BACHELOR OF SCIENCE

IN

MATERIALS SCIENCE

(Applicable from the academic session 2019-2020)

Maulana Abul Kalam Azad University of Technology, West Bengal

(Formerly West Bengal University of Technology)

Haringhata-741249, Nadia, West Bengal, INDIA

Preamble:

Department of Materials Science and Technology under School of Natural and Applied Sciences of Maulana Abul Kalam Azad University of Technology West Bengal (MAKAUT) is introducing a three years Bachelors Course in Materials Science (BSc- Materials Science), with an **emphasis on computational techniques associated with Materials Science and Technology and Nanomaterials**. The under 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 will be decided by the board of studies (B.O.S) of the department following its acceptance and approval.

Purpose:

The B.Sc. Course is systematically designed where students shall be trained on the fundamentals of Physics, Chemistry Mathematics, and Computational Techniques required for understanding and designing of materials. During framing of this syllabus for B.Sc. (Honours) in Materials Science, substantial weightage has been given in both the core subjects as well as skill and ability enhancement of the students. The ultimate goal of the syllabus is to enable the students to have an in-depth knowledge of the subject/s and enhance their scope of employment in the industry. **The programme shall also enable students to develop a deep understanding of various aspects of computational materials science**.

Structure of the Course:

First year of under-graduate study (Semester I &II): During the first two semesters students shall be exposed with six core courses, giving emphasis on basic sciences and mathematics to teach materials behaviour: atomic bonding, thermodynamics, mechanics, and crystal defects. Along with these core courses, special emphasis shall be given to make students digitally equipped. They will learn to handle **computational software** and tool like **MATLAB along with programming language C, Python.**

Second year of under-graduate study (Semester III &IV): The scientific foundation shall be further strengthened by a strong curriculum content consisting of courses in**:** Kinetics of Materials and Transport Phenomena, Materials Behaviour: Mechanical, Electrical & Magnetic, Structure of Materials and processing of materials. A vibrant set of skill enhancement elective (Basics of Artificial Intelligence; Basics of Block Chain Technology, Basics of IOT, Basics of AR/VR) and generic elective (Thinking and Acting like an Entrepreneur; Disciplined approach to Social Entrepreneurship) 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.

Third year of under-graduate study (Semester V &VI): 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. The summers are about giving an exposure to practice materials research through mini-projects, as well as industrial visits.

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. Calcutta University, West Bengal (Consulted for CBCS structure of B.Sc (H) course and for the subject for basic Physical Science)

3. Delhi University, Delhi (Consulted for CBCS structure of B.Sc (H) course and for the subject for basic Physical Science)

4. IIT Kharagpur, 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)

As per the rules of MAKAUT WB, a total of 120 credit points has to be earned by the student to obtain the degree of B.Sc (General) in Materials Science while further 20 credit has to be earned from online MOOCs (Massive Open Online Courses) offered by Coursera, edX, SWAYAM/nptel, nanoHub etc. to get the degree of B.Sc (Honours) in 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: 10+2 Pass-out from any board with Physics/Chemistry, Mathematics/Statistics, Computer Science subject combination. Cut-off marks will be decided by the competent authority.

Duration of the Course: 3 years

Student Intake: 30

OUTLINE OF CHOICE BASED CREDIT SYSTEM

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 Dissertation/Project: An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate study such a course on his own with an advisory support by a teacher/faculty member is called dissertation/project.

2.3 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. Ability Enhancement Courses (AEC): The Ability Enhancement (AE) Courses may be of two kinds: **Ability Enhancement Compulsory Courses (AECC)** and **Skill Enhancement Courses (SEC).** "**AECC**" courses are the courses based upon the content that leads to Knowledge enhancement;

i. Environmental Science and **ii. English/MIL Communication**. These are mandatory for all disciplines. **SEC** courses are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc.

3.1 Ability Enhancement Compulsory Courses (AECC): Environmental Science, English Communication/MIL Communication.

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

- Introducing Research Component in Under-Graduate Courses

Project work/Dissertation is considered as a special course involving application of knowledge in solving / analyzing /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.

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Curriculum Structure

Semester-I							
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Total no of contact hours**			**Credits**
				L	T	P	
Theory							
1	Core Course I	BMS101	Introduction to Materials	3	1	0	4
2	Core Course II	BMS102	Classical Physics for Materials Science	3	1	0	4
3	Core Course III	BMS103	Mathematics I: Vector & Calculus	3	1	0	4
4	Generic Elective I	BMS104	Statistical Methods for Materials Science - I	3	1	0	4
Total Theory				12	4	0	16
Practical							
1	Laboratory I	BMS191	Macroscopic and Microscopic Examination of Materials	0	0	4	2
2	Laboratory II	BMS192	Introduction to Programming using C and MATLAB	0	0	4	2
Total Practical				0	0	8	4
Sessional							
1	Ability Enhancement Compulsory Course (AECCI)	BMS 105	Communicative English	2	0	0	2
Total of Semester-I				14	4	8	22

Semester-II							
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Total no of contact hours**			**Credits**
				L	T	P	
Theory							
1	Core Course IV	BMS201	Quantum Physics for Materials Science	3	1	0	4
2	Core Course V	BMS202	Materials Chemistry	3	1	0	4
3	Core Course VI	BMS203	Mathematics II: Linear Algebra	3	1	0	4
4	Generic Elective II	BMS204	Statistical Methods for Materials Science-II	3	1	0	4
5	Elective III	BMS205	MOOCs Based Course	3	0	0	3
Total Theory				15	4	0	19
Practical							
1	Laboratory I	BMS291	Materials Synthesis Lab	0	0	4	2
2	Laboratory II	BMS292	Data Analysis, Visualization and Interpretation using MATLAB	0	0	4	2
Total Practical				0	0	8	4
Sessional							
1	Ability Enhancement Compulsory Course (AECCII)	BMS 206	Environment & Sustainability	2	0	0	2
Total of Semester-II				17	4	8	25

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Semester-III							
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Total no of contact hours**			**Credits**
				L	T	P	
Theory							
1	Core Course VII	BMS301	Thermodynamics of Materials	3	1	0	4
2	Core Course VIII	BMS302	Kinetics of Materials and Transport Phenomena	3	1	0	4
3	Core Course IX	BMS303	Structure of Materials	3	1	0	4
4	Generic Elective III	BMS304	Thinking and Acting like an Entrepreneur	3	0	0	3
5	Elective IV	BMS305	MOOCs Based Course	3	0	0	3
Total Theory				15	3	0	18
Practical							
1	Laboratory I	BMS391	Introduction to Programming using Python	0	0	4	2
2	Laboratory II	BMS392	Introduction to Finite Element Analysis	0	0	4	2
Total Practical				0	0	8	4
Sessional							
1	Skill Enhancement Course I(A/B/C/D)	BMS 306	SEC– I (Choose either of A/B/C/D from the corresponding table)	2	0	0	2
Total of Semester-III				17	3	8	24

Semester-IV							
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Total no of contact hours**			**Credits**
				L	T	P	
Theory							
1	Core Course X	BMS401	Phase Equilibria and Phase Transformation	3	1	0	4
2	Core Course XI	BMS402	Materials Behavior: Mechanical, Electrical & Magnetic	3	1	0	4
3	Core Course XII	BMS403	Processing of Bulk Materials	3	1	0	4
4	Generic Elective IV	BMS404	Disciplined approach to Social Entrepreneurship	2	0	4	4
5	Elective V	BMS405	MOOCs Based Course	3	0	0	3
Total Theory				14	3	4	19
Practical							
1	Laboratory I	BMS491	Intermediate Programing with Python	0	0	4	2
2	Laboratory II	BMS492	Materials Behavior Lab	0	0	4	2
Total Practical				0	0	8	4
Sessional							
1	Skill Enhancement Course II(A/B/C/D)	BMS 406	SEC– II (Choose either of A/B/C/D except the course chosen in SEC-I from the corresponding table)	2	0	0	2
Total of Semester-IV				16	3	12	25

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Curriculum Structure

Semester-V							
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Total no of contact hours**			**Credits**
				L	T	P	
Theory							
1	Core Course XIII	BMS501	Thin films and Nano Materials	3	1	0	4
3	Core Course XIV	BMS502	Materials Behavior: Electronic and Optical	3	1	0	4
2	Discipline Specific Elective I (A/B/C/D/E/F)	BMS503	DSE – 1 (Choose either of A/B/C/D/E/F from the corresponding table)	3	0	0	3
4	Discipline Specific Elective II	BMS504	DSE II– (MOOCs Based Course)	6	-	-	6
			Total Theory	15	2	0	17
Practical							
1	Laboratory I	BMS591	Nano-Materials Lab	0	0	4	2
			Total Practical	0	0	4	2
Sessional							
1	Elective Course	BMS581	Project Work	0	0	6	3
			Total of Semester-V	15	2	10	22

Semester-VI							
Sl. No.	**Category**	**Subject Code**	**Subject Name**	**Total no of contact hours**			**Credits**
				L	T	P	
Theory							
1	Core Course XV	BMS601	Materials Characterization	3	1	0	4
2	Core Course XVI	BMS602	Design and Selection of Materials	3	0	2	4
3	Discipline Specific Elective III (A/B/C/D/E/F)	BMS603	DSE – III (Choose either of A/B/C/D/E/F except the course chosen in DSE I from the corresponding table)	3	0	0	3
3	Discipline Specific Elective IV	BMS604	DSE IV– (MOOCs Based Course)	6	-	-	6
			Total Theory	15	1	2	17
Practical							
2	Laboratory I	BMS692	Materials Characterization Lab	0	0	4	2
			Total Practical	0	0	4	2
Sessional							
1	Elective Course	BMS681	Project Work	0	0	6	3
			Total of Semester-VI	15	1	12	22

SEM	Core Course (16) 84 credit courses	Ability Enhancement Compulsory Course (AECC) (2) 4 credit courses	Skill Enhancement Course (SEC) (2) 4 credit courses	Elective: Discipline Specific (DSE) (4) 24 credit courses	Elective: Generic (4) 24 credit courses
				Out of 48 credit under elective course, a student has to earn 20 credit from MOOCs based courses	
I (22)	**C1:** Introduction to Materials **(4)** **C2:** Classical Physics for Materials Science **(4)** **C3:** Mathematics I: Vector & Calculus **(4)** **Lab I (2)** **Lab II (2)**	Communicative English **(2)**			Statistical Methods for Materials Science – I **(4)**
II (25)	**C1:** Quantum Physics for Materials Science **(4)** **C2:** Materials Chemistry **(4)** **C3:** Mathematics II: Linear Algebra **(4)** **Lab I (2)** **Lab II (2)**	Environment & Sustainability **(2)**			Statistical Methods for Materials Science-II **(4)** From MOOCs Based course **(3)** credit courses
III (24)	**C1:** Thermodynamics of Materials **(4)** **C2:** Kinetics of Materials and Transport Phenomena **(4)** **C3:** Structure of Materials **(4)** **Lab I (2)** **Lab II (2)**		(A) Basics of AI; (B)Basics of Block Chain Technology, (C) Basics of IOT, (D) Basics of AR/VR **(2)** *(Choose either of A/B/C/D from the corresponding table)*		Thinking and Acting like an Entrepreneur **(4)** From MOOCs Based course **(3)** credit courses
IV (25)	**C1:** Phase Equilibria and Phase Transformation **(3)** **C2:** Materials Behavior: Mechanical, Electrical &		(A)Basics of AI; (B)Basics of Block Chain Technology, (C) Basics of IOT, (D) Basics of		Disciplined approach to Social Entrepreneurship **(4)**

	Magnetic **(4)**		AR/VR **(2)** *(Choose either of A/B/C/D except the course chosen in SEC-I from the*		
	C3: Processing of Bulk Materials **(4)**				From MOOCs Based course **(3)** **credit courses**
	Lab I (2)				
	Lab II (2)				

			corresponding table)		
V **(22)**	**C1:** Thin films and Nano Materials **(4)**			(A)Metallic Materials, (B)Polymeric Materials, (C)Ceramic Materials, (D)Composites Materials, (E)Bio materials, (F)Energy Materials **(3)** *(Choose either of A/B/C/D/E/F from the corresponding table)*	
	C2: Materials Behavior: Electronic and Optical **(4)**			DSE II From MOOCs Based course **(6 = 2+2+2 or 3+3)** **credit courses**	
	Lab I (2)			Project Work **(3)**	
VI **(22)**	**C1:** Materials Characterization **(4)**			(A)Metallic Materials, (B)Polymeric Materials, (C)Ceramic Materials, (D)Composites Materials, (E)Bio materials, (F)Energy Materials **(3)** *(Choose either of A/B/C/D/E/F except the course chosen in DSE-I from the corresponding table)*	
	C2: Design and Selection of Materials **(4)**			DSE III From MOOCs Based course **(6 = 2+2+2 or 3+3)**	

				credit courses	
	Lab I (2)			Project Work **(3)**	

LIST OF ELECTIVES

SEC courses for SEMESTER –III (BMS 306)

Sl. No.	Course Name	Course Provider	Course Duration	Credits	Name of University/Institute
A	Introduction to Artificial Intelligence	edX	4 weeks	2	Microsoft
B	Basics of Internet of Things (IOT)	coursera	4 weeks	2	University of California, Irvine
C	Basics of Block Chain Technology (BCT)	coursera	4 weeks	2	Association of International Certified Professional Accountants
D	Introduction to XR: VR, AR, and MR Foundations	coursera	4 weeks	2	Unity Technologies

SEC courses for SEMESTER –IV (BMS 406)

Sl. No.	Course Name	Course Provider	Course Duration	Credits	Name of University/Institute
A	Introduction to Artificial Intelligence	edX	4 weeks	2	Microsoft
B	Basics of Internet of Things (IOT)	coursera	4 weeks	2	University of California, Irvine
C	Basics of Block Chain Technology (BCT)	coursera	4 weeks	2	Association of International Certified Professional Accountants
D	Introduction to XR: VR, AR, and MR Foundations	coursera	4 weeks	2	Unity Technologies

DSE courses for SEMESTER –V (BMS 503)

Sl. No.	Course Name
A	Metallic Materials
B	Polymeric Materials
C	Ceramic Materials
D	Composite Materials
E	Bio Materials
F	Energy Materials

DSE courses for SEMESTER –VI (BMS 603)

Sl. No.	Course Name
A	Metallic Materials
B	Polymeric Materials
C	Ceramic Materials
D	Composite Materials
E	Bio Materials
F	Energy Materials

MOOC'S BASED COURSES

For Honours degree student earn minimum of 140 credits in 3 years *[out of which up to maximum 20 credits may be earned from the MOOCs based courses]*

Sl. No.	Course Name	Course Provider	Course Duration	Credits	Name of University/Institute
1	Materials Science: 10 Things Every Engineer Should Know	Coursera	5 weeks	2	University of California, Davis
2	Computational Materials Science	nanoHUB	6 weeks	2	University of Illinois
3	Computational Approach to Materials Science and Engineering	NPTEL	6 weeks	2	IIT Bombay
4	Principles of Machine Learning	edx	6 weeks	2	Microsoft
5	Introduction to High Throughput Materials	Coursera	4 weeks	2	Georgia Institute of Technology
6	Materials in Oral Health	Coursera	4 weeks	2	University of Hong Kong
7	Medical Biomaterials	NPTEL	8 weeks	3	IIT Madras
8	Introduction to Physical Chemistry	Coursera	10 weeks	3	The University of Manchester
9	Introduction to Python for Data Science	edx	6 weeks	2	Microsoft
10	Using Python for Research	edx	12 weeks	4	Harvard University
11	Waste to Energy Conversion	NPTEL	8 weeks	3	IIT Roorkee
12	Fundamental concepts of semiconductors	NPTEL	6 weeks	2	IIT Delhi
13	Diffusion in Multicomponent Solids	NPTEL	12 weeks	3	IIT Kanpur
14	Physics of Materials	NPTEL	8 weeks	3	IIT Madras
15	Optoelectronics Materials and Devices	NPTEL	8 weeks	3	IIT Kanpur
16	Nanotechnology and Nanosensors, Part1	Coursera	5 weeks	2	Technion – Israel Institute of Technology
17	Nanotechnology and Nanosensors, Part 2	Coursera	5 weeks	2	Technion – Israel Institute of Technology
18	Nature and Properties of Materials	NPTEL	8 weeks	3	IIT Kanpur

Marking Scheme followed for evaluation of student's performance

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)
(15 + 5 + 5 + 5)
15 (Internal Test)
5 (Attendance)
5 (Quiz)
5 (Class Assignment)

Marks distribution (of Theory paper) and Question Paper pattern followed in MAKAUT WB in all departments for End semester Examination

Sl. No.	Question Type	No. of Questions	No. of Questions have to attend	Marks Allotted	Total
1.	MCQ	1 (a - j) = 10	10 (All are compulsory)	1 mark each	1 * 10 = 10 marks
2.	Short Answer Type	2 to 7 = 6	3 out of 6	3 marks each	3 * 5 = 15 marks
3.	Long Answer Type	8 to 13 = 6	3 out of 6	15 marks each	3 * 15 = 45 marks
				Total marks	(10+15+45) = 70

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

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

Detailed Syllabus

SEMESTER I

(BMS101) Core Course (CC I): Introduction to Materials **L-T-P: 3-1-0 (Credit - 4)**

COURSE OBJECTIVE:

This course will introduce basic concepts of materials around us, different types of materials. This course will help to understand the science behind the formation of material, evolution of materials science and the structure property correlation.

COURSE OUTLINE:

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

2. Crystal Structure and Lattice Imperfections: Bravais lattices, Symmetry, Bragg's Law, Different types of crystal structure, Atomic Packing Factor, Packing density, Hexagonal close packed structure, Coordination number, Point defect. Line defect. Surface Defect. Volume defect.

3. Introduction of Materials: 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. Many electron theories.

4. Classification and properties of Materials: Level of Structure, Metallic Alloys, Ceramic Materials, Polymeric Materials, Magnetic Materials, Electronic Materials. Brief introduction to properties of materials, Bar-chart of properties of material. their physical properties, and selection. Brief introduction to properties of materials, Mechanical property, Concept of stress and strain, elastic and plastic deformation, hardness, Electrical property, ohm's law, electronic and ionic conduction, energy band structure, intrinsic and extrinsic semiconductor, Thermal property, thermal conductivity and thermal diffusivity.

LEARNING RESOURCES:

1. Materials Science and Engineering – William D. Callister, Jr
2. Materials Science and Engineering, A First Course – V. Raghavan

3. Hyperlinks:

A. Web course---http://nptel.iitm.ac.in

B. http://neon.mems.cmu.edu/cramb/Processing/history.html

(BMS102) Core Course (CC II): Classical Physics for Materials Science **L-T-P: 3-1-0 (Credit - 4)**

COURSE OBJECTIVE:

The course will give deeper understanding of fundamental concepts in mechanics such as force, energy, momentum, SHM etc. needed for further studies in Materials Science. It will introduce basic concept of physics responsible for different physical properties of materials.

COURSE OUTLINE:

1. Fundamentals of Dynamics: Review of Newton’s Laws: Mechanistic view of the Universe. Concepts of Inertial frames, force and mass. Solution of the equations of motion (E.O.M.) in simple force held in one, two- and three-dimensions using Cartesian, cylindrical polar and spherical polar coordinate systems

2. Dynamics of systems of particles: Difficulty of solving the E.O.M. for systems of particles. Newton's third Law. External and Internal forces. Momentum and Angular Momentum of a system. Torque acting on a system. Conservation of Linear and Angular Momentum. Centre of mass and its properties. Two-body problem. Variable- mass system: motion of rocket.

3. Work and Energy: Work - Kinetic Energy Theorem. Conservative Forces: Force as the gradient of a scalar field - concept of Potential Energy. Other equivalent definitions of a Conservative Force. Conservation of Energy. Qualitative study of one-dimensional motion from potential energy curves. Stable and Unstable equilibrium. Energy of a system of particles.

4. Oscillations: SHM: Simple Harmonic Oscillations. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time-average values.

5. Superposition of Harmonic Oscillations: Superposition of Collinear Harmonic oscillations: Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences

LEARNING RESOURCES:

1. An Introduction to Mechanics: Daniel Kleppner and Robert Kolenkow, 2nd Edition 2014, Cambridge University Press
2. Fundamentals of Physics: Halliday, Resnick and Walker, 8th Edition 2008, Wiley
3. Introduction to Classical Mechanics: With Problems and Solutions: David Morin, 2008, Cambridge University Press
4. Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson
5. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley
6. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
7. Mechanics, Berkeley Physics, Vol. 1: Kittel, Knight, Ruderman, Helmholz and Moyer, 2nd Edition 2017, Tata McGraw-Hill

A. Hyperlinks:

A. https://courses.edx.org/courses/SNUx/SNU034.005.1x/1T2014/course/

(BMS103) Core Course (CC III): Mathematics I: Vector & Calculus L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE:

The course will help to understand concepts of vector algebra, matrices and determinants and their properties which would help to use the concept of real-world problems.

COURSE OUTLINE:

1. Vector Algebra and Calculus: Recapitulation of Vector Algebra. Idea of linear independence, completeness, basis and representation of vectors. Properties of vectors under rotations. Scalar product and its invariance under coordinate rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively.

2. Vector Differentiation: Scalar and Vector fields. Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities.

3. Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs). Application of double integrals to compute Area, Mass, Volume. Application of triple integral to compute volume.

4. Matrices: Introduction to the idea of a matrix; equality of matrices; special matrices. Algebraic operations of matrices: commutative property, associative property and distributive property. Transpose of a matrix Properties. Symmetric and Skew symmetric matrices. Eigen-values and Eigenvectors. Cayley- Hamilton Theorem. Diagonalization of Matrices. Functions of a Matrix. Determinants: Properties of determinant (statement only); minor, co-factors and Laplace expansion of determinant; Cramer's rule and its application in solving system of linear equations of three variables.

LEARNING RESOURCES:

Text Books:

1. George Arfken and Hans Weber, "Mathematical Methods for Physicists (4th Edition)" Elsvier
2. I. N. Herstein, "Topics in Algebra", John Wiley and Sons.
3. Mary L. Boas, "Mathematical Methods in the Physical Sciences (3rd Edition)
4. B. S. Grewal, "Higher Engineering Mathematics", Khanna Publication, Delhi.

Reference Books:

1. Gilbert Strang: Introduction to linear algebra
2. Peter V. O'Neil, "Advanced Engineering Mathematics", Seventh Edition, Thomson Learning.
3. M. D. Greenberg, "Advanced Engineering Mathematics", Second Edition, Pearson Education.

(BMS104) Generic Elective (GE I): Statistical Methods for Materials Science - I

L-T-P: 3-1-0
(Credit - 4)

COURSE OBJECTIVE:

The course will help to use concepts of statistics which would help to handle large data in Materials Science.

COURSE OUTLINE:

1. Introduction to Statistics: Definition of Statistics. Basic objectives. Applications in various branches of science with examples. Collection of Data: Internal and external data, Primary and secondary Data. Population and sample, Complete enumeration and sample survey, Chart and Diagrams

2. Descriptive Statistics: Univariate Data: Measures of central tendency, Dispersion and shape, Classification and tabulation of univariate data, graphical representation, Frequency curves. Bivariate data: Scatter diagram, Marginal and conditional frequency distribution. Correlation and Regression.

3. Introduction to Probability

Concept of experiments, sample space, event. Definition of Combinatorial Probability. Conditional Probability, Bayes' Theorem. Axioms, Interpretations, and Properties of Probability

LEARNING RESOURCES:

1. S. M. Ross, "A first course in Probability", Prentice Hall.
2. I. R. Miller, J.E. Freund and R. Johnson, "Probability and Statistics for Engineers". Fourth Edition, PHI.
3. A. M. Mood, F.A. Graybill and D.C. Boes, "Introduction to the Theory of Statistics", McGraw Hill Education.

Laboratory I: Macroscopic and Microscopic Examination of Materials (BMS191)

L-T-P: 0-0-4 (Credit - 2)

1. Macroscopic observation of different materials around us.
2. Microscopic observation of different materials around us
3. Mechanical property evaluation of different types of materials
4. Electrical resistivity evaluation of different types of materials
5. Thermal property evaluation of different types of materials

LEARNING RESOURCES:

1. An advanced course in practical physics, Chattapadhyay and Rakshit.
2. Advanced practical Physics, K. G. Mazumdar.

Laboratory II: Introduction to Programming using C and MATLAB (BMS192)

L-T-P: 0-0-4 (Credit - 2)

Basic programming in C

(a) Introduction to Computers. Computer Systems, Computing Environments, Flow charts. Number Systems: Binary, Octal, Decimal, Hexadecimal Introduction to C Language - Background, C Programs, Identifiers, Data Types, Variables, Constants, Input /Output Statements

(b) Operation and Expressions - Arithmetic operators, relational & logical operators.

(c) Decision Making and Branching. Decision making and Looping

(d) Pointers for Inter-Function Communication, Pointers to Pointers, Compatibility, L value and R value, Arrays and Pointers, Pointer Arithmetic and Arrays, Passing an Array to a Function, Memory Allocation Functions, Array of Pointers, Programming Applications, Pointers to void, Pointers to Functions, Command. Line Arguments. Strings - Concepts, C Strings, String Input/Output Functions, Arrays of Strings, String Manipulation Functions

(e) List of practical: Write a C program:

1. To display your name.
2. For addition of two numbers and display the result.
3. To find maximum between two numbers
4. To check whether a number is divisible by 3 and 7 or not
5. Addition of first 10 natural numbers using while loop
6. To find the factorial of given number
7. To print the Fibonacci series in a given range using recursion.

Basic knowledge of MATLAB

(a) Basic operations in MATLAB and Solution of basic arithmetic

(b) Familiarization of students with the syntax of MATLAB

(c) 2D Plotting of data in MATLAB and statistics problems

(d) Introduction to numerical analysis using C & MATLAB

LEARNING RESOURCES:

1. Yashavant Kanetkar, Let us C, 13th Edition BPB Publication

2. E. Balaguruswamy Programming in ANSI C Tata McGraw-Hill

3. Byron Gottfried Schaum's Outline of Programming with C, McGraw-Hill

4. J H Mathews & K D Fink, Numerical Methods Using Matlab

(BMS 105) Ability Enhancement Compulsory Course (AECC I): Communicative English L-T-P:2-0-0 (Credit - 2)

COURSE OBJECTIVE:

The course will help to use English effectively during the entire course curriculum and enable the learner to communicate effectively and appropriately in real life situation.

1. Vocabulary Enhancement: Synonyms, Antonyms, Prefixes and suffixes. Understanding the proper way of letter writing. Comprehension, Passage reading and question answer handling. Noun, Verb, Adjective. Construction of sentences and passages with proper grammar

2. Spelling and Punctuation: Spelling Pitfalls, Grammar Revisited - Review of parts of speech. Proper pronunciation from language lab. Hearing fluent English and identifying and answering questions. Understanding the proper way to utilize punctuation and spelling Pitfalls

3. Functional English: Language functions: descriptive, expressive and social, Types of language functions: to inform, enquire, attract, influence, regulate and entertain. Understanding the importance of communication. Communication in an organization. Types of communication

4. Writing scientific articles and blogs: Strategies for developing reading skills, Skimming and scanning, Predicting, Inferring, Reading critically. Writing small articles, scientific topic discussion and blogs writing. Avoiding plagiarism

LEARNING RESOURCES:

1. S R Inthira&amp, V Saraswathi, Enrich your English a) Communication skills b) Academic skills, CIEFL &amp, OUP
2. R.C. Sharma and K.Mohan Business Correspondence and Report Writing Tata McGraw Hill , New Delhi , 1994
3. Maxwell Nurnberg and Rosenblum Morris, All About Words- A Text Book for English for Engineers &amp, Technologists General Book Depot, New Delhi, 1995

SEMESTER –II

(BMS201) Core Course (CC IV): Quantum Physics for Materials Science

L-T-P:3-1-0 (Credit - 4)

COURSE OBJECTIVE:
This course will introduce basic concepts of quantum physics and correlation to materials science.

1. Introduction to Quantum mechanics: Plank's-Blackbody radiation/UV catastrophe, Einstein, de-Broglie, Heisenberg Uncertainty principle.

2. Schrodinger Equation: Description of a particle using wave packets. Spread of the Gaussian wave-packet for a free particle in one dimension. Fourier transforms and momentum space wavefunction. Position-Momentum uncertainty.

3. General discussion of bound states in an arbitrary potential: Continuity of wave function, boundary condition and emergence of discrete energy levels. Application to one-dimensional problem square well potential.

4. Quantum mechanics of simple harmonic oscillator: Setting up the eigenvalue equation for the Hamiltonian. Energy levels and energy Eigen functions in terms of Hermite polynomials (Solution to Hermite differential equation may be assumed). Ground state, zero-point energy & uncertainty principle, Quantum mechanics in three-dimension

LEARNING RESOURCES:

1. Introduction to Quantum Mechanics, David J. Griffiths, 2nd Edition 2005, Pearson
2. Quantum Physics: Stephen Gasiorowicz, 3rd Edition 2008, Wiley
3. Practical Quantum Mechanics, Flügge, Siegfried, Springer
4. Quantum Mechanics: An Introduction: Walter Greiner, 2001, Springer
4. The Principles of Quantum Mechanics: P. A. M. Dirac, 4th Edition, 1987, Oxford Science Publication
5. Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.

(BMS202) Core Course (CC V): Materials Chemistry **L-T-P: 3-1-0 (Credit - 4)**

COURSE OBJECTIVE:
This course will introduce basic concepts of materials chemistry, synthesis, properties and applications of different types of materials.

COURSE OUTLINE:

1. Basic concepts of Atomic Structure: Know the states of matter, understand atomic electron energy levels, the associated quantum numbers and their relationship to the periodic table, Mathematical describe a wave, Understand the concept of wave-particle duality of light, descriptively explain the Schrodinger's wave equation, Understand atomic bonding and the formation of bands

2. Chemical Bonding: Hybridization, Introduction to Metal organic frame work, GOF, Organometallic. Use of free energy considerations in metallurgy through Ellingham diagrams, Ionic, dipolar and van Der Waals interactions.

3. Acid Base in Chemistry: Identify endothermic/exothermic reactions. Discuss reversibility of chemical reactions. Discuss reaction kinetics and rate equations. Explain function of catalyst, Define acids/bases (Lowry-Bronsted and Lewis) and strength of acids/bases and pH, Calculate pH of aqueous solutions, Explain the functionality of a buffer, Calculate enthalpy changes associated with a chemical reaction

4. Electrochemistry: Chemistry and electricity, Electrochemical cells, Potential differences at interfaces, Standard half-cell potentials, The Nernst equation, Concentration cells, Analytical applications of the Nernst equation, Determination of solubility products, Potentiometric titrations, Measurement of pH, Membrane potential Electrochemical Corrosion,

LEARNING RESOURCES:
1. Materials Chemistry: Bradley D. Fahlman, 3rd Edition, Springer
2. Chemistry: Principles and Applications, by M. J. Sienko and R. A. Plane

(BMS 203) Core Course (CC VI): Mathematics II: Linear Algebra

L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE:
This course will introduce students with linear algebra and complex variables. It will help students to apply mathematical skills in writing mathematical equations to solve material science problems computationally.

COURSE OUTLINE:

1. First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral. (c) Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration.

2. Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes. Diffusion Equation.

3. Laplace Transform (LT): Definition; Existence of LT; LT of elementary functions; First and second shifting properties; Change of scale property; LT of derivative of functions. Convolution theorem (statement only). Inverse LT; Solution of ODE's (with constant coefficients) using LT

4. Complex variables: Introduction to complex variables, Analytic functions, General Cauchy Theorem, Real-Differentiability and the Cauchy-Riemann Equations. Exponential Function. Harmonic Functions

LEARNING RESOURCES:

1. Calculus Volume I and II, Tom Apostol, John Wiley and Sons Inc.
2. Bartle and Sherbert, Introduction to Real Analysis, Third edition, Wiley-India \item Complex Analysis, V.L Ahlfors, McGraw-Hill Inc.
3. Finite Dimensional Vector Spaces, P. R.Halmos, Springer.
4. Introduction To Matrices And Linear Transformations, D.T. Finkbeiner,Courier Corporation.
5. Linear Algebra, S. Lipschutz and M.L.Lipson, Schaums Outline Series, 2009 McGraw Hill.

(BMS 204) Generic Elective (GE II): Statistical Methods for Materials Science-II

L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE:
This course will introduce basic probability and statistics which will help to handle large data set.

COURSE OUTLINE:

1. Introduction to Probability, Probability distributions: discrete & continuous distributions, Binomial, Poisson and Geometric distributions, Uniform, Exponential, Normal, Weibull Distribution, Probability spaces, conditional probability, independence;

2. Discrete random variables, Independent random variables, the Multinomial distribution, Poisson approximation to the Binomial distribution, infinite sequences of Bernoulli trials, sums of independent random variables; Expectation of Discrete Random Variables, Moments, Variance of a sum, Correlation coefficient, Chebyshev's Inequality.

3. Sampling Techniques: Random Sampling. Sampling from finite and infinite populations. Estimates and standard error (sampling with replacement and sampling without replacement), Sampling distribution of sample mean, stratified random sampling

4. Estimation and Hypothesis testing. Multivariate Data Analysis, Maximum likelihood estimate

5. Coefficient of determinant, R square, Residual Analysis, Chi square, p-value, Test for single mean, difference of means and correlation coefficients, test for ratio of variances - Chi-square test for goodness of fit and independence of attributes.

LEARNING RESOURCES:

1. S. M. Ross, “A first course in Probability”, Prentice Hall.
2. I. R. Miller, J.E. Freund and R. Johnson, “Probability and Statistics for Engineers”. Fourth Edition, PHI.
3. A. M. Mood, F.A. Graybill and D.C. Boes, “Introduction to the Theory of Statistics”, McGraw Hill Education.

(BMS 205) Elective III: DIFFUSION IN MULTICOMPONENT SOLIDS

L-T-P: 3-0-0 (Credit - 3)

COURSE OBJECTIVE:
This course will introduce basic knowledge of diffusion in multicomponent solids.

COURSE OUTLINE:

Basics of thermodynamics: laws of thermodynamics, concept of chemical potentials and criteria for equilibrium.

Refresher on Solution Thermodynamics and Phase Stability

Phenomenology of multicomponent diffusion and various frames of reference used for measuring diffusion fluxes

Solving diffusion equation for various boundary conditions including solution of multicomponent diffusion equation

Self diffusion, impurity diffusion, interdiffusion and intrinsic diffusion; Experimental determination of interdiffusion and intrinsic diffusion coefficients

Point defects in crystalline solids and mechanisms of diffusion

Random walk, diffusivity and correlation effects in diffusion

Derivation of correlation factors in some crystalline lattices

Derivation of fundamental driving forces for diffusion: chemical potential gradients and atomic mobilities; cross effects in multicomponent diffusion driven by defect mechanisms

Interrelation between multicomponent diffusion coefficients, atomic jump frequencies and thermodynamic factors

Multiphase diffusion, diffusion structures and phase diagrams

Experimental determination of activation energies for diffusion; Fast diffusion paths: Grain boundary and pipe diffusion

LEARNING RESOURCES:

https://nptel.ac.in/courses/113/104/113104097/

Laboratory I: Materials Synthesis Lab (BMS 291) L-T-P: 0-0-4 (Credit - 2)

1. To determine chloride ion in a given water sample by Argentometric method (using chromate indicator solution)
2. Determination of surface tension and viscosity
3. Thin layer chromatography
4. Ion exchange column for removal of hardness of water.
5. Stereochemistry Lab using software ChemDraw, Chem3D Ultra

Laboratory II: Data Analysis, Visualization and Interpretation using MATLAB (BMS 292)

L-T-P: 0-0-4 (Credit - 2)

1. Basic operations in MATLAB
2. Various loops and scripts
3. Functions of MATLAB
4. 3D plotting of data of materials science and statistics, mesh, surface, plots with special graphics
5. Application of Programming to solve numerical analysis, Cubic method. Bisection method, Errors in numerical computation, Finite differences, Interpolation, Numerical integration and differentiation, Numerical solution of first order differential equations, Systems of linear equations, Methods of least squares, Matrix eigenvalues

(BMS206) Ability Enhancement Compulsory Course (AECC II): Environment & Sustainability

L-T-P: 2-0-0 (Credit - 2)

COURSE OBJECTIVE:
This course will students to nurture the environment and to take care of it. It will help students to know the importance of natural resources and the need for the preservation.

COURSE OUTLINE:
1. Introduction to environmental studies & ecosystems: Multidisciplinary nature of environmental studies: Scope and importance; what is an ecosystem? The structure and function of ecosystem, Energy flow in an ecosystem, food chains, food webs and ecological succession, forest ecosystem, grassland ecosystem, desert ecosystem, aquatic ecosystems

2. Natural resources & its management and conservation: Land resources and land use change: Land degradation, soil erosion and desertification; Deforestation: Causes and impacts, forests, biodiversity and tribal populations; Water: Use and over-exploitation of surface and ground water. Energy resources: Renewable and non-renewable energy sources, use of alternate energy sources and growing energy needs.

3. Environmental pollution & management: Environmental pollution: types, causes, effects and controls; Air, water, soil and noise pollution, Solid waste management: Control measures of urban and industrial waste. Climate change, global warming, Environment Laws: Environment Protection Act, Air (Prevention & Control of Pollution) Act, Water (Prevention and control of pollution) Act, Wildlife Protection Act, Forest Conservation Act; International agreements: Montreal and Kyoto protocols and Convention on Biological Diversity (CBD)

4. Environment & social issues: Human population growth: Impacts on environment, human health and welfare; Resettlement and rehabilitation of project affected persons; case studies; Disaster management: floods, earthquake, cyclones and landslides; Environmental ethics: environmental conservation; environmental communication and public awareness.

LEARNING RESOURCES:

1. Carson, R. 2002. Silent Spring. Houghton Mifflin Harcourt.
2. Gadgil, M., & Guha, R. 1993. This Fissured Land: An Ecological History of India. Univ. of California Press.
3. Gleeson, B. and Low, N . (eds.) 1999. Global Ethics and Environment, London, Routledge.
4. Gleick, P. H. 1993. Water in Crisis. Pacific Institute for Studies in Dev., Environment & Security. Stockholm Env. Institute, Oxford Univ. Press.
5. Groom, Martha J., Gary K. Meffe, and Carl Ronald Carroll. Principles of Conservation Biology. Sunderland: Sinauer Associates, 2006.
6. Grumbine, R. Edward, and Pandit, M.K. 2013. Threats from India's Himalaya dams. Science,339: 36-37.

SEMESTER – III

(BMS 301) Core Course (CC VII): Thermodynamics of Materials

L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE:
This course will introduce basic concepts of materials thermodynamics and help to understand how the entropy of the material changes on the application of heat.

COURSE OUTLINE:

1. **Zeroth and First Law of Thermodynamics**: Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature. Concept of Work & Heat, State Functions, Internal Energy and First Law of Thermodynamics. Its differential form, First Law & various processes. Applications of First Law: General Relation between C_p and C_V, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Coefficient.
2. **Second Law of Thermodynamics**: Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence.
3. **Carnot's Theorem. Applications of Second Law of Thermodynamics**: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.
4. **Entropy**: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature-Entropy diagrams for Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero

LEARNING RESOURCES:

1. Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.
2. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
3. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.

(BMS 302) Core Course (CC VIII): Kinetics and Transport Phenomena of Materials
L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE:
This course will introduce basic concepts of Thermal and Transport Properties in materials. It will make understand the learners how energy transport within the material.

COURSE OUTLINE:

Thermal and Transport Properties of Materials: The thermo-physical and transport properties of solids and fluids, i.e. heat capacity, expansion, viscosity, conduction, convection, and radiation are discussed, along with thermal analysis instrumentation.

1. **Introduction to Transport Phenomena:** Basics of momentum transport: Euler/Lagrangian viewpoint, laminar and turbulent flows, boundary layers, stress tensor.
2. **Shell momentum balances:** Equations of change, dimensional analysis, applications to isothermal flow of Newtonian & non-Newtonian fluids.
3. **Basics of energy transport:** Conductive, convective radiation, dissipation of heat fluxes, steady state, non-steady state heat transfer. Equations of change for non-isothermal systems, dimensional analysis, and applications to steady-state conduction & convection.
4. **Basics of mass transport:** Mechanisms, and mass & molar fluxes, Derivation of equation of continuity for a binary mixture and its application to convection-diffusion problems. Heat transfer.
5. **Diffusion**: Fick's First and Second Laws. Atomistic mechanisms of diffusion: interstitial and substitutional diffusion. Diffusion paths: lattice, grain boundary, Steady vs. unsteady state diffusion.

LEARNING RESOURCES:

1. Transport Phenomena: R. B. Bird, W. E. Stewart, and E. S. Lightfoot, 2nd Edition 2002, Wiley
2. Analysis of Transport Phenomena: W. M. Deen, 1998, Oxford University Press.
3. Fundamentals of Momentum, Heat, and Mass Transfer: J. Welty, C. E. Wicks, R. E. Wilson, and G. L. Rorrer, 5th Edition 2007, Wiley.
4. Introduction to Transport Phenomena: W. J. Thompson, 2000, Prentice Hall.
5. Unit Operations of Chemical Engineering: Warren McCabe, Julian Smith and Peter Harriott, 7th Edition 2017, McGraw-Hill

(BMS 303) Core Course (CC IX): Structure of Materials

L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE:

This unit introduces the concept of a microstructure in materials science and how the property changes depending on the microstructure. The importance of microstructure in determining material properties is introduced.

COURSE OUTLINE:

1. **Crystal Structure**: Crystal systems. Bravais lattices. Symmetry. Miller indices of directions and planes. Bragg's Law. Close-Packed structures: CCP, HCP. Voids in close-packed structures. Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis Central and Non-Central Elements. Reciprocal Lattice, Atomic and Geometrical Factor.
2. **Polymorphism and Allotropy**, Materials of Importance—Tin (Its Allotropic Transformation) Crystal Systems, crystallographic points, directions, and planes, point coordinates, crystallographic directions, crystallographic planes, linear and planar densities
3. **Crystalline Materials:** Single Crystals, Polycrystalline Materials, Anisotropy, X-Ray Diffraction: Determination of Crystal Structures, Non-crystalline Solids
4. **Metallic Materials:** Metals and alloys, Ferrous alloys, Steel, the Phase rule and phase diagrams of Fe-C system and common non-ferrous alloys, Eutectic, Eutectoid, Peritectic diagrams, TTT diagram, Liver rule.
5. **Polymeric Materials:** Classification of Polymers, Structure of Long Chain Polymers, Crystallinity of Long Chain Polymers. polymerizations processes, step polymerizations and addition polymerization, degradation and stabilization of polymers, conducting polymers, common polymers, their synthesis, properties and applications.
6. **Ceramic materials:** Crystal Structures, Silicate Ceramics, Carbon, Imperfections in Ceramics, Ceramic Phase Diagrams

LEARNING RESOURCES:

1. Materials Science and Engineering – William D. Callister, Jr
2. Materials Science and Engineering, A First Course – V. Raghavan
3. Mechanical Metallurgy, George E Dieter. Mcgraw Hill, London.
4. Introduction to Materials Science and Engineering-Web course---http://nptel.iitm.ac.in
5. http://neon.mems.cmu.edu/cramb/Processing/history.html

(BMS 304) Generic Elective (GE III): Thinking and Acting like an Entrepreneur

L-T-P: 3-0-0 (Credit - 3)

COURSE OBJECTIVE:

Gain an understanding of how Entrepreneurial Thought and Action may be applied to opportunities of all kinds including new ventures as well as innovation within existing organizations, in both for profit and not for profit sectors. While the idea itself is an important prerequisite for success, it was rather what these individuals did with it that enabled them to become the success that they are today This course helps you to turn your idea into a real-life business and make it a commercial success. Learn and use a methodology to develop and assess new opportunities that forms the critical first step in moving an idea from concept to launch and implementation

COURSE OUTLINE:

1. **Entrepreneurship**: Theories of Entrepreneurship, Role and Importance of Entrepreneur in Economic Growth
2. **Entrepreneurial Behaviors**: Entrepreneurial Motivation, Need for Achievement Theory, Risk- taking Behavior, Innovation and Entrepreneur
3. **Entrepreneurial Traits**: Definitions, Characteristics of Entrepreneurial Types, Functions of Entrepreneur. Funding---venture capital sources & documentation required
4. **Entrepreneurial Development Program** (EDP), EDPs role, relevance and achievements Role of Government in organizing EDPs, Legal requirements for establishment of a new unit related to tourism

LEARNING RESOURCES:

1. Drucker P.F (2004); Innovation and Entrepreneurship; Elsevier, UK
2. Sexton. D.L & Smilor. R.W (2007); The Art and Science of Entrepreneurship; Springer Science & Business Media
3. Drucker; All Books that are Entitled Strategic Management, Business;
4. Glueck & Robinson; Strategic Management;

Laboratory I: Introduction to Programming using Python (BMS 391)

L-T-P: 0-0-4 (Credit - 2)

1. Introduction to programming in python: Features, setting up path, Working with Python Basic Syntax, Variable and Data Types, Arrays 1D, 2D and Multi-dimensional Arrays, Sparse Matrices. Polynomial representation

2.. Operator Conditional Statements If, If-else, Nested if-else, Looping, For, While, Nested loops Control Statements Break, Continue, Pass String Manipulation

3. Accessing Strings, Basic Operations, String slices, Function and Methods Lists Introduction, accessing list, Operations, working with lists, Function and Methods Tuple Introduction, Accessing tuples

4. List of Practical: 1. Implementation of array operations. 2. Stacks and Queues: adding, deleting elements. 3. Circular Queue: Adding & deleting elements 4. Merging Problem: Evaluation of expressions operations on Multiple stacks & queues 5. Implementation of linked lists: inserting, deleting, inverting a linked list.

Laboratory II: Introduction to Finite Element Analysis (BMS 392)

L-T-P: 0-0-4 (Credit - 2)

1. Introduction to FEM & concepts
2. Mathematical concepts of finite element
3. 1-D BVP problems of 1st order
4. FEM in one dimension
5. Applications: Stiffness of beam and trusses
6. Finite elements in solid mechanics.
7. Application to inviscid flows.
8. Application to viscous fluid mechanics

(BMS 306) Skill Enhancement Course (SEC I) (Choose any one of BMS 306 A/B/C/D)

L-T-P: 2-0-0 (Credit - 2)

BMS 306 (A) INTRODUCTION TO ARTIFICIAL INTELIGENCE

COURSE OBJECTIVE

Artificial Intelligence will define the next generation of software solutions. This computer science course provides an overview of AI, and explains how it can be used to build smart apps that help organizations be more efficient and enrich people's lives. It will help learners to understand how AI can be used to solve materials science problems

COURSE OUTLINE

Introduction to AI. Introduction to neural network, machine learning. Different types of neural network. Activation functions. Back propagation method. Application of AI in solving materials science problem. Text and Speech-Understanding Language, Computer Vision-Seeing the World Through AI, Building AI projects, AI and Society

LEARNING RESOURCES:

1. Introduction to Artificial Intelligence: G. Goswami; Paperback-2013.

2. Hyperlink: https://www.coursera.org/learn/ai-for-everyone/home/welcome

BMS 306 (B) BASICS OF BLOCK CHAIN TECHNOLOGY

COURSE OBJECTIVE

The course covers many key topics in the blockchain space. These include distributed systems and alternative consensus mechanisms, crypto economic and proof-of-stake, fundamental applications of bitcoin and blockchain technology

COURSE OUTLINE

Distributed Systems and Alternative Consensus, Crypto economics and Proof-of-Stake, Enterprise Blockchain: Real-World Applications, Scaling Blockchain: Cryptocurrencies for the Masses, Regulation and Anonymity, A Blockchain-Powered Future

LEARNING RESOURCES:

1. Blockchain Technology Explained: The Ultimate Beginner's Guide About Blockchain Wallet, Mining, Bitcoin,
2.Ethereum, Litecoin, Zcash, Monero, Ripple, Dash, IOTA And Smart Contracts: A. T. Norman; Paperback, 2017.
3. Hyperlink: https://www.edx.org/course/blockchain-advancing-decentralized-technology

BMS 306 (C) BASICS OF IOT

COURSE OBJECTIVE

The course will help to learn about the 'things' that get connected in the Internet of Things to sense and interact with the real-world environment. If we consider the IoT as giving the internet the ability to feel and respond, this course is about the devices that feel and the devices that respond. Students will learn IoT sensors, actuators and intermediary devices that connect things to the internet, as well as electronics and systems, both of which underpin how the Internet of Things works and what it is designed to do.

COURSE OUTLINE

1. Generate IoT concepts and design IoT solutions. Map out the process for an IoT solution, and identify the sensors and other devices required. Evaluate different infrastructure components and network systems, and design the basic network for your IoT ideas.

2. IoT sensors to appear industrial sensors – Description & Characteristics–First Generation – Description & Characteristics–Advanced Generation – Description & Characteristics–Integrated IoT Sensors – Description & Characteristics– Polytronics Systems – Description & Characteristics–Sensors' Swarm – Description & Characteristics–Printed Electronics – Description & Characteristics–IoT Generation Roadmap

3. Technological analysis, Wireless Sensor Structure–Energy Storage Unit–Power Management Unit–RF Unit– Sensing Unit

LEARNING RESOURCES:

1. Internet of Things with Python: G. C. Hillar, Packt Publishing Limited.
2. Hyperlink: https://www.edx.org/micromasters/curtinx-internet-of-things-iot

BMS 306 (D) BASICS OF AR/VR

COURSE OBJECTIVE: The course is introduced to enable learners to enhance their creative skill. It will help to fulfill three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects.

COURSE OUTLINE

VR Design overview, Overview of guidelines, methods, tools; pick team & problem, Physical prototype of potential solution, Overview of tool choices, digital prototype of (key aspects of) solution, AR Overview of guidelines, methods, tools; pick team & problem, Digital Prototyping for AR

LEARNING RESOURCES:

1. Augmented human, Dr. Helen Papagiannis
2. The VR Book: Human-Centered Design for Virtual Reality
3. https//www.coursera.org/learn/xr-introduction

SEMESTER – IV

(BMS 401) Core Course (CC X): Phase Equilibria and Phase Transformation

L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE

It will help to understand the importance and significance of phase equilibrium and phase change from one state to another upon change in energy. The course will help to understand how the with the thermodynamically changes within the material phase changes.

COURSE OUTLINE

1. Phases: Phase transitions, PVT behavior; description of materials – Ideal gas description, van der Waals and cubic equation of state (EOS), Virial EOS, Reduced conditions & corresponding states theories, correlations in description of material properties and behavior

2. Solution Thermodynamics: Fundamental property relationships, free energy and chemical potential, partial properties, definition of fugacity and fugacity coefficient of pure species and species in solution, the ideal solution and excess properties, thermodynamic properties of typical solutions and relationship to molecular interactions

3. Liquid phase properties from vapor – liquid equilibrium (VLE): Gibbs energy, heat effects and property change on mixing Liquid phase properties from VLE, Gibbs energy, heat effects and property change on mixing.

4. VLE at low to moderate pressures: Equilibrium, phase rule & Duhem's theorem, graphical understanding of phase behavior of mixtures, activity coefficient and its use in VLE analysis, Raoult's and Henry's Law approximations, Flash calculations, Bubble and Dew point calculations, Properties of fluids from equations of state

5. Solid State Phase Equilibrium, Phase transformations & multiphase equilibrium. Solubility Limit. One-Component (or Unary) Phase Diagrams. Binary phase diagrams. The Gibbs Phase Rule. Binary Eutectic Systems. Development of Microstructure in Eutectic Alloys. Materials of Importance—Lead-Free Solders. Ceramic and Ternary Phase Diagrams

LEARNING RESOURCES:

1. Introduction to Chemical Engineering Thermodynamics: J. M. Smith, H. C. van Ness and M. M. Abbott, 7th Edition, McGraw – Hill

2. Fundamentals of Thermodynamics: Claus Borgnakke and Richard E. Sonntag, 2009, Wiley

3. Chemical, Biochemical and Engineering Thermodynamics: Stanley I. Sandler, 5th Edition 2017, Wiley

(BMS 402) Core Course (CC XI): Materials Behavior: Mechanical, Electrical & Magnetic
L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE

The course will give a a fundamental understanding of stress-strain curves and it will help to relate the macroscopic mechanical behavior of materials with the microscopic defects present in them. It will help to classify different types of magnetic materials and help to understand how the electrical property changes on application of temperature or defects.

COURSE OUTLINE

1. Mechanical Behavior: States of stress and strain Transformation of stresses in 2-d; Mohr's circle for stress in 2-d Transformation of stress in 3-d; Mohr's circle for stress in 3-d Strain; strain deviator; Mohr's circle for strain Elasticity: origins, isotropic materials, anisotropic material Stress-strain curves; plasticity; empirical relations for stress and strain, criteria for necking, Yield Criteria, Plasticity and the theoretical strength of materials.

2. Deformations: Defects in crystalline solids. Slip by dislocation motion and dislocation theory, Implications of dislocation motion and dislocation multiplication, Slip in crystalline solids, Deformation twinning and kink bands, Elastic properties of dislocations, Dislocations in common crystal structures. Dislocation mobility, stress-strain behavior, and yield point phenomena, Obstacle-based strengthening; introduction to strengthening mechanisms. Work/strain hardening, Grain size hardening, Solid solution hardening and strain aging, Precipitation hardening, Strain gradient hardening and deformation of multiphase aggregates.

3. Electrical properties: Ohm's law, Electrical conductivity. Energy band structures in solids. Conduction in terms of band and atomic bonding models. Electrical resistivity of metals. Electrical characteristics of alloys. Semi conductivity. Temperature dependence of carrier concentration, dielectric behavior, capacitance

3. Introduction to Magnetism: Classification, Dia, Para, Ferro, Antiferro and Ferrimagnetism, Hysteresis in magnetic materials, Langevin and Weiss theories. Quantum theory of diamagnetism, Para magnetism, Hund rule, Crystal field splitting, Exchange interaction, Magnetic anisotropy, Magnetic domains, Magnetic order

LEARNING RESOURCES:

1. A.S.M. Handbook-Vol. 14, Forming and Forging, ASM International.

2. Metal Forming Handbook, Schuler, Springer Berlin Heidelberg.

3. Metal Forming Science and Practice, Ed. John G Lenard, Elsevier Science Ltd., U.K.

4. Electronic, Magnetic, and Optical Materials (Advanced Materials and Technologies)-Pradeep Fulay & Jung-Kun Lee, CRC Press, Taylor & Francis Group.

5. Hyperlink:

https://www.edx.org/course/mechanical-behavior-materials-part-1-mitx-3-032-1x-1

https://www.edx.org/course/mechanical-behavior-materials-part-1-mitx-3-032-1x-2

(BMS 403) Core Course (CC XII): Processing of Bulk Materials

L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE

Primarily, provide the student with an understanding and awareness of the common processing technologies for metallic, ceramic, polymeric, and composite materials.

COURSE OUTLINE

1. Metallic Alloys: Ferrous Alloys. Nonferrous Alloys. Casting. Thermal processing of metals. Annealing. Heat treatment of steels. Precipitation Hardening

2. Ceramics: Fabrication and Processing of Glasses and Glass–Ceramics. Fabrication and Processing of Clay Products. Powder Pressing. Tape Casting

3. Polymers: Polymerization, Polymer Additives, Forming Techniques for Plastics, Fabrication of Elastomers, Fabrication of Fibers and Films

4. Composites: Particle-reinforced composites. Large-particle composites. Dispersion-strengthened composites. Fiber-reinforced composites

LEARNING RESOURCES:

1. W. Kurz and D.J. Fisher, Fundamentals of Solidification, CRC Press, 1998.
2. A. Upadhyaya, G.S. Upadhyaya, Powder Metallurgy: Science Technology and Materials, 2011
3. G.E. Dieter, Mechanical Metallurgy, McGraw Hill, Inc., London, UK, 1992.
4. Thin Film Deposition – Principles and Practice by Donald L. Smith
5. Hyperlink:

A. https://onlinecourses.nptel.ac.in/noc16_mm11

B. https://onlinecourses.nptel.ac.in/noc17_mm02

(BMS 404) Generic Elective (GE IV): Disciplined approach to Social Entrepreneurship

L-T-P: 2-0-4 (Credit - 4)

COURSE OBJECTIVE

The course will encourage the learners to become entrepreneur and teach them to solve the problems through a proper design and thinking towards approach. This course helps you to turn your idea into a real-life business and make it a commercial success. Learn and use a methodology to develop and assess new opportunities that forms the critical first step in moving an idea from concept to launch and implementation

COURSE OUTLINE

1. Fundamentals of social entrepreneurship (Part 1)

- identify the key features of social entrepreneurship
- differentiate between social entrepreneurship and traditional entrepreneurship

2. Fundamentals of social entrepreneurship (Part 2)

- identify the key motivations of social entrepreneurs
- describe the importance of social entrepreneurships in relation to consumers, communities and societies

3. Design thinking for social entrepreneurship

- identify the key stages of design thinking
- understand the role of design thinking in entrepreneurship and social innovation
- use design thinking to generate solutions for a social problem

4. Disciplined approach to social entrepreneurship (Part 1)

- create valuable specificity through market segmentation and defining a beachhead market
- develop an end user profile using multiple personas who share your values
- calculate your potential total addressable market

5. Disciplined approach to social entrepreneurship (Part 2)

- define the customer experience directly related to the product or services you are providing
- quantify the unique value you bring to your target customer using use-case diagrams
- map the process needed to acquire customers/end users

6. Disciplined approach to social entrepreneurship (Part 3)

- develop a business model that incorporates your social values
- determine how you will overcome common obstacles in getting your product/service adopted by customers
- identify and test key assumptions in the business model

LEARNING RESOURCES:

https://www.edx.org/course/disciplined-approach-to-social-entrepreneurship

Laboratory I: Intermediate Programming with Python (BMS 491)

L-T-P: 0-0-4 (Credit - 2)

1. Operations, Working, Functions and Methods Dictionaries Introduction. Accessing values in dictionaries. Working with dictionaries, Properties Functions Defining a function, Calling a function, Types of functions, Function Arguments, Anonymous functions.
2. Global and local variables Modules Importing module, Math module, Random module, Packages, Composition, Input-Output Printing on screen. Reading data from keyboard, Opening and closing file, Reading and writing files, Functions Exception, Handling Exception, Exception Handling, Except clause
3. Searching and Sorting Linear Search, Binary Search, Comparison of Linear and Binary Search, Selection Sort, Insertion Sort, Merge Sort, Quick sort, Shell Sort, Comparison of Sorting Techniques
4. List of practical: 1. Implementation of stacks & queues using linked lists: 2. Polynomial addition, Polynomial multiplication 3. Sparse Matrices: Multiplication, addition. 4. Recursive and Non-Recursive traversal of Trees Threaded binary tree traversal. AVL tree implementation Application of Trees. 5. Application of sorting and searching algorithms Hash tables implementation: searching, inserting and deleting, searching & sorting techniques.

Laboratory II: Materials Behavior Lab (BMS 492) L-T-P: 0-0-4 (Credit - 2)

1. To study the mechanical behavior of materials
2. To study the stress-strain curve of metallic materials, polymers, composites
3. To study the Electrolytic conduction of ionic crystals
4. Electrical transport properties of thin film
5. To study the Band Gap Measurement of semiconductor
7. To study the electrical properties of metallic and composite materials
8. To study the hall effect of a given semiconductor materials
9. To determine the Hysteresis loop of a ferromagnetic materials

(BMS 406) Skill Enhancement Course (SEC II) (Choose either of BMS 406 A/B/C/D except the course chosen in SEC-I) L-T-P: 2-1-0 (Credit - 2)

BMS 406 (A) INTRODUCTION TO ARTIFICIAL INTELIGENCE

COURSE OBJECTIVE

Artificial Intelligence will define the next generation of software solutions. This computer science course provides an overview of AI, and explains how it can be used to build smart apps that help organizations be more efficient and enrich people's lives. It will help learners to understand how AI can be used to solve materials science problems

COURSE OUTLINE

Introduction to AI. Introduction to neural network, machine learning. Different types of neural network. Activation functions. Back propagation method. Application of AI in solving materials science problem. Text and Speech-Understanding Language, Computer Vision-Seeing the World Through AI, Building AI projects, AI and Society

LEARNING RESOURCES:

1. Introduction to Artificial Intelligence: G. Goswami; Paperback-2013.

2. Hyperlink: https://www.coursera.org/learn/ai-for-everyone/home/welcome

BMS 406 (B) BASICS OF BLOCK CHAIN TECHNOLOGY

COURSE OBJECTIVE

The course covers many key topics in the blockchain space. These include distributed systems and alternative consensus mechanisms, crypto economic and proof-of-stake, fundamental applications of bitcoin and blockchain technology

COURSE OUTLINE

Distributed Systems and Alternative Consensus, Crypto economics and Proof-of-Stake, Enterprise Blockchain: Real-World Applications, Scaling Blockchain: Cryptocurrencies for the Masses, Regulation and Anonymity, A Blockchain-Powered Future

LEARNING RESOURCES:

1. Blockchain Technology Explained: The Ultimate Beginner's Guide About Blockchain Wallet, Mining, Bitcoin,
Ethereum, Litecoin, Zcash, Monero, Ripple, Dash, IOTA And Smart Contracts: A. T. Norman; Paperback, 2017.
2. Hyperlink: https://www.edx.org/course/blockchain-advancing-decentralized-technology

BMS 406 (C) BASICS OF IOT

COURSE OBJECTIVE

The course will help to learn about the 'things' that get connected in the Internet of Things to sense and interact with the real-world environment. If we consider the IoT as giving the internet the ability to feel and respond, this course is about the devices that feel and the devices that respond. Students will learn IoT sensors, actuators and intermediary devices that connect things to the internet, as well as electronics and systems,

COURSE OUTLINE

1. Generate IoT concepts and design IoT solutions. Map out the process for an IoT solution, and identify the sensors and other devices required. Evaluate different infrastructure components and network systems, and design the basic network for your IoT ideas.

2. IoT sensors to appear industrial sensors – Description & Characteristics–First Generation – Description & Characteristics–Advanced Generation – Description & Characteristics–Integrated IoT Sensors – Description & Characteristics– Polytronics Systems – Description & Characteristics–Sensors' Swarm – Description & Characteristics–Printed Electronics – Description & Characteristics–IoT Generation Roadmap

3. Technological analysis, Wireless Sensor Structure–Energy Storage Unit–Power Management Unit–RF Unit– Sensing Unit

LEARNING RESOURCES:

1. Internet of Things with Python: G. C. Hillar, Packt Publishing Limited.
2. Hyperlink: https://www.edx.org/micromasters/curtinx-internet-of-things-iot

BMS 406 (D) BASICS OF AR/VR

COURSE OBJECTIVE

The course is introduced to enable learners to enhance their skill in the upcoming areas at present scenario. It will help to fulfill three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects.

COURSE OUTLINE: VR Design overview, Overview of guidelines, methods, tools; pick team & problem, Physical prototype of potential solution, Overview of tool choices, digital prototype of (key aspects of) solution, AR Overview of guidelines, methods, tools; pick team & problem, Digital Prototyping for AR

LEARNING RESOURCES:

1. Augmented human, Dr. Helen Papagiannis
2. The VR Book: Human-Centered Design for Virtual Reality
3. https//www.coursera.org/learn/xr-introduction

SEMESTER – V

(BMS501) Core Course (CXIII): Thin films and Nano Materials

L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE

This course will provide an overview of nanostructures showing their fascinating properties unseen otherwise. The hierarchical development from nano to macro length scale, its adoption in nature (biomimicking), understanding the change in crystal structure. The course will teach the techniques of fabrication of different thin film materials.

COURSE OUTLINE

1. Nanomaterials: Length scales in physics, Nanostructures: 1D, 2D and 3D nanostructures (nanodots, thin films, nanowires, nanorods), Overview of Nanostructures and Nanomaterials: classification, Crystalline nanomaterials and defects therein. Band structure and density of states of materials at nanoscale, Size Effects in nano systems, Quantum confinement: Applications of Schrodinger equation - Infinite potential well, potential step, potential box, quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences.

2. Synthesis of Nanostructure Materials: Top down and Bottom up approach, Photolithography, Ball milling, Gas phase condensation, Vacuum deposition, Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition, Chemical vapor deposition (CVD), Sol-Gel, Electrodeposition, Spray pyrolysis, Hydrothermal synthesis, Preparation through colloidal methods, MBE growth of quantum dots.

3. Growth and structure of films: General features. Nucleation theories Effect of electron bombardment on film structure. Post- nucleation growth Epitaxial films and growth. Structural defects. Preparation methods: Electrolytic deposition, cathodic and anodic films, thermal evaporation, cathodic sputtering, Vacuum science and techniques: Vacuum principles; Vacuum generation - Rotary vane pump, Diffusion Pump, Turbomolecular Pump (TMP), Cryo-Pump; Vacuum measurement - Thermal conductivity vacuum gauges, Ionization vacuum gauges. Surfaces and interfaces in nanostructures. Ceramic interfaces, Superhydrophobic surfaces, Grain boundaries in Nanocrystalline materials, Defects associated with interfaces

LEARNING RESOURCES:

1. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications: Guozhong Cao and Ying Wang, 2nd Edition 2011, World Scientific
2. Introduction to Nanotechnology: Charles P. Poole, Frank J. Owens, 2007, Wiley
3. Introduction to Nanoscale Science and Technology: Massimiliano Di Ventra, Stephane Evoy and James R. Heflin Jr., Springer

(BMS 502) Core Course (CC XIV): Materials Behavior: Electronic and Optical
L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE

This course will develop knowledge on the fundamental principles of electronic band structure, solid state physics, and electricity and optics. These principles will help to describe the origins of the electronic and optical properties of materials. Also, it and how these properties can be engineered to suit particular applications, including diodes, optical fibers, LEDs, and solar cells.

COURSE OUTLINE

1. Electronic Band Structures: Periodic Potential, Central Equation, Understanding Band Diagrams, Engineering conductivity in Semiconductors.

2. Solid-State Devices: Introduction to PN Junctions, Solar Cells, LEDs and their applications

3. Optical Properties: Wave Equation, E/M Waves at Interfaces, Photonic Crystals. Importance of Optical Fiber communication, different types of Fiber, Rays Modes, Step-Index Fiber Structure, Ray optics representation

4. Wave Representation in a Dielectric Slab Waveguide Light Emitting Diodes (LEDs); structure, materials. Luminescence. Photoconductivity

LEARNING RESOURCES:

1. Electronic, Magnetic, and Optical Materials (Advanced Materials and Technologies)-Pradeep Fulay & Jung-Kun Lee, CRC Press, Taylor & Francis Group.

2. Hyperlink: https://www.edx.org/course/electronic-optical-magnetic-properties-mitx-3-024x

(BMS 503) Discipline Specific Elective I (DSE I) (Choose any one of BMS 503 A/B/C/D/E/F)

L-T-P: 4-0-0 (Credit - 4)

BMS 503 (A) Metallic Materials: Introduction to metallic materials. Concepts of Stress and Strain, Elastic Deformation, Stress–Strain Behavior, Anelasticity, Elastic Properties of Materials, Plastic Deformation, Tensile Properties, True Stress and Strain, Elastic Recovery After Plastic Deformation, Compressive, Shear, and Torsional Deformation, Hardness, property variability and design/safety factors variability of Material Properties, Design/Safety Factors.

LEARNING RESOURCES:

1. G.E. Dieter, "Mechanical Metallurgy", McGraw-Hill, 1986.
2. Mechanical Behavior of materials – Thomas H. Courtney
3. R.W. Hertzberg, "Deformation and Fracture Mechanics of Engineering Materials", John Wiley and Sons, 1976.

BMS 503 (B) Polymeric Materials: Introduction to polymeric materials. Mechanical behavior of polymers. stress–strain behavior. Macroscopic deformation. Viscoelastic deformation. Fracture of polymers. Mechanical characteristics. Mechanisms of deformation and for strengthening of polymers. Deformation of Semi crystalline Polymers. Factors that Influence the Mechanical Properties of Semi crystalline Polymers. Materials of Importance—Shrink-Wrap. Polymer Films. Deformation of Elastomers

BMS 503 (C) Ceramic Materials: Introduction to ceramic materials. Ceramic structures. Crystal Structures. Silicate Ceramics. Glasses. Glass–Ceramics. Clay Products. Refractories. Abrasives. Cements. Carbon. Advanced Ceramic Imperfections in Ceramics. Diffusion in Ionic Materials. Ceramic Phase Diagrams. Mechanical properties. Brittle Fracture of Ceramics. Stress–Strain Behavior. Mechanisms of Plastic Deformation

BMS 503 (D) Composites materials: Introduction to composite materials along with its basic requirements and classification; Various models analyzing the design and performance of composite materials; Understanding the composite modulus, strength and fracture behaviour for structural applications. Composites including nano-composites for electrical, superconducting and device applications; Fabrication and processing of metal matrix (MM). Polymer Matrix (PM) and ceramic matrix (CM) composites and their characterization; Fabrication of nano-composites. Secondary processing and joining of various composite materials for structural applications and their fracture behavior and safety.

LEARNING RESOURCES:

1. V.V. Vasiliev and E.V. Morozov, Mechanics and Analysis of Composite Materials, Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 lGB, UK.
2. K.K. Chawala, Ceramic matrix composites,1st ed., Chapman & Hall, London.
3. G. Piatti, Advances in composite materials, Applied Science Publishers Ltd., London

BMS 503 (E) Bio-materials: Introduction: Definition of biomaterials, requirements & classification of biomaterials, Comparison of properties of some common biomaterials. Effects of physiological fluid on the properties of biomaterials. Surface properties of materials, physical and mechanical properties. Metallic implant materials: Stainless steel, Co-based alloys, Ti and Ti-based alloys. Importance of stress-corrosion cracking. Hard tissue replacement implant: Orthopedic implants, Dental implants. Soft tissue replacement implants. 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). Polymers filled with osteogenic fillers (e.g. hydroxyapatite). Biocompatibility & Toxicological screening of biomaterials: Definition of biocompatibility, blood compatibility and tissue compatibility. Toxicity tests: acute and chronic toxicity studies (in situ implantation, tissue culture, hemolysis, thrombogenic potential test, systemic toxicity, intracutaneous irritation test), sensitization, carcinogenicity, mutagenicity and special tests.

LEARNING RESOURCES:

1. Biomaterials Science: An Introduction to Materials in Medicine, By Buddy D. Ratner, et. al. Academic Press, San Diego, 1996.
2. J B Park, Biomaterials – Science and Engineering, Plenum Press, 1984.

BMS 503 (F) Energy materials:

Introduction and overview, operating principle, polarization curves, components,types of fuel cell, low and high temperature fuel cells, fuel cell stacks. Thermodynamics of fuel cell: application of the first and second law to fuel cells, significance of the Gibbs free energy, concept of electrochemical potential and emf, Nernst equation, thermodynamic efficiencies of fuel cell in comparison to Carnot efficiencies, thermodynamic advantage of electrochemical energ y conversion Electrochemistry of fuel cell: electrochemical cells, oxidation and reduction processes, half- cell potentials and the electrochemical series, Faraday's law, faradaic and nonfaradaic processes, current and reaction rate, Fuel cell technology: Types of Fuel Cells, Power management, Thermal management; Fuel cell electrolytes: different types of electrolytes used, ionomeric membrane in PEFC, mechanism of ion transfer in ionomeric membranes, relation between proton conductivity and water content, alternative membranes Hydrogen Production: fossil fuels, electrolysis, thermal decomposition, nuclear, photochemical, photocatalytic, hybrid; Hydrogen Storage: Metal hydrides, chemical hydrides, carbon nano-tubes; sea as the source of Deuterium, methane hydrate, etc. Hydrogen Economy: Hydrogen as an alternative fuel in IC engines; Suitability of Hydrogen as a fuel, and techno-economic aspects of fuel cell as energy conversion device; Hydrogen fuel for transport

LEARNING RESOURCES:

1. Gupta R. B. (2008); Hydrogen Fuel: Production, Transport and Storage, CRC Press

2. Bard A. J., Faulkner L. R., Leddy J., and Zoski, C. G. (1980). Electrochemical methods: fundamentals and applications (Vol. 2), Wiley

Laboratory I: Nano Materials Lab (BMS 591) **L-T-P: 0-0-4 (Credit - 2)**

1. Synthesis of Metal/Metal Oxide Nanoparticle using different techniques.
2. Characterizations using UV visible spectrophotometer, FTIR, X-ray Analysis.
3. Synthesis of Polymeric Nanocomposite.
4. Synthesis of a polymer composite
5. Synthesis of a semiconductor nanoparticles by chemical method
6. Preparation of metal oxide semiconductor thin film
7. Determination of optical absorption characteristics
8. Electrical transport properties of polymer composite
9. Determination of efficiency of a solar cell/electrochemical cell

Elective Course (BMS 581) Project Work **L-T-P: 0-0-6 (Credit - 3)**

Project would be to do some preliminary works that would lead to the detailed project work spanning over Semester V and VI. Seminar presentation would be made by an individual student, and a report would have to be submitted by each student separately.

SEMESTER – VI

(BMS 601) Core Course (CC XV): Materials Characterization

L-T-P: 3-1-0 (Credit - 4)

COURSE OBJECTIVE

To explain different tools and techniques for characterization of different materials. The course will make the students know the working principle of the characterization instruments used to know the change in the property of the materials as their structure changes

COURSE OUTLINE

1. Materials characterization - definition; importance and application. Principles and general methods of compositional, structural and defect characterization.

2. Microscopy techniques: Optical microscopy. Scanning electron microscopy (SEM). Transmission electron microscopy (TEM).

3. Optical and Electron spectroscopies - UV, visible, IR and Raman spectroscopies. Auger and photoelectron spectroscopies Optical characterization techniques: Absorption, transmission, reflection, Fourier transform infrared spectroscopy (FTIR), Photoluminescence, Raman. X-ray photoelectron spectroscopy (XPS).

4. Rutherford characterization techniques backscattering spectrometry (RBS).

5. Mechanical methods: measurement of tensile & flexural moduli, strength, fatigue, creep, fracture toughness, hardness etc.

LEARNING RESOURCES:

1. Characterization of Materials, (2 Volume Set), E. N. Kauffmann (Editor)

2. Physical Principles of Electron Microscopy- R. F. Egerton

3 Materials Characterization-Yang Lang

(BMS 602) Core Course (CC XV): Design and Selection of Materials

L-T-P: 3-0-2 (Credit - 4)

COURSE OBJECTIVE

Material selection is a step in the process of designing any physical object. The course will teach how to design a product so as to minimize cost while meeting product performance goals.

COURSE OUTLINE

Selection of materials as selection of function, shape and process, Evolution of engineering materials, flow chart for designing of materials, Design and Materials Selection Examples, Design involving a new idea or working principle, Applications, redesign or reselection of materials to avoid mis use of materials, General properties of metals, ceramics, polymers and composites, Role of shape factors in materials selection, materials behavior under extreme conditions; corrosion; discussion of design and materials selection strategy; processing and process selection strategy

LEARNING RESOURCES:

1. M.F.Ashby, Materials Selection in Mechanical Design, 4th edition, Elsevier, San Francisco, 2011
2. Materials Selection for Design and Manufacturing: Theory and Practice, Joseph Datsko
3. Materials Selection and Design, Springer, Md Abdul, Salit, Mohd Sapuan, ISBN 978-981-4560-38-2

(BMS 603) Discipline Specific Elective III (DSE III) (Choose any one of BMS 603 A/B/C/D/E/F except the course chosen in DSE I)

L-T-P: 4-0-0 (Credit - 4)

BMS 603 (A) Metallic Materials: Introduction to metallic materials. Concepts of Stress and Strain, Elastic Deformation, Stress–Strain Behavior, Anelasticity, Elastic Properties of Materials, Plastic Deformation, Tensile Properties, True Stress and Strain, Elastic Recovery After Plastic Deformation, Compressive, Shear, and Torsional Deformation, Hardness, property variability and design/safety factors variability of Material Properties, Design/Safety Factors.

BMS 603 (B) Polymeric Materials: Introduction to polymeric materials. Mechanical behavior of polymers. stress–strain behavior. Macroscopic deformation. Viscoelastic deformation. Fracture of polymers. Mechanical characteristics. Mechanisms of deformation and for strengthening of polymers. Deformation of Semi crystalline Polymers. Factors that Influence the Mechanical Properties of Semi crystalline Polymers. Materials of Importance—Shrink-Wrap. Polymer Films. Deformation of Elastomers

BMS 603 (C) Ceramic Materials: Introduction to ceramic materials. Ceramic structures. Crystal Structures. Silicate Ceramics. Glasses. Glass–Ceramics. Clay Products. Refractories. Abrasives. Cements. Carbon. Advanced Ceramic Imperfections in Ceramics. Diffusion in Ionic Materials. Ceramic Phase Diagrams. Mechanical properties. Brittle Fracture of Ceramics. Stress–Strain Behavior. Mechanisms of Plastic Deformation

BMS 603 (D) Composites materials: Introduction to composite materials along with its basic requirements and classification; Various models analyzing the design and performance of composite materials; Understanding the composite modulus, strength and fracture behaviour for structural applications. Composites including nano-composites for electrical, superconducting and device applications; Fabrication and processing of metal matrix (MM). Polymer Matrix (PM) and ceramic matrix (CM) composites and their characterization; Fabrication of nano-composites. Secondary processing and joining of various composite materials for structural applications and their fracture behavior and safety.

BMS 603 (E) Bio-materials: Introduction: Definition of biomaterials, requirements & classification of biomaterials, Comparison of properties of some common biomaterials. Effects of physiological fluid on the properties of biomaterials. Surface properties of materials, physical and mechanical properties. Metallic implant materials: Stainless steel, Co-based alloys, Ti and Ti-based alloys. Importance of stress-corrosion cracking. Hard tissue replacement implant: Orthopedic implants, Dental implants. Soft tissue replacement implants. 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). Polymers filled with osteogenic fillers (e.g. hydroxyapatite). Biocompatibility & Toxicological screening of biomaterials: Definition of biocompatibility, blood compatibility and tissue compatibility. Toxicity tests: acute and chronic toxicity studies (in situ implantation, tissue culture, hemolysis, thrombogenic potential test, systemic toxicity, intracutaneous irritation test), sensitization, carcinogenicity, mutagenicity and special tests.

BMS 603 (F) Energy materials:

Introduction and overview, operating principle, polarization curves, components,types of fuel cell, low and high temperature fuel cells, fuel cell stacks. Thermodynamics of fuel cell: application of the first and second law to fuel cells, significance of the Gibbs free energy, concept of electrochemical potential and emf, Nernst equation, thermodynamic efficiencies of fuel cell in comparison to Carnot efficiencies, thermodynamic advantage of electrochemical energ y conversion Electrochemistry of fuel cell: electrochemical cells, oxidation and reduction processes, half- cell potentials and the electrochemical series, Faraday's law, faradaic and nonfaradaic processes, current and reaction rate, Fuel cell technology: Types of Fuel Cells, Power management, Thermal management; Fuel cell electrolytes: different types of electrolytes used, ionomeric membrane in PEFC, mechanism of ion transfer in ionomeric membranes, relation between proton conductivity and water content, alternative membranes Hydrogen Production: fossil fuels, electrolysis, thermal decomposition, nuclear, photochemical, photocatalytic, hybrid; Hydrogen Storage: Metal hydrides, chemical hydrides, carbon nano-tubes; sea as the source of Deuterium, methane hydrate, etc. Hydrogen Economy: Hydrogen as an alternative fuel in IC engines; Suitability of Hydrogen as a fuel, and techno-economic aspects of fuel cell as energy conversion device; Hydrogen fuel for transport

Laboratory I: Materials Characterization Lab (BMS 692) L-T-P: 0-0-4 (Credit - 2)

1. Particle size analysis
2. Characterization of Materials through optical, XRD, SEM, TEM, FTIR and UV-VIS.
3. Thermal analysis through TGA, DTA and DSC.
4. Determination of Microhardness and Abrasion Resistance.
5. Measurement of electrical conductivity
6. Measurement of electrochemical testing of cell

Elective Course (BMS 681) Project Work L-T-P: 0-0-6 (Credit - 3)

This is the final project work compiling the total work of two semesters. It has to be submitted in form of a bound thesis containing literature review, objective, details of work done, conclusion, reference, etc. Seminar presentation would be made by an individual student, and a report would have to be submitted by each student separately. The evaluation of the thesis will be done by a panel of examiners. Final presentation and viva voce of the project will be based on the project thesis submitted to be conducted by a panel of examiners.