MASTER OF SCIENCE

IN

MATERIALS SCIENCE

(Applicable from the academic session 2021-22)

Maulana Abul Kalam Azad University of Technology, West Bengal

(Formerly West Bengal University of Technology)

Haringhata-741249, Nadia, West Bengal, INDIA

MASTER OF SCIENCE IN MATERIALS SCIENCE

Vision of the Department:

To achieve the status of state of art in the field of Materials Science and Technology by creating an exciting, diverse, collaborative and supportive environment for the creation of professionals with environmental consciousness, social, moral and ethical values along with the competency to face the new challenges of rapid technological advancements in the field of Materials Science and Technology.

Mission of the Department:

- To inculcate ethics, social awareness, morality and responsibility in students to serve the society.
- Nurture and train students for the cutting-edge research fields and technologies based on Materials Science & Technology and other interdisciplinary sciences.
- MST Department is committed to accommodating Materials Science & Technology and allied scientific & technological activities for our learners.
- To develop liaison and collaboration with the globally recognized academic institutions in order to inject new and fresh thinking in teaching, learning and research
- To generate intellectually capable and successful entrepreneurs having environmental consciousness and ethics who can work as an individual or in a group in multi-cultural global environments for continuing significantly towards the betterment of quality of human life.

About the Department:

Materials have always been the keystone of society and are playing a dominant role in our high-tech age. Modern society is heavily dependent on advanced materials such as lightweight composites for faster vehicles, optical fibers for telecommunications, silicon microchips in this age of miniaturization etc.
The Department of Materials Science and Technology has been established to undertake various academic programme on Materials Science and Technology at different levels. The department is also intended to carry out research activities on materials for enhancing the fundamental knowledge as well as nurturing innovative ideas for designing and developing smart and advanced materials.

Programs offered by the department

1. B. Sc in Materials Science (3 years)
2. M. Sc in Materials Science (2 years)
3. M. Tech in Materials Science and Technology (2 years)

About these courses:

These courses span basic to advanced level of physics and chemistry of materials to their mechanical, electrical, magnetic and optical properties and the design, manufacture and applications of metals, alloys, ceramics, polymers, composites, biomaterials, etc. The course curriculum also covers most recent and advanced areas such as Energy harvesting materials, Smart Materials, Materials Data Science and Informatics, Computational Material Science etc.
These courses will provide knowledge on structure, properties, processing and performance of materials. Learners will be able to develop novel computational methodologies and novel routes to address recent challenges on materials design and development.

Thrust area of research: Materials Processing and Characterization, Composite materials for electronic and microelectronic components joining, Advanced Materials, Materials for Energy and Sustainability, Design and Development of Materials using Computational Tools, Materials Data Science and Informatics

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Preamble:

Department of Materials Science and Technology under the School of Natural, Applied & Social Sciences of Maulana Abul Kalam Azad University of Technology West Bengal (MAKAUT WB) is introducing a two years Masters Course in Materials Science (**M. Sc- Materials Science**), with an **emphasis on computational techniques associated with Materials Science and Technology, Nanomaterials and Energy Storage materials**. The post graduate syllabus has been designed following the recommendations and guidelines of University Grants Commission (UGC) according to the Semester Wise Choice Based Credit System (CBCS) scheme. The contents, structure and date of effect of the proposed syllabus has accepted and approved by the board of studies (B.O.S) of the department.

Purpose:

The M. Sc Course is systematically designed where students shall be trained on the advanced level of physics and chemistry of materials along with the chemical and physical, functional properties and Computational Techniques required for understanding and designing of advanced materials necessary for our sustainability. During framing of this syllabus for M.Sc. in Materials Science, substantial weightage has been given in both the core subjects as well as skill and ability enhancement of the students. This interdisciplinary course will acquaint the students with a wide range of scientific and technical skills and knowledge. Excellent opportunities shall be provided to them to improve extra-curricular and leadership skills development. The Term Project and the Major Project are key parts of the curriculum. Students will get to work on different exciting research ideas ranging from designing/synthesis of materials to their applications through both, experimental, theoretical, and computational techniques.

Structure of the Course:

Total Credit requirement for M.Sc. Degree Programme in Materials Science is 92, out of which the Core Course is of 32 credit and Generic Elective is 12, Skill Enhancement Elective Course is 4 while the Discipline Specific Elective is of 8 credits. Laboratory courses have altogether 10 credits which span over the entire 2 years of the program. Apart from this, the Project which spans over all 4 semesters, covers a major part of 24 credits with a compulsory foundation course of 2 credits. The distribution of courses and credits among the four semesters is described below.

First year of M. Sc Materials Science (Semester I &II): Along with the core courses, special emphasis shall be given to making students digitally equipped. They will learn to handle **computational software** and tools like **MATLAB, Origin along with programming language C, Python.**

Second year of M. Sc Materials Science (Semester III &IV): The scientific foundation shall be further strengthened by a strong curriculum content consisting of courses in**:** Materials for Energy Applications, Electronic Materials, Composite Materials. A vibrant set of skill enhancement elective and generic elective courses shall give the students flexibility and exposure to some other discipline/subject/domain which would improve candidate's employability. Tutorials and laboratories will complement lectures.

The core course is specially designed giving adequate emphasis on the new and emerging techniques and understanding of the materials science under the changing regime and global context. The summers are about giving an exposure to practice: materials research through mini-projects, as well as industrial visits. Special care shall be taken for developing entrepreneurship capacity building and excellent opportunity shall be provided to improve extra-curricular and leadership skills.

The final year project is a key part of the curriculum, this can be chosen from a variety of topics given to the students or even students may implement their ideas into practice. Students will get to work on exciting research ideas ranging from designing/synthesis of materials to applications both by experimental and computational techniques.

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Precedence:

During the design of the syllabus, we have to referred the syllabi of some National and International Universities, the names of the institutes are placed hereunder:

National Universities

1. IISC Bangalore- B. Sc (Research) in Materials (Consulted for the course pattern and subjects of Materials Science)

2. Anna University, Chennai and Mangalore University (Consulted for CBCS structure and the subjects of M. Sc Materials Science course

3. Calcutta University, West Bengal (Consulted for course structure of M. Sc course)

4. NIT Durgapur, West Bengal (Consulted for the course pattern and subjects of Materials Science)

International Universities/Institutes

1. University of Manchester-UK (Consulted for the subjects of Materials Science))

2. MIT-USA (Consulted for the subjects of Materials Science)

3. Illinois Institute of Technology, USA (Consulted for the course pattern and subjects of Materials Science)

4. Wright State University, USA (Consulted for the course pattern and subjects of Materials Science)

Hope the proposed curriculum will make it more contextual, viable and suitable to cater the needs of students of Materials Science

Eligibility Criteria: 3-year Bachelor's degree from a UGC-recognized university majoring in materials science/chemical/ physical/ mathematical sciences or equivalent. Cut-off marks will be decided by the competent authority time to time as per requirement.

Duration of the Course: 2 years

Student Intake: 30

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OUTLINE OF THE SYLLABUS

1. Core Course: A course, which should compulsorily be studied by a candidate as a core requirement is termed as a Core course.

2. Elective Course: Generally, a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/ subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill is called an Elective Course.

2.1 Discipline Specific Elective (DSE) Course: Elective courses may be offered by the main discipline/subject of study is referred to as Discipline Specific Elective. The University/Institute may also offer discipline related Elective courses of interdisciplinary nature (to be offered by main discipline/subject of study).

2.2 Generic Elective (GE) Course: An elective course chosen generally from an unrelated discipline/subject, with an intention to seek exposure is called a Generic Elective.

P.S.: A core course offered in a discipline/subject may be treated as an elective by other discipline/subject and vice versa and such electives may also be referred to as Generic Elective.

3. Skill Enhancement Courses (SEC): These courses may be chosen from a pool of courses designed to provide value-based and/or skill-based knowledge.

Project work/Dissertation is considered as a special course involving application of knowledge in solving / analysing /exploring a real-life situation / difficult problem. A Project/Dissertation work would be of 6 credits. A Project/Dissertation work may be given in lieu of a discipline specific elective paper.

Semester wise distribution of course

Subject Type	Semester I	Semester II	Semester III	Semester IV
Core Course	C1, C2, C3	C4, C5, C6	C7, C8	
Discipline Specific Elective			DSE1	DSE2
Generic Elective	GE1	GE2		GE3
Skill Enhancement Course	SEC1		SEC2	
Compulsory Foundation		CF		
Value Added Course			VAC	
Credit Distribution = 92	24	24	24	20
Marks Distribution = 2600	800	800	700	300

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Program Outcomes (POs)

Program Outcome (PO) Upon completion of this 2-year post-graduate degree program, the students will be able:	
PO1. To comprehend the relationship between structure, property, processing and performance of materials.	**Technical competence**
PO2. To acquire experimental and computational skills relevant to addressing practical problems of materials science	**Modern Tool Usage**
PO3. To build a strong independent research aptitude in the field of materials science and enable them to summarize their findings in written reports as well as presentation/demonstration skills	**Research aptitude**
PO4. To find solutions for real life problems and societal issues which demand interdisciplinary as well as transdisciplinary knowledge	**Impact in society/ Societal Responsibilities**
PO5. To develop creative and entrepreneurship skills	**Entrepreneurship skills.**

Part-A

CURRICULUM STRUCTURE

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Semester-I								
Sl. No.	**Subject Category**	**Subject Code**	**Subject Name**	**Marks**	**Total no of contact hours**			**Credits**
					L	T	P	
1	Core Course 1	MMS 101	Fundamentals of Materials Science	100	3	1	0	4
2	Core Course 2	MMS 102	Physics and Chemistry of Solids	100	3	1	0	4
3	Core Course 3	MMS 103	Mechanics and Thermodynamics	100	3	1	0	4
4	Generic Elective (GE1)	MMS 104	Mathematical, Statistical & Numerical Methods for Materials Science-I	100	3	1	0	4
5	Skill Enhancement Course (SEC1)	MMS 105	English for Scientific and Technical Writing	100	2	0	0	2
6	Laboratory-I	MMS 191	Computer Programming with Python & C for Materials Science	100	0	0	4	2
7	Laboratory-II	MMS 192	Fundamental of Materials Science Lab	100	0	0	4	2
8	Sessional	MMS 181	Term Project & Seminar	100	0	0	4	2
			Total Marks	**800**				
			Total Credit of Semester-I		**14**	**4**	**12**	**24**
Semester-II								
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Marks**	**Total no of contact hours**			**Credits**
					L	T	P	
1	Core Course 4	MMS 201	Mechanical Behavior of Materials	100	3	1	0	4
2	Core Course 5	MMS 202	Structure and Imperfections in Solids	100	3	1	0	4
3	Core Course 6	MMS 203	Synthesis and Characterization of Materials	100	3	1	0	4
4	Generic Elective (GE2)	MMS 204	Mathematical, Statistical & Numerical Methods for Materials Science-II	100	3	1	0	4
5	Compulsory Foundation (CF)	MMS 205	Research Methodology & IPR	100	2	0	0	2
6	Laboratory I	MMS 291	Materials Synthesis and Characterizations Lab	100	0	0	4	2
7	Laboratory-II	MMS 292	Computational Materials Science Lab	100	0	0	4	2
8	Sessional	MMS 281	Term Project & Entrepreneurship	100	0	0	4	2
			Total Marks	**800**				
			Total of Semester-II		**17**	**5**	**12**	**24**

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Semester-III									
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Marks**	**Total no of contact hours**			**Credits**	
					L	T	P		
1	Core Course 7	MMS 301	Optical, Electronic & Magnetic Properties of Materials	100	3	1	0	4	
2	Core Course 8	MMS 302	Nanomaterials: Principles and Applications	100	3	1	0	4	
3	Discipline Specific Elective (DSE1)	MMS 303	Elective-1	100	3	1	0	4	
4	Skill Enhancement Course (SEC)	MMS 304	Applications of Artificial Intelligence and Machine Learning	100	2	0	0	2	
5	Laboratory I	MMS 391	Optical, Electronic & Magnetic Properties of Materials Lab	100	0	0	4	2	
6	Sessional-I	MMS 381	Business Economics and Entrepreneurship	100	0	0	4	2	
7	Sessional-II	MMS 382	Major Project-I	100	0	0	12	6	
			Total Marks	**700**					
				Total of Semester-III	**11**	**3**	**20**	**24**	
Semester-IV									
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Marks**	**Total no of contact hours**			**Credits**	
					L	T	P		
1	Discipline Specific Elective (DSE2)	MMS 401	Elective-2	100	3	1	0	4	
2	Generic Elective (GE3)	MMS 402	Elective-3	100	3	1	0	4	
3	Sessional	MMS 481	Major Project-II	100	0	0	24	12	
			Total Marks	**300**					
				Total of Semester-IV	**6**	**2**	**24**	**20**	

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List of Discipline Specific Electives for SEMESTER – 3 (DSE-1)

Sl. No.	Course Name
A	Materials for Energy Application
B	Nuclear Reactor Materials
C	Semiconductor Materials and Device Technology
D	Non-Destructive Testing
E	Materials Processing

List of Discipline Specific Electives for SEMESTER – 4 (DSE-2)

Sl. No.	Course Name
A	Composite Materials
B	Bio Materials
C	Corrosion and Degradation of Materials
D	Thin-film Materials Technology

List of Generic Electives for SEMESTER – 4 (GE-2)

Sl. No.	Course Name
A	E-Waste Materials & its Management
B	Green Chemistry
C	Renewable Energy Management, Sustainability
D	Smart Materials for Energy and Environment Applications

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MOOC'S BASKET (Mode of Delivery: Blended/Online)

Sl. No.	Course Name	Course Provider	Course Duration	Credits	Name of University/Institute
1	Waste to Energy Conversion	NPTEL	8 weeks	2	IIT Roorkee
2	Physics of Materials	NPTEL	8 weeks	2	IIT Madras
3	Medical Biomaterials	NPTEL	8 weeks	2	IIT Madras
4	Optoelectronics Materials and Devices	NPTEL	8 weeks	2	IIT Kanpur
5	Introduction to solar cells (5 wk.) & Organic Solar Cells – Theory & Practice (6 wk.)	coursera	11 weeks	3	Technical Univ. of Denmark
6	Introduction to Thermodynamics: Transferring Energy from Here to There	coursera	8 weeks	2	Univ. of Michigan
7	Introduction to Composites	NPTEL	12 weeks	3	IIT Kanpur
8	Fundamentals of electronic device fabrication	NPTEL	4 weeks	1	IIT Madras
9	Fundamental concepts of semiconductors	NPTEL	6 weeks	2	IIT Delhi
10	Nanotechnology and Nano sensors, Part1 (5 wk.) & Nanotechnology & Nano sensors, Part 2 (5 wk.)	Coursera	10 weeks	3	Technion – Israel Institute of Technology
11	Phase equilibrium thermodynamics	NPTEL	8 weeks	2	IIT Kharagpur
12	Diffusion in Multicomponent Solids	NPTEL	12 weeks	3	IIT Kanpur
13	Nanotechnology in Agriculture	NPTEL	8 weeks	2	IIT Kanpur
14	Nature and Properties of Materials	NPTEL	8 weeks	2	IIT Kanpur
15	Materials Science: 10 Things Every Engineer Should Know	Coursera	5 weeks	2	University of California, Davis
16	Materials Data Sciences and Informatics (5 wk.) & Transmission electron microscopy for materials science (8 wk.)	coursera	13 weeks	4	Georgia Tech Univ. & École Polytechnique Fédérale de Lausanne
17	Introduction to Physical Chemistry	Coursera	10 weeks	3	The Univ. of Manchester

- *This basket is dynamic and courses will be updated accordingly as per its availability*

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Marking Scheme followed for evaluation of student's Continuous Assessment

BASIS FOR CONTINUOUS ASSESSMENT (CA): Continuous assessment marks in each theory course shall be based on any of the following evaluation procedure to be adopted by the faculty concerned with the subject like tests, assignments, power point presentation and viva voice. During each semester four CA has to be conducted CA-1, CA-2, CA-3, CA-4 and best of four will be counted for final evaluation.

Internal assessment marks in each Laboratory course are assessed by the faculty members of the department based on the regular performance in the laboratory, the viva conducted on each experiment, the internal test and the laboratory records submitted by the student. During each semester two internal practical test has to be conducted and termed as PCA-1 & PCA-2 and best of two will be counted for final evaluation

PROJECT REPORT: A project carried out by the student in III and IV semesters will be evaluated in the IV semester as stipulated in the regulations. The internal assessment for the project is evaluated by the faculty members of the department. And, final semester project evaluation will be done by open viva voice. For evaluation purpose of the same one external examiner has to be present.

Theory = 100; **Laboratory = 100**

Distribution of Marks for Theory paper

Each Theory paper marks (100) is divided as = 70 (End Semester Examination) + 30 (Continuous Assessment)

Theory (100)

70
(End Semester Examination)
End Semester Examination will be held in the month of December for Odd Semester and in the month of May for Even semester on schedules dates as notified by COE.

30
(Continuous Assessment)
(25 + 5)
25 (CA)
5 (Attendance)

Distribution of Marks for Laboratory

Each Laboratory marks (100) is divided as = 60 (End Semester Examination) + 40 (Internal Assessment)

Laboratory (100)

60 marks
(End Semester Examination)
(External)

2 Experiments to be performed
or
2 Computer programs to be written
30 marks
Duration of Exam: 3 hours
10 marks: Viva (to judge the concept of the student)
15 marks: Lab copy
5 marks: Attendance

40 marks
(Internal Assessment)
25 marks: For experiments performed (in whole Semester)
5 marks: Viva Voice
5 marks: Lab copy maintenance
5 marks: Attendance

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Distribution of marks for attendance

Sl. No.	Attendance Range	Marks to be allotted
1	75% >	1
2	80% >	2
3	85% >	3
4	90%	4
5	90% >	5

Grading System

Sl. No.	Range of Marks	Letter Grade	Marks
1	40-50	D(Pass)	5
2	50-60	C (Average)	6
3	60-70	B (Good)	7
4	70-80	A (Very good)	8
5	80-90	E (Excellent)	9
6	90-100	O (Outstanding)	10
7	Less than 40	Fail	
8	--	Absent	0

Part-B

DETAILED

STRUCTURE

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MMS 101: FUNDAMENTALS OF MATERIALS SCIENCE **Credit: 4 = 3-1-0**

Course Objectives: The course helps to understand the relationship between different types of crystal structures with the properties of materials. It serves as a foundation for understanding the structure-property correlation in developing materials.

Unit I Evolution of materials science **14 L**

Understanding the Materials around us and the science behind the materials, Structure property correlation, Modern Materials Need. Materials for Engineering Applications., Processing/Structure/Properties/Performance Correlations, Case Study: Importance of different materials to be discovered. Introduction to different types of properties of Materials

Unit II Crystal Geometry and Structure Analysis **14 L**

Crystal structure, lattice and basis, primitive and non-primitive unit cells, symmetry elements, Crystal systems, Crystal planes and directions - Miller indices. Structure analysis by X-rays - Atomic scattering factor. Bragg's law, Lattice and Geometrical structure factor - systematic absences – SC, BCC, FCC, NaCl and diamond structure. Reciprocal lattice. Rotation and Powder methods of X-ray analysis

Unit III Classification of Materials **10 L**

Metallic Materials, Ceramic Materials, Polymeric Materials, Composite Materials, Biomaterials, Properties and their Applications

Unit IV Band theory of solids **14 L**

Electronic energy band theory, classical free electron theory of solids, Sommerfeld quantum free electron theory of a solid, Bloch wave-functions for a periodic potential, Kronig-Penny model and energy bands. Fermi energy and Fermi surfaces, effective mass of an electron, Brillouin zones & Reciprocal lattice.

Course Outcome: On completion of this course, a student will be able to:

1. Define and classify different types of materials such as metals, ceramics polymers and their composites based on their properties
2. Describe the general methods for the synthesis of different types of materials along with their properties and applications.
3. Select the appropriate material or material combination for developing new materials that would be required for specific/ customized applications

Text Books

1. Materials Science and Engineering, A First Course – V. Raghavan
2. R. Balasubramaniam, Callister's Materials Science & Engineering
3. J. F. Shackelford, M. K. Muralidhara, Introduction to Materials Science for Engineer

Reference Books

1. Elements of Materials science and Engineering – Lawrence H Van Vlack (Pearson, Delhi 2014)
2. Materials Selection in Mechanical Design, 2nd Ed., Ashby (Butterworth/Heinemann, 1999)
3. Rolf E. Hummel, Understanding Materials Science: History, Properties, Applications

Online Link: Introduction to Materials Science and Engineering-Web course---http://nptel.iitm.ac.in

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PO-CO Mapping	PO1	PO2	PO3	PO4	PO5
CO1	3	1	1	1	1
CO2	3	3	1	3	1
CO3	1	1	1	1	3

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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MMS 102: Physics and Chemistry of Solids **Credit: 4 = 3-1-0**

Course Objectives: This course will introduce basic concepts of materials chemistry, synthesis, properties and applications of different types of materials. This course will introduce the students to the fundamental knowledge about the different physical, chemical and functional properties of materials.

Unit I Fundamentals of Chemical Bonding **10L**

Chemical bonding and Shapes of Molecules, Ionic or electrovalent, Covalent and Vander walls bonds; Molecular orbital theory, Types of hybridization and shapes of some common molecules, Coordination Chemistry

Unit II Introduction to Transport Phenomena **14L**

Basics of momentum transport: Euler/Lagrangian viewpoint, laminar and turbulent flows, boundary layers, stress tensor. Conductive, convective radiation, dissipation of heat fluxes, steady state, non-steady state heat transfer. Concept of electrical and thermal resistivity, Different scattering mechanisms, Matthiessen's rule,

Unit III Diffusion in Solids **10L**

Fick's laws; Diffusion mechanism; Study state diffusion; Non steady state diffusion; Factors that influence diffusion, The Kirkendal effect; Diffusion in alkali halides; Ionic conductivity

Unit IV Electrical Properties of Materials **12L**

Ohm's law; Electrical conductivity; Electronic and ionic conduction; conduction in terms of band and atomic bonding model; electron mobility; electrical resistivity of metals; conduction in ionic materials; Electrical conductivity of semiconductors with temperature; Electrical properties of polymers

Unit V Magnetic Properties **10L**

Classification of magnetic materials- origin of magnetism – Langevin and Weiss theories - - magnetic anisotropy - magnetic domains - molecular theory – hysteresis - hard and soft magnetic materials, magnetoresistance -

Course Outcome: On completion of this course, a student will be able to:

1. Understand the basic concepts of chemical bonding and diffusion in solids
2. Achieve their basic knowledge about the electrical and magnetic properties of materials
3. Apply their acquired knowledge to create new materials

Text Books

1. V. Raghavan, Materials Science and Engineering: A First Course. PHI Learning, 2015.
2. S.O. Kasap. Principles of Electronic Materials and Devices. McGraw-Hill Education, 2017.

REFERENCES

1. The Physics and Chemistry of Solids- Elliott Stephen (Wiley, 2010)

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PO-CO Mapping	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	3	1
CO2	3	3	1	1	1
CO3	1	1	1	1	3

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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MMS 103: Mechanics and Thermodynamics **Credit: 4 = 3-1-0**

Course Objectives: This course will introduce basic concepts of Classical and Quantum Mechanics. It will help students understand the concepts laws of thermodynamics its applications and phase equilibria

UNIT I Classical Mechanics **14 L**

Survey of elementary principles: review of the Newtonian mechanics, constraints, Lagrange's equation, Its application to simple problems. The equation of motion, the equivalent one-dimensional problem, Virial theorem, Differential equation for the orbit, inverse square law of force, scattering in central force field. Variational Principles and Lagrange's equations: calculus of variations, Hamilton's principle, derivation of Lagrange's equation from Hamilton's principle, its application, conservation and symmetry property.

UNIT II Quantum Mechanics **14 L**

Quantum Physics: Uncertainty principle. Interpretation of the wave particle dualism and complementarity. Wave Equation and Operators: The Schroedinger equation - free particle in one and three dimensions. Mean squared deviation. Simultaneous eigen functions. Normalization of wave functions and statistical interpretation - Box normalization the Dirac delta functions. Stationary states - particle in one dimensional square well potential, potential barriers - transmission and reflection coefficients. Simple problems and Applications. Maxwell – Boltzmann, Bose- Einstein and Fermi-Dirac statistics – Comparison of MB, BE and FD statistics.

UNIT III Laws of thermodynamics **14 L**

Internal energy- Enthalpy- Entropy- Helmholtz and Gibbs free energies – Thermodynamic relations – Euler equation – Maxwell's relations and applications – Chemical Potential- Gibb's phase rule – phase equilibria- First order phase transition in single component systems – Second order phase transition. First law - Internal energy, work in various systems, heat capacities, enthalpy, flow processes, Second law - Carnot theorem, Clausius inequality,

UNIT IV Statistical Thermodynamics **12 L**

Planck's Radiation law- Stefan-Boltzmann law – Einstein model of a solid – Bose condensation – Classical partition function and classical ideal gas – Equipartition theorem – Semiconductor statistics – Statistical equilibrium of electrons in semiconductors.

Course Outcome: On completion of this course, a student will be able to:

1. Conceptualize the fundamentals of classical and quantum mechanics
2. Understand the concepts of Laws of Thermodynamics and its different applications in materials designing
3. Understand the basic concepts of heat and mass transfer, the equations governing them and its application

Text Books

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
2. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.

3. H. Goldstein, Classical Mechanics
4. Rana & Jog, Classical Mechanics

REFERENCE BOOKS:

1. Corben & Stehle, Classical Mechanics
2. Landau and Lifshitz, Mechanics
3. Quantum mechanics – Leonard I Schff, 4th edition (McGraw Hill Education Pvt Limited, 2014)
4. Quantum Mechanics – Sokolov (MIR Publications Moscow, 1984)

Online Link: Introduction to Thermodynamics: Transferring Energy from Here to There, coursera, 8 weeks, 2 credit, Univ. of Michigan

PO-CO Mapping	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	3	1
CO2	2	3	1	1	1
CO3	3	1	1	1	2

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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MMS 104: Mathematical, Statistical & Numerical Methods for Materials Science-I

Course Objectives: This course will introduce students to basics of linear algebra and numerical methods to solve the differential equation, integration and different methods of numerical problem solution. It will also help the students to describe the data and hence compute the various descriptive measures

UNIT 1: Linear Algebra, Complex Variables and its Applications **14 L**

Matrix and Determinants: Matrix Inversion, Eigen-values, Eigen-vector, Diagonalization of Real Symmetric Matrix by Jacobi's Method. First Principle Approach. Laplacian-Vector operators in curvilinear coordinates Gauss, Green and Stokes theorems- Applications - Vector spaces. Complex numbers and functions, Complex Integration, Elements of complex variables, Taylor series, Laurent Series, Singularities, and zeros, Residue theorem and integration

Unit 2: Linear and non-linear equations **14 L**

Solution of Algebra and transcendental equations, Bisection, Falsi position and Newton-Raphson Methods-Basic Principles-Formulae-algorithms. Simultaneous equations: Solutions of simultaneous linear equations-Gauss elimination and Gauss Seidel iterative methods-Basic Principles-Formulae-Algorithms, Pivotal Condensation.

UNIT 3: Descriptive Statistics **12 L**

Frequency distribution - Graphs of frequency distribution - Descriptive Measures - Quartiles and Percentiles - Calculation of sample mean and population mean

UNIT 4: HYPOTHESIS TESTING **12 L**

Sampling Distributions- Central Limit Theorem - Testing a Statistical Hypothesis - Tests Concerning Means and variances - Independence of Attributes - Goodness of Fit

Course Outcome: On completion of this course, a student will be able to:

1. Solve large system of linear & non-linear equations and matrix and determinants using computational tools
2. Understand the basic concepts in numerical and statistical analysis, and its applications in materials science
3. Formulate mathematical model towards new materials development and analysis

Text books:

1. V. Rajaraman, Computer Oriented Numerical Methods, PHI, 1993.
2. E. Balaguruswamy, Numerical Methods, Tata McGraw Hill, 2017.

Reference texts:

1. F. Acton, Numerical Methods that Work, Harper and Row, 1997.
2. S. D. Conte and C.D.Boor, Elementary Numerical Analysis, McGraw Hill, 2005.
3. S. S. Shastri, Introductory Methods of Numerical Analysis, PHI, 2012

MASTER OF SCIENCE IN MATERIALS SCIENCE

PO-CO Mapping	PO1	PO2	PO3	PO4	PO5
CO1	1	3	2	2	1
CO2	3	3	3	3	1
CO3	2	3	1	1	3

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

MASTER OF SCIENCE IN MATERIALS SCIENCE

MMS 105: English for Scientific and Technical Writing **Credit: 2 = 2-0-0**

Course Objectives: The course will teach how to improve writing skills and level of readability and will guide how to write a good quality paper. It will also emphasize that the student not only present written reports but also become independent with good presentation skills

UNIT I INTRODUCTION TO RESEARCH PAPER WRITING **5 L**

Planning and Preparation, Word Order, breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

UNIT II PRESENTATION SKILLS **6 L**

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Introduction

UNIT III TITLE WRITING SKILLS **5 L**

Key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check

UNIT IV RESULT WRITING SKILLS **6 L**

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions

Course Outcome: On completion of this course:

1. A student will be able to communicate his / her understanding / ideas with others in written and verbal form
2. Students will be trained to develop their soft skills and self development abilities

REFERENCES

1. Adrian Wallwork , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011
2. Day R How to Write and Publish a Scientific Paper, Cambridge University Press 2006

PO-CO Mapping	PO1	PO2	PO3	PO4	PO5
CO1	1	1	3	1	3
CO2	1	1	3	1	3

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

MMS 191: Laboratory-I: Computer Programming with Python & C for Materials Science
Credit: 2 = 0-0-4

Course Objectives

1. To know how to use different operating systems of the computer.
2. To Understand the principles of Python and acquire skills in programming in python.
3. To Interpret the fundamental Python syntax and semantics and be fluent in the use of Python control flow statements.

Module 1

Unit-1: Basics of Programming

a. How to use different operating system - MS DOS, MS WINDOW, UNIX, Linux

b. Algorithm & flow chart of any programming C & Python

Running Code in the Interactive Shell, Input, Processing and Output, Editing, Saving and Running a Script, Working of Python. Variables, Expressions and Statements: Values and Data Types, Variables, Keywords, String Literals, Escape Sequences, Operators and Operands, Expressions and Statements, Interactive mode and Script mode, Order of Operations, Comments.

Unit-2: Advanced language programming

Python programming, Data Nature, Operator, statement, functions, object-oriented programming, modules may be practised for small standard problems), String Handling, Control Structures, Python Functions

Module 2

List of Program

1. Running Code in the Interactive Shell, Input, Processing and Output, Editing, Saving and Running a Script
2. Implementation of array operations.
3. Stacks and Queues: adding, deleting elements.
4. Circular Queue: Adding & deleting elements
5. Merging Problem: Evaluation of expressions operations on Multiple stacks & queues
6. Implementation of linked lists: inserting, deleting, inverting a linked list.

Reference texts

1. Linux Command Line and Shell Scripting Bible, 3rd Edition, Wiley
2. Compueter programming in FORTRAN 77, Y. Rajaramann
3. M. Lutz, Learning Python Powerful Object-Oriented Programming, O'reilly Media, 5th Edition 2018.
4. T. A. Budd, Exploring Python, Tata MCGraw Hill Education Private Limited, 1st Edition, 2011,.
5. A. Downey, J. Elkner, C. Meyers, How to think like a computer scientist: learning with Python, Green Tea Press, Wellesley, Massachusetts, 2012.

MMS 192: Laboratory-II: Fundamental Materials Science Lab **Credit: 2 = 0-0-4**

Objective: On completion of the course the learner shall be able to:

- Measure materials properties using experimental techniques
- Relate the concepts learned with the functioning of everyday devices

1. Mechanical Strength of Materials: Tensile and Compression strength of Metals/Polymers/ceramics
2. Synthesis of a polymer composite and its micro-structural observations.
3. Testing of electrical properties of polymer composite
4. Resistivity by Four Probe Method
5. Every student will have to propose and carry out at least one self-designed project

Virtual Lab (https://www.vlab.co.in/broad-area-physical-sciences)

1. Characteristics of Zener diode
2. The Study of Phase Change
3. Heat transfer by Conduction
4. Heat Transfer by Radiation
5. Temperature Coefficient of Resistance

MMS 181: Term Project-I **Credit: 2 = 0-0-2**

Students will be assigned with research articles for review, explanations with applications which will be submitted as a term paper to the department. A presentation will be made and delivered in presence of the departmental faculty members for assessment.

MASTER OF SCIENCE IN MATERIALS SCIENCE

Semester 2

MMS 201: Mechanical Behavior of Materials **Credit: 4 = 3-1-0**

Detailed syllabus will be discussed and finalised in next BoS meeting

Course Objectives: The course will explain the principles behind different mechanical behaviour of materials and the mechanisms of creep and development of heat resistant materials

UNIT I Deformation **14 L**

Fundamental mechanisms responsible for creep - dislocation creep-dislocation glide - grain-boundary sliding - deformation-mechanism - creep-induced fracture - heat resistant materials -creep in polymers – super plasticity, Fatigue parameters and S-N curves - fatigue strength - effect of mean stress on fatigue life - mechanisms of fatigue: fatigue crack nucleation, fatigue crack propagation - linear elastic fracture mechanics applied to fatigue - environmental effects in fatigue - fatigue testing: conventional fatigue tests,

UNIT II Fracture **14 L**

Macroscopic aspects: theoretical tensile strength, stress concentration and Griffith criterion of fracture, crack propagation with plasticity, linear elastic fracture mechanics, fracture toughness - microscopic aspects: fracture in metals, fracture in ceramics, fracture in polymers - fracture testing: impact testing, plane-strain fracture toughness test, crack opening displacement testing, j-integral testing, flexure test (three-point bend test, four-point bending), fracture toughness testing of brittle materials (Chevron notch test , indentation methods for determining toughness).

UNIT III Elasticity and Viscoelasticity **14 L**

Longitudinal stress and strain - strain energy density- shear stress and strain - poison's ratio, Elastic properties of polycrystals- elastic properties of metals, ceramics and polymers - elastic constants of unidirectional fiber reinforced composite – viscoelasticity - storage and loss moduli - rubber elasticity.

UNIT IV Plasticity **14 L**

Plastic deformation in tension: tensile curve parameters, necking, strain rate effects - plastic deformation in compression testing, plastic deformation of polymers: stress - strain curves, glassy polymers, semicrystalline polymers, microscopic deformation mechanism - temperature dependence and viscosity – hardness: macro & micro indentation tests, nanoindentation.

Course Outcome: Upon completion of the subject, the student should be able to:

1. Understand the mechanical properties of materials from a fundamental physics perspective using appropriate mechanical testing instrument
2. Design and select materials based on the principles of fracture mechanics for desired applications
3. Formulate different failure of materials and suggest ways to strengthen their mechanical properties

Text Books:

1.Mechanical Metallurgy – George E. Dieter

2.Principles of Heat Treatment of Steels- R.C. Sharma

Reference Books

1. Materials Science and Engineering – William D. Callister, Jr.
2. Mechanical Behavior of materials – Thomas H. Courtney
3. Mechanics of composite materials – Autar K. Kaw
4. Engineering Physical Metallurgy and Heat Treatment - Y. Lakhtein (Mir Publisher)

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MMS 202: Structure and Imperfections in Solids — Credit: 4 = 3-1-0

Detailed syllabus will be discussed and finalised in next BoS meeting

MMS 203: Synthesis and Characterization of Materials — Credit: 4 = 3-1-0

Course Objectives: The objective of the course is to introduce the important characterization techniques to the students and to make the students understand some important mechanical and thermal analysis techniques. It will also make the students familiarize with microscopy and spectroscopy

Unit I: Introduction **6 L**

Importance and applications of different characterization techniques. Principles and general methods of compositional, structural and defect characterization.

Unit II: Synthesis of Nanostructured Materials **12 L**

Vacuum deposition -Physical vapor deposition (PVD) - chemical vapor deposition (CVD) – laser ablation- Sol-Gel- Ball milling, hydrothermal synthesis – carbon nanotubes and graphene synthesis.

Unit III Diffraction techniques & **Microscopy** **14 L**

X-ray Diffraction, Microscopy I - Optical, electron (TEM & SEM)
Microscopy II – Scanning probe methods (STM, AFM)

Unit IV Spectroscopy **10L**

Optical spectroscopies - UV, visible, IR and FTIR
Electron spectroscopies - Auger and photoelectron spectroscopies

Unit V Mechanical and Thermal methods **14 L**

Mechanical Methods: Measurement of tensile & flexural moduli, strength, fatigue, creep, fracture toughness, hardness etc
Thermal methods: DTA, TGA, DSC, TMA and DMA

Reference Books:

1. Materials Characterization-Yang Lang
2. Dieter K. Schroder - Semiconductor material and device characterization
3. Materials Characterization Techniques- Sam Zhang, Lin Li, Ashok Kumar
4. Auger and X-ray photoelectron spectroscopy- D. Briggs and M. P. Seah
5. An Introduction to Material Characterization- P. R. Khangaonkar
6. Characterization of Materials, (2 Volume Set), E. N. Kauffmann (Editor)
7. Physical Principles of Electron Microscopy- R. F. Egerton

MMS 204: Mathematical, Statistical & Numerical Methods for Materials Science-II

Course Objectives: The course helps to understand the numerical methods to solve the differential equation and integration and it will enable students to learn the basic principles of experimental design and hence carry out the analysis of variance

UNIT 1: Integral Transforms & Differential Equations 14 L

Harmonic analysis, Fourier transform-properties-transforms of simple functions and derivatives- Convolution theorems – Applications - Laplace's transform – properties -Transform of simple functions and derivatives-periodic functions-Convolution theorem-Application to solve differential equation. Review of First Order and Second Order Differential equations- Laplace's equation - Method of separation of variables - Fourier series solution in cartesian coordinates. Reducible and irreducible representation -

Unit 2: Numerical Solution of differential equations and integration 14 L

Interpolations: Concept of linear interpolation-Finite differences-Newton's and Lagrange's interpolation formulae-principles and Algorithms Numerical differentiation and integration: Numerical differentiation-algorithm for evaluation of first order derivatives using formulae based on Taylor's Series, Numerical integration-Trapezoidal Rule, Simpson's 1/3 Rule, Weddle's Rule, Gauss Quadrature Formulae-Algorithms. Error in numerical Integration. Taylor's Series Method, Euler's Method, Modified Euler's Method, Runge-Kutta Method, Predictor-Corrector Method

UNIT 3: Analysis of variances & nonparametric methods 12 L

One way and two-way classification - Completely Randomized Design - Randomized Block Design - Latin Square Design. Sign Test - Wilcoxon's Signed Rank Test - Rank Sum Tests - Tests of Randomness - Kolmogrov Smirnov and Anderson Darling Tests

UNIT 4 Calculations Using R/Python/MATLAB 12 L

Classification and tabulation of data - Graphical representation - Calculation of central tendency and dispersion of data - Implementation of skewness, moments and kurtosis - Hypothesis Testing - Implementation of ANOVA, sign test and rank sum test.

Course Outcome: On completion of this course, a student will be able to:

1. Learn advanced mathematical techniques necessary to solve engineering problems
2. Understand the basic concepts in numerical methods to estimate the solutions to ordinary differential equations and also get expose to use of statistics.
3. It equips the students to implement the various concepts learnt using various computational tools like R/Python/MATLAB

Text books:

1. E. Balaguruswamy, Numerical Methods, Tata McGraw Hill, 2017.
2. S. D. Conte and C.D.Boor, Elementary Numerical Analysis, McGraw Hill, 2005.
3. S. S. Shastri, Introductory Methods of Numerical Analysis, PHI, 2012.
4. Gupta S. C. and Kapoor V. K, "Fundamentals of Mathematical Statistics", Sultan Chand and Sons, 11th Edition, New Delhi, 2002.

5. John E. Freund ," Mathematical Statistics with Applications", 8th Edition, Pearson Education, New Delhi, 2017.

REFERENCES

1. A. Kharab and R.B. Guenther. An Introduction to Numerical Methods: A MATLAB Approach. CRC Press, 2018.

2. J. H. Mathews and K. D. Fink. Numerical Methods using MATLAB. Pearson Education India, 2015.

3. C. Woodford and C. Phillips. Numerical Methods with worked examples: MATLAB edition. Springer, 2014.

4. S.S.Sastry. Introductory Methods of Numerical Analysis. Prentice Hall India Learning Private Limited, 2012.

5. Richard A. Johnson, Irwin Miller and John Freund, "Miller and Freund's Probability and Statistics for Engineers", 8th edition, Pearson Education, New Delhi, 2015.

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MMS 205: Research Methodology & IPR **Credit: 2 = 2-0-0**

Course Objectives: The course helps to gain knowledge for an overview of the research methodology and ability to explore the technique of defining a research problem. This will also help to gain knowledge of various forms of the intellectual property, its relevance and business impact in the changing scenario of global business environment.

Unit 1: Introduction to Research **5 L**

Definition of problem: Necessity of defining problem, Technique involved in defining a problem. Surveying the available literature. Techniques involved in solving the problem: Different methods used to solve a problem.

Unit 2: Design of Research Plan **10 L**

Research Design: Subject of study; Type of data required; Method of data collection; Style of data presentation. Developing a research plan: Research objective; Information required for solving the problem, Methods of data collection: Experimental methods.

Unit 3: Applications of Software in Research **7 L**

Computer: Basic of Computer Operating System: Using Windows – Directory structures – command structure (Document preparation, EXCEL, PowerPoint Presentation). Numerical analysis. Figure Plotting: using R/Origin/MATLAB etc. Figure insertions in documents. Web Browsing for Research literature

Unit 4 Nature of Intellectual Property **6 L**

Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. Patent Rights: Scope of Patent Rights. New Developments in IPR

Course Outcome: On completion of this course, a student will be able to:

1. Search the literatures, define a research problem and capable of designing a research plan to solve the desired problem
2. Apply different software tools for computer programming to design new materials modelling
3. Able to analyse the data obtained from experimental work

Text Book

1. Research Methodology: Methods and Techniques by C.R. Kothari.

References:

1. S. Melville and W. Goddard, Research methodology: an introduction for science & engineering students, Juta & Co. limited, 2nd edition, 2007.
2. W. Goddard and S. Melville, Research Methodology: An Introduction.
3. R. Kumar, Research Methodology: A Step by Step Guide for beginners, Sage Publication, 3rd Edition,. 4. Halbert, Resisting Intellectual Property, Taylor & Francis Ltd, 2007.

MASTER OF SCIENCE IN MATERIALS SCIENCE

PO-CO Mapping	PO1	PO2	PO3	PO4	PO5
CO1	1	1	3	2	1
CO2	1	3	3	2	3
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Correlation levels 1, 2 or 3 as defined below:

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MASTER OF SCIENCE IN MATERIALS SCIENCE

MMS 291: Laboratory-I: Materials Synthesis & Characterization Lab **Credit: 0-0-4**

Detailed syllabus will be discussed and finalised in next BoS meeting

1. Synthesis of a polymer composite
2. Synthesis of a nanoparticles by chemical method
3. Synthesis of different materials joints and testing their properties viz. mechanical, electrical, functional
4. Electrical properties of polymer composite
5. Electrical conductivity of metals and alloys with temperature-four probe method
6. Determination of thermal stability of polymer composite
7. Structural characterization of nanomaterials

MMS 291: Laboratory-I: Computational Lab **Credit: 0-0-4**

Detailed syllabus will be discussed and finalised in next BoS meeting

Course Objectives

1. To understand analytical, developmental and technical principles that relate to Numerical Linear Algebra,
2. Numerical Methods for solving Differential Equations, and Numerical Optimization, develop the academic abilities required to solve problems and applications in Numerical Analysis.
3. Numerical Optimization and critically assess relevant aspects of the industry,
4. To demonstrate an ability to initiate and sustain in-depth research in Numerical Analysis or Numerical Optimization.

List of Practical

1. Introduction to Scilab, Python and MATLAB
2. Numerical solution of different integral and differential equations using Scilab/Python/MATLAB
3. Gauss-Jordon method. Inverse of a matrix
4. Determination of roots by Newton's Raphson method.
5. Determination of roots by Bisection method.
6. Numerical integration by Trapezoidal method.
7. Numerical integration by Simpson's 1/3 method
8. Solution of simple boundary value problem by a. Finite element and b. Boundary element method.
9. Solution of system of Non-linear equations by Newton's method.
10. Computational Materials Modelling: DFT, Monte Carlo, Molecular Dynamics

MMS 281: Term Project-II **Credit: 0-0-2**

Students will be assigned with topics for review, explanations with applications which will be submitted as a term paper to the department programme coordinator. A presentation will be made and delivered in presence of the departmental faculty members for assessment.