biopolymers: Introduction, types, extraction, cellulose, hemicellulose, lignin and cellulose nanocrystal, vulcanization of natural rubber, and compounding engineering.
- 3.2 Polymer Matrix Composites (PMCs): Thermoplastic versus thermoset matrices. Interfacial bonding mechanisms, fiber wetting, and processing techniques (Resin transfer molding, pultrusion, filament winding).

- 3.3 Carbon Fiber Processing: Precursor selection (PAN, pitch), stabilization, carbonization and graphitization kinetics and applications
- 3.4 Activated carbon (AC): Introduction, precursor and carbonization, activation mechanism Physical versus chemical, physical structure and surface chemistry, adsorption equilibrium and kinetics, industrial applications and regeneration

4. Metallurgy and Powder Technology [10 hours]

- 4.1 Ore extraction and rare earth elements: Major Ores in Nepal, mining processing: Hydrometallurgy, pyrometallurgy and electrometallurgy, different types of rare earth elements, extraction, isolation and applications
- 4.2 Solidification nucleation, crystal growth, grain structure, solidification defects (Shrinkage, gas porosity) concept of solidification of metals, cooling curves, driving force for solidification
- 4.3 Alloy processing and heat treatment: Solidification kinetics, phase transformations (TTT/CCT diagrams). Advanced heat treatments (Maraging, precipitation hardening). Mechanical alloying and severe plastic deformation
- 4.4 Reinforcing and compaction of materials: Powder metallurgy fundamentals, compaction mechanics (Die pressing, isostatic pressing) and particle size distribution optimization for maximum green density

5. Environmental and Sustainable Infrastructure Engineering [20 hours]

- 5.1 Fertilizer/Manure Processing: Synthesis of nitrogenous, phosphatic, and potassium fertilizers (Haber-Bosch optimization, wet phosphoric acid process). Nutrient recovery from organic manure, anaerobic digestion and pelletization
- 5.2 Urbanization Engineering: Impact of industrialization on civil infrastructure. Sustainable concrete technologies, smart materials for urban environments and lifecycle assessment (LCA) of civil structures
- 5.3 Plastic waste management and Processing: Mechanical versus chemical recycling (Pyrolysis, gasification, depolymerization). Microplastic mitigation strategies and upcycling plastics into high-value chemicals
- 5.4 Deodorization/solid waste management: Gas-phase biofiltration, activated carbon adsorption and chemical scrubbing for odor control. Integrated municipal solid waste management, landfill engineering, and leachate treatment
- 5.5 Thermo-resistive materials (Thermal Insulators): Heat transfer mechanisms (Conduction, convection, radiation) in porous media. Processing of aerogels, vacuum insulation panels (VIPs) and refractory ceramics for extreme thermal insulation
- 5.6 Additive manufacturing (3D/4D Printing) of materials: Processing parameters for 3D printing ceramics, polymers, and metals (Direct metal laser sintering, stereolithography)

Assignments/Laboratory works

1. Determination of Iodine number to characterize activated carbons
2. Determination of Methylene blue number to characterize activated carbons
3. Fabrication of polymeric nanofibers using electrospinning
4. Synthesis of ceramic nanoparticles using hydrothermal process
5. Synthesis of metal/ceramic or ceramic/polymer nano-composite
6. Electrode preparation from the activated carbon by drop casting methods

Evaluation Schemes**a. Internal Evaluation**

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	10	9
2	10	12
3	10	12
4	10	9
5	20	18
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Materials Processing and Manufacturing Science, Rajiv Asthan, Ashok Kumar and Narendra Dahotre; Elsevier (2006)
2. Introduction to the Principle of Ceramic processing; J.S. Reed, John Wiley and Sons, New York (1989).
3. Treatise on Materials Science and Technology: Materials Processing: Academic Press Inc. New York (2001)

4. Materials Processing, 1st Edition, A Unified Approach to Processing of Metals, Ceramics and Polymers; Lorraine Francis, eBook ISBN: 9780123851338, Hardcover ISBN: 9780123851321, Imprint: Academic Press, (2015).
5. Comprehensive Materials Processing, ISBN-13: 978-0080965321; Edited by Saleem Hashmi (2014)
6. Introduction to Ceramics – W D Kingery, H K Bower and U R Uhlman (John Wiley, 1960)
7. Glasses and vitreous state – J Zarzycki (Cambridge University Press, 1991)
8. Comprehensive Materials Processing, ISBN-13: 978-0080965321; Edited by Saleem Hashmi (2014)
9. Introduction to Polymer Clay Nanocomposites- Gurses Ahmet (Composites Pan Stanford, 2015)
10. Biopolymer Nanocomposites- Processing, Properties and Applications- Dufresne Alain and Sabu Thomas (John Wiley and Sons, 2016).
11. Fiber Reinforced Composites- Mallick P K (CRC Press, 2008).
12. Selection of Engineering Materials- G Lewis, (Prentice Hall, 1990).
13. Engineering Materials and Their Applications- R A Flinn and P K Trojan, (Jaico, 1998).

MATERIAL SCIENCE II**ENSHMS552****Credits: 4****Year: I****Part: II****Course Objectives**

The objective of this course is to provide the advanced knowledge on dielectric optical, electrical, magnetic and superconducting properties of materials for device applications. After completing the course, students will be able to apply theoretical knowledge in analysis, design and research work of respective materials.

1. Dielectric Materials and Polarization**[14 hours]**

- 1.1 Introduction: Polarization, local and macroscopic fields, polarizability
- 1.2 Lorentz Internal field: Clausius- Mossotti relation
- 1.3 Dielectric constant: Temperature dependence of static permittivity, complex permittivity, dielectric loss, frequency dependence of polarization, experimental determination of dielectric constant and dielectric loss by Schering bridge method
- 1.4 Mechanism of polarization: Electronic, ionic and orientational polarization
- 1.5 Piezo and Pyro electricity, materials and their applications
- 1.6 Ferroelectricity, dipole theory of ferroelectrics, Curie-Weiss law, ferroelectric materials and applications
- 1.7 Phase transitions, first and second order type, phenomenological theory of phase transition

2. Electrical Properties for Device Applications**[12 hours]**

- 2.1 Classical free electron model
- 2.2 Origin of the Quantum Free Electron Model
- 2.3 Maxwell-Boltzmann distribution, Bose-Einstein distribution and Fermi-Dirac distribution
- 2.4 Density of states (1D and 3D)
- 2.5 Types of semiconductors, semiconductor fabrication, crystal growth and techniques
- 2.6 Hall effect (Classical and quantum hall effect)

3. Magnetic Materials and Properties**[12 hours]**

- 3.1 Classification of magnetic materials: Dia, Para, Ferro, Antiferro and Ferri-magnetic materials
- 3.2 Classical and quantum theories of diamagnetic materials, qualitative explanation of paramagnetic materials
- 3.3 Ferromagnetic materials: Domain wall, domain theory and hysteresis; Weiss molecular field theory and Curie Weiss law; Magnon, quantum mechanical theory for ferromagnetism; Heisenberg's exchange theory, magnetic anisotropy;
- 3.4 Soft and hard magnetic materials, metals, alloys and ceramic materials, applications
- 3.5 Applications of magnetic materials in data storage: Magnetic bubble domains. Magnetic bottle

4. Optical Properties and Devices**[12 hours]**

- 4.1 Interaction of solid with radiation,
- 4.2 Optical constants; Optical conductivity, absorption of radiation in metals,
- 4.3 Semiconductors and insulators; Edge absorption and excitons;
- 4.4 Luminescence; Phosphorescence and fluorescence; Photoluminescence, Electroluminescence;
- 4.5 Thermo-luminescence, Cathodo-luminescence
- 4.6 Materials and devices: Photoconductive devices; Solar cells; LED Luminescent materials:
- 4.7 ZnS phosphors, Thallium activated alkali halides.

5. Superconductivity I (Low Temperature)**[10 hours]**

- 5.1 Historical preview on materials and theoretical aspects of low-temperature superconductivity
- 5.2 Introduction of transition temperature, critical magnetic field, isotope, pressure, critical current, persistent current,
- 5.3 Meissner effect; Type I and Type II superconductors;
- 5.4 Thermodynamics of superconductors: Free energy, entropy, specific heat, latent heat
- 5.5 London equation, coherence length, flux quantization.

Assignments/ Case Study

1. Study of variation of green density of pellets of powder sample with respect to load then study the porosity of the sintered sample
2. Determination of band gap of semiconductor sample using four probe method
3. Study of PE hysteresis loop of a ferroelectric sample using Shower-Tower Hysteresis loop tracer
4. Determination of Planck's Constant using photo-cell
5. Study of microstructure of a ceramic sample and calculation of its grain size using optical microscope
6. Study of dielectric constant of a ceramic sample (BaTiO_3) using LCR meter
7. Study of temperature and frequency dependent of resistance of a sample using four-probe method and apply Arrhenius distribution to find activation energy
8. Study of phase transition behavior of ferroelectric sample using phenomenological theories. (Simulation/computation study)

Evaluation Schemes**a. Internal Evaluation**

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks distribution*
1	14	15
2	12	12
3	12	12
4	12	12
5	10	9
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Callister, W. D., Rethwisch, D. G. (2024). Materials science and engineering: An introduction. John Wiley & Sons.
2. Kittel, C. (2005). Introduction to solid state physics. John Wiley & Sons.
3. Dekker, A. J. (1986). Solid state physics. Macmillan Education.
4. Anderson, J. C., Leaver, K. D., Rawlings, R. D., Leavers, P. S. (2003). Materials science for engineers. CRC Press.
5. Smart, L. E., Moore, E. A. (2012). Solid state chemistry: An introduction. CRC Press.
6. Lovell, M. C., et al. (1984). Physical properties of materials. ELBS.
7. Allison, J. (1985). Electronic engineering materials and devices. Tata McGraw-Hill.
8. Van Vlack, L. H. (1989). Elements of materials science and engineering. Addison-Wesley.
9. Puri, R. K., Babbar, V. K. (2018). Solid state physics. S. Chand & Company.