Indian Institute of Technology Indore

Curriculum and Courses of Study for Bachelor of Technology: Metallurgical Engineering and Materials Science

October 2025

[After incorporating decisions of the 57th meeting of the Senate held on October 17, 2025]

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Curriculum of 1st year BTech (common to all the Departments)

Semester I

Curriculum of 1st Year B. Tech. Program (From AY 2010-11 to AY 2013-14)				**Curriculum of 1st Year B. Tech. Program** (From AY 2014-15 to AY 2018-19)			
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**	**Course Code**	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
CH 103	Chemistry	3-1-0	4	CH 103	Chemistry	3-1-0	4
MA 103	Mathematics-I (Calculus)	3-1-0	4	MA 105	Calculus	3-1-0	4
PH 103	Physics-I (Modern Physics)	2-1-0	3	PH 105	Physics-I	2-1-0	3
HS 107	English Language and Literature	2-0-0	2	HS 159	English Language and Communication	0-3-0	3
CS 103	Computer Programming	2-0-0	2	CS 103	Computer Programming	2-0-0	2
CH 153	Chemistry Lab	0-0-3	1.5	CH 153	Chemistry Lab	0-0-3	1.5
HS 157	English Language Lab	0-0-2	1				
CS 153	Computer Programming Lab	0-0-3	1.5	CS 153 ***(upto AY 2017-18)*** IC 151 ***(from AY 2018-19 onwards)***	Computer Programming Lab	0-0-3	1.5
ME 153	Engineering Graphics	1-0-3	2.5	IC 153	Engineering Graphics	1-0-3	2.5
NC 101/ NO 101/ NS 101	National Cadet Corps (NCC) National Sports Organization (NSO) National Service Scheme (NSS)	0-0-0 0-0-0 0-0-0	P/NP P/NP P/NP	NC 101/ NO 101/ NS 101	National Cadet Corps (NCC) National Sports Organization (NSO) National Service Scheme (NSS)	0-0-0 0-0-0 0-0-0	P/NP P/NP P/NP
	Total	**13-3-11**	**21.5**		**Total**	**11-6-9**	**21.5**

Semester II

Curriculum of 1st Year B. Tech. Program (From AY 2010-11 to AY 2013-14)				Curriculum of 1st Year B. Tech. Program (From AY 2014-15 to AY 2018-19)			
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**	**Course Code**	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
MA 104	Mathematics-II(Linear Algebra and Ordinary Differential Equations-I)	3-1-0	4	MA 106	Linear Algebra and Ordinary Differential Equations-I	3-1-0	4
PH 104	Physics-II (Electricity and Magnetism)	2-1-0	3	PH 106	Physics-II	2-1-0	3
				BSE 102	Bio-Sciences	2-1-0	3
HS 108	Fundamentals of Economics	3-0-0	3	HS 108	Fundamentals of Economics	3-0-0	3
EE 104	Basic Electrical and Electronics Engineering	2-1-0	3	EE 104	Basic Electrical and Electronics Engineering	2-1-0	3
ME 104	Basic Mechanical Engineering	3-0-0	3	ME 106	Basic Mechanical Engineering	2-1-0	3
PH 154	Physics Lab	0-0-3	1.5	PH 156	Physics Lab	0-0-3	1.5
EE 154	Basic Electrical and Electronics Engineering Lab	0-0-2	1	EE 154	Basic Electrical and Electronics Engineering Lab	0-0-2	1
ME 154	Basic Manufacturing Techniques	2-0-2	3	IC 156	Basic Manufacturing Techniques	0-0-3	1.5
NC 102/ NO 102/ NS 102	National Cadet Corps (NCC) National Sports Organization (NSO) National Service Scheme (NSS)	0-0-0 0-0-0 0-0-0	P/NP P/NP P/NP	NC 102 / NO 102 / NS 102	National Cadet Corps (NCC) National Sports Organization (NSO) National Service Scheme (NSS)	0-0-0 0-0-0 0-0-0	P/NP P/NP P/NP
	Total	**15-3-7**	**21.5**		**Total**	**15-4-8**	**23**

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Sections and Course structure of 1st year BTech (from AY 2019-20 to AY 2022-23)

Section-A (CSE + CE + MEMS) **Classroom No. 1B-201, Titanium POD**				**Section-B (EE + ME)** **Classroom No. 1D-105, Chromium POD**			
1st (i.e. Autumn) Semester							
Course Code	**Course Title**	**Teaching Hours (L-T-P)**	**Credits**	**Course Code**	**Course Title**	**Teaching Hours (L-T-P)**	**Credits**
CH 103	Chemistry	3-1-0	4	BSE 102	Bio-Sciences	2-1-0	3
MA 105	Calculus	3-1-0	4	MA 105	Calculus	3-1-0	4
PH 105	Physics-I	2-1-0	3	PH 106	Physics-II	2-1-0	3
CS 103	Computer Programming	2-0-0	2	EE 104	Basic Electrical and Electronics Engineering	2-1-0	3
				ME 106	Basic Mechanical Engineering	2-1-0	3
HS 159	English Language and Communication	0-3-0	3	HS 108	Fundamentals of Economics	3-0-0	3
CH 153	Chemistry Lab	0-0-3	1.5	PH 156	Physics Lab	0-0-3	1.5
IC 151	Computer Programming Lab	0-0-3	1.5	EE 154	Basic Electrical and Electronics Engineering Lab	0-0-2	1
IC 153	Engineering Graphics	1-0-3	2.5	IC 156	Basic Manufacturing Techniques	0-0-3	1.5
NO 101	National Sports Organization (NSO)	0-0-0	P/NP	NO 101	National Sports Organization (NSO)	0-0-0	P/NP
	Total	**11-6-9**	**21.5**		**Total**	**14-5-8**	**23**
2nd (i.e. Spring) Semester							
BSE 102	Bio-Sciences	2-1-0	3	CH 103	Chemistry	3-1-0	4
MA 106	Linear Algebra and Ordinary Differential Equations-I	3-1-0	4	MA 106	Linear Algebra and Ordinary Differential Equations-I	3-1-0	4
PH 106	Physics-II	2-1-0	3	PH 105	Physics-I	2-1-0	3
EE 104	Basic Electrical and Electronics Engineering	2-1-0	3	CS 103	Computer Programming	2-0-0	2
ME 106	Basic Mechanical Engineering	2-1-0	3				

HS 108	Fundamentals of Economics	3-0-0	3	HS 159	English Language and Communication	0-3-0	3
EE 154	Basic Electrical and Electronics Engineering Lab	0-0-2	1	IC 151	Computer Programming Lab	0-0-3	1.5
PH 156	Physics Lab	0-0-3	1.5	CH 153	Chemistry Lab	0-0-3	1.5
IC 156	Basic Manufacturing Techniques	0-0-3	1.5	IC 153	Engineering Graphics	1-0-3	2.5
NO 102	National Sports Organization (NSO)		P/NP	NO 102	National Sports Organization (NSO)		P/NP
	Total	**14-5-8**	**23**		**Total**	**11-6-9**	**21.5**

Sections and Course structure of 1st year BTech (from AY 2023-24 onwards)

Section-A (CSE+CE+MEMS+CH+EP)				Section-B (EE+ME+MC+SSE)			
Semester-I	**Autumn Semester**			**Semester-I**	**Autumn Semester**		
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**	**Course Code**	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
EE 101	Basic Electrical Engineering	1-1-0	2	EE 101	Basic Electrical Engineering	1-1-0	2
ME 101	Engineering Mechanics	2-0-0	2	ME 101	Engineering Mechanics	2-0-0	2
PH 107	Basics of Physics	2-1-0	3	CH 105	Chemistry	3-0-0	3
PH 157	Physics Lab- I	0-0-2	1	CH 155	Chemistry Lab	0-0-2	1
MA 101N	Calculus-I (half Semester)	3-1-0 (=4/2)	2	MA 101N	Calculus-I (half Semester)	3-1-0 (=4/2)	2
MA 103N	Calculus-II (half Semester)	3-1-0 (=4/2)	2	MA 103N	Calculus-II (half Semester)	3-1-0 (=4/2)	2
HS 109	Language and Composition	2-0-0	2	HS 109	Language and Composition	2-0-0	2
HS XXX	Flexible Elective (HSS)	1-0-0	1	HS XXX	Flexible Elective (HSS)	1-0-0	1
IC 152	Makerspace	1-0-6	4	CS 103	Computer Programming	2-0-0	2
CS 103	Computer Programming	2-0-0	2	IC 151	Computer Programming Lab	0-0-3	1.5
IC 151	Computer Programming Lab	0-0-3	1.5	NO 101	National Sports Organization (NSO)	0-0-0	P/NP
NO 101	National Sports Organization (NSO)	0-0-0	P/NP				
	Total	**14-3-11**	**22.5**		**Total**	**14-2-5**	**18.5**

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Semester-II	Spring Semester		
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
BSE 102	Biosciences	2-1-0	3
MA 102N	Linear Algebra (half Semester)	2-1-0 (=3/2)	1.5
MA 104N	Differential Equations-I (half Semester)	2-1-0 (=3/2)	1.5
ES 102	Environmental Studies: Scientific and Engineering Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 102	Environmental Studies: Social Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 104	Fundamentals of Economics	2-0-0	2
CH 105	Chemistry	3-0-0	3
CH 155	Chemistry Lab	0-0-2	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective (HSS)	1-0-0	1
NO 102	National Sports Organization (NSO)	0-0-0	P/NP

Semester-II	Spring Semester		
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
BSE 102	Biosciences	2-1-0	3
MA 102N	Linear Algebra (half Semester)	2-1-0 (=3/2)	1.5
MA 104N	Differential Equations-I (half Semester)	2-1-0 (=3/2)	1.5
ES 102	Environmental Studies: Scientific and Engineering Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 102	Environmental Studies: Social Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 104	Fundamentals of Economics	2-0-0	2
IC 152	Makerspace	1-0-6	4
PH 107	Basics of Physics	2-1-0	3
PH 157	Physics Lab- I	0-0-2	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective (HSS)	1-0-0	1

	Total	**14-3-2**	**18**

NO 102	National Sports Organization (NSO)	0-0-0	P/NP
	Total	**14-4-8**	**22**

Curriculum of 2nd Year BTech (Metallurgical Engineering and Materials Science)

Semester III

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
ZZ XXX	Course-I for Minor Program	X-X-X	3
MA 203	Complex Analysis and Differential Equations-II	3-1-0	4
MM 201	Mechanics of Materials	2-1-0	3
MM 203	Physical Metallurgy-I	2-1-0	3
MM 205	Materials Science	2-1-0	3
MM 207	Thermodynamics	2-1-0	3
MM 251	Mechanics of Materials Lab	0-0-3	1.5
IC 211	Experimental Engineering Lab	0-0-3	1.5
	Total		**19/ 22**

Curriculum of BTech Program in MEMS

Semester III (From AY 2024-25 onwards) **(Batch admitted in and after AY 2023-24)**

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
ZZ xxx	Course-I for Minor Program	x-x-x	3
MA 205	Complex Analysis	3-1-0-2 (1/2 semester)	2
MA 207	Differential Equations-II	3-1-0-2 (1/2 semester)	2
MM 209	Structure of Materials	2-1-0	1.5
MM 211	Physics of Materials	2-1-0	1.5
MM 215	Mechanical Behaviour of Materials	2-1-0	3
MM 217	Transport Phenomena	2-1-0	3
MM 219	Thermodynamics of Materials	2-1-0	3
MM 257	Metallography Lab	0-0-2	1
MM 255	Mechanical Behaviour of Materials Lab	0-0-2	1
MM 2XX	Department Electives- I	2-1-0	3
	Total		**21/24**

Options for Electives I (III Semester) (From AY 2024-25 onwards) (Batch admitted in and after AY 2023-24)			
Course Code	**Subject Name**	**Weekly Contact Hours (L-T-P)**	**Credits**
MM 221	Finite Element Simulations in Materials	2-1-0	1.5
MM 223	Statistical Mechanics for Materials Science	2-1-0	1.5
MM 225	Materials Economics and Sustainability	2-1-0	1.5
MM 229	Nucleation and Crystal Growth	2-1-0	1.5

Semester IV (Till AY 2023-24)

Course Code	**Subject Name**	**Weekly Contact Hours (L-T-P)**	**Credits**
ZZ XXX	Course-II for Minor Program	X-X-X	3
MA 204	Numerical Methods	3-0-2	4
MM 202	Extractive Metallurgy	2-1-0	3
MM 204	Physical Metallurgy–II	2-1-0	3
MM 206	Transport Phenomenon	2-1-0	3
MM 208	Theory of Metal Forming	2-1-0	3
MM 254	Physical Metallurgy Lab	0-0-3	1.5
MM 258	Metal Forming Lab	0-0-3	1.5
	Total		**19/ 22**

4th Curriculum of BTech Program in MEMS (IV Semester) (From AY 2024-25 onwards) (From Batch admitted in and after 2023)			
Course Code	**Subject Name**	**Weekly Contact Hours (L-T-P)**	**Credits**
ZZXXX	Course -II for minor program	X-X-X	3
MA 204N	Numerical Methods	2-0-2	3
MM 212	Casting and Welding Technology	2-1-0 (Half Semester)	1.5
MM 210	Powder Metallurgy and Additive Manufacturing	2-1-0 (Half Semester)	1.5
MM 208	Theory of Metal Forming	2-1-0	3

MM 216	Physical Metallurgy	2-1-0	3
MM 214	Materials Characterization	2-0-2	3
MM 252	Casting and Welding Technology Lab	0-0-2	1
MM 258N	Metal Forming Lab	0-0-2	1
MM 2XX	Department Elective II	2-1-0	3
ZZ XXX	Institute Elective I	2-1-0	3
Total		**14-5-8**	**23/26**

Elective Courses (IV Semester)			
Course Code	**Course Name**	**(L-T-P)**	**Credit**
MM 226	Materials Informatics	2-1-0	1.5
MM 228	Ceramic Science and Technology	2-1-0	1.5
MM 230	Diffusion in Solids	2-1-0	1.5
MM 232	Thin Film Technology	2-1-0	1.5

3rd Year B. Tech. (Metallurgical Engineering and Materials Science)

Semester V (Till Batch admitted 2022)

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
ZZ XXX	Course-III for Minor Program	X-X-X	3
MM 301	Polymer Technology	2-1-0	3
MM 303	Introduction to Electrochemistry	2-1-0	3
MM 305	Iron and Steel Making	2-1-0	3
MM 307	Composites	2-1-0	3
MM 309	Computational Methods for Materials	2-0-2	3
MM 351	Polymer Technology Lab	0-0-3	1.5
MM 357	Composites Development Lab	0-0-3	1.5
	Total		**18/ 21**

3rd Year Curriculum of BTech Program in MEMS – V Semester

(From AY 2025-26 onwards) (From Batch admitted in and after 2023)

Course Code	Course Name	(L-T-P)	Credit
ZZ 3XX	Course -III for minor program	X-X-X	3
MM 309N	Computational Methods for Materials	2-1-0	3
MM 305N	Iron and Steel Making	2-1-0	3
MM 311	Optical and Magnetic Properties of Materials	2-1-0 (Half Semester)	1.5
MM 313	Non-ferrous Extractive Metallurgy	2-0-2	3
MM 315	Polymer and Composites	2-1-0	3
MM 353	Computational Methods for Materials Lab	0-0-2	1
MM 355	Polymer and Composites Lab	0-0-2	1
MM 3XX	Department Elective - III	2-1-0	3
ZZ 3XX	Institute Elective - II	2-1-0	3
Total		**13-5.5-6**	**21.5/24.5**

Elective Courses (V Semester)			
Course Code	**Course Name**	**(L-T-P)**	**Credit**
MM 317	Lightweight Materials for Structural Applications	2-1-0	1.5
MM 319	Superalloys for High Temperature Applications	2-1-0	1.5
MM 321	Mechanical Behavior of Materials at Nanoscale	2-1-0	1.5
MM 323	Phase Transformation of Nanoalloys	2-1-0	1.5
MM 325	Advances in Metals and Alloys Processing	2-1-0	3

Semester VI (Till Batch admitted 2022)

Course Code	**Subject Name**	**Weekly Contact Hours (L-T-P)**	**Credits**
HS 302	Environmental Studies: Social Aspects (Half Semester course)	3-0-0	1.5
ES 302	Environmental Studies: Scientific and Engineering Aspects (Half Semester course)	3-0-0	1.5
MM 302	Welding and Foundry Engineering	2-1-0	3
MM 304	Corrosion Engineering	2-1-0	3
MM 306	Powder Metallurgy	2-1-0	3
MM 308	Thin Films and Nanostructures	2-1-0	3
MM 310	Ceramics Technology	2-1-0	3
MM 352	Welding and Foundry Engineering Lab	0-0-3	1.5
MM 354	Corrosion Engineering Lab	0-0-3	1.5
	Total		**21**

3rd Year Curriculum of BTech Program in MEMS – VI Semester (From AY 2025-26 onwards) (From Batch admitted in and after 2023)			
Course Code	**Subject Name**	**Weekly Contact Hours (L-T-P)**	**Credits**
ZZ 3XX	Course -IV for minor program	X-X-X	3
MM 312	Electrochemistry and Corrosion Engineering	2-1-0	3
MM 314	Semiconductor Materials and Devices	2-1-0	3
MM 316	Microstructure Engineering of Alloys	2-1-0	3
MM 356	Electrochemistry and Corrosion Engineering Lab	0-0-2	1
MM 358	Semiconductor and Thin Films Lab	0-1-2	2
MM 3XX	Institute Elective -III	2-1-0	3
MM 3XX	Department Elective - IV	2-1-0	3
MM 3XX	Department Elective - V	2-1-0	3
	Total	**12-6-4**	**20/23**

Elective Courses (VI Semester)			
Course Code	**Course Name**	**(L-T-P)**	**Credit**
MM 318	Multicomponent Alloys	2-1-0	3
MM 320	Crystallographic Texture and Crystal Plasticity	2-1-0	3
MM 322	Surface Engineering of Alloys	2-1-0	3
MM 324	Sustainable Geotechnics	2-1-0	3
MM 3XX	Advances in Sintering Technology	2-1-0	1.5
MM 3XX	Mechanical Behavior at Nanoscale	2-1-0	1.5
MM 3XX	Phase Transformation of Nano-Alloys	2-1-0	1.5
MM 3XX	Genetic Algorithms in Engineering Process Modeling	2-1-0	1.5
MM 3XX	Metallic Glass	2-1-0	1.5
MM 3XX	CO2 Capture and Utilisation	2-1-0	1.5
MM 3XX	Engineered Soft Materials	2-1-0	1.5
MM 3XX	High Entropy Materials	2-1-0	1.5
MM 3XX	Advanced Materials and Processes	2-1-0	3
MM 3XX	Fuels, Furnaces and Refractories	2-1-0	3
MM 3XX	Functional Coatings	2-1-0	3

4th Year B. Tech. (Metallurgical Engineering and Materials Science)

Semester VII

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
MM 493	**B Tech Project (BTP)** 1. Student can do BTech project either outside the institute or within the institute under a supervision of an IIT Indore Faculty. 2. Summer Internship, if any, will be part of B Tech Project. 3. The choice is to be made latest by 30th April. 4. Duration: 6-7 months during 2nd week of May to Last week of Nov. 5. Last Date of Thesis submission: 1st week of Dec. 6. Last Date of Submission of Grades: 2nd week of Dec.	0-0-40	20
	Total	0-0-40	**20**

4th Year Curriculum of BTech Program in MEMS – VII Semester (From AY 2026-27 onwards) (From Batch admitted in and after 2023)			
Course Code	**Subject Name**	**Weekly Contact Hours (L-T-P)**	**Credits**
ZZ XXX	Course-V for Minor project/field study/white paper/domain comprehension (Seminar)/Lab course	x-x-x	2
ZZ 493N	B. Tech Project (BTP)	0-0-32	16
ZZ 495 **OR** ZZ XXX	Internship **OR** Professional/ Societal-Connect basket course	x-x-x	1.5
	Total		**17.5/19.5**

Semester VIII (from AY 2016-17 to AY 2019-20)

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
MM 402/ MM 602	Design and Selection of Materials	2-1-0	3
ZZ xxx	Open Elective-I	x-x-x	3

ZZ xxx	Open Elective-II	x-x-x	3
ZZ xxx	Open Elective-III (or Course-IV for Minor Program)	x-x-x	3
ZZ xxx	Open Elective-IV (or Course-V for Minor Program)	x-x-x	3
	Total		**15**

Semester VIII (from AY 2020-21 to AY 2026-27)

Course Code	Subject Name	Weekly Contact Hours (L-T-P)	Credits
MM 402/ MM 602	Design and Selection of Materials	2-1-0	3
MM xxx	Department Elective-I	x-x-x	3
MM xxx	Department Elective-II	x-x-x	3
ZZ xxx	Open Elective-I (or Course-IV for Minor Program)	x-x-x	3
ZZ xxx	Open Elective-II (or Course-V for Minor Program)	x-x-x	3
	Total		**15**

Curriculum of BTech Program in MEMS – VII Semester (From AY 2026-27 onwards) (From Batch admitted in and after 2023)			
Course Code	**Subject Name**	**Weekly Contact Hours (L-T-P)**	**Credits**
MM 4XXX	Department Elective-VI	2-1-0	3
MM 4XXX	Department Elective-VII	2-1-0	3
MM 4XXX	Department Elective-VIII	2-1-0	3
ZZ 4XXX	Institute Elective-IV	2-1-0	3
ZZ 4XXX	Institute Elective-V	2-1-0	3
	Total	**10-5-0**	**15**

MEMS Courses available for the Open Elective Courses in the 8th Semester of B.Tech in MEMS

MM 404 Creep, Fatigue and Fracture Mechanics (2-1-0-3)

MM 405/ MM 605 Green Hydrogen: Materials and Technologies (2-1-0-3)

MM 406 Electronics Materials (2-1-0-3)

MM 408 Bio-Materials (2-1-0-3)

MM 410 Modern Materials (2-1-0-3)

MM 412 Surface Modification (2-1-0-3)

MM 414 Particulate Processing (2-1-0-3)

MM 416 Modeling and Simulation in Materials Engineering (2-0-2-3)

MM 418 Defects and Failures in Manufacturing and Services (2-1-0-3)

MM 420 Metallurgical Plant Design (2-1-0-3)

MM 422 Sintering Technology (2-1-0-3)

MM 424 Magnetic Materials (2-1-0-3)

MM 426 Advanced Materials Processing (2-1-0-3)

MM 428 Intelligent Materials (2-1-0-3)

MM 430/ 730 Two: Dimensional Materials and Electronic Devices (2-1-0-3)

ME 436/ ME 736 Finite Element Analysis (2-0-2-3)

MM 442/ MM 642: Quality Assurance in Metallurgy (2-0-2-3)

MM 647/ MM 447: Metallurgical Thermodynamics and Phase Transformations (2-1-0-3)

MM 448/ MM 648: Solidification and Phase Field Modeling (2-0-2-3)

MM 449/ MM 649: Advance Welding Technology (2-0-2-3)

MM 450/ MM 650: Ferrous and Non-Ferrous Alloys (2-1-0-3)

MM 451/ MM 651: Non-destructive Evaluation (2-0-2-3)

MM 452/ MM 652: Thermomechanical Processing (2-0-2-3)

MM 453/ MM 653: Non-equilibrium Processing of Materials (2-1-0-3)

MM 454/ MM 654: Advanced Foundry Technology (2-0-2-3)

MM 457/ MM 657: Advances in Energy Storage Materials (2-1-0-3)

MM 474/ MM 674: Fluorescence Phenomenon (2-1-2-4)

MM 475/ MM 675: Advanced Fracture Mechanics (2-1-0-3)

MM 477/ MM 677 High Temperature Deformation of Materials (2-1-0-3)

MM 479/ MM 679: Fundamentals and Engineering of Solar Energy Devices (2-1-0-3)

MM 481/ MM 681: High Pressure Materials Processing (2-1-0-3)

MM 483/ MM 683: Analysis and Modelling of Welding (2-0-2-3)

MM 485/ MM 685: Materials Degradation (2-0-2-3)

MM 486/ MM 686: Applied Photoelectrochemistry (2-1-0-3)

MM 487/ MM 687: Advanced Battery Technologies (2–1–0-3)

MM 488/ MM 688: Electroceremics (2-1-0-3)

Elective Courses (VIII Semester)			
Course Code	**Course Name**	**(L-T-P)**	**Credit**
MM 3XX	High Strain Rate Deformation	2-1-0	1.5
MM 3XX	Dislocation Theory	2-1-0	1.5
MM 3XX	Mechanical Alloying	2-1-0	1.5
MM 3XX	High-Pressure Torsion for Alloy Development	2-1-0	1.5
MM 4XX/6XX	Non-Ferrous Alloys for Engineering Applications	2-1-0	3
MM4XX/6XX	Symmetry and Properties of Crystals	2-1-0	3
MM 4XX/6XX	Materials Manufacturing and Quality Assurance	2-0-2	3
MM 4XX/6XX	Defects in Materials	2-1-0	3
MM 6XX/4XX	Semiconductor Processing Technology	2-1-0	3
MM 4XX/6XX	Materials for Devices (Currently MSE 607: 2-1-2-4)	2-1-0	3
MM 4XX/6XX	Thin Film and Devices (Currently MSE 724: 2-1-2-4)	2-1-0	3
MM 4XX/6XX	Single Crystal Growth Techniques (Currently MSE 725: 2-1-2-4)	2-1-0	3

Structure of the Minor programs [from AY 2014-15 to AY 2020-21]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in HSS: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Astronomy (from AY 2016-17):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses***.*** Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	Minor Program in BSBE	Minor Program in Chemistry	Minor Program in Humanities and Social Sciences	Minor Program in Astronomy (from AY 2016-17 onwards)
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I	AA 201: Introduction to Astronomy
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 206: Paradigms and Turning Points # HS 208: French Language-II HS 210: Indian Economy HS 211: German Literature and Culture Studies HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 311: Life and Thought of Gandhi HS 313: History of Early Cinema	AA 301: High Energy Astronomy

			HS 315: Sociology of Science and Technology HS 323: International Economics HS 341: Appreciating Indian English Literature	
8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 418/ 618: Sustainability Studies HS 424/ HS 624: Econometrics-I IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

& *A student who takes CH 202 will not be allowed to take ME 416/616 in his/her 8th Semester*

Structure of the Minor programs [For AY 2021-22]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in HSS: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Astronomy (from AY 2016-17):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses***.*** Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Humanities and Social Sciences**	**Minor Program in Astronomy (from AY 2016-17 to AY 2021-22)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I	AA 201: Introduction to Astronomy
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 206: Paradigms and Turning Points # HS 208: French Language-II HS 210: Indian Economy HS 211: German Literature and Culture Studies HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to	CH 301: Functional	HS 311: Life and Thought of Gandhi	AA 301: High Energy

	Molecular Biology	Materials	HS 313: History of Early Cinema HS 315: Sociology of Science and Technology HS 323: International Economics HS 341: Appreciating Indian English Literature	Astronomy AA 303: IoT for Space Applications
8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling BSE 419/ BSE 619: Renewable Energy Technologies EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 418/ 618: Sustainability Studies HS 424/ HS 624: Econometrics-I IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

& *A student who takes CH 202 will not be allowed to take ME 416/616 in his/her 8th Semester*

Structure of the Minor programs [from AY 2022-23 onwards]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in Economics: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Liberal Arts**

5. **Minor Program in Astronomy and Space Engineering (from AY 2022-23):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses**.** Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Economics (from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**	**Minor Program in Liberal Arts (from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**	**Minor Program in Astronomy (from AY 2016-17 to AY 2021-22) Minor Program in Astronomy and Space Engineering (from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 209: Intermediate Microeconomics	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I	AA 201: Introduction to Astronomy

4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 210: Indian Economy	HS 206: Paradigms and Turning Points HS 208: French Language-II HS 211: German Literature and Culture Studies HS 212: History of India after Independence, 1947-2000 HS 213: Cognitive Psychology HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 323: International Economics HS 325: Industrial Organization	HS 311: Life and Thought of Gandhi HS 313: History of Early Cinema HS 315: Sociology of Science and Technology HS 321: History of Modern Indian Business HS 327: Mind, Action, and Technology HS 341: Appreciating Indian English Literature	AA 301: High Energy Astronomy AA 303: IoT for Space Applications

8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling BSE 419/ BSE 619: Renewable Energy Technologies EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	HS 418/ 618: Sustainability Studies IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 424/ HS 624 Econometrics-I HS 431: Innovation and Intellectual Property Rights	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies HS 446: Music and Literary Modernism HS 481/ HS 681: Language, Mind and Society	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 410/ AA 410: Spatial Informatics AA 412/ AA 612: Microwave Remote Sensing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

Structure of the Minor programs for AY 2024-25 onwards (For all UG batches admitted in and after AY 2023-24)

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in Economics: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Liberal Arts**

5. **Minor Program in Astronomy and Space Engineering (from AY 2022-23):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses**.** Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Economics From AY 2024-25 (Batch Admitted in and after AY 2023-24)**	**Minor Program in Liberal Arts From AY 2024-25 (Batch Admitted in and after AY 2023-24)**	**Minor Program in Astronomy From AY 2024-25 (Batch Admitted in and after AY 2023-24)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 209: Intermediate Microeconomics	HS 211: German Literature and Culture Studies HS 212: History of India after Independence, 1947-2000 HS 203: Psychology HS 205: Sociology HS 221 Fundamentals of	AA 201: Introduction to Astronomy

				Linguistics HS 223 Language Variation: Culture and Society	
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 210: Indian Economy	HS 206: Paradigms and Turning Points HS 214: History of Indian Culture and Civilization HS 213: Cognitive Psychology HS 224 Contemporary Short Fiction HS 226 Sociology of Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 323: International Economics HS 321: History of Modern Indian Business	HS 311: Life and Thought of Gandhi HS 327: Mind, Action, and Technology HS 341: Appreciating Indian English Literature	AA 301: High Energy Astronomy AA 303: IoT for Space Applications
6TH : Minor 4			HS 325: Industrial Organization	HS 315: Sociology of Science and Technology HS 328 Philosophy and Film HS 330 Graphic Literature	

7th : (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)

Syllabi
of
Metallurgy Engineering and Materials Science Courses
(From AY 2017-18 onwards)

Course Code	**MM 201**
Title of the Course	**Mechanics of Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Elastic and plastic behaviour, stress–strain relationship for elastic behaviour, elements of plastic deformation of metallic materials. Mohr's circle, yielding theories Elements of theory of plasticity, dislocation theory properties of dislocation, stress fields around dislocations, application of dislocation theory to work hardening, solid solution strengthening, grain boundary strengthening, dispersion hardening Ductile and brittle fracture, Charpy and Izod testing, significance of DBTT, ECT, NDT and FATT; elements of fractography - Griffith's theory, LEFM– COD and J integral – determination of KIC, COD and J integral Characteristics of fatigue failure, initiation and propagation of fatigue cracks, factors affecting fatigue strength and methods of improving fatigue behaviour – testing analysis of fatigue data, mechanics of fatigue crack propagation, corrosion fatigue Introduction to creep - creep mechanisms, creep curve, variables affecting creep, accelerated creep testing, development of creep resistant alloys, Larsen Miller parameter - Manson Hafred parameter.
Suggested Books	1. G.E. Dieter, **Mechanical Metallurgy**, McGraw Hill Inc. New York, 1988. 2. R.M. Rose, L.A. Shepard, J. Wulff, **Structure and Properties of Materials**, Volume III, 4th Edition, John Wiley, 1984.

Course Code	**MM 202**
Title of the Course	**Extractive Metallurgy**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Minerals of economic importance, commination techniques, size classification, Flotation, gravity and other methods of mineral processing; agglomeration, pyro- hydro- and electro-metallurgical processes; material and energy balances; principles and processes for the extraction of non-ferrous metals – aluminum, copper, zinc, lead, magnesium, nickel, titanium and other rare metals; iron and steel making – principles, role structure and properties of slags, metallurgical coke, blast furnace, direct reduction processes, primary and secondary steel making, ladle metallurgy operations including deoxidation, desulphurization, sulphide shape control, inert gas rinsing and vacuum reactors; secondary refining processes including AOD, VAD, VOD, VAR and ESR; ingot and continuous casting; stainless steel making, furnaces and refractories.
Suggested Books	1. T. Rosenqvist, **Principles of Extractive Metallurgy**, McGraw-Hill Book Company, New York, 1983 2. H.S. Ray and A. Ghosh**, Principles of Extractive Metallurgy**, Wiley Eastern Ltd., New Delhi, 1991) 3. H.S. Ray, R. Sridhar, K.P. Abraham, **Extraction of Nonferrous Metals**, Affiliated East West Press Pvt Ltd., New Delhi, 2007. 4. H.S. Ray, B.P Singh, S Bhattacharjee, **Energy in Minerals and Metallurgical Processes**, Allied Publishers Ltd, New Delhi, 2005. 5. W.H. Dennis, **Extractive Metallurgy**, Philosophical Library, New York, 1965. 6. F. Habashi, **Principles of Extractive Metallurgy**, Vol.1, Gordon and Breach, New York, 1969. 7. W.G. Davenport, A.K. Biswas, **Extractive Metallurgy of Copper**, Pergamon Publishing Company. 8. J.L. Bray, **Non-ferrous Production Metallurgy**, Wiley, New York, 1954. 9. Handbook of Extractive Metallurgy: Fathi Habashi; Wiley-VCH

Course Code	**MM 203**
Title of the Course	**Physical Metallurgy-I**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	**Classification of transformations:** Phase Transformation of first degree and second degree, Energy aspects of first degree and second degree, Energy aspects of homogeneous and heterogeneous nucleation, nucleation ratio, fraction transformed at constant rates of nucleation and growth, Nucleation in solids. Austenite-Pearlite transformation, role of diffusion and temperature on lamellar spacing. **Bainite transformation:** Nature of carbide in bainite, upper and lower bainite, isothermal transformation in austempered ductile iron. **Martensitic transformation:** Crystallographic aspects and mechanism of atom movements, comparison between twinning and martensitic transformation, effect of grain size, Plastic deformation, arrested cooling on kinetics. **Order-Disordered transformations:** Common structures in ordered alloys, Variation of order with temperature, Determination of degree of ordering, Effect of ordering on properties, applications. **Precipitation hardening:** Structural changes, Mechanism and integration of reactions, Effect of retrogression, Double peaks, Spinoidal decomposition. Recovery, recrystallization and grain growth: property changes, Driving forces, N-G aspects, annealing twins, textures in cold worked and annealed alloys, polygonization.
Suggested Books	1. V. Raghavan, **Solid State Phase Transformations**. PHI Learning Pvt. Ltd., 1987. 2. D.A. Porter, E.E. Kenneth, M. Sherif, **Phase Transformations in Metals and Alloys**, CRC press, 2009. 3. P. Haasen, **Phase Transformations in Materials**. Wiley-VCH, 1991. ISBN 3-527-30256-5 4. R.W. Cahn, **Phase Transformations in Materials**. VCH, 1991 - Technology & Engineering, ISBN 3527268189, 9783527268184 5. R.E. Smallman, **Modern Physical Metallurgy**, Elsevier, 2013, ISBN: 9780080982236 (e-book); 9780080982045 (printed book) 6. R. Abbaschian, L. Abbaschian, R.E. Reed-Hill, **Physical Metallurgy Principles**, Cengage Learning Stamford, USA, 2010, ISBN 0495082546.

Course Code	**MM 204**
Title of the Course	**Physical Metallurgy-II**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	**Plastic deformation of single crystal:** Lattice defects, Slip in perfect lattice, easy glide, slip by dislocation movement, Critical resolved shear stress for slip, deformation by twinning, Stacking faults, Strain hardening of single crystal. **Dislocation Theory:** Methods of observation of dislocations, Elastic properties of dislocations, strain energy of dislocations. Forces on and between dislocations, Dislocations in FCC and other crystal structures. Multiplication of dislocations. Dislocation pileups, Strengthening of dislocations. Work hardening. **Diffusion in solids:** Fick's laws of diffusion, Solutions of Fick's law and their applications to metallurgical problems, Kirkendall effect, Atomic movements in diffusion. **Strengthening mechanisms:** Strengthening by grain boundaries, Yield point phenomenon, Strain ageing, Solid solution strengthening from fine particles, fiber strengthening, strengthening due to point defects, Cold Working. **Phase Transformations:** Nucleation and growth considerations, Homogeneous and heterogeneous nucleation. Martensitic transformations, Order-disorder changes, Precipitation hardening, Solution treatment Aging treatment, Nucleation of precipitates, Theories of structural changes during ageing, Study of Al-Cu system, Theories of precipitation hardening. Fractures: Theoretical strength of materials, Types of fractures, Griffith theory of brittle fracture, ductile to brittle transition, ductile fracture, Notch effects.
Suggested Books	1. R. Abbaschian, L. Abbaschian, R.E. Reed-Hill, **Physical Metallurgy Principles**, Cengage Learning Stamford, USA, 2010, ISBN 0495082546. **2.** R.E. Smallman, **Modern Physical Metallurgy**, Elsevier, 2013, ISBN: 9780080982236 (e-book); 9780080982045 (printed book) 3. G.E. Dieter, **Mechanical Metallurgy**, McGraw Hill Inc. New York, 1988. 4. Brophy, Rose and Wulff, **Thermodynamics of Structure** (Vol. II), Wiley Eastern Pvt. Ltd. New Delhi. 5. Hayden, Moffat and Wulff, **The Structure and Properties of**

	Materials, Vol. III (Mechanical Behavior) Wiley Eastern Pvt. Ltd. New Delhi. 6. H. Derek, **Introduction to Dislocations**, Pergamon Press.

Course Code	**ME 205** [from AY 2010-11 to AY 2015-16] **MM 205** [for AY 2016-17 only]
Title of the Course	**Materials Science**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgical Engineering/Mechanical Engineering
Pre–requisite, if any	Nil
Scope of the course	
Course Syllabus	Introduction and classification of Engineering Materials Structure of Metals and Alloys Iron-carbon Phase Diagrams Classification and Properties of Steels, Properties and Industrial applications of alloys steels, tool steels, stainless steels and cast irons. Principles of Heat Treatment of Steels and alloys, Case-Hardening of steels. Properties and uses of non-ferrous materials: Brasses and bronzes, aluminum and its alloys, zinc, tin alloys, nickel and titanium alloys. Mechanical behavior of metals. Cold and hot working of metals. Fracture, fatigue and creep behavior of metals. Corrosion and its prevention.
Suggested Books	**Text Books** 1. W.D. Callister, Jr., "**Materials Science and Engineering**", Wiley India (P) Ltd., 2007. 2. V. Raghvan, **Material Science and Engineering,** Prentice Hall of India Pvt. Ltd. New Delhi. 3. G.E. Dieter, **Mechanical Metallurgy**, McGraw Hill Book Company (UK) Ltd. London, 1988. 4. R.E. Reed-Hill; **Physical Metallurgy Principles** (4th Edition), Cengage Learning, 2003 **Reference Books** 1. F.C. Compbell '**Elements of Metallurgy and Engineering Alloys'**, ASM International, Ohio, 2008 2. R.E. Smallman, A.H.W. Nagan, "**Physical Metallurgy and Advanced Materials**', 7th edition, Elsevier, 2007 3. D.A. Porter and K.E. Easterling, **Phase Transformations in Metals and Alloys**, 2nd edition, Chapman and Hall, London 1992

Course Code	**MM 205** [from AY 2017-18 onwards]
Title of the Course	**Materials Science**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Historical perspective of Materials Science. Why study properties of materials. Classification of materials. Advanced Materials, Future materials and modern materials Atomic Structure, Interatomic Bonding and Structure of Crystalline Solids Atomic structure. Atomic bonding in solids, Crystal structures, Crystalline and non-crystalline materials. Miller indices. Anisotropic elasticity. Elastic behavior of composites. Structure and properties of polymers. Structure and properties of ceramics. Imperfections in Solids Point defects. Theoretical yield point. Line defects and dislocations. Interfacial defects. Bulk or volume defects. Atomic vibrations Module 4: Mechanical Properties of Metals Elastic deformation. Plastic deformation. Interpretation of tensile stress-strain curves Yielding under multi-axial stress. Yield criteria and macroscopic aspects of plastic deformation. Property variability and design factors Diffusion mechanisms. Steady and non-steady state diffusion. Factors that influence diffusion. Non-equilibrium transformation and microstructure Dislocations and Strengthening Mechanisms Dislocation and plastic deformation. Mechanisms of strengthening in metals. Recovery, recrystallization and grain growth. Strengthening by second phase particles. Optimum distribution of particles. Lattice resistance to dislocation motion Phase Diagrams Equilibrium phase diagrams. Particle strengthening by precipitation. Precipitation reactions. Kinetics of nucleation and growth. The iron-carbon system. Phase transformations. Transformation rate effects and TTT diagrams. Microstructure and property changes in iron-carbon system. Ductile and brittle fracture. Fracture mechanics. Impact fracture. Ductile brittle transition. Fatigue. Crack initiation and propagation. Crack propagation rate. Creep. Generalized creep behavior. Stress and temperature effects Applications and Processing of Metals and Alloys Types of metals and alloys. Fabrication of metals. Thermal processing of metals. Heat treatment. Precipitation hardening.
Suggested Books	1. W.D. Callister, **Material Science for Engineers: An Introduction**, John Wily and Sons, Inc. ISBN-10: 0471736961

	2. C.S. Barrett, T.B. Massalski, **Structure of Metals**, McGraw Hill, New York. ISBN 0070038155 9780070038158 3. D.R. Askeland, P.P. Fulay, W.J. Wright, **The Science and Engineering of Materials**, Global Engineering, ISBN-10: 0495296023 4. P.E.J. Flewitt, R.K. Wild, **Physical Methods for Material Characterization**, Institute of Physics Publishing. 5. J.B. Benedict. Recent Advances in Crystallography, , In Tech. ISBN 978-953-51-0754-5 6. B.D. Cullity Addison **Elements of X-ray Diffraction**, Wesley Publishing Co. 7. A.R. West, **Solid State Chemistry and its Applications**, Wiley Student Edition, ISBN10: 497001471

Course Code	**MM 206**
Title of the Course	**Transport Phenomenon**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Fundamentals of momentum transport. Nature of fluids, Compressibility, Newton's law of viscosity, Newtonian fluid, No-slip condition, Transition to turbulence, Bernoulli equation, Fundamentals of heat transport, Fourier's law of heat conduction, Heat transfer from sphere and circular cylinder, Multiphase flow, Gas-liquid two-phase flow, Solid-liquid two-phase flow, Measurement method, Pressure, Velocity, Heat transfer coefficient, Bubble characteristics such as gas holdup. Mixing and separation, Mixing methods, Separation methods. Transport phenomena in real processes, Refining process, Continuous casting process
Suggested Books	1. A. Ghosh, **Text Book of Materials and Metallurgical Thermodynamics**, Prentice Hall of India Pvt. Ltd. New Delhi 2003. 2. A. K. Mohanty, **Rate Processes in Metallurgy**, Prentice-Hall India Ltd., 2000. 3. G.H. Geiger and D.R. Poirer, **Transport Phenomena in Metallurgy**, Addison- Wesley Publishing Co., Reading, Mass., 1974. 4. Y.K. Rao, **Stoichiometry and Thermodynamics of Metallurgical Processes**, Cambridge Univ. Press, 1985. 5. O.J. Ilegbusi, M. Iguchi, and W. Wahnsiedler, **Mathematical and Physical Modeling of Materials Processing Operations**, Chapman & Hall, 1999.

Course Code	**MM 207**
Title of the Course	**Thermodynamics**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Laws of thermodynamics, concepts of reversibility, internal energy, enthalpy, entropy, maximum work, free energy, Maxwell's equations and Gibbs-Helmholtz equation, Clausius-Clapeyron equation, fugacity, activity and equilibrium constant, Sigma function, Concept of chemical potential, homogeneous and heterogeneous equilibria, phase rule, Thermodynamics of solutions, concepts of partial molal properties, Thermodynamics of reversible cells, basic kinetic laws, order of reactions, rate constant, elementary and complex reactions, rate limiting steps, Arrhenius equations, theories of reaction rates – simple collision theory, activated complex theory
Suggested Books	1. A. Ghosh, **Text Book of Materials and Metallurgical Thermodynamics**, Prentice Hall of India Pvt. Ltd. New Delhi, 2003. 2. D.R. Gaskell, **Introduction to Thermodynamics of Materials**, Taylor and Francis, 2003. 3. G.S. Upadhyaya, R.K Dube, **Problems in Metallurgical Thermodynamics and Kinetics**, Pergamon, NewYork, 1982 4. Y.K. Rao, **Stoichiometry and Thermodynamics of Metallurgical Processes**, Cambridge Univ. Press, 1985. 5. J.J. Moore, **Chemical Metallurgy**, Butterworh-Heinemann, 1994.

Course Code	**MM 208**
Title of the Course	**Theory of Metal Forming**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	The course emphasizes the fundamental principles of plastic deformation of metals, mechanics associated with the metal forming, mathematical analysis of various forming methods and recent advancements in metal forming.
Outcomes	• Knowledge of mathematical formulation for a given forming process • Application of the knowledge to various forming processes • Analyse the experimental data and able to construct the processing maps
Course Syllabus	• Plasticity: Mohr's circle representation of a state of stress, Yield criteria, Plastic stress vs. strain relations • Mechanics of Metal Forming: Slab analysis, Uniform deformation energy, Slip line field theory, Upper and lower bound methods etc. Concepts of friction hill • Forming Processes: Analysis of plastic deformation in Forging, Rolling, Extrusion, Drawing, Process parameters and Design considerations, Defects and remedies in the forming processes, Sheet metal forming, Forming Limit Diagram • Metallurgical aspects of Metal forming: Concepts of strain rate sensitivity and its importance, Superplasticity, Workability, Introduction to Processing maps and their construction, Microstructural mechanisms during metal working • Advances in Forming: Laser shock forming, HERF techniques, Super-plastic forming, Hydro-forming, Stretch forming etc.
Suggested Books	**Text Books:** 1. G. Dieter, Mechanical Metallurgy, 1988, McGraw Hill, ISBN: 9780071004060. **Reference Books:** 2. W. F. Hosford, R. M. Caddell, Metal Forming: Mechanics and Metallurgy, Cambridge University Press, 2007, ISBN: 9780511354533. 3. A. Sluzalec, Theory of Metal Forming Plasticity: Classical and Advanced Topics, Springer, 2003, ISBN: 9783540406488.

Course Code	**MM 209**
Title of the Course	**Structure of Materials**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	This course discusses about the basic crystallography of solids and the crystal structures of various materials
Outcomes	To understand the crystal structures of various materials which are very important to understand their physical, chemical and mechanical properties
Course Syllabus	• Atomic interactions and bonding • Periodicity in Crystals, Weigner-Seitz Unit Cell, Number of lattice points per Unit Cell, Crystal Systems, Miller Indices of planes and directions, Miller-Bravais Indices • Symmetry elements and point groups • Crystal structures: SC, BCC, FCC, HCP, DC, complex structures or compounds, Reciprocal lattice • Packing of equal spheres in 2-dimensions and 3-dimensions, Voids in Close Packing Size and Coordination of the Voids, Packing of unequal spheres in 3-dimensions and effect of radius ratio
Suggested Books	**Text Books:** 1. W. D. Callister, Jr., Materials Science and Engineering, Wiley, 2007, ISBN: 9781118324578. 2. C. Kittel, Introduction to Solid State Physics, John Wiley & Sons, 2015, ISBN: 8126535180. **Reference Books:** 3. A.R. West, Solid State Chemistry and its Applications, Wiley, 2014, ISBN: 9781119942948.

Course Code	**MM 210**
Title of theCourse	**Powder Metallurgy and Additive Manufacturing**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of theConcerned Department	Metallurgical Engineering and Materials Science
Pre-requisite,if any	None
Objectives ofthe Course	This course will cover the principles and practices of metal powderproduction, sintering techniques and basics of additive manufacturing.
Outcomes	To understand the basics and applications of powder metallurgytechniques for engineering applications and additive manufacturing
Course Syllabus	• **Introduction:** Powder Metallurgy Overview, Indian KnowledgeSystem • **Powder production and characteristics:** Mechanical, Chemical, and Physical Production methods, Powdercharacteristics and treatment • **Powder Compaction and Sintering:** Die Compaction, IsostaticCompaction, Green Strength, Solid State Sintering, Hot IsostaticCompaction, Liquid Phase Sintering, Spark Plasma Sintering, Post Sintering Operations and Quality Control • **Introduction to Additive manufacturing:** Binder Jetting, Directed Energy Deposition, Powder Bed Fusion, Laser beam melting, Selective laser sintering • 3D printing of metallic and polymer systems • Typical components manufactured by powder metallurgy

SuggestedBooks	**Text Books:** 1. Anish Upadhyay, Powder Metallurgy: Science, Technologyand Materials, University Press, 2011, ISBN: 9788173717178. 2. R.M. German, Powder Metallurgy- Principles and Applications, MPIF, Princeton, 1994, ISBN: 0976205718. 3. C.K. Chua, and K.F. Leong, 3D Printing and Additive Manufacturing: Principles and Applications, World Scientific Publishing, 2017, ISBN: 9789813146754. **Reference Books:** 4. P.C. Angelo, R. Subramaniam, Powder Metallurgy - Science,Technology and Application, Prentice Hall India, 2008, ISBN: 9789391818487. 5. ASM Handbook, Vol. 7, Powder Metallurgy, ASM International, 2010, ISBN: 9781627080893.

Course Code	**MM 211**
Title of the Course	**Physics of Materials**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	To understand the physical properties of materials using physics concepts
Outcomes	To acquire the knowledge on physical properties of materials using classical and quantum mechanical aspects.
Course Syllabus	• Brief about statistical distributions (MB, FD, BE), Ideal gas, electron gas, Drude model for electron gas, limitation of Drude model, Drude-Sommerfeld model • Free electron theory, Density of energy states, Fermi energy, Fermi surface • Electron in periodic potential, Kronig-Penney model, Nearly free-electron model, Tight-binding approximation, Reciprocal space, Brillouin zones
Suggested Books	**Text Books:** 1. C. Kittel, Introduction to Solid state physics, Wiley, 2017, ISBN: 9788126535187. 2. A. Piroth, Fundamentals of the Physics of Solids, Springer-Verlag, 2009, ISBN: 9783540853152. **Reference Books:** 3. A. Moliton, Solid State Physics for Electronics, Wiley, 2009, ISBN: 9781848210622.

Course Code	**MM 212**
Title of theCourse	**Casting and Welding Technology**
Course Category	Department Core
Credit Structure	L-T-Credits 2-1-0-1.5 (half semester)
Name of theConcerned Department	Metallurgical Engineering and Materials Science
Pre–requisite,if any	None
Objectives ofthe Course	The course is designed for systematic understanding on various casting process, solidification fundamentals, casting defects, various welding process, fusion welding techniques, solid-state welding techniques, advances in casting and welding
Outcomes	To be familiar in casting techniques, solidification, welding techniques, advanced welding process, casting and welding defects.
Course Syllabus	**Casting Technology:** Pattern making, Study of moulding sands and their testing methods, Technology of mould making and core making, Principle of runner, riser and gate design for castings, Casting defects and their prevention, Different Casting Processes such as lost wax casting, die casting, precision casting, lost form casting, centrifugal casting, Chvorinov's rule, Solidification time, solidification principles and microstructure evolution. **Welding Technology:** Fusion welding processes, Fusion welding fundamentals, HAZ, various fusion welding processes like laser welding, EBW, plasma arc welding etc, Solid state joining and welding processes like friction stir welding, explosive welding, magnetic pulse welding, etc. Welding of dissimilar metals, Brazing and Soldering, Adhesive bonding, Heat transfer calculations in welding, Welding defects and remedies.
Suggested Books	**Text Books:** 1. A. K. Chakraborti, Casting Technology and Cast Alloys, Prentice Hall India, 2005, ISBN: 978-8120327795. 2. Lindberg and Braton, Welding and Other Joining Processes, Ally & Bacon Inc., 1976. ISBN: 978-0205050000. **Reference Books:** 3 1. G. J. Davies, Solidification and Casting, Applied Science Publishers Ltd, 1973, ISBN: 0853345562. 4. P. L. Jain, Principles of Foundry Technology, McGraw Hill Education, 2017, ISBN: 9780070151291. 5.L.M. Gourd, Principles of Welding Technology, ELBS Longman, 1986, ISBN: 978-8176490290

Course Code	**MM 214**
Title of theCourse	**Materials Characterization**
Course Category	Departmental Core
Credit Structure	L-T-P- Credits2-0- 2-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite,if any	None
Objectives ofthe Course	This course will cover the basic principles of X-ray diffraction, scanning electron microscopy and transmission electron microscopy and spectroscopy techniques with instrument details and data acquiring methods
Outcomes	Knowledge of basics of crystallography, Learning of SEM and TEM imagesanalyse and electron diffraction patterns, Understanding and analysis of materials properties using spectroscopic and other techniques.
Course Syllabus	● Spectroscopy: UV-Visible Absorption, Fluorescence and Emission, FT-IR, Raman, XPS, XAS, ARPES, SIMS, XANES, ● X-ray diffraction: Bragg's law, Ewald Sphere, Laue Equations; Powder Diffraction Method, Diffractometer; Structure Factor, Crystal Structure Determination; Peak Broadening; Crystallite Size and Strain Determination; Order-Disorder Transformation; Residual Stress; GI XRD, ● Microscopy: Optical micrography, Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Microanalysis (EDS), Wavelength Dispersive X-ray microanalysis (WDS); EPMA, Scanning tunnelling microscopy (STM), Atomic force microscopy (AFM), Transmission Electron Microscopy (TEM): SADP, STEM, HAADF imaging; EELS, ● Thermal characterization techniques: DSC, TGA, DTA, Dilatometry, ● Representative list of experiments: ▪ Optical bandgap calculation of metal oxide films using UV Visible spectrometer ▪ Study relative emission properties of doped and undoped metal oxide films using Fluorescence ▪ Analyse the surface group polymer materials using FT-IR ▪ Analyze X-ray diffraction patterns of different samples ▪ Microstructural analysis using optical microscope and SEM ▪ TGA analysis of ceramic and polymer samples

SuggestedBooks	**Text Books:** 1. C.N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, McGraw Hill, 2017, ISBN: 9352601734. 2. B. D. Cullity, Elements of X-Ray Diffraction, Pearson, 2001, ISBN: 0201610914. 3. J.I. Goldstein, A.D. Romig, D.E. Newbury, C.E. Lyman, P. Echlin, C. Fiori, D.C. Joy, E. Lifshin, Scanning Electron Microscopy and X-Ray Microanalysis: A Textbook for Biologists, Materials Scientists and Geologists; Springer, 2018,ISBN: 149396674X. 4. D. B. Williams, C. Barry Carter, Transmission Electron Microscopy -A Textbook for Materials Science; Springer, 2009,ISBN: 038776500X. **Reference Books:** 5. H.H. Willard, L.L. Merritt, J.A. Dean, F.A. Settle, InstrumentalMethods of Analysis, C.B.S. Publishers, 1991, ISBN: 0534981445.

Course Code	MM 215
Title of the Course	**Mechanical Behavior of Materials**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	To introduce the students to basic concepts of plasticity and mechanism of plastic deformation and its relevance to engineering applications
Outcomes	• To understand the different aspects of plasticity. • To know the importance of dislocations in plastic deformation of metals and understand the relevant mechanism for slip and strengthening of metals.
Course Syllabus	• Elasticity: Tensor algebra: Properties of Vectors and Tensor, Transformation of vectors and tensor, Cauchy's stress tensor, Stress deviator, Strain tensor, Elastic stress-strain relations for isotropic solids, strain energy density • Plasticity: Stress-strain curve, Engineering and true values of stress and strains, Elementary theories of plasticity, Theoretical shear strength of crystalline materials, Dislocation theory, Peierls-Nabarro stress, CRSS, Slip and twinning, Dislocation energy and velocity, Schmid analysis • Strengthening mechanisms: Strain hardening of FCC single crystal, Work hardening, Solid Solution Strengthening, Grain boundary Strengthening, Precipitation and dispersion hardening • Fracture and Failure: Ductile and brittle fracture, Charpy and Izod testing, the significance of DBTT, NDT, and FATT, Stress concentration factor, Strain energy release rate, Griffith's theory, LEFM approach, Determination of KIC • Fatigue: Characteristics of fatigue failure, S-N curve, Low and high cycle fatigue, Fatigue crack growth • Creep: Creep curve, Creep mechanisms, Introduction to Ashby map and their construction, Larsen Miller parameter, Development of creep resistant alloys
Suggested Books	**Text Books:** 1. G. Dieter, Mechanical Metallurgy, McGraw-Hill, 1988, ISBN: 9780071004060. 2. T. H. Courtney, Mechanical Behavior of Materials, Waveland Pr Inc, 2005, ISBN: 1577664256. **Reference Books:** 3. R.W. Hertzberg et.al, Deformation & Fracture Mechanics of Engineering Materials, Wiley, 2012, ISBN:

	9780470527801. 4. W. F. Hosford, R. M. Caddell, Metal Forming: Mechanics and Metallurgy, Cambridge University Press, 2007, ISBN: 9780511354533. 5. M. Meyers, K. Chawla, Mechanical Behavior of Materials, Cambridge University Press, 2008, ISBN: 9780511810947.

Course Code	**MM 216**
Title of theCourse	**Physical Metallurgy**
Course Category	Departmental Core
Credit Structure	L-T-P- Credits 2-1- 0-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite,if any	None
Objectives ofthe Course	This course covers the basic concepts of diffusion, alloy theory, crystal interface and boundaries along with industrial application of metallic and ceramic phase diagrams.
Outcomes	To understand the basics of materials-structure-properties correlations andphase diagrams.
Course Syllabus	Review of structure of metals and crystal defects: Interface coherence, Interfacial energy effects, Misfit strain effects Diffusion in solids: Fick's laws of diffusion, diffusion mechanism, Kirkendall effect, Darken's equations, Glissile interface, Interfacemigration Theory of alloy Phases: Hume-Rothery rule, Solid solution, Intermediate phases, Solid state immiscibility Phase diagrams: Phase rule, Unary, Binary and Ternary systems,Lever rule, Microstructures, Invariant reactions Iron-carbon phase diagram: steels and cast irons, Classification offerrous system, International standards Nucleation rate and different type of growth considerations, TTTand CCT diagrams Case studies of simple ceramics systems
SuggestedBooks	**Text Books:** 1. R. Abbaschian, L. Abbaschian, R. E. Reed-Hill, Physical Metallurgy Principles, Cengage Learning, 2009, ISBN: 9780495082545. 2. R.E. Smallman, Modern Physical Metallurgy, Elsevier, 2013,ISBN: 9780080982045. **Reference Books:** 3. D.A. Porter, E.E. Kenneth, M. Sherif; Phase Transformations inMetals and Alloys, CRC press, 2009, ISBN: 9781439883570. 4. F. C. Campbell; Phase Diagrams: Understanding the Basics,ASM International, 2012, ISBN: 9781615038350.

Course Code	**MM 217**
Title of the Course	**Transport Phenomena**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	The course focuses on the concepts of fluid flow, heat transfer and mass transfer with behaviour and processing of engineering materials.
Outcomes	To learn: • Mathematical foundations of transport phenomena • Fundamental of Momentum transfer, Heat transfer, mass transfer
Course Syllabus	• Mathematical foundations of transport phenomena, Tensors, Control volume formulation and concept of balance • Fundamentals of momentum transport: Navier-Stokes equation, Nature of fluids, Compressibility, Newton's law of viscosity, Newtonian and non-Newtonian fluids, No-slip and No-Shear conditions, Transition to turbulence, Boundary layer theory, Bernoulli equation, exact solutions for simple geometries: rectangular, cylindrical and spherical coordinate systems. Friction factors and correlations. Application of fluid flow solutions to materials processing. • Fundamentals of heat transport: Governing equations for heat transfer, Fourier's law of heat conduction, Exact solutions for heat transfer problems, Empirical correlations, Heat transfer from sphere and circular cylinder, Heat transfer coefficient, Radiation: Black body radiation, Stefan-Boltzman Law, Kirchhoff's Law, heat transfer coupled with fluid flow. • Fundamentals of Mass transfer, Significance of dimensionless numbers, Similarity across transport phenomena.
Suggested Books	**Text Books:** 1. D.R. Poirier and G.H. Geiger: Transport phenomena in materials processing, Springer, ISBN: 9783319485652. 2. R. B. Bird, W. E. Stewart, E. N. Lightfoot: Transport phenomena, Wiley, ISBN: 9788126508082. **Reference Books:** 3. J. R. Welty, C. E. Wicks, R. E. Wilson, G. Rorrer, Fundamentals of Momentum, Heat and Mass Transfer, Wiley, 2008, ISBN: 9780470128688. 4. R. W. Fox, A. T. McDonald, Introduction to Fluid Mechanics, Wiley, 2010, ISBN: 9780470547557.

Course Code	**MM 219**
Title of theCourse	**Thermodynamics of Materials**
Cours Category	Departmental Core
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite,if any	None
Objectives ofthe Course	The course focuses on basic concept, thermodynamic functions,thermodynamic solutions, phase equilibria, electrochemical cell, reaction equilibria and Free energy composition diagram.
Outcomes	• To learn about the basic concept of thermodynamics, • To understand thermodynamics of solutions, phase equilibria, electrochemical cells, reaction equilibria and free energy compositiondiagram for binary system.
Course Syllabus	• Introduction: Laws of thermodynamics and its applications, Carnot Cycle, Statistical interpretation of entropy and disorder • Thermodynamic functions: Helmholtz free energy, Gibbs free energy,Maxwell's relations, Gibbs-Helmholtz equations • Thermodynamic of open systems: Concept of Chemical potential,fugacity, activity • Thermodynamics of solutions: Raoult's and Henry's Law, activity of a component, Regular solutions, Gibbs-Duhem equation and its application, non-ideal solutions, Sievert's Law, activity and alternative standard states, dilute solutions and interaction parameters. • Phase equilibria in single component system: variation of Gibbs free energy with temperature and pressure, Clausius-Clapeyron equation, P-T diagram • Reaction Equilibria: Equilibrium constant, Reaction equilibria for (a) homogeneous reactions consisting of gas mixtures, (b) heterogeneous reactions consisting of condensed phases and gas mixtures, EllinghamDiagram • Introduction to Free energy composition diagram

SuggestedBooks	**Text Books:** 1. R. A. Swalin, Thermodynamics of Solids, Wiley-VCH; 1972,ISBN**:** 970471838548. 2. D. R. Gaskell, Introduction to Thermodynamics of Materials,CRC Press, 2008, ISBN: 9781439851500. **Reference Books:** 3. L. Darken and R. W. Gury, Physical Chemistry of Metals, CBSPublisher, 2002, ISBN**:** 9788123914794. 4. D.A. Porter and K.E. Easterling, Phase Transformation CRCPress, 2009, ISBN: 9781420062106. 5. D.A. Porter, K.E. Easterling, M. Sherif; Phase Transformationsin Metals and Alloys, CRC Press, 2009, ISBN: 9781439883570.

Course Code	**MM 221**
Title of the Course	**Finite Element Simulations in Materials**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	The course covers the basic concepts of finite element methods analysis
Outcomes	• Learning of basic concepts of FEM • Application of FEM analysis for problems in materials engineering
Course Syllabus	• **Basic concepts:** The standard discrete system, Finite elements of an elastic continuum-displacement approach, Generalization of the finite element concepts; weighted residual and variational approaches. Strong form and weak form. • **Finite element method:** Displacement approach, Stiffness matrix and boundary conditions, Natural coordinates, Element types: triangular, rectangular, quadrilateral, Isoparametric elements and numerical integration: One dimensional and two dimensional. • **Application to structural mechanics problems:** plane stress and plane strains. Few examples on solving boundary value problems using MATLAB/ABAQUS/COMSOL software.
Suggested Books	**Text Books:** 1. C. S. Krishnamoorty, Finite Element Analysis, McGraw Hill, 2017, ISBN: 9780074622100. 2. D. V. Hutton, Fundamentals of Finite Element Analysis, McGraw Hill, 2017, ISBN: 9780070601222. **Reference Books:** 3. S. S. Rao, Finite Element Method in Engineering, Elsevier, 2004, ISBN: 0750678283. 4. Erik G. Thompson, Introduction to the Finite Element Method: Theory, Programming and Applications, Wiley, 2004, ISBN: 9780471267539. 5. H. C. Martin, G. F. Carey, Introduction to Finite Element Analysis - Theory and Application, McGraw Hill, 1975, ISBN: 0070994390.

Course Code	**MM 223**
Title of the Course	**Statistical Mechanics for Materials Science**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	Understanding the fundamental ideas of statistical mechanics and its importance in materials science and engineering
Outcomes	To apply the concepts of statistical mechanics in materials engineering
Course Syllabus	• **Introduction to statistical mechanics**: Significance of statistical mechanics, Probability & Statistics, Concept of Macrostate, Microstate and Ensembles • **Classical Statistical Mechanics**: Microcanonical, Canonical and Grand Canonical ensemble, Phase Space, Maxwell-Boltzmann Distribution Law • **Quantum Statistical Mechanics**: Identical particles, Fermions and Bosons, Fermi- Dirac distribution function. Effect of temperature on Fermi-Dirac distribution function, Density of States, Fermi-energy. Bose Einstein distribution function and Bose- Einstein Condensation, Materials properties based on quantum statistical mechanics
Suggested Books	**Text Books:** 1.B. Bagchi, Statistical Mechanics for Chemistry and Materials Science, CRC Press, 2018, ISBN: 9780429833601. 2. R. K. Pathria, Statistical Mechanics, Oxford, 1997, ISBN: 0750624698. **Reference Books:** 3. K. Huang, Statistical Mechanics, Wiley, 2008, ISBN: 9788126518494.

Course Code	**MM 225**
Title of the course	**Materials Economics and Sustainability**
Course Category	Department Elective
Credit structure	2-1-0-1.5 (half semester)
Name of the concerned department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	Nil
Objectives of the course	The course aims to provide students with knowledge of economic considerations in materials engineering and importance of materials sustainability
Outcomes	• Economic impact of materials • Material selection towards sustainability and understanding of materials for future trends
Course syllabus	• Introduction to the relationship between material cost, abundance, and usage, cost of Materials: raw materials, processing/purification, materials transport etc, The technological aspect of material cost, role of materials economy in manufacturing • Economics of engineering materials design and selection, cost reduction using materials engineering • Application-driven economics and future materials, Sustainable materials and circular economy, life cycle of important metals, market analysis of engineering materials; Production, consumption and price trends of metals
Suggested books	**Text Books:** 1. M. F. Ashby, Materials and Sustainable Development, Butterworth-Heinemann, 2015, ISBN: 0081001762. 2. P. Heck, Material Flow Management Systems, Technology and Finance for a Sustainable Future, Springer, ISBN: 9783540360155 **Reference Books:** 3. A. G. Peñas, Gaurav Sharma, New Materials for a Circular Economy, Materials Research Forum, 2023, ISBN: 1644902621. .

Course Code	**MM 229**
Title of the Course	**Nucleation and Crystal Growth**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	Fundamentals of Materials Science
Objectives of the Course	To introduce the students with the fundamentals physical processes involved in the nucleation and growth of crystals
Outcomes	Upon completion of the course, students are expected to gain an understanding of the fundamental physical and chemical processes which are involved in crystal growth.
Course Syllabus	• Nucleation phenomena, concepts of critical nucleus, types of nucleation, theory of nucleation, mechanism and growth kinetics ofisolated crystals. • Introduction to various crystal growth techniques (solution, gel, meltand vapour), low temperature solution growth, high temperature solution growth, solubility phase diagram, types of gels, Single and double diffusion method, chemical reduction method, Bridgman Technique, Czochralski Technique, Zone melting Technique, hydrothermal method.
SuggestedBooks	**Text Books:** 1. I. V. Markov, Crystal Growth for Beginners, World Scientific,2004, ISBN: 9789812382450. 2. H.L. Bhat, Introduction to Crystal Growth: Principles and Practice, Taylor & Francis, CRC Press, 2014, ISBN: 9781439883334. **Reference Books:** 3. G. Dhanaraj, K. Byrappa, V. Prasad, M. Dudley. Handbook ofCrystal Growth, Springer, 2010, ISBN: 9783540741824.

Course code	MM 226
Title of the course	**Materials Informatics**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	Familiarity with basic Materials Science and Engineering principles, crystal structures, phase diagrams, and mechanical properties.
Objectives of the course	To introduce the interdisciplinary field of materials informatics, and application of data science in Materials Science and Engineering
Outcomes	• Acquire skills in data analysis, machine learning, and computational modelling for materials science and engineering applications • Apply materials informatics techniques to real-world materials problems
Course syllabus	• Introduction to materials informatics- definition, scope and importance. Overview of data sources and understanding of different data types in materials science, Data processing and analysis using statistical methods • Overview of existing databases for materials informatics - Supervised learning techniques like SVM, KNN, Tree, neural networks and Evolutionary neural networks Unsupervised learning techniques, including PCA, K-means clustering, and linear regression. Introduction to machine learning tools, and its application to materials discovery. Structure property relationships and property models • Case studies and applications in various materials systems, Limitations of different methods and future trends
Suggested books	**Text Books:** 1. K. Rajan, Informatics for Materials science and engineering, Butterworth-Heinemann, 2015, ISBN: 9780123943996. 2. O. Isayev, A. Tropsha, S. Curtarola, Materials Informatics: Methods, Tools and Applications, Wiley, 2019, ISBN: 9783527341214. **Reference Books:** 3. S.R.Kalidindi, Hierarchical Materials Informatics, Butterworth-Heinemann, 2015, ISBN: 9780124103948.

Course code	**MM 228**
Title of thecourse	**Ceramic Science and Technology**
Course Category	Department Elective
Credit Structure	L - T - P – Credits 2-1-0-1.5 (half semester)
Name of theConcerned Department	Metallurgical Engineering and Materials Science
Pre-requisite,if any	None
Objectives ofthe course	The course provides fundamental aspects of ceramics and theirapplications.
Outcomes	• To acquire knowledge of fundamental principles that govern thestructure of ionically & covalently bonded ceramics, including glasses, refractories, electro ceramics, etc. • To gain insights into defect formation mechanisms in ceramics andtheir impact on the functional properties of the ceramics
Course Syllabus	• Definitions and classifications; Pauling's rules. • **A Few Important Binary & Complex Structure:** Rock-Salt, Fluorite, Spinel, Perovskite, Silicates, Mullite, Olivine, Garnet, etc. • Sintering Phenomenon in Polycrystalline Ceramics • **Defects in Ceramics:** Stoichiometric and non-stoichiometric defects; Kröger-Vink notation; Defect equilibria & Brouwer diagrams. • **Glass:** Definition; Formation mechanism; Structure models;Zachariasen's rules; Network formers, modifiers, and intermediates. • **Application of Ceramic Materials:** Glass industry; Glazes & Enamels; Whitewares; Cement & Concrete; Advanced ceramics - energy storage, microelectromechanical systems,optoelectronic devices, etc

SuggestedBooks	**Text Books:** 1. D. Kingery, H. K. Bowen, and D. R. Uhlmann, Introduction to Ceramics, 2nd Edition, Wiley India Pvt. Ltd., 2012, ISBN:978-8126539994. **Reference Books:** 2. Richard J. D. Tilley, Defects in Solids, John Wiley & Sons, 2018, ISBN: 9780470077948. 3. Anthony R. West, Solid State Chemistry and its Applications,Wiley, 2014, ISBN: 978-1119942948. 4. K. P. Misra and R.D.K. Misra, Ceramic Science and Engineering: Basics to Recent Advancements, Elsevier, 2022, ISBN: 9780323899567.

Course Code	**MM 230**
Title of the Course	**Diffusion in Solids**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of theConcerned Department	Metallurgical Engineering and Materials Science
Pre-requisite if any	Familiarity with materials science fundamentals, encompassing materials thermodynamics and material structures, is preferred.
Objectives ofthe Course	This course provides in-depth understanding of solid-state diffusionprocesses and explores its significance in practical applications.
Outcomes	• To get understanding of diffusion phenomena • To be able to solve diffusion equations for various processes andselecting appropriate diffusion coefficient types
Course Syllabus	• Laws of diffusion: Basic concepts of thermodynamics related to diffusion, Various frames of reference used for measuring diffusion fluxes, application of diffusion to various metallurgical processes • Atomic mechanism of diffusion: Formation of defects, mechanisms of diffusion, concept of random walk, diffusion in ordered phases • Diffusion parameters: Various diffusion coefficients, experimental determination, Matano-Boltzmann analysis, Den Broeder and Wagner's approach, Problem of finding the initial contact plane.
SuggestedBooks	**Text Books:** 1. P. Shewmon, Diffusion in solids, Springer, 2016, ISBN:9780873391054. 2. J. Philibert, Atom movements: Diffusion and mass transports insolids, EDP Sciences, 2012, ISBN: 2759801721. **Reference Books:** 3. H. Mehrer, Diffusion in solids: fundamentals, methods, materials,diffusion-controlled processes, Springer, 2009, ISBN: 0263849058. 4. D. A. Porter, and K. E. Easterling, Phase transformations in metalsand alloys, Nelson Thornes Ltd, 2009, ISBN: 0412450305.

Course code	**MM 232**
Title of thecourse	**Thin Film Technology**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-1.5 (half semester)
Name of theConcerned Department	Metallurgical Engineering and Materials Science
Pre-requisite ifany	Fundamentals of Materials Science
Objectives ofthe Course	This course introduces the concepts of physics of vacuum science, thinfilm formation and the various methods to develop thin films.
Outcomes	Upon completion of the course, students will understand the science ofthin film growth, various technologies to develop thin films and their applications.
Course syllabus	Fundamentals of nucleation and film formation, Introduction to vacuumscience and technology, Thin film deposition techniques: Physical Vapour Depositions: resistive heating and electron beam evaporations, sputtering, magnetron sputtering, reactive sputtering, RF sputtering, pulsed laser deposition. Chemical Vapour Deposition Methods: atmospheric pressure (APCVD), low pressure (LPCVD), Ultra-High Vacuum (UHVCVD), Microwave Plasma-Assisted (MPCVD), plasma enhanced (PECVD); Atomic layer deposition, Molecular beam epitaxy (MBE).
SuggestedBooks	**Text Books:** 1. K. L. Chopra, Thin Film Phenomena, McGraw-Hill, 1969,ISBN: 9780070107991. 2. M. Ohring, The Materials Science of Thin Films, AcademicPress Inc., 1991, ISBN: 9780125249904. **Reference Books:** 3. A. Gowsami, Thin Film Fundamentals, New Age International1996, ISBN: 978-8122408584.

Course Code	**MM 251**
Title of the Course	**Mechanics of Materials Lab**
Credit Structure	L-T-P-Credits 0-0-3-1.5
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Tensile tests on cylindrical or plate specimens; Fracture Mechanics tests; Fatigue Tests (axial and bending); Impact and Thermal Shock testing of the large area samples; Residual stress measurement; Fatigue tests (axial and bending); Modulus of Elatcicty, Flexural test; Poisson ratio flexural test; Cantilever flexural test
Suggested Books	**1.** Suryanarayana, **Testing of Metallic Materials**, Prentice Hall India, New Delhi, 1979.

Course Code	**MM 252**
Title of the Course	**Casting and Welding Technology Lab**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 0-0-2-1
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	This lab course demonstrates experiments in different types of casting and welding technology.
Outcomes	Students will be able to learn experimental skills in casting and welding technology.
Course Syllabus	**List of Representative Experiments** • To study and observe various stages of casting through demonstration of Sand- Casting Process (a) To prepare a pattern for given object for lost form casting. (b) To prepare a molasses sand mold from the prepared pattern • Preparation of as-cast and suction cast Cu-Sn alloy through demonstration of Vacuum arc melting cum suction casting technique. • Preparation of light-weight Al-based alloy through demonstration of stir casting cum squeeze casting technique. • Casting of Steel through demonstration of Induction melting cum casting technique. • To study TIG and MIG welding process. To prepare weld joint and to study on effect of process parameter on weld joint • To study CMT welding Process. To prepare weld joint using CMT welding, study on effect of process parameter on weld joint • To study friction stir welding Process. To prepare weld joint using friction stir welding, study on effect of process parameter on weld joint. • To study Diffusion welding process. To prepare weld joint using diffusion welding, study on effect of process parameter on weld joint
Suggested Books	**Reference Books:** 1. A. K. Chakraborti, Casting Technology and Cast Alloys, Prentice Hall India New Delhi, 2005, ISBN: 978-8120327795. 2. G. J. Davies, Solidification and Casting, Applied Science Publishers Ltd, London, 1973, ISBN: 0-853345562. 3. P. L. Jain, Principles of Foundry Technology, McGraw Hill Education, 2017, ISBN: 978-0070151291. 4. Lindberg and Braton, Welding and Other Joining

	Processes, Ally & Bacon Inc., Boston, 1976, ISBN: 978-0205050000. 5. L.M. Gourd, Principles of Welding Technology (2nd Edition), ELBS Longman, 1986, ISBN: 978-8176490290.

Course Code	**MM 254**
Title of the Course	**Physical Metallurgy Lab**
Credit Structure	L-T-P-Credits 0-0-3-1.5
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Introduction to metallographic specimen preparation; Metallography and Image analysis; Optical microscopy of ferrous and non ferrous samples; Quantitative Metallography; X-Ray diffraction in material analysis; Nucleation, recovery and recrystallization behaviors analysis; Thermal analysis for phase transformation studies.
Suggested Books	Same as MM 203 and MM 204

Course Code	**MM 255**
Title of the Course	**Mechanical Behaviour of Materials Lab**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 0-0-2-1
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	None
Objectives of the Course	This lab course demonstrates basic experiments to understand mechanical behavior of materials
Outcomes	To learn various experiments about mechanical properties of materials and understand its analysis
Course Syllabus	**List of Representative Experiments:** • Determination of Brinell, Vickers, and Rockwell hardness of materials • Determination of impact toughness by Izod and Charpy method • Determination of quasi-static tensile and compression properties of the given metallic alloys at room/high temperatures from the stress vs. strain curves • Determination of bending strength of materials and fracture toughness measurement using the three-point bending method. • Determination of full-field displacement of a given tensile / compression sample using digital image correlation. • Development of the creep curve of a given sample • Determination of high strain rate compression strength of given metallic sample • Fractographic examination using SEM
Suggested Books	**Reference Books:** 1. A.V.K. Suryanarayana, Testing of Metallic Materials, Prentice Hall, 1979, ISBN: 9789352300372. 2. G. Dieter, Mechanical Metallurgy, 1988, McGraw Hill, 1988, ISBN: 9780071004060.

Course Code	**MM 257**
Title of theCourse	**Metallography Lab**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 0-0-2-1
Name of theConcerned Department	Metallurgical Engineering and Materials Science
Pre-requisite,if any	None
Objectives ofthe Course	This lab course demonstrates the experiments to understand the fundamentaland microstructural aspects of Physical Metallurgy
Outcomes	• To learn various metallographic preparation techniques. • To learn experimental and numerical methods for analysis in PhysicalMetallurgy
Course Syllabus	**List of Representative Experiments:** • Metallographic sample preparation (grinding, polishing) of ferrous alloys, and non-ferrousalloys • Metallographic sample preparation of ceramic and compositesamples • Optical Microscopy of typical carbon steel and stainless-steelsamples • Optical microscopy of cast irons • Optical Microscopy of typical non-ferrous samples • Optical microscopy of typical ceramic and composite samples • Effect of different etchants to observe microstructure of steel samples • Quantitative microstructural analysis • Determination of ASTM grain size and Inclusion rating of steel • Effect of cooling rate on microstructure evolution of steel samples • Microstructure observations of cold worked, hot worked, annealedand decarburised samples
SuggestedBooks	**Reference Books:** 1. R. Abbaschian, L. Abbaschian, R. E. Reed-Hill, Physical Metallurgy Principles, Cengage Learning, 2009, ISBN: 970495082545. 2. D.A. Porter, K.E. Easterling, M. Sherif, Phase Transformations in Metals and Alloys, CRC Press, ISBN: 9781439883570. 3. F. C. Campbell, Phase Diagrams: Understanding the Basics, ASMInternational, ISBN: 9781615038350. 4. R.E. Smallman, Modern Physical Metallurgy, Elsevier, 2013, ISBN: 9780080982045.

Course Code	**MM 258**
Title of the Course	**Metal Forming Lab**
Credit Structure	L-T-P-Credits 0-0-3-1.5
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Experiments on Hot rolling; cold rolling open die forging, closed die forging, Deep drawing, Extrusion, super plastic forming, Hydro forming
Suggested Books	Same as MM 208

Course Code	**MM 258N**
Title of the Course	**Metal Forming Lab**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 0-0-2-1
Name of the Concerned Discipline	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	This lab course covers experiments to understand various metal forming processes
Outcomes	• To understand the principles of various metal forming methods. • To analyse the processing parameters and quality control aspects in different processes
Course Syllabus	**List of Representative Experiments:** • Introduction and hands-on training of basic instruments used in metal forming • Determining strain distribution on the stretched aluminium and steel sheets • Open-die forging of steel and aluminium • Close-die forging of steel and aluminium • Determining friction and wear (in relation to the metal forming operations) • Sheet metal forming and determination of FLD at room temperature • Cold and hot rolling of metallic samples • Wire drawing of metallic samples • Extrusion of metallic samples • Quality Control: NDT tests in metal forming • Application of forming: Designing the process flow and manufacturing the actual components • Introduction to metal forming industry practices (with the help of educational videos)
Suggested Books	**Reference Books:** 1. G. Dieter, Mechanical Metallurgy, McGraw Hill, 1988, ISBN: 9780071004060 2. W. F. Hosford, R. M. Caddell, Metal Forming: Mechanics and Metallurgy, Cambridge University Press, 2007, ISBN: 9780511354533. 3. H.S. Ray, B.P Singh, S Bhattacharjee, Energy in Minerals and Metallurgical Processes, Allied Publishers Ltd, 2005, ISBN: 9788177648744.

Course Code	**MM 301**
Title of the Course	**Polymer Technology**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Chemistry of high polymers: Monomers, functionality, degree of polymerizations, classification of polymers, glass transition, melting transition, criteria for rubberiness, polymerization methods: addition and condensation; their kinetics, metallocene polymers and other newer techniques of polymerization, copolymerization, monomer reactivity ratios and its significance, kinetics, different copolymers, random, alternating, azeotropic copolymerization, block and graft copolymers, techniques for copolymerization-bulk, solution, suspension, emulsion. Polymer Characterization: Solubility and swelling, concept of average molecular weight, determination of number average, weight average, viscosity average and Z-average molecular weights, polymer crystallinity, analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA), microscopic (optical and electronic) techniques. Synthesis and properties: Commodity and general purpose thermoplastics: PE, PP, PS, PVC, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, PC, PBT, PSU, PPO, ABS, Fluoropolymers Thermosetting polymers: PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds. Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex, SBR, Nitrile, CR, CSM, EPDM, IIR, BR, Silicone, TPE. environmental stress cracking resistance
Suggested Books	1.

Course Code	**MM 302**
Title of the Course	**Welding and Foundry Engineering**
Credit Structure	L-T-P-Credits: 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	**Casting Process:** Introduction to casting, pattern materials, allowances, coding, types, moulds, mould making, sand, properties, types and testing of sands, core making, type of cores, single box, two box and 3 box moulding processes, runner, riser and gate. **Special Casting Processes:** Pressure die casting, Centrifugal, continuous, investment, shell moulding, squeeze, electro slag casting, CO_2 moulding, Plaster mould castings, Antioch process, Slush casting **Welding Processes:** Introduction to soldering, brazing and welding types of joining, plane of welding, edge preparation, filler material, flux, shielding gases, fusion welding, gas welding, gas flame types, manual arc welding, arc theory, power supply, braze welding, Thermit welding, Resistance welding, spot, seam, projection, percussion & flash. **Special Welding Processes:** Atomic, H_2 arc welding, Shielded gas arc welding, GMAW, GTAW, Submerged arc welding, Electro slag welding, friction welding, explosive welding, Underwater welding, Diffusion bonding, EBW, LBW, PAW, Stud welding, welding of dissimilar materials, Friction stir welding.
Suggested Books	1. Lindberg and Braton, **Welding and Other Joining Processes**, Ally & Bacon Inc., Boston, 1976. 2. Flinn, **Fundamentals of Metal Casting**, Addison-Wesley, Reading, 1963. 3. J. Szekely, J.E. Evans, J.K. Brimacambe, **The Mathematical and Physical Modelling of Primary Metal Processing Operations**, Wiley, 1988. 4. H.S. Ray, **Kinetics of Metallurgical Reactions**, Oxford & IBH Publishing Co. Pvt. Ltd., 1993. 5. J. Szekely, J.W. Evans and H.Y. Sohn, **Gas–Solid Reactions**, Academic Press, New York, 1976. 6. L.M. Gourd, **Principles of Welding Technology (**2nd Edition**)**, ELBS Longman, 1986. 7. A. C. Davies, **Welding**, Cambridge University Press, 1996. 8. P. L. Jain, **Principles of Foundry Technology**, Tata McGraw Hill, 2001. 9. Heine, Loper and Rosenthal, **Principles of Metal Casting**, Tata McGraw Hill, 1996 10. A. K. Chakraborti, **Casting Technology and Cast Alloys**, Prentice Hall India New Delhi, 2005.

Course Code	**MM 303**
Title of the Course	**Introduction to Electrochemistry**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	**Electrode-electrolyte interface:** The electrical double layer. The Helmholtz-Perrin parallel-plate model, Gouy-Chapman diffuse-charge model and the Stern model. **Corrosion:** Electrochemical mechanism of corrosion. Types of corrosion, various methods of corrosion control. D.C **Polarography:** Dropping mercury electrode-polarography Instrumentation-polarogram. **Types of limiting Currents:** Adsorption, Diffusion, Kinetic. Ilkovic equation and its consequences. Applications of polarography. Determination of stability constant of complex. **Cyclic Voltammetry:** Principle, instrumentation, reversible and irreversible cyclic voltammograms. Applications. Cyclic voltammetric study of insecticide parathion. **Electro-Organic synthesis:** Electro chemical reduction of carboxylic acids, Electrochemical reduction of nitro compounds. **Anodic oxidation of metals:** Characteristics of anodic oxide films. Instrumentation –break down voltage. Industrial applications of anodic oxide films
Suggested Books	1. J.O.M. Bockris, A.K.N. Reddy, **Modern Electrochemistry** Plenum Publishers, 2000 2. S. Glasstone, **Introduction to Electrochemistry**, 2012 3. D. Pletcher, **Industrial Electrochemistry**, Chapman & Hall 4. Lowenheim, **Fundamental Principles of Modern Electroplating**, John Wiley & Sons Inc. New York, 2011

Course Code	**MM 304**
Title of the Course	**Corrosion Engineering**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	The technology & evaluation of corrosion. Economics, safety, electrochemical nature of corrosion, the forms of corrosion and corrosion rate determination. Electrochemical thermodynamics and electrode potential. Electrode sign conventions, potential/pH diagrams, and experimental measurements. Electrochemical kinetics of corrosion. Faraday's Law, mixed potential theory, experimental methods, and instrumentation. Passivity and properties of passive films on metals. Alloy evaluation and experimental methods. Polarization methods for measuring corrosion rates. Tafel extrapolation & polarization resistance, instrumental methods and commercial corrosion monitoring devices. Galvanic, concentration cell, pitting and crevice corrosion. How to characterize the different forms of corrosion, their evaluation and prevention methods. Effects of metallurgical structure on corrosion. Intergranular corrosion, weldment corrosion, and susceptibility to hydrogen damage. Corrosion in selected corrosive environments. Specific examples of typical corrosion problems encountered in engineering applications, sulfur bearing solutions, soils, acids, and concrete. Coatings & inhibitors. Organic coatings, paints, metallic coatings, inhibitors. Materials selection and design. Alloy selection, designing to prevent corrosion, and economics
Suggested Books	1. M.G. Fontana, N.D. Greene, **Corrosion Engineering**, McGraw-Hill, New York, 1978. 2. H.H. Uhlig, R.W. Revie, **Corrosion and Corrosion Control** (3rd Ed), Jonh Wiley & Sons Inc. New York, 1985. 3. K.R. Trethewey, J. Chamberlain, **Corrosion for Students of Science and Engineering**, Longman Sci. & Technical, 1988. 4. A.J. Bard, L.R. Faulkner, **Electrochemical Methods: Fundamentals & Applications**, John Wiley & Sons Inc. New York, 1980.

Course Code	**MM 305**
Title of the Course	**Iron and Steel Making**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Classification of furnaces; different kinds of furnaces; heat balance, energy conservation and energy audit; parts, construction and design aspects of blast furnace (B/F), ancillary equipment; blast furnace instrumentation Blast furnace reactions; partitioning of solute elements between the metal and the slag; reactions in blast furnace; blast furnace slags; mass balance and heat balance calculations Blast furnace operations; B/F irregularities and remedial measures, B/F refractories and causes of failure, modern trends in B/F technology; overview of direct reduction processes, electric smelting; production of DRI (HBI/Sponge iron) Review of traditional steel making; thermodynamics of steelmaking; air/O2 impurity interaction, slag metal interaction; foaming slag; removal of S and P; de-oxidizers, refining, alloying Open hearth furnace; Bessemer converter; bottom blown and top blown processes; slag practices and sequencing; LD, VD, AOD and VOD; ladle metallurgy and injection metallurgy; electric arc furnace and DRI usage; ingot casting and continuous casting; energy, environmental and quality considerations
Suggested Books	1. O. P. Gupta, **Elements of Fuels, Furnace and Refractories** (2nd Edition), Khanna Publications Delhi, 1990. 2. G.R, Bashforth, **Manufacture of Iron and Steel** (Vol. I-IV), Asia Publ., 1996. 3. R.H. Tupkary, V.R., Tupkary **Modern Iron Making**, Khanna Publications, Delhi, 2004

Course Code	**MM 306**
Title of the Course	**Powder Metallurgy**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Introduction: Development of powder metallurgy-scope of powder metallurgy, characterization of metal powders, physical properties-particle size and shape determination, technological properties-apparent density, flow rate etc. and chemical properties. Powder manufacture: Reduction, electrolysis, and atomization processes. Compaction and sintering: Die compaction and other consolidation techniques, sintering, sintering with liquid phase. Powder metallurgy products: Bearing, filters, friction parts, hard metals, refractory metals, contact materials, magnetic materials, structural parts, dispersion strengthened materials.
Suggested Books	1. G.S. Upadhyaya, **Powder Metallurgy Technology**, Cambridge International Science Publishing, 1998. 2. P.C. Angelo, R. Subramaniam, **Powder Metallurgy - Science, Technology and Application,** Prentice Hall India Ltd. New Delhi, 2008. 3. R.M. German, P**owder Metallurgy- Principles and Applications**, MPIF, Priceton, 1994. 4. ASM Handbook, Vol. 7, Powder Metallurgy, ASM International, 2010.

Course Code	**MM 307**
Title of the Course	**Composites**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Introduction General characteristics of composites; advantages and disadvantages, application trends. Basic Materials Characteristics of fibers, matrices, interface bonding, adhesives; microstructure of composites. Processing/Manufacturing Traditional and novel approaches; process fundamentals. Composite Micromechanics Basic concepts, stiffness, strength, thermal and moisture expansion. Composite Mechanics Theory Laminate theory; use of a computer based analysis package; macromechanical behavior of a ply, out-of-plane effects. Failure and Strength Design Failure criteria, Laminate Strength, Stress Concentrations. Composite Behavior and Applications How do actual composites for aerospace, automotive, sporting goods, high temperature applications behave? Problem areas, long-term performance, influence of structural geometries
Suggested Books	1. K.K. Chawala, **Composite Materials** (2nd ed.), Springer-Verlag, New York, 1987. 2. P.M. Ajayan, L.S. Schadler, P.V. Braun, **Nanocomposite Science and Technology**, Wiley-VCH Verlag GmbH Co. KGaA, Weinheim, 2003. 3. V.V. Vasiliev, E.V. Morozov, **Mechanics and Analysis of Composite Materials**, Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 lGB, UK, 2001. 4. K.K. Chawala, **Ceramic Matrix Composites**, (1st ed.), Chapman & Hall, London, 1993 5. G. Piatti, **Advances in Composite Materials**, Applied Science Publishers Ltd., London, 1978

Course Code	**MM 308**
Title of the Course	**Thin films and Nano-Structures**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Physics of low-dimensional materials, 1D, 2D and 3D confinement, Density of states, Excitons, Coulomb blockade, Surface plasmon, Size and surface dependence of physical, electronic, optical, luminescence, thermodynamical, magnetic, catalysis, gas sensing and mechanical properties. Physical and chemical techniques for nanomaterial synthesis, Assembling and self organization of nanostructures, Nanoscale manipulation, N Physical Vapor Deposition - Hertz Knudsen equation; mass evaporation rate; Knudsen cell, Directional distribution of evaporating species Evaporation of elements, compounds, alloys, Raoult's law; e-beam, pulsed laser and ion beam evaporation, Glow Discharge and Plasma, Sputtering - mechanisms and yield, dc and rf sputtering, Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering, Hybrid and Modified PVD- Ion plating, reactive evaporation, ion beam assisted deposition, Chemical Vapor Deposition - reaction chemistry and thermodynamics of CVD; Thermal CVD, laser & plasma enhanced CVD, Chemical Techniques - Spray Pyrolysis, Electrodeposition, Sol-Gel and LB Techniques, Nucleation & Growth: capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth, stages of film growth & mechanisms, amorphous thin films, Epitaxy - homo, hetero and coherent epilayers, lattice misfit and imperfections, epitaxy of compound semiconductors, scope of devices and applications.
Suggested Books	1. D. Mobius, R. Miller, **Organized Monolayers and Assemblies: Structure, Processes and Function**, Elsevier Science 2004 2. M. Rieth, **Nano Engineering in Science & Technology,** World Scientific Publishing Co., Inc 2003 3. K. Holmberg, B. Jonsson, B. Kronberg, B. Lindman, **Surfactants and Polymers in Aqueous Solution**, Wiley 2004. 4. J. Lyklema, **Fundamentals of Interface and Colloid Science**, Academic Press, 5. Z.L Wang **Characterization of Nanophase Materials,** Wiley VCH, 2000. 6. G. Schmidt, **Nanoparticles: From theory to applications**, Wiley, 2004. 7. D.F. Evans and W. Hkan, **The Colloidal Domain: Where**

	Physics, Chemistry, Biology, and Technology Meet, Wiley VCH 1999.

Course Code	**MM 309N**
Title of the Course	**Computational Methods for Materials**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Atomistic Level Modelling: Review of thermodynamic laws, micro & macro state, ergodic system, partition function, statistical mechanics, thermodynamic ensembles, Monte Carlo simulation- Markov process, algorithm and application of MC simulation (percolation problem etc). molecular dynamics-force fields, MD algorithm, accelerating MD, verlet algo, leap frog method, velocity verlet method, gear algo, particle mesh method, multipole method, fast multipole method. multiscale modelling & simulation of materials, System size vs computation time, Parallel processing. Ab Initio Methods: Density functional theory, quantum mechanics, schrodinger wave equation, many particle system, car parrinello method, born openheimer approximation, hohenberg-kohn theorem, kohn sham formulation, local density approximation, bloch's theorem, pseudo potential, energy minimisation techniques, examples of crystals and non-crystals. Lattice Mesoscale methods: Lattice gas automata, lattice director model. Coarse graining: Particle based models-Lattice gas model, connolly williams approximation, spatial models, dynamic (temporal) models, application to polymer and polar materials. grain continuum modelling, computational micro-mechanics, multiscale coupling. Term Paper on application of Multiscale Modelling to Composite damage Dislocation behaviour Phase field modelling Modelling of grain growth and microstructure in polycrystalline materials Modelling of structural materials And other recent advances based on literature survey
Suggested Books	1. K. Ohno, K. Esfarjani, Y. Kawazoe, **Computational Material Science,** Springer, 2003. 2. Z. H. Barber, **Introduction to Materials Modeling**, Maney Publishing, 2001.

Course Code	**MM 310**
Title of the Course	**Ceramics Technology**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	**Refractories:** Classification, Modern trends and developments, Basic raw materials, Elementary idea of manufacturing process technology, Flow diagram of steps necessary for manufacture, basic properties and areas of application. **Whitewares:** Classification and type of Whitewares, Elementary idea of manufacturing process technology including body preparation, basic properties and application areas. **Ceramic Coatings:** Types of glazes and enamels, Elementary ideas on compositions, Process of enameling & glazing and their properties. **Glass:** Definition of glass, Basic concepts of glass structure, Batch materials and minor ingredients and their functions, Elementary concept of glass manufacturing process, Different types of glasses, Application of glasses. **Cement and Concrete:** Concept of hydraulic materials, Basic raw materials, Manufacturing process, Basic compositions of OPC, Compound formation, setting and hardening, Tests of cement and concrete.
Suggested Books	1. M. Barsoum, M.W. Barsoum, **Fundamentals of Ceramics**, CRC Press, 2002, ISBN 9780750309028. 2. F. Singer, **Industrial Ceramics,** Springer, 2013. ISBN: 9401752591. 3. W.D. Kingery, **Introduction to Ceramics,** 1960, ISBN: 0471478601. 4. F.H. Norton, **Elements of Ceramics,** 1952 ISBN: 9780201053067 5. W.F. Smith, **Principles of Materials Science and Engineering,** 1986, ISBN: 0073529249.

Course Code	**MM 351**
Title of the Course	**Polymer Technology Lab**
Credit Structure	L-T-P-Credits 0-0-3-1.5
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Polymer testing: Mechanical-static and dynamic tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact, toughness. Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity, swelling, ageing resistance
Suggested Books	Same as MM 301

Course Code	**MM 352**
Title of the Course	**Welding and Foundry Engineering Lab**
Credit Structure	L-T-P-Credits 0-0-3-1.5
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	GMA & MMA Welding Practice and Demonstration + TIG Welding Demonstration & Polymer Joining 1 Brazing and Gas Welding Practice and Demonstration Demonstration & Practice of thermocole pattern making, molasses mold making + Demonstration of green sand mold making, and metal pouring in both molds
Suggested Books	1. Lindberg and Braton, **Welding and Other Joining Processes**, Ally & Bacon Inc., Boston, 1976. 2. Flinn, **Fundamentals of Metal Casting**, Addison-Wesley, Reading, 1963. 3. J. Szekely, J.E. Evans, J.K. Brimacambe, **The Mathematical and Physical Modelling of Primary Metal Processing Operations**, Wiley, 1988. 4. H.S. Ray, **Kinetics of Metallurgical Reactions**, Oxford & IBH Publishing Co. Pvt. Ltd., 1993. 5. J. Szekely, J.W. Evans and H.Y. Sohn, **Gas–Solid Reactions**, Academic Press, New York, 1976. 6. L.M. Gourd, **Principles of Welding Technology (**2nd Edition**)**, ELBS Longman, 1986. 7. A. C. Davies, **Welding**, Cambridge University Press, 1996. 8. P. L. Jain, **Principles of Foundry Technology**, Tata McGraw Hill, 2001. 9. Heine, Loper and Rosenthal, **Principles of Metal Casting**, Tata McGraw Hill, 1996 10. A. K. Chakraborti, **Casting Technology and Cast Alloys**, Prentice Hall India New Delhi, 2005.

Course Code	**MM 354**
Title of the Course	**Corrosion Engineering Lab**
Credit Structure	L-T-P-Credits 0-0-3-1.5
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Principle of corrosion protection, methods of corrosion protection, better design, materials selection, barrier coatings, cathodic protection, anodic protection, inhibitor chemicals. Tools for corrosion inspection, corrosion monitoring, corrosion management
Suggested Books	1. M.G. Fontana, N.D. Greene, **Corrosion Engineering**, McGraw-Hill, New York, 1978. 2. H.H. Uhlig, R.W. Revie, **Corrosion and Corrosion Control** (3rd Ed), Jonh Wiley & Sons Inc. New York, 1985. 3. K.R. Trethewey, J. Chamberlain, **Corrosion for Students of Science and Engineering**, Longman Sci. & Technical, 1988. 4. A.J. Bard, L.R. Faulkner**, Electrochemical Methods: Fundamentals & Applications**, John Wiley & Sons Inc. New York, 1980.

Course Code	**MM 357**
Title of the Course	**Composites Development Lab**
Credit Structure	L-T-P-Credits 0-0-3-1.5
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Fabrication of Metal Matrix Composites: Commonly used Matrices,Basic Requirements in Selection of constituents, solidification processing of composites - XD process, Spray processes - Osprey Process, Rapid solidification processing, Dispersion Processes - Stir-casting & Compocasting,Screw extrusion, Liquid metal impregnation technique - Squeeze casting,Pressure infiltration, Lanxide process, Pinciple of molten alloy infiltration, rheological behaviour of meltparticle slurry, Synthesis of In situ Composites; Fabrication of Polymer Matrix Composites - Commonly used Matrices Basic Requirements in selection of Constituents, Moulding method, Low pressure closed moulding, pultrusion, Filament winding, Fabrication of ceramic matrix composites - Various techniques of vapour deposition, Liquid phase method and Hot pressing etc., Fabrication of nano-composites
Suggested Books	1. K.K. Chawala, **Composite Materials** (2nd ed.), Springer-Verlag, New York, 1987. 2. P.M. Ajayan, L.S. Schadler, P.V. Braun, **Nanocomposite Science and Technology**, Wiley-VCH Verlag GmbH Co. KGaA, Weinheim, 2003. 3. V.V. Vasiliev, E.V. Morozov, **Mechanics and Analysis of Composite Materials**, Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 lGB, UK, 2001. 4. K.K. Chawala, **Ceramic Matrix Composites**, (1st ed.), Chapman & Hall, London, 1993 5. G. Piatti, **Advances in Composite Materials**, Applied Science Publishers Ltd., London, 1978

Course code	**MM 309N**
Title of the course	**Computational Methods for Materials**
Course Category	Department Core
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	Introduction to Materials Science and Engineering, Thermodynamics
Scope of the course (Objectives)	This course introduces the fundamentals to computational modeling methods. It provides the students with the skills to understand and apply these methods to common materials modelling software to materials science and engineering domain
Course Outcomes	Upon completion of the course, students are expected to: • Explain the fundamentals principles of various computational modelling techniques, equipping them to model materials behavior at various scales • Use the relevant software to solve the real problems in the materials field
Course Syllabus	• Thermodynamic approach to modelling, molecular dynamics (MD): concept of unit cell, supercells, reciprocal lattice, interatomic potentials, integration schemes (Euler, Verlet, Velocity-Verlet), equilibration techniques and velocity rescaling, implementation of and considerations in MD • Basics of quantum mechanics and Born-Oppenheimer approximation, density functional theory, pseudopotential, local density approximation (LDA), generalized gradient approximation (GGA), Bloch's theorem and other considerations • Monte Carlo methods: ensemble averages, metropolis algorithm, Ising model, kinetic Monte Carlo methods • Other methods: multiscale modelling, CALPHAD approach, integrated computational materials engineering (ICME), application of machine learning methods to materials problems
Suggested books	**Text Books** 1. R. LeSar, Introduction to Computational Materials Science, Cambridge University Press, 2013, ISBN: 0521845874 2. J. G. Lee, Computational Materials Science - An Introduction, CRC Press, 2017, ISBN: 9781315368429 **Reference Books:** 3. W. Andreoni, S. Yip, Handbook of Materials Modelling, Methods: Theory and Modeling, Springer Cham, 2020, ISBN: 9783319446769 4. D. Raabe, Computational Materials Science: The Simulation of Materials, Microstructures and Properties, Wiley-VCH Verlag

	GmbH, 1998, ISBN: 9783527295418 5. M.P. Allen and D.J. Tildesley, Computer Simulation of Liquids, Oxford University Press, 2017, ISBN: 9780198803195

Course code	**MM 305N**
Title of the course	Iron and Steel Making
Credit Structure	L - T - P - Credits 2 - 1 - 0 - 3
Name of the Concerned Department	MEMS
Pre-requisite, if any	NA
Scope of the course	To equip the manpower with ferrous extraction knowledge to fulfil the demands of growing steel and manufacturing sectors worldwide
Course outcome	Students will learn fundamental and practical aspects of process metallurgy, applied thermodynamics in iron and steel making, blast furnace ironmaking, various routes of iron and steel making challenges and solutions in iron and steel making
Course Syllabus	**Ironmaking:** • Introduction to the iron and steel Industry in India and worldwide • Blast furnace iron making: plant construction and process description; raw materials and their preparation; blast furnace gas cleaning; hot-blast stove. production of metallurgical coke • Thermodynamics of iron making; various zones and physical/chemical processes in each zone; material and enthalpy balance • Blast furnace irregularities, recent improvements • Alternative routes of iron production: smelting-reduction processes (like COREX, FINEX, etc.), DRI making **Steel making:** • Thermodynamics of steel making • Primary steel making: BOF and EAF; reactions and process dynamics • Secondary steel making: deoxidation, argon stirring, desulphurization, inclusion shape control, degassing; Stainless-steel manufacturing • Continuous Casting: fluid flow in the tundish and mould, heat transfer in the mould, segregation, inclusion control • Introduction to green steel making technology
Suggested Books	**Text books:** 1. A. Ghosh and A. Chatterjee: *Ironmaking and Steelmaking: Theory and Practice*, PHI Learning, 2008. ISBN: 9788120332898 2. D. Mazumdar: *A First Course in Iron and Steelmaking*, Universities Press, Orient Blackswan Pvt. Ltd., New Delhi, 2015. ISBN: 9788173719394 **Reference books:** 3. J.C. Peacey, W. G. Davenport: *The Iron Blast Furnace:*

	Theory and Practice, Pergamon Press, 1979, ISBN: 9780080232584 4. Richard J. Fruehan: *The Making, Shaping, and Treating of Steel, 11th Edition, Steelmaking and Refining*, Association for Iron & Steel Technology (AIST), 1998, ISBN: 9780930767020 5. B.P. Bhardwaj, Steel and Iron Handbook, NIIR PROJECT CONSULTANCY SERVICES, 2014, ISBN: 9789381039304 6. Metals Handbook Desk Edition 2nd Edition, 1 December 1998 by ASM International Handbook Committee (Author), J. R. Davis (Editor) ISBN-10: 0871706547

Course Code	MM 311
Title of the Course	**Optical and Magnetic Properties of Materials**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2-1-0-1.5 (3/2) (half semester)
Name of the Concerned Discipline	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This course will help students develop both a quantitative and a qualitative understanding of optical and magnetic properties of materials
Learning Outcomes	Students will learn about the fundamental, properties and applications of optical and magnetic materials
Course Syllabus	• Optical properties: light-matter interaction; absorptivity, reflectivity, refractivity, transmittivity, Maxwell equations, Classical and quantum approach to optical properties • Magnetic properties: types of magnetism (dia-, para-, ferro-, antiferro-, and ferri-), quantum description of magnetism • Superconductivity: Meissner effect, Type I and Type II superconductors, BCS theory • Applications: solar cells, light-emitting diode, magnetic levitation, magnetic resonance imaging, etc.
Suggested Books	**Text Books:** 1. P. Fulay, J.K. Lee, Electronic, Magnetic, and Optical Materials, 2nd Edition, CRC Press, 2016, ISBN: 9781498701693 2. C. Kittel, Introduction to Solid State Physics, Wiley, 2012, ISBN: 9788126535187 **Reference Book:** 3. C.G. Stefanita, Magnetism: Basics and Applications, Springer, 2012, ISBN: 9783642229763

Course Code	MM 313
Title of the Course	**Non-ferrous Extractive Metallurgy**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Discipline	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	The course aims to provide basic knowledge to the students about different extractive metallurgical processes for the extraction of non-ferrous metals and their refining
Learning Outcomes	On completion of the course, the students will have thorough understanding of the different extractive metallurgical process used for the extraction of non-ferrous metals.
Course Syllabus	• **Introduction to non-ferrous metals extraction:** Occurrence and sources, Methods of beneficiation: Comminution, classification and concentration, flotation. General methods of extraction: Pyro-, hydro- and electro-metallurgy • **Extraction of metals from oxides:** Aluminium; Bayers process for alumina production, Hall-Heroult process; Magnesium: Pidgeon process; Tin: Rotary furnace smelting • **Extraction of metals from sulphide ores:** Copper; Smelting and converting; Zinc; Imperial smelting process; Nickel: Carbonyl process • **Extraction of metals from halides:** Titanium; Kroll's process; Nuclear metals like Uranium • **Extraction of precious metals:** Gold: Amalgamation process; Silver: Park's process • Utilization of metallurgical/e-wastes • Metal refining, Distillation, Zone refining, etc. **List of representative experiments:** • To perform sampling and sieve analysis of crushed ore • Crushing of ore/coal using jaw crusher and study the size distribution using sieving • Verification of Rittinger's Law and determination of reduction ratio during crushing of ore/coal in jaw crusher • To study the effect of residence time on ball mill grinding of a given material • To separate coal from a mixture of coal and, stones or quartz by jigging and determine the weight fractions of the products • To study the beneficiation of an ore pulp using froth floatation cell • To perform calibration of a thermocouple and determination of temperature profile of a furnace • To determine the calorific value of a given solid fuel using

	bomb calorimeter • To study the roasting kinetics of a sulphide ore in an oxidizing environment • To study the electrowinning process of copper from aqueous solution
Suggested Books	**Text books:** 1. T. Rosenqvist, Principles of Extractive Metallurgy, McGraw-Hill Book Company, 1983, ISBN: 9781878907134 2. H.S. Ray, R. Shridhar, K.P. Abraham, Extraction of Nonferrous metals, Affiliated East-West Press Pvt Ltd., 1985, ISBN: 8185095639 **Reference books:** 3. G.S. Upadhyaya, R.K. Dube, Problems in Metallurgical Thermodynamics and Kinetics, Pergamon Press, 1977, ISBN: 9780080208657 4. S. Bhattacharjee, V.N. Misra, H.S. Ray and B.P. Singh, Energy in Minerals and Metallurgical Industries, Allied Publishers Ltd, 2005, ISBN: 9788177648744 5. O.D. Neikov, S.S. Naboychenko, N.A. Yefimov, Handbook of Non-Ferrous Metal Powders: Technologies and Applications, Elsevier, 2019, ISBN: 9780081005439 6. Metals Handbook Desk Edition 2nd Edition, 1 December 1998 by ASM International Handbook Committee (Author), J. R. Davis (Editor) ISBN-10: 0871706547

Course Code	MM 315
Title of the Course	**Polymer and Composites**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 2 –1 – 0 – 3
Name of the Concerned Discipline	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This course is to provide a basic aspect of the polymers and composites, its fabrication, analysis, performance, and mechanics
Learning Outcomes	Students will have understanding on basics of processing, structure, characterization and properties of polymers and composites and their engineering applications.
Course Syllabus	**Polymers:** • **Introduction to Polymers:** Thermo-physical properties such as glass transition, melting transition, criteria for rubberiness • **Polymerisation and processing:** Polymerisation reactions and techniques, Processing (extrusion, molding, compounding and mixing, thermoforming etc.) • **Polymer Technology:** Commercial importance; additives for plastics; stabilizers, fillers, plasticizers and extenders, lubricants and flow promoters, flame retardants, blowing, colourants, cross-linking and biodegradation additives • **Engineering Plastics and Rubber Technology:** Thermoplastic, thermosets, hydrogels, conducting polymers. Rubber and elastomers, vulcanization, natural and synthetic rubbers • **Polymer characterization:** Molecular Weight and density, melting point, glass transition, heat capacity, mechanical and viscoelasticity **Composites:** • **Introduction to Composite materials:** Classifications, applications, types of reinforcement, types of matrices, reinforcement-matrix interface, interfacial bonding • **Composites manufacturing techniques:** Fabrication and processing of metal, ceramic and polymer matrix-based composites; Solid and liquid state processing • **Mechanics of Composites:** structural composite; Continuous fibres – iso-stress and iso-strain conditions, ,Theory of stress transfer, Modulus and strength of discontinuous fibres composites, basic analysis of orthotropic lamina, laminated composites, strengthening mechanism of composites such as dispersion strengthening and dislocation strengthening in particulate metal matrix, load transfer strengthening in

	polymer matrix, crack deflection and bridging in ceramic matrix composites or mixed strengthening, etc., shear lag model, mechanical testing of composites, failure criteria
Suggested Books	**Text Books:** 1. R.J. Young and P.A. Lovell, Introduction to Polymers, 3rd Edition, CRC Press, 2011, ISBN: 9780849339295 2. R.H. Broutman, L.J. Krock, Modern Composite Materials, Addison-Wesley Publishing Company, Inc., 1967, ISBN: 9780201006292 3. B.D. Agrawal, L.J. Browtman, A. Chandrashekhara, Analysis and Performance of Fibre Composites, Wiley Publications, 2016, ISBN: 9788126536368 **Reference Books:** 4. C.E. Carraher Jr, Introduction to Polymer Chemistry, 3rd Edition, CRC Taylor & Francis, 2010, ISBN: 0849370477 5. T. W. Clyne and D. Hull, An Introduction to Composite Materials, Cambridge University Press, 2019, ISBN: 9780521860956

Course Code	MM 353
Title of the Course	**Computational Methods for Materials Lab**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 0-0-2-1
Name of the Concerned Discipline	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This lab course covers experiments to learn various computational techniques utilized for materials engineering
Learning Outcomes	Students will be able to learn computational techniques to understand various aspects of materials
Course Syllabus	**List of representative experiments:** • Implementation of rotation symmetry elements on a point • Creating a 2D lattice and estimating the nearest neighbour bonds • Estimation of cohesive energy, lattice parameters and bulk modulus at 0 K • Estimation of lattice parameter as a function of temperature • Evaluating defect formation energies (vacancy and interstitial) • Generation of stress-strain curves in tension or compression • Implementation of Monte-Carlo method using metropolis algorithm • Estimation of lattice parameters, cohesive energies and bulk modulus in pure metals and compounds using density functional theory calculations • Implementation of Ising model and estimation of stacking fault energies • Demonstration of machine learning scripts on datasets to estimate the materials properties
Suggested Books	**Reference books:** 1. R. LeSar, Introduction to Computational Materials Science, Cambridge University Press, 2013, ISBN: 97811390333982 2. J.G. Lee, Computational Materials Science - An Introduction, CRC Press, 2017, ISBN: 9781138582552 3. M.P. Allen and D.J. Tildesley, Computer Simulation of Liquids, Oxford University press, 2017, ISBN: 9780198803195 4. Z. H. Barber, Introduction to Materials Modeling, Maney Publishing, 2001, ISBN: 9781902653761 5. K. Ohno, K. Esfarjani, Y. Kawazoe, Computational Materials Science, Springer, 2003, ISBN: 9783540639619

Course Code	MM 355
Title of the Course	**Polymer and Composites Lab**
Course Category	Departmental Core
Credit Structure	L-T-P-Credits 0-0-2-1
Name of the Concerned Discipline	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This laboratory course is designed to provide experimental knowledge related to the fabrication and analysis of various properties of polymer and composites
Learning Outcomes	Students will be able to: • Understand various processing techniques of polymers and composites • Analyze properties of polymers and composites with different methods
Course Syllabus	**List of representative experiments:** • To synthesize a conducting polymer • Processing of polymer by electrospinning • To determine the Hardness for different polymers using durometer (in shore A and D scale) • To evaluate the hydro-phobic/philic nature of polymers • To identify the glass transition temperature of given polymer • To prepare fibre reinforced polymer composite using hand-lay-up technique • Tuning and measurement of conductivity of carbon nanofiber reinforced polystyrene composite • To study the fabrication process and analysis of metal matrix composite • To study the fabrication process and analysis of ceramic matrix composite • To prepare nanocomposite for functional applications • To determine the tensile and flexural strength of composites
Suggested Books	**Reference books:** 1. R.J. Young and P.A. Lovell, Introduction to Polymers, 3rd Edition, CRC Press, 2011, ISBN: 9780849339295 2. B.D. Agrawal, L.J. Browtman, A. Chandrashekhara, Analysis and Performance of Fibre Composites, John Wiley Publications, 2016, ISBN: 9788126536368

Course Code	MM 317
Title of the course	**Lightweight Materials for Structural Applications**
Course Category	Department Elective
Credit structure	2-1-0-1.5 (3/2) (half semester)
Name of the concerned department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	None
Objectives of the course	The course covers the concept of lightweighting and major lightweight materials used for structural applications
Outcomes	• Understand the concept of lightweighting in automotive and aerospace industries • Learn about important light weighting materials and their characteristics, processing, and properties and applications
Course syllabus	• **Concept of lightweighting:** Environmental impact of lightweight construction, strategies for lightweighting, concept of life cycle analysis • **Light weight metals and alloys:** Aluminium alloys, Magnesium alloys, Titanium alloys, Advanced steel • **Composites and structural ceramics:** Light weight metal, polymer and ceramic matrix composites; characteristics, properties and processing • **Case studies:** Case studies of lightweighting examples in different industries such as automotive and aerospace
Suggested books	**Text Books:** 1. F. C. Campbell, Lightweight Materials: Understanding the Basics, ASM International, 2012, ISBN: 1615038493 2. K. Kumar, B. S. Babu, J. Paulo Davim, Light Weight Materials: Processing and Characterization, Wiley, 2021, ISBN: 9781786307972 **Reference Books:** 3. I. Polmear, D. StJohn, J. F. Nie, M. Qian, Light Alloys: Metallurgy of the Light Metals, Elsevier Science, 2017, ISBN: 9780080994314 4. S. Thirumalai Kumaran, T. J. Ko, S. S. Kumar, T. Varol, Materials for Lightweight Constructions, 2024, CRC Press: ISBN: 9781032171746

Course code	MM 318
Title of the course	**Multicomponent Alloys**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	Fundamentals of Materials Science
Scope of the course	The course focuses on design, processing, properties applications of multicomponent materials
Learning Outcomes	Students will learn about the overview of multicomponent alloys, multicomponent alloy forming criteria, manufacturing methods and applications etc.
Course syllabus	**Introduction:** Basic concepts of multicomponent alloys, Classification, thermodynamics and kinetics of HEAs and MGs. **Design, synthesis and processing:** Design criteria for HEAs and MGs; Liquid-, solid- and gas-state synthesis processes such as arc melting-rapid quenching method, powder metallurgy, plasma and thermal spray etc. **Deformation behaviour of HEAs, MGs and other multicomponent alloys:** Inhomogeneous and homogenous deformation, shear band mechanism, elastic, plastic and anelastic deformation, fatigue, fracture behaviour and morphology. **Structural and functional Properties:** Mechanical, wear, oxidation behaviour, diffusion barrier properties; electrical, electrochemical, catalytic, thermal, thermoelectric, magnetic, irradiation resistance. **Applications:** Aerospace, high-temperature and nuclear, biomedical, automotive industry, energy and electronics.
Suggested books	**Text Books:** 1. Z. Jiao, T. Yang, Advanced Multicomponent Alloys: From Fundamentals to Applications, Springer, 2023, ISBN: 9789811947452 2. B. S. Murty, J.W. Yeh, S. Ranganathan, P. P. Bhattacharjee, High Entropy Alloys, Elsevier, 2019, ISBN: 9780128160671 3. C. Suryanarayana, A. Inoue, Bulk Metallic Glasses, CRC Press, 2011, ISBN: 9781439859698 **Reference Books:** 4. K. Biswas, N.P. Gurao, T. Maiti, R. Mishra, High Entropy Materials: Processing, Properties and Applications, Springer-Nature, 2022, ISBN: 9789811939181 5. M.C. Gao, J.W. Yeh, P.K. Liaw, Y. Zhang, High entropy alloys: Fundamental and applications, Springer International Publishing, 2016, ISBN: 3319270133 6. M. Miller, P. Liaw, Bulk Metallic Glasses: An overview, Springer, 2008, ISBN: 9780387489209

Course Code	MM 319
Title of the Course	**Superalloys for High Temperature Applications**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-1.5 (3/2) (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	Familiarity with basics in Materials Science and Engineering principles, crystal structures, phase diagrams, and mechanical properties
Objectives of the Course	This course introduces superalloys in the category of strategic materials used in aerospace industries in extreme conditions. The course deals with the structure and properties of prototypical Ni-base superalloys
Outcomes	• Understanding the role of alloying and its implications on the microstructure and properties of superalloys • Insights on selection and processing of superalloys for high-temperatures applications
Course Syllabus	• Introduction to materials for high temperature applications • Materials requirement for aero engines, evolution of superalloys and its properties, physical metallurgy of superalloys, origins of strength, yield strength anomaly, creep and fatigue behavior of Ni-base and Co-base superalloys • Deformation mechanisms at elevated temperature, processing, optimization of chemistry, and microstructure evolution • Guidelines of design of turbine blade and disc alloys • Introduction to computational tools, advances and future superalloy design and development trends
Suggested Books	**Text Books:** 1. R. C. Reed, The Superalloys - Fundamentals and Applications, Cambridge University Press, 2006, ISBN: 9780511541285 2. M. J. Donachie, S. J. Donachie, Superalloys: A Technical Guide, ASM International, 2002, ISBN: 9780871707499 **Reference Books:** 3. B. Geddes, H. Leon, X. Huang, Superalloys: Alloying and Performance, ASM International, 2010, ISBN: 9781627083133 4. L. Nazé, V. Maurel, G. Eggeler, J. Cormier, G. Cailletaud, Nickel Base Single Crystals Across Length Scales, Elsevier Science, 2021, ISBN: 9780128193570 5. J.H. Westbrook, R.L. Fleishcher, Intermetallic Compounds – Principles and Practice: Progress, 2002, ISBN: 9780470845851

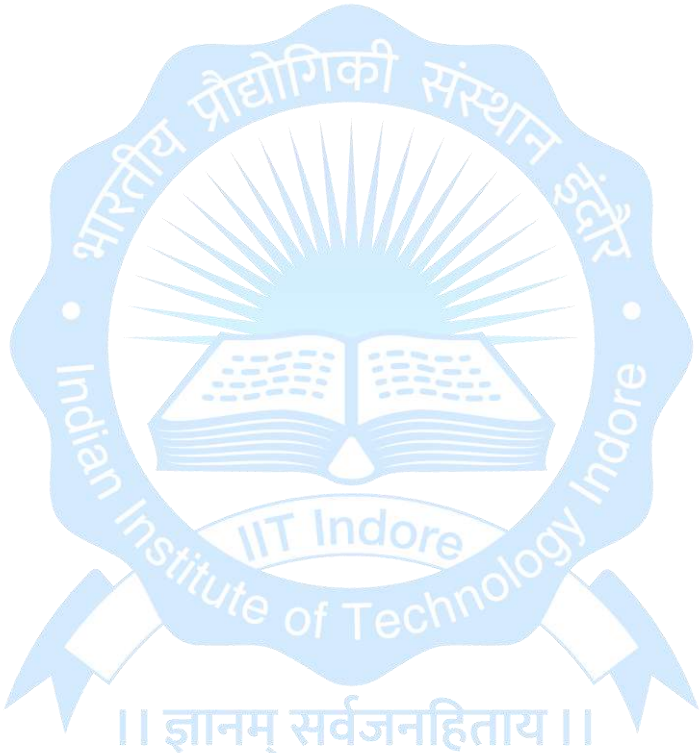
Course code	MM 320
Title of the course	Crystallographic Texture and Crystal Plasticity
Course Category	Department Elective
Credit Structure	L - T - P – Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	Understanding of Structure of Materials and Dislocation Theory
Scope of the course (Objectives)	This course aims to provide students with a fundamental understanding of crystallographic texture, its measurement, and evolution during processing, along with the principles of crystal plasticity.
Course Outcomes	By the end of this course, students will be able to analyse crystallographic textures and their evolution during processing, understand slip systems and dislocation mechanisms in plastic deformation, and apply basic crystal plasticity models to predict anisotropy and mechanical behavior in materials.
Course Content	**Crystal Symmetry and Representation**: Crystal symmetry, stereographic projection, and Wulff net. **Crystallographic Texture**: Fundamentals; representation (pole figures, ODF, inverse pole figures, CSL and orientation relationship); measurement techniques (XRD, EBSD); evolution during processing (solidification, deformation, annealing, phase transformation); typical textures in BCC/FCC/HCP metals; and the effect on material properties. **Deformation and Slip**: Deformation gradient, polar decomposition, lattice rotation, velocity gradient, slip systems in FCC/BCC/HCP crystals, and independent slip systems **Crystal Plasticity**: Schmid's law, generalized Schmid's law, Taylor model, Taylor factor, Bishop–Hill procedure, yield surface approximations (Sachs/Bishop–Hill), and applications to anisotropy, texture evolution, and forming limits. Introduction to self-consistent mean-field models and finite element-based full-field crystal plasticity
Suggested Books	**Text books:** 1. V. Randle, O. Engler, Introduction to Texture Analysis: Macrotexture, Microtexture, and Orientation Mapping, CRC Press, 2000, ISBN: 9789056992489 2. U.F. Kocks, C.N. Tomé, H.-R. Wenk, Texture and Anisotropy: Preferred Orientations in Polycrystals and their Effect on Materials Properties, Cambridge University Press, 1998, ISBN: 9780521794206 **Reference books:** 3. J.F. Nye, Physical Properties of Crystals: Their Representation by Tensors and Matrices, Oxford University Press, 1985, ISBN: 9780198511656 4. D. Hull, D.J. Bacon, Introduction to Dislocations, Elsevier, 2011, ISBN: 9780080966724

Course Code	MM 321
Title of the Course	**Mechanical Behavior of Materials at Nanoscale**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-1.5 (3/2) (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Objectives of the Course	The course, in particular, highlights the important mechanical characterization tools to investigate the deformation of materials at sub-micron or nanometer length scales
Outcomes	• Knowledge of length scales in materials and mechanics at different scales • Knowledge on Experimental techniques at nano-length scales
Course Syllabus	• Nanoscale Mechanics and Experimental techniques: Nanoindentation, In-situ Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM) methods, Plastic deformation at nanoscale • Failure processes in nanomaterials, Scale dominant mechanisms in Nanomaterials, Modeling of deformation of Nanomaterials
Suggested Books	**Text Book:** 1. K.T. Ramesh, Nanomaterials: Mechanics and Mechanisms, Springer, 2009, ISBN: 9780387097824 **Reference Books**: 2. Anthony C. Fischer-Cripps, Nanoindentation, Springer, 3rd edition, 2011, ISBN: 9781461429609 3. M. A. Meyers, K. K. Chawla, Mechanical Behavior of Materials, Cambridge University Press, 2nd edition, 2008, ISBN: 9780521866750 4. G. Z. Voyiadjis, M. Yaghoobi, Size Effects in Plasticity From Macro to Nano, Academic Press, 1st Edition, 2019, ISBN: 9780128122365

Course Code	**MM 322**
Title of the Course	**Surface Engineering of Alloys**
Course Category	Department Elective
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	To introduce students to the developments in surface engineering processes, process technology, challenges, and research aspects
Learning Outcomes	Students will learn about the fundamental of surface science and engineering, surface engineering processes and applications
Course Syllabus	• Introduction: Importance of surface properties in engineering applications; Status of surface engineering and classifications, Causes and mechanisms of surface damage, Material loss due to corrosion and wear • Basics of surface Engineering: Thermodynamics of surface, Interfacial tension and adhesion, surface dependent engineering properties, Surface modification technology for alloys • Techniques for Surface Engineering: flame hardening, induction hardening, carburizing, nitriding, diffusion assisted surface alloying, electroplating, Electrodeposition, Electroless platting, Hard anodizing, Hot dipping, Ion plating, Thermal spray, Plasma spraying, chemical vapour deposition and physical vapour deposition and other processes • Characterization and testing of surface engineered alloys/components • Case studies and Current research in surface engineering
Suggested Books	**Text Books:** 1. P.A. Dearnley, Introduction to Surface Engineering, Cambridge University Press, 2017. ISBN: 1316785084, 9781316785089 2. K.G. Budinski, Surface Engineering for Wear Resistance, Prentice Hall, 1988. ISBN: 0138779376, 978-0138779375 **Reference Books:** 3. D.K. Dwivedi, Surface Engineering – Enhancing Life of Tribological Components, Springer (India) Pvt. Ltd., 2018. ISBN: 9788132237778 4. B. R. Sunil, Surface Engineering by Friction-Assisted Processes: Methods, Materials, and Applications, CRC Press, 2019. ISBN: 978-8170356288 5. A. Mathews, Advanced Surface Coatings: A Handbook of Surface Engineering, Spinger, 2012, ISBN: 9789401053525

Course Code	MM 323
Title of the course	**Phase Transformation of Nanoalloys**
Course Category	Department Elective
Credit structure	2-1-0-1.5 (3/2) (half semester)
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	None
Objectives of the course	This course will introduce processing-microstructure-property-performance relationships in nanoalloys
Outcomes	To learn the basics of the phase transformation of nanoalloys and the fundamental issues of this phase transformation
Course Syllabus	• **Introduction to Nanoalloys:** Different types of morphology, thermodynamics, shape evolution, fundamental issue on phase transformation • **Physical and chemical synthesis:** processes, nucleation and growth, melting, solidification diffusion/intermixing. • **Melting and solidification of free and embedded nanoalloys:** single-phase, multiphase alloys • **Melting and solidification of Nanoalloys:** Single-phase and multiphase free-standing, embedded nanoalloys (single-phase, two-phase, and three-phase structures) • **Application of nanoalloys:** magnetic, optical, catalysis, biomedical, etc.
Suggested books	**Text Book:** 1. F. Calvo, Nanoalloys: from fundamentals to emergent applications, Elsevier, 2013, ISBN: 9780123944016 **Reference Books:** 2. D. Alloyeau C. Mottet, C. Ricolleau, Nanoalloys: Synthesis, Structure and Properties, Springer, 2012, ISBN: 9781447140146 3. M.M. Mariscal, O.A. Oviedo, E.P.M. Leiva, Metal clusters and nanoalloys: from modeling to applications. Springer, 2012, ISBN: 978149394176-6

Course Code	MM 325
Title of the course	**Advances in Metals and Alloys Processing**
Course Category	Department Elective
Credit structure	2-1-0-3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	None
Objectives of the course	The course is designed for systematic understanding on advanced materials processing techniques like advances casting, advanced joining, advanced metal forming techniques and design
Outcomes	After completion of course students will be familiar in Advanced materials processing techniques in order to satisfy the industrial needs.
Course Syllabus	• Introduction to advanced alloys processing, need and development of processes, applications • **Advances in casting processes:** stir casting, squeeze casting, Slip casting, gel casting, semi-solid, pressure die, etc. and their applications • **Advances in powder processing:** hot and cold isostatic pressing, microwave sintering, spark plasma sintering, secondary treatments and case studies • **Advanced joining processes:** advances in TIG, MIG, plasma, friction welding, friction stir welding electron beam welding, hybrid welding processes, laser beam welding, ultrasonic welding, etc. and their process variables, applications and advantages • **Advanced metal forming:** high energy rate forming, explosive forming, hydraulic forming, magnetic pulse forming, super plastic forming, flow forming
Suggested books	**Text Books:** 1. R. W. Heine, C.R. Loper, P.C. Rosenthal, Principles of Metal Casting, Tata McGraw Hill Education Private Limited, 2003, ISBN: 9780070278967 2. B. Raj, V. Shankar, A.K. Bhaduri, Welding Technology for Engineers, Narosa Publishers, 2020, ISBN: 9788173196072 3. I. Chang, Y. Zhao, Advances in Powder Metallurgy: Properties, Processing and Applications, Woodhead Publishing, 2013, ISBN: 9780857094209 4. S. Kumar, Technology of Metal Forming Processes, Prentice-Hall, Inc., 2008, ISBN: 978-8120334250 **Reference Books:** 5. S.V. Nadkarni, Modern Arc Welding Technology, Oxford IBH Publishers, 1996, ISBN: 978-8120416765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Course Code	**MM 402/ MM 602**
Title of the Course	**Design and Selection of Materials**
Credit Structure	L-T-P-Credits: 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Materials and Design, Evolution of Engineering Materials, Material Resource in Indian Context, Classification of Materials, Materials Selection for automotive and aerospace. Material Properties; The Role of Crystal Structure. Metals and Metallic Structure, metallic alloys, ceramics & glasses, Introduction to Polymeric Materials, Phases and microstructure of Polymers, Polymers for Mechanical Design, Material Selection using Ashby Method, Case Studies, Multiple Constraints in material selection, Multiple Objectives, Role of Materials in Shaping the Product Character
Suggested Books	1. M.F. Ashby, **Materials Selection in Mechanical Design**, 4th Edition, Elsevier, San Francisco, 2011; ISBN 978-1-85617-663-7. 2. Cambridge Engineering Selector (CES EduPack), Granta Design Limited, Cambridge, UK, 2010, www.grantadesign.com. Cases studies provided by the instructor 3. W.D. Callister, Materials Science for Engineering: An Introduction, 7th Edition, Wiley, 2007. ISB 978-0-471-73696-7.

Course Code	**MM 405/ MM 605**
Title of the Course	**Green Hydrogen: Materials and Technologies**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Discipline	Metallurgy Engineering and Materials Science
Pre-requisite, if any	Fundamental knowledge of materials science, materials synthesis/fabrication, materials characterization and electrochemistry
Scope of the Course	The course provides the learning on various aspects of green hydrogen energy: fundamentals of materials and technologies for green hydrogen production, storage and its applications.
Course Syllabus	**1. HYDROGEN ENERGY OVERVIEW:** Green hydrogen in global energy scenarios. **2. METHODS AND TECHNOLOGIES FOR GREEN HYDROGEN PRODUCTION:** Water-electrolysis: mechanisms of oxygen evolution reaction and hydrogen evolution reaction. Solar driven water splitting: photocatalytic & Photoelectrochemical, Biological and bio-electrochemical, Thermochemical, Electrolyzer Technologies: alkaline water electrolyser, proton exchange membrane, solid oxide electrolyzer, anion exchange membrane, proton conducting ceramic. **3. MATERIALS FOR GREEN HYDROGEN PRODUCTION**: Catalytic materials based on different electrolyzer technologies, solar driven water splitting, thermochemical and bio electrochemical water splitting. Materials challenges and research scope. **4. HYDROGEN STORAGE**: Physical storage technologies, Materials storage: metal hydrides, metal alanates, amino borane, metal amides, amine metal borohydrides, chemical hydrogen storage, carbon materials, nanostructured adsorbents.
Suggested Books	• K. S. V. Santhanam, R. J. Press, Massoud J. Miri, A. V. Bailey, G. A. Takacs : *Introduction to Hydrogen Technology*: 2nd Edition : John Wiley and Sons Ltd : USA : 2017 : 9781119265573. • Bent Sorensen and Giuseppe Spazzafumo, *Hydrogen And Fuel Cells*, Acad Pr, 2018, ISNB: 9780081007082 • Mario Pagliaro and Athanasios G. Konstandopoulos, *Solar Hydrogen: Fuel of The Future,* RSC, 2012, ISBN: 781849731959 • Paulo Emilio Miranda, *Science and Engineering of Hydrogen-Based Energy Technologies*, Academic Press, 2018 ISBN: 9780128142516 • Kent Olsen, *Advanced Concepts of Hydrogen Storage Technology*, Clanrye International, 2015, ISNB: 9781632400178

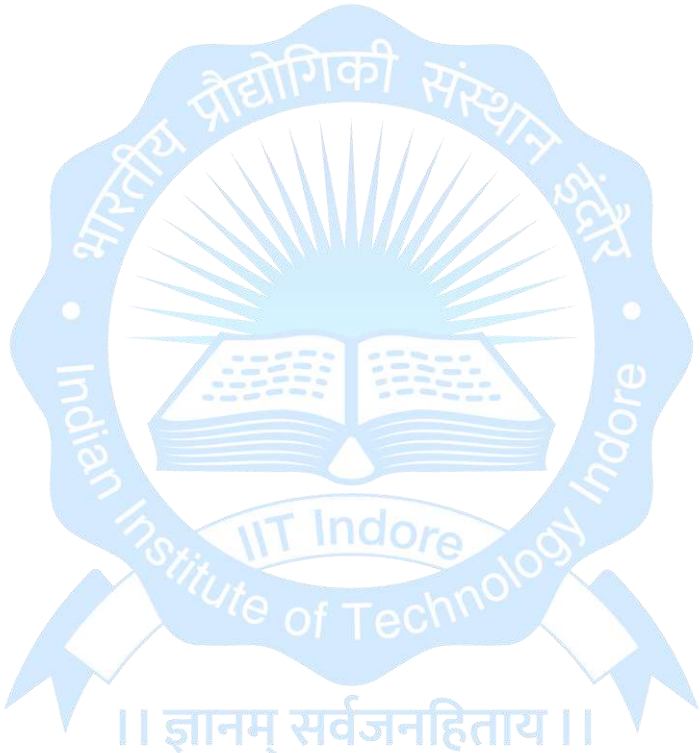
Course Code	**MM 416**
Title of the Course	**Modeling and Simulation in Materials Engineering**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Introduction and Fundamentals: Multiscales Modeling and Simulation in Materials & Science Ab Initio Methods, Statistical Machines, Monte Carlo Simulation, Molecular Dynamics, Grrin continuum modeling. Computational micro- mechanics Multiscale coupling. Application of Multiscale Modeling: Modeling dislocation behavior, Phase field modeling, Modeling of grain growth and microstructure in polycrystalline materials, Modeling of structural materials.
Suggested Books	**1.** R. Dierk, **Computational Materials Science**, Wiley VCH Verlag GmbH, 1998 **2.** Z. Xiao Guo (Ed), **Multiscale Materials Modelling: Fundamental and Applications,** Woodhead Publishing Limited, Cambridge, 2007 **3.** Z.H. Barber, **Introduction to Materials Modeling**, Maney Publishing, 2005.

Course Code	**MM 428**
Title of the Course	**Intelligent Materials**
Credit Structure	L-T-P-Credits: 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	
Course Syllabus	Composites, Smart materials and their properties, Piezoelectric, magneto structure, Shape memory materials, Electro Rhieological fluids, Optical fibers, actuation, sensing and control augmentation, distributed/discrete sensing and actuation, methods of analyses, finite elements, applications: Vibration suppression, shape control, sizing and optimization.
Suggested Books	1. L. Meirovitch, **Dynamics and Control of Structures**, John Wiley & Sons Inc. New York, 1992. 2. M.V. Gandhi, B.S. Thompson, **Smart Materials and Structures** (2nd edition), Chapman & Hall, 1992. 3. H.S. Guran, H.S. Tzou, G.L. Anderson, M. Natori, **Structure Systems: Smart Structures, Devices and System** (Part 1), and **Materials and Structures** (Part 2), World Scientific Publications, 1998. 4. U. Gabbert, H.S. Tzou, **Smart Structures and Structuronic System**, Kluwer Academic Publishers, 2001. 5. H.T. Banks, R.C. Smith, and Y.W. Qang, **Smart Material structures: Modeling, Estimation and Control** (6th edition), John Wiley & Sons New York, 1997.

Course Code	**MM 430/ MM 730**
Title of the Course	**Two Dimensional Materials and Electronic Devices**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre-requisite, if any	Basic knowledge in nanomaterials fabrication, characterization, devices integration and electronic devices.
Scope of the Course	To gain fundamental knowledge about the world of 2-D materials. The course will develop an understanding on 2-D materials fabrication, classification, and characterization. It will deliver an idea, how 2-D materials can be applied in electronics devices and its importance and advantages.
Course Syllabus	Introduction to 2-D Materials. Stable 2-D layer: Theoretical Consideration to Experimental Demonstration. Overview of 2-D Materials: Graphene, Silicene, Germanene, Phosphorene, Stanene, Transition-Metal-Chalcogene, MX-enes etc. Graphene: Discovery, Structure, Its Derivatives and Applications. Fabrication and Characterization of Graphene and other 2-D Materials. Electronic Properties of 2-D materials: Band Structure, Mobility, Quantum Hall Effect etc. Surface Functionalization and Modification. Surface Controlled Electrical and Optical Properties of 2-D Materials. 2-D Materials in Electronic Devices, 2-D Transistors – State of The Art; Graphene MOSFET (GFET); GFET for Digital Electronics, 2-D Materials Based Transistors: RF Transistor; Multi-Gate FET, Inter-layer Tunnelling FET.
Suggested Books	1. M. Aliofkhazraei, and N. Ali, *Two-Dimensional Nanostructures,* CRC Press, 2012, ISBN:9781439866658 2. J.H. Warner, F. Schaffel, M. H. Rummeli and A. Bachmatiuk, *Graphene : Fundamentals and Emergent Applications*, Elsevier,2013, ISBN: 9780123945938 3. V. Skakalova, A. B. Kaiser, *Graphene: Properties, Preparation, Characterisation and Devices,* Woodhead Publishing, 2014, ISBN: 9780857095084 4. F. Iacopi, J. J. Boeckl and C. Jagadish; *2D Materials*, Academic Press, 2016, ISBN:9780128043370 5. Kolobov, Alexander V., Tominaga, Junji, *Two-Dimensional Transition-Metal Dichalcogenides* , Springer, 2016, ISBN: 9783319314501 6. M. Raghu, *Graphene Nanoelectronics: from Materials to Circuits*, Springer, 2012, ISBN: 9781461405481 7. M. Houssa, A. Dimoulas and A. Molle, *2D Materials for Nanoelectronics,* CRC Press , 2016, ISBN: 9781498704175

Course Code	**MM 442/ MM 642**
Title of the Course	**Quality Assurance in Metallurgy**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
Scope of the Course	To inculcate quality management and analytical industrial problem solving skills in our students so that readymade technical manpower will be available for industries.
Course Syllabus	Inventory management; Colour code system; Heat number; Metallurgical parameters; Relevant materials testing standards (ASTM, ISO, DIN, etc.) for inclusion rating; C2R2S2, grain size and other specific customer requirement; Laboratory quality system (ISO17025, NADCAP, NABL accreditation); Process flow chart; Six sigma; 5S; PDCA, root cause analysis, Kaizen and other relevant lean manufacturing quality tools for continuous improvement in materials processing; Idea and talent management; various quality standard for quality control, such as ISO9000:2008; TS16949, etc.; Non-destructive testing; Introduction to Environmental management standards, such as ISO 14000 family; Statistical quality control tools; Total quality management (TQM); GATE review criteria; Process and product oriented research for sustainable development; Case studies and practical exposure to industries.
Suggested Books	1. W. M. Fed,**Lean Manufacturing: Tools, Techniques, and How to Use Them,** 1st Edition, CRC Press Series on Resource management, 2000, ISBN: 978-1574442977. 2. ASTM International: **https://www.astm.org/Standard/standards-and-publications.html** 3. A. J. Duncan**, Quality Control and Industrial Statistics**, Richard D.Irwin, Inc,1974, ASIN: B01LQEKJ2M.

Course Code	**MM 447/ MM 647**
Title of the Course	**Metallurgical Thermodynamics and Phase Transformations**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
Scope of the Course	To develop critical thinking and analytical problem solving skills related to macroscopic thermodynamics and kinetics in Metallurgy and Materials Engineering.
Course Syllabus	Introduction to metallurgical thermodynamics and concept of equilibrium; Clausius–Clapeyron equation; Phase diagram for unary system; Pressure-temperature-volume surface; Free energy of solution; Free energy–composition diagram; Evolution of Phase diagram; Phase rule and binary phase diagram; Fe-C equilibrium phase diagram; Introduction to ternary phase diagram; Free energy of intermediate phase; Metastable phase diagram; Miscibility gap in phase diagram; Kauzmann paradox and the glass transition; Free energy of undercooled liquid; Stability criteria for phase formation; Solid state phase transformations; Order of transformation; Thermodynamics of homogeneous and heterogeneous nucleation; Diffusion: Self-diffusion, Inter-diffusion, The Kirkendall effect, Capillarity-Driven diffusion, Stress-driven diffusion; Atomistic mechanisms of diffusion, Interphase layer Growth in inter-diffusion, Role of micro structure in diffusion: Short-circuits, Rate of reaction; Kinetics of phase changes; Kinetics in the diffusion-controlled regime, Sintering, Process of nucleation and growth; Gibbs-Thomson Effect; Grain-growth kinetics in two and three dimensions; Time-Temperature-Transformation diagrams; Continuous cooling transformation curves.
Suggested Books	1. D. R. Gaskell and D. E. Laughlin, **Introduction to thermodynamics of materials,** Sixth Edition, CRC Press, 2017, ISBN-13: 978-1498757003. 2. D. A. Porter, and K. E. Eastering, *Phase Transformations in Metals and Alloys,*Chapman & Hall, London, New York, 1992, ISBN: 0442316380. 3. R. W. Balluffi, S. M. Allen, W. C. Carter, **Kinetics of Materials**, Wiley, New York, 2005, ISBN: 9780471246893. 4. D. V. Ragone, **Thermodynamics of Materials**, Vol 1-2, Wiley, New York, 1994, ISBN: 978-0-471-30885-0. 5. Bashforth, **Manufacture of Iron and Steel**. Vol I and II, Asia Publishing House, 1996, ISBN: 9781504122511.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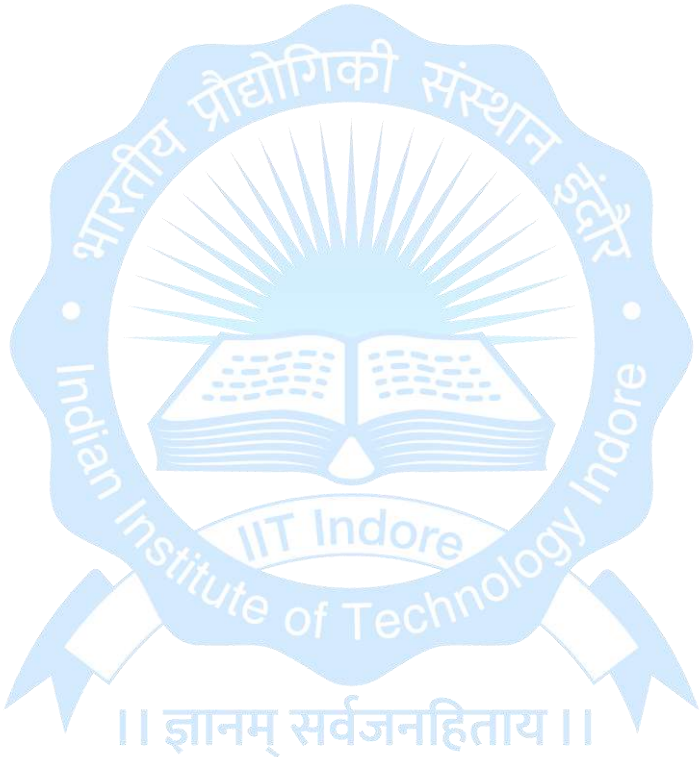
Course Code	**MM 448/ MM 648**
Title of the Course	**Solidification and Phase Field Modeling**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Department of Metallurgy Engineering and Materials Science
Pre-requisite, if any	None
Scope of the Course	Solidification processing is considered as one the most important processing technique used by engineers to manufacture structural and functional components in automobile and electronic industries. More than 90% of all metallic materials used in daily human life are synthesized from the liquid state as their parent phase. This course is intended to make the students familiar with the science and technology of solidification processing of materials, undercooled metallic melts, as well as phase field modelling of microstructure development.
Course Syllabus	Heat transfer in solidification, continuous and ingot casting processes, structure of castings and ingots, defects in casting, macro- and micro-segregation and homogenization, design of risering and gating in castings. Thermodynamics of solidification, nucleation and growth, Gibbs-Thomson effect, anisotropy and faceting, directional solidification-growth of single crystals. Alloy solidification, mathematical analysis of solute redistribution during solidification: Solidification at equilibrium and non-equilibrium condition. Scheil and Flemings solidification model, Stability of interface and constitutional undercooling, Mullins-Sekerka criterion, Cellular and dendrite growth. Physics of dendritic growth: Ivantsov's transport model and solution, Marginal stability hypothesis, Free dendritic theories: Lipton-Glicksman-Kurz (LGK) theory, Lipton-Kurz-Trivedi (LKT) theory, Microscopic solvability (MS) theory. primary and secondary dendrite arm spacing, Rayleigh instability. Solidification microstructures of multiphase alloys such as eutectic, peritectic and monotectic alloys, coupled growth and phase selection, rapid solidification processing, phase selection kinetics in undercooled metallic melt. Phase field modeling for microstructure evolution during solidification.
Suggested Books	1. G. J. Davies, **Solidification and Casting**, Applied Science Publishers Ltd, London, 1973, ISBN: 0-853345562. 2. W. Kurz, D.J. Fisher, **Fundamental of Solidification**, Trans Tech Publications, Switzerland, 1992, ISBN: 0-878495223. 3. M.E. Glicksman, **Principles of Solidification**, Springer, New York, 2010, ISBN: 9781441973436. 4. J.A. Dantzig, M. Rappaz, **Solidification**, EPFL Press, Switzerland, 2016, ISBN: 9780849382383. 5. D. M. Herlach, D.M. Matson, **Solidification of Containerless Undercooled Melts**, Wiley-VCH, 2012, ISBN:9783527331222. 6. S. BulentBiner, **Programming Phase-Field Modeling**,

	Springer, 2017,ISBN: 9783319411941.



Course Code	**MM 449/ MM 649**
Title of the Course	**Advance Welding Technology**
Contact Hours	L-T-P-Credits 2-0-2-3
Name of the Concerned Department/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	In this course students learn briefly on joining of materials basics and extensively on advanced joining techniques, process selection and design of weld joint
Course Syllabus	Introduction to joining of materials, Advances in joining of materials Solid State Joining Processes (Pressure welding, friction welding, explosive welding, ultrasonic welding, diffusion bonding, resistance welding); Brazing and Soldering (Filler materials and fluxes, heating methods, wetability, joint design); Adhesive bonding (Types of adhesive, wetability, surface preparation, joint design) Fusion welding fundamentals, Fusion welding processes (Oxyacetylene torch welding, Manual metal arc welding, MIG and TIG welding, submerged arc welding, electron beam and laser welding), recent trends in fusion welding. Welding specific materials - Plain carbon, low alloy steels, stainless steels, copper and copper alloys, nickel and nickel alloys, aluminum and aluminum alloys (similar and dissimilar materials joining). Modern welding techniques (Pulsed TIG, Pulsed electron beam, Laser welding, plasma and friction stir welding); Welding defects; Quality Assurance of Welding Operations (Non-destructive testing, safety, measurement, control and recording); Process selection and joint deign with case studies
Suggested books	1. M. Robert, **Joining of Materials and Structures**, 1st Edition, Elsevier, 2004,**ISBN:** 9780750677578. 2. S. Kou, **Welding Metallurgy**, 2nd Edition, Wiley, 2002, ISBN: 9780471434917. 3. H. Granjon**, Fundamentals of Welding Metallurgy**, 1st Edition, Elsevier, 1991, ISBN: 9781855730199.

Course code	**MM 650/ MM 450**
Title of the course	**Ferrous and Non-Ferrous Alloys**
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre-requisite, if any	Fundamentals of materials science
Scope of the course	This course introduces students to the advanced alloys and develops literacy about the technologically important alloy-systems used in automotive, aerospace and nuclear industries. This course implicates the fundamental concepts in the metallurgy of the advanced alloys.
Course Syllabus	Ferrous alloys: Alloy Steels – General Introduction, Maraging Steels (Heat-treatment Cycle, Aging behavior), High-Strength Low-Alloy Steels (Role of Microalloying of Steels), Ultra-High Strength Steels (Role of Alloying Elements), Dual-Phase Steels, Stainless Steels (Fe-Cr-Ni System, Schaeffler Diagram, Precipitation of Carbides/Nitrides, Microstructural Aspects of Various Types of SS, Ni-free Duplex SS, Embrittlement Phenomena), Tool Steels (Secondary Hardening, Types of Carbides), TRIP-assisted Steels (Microstructural evolution, Stress induced transformation, Role of alloying elements, Factors affecting performance, Concept of &#948_-TRIP Steel), Bearing Steels (Metallurgical & Engineering Requirements of Steel, Microstructural Aspects, Microcracking, Spheroidise Annealing, Inclusions, Aerospace Bearings), IF Steels. Non-ferrous alloys: Nickel-Based Superalloys (Microstructural features, Role of Alloying Elements, Strengthening Mechanisms, Heat-Treatments, Dispersion-Hardened Superalloys), Titanium Alloys (Deformation Modes, Effect of Alloy Addition on Phase Diagrams, Alloy Classification, Phase Transformations, Microstructures, Hardening Mechanisms of Alfa- & Beta-Phases, Microstructure in Dependent of Processing, Basic Correlation between Microstructure & Mechanical Properties, Ti-based Intermetallic Compounds), Aluminum Alloys (Microstructures of Al-Si Alloys, Modified/Unmodified Al-Si Alloys, Aging Process in Al-4%Cu alloy), Brass, Bronze. Special alloys: Bulk Nanostructured Steels – the Latest Development in Steels, Mechanically Alloyed Metals, Shape Memory Alloys, Metallic-glass Forming Alloys, Nuclear Power Plant Alloys (Irradiation Damages in Microstructure, Irradiation Hardening, Concepts of ODS Steels).

Suggested Books	1. H. K. D. H. Bhadeshia, R. W. K. Honeycombe, ***Steels*** **, Microstructure and Properties**, Butterworth-Heinemann Publications, Elsevier, UK, 2006, ISBN, 9780750680844 2. R. E. Smallman, A. H. W. Ngan, ***Physical Metallurgy and Advanced Materials***, Elsevier, USA, 2007, ISBN, 9780750669061 3. G. Lutjering, J.C. Williams, ***Titanium***, Springer-Verlag, Berlin, 2003, ISBN, 9783540713975 4. R.C. Reed, ***The Superalloys, Fundamentals and Applications***, Cambridge University Press, UK, 2006, ISBN-13, 978-0521070119

Course Code	**MM 451/ MM 651**
Title of the Course	**Non-destructive Evaluation**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	Nil
Scope of the Course	Student will understand the basic principles of various methods used for nondestructive evaluation, fundamentals, and discontinuities in different product forms, importance of NDE, applications, and limitations of nondestructive testing (NDT) methods. Students will be able to cultivate in-depth understanding on the importance of NDT in the relevant industries.
Course Syllabus	**Introduction**: Need for inspection, types of inspection system, Quality of inspection, Reliability of defect detection and benefits of NDE. **Visual Inspection**: Basic principles and applications, borescope; rigid chamber scopes; endoscope; videoscope; robotic crawlers. **Liquid Penetrant Inspection**: Physical principles, procedures of testing, penetrant testing materials, applications and limitations. **Magnetic Particle Testing**: Principle of MPT, Magnetization techniques, procedure used for testing a component, equipment used for MPT, applications and limitations. **Ultrasonic Testing**: Basic principles of sound beam, ultrasonic transducers, type of display, inspection methods, identification of defects, immersion testing, applications and limitations. **Acoustic Emission Testing (AET)**: Principles, technique, Instrumentation and applications. **Techniques used for Eddy Current Testing:** Basic principles, various probes, pulsed eddy current testing; low frequency eddy current testing; SQUID-based eddy current testing; and mechanical impedance analysis; Applications and limitations. **X-ray and Neutron Radiography**: Basic principles, electromagnetic radiation sources, effect of radiation in film, radiographic imaging, inspection techniques, applications and limitations. Shearography, Vibrothermography, Thermography, Laser Interferrometry, Acoustic microscopy, Microwave Testing: Working principles and applications. Case study; Statistical methods for quality control.

Suggested Books	1. B. Raj, T. Jayakumar, M. Thavasimuthu, **Practical Non-destructive Testing**, 3rd Edition,Narosa, New Delhi, 2007, ISBN: 9788173197970. 2. ASM handbook committee,**Nondestructive Evaluation and Quality Control**,Metals Handbook, Vol. 17, ASM International, ISBN: 0871700077. 3. J. Prasad, C. G. Nair, **Nondestructive Test and Evaluation of Materials,** McGraw-Hill Education, 2008, ISBN: 9780070077461.

Course Code	**MM 452/ MM 652**
Title of the Course	**Thermomechanical Processing**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Department of Metallurgy Engineering and Materials Science
Pre-requisite, if any	None
Scope of the Course	This course deals with advanced thermomechanical processing to understand the development of unique microstructure.
Course Syllabus	General Introduction, Microstructure and Properties, Plasticity, Work Hardening, Softening mechanisms, Deformation mechanism, Phase transformations, Textural developments during thermomechanical processing, Residual stress, Processing maps and constitutive Modelling, Forming techniques: Forging, Rolling, Deep drawing, Sheet metal forming, Defects in thermomechanical processing, Physical simulation of properties, Case studies: Aluminum alloys, Steels, Hexagonal alloys, High entropy alloys.
Suggested Books	1. B. Verlinden, J. Driver, I. Samajdar, R. D. Doherty, Edited by R. W. Cahn, Thermo-Mechanical Processing of Metallic Materials, Elsevier, 2007,ISBN: 9780080444970 2. B.S. Altan, Severe Plastic Deformation: Towards Bulk Production of Nanostructured Materials, Nova Publishers, New York, 2006, ISBN: 1-59454-508-1. 3. M.J. Zehetbauer, R.Z. Valiev, Nanomaterials by Severe Plastic Deformation, Wiley-VCH, Germany, 2004, ISBN: 9783527604944. 4. A. Rosochowski, Severe Plastic Deformation Technology, Whittles Publishing, UK, 2017, ISBN: 9781849950916. 5. Y. T. Zhu, V. Varyukhin, Nanostructured Materials by High-Pressure Severe Plastic Deformation, Springer, Netherlands, 2006, ISBN-10: 1402039212. 6. T. C. Lowe, R. Z. Valiev, Investigations and Applications of Severe Plastic Deformation, Springer, Netherlands, 2000, ISBN: 9780792362814.

Course Code	**MM 453/ MM 653**
Title of the Course	**Non-equilibrium Processing of Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre-requisite, if any	None
Scope of the Course	This course is intended to make the students familiar with the different non-equilibrium processing techniques and various novel materials and its possible applications.
Course Syllabus	**Introduction:** Thermodynamics and kinetics of metastable phase formation. **Non-equilibrium processing methods (NEPM)**: Rapid solidification, Mechanical alloying, Laser processing, Thermal plasma processing, Spray forming, Ion-mixing, Physical vapor deposition, Chemical vapor deposition, Combustion synthesis. **Nanostructured materials:** Classification, preparation, structure, stability, properties, application and future direction. **Special alloys:** Introduction, properties, applications and future aspects. Case studies: Bulk amorphous alloys, Quasi-crystalline alloys, Shape memory alloys, Superalloys, Heusler alloys, High entropy alloys.
Suggested Books	1. C. Suryanarayana, **Non-equilibrium Processing of Materials**, Elsevier, 1999, ISBN: 0080426972. 2. B.S. Murty, J.W. Yeh, S. Ranganathan, **High Entropy Alloys**, Elsevier, UK, 2014, ISBN: 9780128002513. 3. R. E. Smallman, A. H. W. Ngan, **Physical Metallurgy and Advanced Materials**, 7th Edition, Elsevier, 2007, ISBN: 9780080552866. 4. R.C. Reed, **The superalloys: fundamentals and applications**, Cambridge University Press, 2006, ISBN-13: 9780511245466. 5. Dimitris C. **Lagoudas**, **Shape Memory Alloys Modeling and Engineering Applications**, Springer, 2008, ISBN: 9780387476841.

Course Code	**MM 454/ MM 654**
Title of the Course	**Advanced Foundry Technology**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Department of Metallurgy Engineering and Materials Science
Pre-requisite, if any	None
Scope of the Course	This course introduces students to different foundry techniques, different alloy systems by casting routes, casting defects.
Course Syllabus	Introduction to Casting technology, Solidification analysis for metals and alloys, Technology of patternmaking, Study of molding sands and their testing methods, Technology of mould making and core making, Special sand moulding processes, Principles of gating design for castings, Principles of risering design for castings, Special casting methods, Melting furnaces, Melting and pouring practices for production of Cast Iron family, steel and non-ferrous metals and alloys, Fettling and Heat treatment of castings, Casting defect and its diagnostic methods.
Suggested Books	1. R.W. Heine, C.R. Loper, P.C. Rosenthal, **Principles of Metal Casting**, McGraw Hill Education, New York, USA, 1976, ISBN: 9780070993488. 2. A. Ghosh, A.K. Mallik, **Manufacturing Science**, Affiliated East-West Press Pvt. Ltd., India, 2010, ISBN-10: 8176710636. 3. P.L. Jain, **Principles of Foundry Technology,** 5th Edition, Mcgraw Hill Education, 2009, ISBN: 9780070151291. 4. A.K. Chakrabarti, **Casting Technology and Cast Alloys**, PHI Learning Pvt. Ltd., 2005, ISBN: 9788120327795. 5. B. Ravi, **Metal Casting: Computer - Aided Design and Analysis**, Phi Learning Pvt. Ltd, 2010, ISBN: 9788120327269, 8120327268. 6. D. Kumar, S.K. Jain, **Foundry Technology**, Cbs Publisher, 2007, ISBN: 9788123902906. 7. P. Beeley, **Foundry Technology**, Butterworth-Heinemann, 2001, ISBN: 0750645679. 8. O.P. Khana, **Foundry Technology**, Dhanpat Rai Publications, 2011, ISBN: *ISBN*-10: 8189928341. 9. K.P. Sinha, D.B. Goel, **Foundry Technology**, Standard Publishers Distributors, 2006, ISBN: 8186308121. 10. G. Sutradhar, **Principles of Foundry Process Design**, New Age International Pvt. Ltd, 2010, ISBN 10: 8122434053.

Course Code	**MM 457/ MM 657**
Title of the Course	**Advances in Energy Storage Materials**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Department of Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This course is designed for the students of science and engineering Departments to understand the use of nanomaterials in the advancement of energy storage devices. Potential of nanomaterials will be detailed for the significant enhancement in functionality of electrochemical devices. The basics of electrochemical devices and cutting edge research developments will be covered from various books, research reports, articles and review papers.
Course Syllabus	Introduction to nanomaterials, Overview of the basic characteristic differences between nanomaterials and conventional materials, Overview of the types and architectures of nanomaterials with relevance to the applications in energy storage/conversion devices, Electrochemical interfaces at the nanoscale. **Characteristics and properties**: Effects of crystal structures, orientations, various dimensions, and aspect ratio at nano/micro scales, Morphological and structural stability during operation, Issues of diffusivity, Importance of chemical, physical and mechanical properties. **Devices**: Importance, working principles, characterization, and fabrication of advanced electrochemical energy storage and conversion devices like Electrochromic Smart windows, Supercapacitors, Li/Na-ion batteries, and fuel cells, etc. **Nanomaterials for devices**: Beneficial aspects of nanomaterials to improve device performance, Nanomaterials used and problems associated in electrochemical energy storage and conversion devices, Possible ways to overcome limitations, Potentials of nanostructures/nanomaterials for further significant enhancement in functionality. Present scenario and necessities of efforts on fabricating of nanomaterials for designing aforesaid applications.
Suggested Books	1. E. R. Leite, **Nanostructured Materials for Electrochemical Energy Production and Storage**, Springer, 2009, ISBN: 978-0-387-49323-7. 2. B. E. Conway, **Electrochemical Supercapacitors Scientific Fundamentals and Technological Applications**, Springer, 1999, ISBN: 9781475730586. 3. D. Linden, T. B. Reddy, **Handbook of Batteries,** 3rd Edition, McGraw-Hill, 2002, ISBN-13: 9780071359788. 4. C. G. Granqvist**, Handbook of Inorganic Electrochromic Materials**, Elsevier, 1995, ISBN: 9780080532905.

Course code	**MM 474/ MM 674**
Title of the course	**Fluorescence Phenomenon**
Credit Structure	L - T - P - Credits 2-1-2-4
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre-requisite, if any	NA
Scope of the course	The objective of course will be an asset to build up concept about phenomenon of fluorescence involved in development of materials. The course will illustrate the broad overview of various phenomenon and applications of fluorescence in materials science and engineering.
Course Syllabus	Introduction to fluorescent phenomenon, basic concepts and instrumental techniques involved in fluorescence, Time-domain lifetime measurements, Dynamics of solvent and spectral relaxation, Aggregation induced emission (AIE), Chelation induced fluorescence (CHEF), Quenching of fluorescence, Fluorescence resonance energy transfer (FRET), Fluorescence anisotropy, Intramolecular charge transfer (ICT), Twisted intramolecular charge transfer (TICT), Photoinduced electron transfer (PET), Effect of solvent and molecular conformation on emission, Time-resolved energy transfer and conformation distributions of biopolymers, protein fluorescence, fluorescence sensing, Nucleic acids fluorescence, live-cell imaging, applications of fluorescent phenomenon in disease detection. Laboratory Experiment: Demonstration of the fluorescence phenomenon in development of emissive materials.
Suggested Books	1. J. R. Lakowicz, ***Principles of Fluorescence Spectroscopy****, 3rd edition,* Springer Science + Bussines Media, New York, USA, 2006, 780387312781 2. J. R. Albani, ***Principles and Applications of Fluorescence Spectroscopy****,* Blackwell Publishing, Lowa, USA, 2007, 9781405138918 3. E. Wehry, ***Modern Fluorescence Spectroscopy****,* Plenum Press, New York and London, 1976, 9781468425833 4. O. S. Wolfbeis, *Fluorescence Spectroscopy,* New Methods and Applications : Springer-Verlag : Berlin, Heidelberg : 1993 : 9783642773747

Course Code	**MM 475/ MM 675**
Title of the Course	**Advanced Fracture Mechanics**
Contact Hours	L-T-P-Credits 2-1-0-3
Name of the Concerned Department/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	In this course students can learn about the fracture concepts, fracture mechanics basics, equations governing fracture and fracture mechanics, concept of fracture toughness and experimental measurement of fracture toughness. Advanced topics in fatigue of materials and creep.
Course Syllabus	Introduction to Fracture Mechanics, Theory of Elasticity and Plasticity, Mohr's circle, equivalent stress, stress tensors. Fracture, Theories of brittle and ductile fracture, Theoretical cohesive strength, strain energy release rate, Griffith theory, Stress intensity actor, relation between strain energy release rate and stress intensity factor, Ductile to brittle transition, instability in plastic deformation. Linear elastic fracture mechanics, elastic plastic fracture mechanics, fracture toughness and test methods, J-integral, R- Curve, CTOD. Fatigue of materials, basic terminology in fatigue, mechanism of fatigue, S-N curve, high cycle fatigue, Effect of mean stress on fatigue, good man diagram, low cycle fatigue, factors affecting fatigue of materials, fatigue crack growth, crack closure, thermal fatigue, fretting fatigue, corrosion fatigue, design to mitigate fatigue failure. Creep of materials, mechanisms of creep, creep curve, deformation mechanism maps, and basic equations governing creep. Creep-fatigue interaction, Damage tolerant design.
Suggested books	1. R. W. Hertzberg, R. P. Vinci, J. L. Hertzberg, **Deformation and Fracture Mechanics of Engineering Materials**, 5th Edition,Wiley,2012, ISBN-10: 0470527803. 2. G. E. Dieter, **Mechanical Metallurgy**, 3rd Edition,McGraw-Hill, 2017, ISBN: 0071004068. 3. T. L. Anderson, **Fracture Mechanics: Fundamentals and Applications**, 4th Edition, CRC Press, 2017, ISBN-10: 1498728138. 4. R. J. Sanford, **Principles of Fracture Mechanics**, 1st Edition,Pearson, 2002, ISBN-10: 0130929921.

Course Code	**MM 477/ MM 677**
Title of the Course	**High Temperature Deformation of Materials**
Contact Hours	L-T-P-Credits 2-1-0-3
Name of the Concerned Department/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This course provides basic understanding of d the various deformation mechanisms that take place under given stress and temperature.
Course Syllabus	Creep of materials. Creep curve, mechanisms of creep. structural changes during creep, equations governing creep of metals, stress rupture test. Creep resistance materials, super alloys, dispersion strengthening materials, refractory materials. Fatigue of materials, effect of temperature on fatigue behavior, high temperature fatigue, thermal fatigue, thermo mechanical fatigue. Creep fatigue interaction. Thermal barrier coatings. Deformation Mechanism Maps (Ashby and Langdon-Mohamed). Applications of Deformation Mechanism Maps [turbines, nuclear reactor components, metal forming and shaping, etc.
Suggested books	1. W. D. Callister, **Materials Science and Engineering: An Introduction**, 7th Edition, John Wiley & Sons, 2014, ISBN: 9781118324578. 2. J. S Zhang, **High Temperature Deformation and Fracture of Materials**, 1st Edition, Elsevier,2010, ISBN: 9780857090805. 3. M. A. Meyers, K. K. Chawla, **Mechanical Behavior of Materials**, Cambridge University Press, 1999, ISBN: 9780521866750. 4. G. E Dieter, **Mechanical Metallurgy**, 1st Edition, McGraw Hill Education, 1976, ISBN: 9780070168916.

Course Code	**MM 479 / MM 679**
Title of the Course	**Fundamentals and Engineering of Solar Energy Devices**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Department of Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	This course introduces various aspects of the solar energy devices to the students from science and engineering Departments. This course is intended to educate the students in basics, limitations, advantages, solar cell characteristics, design, fabrication, and applications of solar cells.
Course Syllabus	**Fundamentals and basics concepts**:Working principle of solar cell, fundamental of photoelectric conversions (*charge excitation, conduction, separation, and collection*), Light absorption and reflections, Solar energy conversion (P*hotovoltaic, Solar thermal and photochemical*), Shockley–Queisser Limit (*Efficiency, Recombination time, AM1.5 radiation*), Generation and recombination of electron-hole pairs, recombination processes (*Radiative, Auger, Schokley-Read-Hall, direct/Langevin type, trap assisted, direct, interfacial, geminate, and non-geminate recombination*) and possible losses. **Characteristic:** Equivalent circuits of the solar cell, Physical aspects of efficiency, Irradiation and series/shunt resistances on the open-circuit voltage (V_{OC}) and short-circuit current (I_{SC}), Dark and illuminated characteristics, Dark current, Light generated current, Effects of shading, Significance of various parameters (O*ut-put parameter, FF, solar cell η, I_{SC}, V_{OC}, Quantum efficiency, Maximum power point operation*), Antireflections coating, Practical efficiency limit (P*arasitic resistance, Losses in I_{SC}, V_{OC}, and FF, Effects of temperature, Series and shunt resistance, high irradiance*), Theoretical Limits, Challenges, and New Ideas. **Solar Cell Devices**: Basic structure, modeling, advantages, disadvantages and challenges, Generations of solar cells, Si solar cell (*Single- and Poly- Crystalline, Amorphous, and Hybrid*), Thin film solar cells (*Amorphous silicon, Cd-Te, Cd-Se, CZTS, CIGS solar cells*), Grätzel& tandem cell(Metal-Oxide micro/nano-structures; *fabrication,Mechanism, Key efficiency parameters, Substrate effect, Examples of dyes for photosensitization, Electrolytes, Influence of additives on the performance,*), Heterojunction organic, Perovskite, Quantum dots and Hybrid solar cell (*types, materials used, compositions of components, processing, architectures, efficiency limits, stability issues, temperature effect*), Emerging new technologies. Over view of potential hazards, Solar energy storage/utilization (*Batteries, Supercapacitor, Display devices, Emitters, and Generators etc.*), Status and prospective of *PV technology*.
Suggested Books	1. A.McEvoy, T.Markvart, L.Castaner, **Solar Cells: Materials, Manufacture and Operation,** 2nd Edition, Elsevier, 2013,

	ISBN: 9780080993799. 2. T. Soga, **Nanostructured Materials for Solar Energy Conversion**, Elsevier, 2006, ISBN: 9780444528445. 3. D. Yogi Goswami, **Principles of Solar Engineering,** 3rd Edition, CRC Press, 2015, ISBN: 9781466563780. 4. A. L. Fahrenbruch, R.Bube, **Fundamentals of Solar Cells**, Elsevier, 1983, ISBN: 9780323145381. 5. C. J. Chen, **Physics of Solar Energy,** John Wiley & Sons, Inc., 2011, ISBN: 9780470647806. 6. P.Wurfel, **Physics of Solar Cells: From Basic Principles to Advanced Concepts,** 2nd Edition, Wiley-VCH, 2005, ISBN:9783527408573. 7. L Fraas, L. Partain, **Solar Cells & Their Applications,** 2nd Edition, John Wiley & Sons, 2010, ISBN: 9780470446331. 8. M. A. Green, **Third Generation Photovoltaics: Advanced Solar Energy Conversion**, Springer, 2005, ISBN: 9783540265634.

Course code	**MM 481/ MM 681**
Title of the course	**High Pressure Materials Processing**
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre-requisite, if any	NA
Scope of the course	This course is designed for the students of science and engineering Departments to understand the use of High pressure for materials synthesis and properties studies under high pressure. This course provides new insight for basic, applied and industrial applications.
Course Syllabus	Introduction to High Pressure Materials Synthesis Technique and basic principles, Pressure effects in material synthesis and physics/science behind it, Comparison of solid-medium and gas-medium pressure techniques, Solid-medium ultra-high-pressure low-temperature O2 annealing, Gas-medium high-pressure synthesis. High Pressure Materials Synthesis Techniques: Encapsulation techniques, Shock-wave methods, Diamond-anvil cells, Cubic Anvil and Belt type. Synthesis of Novel Materials under high pressure: General features of high-pressure processes, calibration of parameters etc., High Pressure synthesis of Mechanical Materials and new layered structures, Polymers etc. Application of high-pressure techniques: magnetic materials, diamonds, gems, Wide band gap semiconductors, Electronic and Optical Materials, etc.
Suggested Books	1. R. S. Bradley, ***High Pressure Physics and Chemistry***, Academic Press, Cambridge, USA, 1963, 0121240029 2. K. D. Timmerheld, ***High-Pressure Science and Technology***, Springer, Berlin, Germany, 1979, 9780306400698 3. M. I. Eremets, ***High Pressure Experimental Methods***, Oxford University Press, United Kingdom, 1996, 9780198562696 4. R. V. Eldic and F. G. Kramer, ***High Pressure Chemistry, Synthetic, Mechanistic, and Supercritical Applications***, Wiley, New York, 2002, 9783527612635

Course Code	**MM 483/ MM 683**
Title of the Course	**Analysis and Modelling of Welding**
Contact Hours	L-T-P-Credits 2-0-2-3
Name of the Concerned Department/School	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	Welding is an important fabrication process in manufacturing industries. This course deals with the detailed analysis and modelling techniques that apply to the differentphenomena that take place during welding processes.
Course Syllabus	Introduction to fusion welding processes, Heat sources, Heat removal. Thermal modelling, Analytical solution to weld thermal field, Zones in a weldment, Phase change. Fluid flow in the weld pool, Fusion zone, Conduction mode and Keyhole mode. Introduction to micro-segregation, Solute redistribution, Microscale, Microstructure evolution. Solute transfer at Macroscale. Defects in fusion welds, Effects of dilution, Weld Cladding. Distortion in welding, Dissimilar welding, Solutions to Dissimilar welding. Numerical solutions to thermal field and fluid flow in welding.
Suggested books	1. S. Kou, **Welding Metallurgy**, 2nd Edition, John Wiley & Sons, 2002, ISBN: 9780471434917. 2. R. W. Messler, **Principles of Welding: Processes, Physics, Chemistry and Metallurgy**, Wiley-VCH, 1999, ISBN-13:978-0471253761. 3. J. F. Lancaster, **Metallurgy of Welding**, Abington Publishing, England, 1999, ISBN: 1855734281. 4. D. R. Gaskell, **An Introduction to Transport Phenomena in Materials Engineering**, 2nd Edition, Momentum Press, New York, 2013, ISBN-13: 978-6065-35-3. 5. S. V. Patankar, **Numerical Heat Transfer and Fluid Flow**, McGraw-Hill Book Company, New York,1980, ISBN: 0070487405.

Course Code	**MM 485/ MM 685**
Title of the Course	**Materials Degradation**
Credit Structure	L-T-P-Credits 2-0-2-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre–requisite, if any	None
Scope of the Course	To start from the fundamentals and provide an integrated and up-to-date picture of degradation of engineering materials used in the current industry. This course will concentrate on the materials, forms of degradation and their mechanism that are most relevant to the largest number of current industrial applications.
Course Syllabus	Introduction to materials degradation; Corrosion standards; Electrochemical corrosion of metallic materials; General corrosion; Localized corrosion; Introduction to electrochemical impedance spectroscopy (EIS); Metallurgical influenced corrosion; Mechanically assisted corrosion; Environmentally induced cracking; CO_2 corrosion of mild steel; materials degradation in nuclear power plant; Corrosion in automotive industry; Corrosion in aerospace industry; Corrosion in Aircraft industry; Corrosion in electronic industry; Degradation issues of concrete and polymer materials; Degradation issues in metallic implants; Electro-chemo-mechanical degradation of high-capacity battery electrode materials; Degradation of dental materials; Corrosion in the Brewery Industry; Biodetoriation of materials.
Suggested Books	1. ASM committee,**ASM Handbook on Corrosion,**9th Edition, Vol 13, 1992, ISBN: 9780871707079. 2. J. R. David, **Corrosion: understanding the basics,** ASM international, Materials Park, Ohio, 2000,ISBN-10: 0824799178. 3. A. M. El-Sherik, **Trends in Oil and Gas Corrosion Research and Technologies,** Woodhead Publishing. 2017, ISBN: 9780081011058.

Course code	**MM 486/ MM 686**
Title of the course	**Applied Photoelectrochemistry**
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre-requisite, if any	Basic knowledge of Semiconductors, Optoelectronic Properties and Electrochemistry
Scope of the course	The course is designed to provide the fundamentals knowledge of Photoelectrochemistry and its application in solar light harvesting. The student would get comprehensive understanding on phenomenon's that are occurring at the interface of semiconductor and electrolyte. To introduce the nanostructure photoelectrode and their impact as well as recent advancement in semiconductor photoelectrodes.
Course Syllabus	1. Introduction: Electrochemistry and Electrochemical Cells, Electrodes: Anode and Cathode, Equilibrium Potential of Electrode Reactions, Cathodic and Anodic Reactions, Electrode Reactions in Electron Transfer. 2. Semiconductor Photoelectrodes: Electron Energy Bands of Semiconductors, Chemical Potential and Electrochemical Potential, Graphical Representation of Energy Levels, Theory of Junction Formation, Metal-Schottky Junction, Semiconductor– Electrolyte Junction, Flow of Carriers Across the Junction, Depth of Charge Separation at the Interface of n- and p-Type Semiconductors, Nature of Potential at the Interface, Width of the Space Charge Region, and Quasi-Fermi Levels (QFLs). Semiconductor–Electrolyte Junction Under Illumination: Open Circuit Potential, Photovoltage and Photocurrent, Photocurrent Conversion Efficiency. 3. Nanostructured Semiconductor Photoelectrodes: Band Bending in Nanostructures, Effect of Surface Area, Determination of Quasi-Fermi Level Positions, Surface States and Fermi Level Pinning, Surface Recombination, Charge Separation and Collection, Charge Compensation and Charge Trapping. 4. Photoelectrochemical Water Splitting: Concept of Solar Driven Water Splitting and Production of Chemical Fuels/Hydrogen. Prospective Materials for Solar Driven Water Splitting and Associated Challenges. The Advanced Materials Design: Harvesting of Wider Solar Spectrum, Effective Separation and Transportation of Photo Charge Carriers, Earth Abundant Elements based Nanostructures.
Suggested Books	1. Norio Sato, ***Electrochemistry at Metal and Semiconductor Electrodes***, Elsevier, The Netherlands, 2005, 0444828060 2. Yurii Pleskov, ***Semiconductor Photoelectrochemistry***, Springer, New York, USA, 2012, 9781468490800 3. Mary D Archer and Arthur J Nozik, ***Nanostructured and***

	Photoelectrochemical Systems for Solar Photon Conversion, World Scientific, London, 2008, 10 1860942555 4. R. Krol and M. Grätzel, ***Photoelectrochemical Hydrogen Production***, Springer, USA, 2011, 9781461413806

Course code	**MM 487/ MM 687**
Title of the course	**Advanced Battery Technologies**
Course Category	Institute Elective
Credit Structure	L - T - P - Credits 2 – 1 – 0 - 3
Name of the Concerned Department	Metallurgical Engineering and Materials Science
Pre-requisite, if any	Any basic course(s) on electrochemistry and crystal structure
Scope of the course (Objectives)	• Theoretical and practical aspects of secondary (rechargeable) batteries. • Emphasis on recent advances in Li-ion, Na-ion, solid-state, and alkali metal battery technologies.
Course Outcomes	Upon completion of the course, students are expected to: • have acquired knowledge of various cell chemistries, battery materials, and battery figures of merit. • apply the knowledge of key battery parameters to select the appropriate battery chemistry for target applications such as grid storage, electric vehicles, portable electronics, etc.
Course Content	• **Fundamentals of batteries:** *Basic battery terminologies; Historical development of alkali cells.* • **Alkali-ion batteries**: *Types of electrodes, electrolytes, and interfaces (SEI and CEI).* • **Ion transport dynamics across electrodes and electrolytes**. • **Characterization techniques for cell/batteries:** *CV; GCD (CCC, CVC, etc.); GITT; EIS.* • **Factors limiting battery performance:** *Importance of crystal structure, particle morphology, and active material loading.* • **Catastrophic battery failure & capacity fading mechanisms**: *Thermal runaway; the role of BMS.* • **Battery pack design**: *Role of impedance matching and appropriate cell configuration.* • **Issues with the current battery technologies**: *Safety; Sustainability; Technical challenges with fast charging.* • **Emerging battery technologies**: *Na-ion; All-solid-state; Li-S; Li-Air; Anode free batteries.*

Suggested Books	**Text Books:** 1. R. Korthauer : **Lithium-Ion Batteries - Basics and Applications** : Springer Berlin, Heidelberg : 2018 : **ISBN**- 9783662530696 2. K. P. Birker (editor) : **Modern Battery Engineering – A Comprehensive Introduction**, World Scientific Publishing Co. Pte. Ltd.: 2019 : **ISBN**- 9789811215988 **Reference Books:** 3. K. W. Beard (editor) : **Linden's Handbook of Batteries, 5th Edition**, McGraw-Hill : 2019 : **ISBN**- 9781260115925 *4.* P. Enge, N. Enge, and S. Zoepf : **Electric Vehicle Engineering**: McGraw-Hill : 2021 : **ISBN**- 9781260464078

Course code	**MM 688/ MM 488**
Title of the course	**Electroceramics**
Credit Structure	L - T - P – Credits 2-1-0-3
Name of the Concerned Department	Metallurgy Engineering and Materials Science
Pre-requisite, if any	NA
Scope of the course	The course provides a comprehensive treatment of fundamental aspects of electroceramics and their applications.
Course Syllabus	A brief review of the structure of selected ceramic materials, Defects Equilibria, Diffusion Kinetics, Theory of Ionic Conduction, Applications of Ionic Conductors: Fuel Cells, Batteries, etc. Polarization in Static and Alternating Electric Fields, Clausius–Mossotti Relation, Linear & Nonlinear Dielectrics and their Applications: Capacitors, Sensors, Actuators, Data Storage Devices, Ferroelectric Random Access Memories (Fe-RAM), Magnetoelectric Coupling and Multiferroicity, Electroceramics Fabrication-Technology.
Suggested Books	1. W. D. Kingery, H. K. Bowen, and D. R. Uhlmann, ***Introduction to Ceramics***, 2nd Edition, Wiley India Pvt. Ltd., New Delhi, India, 2012, 978-8126539994 2. L. L. Hench and J. K. West, ***Principles of Electronic Ceramics***, Wiley-Interscience, New Jersey, United States, 1990, 978-0471618218 3. A. J. Moulson and J. M. Herbert, ***Electroceramics , Materials, Properties, Applications***, John Wiley & Sons, West Sussex, England, 2003, 978-0470864975 4. Anthony R. West, ***Solid State Chemistry and its Applications***,2nd Edition, Wiley, New Delhi, India, 2014, 978-1119942948 5. Nava Setter (editor), ***Electroceramic***-Based MEMS, Springer US, 2005, ISBN: 978-1441936042

Suggested Books	**Text Books:** 6. R. A. Swalin, Thermodynamics of Solids, Wiley-VCH; 1972,ISBN**:** 970471838548. 7. D. R. Gaskell, Introduction to Thermodynamics of Materials, CRC Press, 2008, ISBN: 9781439851500. **Reference Books:** 8. L. Darken and R. W. Gury, Physical Chemistry of Metals, CBS Publisher, 2002, ISBN**:** 9788123914794. 9. D.A. Porter and K.E. Easterling, Phase Transformation CRC Press, 2009, ISBN: 9781420062106. 10. D.A. Porter, K.E. Easterling, M. Sherif; Phase Transformationsin Metals and Alloys, CRC Press, 2009, ISBN: 9781439883570.