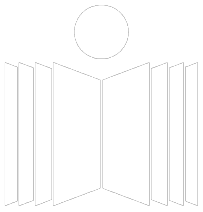
Masters & PhD
Courses of Study



भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Contents

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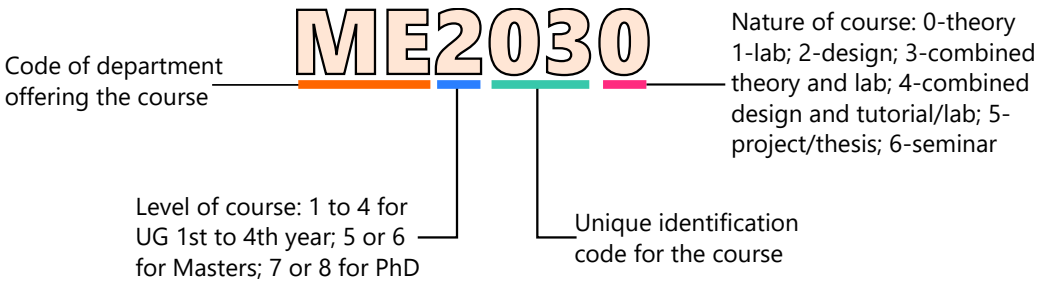
1 | Introduction

1.1 Glossary of Terms

- **Credit:** The quantitative measure of recognition given to a course, stated in semester hours. Typically, a theory course running for a full a semester with three contact hours per week would be 3 credits. Similarly, a lab course with the same number of contact hours would be 2 credits.
- **Major:** The primary set of discipline-specific coursework pertaining to the student's department/discipline
- **Minor:** Additional basket of coursework done from a discipline different from the student's original discipline (and would also find mention in the final degree) Honors: Additional basket of coursework done in the same discipline as the student's original discipline (and would also find mention in the final degree)
- **Double Major:** Coursework pertaining to two departments/disciplines and leading to two separate degrees.
- **Additional Course:** An additional course taken by the student over and above the minimum credit requirements of the degree. Pre-requisite: The preliminary requirement, usually successful completion of another course, that must be met before a course can be taken.
- **Elective:** Course chosen by the student and which would form part of his/her degree requirements.
- **Free Elective:** A course of the student's choice, to be selected from the any department (subject to meeting the pre-requisites)
- **Core Elective:** A course of the student's choice, to be selected from the same department (or offered by a different department, but identified as "core" by one's department)
- **LA/CA Elective:** A course of the student's choice, to be selected from the Liberal Arts and Creative Arts category
- **Science Elective:** A course of the student's choice, to be selected from the Maths, Physics & Chemistry list of courses
- **Fractal Segment:** The part or duration of a semester in which a particular course is offered

1.2 Course Numbering Scheme

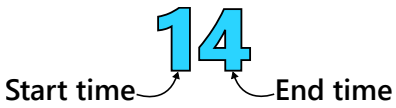
Each course is denoted by a course number consisting of two letters followed by four numerals.



1.3 Fractal Segments

In the fractal system, a semester is divided into six segments. Each segment is approximately 2.5 to 3 weeks in duration. Every fractal course is accompanied by a two-digit segment number indicating the duration of the course. The first number denotes the segment in which a course will begin and the second number the segment in which it will be completed. For example, Segment 34 means, a particular course will begin in segment-3 and finish at the end of segment-4. Typically, a course running for full the semester (i.e., all six segments) would be

3-credits; so each segment will be equivalent to 0.5 credit. Accordingly, the credit of a course will be decided, based on its segment data. For example, if the segment of a course is 56, it implies that the course will be running in two segments (5 & 6). Hence, it will be $0.5 \times 2 = 1$ credit.



	SEMESTER					
SEG CREDITS	1	2	3	4	5	6
0.5	11	22	33	44	55	66
1.0	12		34		56	
1.5	13			46		
2.0	14					
2.0			36			
3.0	16					

2 | Department of Artificial Intelligence

2.1 MTech 2Year

- Communication Skills and *industry lecture series may be taken either in sem 1 and sem 2 depending on the availability.
- Department electives can be completed any semester, within the first 1 years
- Electives not in the lists above can be considered in a given basket with approval of faculty advisor

Code	Credits	Course Title
Semester 1		
AI5030	3	Probability and Stochastic Processes
AI5000	3	Foundations of Machine Learning
EE5609	3	Matrix Theory
CS6013/ID2230[1]	3	Advanced Data Structures and Algorithms / Data Structures and Applications
LA5180	1	LA 5180 communication Skills : Advanced*
Semester 2		
AI5100	3	Deep Learning
XXXX	9	AI Electives (see Baskets)
AI5016	1	Industry Lectures*
Summer		
AI6105	3	Thesis Stage - I
Semester 3		
AI6205	9	Thesis Stage - II
Semester 4		
AI6305	12	Thesis Stage - III
Electives		

1. Either CS6013 or ID2230

2.2 MTech 3Year (july Admission)

- *Communication Skills and *industry lecture series may be taken either in sem 1 and sem 2 depending on the availability.
- Department electives can be completed any semester, within the first 2 years.
- Electives not in the lists above can be considered in a given basket with approval of faculty advisor

Code	Credits	Course Title
Semester 1		
AI5030	3	Probability and Stochastic Processes
AI5000	3	Foundations of Machine Learning
EE5609	3	Matrix Theory
LA5180	1	Communication Skills : Advanced

Code	Credits	Course Title
Semester 2		
AI5100	3	Deep Learning
XXXX	6	AI Electives (see Baskets)
AI5016	1	Industry Lectures*
Semester 3		
AI6115	3	Thesis Stage - I
CS6013/ID2230	3	Advanced Data Structures and Algorithms / Data Structures and Applications
XXXX	3	AI Electives (see Baskets)
Semester 4		
AI6215	6	Thesis Stage - II
Semester 5		
AI6315	6	Thesis Stage - III
Semester 6		
AI6415	9	Thesis Stage - IV
Electives		

2.3 MTech 3Year (Jan Admission)

- *Communication Skills and *industry lecture series may be taken either in sem 1 and sem 2 depending on the availability.
- Department electives can be completed any semester, within the first 2 years
- Electives not in the lists above can be considered in a given basket with approval of faculty advisor

Code	Credits	Course Title
Semester 1		
AI5030	3	Probability and Stochastic Processes
AI5100	3	Deep Learning
XXX	3	AI Electives (see Baskets)
LA5180	1	Communication Skills : Advanced*
Semester 2		
AI5000	3	Foundations of Machine Learning
EE5609	3	Matrix Theory
CS6013/ID2230	3	Advanced Data Structures and Algorithms / Data Structures and Applications
AI5016	1	Industry Lectures*
Semester 3		
AI6115	3	Thesis Stage - I
XXXX	6	AI Electives (see Baskets)
Semester 4		
AI6215	6	Thesis Stage - II
Semester 5		
AI6315	6	Thesis Stage - III
Semester 6		
AI6415	9	Thesis Stage - IV
Electives		

3 | Department of Additive Manufacturing

3.1 MTech 2Year

Code	Credits	Course Title
Semester 1		
AM5010	3	Fundamentals of Additive Manufacturing
AM5020	2	Product Design and Prototyping
BM4190	2	Biofabrication
AM5030	2	Materials for Additive Manufacturing

4 | Department of Biomedical Engineering

4.1 MTech 2Year

Code	Credits	Course Title
July		
LA5180	1	English Communication
January		
BM6006	1	Industry Lectures
BM7106[1]	3	Special Topics in Microscopy
BM7080[1]	3	Biophotonics
BM6246	1	Biodesign
BM6243	2	Neuromechanics
BM6163[2]	1	Molecular Technology
July		
BM6146	1	Clinical Immersion
January		
BM6140	2	Theor. and Comp. Neuroscience
BM6126[3]	1	Regenerative Medicine
BM6120	2	Tissue Engineering
BM6110	2	Nanomedicine
BM6090	2	Biomedical Imaging
BM6080	2	Advanced Biomechanics
BM6070	2	Biomicrofluidics
BM6023	1	Cell Technology
BM6013	1	Adv Molecular Imaging
July		
BM5193	1	Product Design and Prototyping
January		
BM5170	3	Ultrasound in Medicine
BM5160	2	Mechanics of Bio-fluids
BM5141	1	Advanced Biomaterials
July		
BM5110	1	Lab On Chip
January		
BM5093	2	Biofabrication Technology
July		
BM5090	1	Biomaterials

Code	Credits	Course Title
January		
BM5081	2	Neurotechnology and Bci Lab
BM5080	2	Neurotechnology and Bci Theory
July		
BM5070	1.5	System Physiology
BM5060	0.5	Cell Physiology
BM5040	1	Biomechanics
BM5023	2	Biomedical Devices
BM5013	2	Sensors and Transducers in Healthcare
BM4190	2	Biofabrication
BM5033	2	Statistical Inference Methods in Bioengineering
BM5020	3	Artificial Intelligence in Biomedical and Healthcare
January		
BM6123[3]	3	Tissue Engineering Lab
BM7180	3	Modern Optics for Enginers and Physcists
BM6125	2	Indepedent Research Proposal

1. BM6090
2. BM6023
3. BM6120

4.2 PhD

Code	Credits	Course Title
January		
BM6006	1	Industry Lectures
BM7106[1]	3	Special Topics in Microscopy
BM7080[1]	3	Biophotonics
BM6246	1	Biodesign
BM6243	2	Neuromechanics
BM6163[2]	1	Molecular Technology
July		
BM6146	1	Clinical Immersion
January		
BM6140	2	Theor. and Comp. Neuroscience
BM6126[3]	1	Regenerative Medicine
BM6120	2	Tissue Engineering
BM6110	2	Nanomedicine
BM6090	2	Biomedical Imaging
BM6080	2	Advanced Biomechanics
BM6070	2	Biomicrofluidics
BM6023	1	Cell Technology
BM6013	1	Adv Molecular Imaging
July		
BM5193	1	Product Design and Prototyping
January		
BM5170	3	Ultrasound in Medicine
BM5160	2	Mechanics of Bio-fluids
BM5141	1	Advanced Biomaterials
July		

Code	Credits	Course Title
BM5110	1	Lab On Chip
January		
BM5093	2	Biofabrication Technology
July		
BM5090	1	Biomaterials
January		
BM5081	2	Neurotechnology and Bci Lab
BM5080	2	Neurotechnology and Bci Theory
July		
BM5070	1.5	System Physiology
BM5060	0.5	Cell Physiology
BM5040	1	Biomechanics
BM5023	2	Biomedical Devices
BM5013	2	Sensors and Transducers in Healthcare
BM4190	2	Biofabrication
BM5033	2	Statistical Inference Methods in Bioengineering
BM5020	3	Artificial Intelligence in Biomedical and Healthcare
January		
BM6123[3]	3	Tissue Engineering Lab
BM7180	3	Modern Optics for Enginers and Physcists
BM6125	2	Indepedent Research Proposal

1. BM6090
2. BM6023
3. BM6120

5 | Department of Biotechnology

5.1 MTech 2Year

Code	Credits	Course Title
Semester 1		
BT6390[1]	3	Advanced Cell Biology
BT5010[1]	3	Biochemistry
BT6113[2]	2	Structural Bioinformatics
BT6143[2]	3	Gene Technology
BT6060[2]	2	Protein Misfolding in Neurodegenerative Diseases
BT6123[2]	2	Cell Technology
BT7280[2]	2	Pharmacology and Physiology of Receptors
BT6050[2]	2	Circadian Clocks: Mechanisms and Functions
BT6303[2]	2	Proteomics: Techniques and Applications
BT6053[2]	2	Advanced Microscopy and Image Processing
BT6330[2]	2	RNA Biology and Therapeutics
Semester 2		
BT6183[1]	2	Molecular Biotechnology
BT6020[1]	3	Immunology
BT6150[2]	2	Molecular Basis of Cancer
BT6223[2]	2	Pharmaceutical Biotechnology
BT6670[2]	2	Stem Cell Biology and Regenerative Medicine
BT6133[2]	2	Protein Technology
BT4020[2]	1	Essential Fatty Acids-biochemistry, Physiology and Clinical Significance
BT6063[2]	1	Animal Models in Medical Research
BT6180[2]	1	Macromolecular Crystallography
BT6040[3]	1	Industrial Lecture
BT5060[2]	2	Genome Organization and Gene Regulation
BT5050[2]	2	Medical Microbiology and Infectious Diseases
BT6083[2]	2	Programming for Biomacromolecular Data Analysis
Semester 1		
BT6035	12	Thesis
Semester 2		
BT6045	12	Thesis

1. CORE
2. Elective
3. soft skill

5.2 PhD

Code	Credits	Course Title
Semester 1		
BT6390[1]	3	Advanced Cell Biology
BT5010[1]	3	Biochemistry
BT6113[1]	2	Structural Bioinformatics
BT6143[1]	3	Gene Technology
BT6060[1]	2	Protein Misfolding in Neurodegenerative Diseases
BT6123[1]	2	Cell Technology
BT7280[1]	2	Pharmacology and Physiology of Receptors
BT6050[1]	2	Circadian Clocks: Mechanisms and Functions
BT6303[1]	2	Proteomics: Techniques and Applications
BT6053[1]	2	Advanced Microscopy and Image Processing
Semester 2		
BT6183[1]	2	Molecular Biotechnology
BT6020[1]	3	Immunology
BT6150[1]	2	Molecular Basis of Cancer
BT6223[1]	2	Pharmaceutical Biotechnology
BT6670[1]	2	Stem Cell Biology and Regenerative Medicine
BT6133[1]	2	Protein Technology
BT6063[1]	1	Animal Models in Medical Research
BT6180[1]	1	Macromolecular Crystallography
BT6040[2]	1	Industrial Lecture
BT5060[1]	2	Genome Organization and Gene Regulation
BT5050[1]	2	Medical Microbiology and Infectious Diseases
BT6083[1]	2	Programming for Biomacromolecular Data Analysis

1. Elective
2. soft skill

6 | Department of Climate Change

6.1 MTech 2Year

Code	Credits	Course Title
CC5050	2	Waste Management and Climate Change
CC5060	1	Entrepreneurship Opportunities in Climate Change
CC5070	1	Space Weather Impacts On Climate Climate Change
CC5110	3	Earth's Climate and Atmospheric Sciences
CC5120	3	Climate Monitoring and Variability
CC5130	2	Atmospheric Electricity
CC5140	2	Climate Governance
CC5150	2	Cutting Carbon From Transportation
CC5200	3	Rs, GIS and Climate Change
CC5210	1	Climate Change and Design Innovation
CC5220	2	Climate Mitigation
CC5230	2	Renewable Energy Technology
CC5240	2	Data Modeling in Atmospheric Sciences
CC5250	2	Optimal Instrumentation in Climate Science
CC5260	2	Parallel Programming for High Performance Computing
CC5310	2	United Nations Sustainable Development Goals (un Sdgs)
CC5510	1	Human Dimensions of Climate Change
CC5533	1	Advanced Computing
CC6080	1	High Performance Computing in Weather Research and Forecast/gcm
CC6210	2	Climate Modeling
CC6005	2	MTech Thesis Stage-i
CC6015	12	MTech Thesis Stage-ii
CC6025	10	MTech Thesis Stage-iii
CC6080	1	High Performance Computing in Weather Research and Forecast/gcm
CC6210	2	Climate Modeling
CC5533	1	Advanced Computing
SSXXXX	1	Industry Lectures
SSXXXX	1	English Communication

7 | Department of Civil Engineering

7.1 MTech 2Year in EWRE (2019)

Code	Credits	Course Title
Semester 1		
CE6500	3	Engineering Hydrology And Hydrologic Systems
CE6510	3	Open Channel Hydraulics and Sediment Transport
CEXXXX	3	Elective-1
CEXXXX	3	Elective-2
CE6011	2	Computer Methods In Civil Engineering
CE6006	0	Seminar
Semester 2		
CE6520	3	Irrigation And Watershed Management
CE6530	3	Groundwater Modeling
CE6511	2	Hydraulic And Hydrologic Simulation Lab
CEXXXX	3	Elective-3
Semester 3		
CEXXXX	3	Elective-4
CE6015	13	Master's Thesis
Semester 4		
CE6025	12	Master's Thesis
Electives		
ME5010	3	Mathematical Methods for Engineers
CE6540	3	Contaminant Hydrology And Remediation
CE6550	0	None
CE6560	0	None
CE6570	0	None
CE6580	0	None
CE6590	0	None
CE6610	3	Remote Sensing and GIS Applications To Civil Engineering
CE6620	3	Water Resources Systems Planning And Management
CE6630	3	Water Quality Modeling
CE6640	3	Multiphase Flow in Porous Media
CE6650	3	Hydraulic Transients
CH5020	0	None

7.2 MTech 2Year in Wre (2020)

Code	Credits	Course Title
Semester 1		
CE6500	3	Engineering Hydrology and Hydrologic Systems

Code	Credits	Course Title
CE6520	2	Irrigation Water Management
CE6501	2	Applied Computational Laboratory
CEXXXX	3	Elective-1
ME5330/CEXXXX	3	Elective-2

7.3 MTech 2Year in EE (2020)

Code	Credits	Course Title
Semester 1		
CE5110	3	Physico-chemical Processes
CE5120	3	Air Pollution and Control
CEXXXX	2	Elective 1
CEXXXX	3	Elective 2
Semester 2		
CE5210	3	Bio-chemical Processes in Water and Wastewater Engineering
CE5220	2	Solid Waste Management
CE5211	2	Advanced Environmental Lab
CEXXXX	3	Elective 3
CE5116	1	Industrial Seminar
LAXXX	1	English Communication
Semester 3		
CE6015	12	Masters Thesis
Semester 4		
CE6025	12	Masters Thesis

7.4 MTech 2Year in Geotech (2022)

Code	Credits	Course Title
Semester 1		
CE5310	3	Advanced Soil Mechanics
CE5330	3	Soil Dynamics
CEXXXX	3	Elective I
YYXXXX	3	Elective II
YYXXXX	1	English Communication
Semester 2		
CE5300	3	Advanced Foundation Engineering
CE5340	3	Ground Modification Techniques
CEXXXX	3	Elective III
CEXXXX	3	Elective IV
YYXXXX	1	Industrial Seminar
Semester 3		
CE5015	12	Master's Thesis
Semester 4		
CE5025	12	Master's Thesis

Code	Credits	Course Title

7.5 MTech 2Year in Geotech (2021)

Code	Credits	Course Title
Semester 1		
CE6310	3	Advanced Soil Mechanics
CE6330	3	Soil Dynamics
CEXXXX	3	Elective I
YYXXXX	3	Elective II
YYXXXX	1	English Communication
Semester 2		
CE6300	3	Advanced Foundation Engineering
CE6340	3	Ground Modification Techniques
CEXXXX	3	Elective III
CEXXXX	3	Elective IV
YYXXXX	1	Industrial Seminar
Semester 3		
CE6015	12	Master's Thesis
Semester 4		
CE6025	12	Master's Thesis

7.6 MTech 2Year in Geotech (2020)

Code	Credits	Course Title
Semester 1		
CE6310	3	Advanced Soil Mechanics
CE6330	3	Soil Dynamics
CEXXXX	3	Elective I
CEXXXX	3	Elective II
CE6302	1	Design Studio
Semester 2		
CE6300	3	Advanced Foundation Engineering
CEXXXX	3	Elective III
CEXXXX	3	Elective IV
CEXXXX	2	Elective V
CEXXXX	1	English Communication
CEXXXX	1	Industrial Seminar
Semester 3		
CE6015	12	Master's Thesis
Semester 4		
CE6025	12	Master's Thesis

7.7 MTech 2Year in Structural (2019

Code	Credits	Course Title
Semester 1		
CE6110	3	Advanced Structural Mechanics
CE6120	3	Applied Elasticity And Plasticity
CE6212	3	Advanced Reinforced Concrete
CE6011	2	Computer Methods In Civil Engineering
CE6170	1	Mathematical Methods In Civil Engineering
Semester 2		
CE6130	3	Finite Element Analysis
CE6131	1.5	Finite Element Lab
CE6140	3	Structural Dynamics
CE6002	2	Design Studio
CE6111	1.5	Structures Lab

7.8 MTech 2Year in Structural (2020

Code	Credits	Course Title
Semester 1		
CE6110	3	Advanced Structural Mechanics
CE6120	3	Applied Elasticity And Plasticity
CE6212	3	Advanced Reinforced Concrete

7.9 MTech 2Year in Structural (2021

Code	Credits	Course Title
Semester 1		
CE6110	3	Advanced Structural Mechanics
CE6120	3	Applied Elasticity And Plasticity
CE6212	3	Advanced Reinforced Concrete
CEXXXX	3	Elective 1
CE6111	1.5	Structures Lab

7.10 MTech ACM in EWRE (2019)

Code	Credits	Course Title
Semester 1		
CE6500	3	Engineering Hydrology And Hydrologic Systems
CE6510	3	Open Channel Hydraulics and Sediment Transport
CE6540	3	Contaminant Hydrology And Remediation
CE 6011	2	Computer Methods in Civil Engineering

7.11 MTech ACM in Geotech

Code	Credits	Course Title
Semester 1		
CE6310	3	Advanced Soil Mechanics
CE6330	3	Soil Dynamics
CE6352	3	Design of Earth Structures
CEXXXX	3	Elective I
CE6212	3	Advanced Reinforced Concrete
CE6011	2	Computer Methods In Civil Engineering
Semester 2		
CE6300	3	Advanced Foundation Engineering
CE6340	3	Ground Modification Techniques
CE6120	3	Applied Elasticity And Plasticity
CE5390	3	Pavement Geotechnics
CE6232	3	Advanced Steel Design

7.12 MTech ACM in Structural

Code	Credits	Course Title
Semester 1		
CE6110	3	Advanced Structural Mechanics
CE6120	3	Applied Elasticity And Plasticity
CE6212	3	Advanced Reinforced Concrete
CE6170	1	Mathematical Methods In Civil Engineering
CE6011	2	Computer Methods In Civil Engineering
CE6310	3	Advanced Soil Mechanics
Semester 2		
CE6130	3	Finite Element Analysis
CE6131	1.5	Finite Element Lab
CE6140	3	Structural Dynamics
CE6222	3	Prestressed Concrete Design
CE6232	3	Advanced Steel Design
CE6002	2	Design Studio (structural)
CE6111	1.5	Structures Lab

7.13 MTech 3Year in Geotech (2021)

Code	Credits	Course Title
Semester 1		
CE6310	3	Advanced Soil Mechanics
CEXXXX	3	Elective I
YYXXXX	1	English Communication
Semester 2		
CE6300	3	Advanced Foundation Engineering
CE6340	3	Ground Modification Techniques
YYXXXX	1	Industrial Seminar
Semester 3		
CE6330	3	Soil Dynamics
YYXXXX	3	Elective II
CE6035	4	Master's Thesis

Code	Credits	Course Title
Semester 4		
CEXXXX	3	Elective III
CEXXXX	3	Elective IV
CE6045	4	Master's Thesis
Semester 5		
CE6055	8	Master's Thesis
Semester 6		
CE6065	8	Master's Thesis

7.14 MTech 3Year in Structural

Code	Credits	Course Title
Semester 1		
CE6110	3	Advanced Structural Mechanics
CE6011	2	Computer Methods In Civil Engineering
Semester 2		
CE6130	3	Finite Element Analysis
CE6131	1.5	Finite Element Lab
CE6140	3	Structural Dynamics
CE6006	0	Seminar
Semester 3		
CE6212	3	Advanced Reinforced Concrete
CE6111	1.5	Structures Lab
CE6035	0	Master's Thesis
CE6120	3	Applied Elasticity And Plasticity
Semester 4		
CE6232	3	Advanced Steel Design
CE6222	3	Prestressed Concrete Design
CE6002	2	Design Studio
CE6035	0	Master's Thesis
Semester 5		
CE6035	0	Master's Thesis
Semester 6		
CE6035	0	Master's Thesis
Electives		
CE6200	3	Condition Assessment And Strengthening
CE6232	3	Advanced Steel Design
CE6222	3	Prestressed Concrete Design
CE6150	3	Structural Stability
CE6002	2	Design Studio
CE6120	3	Applied Elasticity And Plasticity
CE6160	3	Theory Of Plates And Shells
ME5010	3	Mathematical Methods for Engineers
CH5050	3	Heterogeneous Catalytic Reaction Engineering

7.15 PhD

- Four courses in the first two semester

8 | Department of Chemical Engineering

8.1 MTech 2 Year 2020+

- The list of departmental electives is given below. However, the list of offered electives in a particular semester will be informed to the student during pre-registration and beginning of the semester.

Code	Credits	Course Title
Semester 1		
CH5010	3	Advanced Numerical Methods
CH5050	3	Heterogeneous Catalytic Reaction Engineering
CH5060	3	Advanced Process Control
CH5460	1	Process Integration
CH5091	2	Process Engineering Lab
LA5180	1	English Communication Skill: Advanced
CHXXXX	3	Electives
Semester 2		
CH5080	3	Advanced Transport Phenomena
CH5030	2	Molecular Thermodynamics
CH5101	2	CFD Lab
CH5036	1	Industry Lectures
CH5015	3	Thesis (stage 1)
CHXXXX	4	Electives
Semester 3		
CH5025	9	Thesis (stage 2)
Semester 4		
CH5035	12	Thesis (stage 3)
Electives		
CH5120	2	Advanced Biochemical Engineering
CH5180	2	Viscous Fluid Flow
CH5190	3	Molecular Modelling of Catalytic Reactions
CH5200	2	Passive Microrheology
CH5220	2	Multiphase Flow Reactors
CH5230	2	Colloids, Emulsions and Foams
CH5240	2	Multi-objective Optimisation Under Uncertainty
CH5250	2	Food Rheology
CH5260	2	Concepts of Biorefinery
CH5290	2	Linear and Nonlinear Stability of Fluid Flows
CH5290	2	Linear and Nonlinear Stability of Fluid Flows
CH5300	3	Light Scattering Methods for Complex Fluids
CH5320	2	Fundamentals of Droplet Drying
CH5390	1	Microfluidic Platform for Cell Culture and Diagnostics
CH5520	2	Physicochemical Fundamentals for Chemical Engineers
CH6003	3	Microreactors Design and Fabrication
CH6020	1	Sustainable Energy
CH6040	1	Process Intensification

Code	Credits	Course Title
CH6080	1	Introduction to Cardiovascular Mechanics
CH6090	2	Advanced Mineral Processing
CH6100	3	Electrochemical Engineering
CH6120	2	Fluidization Technology
CH6140	2	Petroleum Refinery
CH6170	1	Interfacial Chemistry
CH6180	1	Statistical Design and Analysis
CH6190	3	Modern Probability Theory
CH6220	2	Advanced Soild-liquid Separations
CH6250	1	Engineering Materials
CH6270	1	Introduction to Nanotechnology
CH6300	3	Cardiovascular Mechanics
CH6310	2	Introduction to Statistical Hypothesis Testing
CH6330	1	Systems Biology
CH6340	2	Introduction to Microfluidics and Microreactors
CH6370	2	Statistical Computing
CH6420	2	Non-newtonian Fluid Mechanics
CH6450	1	Introduction to System Identification
CH6460	2	Bio-process Technology
CH6470	2	System Identification Theory
CH6480	2	Principles of Heterogeneous Catalysis
CH6550	2	Chemical Reactor Modeling
CH6580	2	Advanced Mineral Processing
CH6610	2	Fuel Cell Technology
CH6620	1	Intermolecular Forces
CH6630	2	Membrane Separation Process
CH6640	2	Optimization Techniques - I
CH6650	1	Introduction to Stochastic Differential Equations
CH6670	2	Theory Of stochastic Differential Equations
CH6680	1	Drug Delivery Systems
CH6690	2	Energy Storage Systems
CH6710	2	Concepts in Soft Matter Systems
CH6710	2	Concepts in Soft Matter Systems
CH6720	2	Basics of Nanosciences and Nanotechnology
CH6730	2	Nature Inspired materials engineering
CH6760	2	Molecular Theory of Polymeric Fluids
CH6770	2	Introduction to Applied Statistical Mechanics
CH6780	1	Soft Computing in Process Modeling
CH6810	2	Computational Fluid Dynamics
CH6820	2	Nature Inspired Optimization
CH6830	1	Surface Interactions
CH6840	2	Biomaterials Science and Engineering
CH6860	1	Data Analysis Tools for Experimental Research
CH6870	1	Machine Learning in Process Systems Engineering

8.2 PhD

- PhD scholars can take only 5th and higher-level courses.
- Credit requirement: Credit requirement should be completed within second semester
- MTech To PhD conversion: Credit requirement is 12. However, credit waiver can be given by doctoral committee for up to 6 credits based on the merit of the case.
- BTech to PhD Conversion: The total number of credits required to be completed after conversion is 24-27.

Code	Credits	Course Title
PhD Regular		
CHXXXX	12	Me/mtech

Code	Credits	Course Title
CHXXXX[1]	12	MTech From Iit
PhD direct		
CHXXXX	24	Btech/msc
PhD External		
CHXXXX	Same as PhD regular	Same As PhD Regular

1. Note: Credit waiver can be given by doctoral committee for up to 6 credits based on the merit of the case.

9 | Department of Computational Mechanics

9.1 MTech 2Year

Code	Credits	Course Title
Odd		
ME5139	3	Finite Element Method
ME5339	3	Computational Fluid Dynamics
ME5769	1.5	Applied Solid Mechanics
ME5779	1.5	Applied Fluid Mechanics
ME5909	2	Additive Manufacturing Technology
Even		
ME5789	3	Computational Dynamics and Vibrations
ME5819	3	Advanced Computational Fluid Dynamics
ME5799	3	Topics in Computational Mechanics
ME5899	2	Structural Optimization
ME5429	1	Finite Element Method Lab
ME5449	1	Computational Fluid Dynamics Lab

10 | Department of Computer Science and Engineering

10.1 MTech 2Year

- Total Credit Requirement in Semester 1 and 2 is 26 Credits.
- In Semester 1 and 2, the total credits that the students can register is Min-9 and Max-16.
- In Semester 1 and 2, a maximum of 3 credits may be taken in mathematics department or any engineering department with the approval of DPGC.
- The selection of thesis guide will be done in the second semester.
- A core elective is a graduate level elective offered by the CSE department and is indicated by course code beginning with CS5 or CS6.
- Please refer for details `https://www.cse.iith.ac.in/assets/pdf/MTechCurriculum2020.pdf`

Code	Credits	Course Title
Semester 1		
CS6013	3	Advanced Data Structures and Algorithms
CS5996[1]	1	Industry Lecture Series
LA5180[1]	1	Communication Skills Advanced
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
Semester 2		
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CS6035[2]	4	Thesis (stage-1)
Semester 3		
CS6045	8	Thesis (stage-2)
Semester 4		
CS6055	12	Thesis (stage-3)

1. Whenever offered
2. Summer Semester

10.2 MTech 3year

- Total Credits Requrement in semesters 1, 2, 3, and 4 is 26 Credits. The curriculm given here is only a guideline.
- Toward fulfilling the requirement of core elective credits, in the first four semesters, a maximum of 3 credits may be taken in mathematics department or any engineering department with the approval of DPGC

- In their first four semesters, students must register for at least 3 course credits per semester. Also, students shall not be allowed to register for more than 13 course credits in any semester
- A core elective is a graduate level elective offered by the CSE department and is indicated by course code that begins with CS5 or CS6.
- The curriculum for the students who register in the January will be similar. But they will be required to take the CS6013: Advanced Data Structures and Algorithms course in the August Semester when this course is offered
- Please refer for details `https://www.cse.iith.ac.in/assets/pdf/MTechCurriculum2020.pdf`

Code	Credits	Course Title
Semester 1		
CS6013	3	Advanced Data Structures and Algorithms
CS5996[1]	1	Industry Lecture Series
LA5180[1]	1	Communication Skills Advanced
CSXXXX	3	Core Elective
Semester 2		
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
Semester 3		
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
Semester 4		
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CS6035	4	Thesis (stage-1)
Semester 5		
CS6045	8	Thesis (stage-2)
Semester 6		
CS6055	12	Thesis (stage-3)

1. Whenever offered

10.3 MTech Dual Degree

- Toward fulfilling the requirement of core elective credits, in the first four semesters, a maximum of 3 credits may be taken in mathematics department or any engineering department with the approval of DPGC
- In 7,8 semesters, students must register for at least 3 course credits per semester. Also, students shall not be allowed to register for more than 7 course credits.
- A core elective is a graduate level elective offered by the CSE department and is indicated by course code that begins with CS5 or CS6.
- Overall, PG course credits total to 14
- Please refer for details https://www.cse.iith.ac.in/assets/pdf/MTechCurriculum2020.pdf

Code	Credits	Course Title
Semester 7		
CSXXXX	3	Core Elective
Semester 8		
CSXXXX	3	Core Elective
Semester 9		
CS5996[1]	1	Industry Lecture Series
LA5180[1]	1	Communication Skills Advanced

Code	Credits	Course Title
CSXXXX	3	Core Elective
Semester 10		
CSXXXX	3	Core Elective
Semester 8		
CS6035[2]	4	Thesis (stage-1)
Semester 9		
CS6045	8	Thesis (stage-2)
Semester 10		
CS6055	12	Thesis (stage-3)

1. Whenever offered
2. Summer

10.4 MDS

Code	Credits	Course Title
Semester 1		
CS6660	3	Mathematical Foundations of Data Sciences
CSXXXX	3	MDS Core Elective 1
Semester 2		
CSXXXX	3	MDS Core Elective 2
CSXXXX	3	MDS Core Elective 3
Semester 3		
CSXXXX	3	MDS Core Elective 4
CSXXXX	3	MDS Core Elective 5
Semester 4		
CSXXXX	3	MDS Core Elective 6
CSXXXX	3	MDS Core Elective 7
Semester 5		
CSXXXX	12	Capstone Project 1
Semester 6		
CSXXXX	12	Capstone Project 2
MDS Core Elective		
CS5300	3	Parallel and Concurrent Programming
CS5360	3	Advanced Computer Architecture
CS5560	3	Probabilistic Models for Machine Learning
CS5580	3	Convex Optimization - Theory
CS5700	3	Text Processing and Retrieval
CS5803	3	Natural Language Processing
CS6360	3	Advanced Topics in Machine Learning
CS6370	3	Information Retrieval
CS6483	3	Constraint Programming
CS6490	3	Hardware Architecture for Deep Learning
CS6510	3	Applied Machine Learning

10.5 MTech NIS

- Total Credit Requirement in Semester 1 and 2 is 26 Credits.
- For details refer https://www.cse.iith.ac.in/assets/pdf/Networks-and-Information-Security-Curriculum.pdf
- A core elective is a graduate level elective offered by the CSE department and designated for NIS Core Elective by DPGC and is indicated by course code beginning with CS5 or CS6.

Code	Credits	Course Title
Semester 1		
CS6013	3	Advanced Data Structures and Algorithms
CS5060	3	Advanced Computer Networks
CS6160	3	Cryptology
CS5996[1]	1	Industry Lecture Series
LA5180[1]	1	Communication Skills Advanced
CSXXXX	3	Core Elective
Semester 2		
CSXXXX	3	Network Security
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CS6035[2]	4	Thesis (stage-1)
Semester 3		
CS6045	8	Thesis (stage-2)
Semester 4		
CS6055	12	Thesis (stage-3)

1. Whenever offered
2. Summer Semester

10.6 PhD (regular)

- A core elective is a graduate level elective offered by the CSE department and is indicated by course code beginning with CS5 or CS6.
- In each of the semesters 1 to 2, a maximum of 9 credits can be taken. The curriculum given here is only a reference.
- Toward fulfilling the requirement of core elective credits, the student is allowed to take up to 6 credits in mathematics or other engineering department with the permission of DPGC.
- The curriculum for the students who register in the January will be similar. But they will be required to take the CS6013: Advanced Data Structures and Algorithms course in the August Semester when this course is offered.
- Please refer for details https://www.cse.iith.ac.in/assets/pdf/CSEPhDRequirements-2020.pdf

Code	Credits	Course Title
Semester 1		
CS6013	3	Advanced Data Structures and Algorithms
CSXXXX	3	Core Elective
Semester 2		
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective

10.7 PhD Direct

- A core elective is a graduate level elective offered by the CSE department and is indicated by course code beginning with CS5 or CS6.
- In each of the semesters 1 to 2, a maximum of 15 credits can be taken. The curriculum given here is only a reference.
- Toward fulfilling the requirement of core elective credits, the student is allowed to take up to 12 credits in mathematics or other engineering department with the permission of DPGC.
- The curriculum for the students who register in the January will be similar. But they will be required to take the CS6013: Advanced Data Structures and Algorithms course in the August Semester when this course is offered.
- Please refer for details https://www.cse.iith.ac.in/assets/pdf/CSE_PhD_Requirements-2020.pdf

Code	Credits	Course Title
Semester 1		
CS6013	3	Advanced Data Structures and Algorithms
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
Semester 2		
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective

11 | Department of Chemistry

11.1 MSc

Code	Credits	Course Title
Semester 1		
CY5010	3	Stereochemistry, Reaction Mechanism, Rearrangements
CY5110	3	Concepts in Inorganic Chemistry
CY5210	3	Electrochemistry and Chemical Kinetics
CY5120	3	Solid State Chemistry
CY5240	3	Quantum Chemistry and Molecular Spectroscopy (phd)
CY5011	2	Organic Chemistry Practicals
CY5111	2	Inorganic Chemistry Practicals
Semester 2		
CY5020	3	Advanced Organic Chemistry of Multiple Bonds
CY5130	3	Advanced Inorganic Chemistry
CY5230	3	Statistical Thermodynamics and Surface Science
CY5250	3	Chemical Binding and Molecular Symmetry
CY5030	3	Spectroscopy and Applications
CY5211	2	Physical Chemistry Practicals
Semester 3		
CY6010	3	Synthetic Methodology in Organic Chemistry
CY6110	3	Metals in Biological Systems
CY6220	3	Physical Methods in Chemistry
CY6211	3	Advance Laboratory Techniques in Chemistry
CY6XXX	3	Free Elective
CY6015	0	MSc Project
Semester 4		
CY6XXX	3	Free Elective
CY6XXX	3	Free Elective
CY6016	12	MSc Project 2

11.2 PhD

- The minimum course credit for PhD students is 12 and need to complete within the first two semesters of joining the institute. Students should registered the theory courses with ID numbers CY5XXX and above.

Code	Credits	Course Title
CYXXXX	3	Elective
CYXXXX	3	Elective
CYXXXX	3	Elective
CYXXXX	3	Elective

12 | Department of Design

12.1 MDes

Code	Credits	Course Title
Semester 1		
DS5013	3	Design Fundamentals
DS5020	3	History of Art and Design
DS5033	3	Design Process and Methodology
DS5233	2	Contemporary Visual Culture
DS5064	1	Design Drawing and Sketching
DS5076	1	Design Lecture Series
Semester 2		
DS5103	3	Graphics and Information Design
DS5173	3	Photography and Imaging
DS5313	3	Moving Images and Animation
DS5183	3	Film Making
DS5253	3	Strategies for Sustainable Design
DS5153	3	Interaction Design, Ai, Virtual Environments
Semester 1		
DS5353	3	Ergonomics for Industrial Designers
Semester 2		
DS5323	3	Space Design
DS5333	3	Product Semantics
DS5343	3	Advanced Materials Design
DS5403	3	Digital Storytelling
DS5413	3	UI and UX
Semester 1		
DS5363	3	Curating Design
Semester 2		
DS5373	3	Inhabitants, Users, Subjects
DS5383	3	Technology and Experience
Semester 3		
DS6245	5	Design Studies Project
DS6076	2	Design Research Seminar
DS6080	2	Entrepreneurship Skills
DS6225	3	Specialization Project 1
DS6205	3	Specialization Project 2
DS5086	2	Internship
Semester 4		
DS6115	12	Final M.des Project

12.2 PhD

Code	Credits	Course Title
DS7010	3	Design Research
DS7024	3	Research Project 1
DS7050	3	Research Methodologies

13 | Department of Design by Practice

13.1 MTech 2Year

Code	Credits	Course Title
Semester 1		
DS5019[1]	3	Design Fundamentals
DS5029[1]	3	History of Design
DS5239[1]	2	Contemporary Visual Culture
DS5339[1]	2	Product Semantics
DS5039[1]	3	Design Process and Methodology
DS5079	1	Design Lecture Series
Semester 2		
DS5109[2]	3	Graphics and Information Design
DS5179[2]	3	Photography and Imaging
DS5319[2]	3	Moving Images and Animation
DS5189[2]	3	Film Making
DS5259[2]	3	Strategies for Sustainable Design
DS5159[2]	3	Interaction Design, Ai, virtual Environments
DS5329[2]	3	Space Design
DS5349[2]	3	Advanced Materials in Design
DS5379[2]	3	Data and Information Visualization
DS5369[2]	3	Experimental Typography
DS5069[2]	1	Design Drawing and Sketching
Semester 3		
DS6079[1]	3	Design Research Seminar
DS6089[1]	2	Entrepreneurship Skills/startups
DS6119[1]	6	M.des Thesis Part I
DSXXXX[1]	1	Internship/case Study Presentation
Semester 4		
DS6119[1]	12	M.des Thesis Part II

1. Department Core
2. Department Elective

14 | Department of Electrical Engineering

14.1 MTech 2Year in CSP

Code	Credits	Course Title
Semester 1		
EE5807	2	Advanced DSP
EE5817	2	Random Variables
EE5827	1	Random Processes
EE5837	1	Digital Modulation
EE5801	3	CSP Lab
EEXXXX	4	Core Electives
Semester 2		
EE5847	1	Information Theory
EEXXXX	5	Core Electives
XXXXXX	3	Free Electives
EE5811	2	Fpga Lab
EE5815	2	Mtech Thesis Stage – 1
Semester 3		
EE5825	2	Mtech Thesis Stage – 2
EE5835	10	Mtech Thesis Stage – 3
EE5845	10	Mtech Thesis Stage – 4

14.2 MTech 2Year in Micro (Aug Entry

Code	Credits	Course Title
Semester 1		
EE5107	2	Semiconductor Physical Electronics
EE5117	1	Microelectronic Device Physics
EE5127	2	Analog IC Design
EE5128	1	Analog IC Design Lab
EE5137	1	Mixed Signal Circuit Design
EE5147	2	Digital IC Design
EE5148	1	Digital IC Design Lab
EE5157	1	CMOS Processing and Wafer Technology
EEXXXX	2	Electives
Semester 2		
EE5168	1	Embedded Systems: Hardware Languages
EE5158	2	Advanced Digital IC Design
EE5149	2	VLSI Technology
EE5129	1	Advanced Analog IC Design
EE5159	2	Microfabrication and Device Simulation Laboratory
EE5138	2	Chips to System Design Laboratory

Code	Credits	Course Title
EEXXXX	2	Elective
EEXXXX	3	Thesis Stage 1
Semester 3		
EE5136	2	IC Characterisation Laboratory
EEXXXX	9	Thesis Stage 2
Semester 4		
EEXXXX	12	Thesis Stage 3

14.3 MTech 2Year in Micro (Jan Entry

Code	Credits	Course Title
Semester 1		
EE5168	1	Embedded Systems: Hardware Languages
EE5158	2	Advanced Digital IC Design
EE5149	2	VLSI Technology
EE5129	1	Advanced Analog IC Design
EE5159	2	Microfabrication and Device Simulation Laboratory
EE5138	2	Chips to System Design Laboratory
EE5136	2	IC Characterisation Laboratory
EEXXXX	2	Elective
Semester 2		
EE5107	2	Semiconductor Physical Electronics
EE5117	1	Microelectronic Device Physics
EE5127	2	Analog IC Design
EE5128	1	Analog IC Design Lab
EE5137	1	Mixed Signal Circuit Design
EE5147	2	Digital IC Design
EE5148	1	Digital IC Design Lab
EE5157	1	CMOS Processing and Wafer Technology
EEXXXX	2	Electives
EEXXXX	3	Thesis Stage 1
Semester 3		
EEXXXX	12	Thesis Stage 3

14.4 MTech 2Year in PEPS

Code	Credits	Course Title
Semester 1		
EE5207	1	Steady State Modelling of Power Systems
EE5217	2	Computer Aided Power System Analysis
EE5227	1	Basics of Power Electronic Converters
EE5237	2	Analysis and Design of Power Electronic Converters
EE5247	2	Dynamics of Power System Components
EE5257	1	Power System Stability Analysis
Semester 2		
EE5267	1	Analysis of DC Machines and Reference Frame Theory
EE5277	2	Analysis of AC Machines
EEXXXX	6	Departmental Electives

Code	Credits	Course Title
Semester 3		
EEXXXX	2	Departmental Electives
EE6201	2	Power System Lab
EE6211	2	Power Electronics Lab
EE6205	6	Thesis Stage 1
Semester 4		
EE6215	18	Thesis Stage 2

14.5 MTech 2Year in SysCon

Code	Credits	Course Title
Semester 1		
EE5440	1	Classical Control Techniques for Mimo Systems
EE5450	2	State Feedback Control
EE5817	2	Random Variables
EE5827	1	Random Processes
EE6640	2	Queuing Theory
EEXXXX	4 – 6	Electives
Semester 2		
EE5460	2	Analysis of Nonlinear Systems
EE5221	2	Advanced Control Lab
EE5406	2	Systems and Control Seminar
EEXXXX	8 – 6	Electives
Semester 3		
EE6415	10	SysCon - M.tech. Stage-1
Semester 4		
EE6425	12	SysCon - M.tech. Stage-2
Electives		

14.6 MTech ACM in CSP

Code	Credits	Course Title
Semester 1		
EE5807	2	Advanced DSP
EE5817	2	Random Variables
EE5827	1	Random Processes
EE5837	1	Digital Modulation
EE5801	3	CSP Lab
XXXXXX	3	Free Electives
Semester 2		
EE5847	1	Information Theory
EEXXXX	9	Core Electives
XXXXXX	3	Free Electives
EE5811	2	Fpga Lab
Semester 3		

Code	Credits	Course Title
EEXXXX	3	Core Electives
XXXXXX	3	Free Electives

14.7 MTech ACM in Micro

Code	Credits	Course Title
Semester 1		
EE5107	2	Semiconductor Physical Electronics
EE5117	1	Microelectronic Device Physics
EE5127	2	Analog IC Design
EE5128	1	Analog IC Design Lab
EE5137	1	Mixed Signal Circuit Design
EE5147	2	Digital IC Design
EE5148	1	Digital IC Design Lab
EE5157	1	CMOS Processing and Wafer Technology
EE5167	2	Embedded System Hardware and Design
EE5199	1	Introduction to Mems
EEXXXX	1	Elective
Semester 2		
EE5168	1	Embedded Systems: Hardware Languages
EE5158	2	Advanced Digital IC Design
EE5149	2	VLSI Technology
EE5129	1	Advanced Analog IC Design
EE5159	2	Microfabrication and Device Simulation Laboratory
EE5138	2	Chips to System Design Laboratory
EE7117	2	More Than Moore Electronics
EEXXXX	3	Electives
Semester 3		
EEXXXX	6	Electives
EEXXXX	3	Self Study

14.8 MTech ACM in PEPS

Code	Credits	Course Title
Semester 1		
EE5207	1	Steady State Modelling of Power Systems
EE5217	2	Computer Aided Power System Analysis
EE5227	1	Basics of Power Electronic Converters
EE5237	2	Analysis and Design of Power Electronic Converters
EE5247	2	Dynamics of Power System Components
EE5257	1	Power System Stability Analysis
EEXXXX	3	Departmental Electives
XXXXXX	3	Free Electives
Semester 2		
EE5267	1	Analysis of DC Machines and Reference Frame Theory
EE5277	2	Analysis of AC Machines
EE5287	1	Basics of Power System Protection
EE5297	2	Advanced Power System Protection
EEXXXX	6	Departmental Electives
XXXXXX	3	Free Electives

Code	Credits	Course Title
Semester 3		
EEXXXX	2	Departmental Electives
EE6201	2	Power System Lab
EE6211	2	Power Electronics Lab

14.9 MTech 3Year in CSP (Aug entry)

Code	Credits	Course Title
Semester 1		
EE5807	2	Advanced DSP
EE5817	2	Random Variables
EE5827	1	Random Processes
EE5837	1	Digital Modulation
EE5801	3	CSP Lab
Semester 2		
EE5847	1	Information Theory
EEXXXX	4	Core Electives
EE5811	2	Fpga Lab
Semester 3		
EEXXXX	3	Core Electives
XXXXXX	3	Free Electives
EE5915	2	Mtech Thesis Stage – 1
Semester 4		
EEXXXX	2	Core Electives
EE5925	6	Mtech Thesis Stage – 2
Semester 5		
EE5935	8	Mtech Thesis Stage – 3
Semester 6		
EE5945	8	Mtech Thesis Stage – 4

14.10 MTech 3Year in CSP (Jan entry)

Code	Credits	Course Title
Semester 1		
EEXXXX	4	Core Electives
XXXXXX	3	Free Electives
Semester 2		
EE5807	2	Advanced DSP
EE5817	2	Random Variables
EE5827	1	Random Processes
EE5837	1	Digital Modulation
EE5801	3	CSP Lab
Semester 3		
EE5847	1	Information Theory
EEXXXX	3	Core Electives

Code	Credits	Course Title
EE5811	2	Fpga Lab
EE5915	2	Mtech Thesis Stage – 1
Semester 4		
EEXXXX	2	Core Electives
EE5925	6	Mtech Thesis Stage – 2
Semester 5		
EE5935	8	Mtech Thesis Stage – 3
Semester 6		
EE5945	8	Mtech Thesis Stage – 4

14.11 MTech 3Year in Micro (Aug Entry

Code	Credits	Course Title
Semester 1		
EE5107	2	Semiconductor Physical Electronics
EE5127	2	Analog IC Design
EE5128	1	Analog IC Design Lab
EE5147	2	Digital IC Design
EE5148	1	Digital IC Design Lab
EE5157	1	CMOS Processing and Wafer Technology
Semester 2		
EE5158	2	Advanced Digital IC Design
EE5149	2	VLSI Technology
EE5129	1	Advanced Analog IC Design
EE5159	2	Microfabrication and Device Simulation Laboratory
EEXXXX	3	Thesis Stage 1
Semester 3		
EE5136	2	IC Characterisation Laboratory
EE5117	1	Microelectronic Device Physics
EE5137	1	Mixed Signal Circuit Design
EEXXXX	1	Electives
EEXXXX	4	Thesis Stage 2
Semester 4		
EE5138	2	Chips to System Design Laboratory
EE5168	1	Embedded Systems: Hardware Languages
EEXXXX	4	Thesis Stage 3
Semester 5		
EEXXXX	3	Electives
EEXXXX	4	Thesis Stage 4
Semester 6		
EEXXXX	9	Thesis Stage 5

14.12 MTech 3Year in Micro (Jan Entry

Code	Credits	Course Title
Semester 1		
EE5158	2	Advanced Digital IC Design
EE5149	2	VLSI Technology
EE5129	1	Advanced Analog IC Design
EE5159	2	Microfabrication and Device Simulation Laboratory
EE5168	1	Embedded Systems: Hardware Languages
Semester 2		
EE5107	2	Semiconductor Physical Electronics
EE5127	2	Analog IC Design
EE5128	1	Analog IC Design Lab
EE5147	2	Digital IC Design
EE5148	1	Digital IC Design Lab
EEXXXX	3	Thesis Stage 1
Semester 3		
EE5138	2	Chips to System Design Laboratory
EEXXXX	3	Electives
EEXXXX	4	Thesis Stage 2
Semester 4		
EE5136	2	IC Characterisation Laboratory
EE5117	1	Microelectronic Device Physics
EE5137	1	Mixed Signal Circuit Design
EE5157	1	CMOS Processing and Wafer Technology
EEXXXX	4	Thesis Stage 3
Semester 5		
EEXXXX	1	Electives
EEXXXX	4	Thesis Stage 4
Semester 6		
EEXXXX	9	Thesis Stage 5

14.13 MTech 3Year in PEPS (Aug entry)

Code	Credits	Course Title
Semester 1		
EE5207	1	Steady State Modelling of Power Systems
EE5217	2	Computer Aided Power System Analysis
EE5227	1	Basics of Power Electronic Converters
EE5237	2	Analysis and Design of Power Electronic Converters
Semester 2		
EE5267	1	Analysis of DC Machines and Reference Frame Theory
EE5277	2	Analysis of AC Machines
EEXXXX	3	Departmental Electives
Semester 3		
EE5247	2	Dynamics of Power System Components
EE5257	1	Power System Stability Analysis
EEXXXX	1	Departmental Electives
EE6201	2	Power System Lab
Semester 4		
EEXXXX	4	Departmental Electives

Code	Credits	Course Title
EE6225	4	Thesis Stage 1
Semester 5		
EE6211	2	Power Electronics Lab
EE6235	8	Thesis Stage 2
Semester 6		
EE6245	12	Thesis Stage 3

14.14 MTech 3Year in PEPS (Jan entry)

Code	Credits	Course Title
Semester 1		
EE5267	1	Analysis of DC Machines and Reference Frame Theory
EE5277	2	Analysis of AC Machines
EEXXXX	2	Departmental Electives
Semester 2		
EE5207	1	Steady State Modelling of Power Systems
EE5217	2	Computer Aided Power System Analysis
EE5227	1	Basics of Power Electronic Converters
EE5237	2	Analysis and Design of Power Electronic Converters
EE6201	2	Power System Lab
Semester 3		
EEXXXX	6	Departmental Electives
Semester 4		
EE5247	2	Dynamics of Power System Components
EE5257	1	Power System Stability Analysis
EE6211	2	Power Electronics Lab
EE6225	4	Thesis Stage 1
Semester 5		
EE6235	8	Thesis Stage 2
Semester 6		
EE6245	12	Thesis Stage 3

14.15 MTech 3years in SysCon

Code	Credits	Course Title
Semester 1		
EE5440	1	Classical Control Techniques for Mimo Systems
EE5450	2	State Feedback Control
EE5817	2	Random Variables
EE5827	1	Random Processes
EEXXXX	1 – 3	Electives
EE5606	2	Convex Optimisation
Semester 2		
EE5221	2	Advanced Control Lab
EEXXXX	3 – 5	Electives

Code	Credits	Course Title
Semester 3		
EE5600	1	Introduction to AI and ML
EE5327	1	Optimization
EE5406	2	Systems and Control Seminar
EEXXXX	5 – 3	Electives
Semester 4		
EE6435	5	SysCon (ra) – M.tech. Thesis Stage 1
EEXXXX	3 – 1	Electives
Semester 5		
EE6445	7	SysCon (ra) – M.tech. Thesis Stage-2
Semester 6		
EE6455	10	SysCon (ra) – M.tech. Thesis Stage-3
Electives		
EE5470	1	Nonlinear Control Techniques
EE5490	2	Robust Control Techniques
EE5480	1	Optimal Control
EE5300	3	Digital Signal Processing
CH5010	3	Advanced Numerical Methods

14.16 PhD

- Regular PhD entry candidates need to take 12 credits.
- For candidates joining PhD directly from BTech, 24 credits of course work is required.
- The load distribution is flexible and can be discussed with the faculty adviser.

15 | Department of Entrepreneurship and Management

15.1 MTech

Code	Credits	Course Title
Semester 1		
EM5090	3	Accounting and Finance for Entrepreneurs
EM5110	1	Foundations of Techno-entrepreneurship
FC4658/EM4010	1	HR and Leadership
EM5020	1	Innovation Management
EM5040	1	Game Theory for Startups
EM5080	1	Introduction to Marketing
EM5120	1	Economics for Technocrats
LA1260	1	Fundamentals of Organizational Structure
EM5650	1	Introduction to Sales and Marketing
Semester 2		
EM6010	3	Strategic Management
EM6040	3	Operational Entrepreneurship
EM6080	1	Marketing for New Ventures
EM6130	1	Introduction to Intellectual Property Rights
EM6096	1	Industry Lecture
Semester 3		
EM6085	12	Project Stage I- Problem Definition and Business Plan Development and Mentoring
Semester 4		
EM6095	12	Project Stage 2 – Developing a Prototype Or Proof of Concept
Semester 2		
EM6090	1	Customer Acquisition

16 | Department of E-Waste Resource Engineering and Management

16.1 MTech 2Year 2020

- 24 Thesis

Code	Credits	Course Title
Semester 1		
EW5010[1]	3	Introduction to Waste Management
EW5020[1]	3	E-waste Recycling Methods
EW5100[2]	2	Design Concepts of Project Capacity to a Viable Scale
EW5120[3]	2	Swot Analysis and Risk Management
MS5390[4]	3	Electrometallurgy
CH5010[5]	3	Advanced Numerical Methods
Semester 2		
EW5070[1]	3	Instrumentation and Characterization
EW5080[1]	2	Hydrometallurgy
EW5060[1]	1	Trace Metal Analysis
EW5090[1]	1	Supply Chain Management and Circular Economy
ID1050[1]	1	Introduction to AI
EW5100[1]	1	Industrial Lectures Series
LA5180[1]	1	English Communication Skills:advanced
EE5342[6]	1	Detection Theory
EE5357[7]	1	Estimation Theory
CH5030[8]	2	Molecular Thermodynamics
EW5110[9]	3	Global Government Policies On E-waste Mgmt and Business Calculations
EW5130[10]	3	Instrumentation for Efficient Recycling and Automation
Semester 3		
EW5015	12	Thesis (stage 1)
Semester 4		
EW5025	12	Thesis (stage 2)

1. Core
2. Elective A1
3. Elective A2
4. Elective B1
5. Elective B2
6. Elective C1
7. Elective C2
8. Elective C3
9. Elective D1
10. Elective D2
11. 26 Theory

16.2 MTech 2Year 2022

- Institute core
- Institute core
- 24 Thesis

Code	Credits	Course Title
Semester 1		
EW5010[1]	3	Introduction to Waste Management
MS5640[1]	3	Advanced Concepts in Process Metallurgy
MS5390[2]	3	Electrometallurgy
CH5010[3]	3	Advanced Numerical Methods
EW5100[4]	2	Design Concepts of Project Capacity to a Viable Scale
EW5120[5]	2	Swot Analysis and Risk Management
LA5180[1]	1	English Communication Skills:advanced

1. Core
2. Elective A1
3. Elective A2
4. Elective B1
5. Elective B2

17 | Department of Energy Science and Technology

17.1 MTech 2Year

Code	Credits	Course Title
Semester 1		
ET5010[1]	2	Fundamentals of Electrochemistry
ET5020[1]	3	Electrochemical Energy Storage Systems: Batteries, Fuel Cells and Supercapacitors
ET5030[1]	2	Non-conventional Energy Sources and Environment
ET5040[1]	1	Energy Management
MS5030[2]	3	Materials Synthesis and Characterization
ET5060[1]	2	Bio-energy
LA5180[3]	1	English Communication
ET5280[1]	1	Industry Lecture Series
Semester 2		
ET5210[1]	3	Power Systems Engineering and Converters for Renewable Applications
ET5220[1]	2	Photovoltaic (pv) Technology
ET5230[1]	1	Energy Audit
ET5211[4]	2	Energy Conversion and Storage Devices (lab-2)
ET5240[5]	2	Hydrogen Economy
ET5260[6]	1	Electric Vehicles
ET5212[7]	1	Laboratory Methods in Electrochemistry and Related Analysis
LA5180[8]	1	English Communication
CH6610[9]	2	Fuel Cell Technology
CH6140[9]	2	Petroleum Refinery
CH6860[9]	1	Data Analysis Tools for Experimental Research
CH5030[9]	2	Molecular Thermodynamics
CH5080[9]	3	Advanced Transport Phenomena
Semester 3		
CHXXXX	12	Thesis Stage I
Semester 4		
CHXXXX	12	Thesis Stage II

1. Dept. Core
2. Dept. Core, Offered by MSME
3. Compulsory, offered by LA department
4. Dept. Core, Limited to EST students
5. Dept elective
6. Dept elective, Its better if you have taken ET5020
7. Dept elective, Limited to EST students, In this course, students will learn advanced electro-analytical methods that can be applied to study systems of technological interest (e.g., batteries, solar cells, fuel cells and so forth). Students will get a hands-on experience in electrochemical measurements.
8. Offered by LA dept., Compulsory (If you missed in Semester I you can take in Semester II)
9. Offered by CHE, Elective

18 | Department of Electronic Vehicles

18.1 MTech 2Year

- Core Courses: 12 Credits, Electives to be selected form the list of courses mentioned below

Code	Credits	Course Title
Semester 1		
ME5710	2	Design of EV
ME5800	1	Testing and Certification of EV
EE5210	3	Characteristics of Power Electronic Switches, Drive Circuits, AC to DC Rectifiers (single Phase/t
ET5020	3	Electrochemical Energy Storage Systems: Batteries, Fuel Cells and Super Capacitors
ET5040	1	Energy Management
EE5167	2	Embedded System Hardware and Design
EV6115	12	Thesis Stage - 1
Semester 2		
ME5670	3	Vehicle Dynamics and Modeling
IS5033	3	Embedded Programming
ET5220	2	Photovoltaic (pv) Technology
CH6610	2	Fuel Cell Technology
ME5040	1.5	Computational Fluid Dynamics Tools
ME5421	1	FEM Lab
DS5253	3	Strategies for Sustainable Design
DS5343	3	Advanced Materials Design
Semester 3		
ME5480	3	Sustainable Energy Technology: Energy Sources, Energy Efficiency, Storage and Optimization
ME5340	3	IC Engine Combustion and Pollution
DS4013	2	Automobile Design Explorations
DS5423	2	Design Thinking for EV
DS5413	3	UI and UX
DS5443	2	Life-cycle Analysis for EV
DS5403	3	Digital Storytelling
DS5463	2	Product System and Service Design for EV
DS5353	3	Ergonomics for Industrial Designers
Semester 4		
EV6125	12	Thesis Stage - 2
EE5240	3	Electrical Machines and Analysis Control
EE6360	3	Multimedia Communication Systems
ET5230	1	Energy Audit
ME5650	3	Engineering Noise Control
SM5013	1	Autonomous Navigation
SM5033	1	Internet of Things (iot)
ET5260	1	Electric Vehicles
SM5043	3	Traffic Engineering and Intelligent Transportation Systems
ME5700	3	Analysis and Design of Composite Structures

19 | Department of Integrated Sensor Systems

19.1 MTech 2Year

- With the permission of Guide/MTech co-ordinator, a student can select alternate elective from the "Electives" mentioned below or any other suitable course from other department.

Code	Credits	Course Title
Semester 1		
IS5010	2	Smart Material and Transducers
IS5013	3	Fabrication Technology and Characterization
IS5020	3	Physics of Low Dimensional Systems and Quantum Devices
IS5030	2	Computational Modelling Techniques
IS5050	1	Industry Lecture Series (12 Lectures By Experts)
ISXXXX	2 or 3	Elective –i
Semester 2		
LA5180	1	English Communication Skills: Advanced
IS5023	3	Circuits and Packaging
IS5033	3	Embedded Programming
IS5040[1]	2	Intelligent Signal Processing Using Ai/iot
ISXXXX*[2]	2(or 3)*	Elective –ii
ISXXXX*[2]	2(or 3)*	Elective –iii
ISXXXX*[2]	2(or 3)*	Elective –iv
Semester 3		
IS5015	12	Thesis Stage -1
Semester 4		
IS5025	12	Thesis Stage -2
Basket 1		
EE5139	2	Power Management Integrated Circuit Design
EE7120	2	CMOS Sensors
PH6168	2	Spintronics
EE6160	2	Mesoscopic Carrier Transport
EE6151	2	Topics in Nanophotonics
XXXX	0	Any Suitable Course As Per Advice of Your Guide
Basket 2		
CH6890	1	Introduction to Microfluidics
PH6438	2	Fundamentals of Semiconductors Physics and Devices
EE5107	2	Semiconductor Physical Electronics
EE6140	3	Introduction to Biosensor Technology
EE6180	3	Biomedical IC Design
EE6410	3	Biomedical IC Design
XXXX	0	Any Suitable Course As Per Advice of Your Guide/fa

Code	Credits	Course Title
Basket 3		
EE5170	3	Thin-film Transistors
PH7013	3	Advanced Optical Instrumentation
PH6448	2	Microfabrication Techniques
CY7040	3	Organic Electronics and Photonics
MS5270	3	2d Materials: Synthesis, Characterization and Applications
PH6198	2	Organic Electronics
BM6110	2	Nanomedicine
XXXX	0	Any Suitable Course As Per Advice of Your Guide/fa
Electives		
BM4190	2	Biofabrication
BM6110	2	Nanomedicine
CH6730	2	Nature Inspired materials engineering
CH6720	2	Basics of Nanosciences and Nanotechnology
PB5220	0	Advanced Fabrionics
CH5390	1	Microfluidic Platform for Cell Culture and Diagnostics
CH6840	2	Biomaterials Science and Engineering
CH6770	2	Introduction to Applied Statistical Mechanics
CH5290	2	Linear and Nonlinear Stability of Fluid Flows
CY7040	0	Organic Electronics and Photonics
CY7230	0	Nanochemistry and Applications
CY8998	0	Applications of 3d Printing in Chemistry
CY5230	3	Statistical Thermodynamics and Surface Science
CY5220	0	Solid State Chemistry
CY8938	0	Modern Molecular Simulation Methods
EE6140	3	Introduction to Biosensor Technology
EE7120	2	CMOS Sensors
EE6150	3	Nanophotonics and Metamaterials
EE5611	2	Machine Learning Applications for Wireless Communications
EE5607	1	ML – Hardware Implementation
EE5170	3	Thin-film Transistors
EE5167	2	Embedded System Hardware and Design
EE5168	1	Embedded Systems: Hardware Languages
EE5147	2	Digital IC Design
EE5148	1	Digital IC Design Lab
EE5127	2	Analog IC Design
EE5128	1	Analog IC Design Lab
EE5158	0	Advanced Digital IC Design
EE5159	0	Microfabrication and Device Simulation Laboratory
EE5110	3	Semiconductor Device Modeling
EE5139	2	Power Management Integrated Circuit Design
EE5300	3	Digital Signal Processing
EE6120	3	Nanoelectronics: Principles and Devices
EE6160	2	Mesoscopic Carrier Transport
EE6180	3	Biomedical IC Design
EE6410	3	Biomedical IC Design
EE7110	3	More Than Moore Electronics
ME5010	3	Mathematical Methods for Engineers
ME5130	3	Finite Element Method
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5660	3	Applied Micro and Nanomechanics in Engineering
MS5010	3	Functional Properties of Materials
MS5030	3	Materials Synthesis and Characterization
MS5080	3	Thin Films Technology
MS5140	3	Introduction to Computational Methods in Materials Science
MS5270	3	2d Materials: Synthesis, Characterization and Applications
MS5290	3	Plasmonics: Fundamentals to Advanced Applications

Code	Credits	Course Title
PH4268	2	Solid State Physics
PH6168	2	Spintronics
PH6198	2	Organic Electronics
PH6317	1	Physics and Applications of Functional Materials
PH6438	2	Fundamentals of Semiconductors Physics and Devices
PH6448	2	Microfabrication Techniques
PH7013	3	Advanced Optical Instrumentation
CS6230	3	Optimization Methods in Machine Learning
CS6510	3	Applied Machine Learning

1. IS5040 to be offered along with EE6410; Other substitutes: EE5158/EE5147/EE5611
2. Total elective credits including 1st semester elective (I+II+III+IV) should not exceed 8

19.2 MTech 3Year

- Thesis credit can be variable from 3-6 semester as advised by Advisor. Total thesis credit should not exceed 24.
- With the permission of Guide/MTech co-ordinator, a student can select alternate elective from the "Electives" mentioned below or any other suitable course from other department.

Code	Credits	Course Title
Semester 1		
IS5010	2	Smart Material and Transducers
IS5013	3	Fabrication Technology and Characterization
IS5020	3	Physics of Low Dimensional Systems and Quantum Devices
IS5030	2	Computational Modelling Techniques
IS5050	1	Industry Lecture Series (12 Lectures By Different Experts)
ISXXXX	2 or 3	Elective –i
Semester 2		
LA5180	1	English Communication Skills: Advanced
IS5023	3	Circuits and Packaging
IS5033	3	Embedded Programming
IS5040[1]**	2	Intelligent Signal Processing Using Ai/iot
ISXXXX*[2]	2(or 3)*	Elective –ii
ISXXXX*[2]	2(or 3)*	Elective –iii
ISXXXX*[2]	2(or 3)*	Elective –iv
Semester 3		
IS5035[3]	0	Thesis Stage -1
Semester 4		
IS5045[3]	0	Thesis Stage -2
Semester 5		
IS5055[3]	0	Thesis Stage -3
Semester 6		
IS5065[3]	0	Thesis Stage -4
Basket 1		
EE5139	2	Power Management Integrated Circuit Design
EE7120	2	CMOS Sensors
PH6168	2	Spintronics
EE6160	2	Mesoscopic Carrier Transport
EE6151	2	Topics in Nanophotonics
XXXX	0	Any Suitable Course As Per Advice of Your Guide

Code	Credits	Course Title
Basket 2		
CH6890	1	Introduction to Microfluidics
PH6438	2	Fundamentals of Semiconductors Physics and Devices
EE5107	2	Semiconductor Physical Electronics
EE6140	3	Introduction to Biosensor Technology
EE6180	3	Biomedical IC Design
EE6410	3	Biomedical IC Design
XXXX	0	Any Suitable Course As Per Advice of Your Guide
Basket 3		
EE5170	3	Thin-film Transistors
PH7013	3	Advanced Optical Instrumentation
PH6448	2	Microfabrication Techniques
CY7040	3	Organic Electronics and Photonics
MS5270	3	2d Materials: Synthesis, Characterization and Applications
PH6198	2	Organic Electronics
BM6110	2	Nanomedicine
XXXX	0	Any Suitable Course As Per Advice of Your Guide
Electives		
BM4190	2	Biofabrication
BM6110	2	Nanomedicine
CH6730	2	Nature Inspired materials engineering
CH6720	2	Basics of Nanosciences and Nanotechnology
PB5220	0	Advanced Fabrionics
CH5390	1	Microfluidic Platform for Cell Culture and Diagnostics
CH6840	2	Biomaterials Science and Engineering
CH6770	2	Introduction to Applied Statistical Mechanics
CH5290	2	Linear and Nonlinear Stability of Fluid Flows
CY7040	0	Organic Electronics and Photonics
CY7230	0	Nanochemistry and Applications
CY8998	0	Applications of 3d Printing in Chemistry
CY5230	3	Statistical Thermodynamics and Surface Science
CY5220	0	Solid State Chemistry
CY8938	0	Modern Molecular Simulation Methods
EE6140	3	Introduction to Biosensor Technology
EE7120	2	CMOS Sensors
EE6150	3	Nanophotonics and Metamaterials
EE5611	2	Machine Learning Applications for Wireless Communications
EE5607	1	ML – Hardware Implementation
EE5170	3	Thin-film Transistors
EE5167	2	Embedded System Hardware and Design
EE5168	1	Embedded Systems: Hardware Languages
EE5147	2	Digital IC Design
EE5148	1	Digital IC Design Lab
EE5127	2	Analog IC Design
EE5128	1	Analog IC Design Lab
EE5158	0	Advanced Digital IC Design
EE5159	0	Microfabrication and Device Simulation Laboratory
EE5110	3	Semiconductor Device Modeling
EE5139	2	Power Management Integrated Circuit Design
EE5300	3	Digital Signal Processing
EE6120	3	Nanoelectronics: Principles and Devices
EE6160	2	Mesoscopic Carrier Transport
EE6180	3	Biomedical IC Design
EE6410	3	Biomedical IC Design
EE7110	3	More Than Moore Electronics
ME5010	3	Mathematical Methods for Engineers

Code	Credits	Course Title
ME5130	3	Finite Element Method
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5660	3	Applied Micro and Nanomechanics in Engineering
MS5010	3	Functional Properties of Materials
MS5030	3	Materials Synthesis and Characterization
MS5080	3	Thin Films Technology
MS5140	3	Introduction to Computational Methods in Materials Science
MS5270	3	2d Materials: Synthesis, Characterization and Applications
MS5290	3	Plasmonics: Fundamentals to Advanced Applications
PH4268	2	Solid State Physics
PH6168	2	Spintronics
PH6198	2	Organic Electronics
PH6317	1	Physics and Applications of Functional Materials
PH6438	2	Fundamentals of Semiconductors Physics and Devices
PH6448	2	Microfabrication Techniques
PH7013	3	Advanced Optical Instrumentation
CS6230	3	Optimization Methods in Machine Learning
CS6510	3	Applied Machine Learning

1. IS5040 to be offered along with EE6410; Other substitutes: EE5158/EE5147/EE5611
2. Total elective credits including 1st semester elective (I+II+III+IV) should not exceed 8
3. Credit 6: Variable

20 | Department of Liberal Arts

20.1 MA

- Please note that this the tentative curriculum of a new program. Hence, some minor changes might be expected.

Code	Credits	Course Title
LA5070	3	Rural and Urban Development Policy
LA5050	3	Social Research Methods
LA5110	3	Principles of Economics
LA5120	3	Health and Society
LA6090	3	Contemporary India
LAXXXX	3	Gender and Development
LA5020	3	Science and Technology
LAXXXX	3	Elective 1
LAXXXX	3	Elective 2
LAXXXX	3	Free Elective
LAXXXX	6	Summer Project
LA5010	3	State and Humanitarianism
LAXXXX	3	Elective 1
LAXXXX	3	Elective 2
LAXXXX	3	Free Elective
LAXXXX	12	Dissertation
LA5090	3	Media and Development
LA5080	3	Cultural Perspectives On Development: Examining Race, Class, Gender
LA4060	3	Indian Economic Development
LA5040	3	Psychology and Social Justice
LA6240	3	Sociology of Globalisation
LA6270	3	Chronic Disease Management
LA5060	3	Environment and Sustainability
LA6440	3	Visual Anthropology
LA5200	3	Social Exclusion, Social Justice and Development
LA5190	3	Development Economics
LA5210	3	Introduction to Econometrics and Impact Evaluation
LA5030	3	Basic Econometrics and Forecasting
LA6510	3	Development Theory and Policy
LA6530	3	Environment and Society
LA6520	3	Disability, Mental Health, and Development
LA6630	3	Population and Human Development
LA6540	3	Health Economics and Policy
LA6610	3	Labour and Development
LA6470	3	Migration, Mobility and Development
LA5015	0	Dissertation
LA5025	0	Summer Internships

20.2 PhD

Code	Credits	Course Title
Semester 1 and 2		
LA6010	3	Qualitative Research Methods
LA6020	3	Advanced Health Psychology
LA6040	3	Theories On Culture
LA6060	3	Medical Anthropology
LA6070	3	Literary and Critical Theory
LA6080	3	Positive Psychology
LA6090	3	Contemporary India
LA6100	3	Modernism
LA6110	3	Critical Psychology
LA6120	3	Advanced Theory in Sociology and Social Anthropology
LA6130	3	Issues in International Finance
LA6140	3	Quantitative Research Methods for Behavioural Sciences
LA6160	3	American Transcendentalism
LA6170	3	American Fiction After 1945
LA6190	3	Continental Aesthetics: From the Eighteenth Century to the P
LA6200	3	Advanced Econometrics
LA6210	3	Advanced Macroeconomics
LA6220	3	Culture and Mental Health
LA6230	3	Political History of Women's Movement in India
LA6240	3	Sociology of Globalization
LA6260	3	Logical Foundations of Language and Cognition
LA6270	3	Chronic Disease Management
LA6280	3	Psychological Resilience
LA6300	3	Anthropology and Popular Culture
LA6310	3	Films: A Theoretical Introduction
LA6320	3	The English Colloquium: Research Methods
LA6350	3	Advanced Introduction to Science, Technology, and Society
LA6360	3	Anthropology of Kinship
LA6370	3	Organizational Theory
LA6380	3	Advanced Theories in Social Anthropology II
LA6390	3	Media and Popular Culture
LA6400	3	Humor and Well-being
LA6440	3	Visual Anthropology
LA6450	3	Literature and Culture of the Diaspora
LA6460	3	Scholarly Research and Writing in the Humanities: Pedagogy
LA6015	3	Advanced Topics in Xxxx 1
LA6065	3	Advanced Topics in Xxxx 2
LA6520	3	Disability, Mental Health, and Development
LA6430	3	Care and Care-giving: Interdisciplinary Perspectives
LA6540	3	Health Economics and Policy
LA6560	3	Learning and Memory
LA6570	3	The Rise of Postsecular Studies in Literary Theory
LA6920	3	Lyric Theory
LA6620	3	Impact Evaluation
LA6650(PENDINGSENATEAPPROVAL)	3	Mental Health and the Strengths Perspective (pending Senate
LA6660	3	Sensation and Perception
LA6640	3	Statistics
LA6610	3	Labour and Development
LA6580	3	Language, Cognition and Computation
LA6590	3	Natural Language and Natural Meaning
LA6630	3	Population and Human Development
LA6510	3	Development Theory and Policy
Semester 2		
LA6530	3	Environment and Society

Code	Credits	Course Title
LA6470	3	Migration, Mobility and Development

21 | Department of Mathematics

21.1 MSc

Code	Credits	Course Title
Semester 1		
MA4010	3	Analysis of Functions of a Single Variable
MA4020	3	Linear Algebra
MA4040	3	Probability Theory
MA4070	3	Algebra I - Groups and Rings
MA5010	3	Combinatorics and Graph Theory
LA5180	1	English Communication Skills: Advanced
Semester 2		
MA4030	3	Ordinary Differential Equations
MA4080	3	Measure and Integration
MA4090	3	Multivariable Calculus
MA5040	3	Topology
MA4051	3	Basics of Programming
MA5070/MA4240	3	Elective - Algebra II / Applied Statistics
Semester 3		
MA4060	3	Complex Analysis
MA5020	3	Functional Analysis
MA5030	3	Partial Differential Equations
MA5060	3	Numerical Analysis
MA5315	3	Project I
MA****	3	Dept. Elective / Free Elective
Semester 4		
MA****	6	Dept. Elective
MA5415	3	Project II
XX****	3	Free Elective / Dept. Elective
MA**/MA5425**	3	Dept. Elective / Project III

21.2 PhD

- Each student is expected to complete the course work worth 12 credits within the first two semesters after his/her registration.
- The courses are usually suggested by the faculty advisor in tune with the interests of the student.
- The department offers many higher level advanced courses and typically the student is expected to choose his/her courses from among these.

22 | Department of Medical Device Innovation

22.1 MTech 2Year

Code	Credits	Course Title
Semester 1		
MD6116	2	Design Thinking
MD5520	3	Physio-anatomy and Patho-physiology of Diseases
MD6193	3	3-d Rapid Prototyping and Modelling
BM5023	2	Biomedical Devices
MD6155	2	Clinical Immersion (stage I)
Semester 2		
MDXXXX	2	Technical Elective
MD6226	2	Biodesign Process
MD6255	4	Clinical Immersion (stage Ii)
MD6245	4	Capstone Project (stage I)
Semester 3		
MD6355	12	Capstone Project (stage Ii)
Semester 4		
MD6465	8	Capstone Project (stage Iii)
MD6411	1	Intellectual Property and Rights
MD6421	1	Biomedical Devices Standards and Regulations
MD6416	2	Business Plan and Entrepreneurship
LA5180(II)	1	English for Communications
BM6026	1	Industry Lectures P/f
Semester 2		
MD5720[1]	2	Flexible and Wearable Electronics

1. Technical Elective

23 | Department of Mechanical and Aerospace Engineering

23.1 MTech in AE (2022)

Code	Credits	Course Title
Semester 1		
ME5010[1]	3	Mathematical Methods for Engineers
AE5010	3	Introduction to Flight
ME5130	3	Finite Element Method
AE5020	3	Aerospace Structural Mechanics
LAXXXX	1	English Communication
Semester 2		
AE5030	3	Flight Vehicle Aerodynamics
ME5700	3	Analysis and Design of Composite Structures
MEXXXX	1	Seminar
MEXXXX	6	Department Electives
MEXXXX	1	Industry Lectures
Semester 3		
ME6005	12	Thesis Stage-1
Semester 4		
ME6505	12	Thesis Stage-2
Semester-2 Electives		
ME5610	3	Fracture Mechanics
ME5690	3	Advanced FEM
AE5040	3	Aeroelasticity
ME5723	3	Experimental Solid Mechanics
ME6040	3	Machine Learning and Its Applications
ME5810	3	Advanced Computational Fluid Dynamics
ME5860	1	Introduction to Combustion and Reactor Models
ME5870	2	Chemical Kinetics and Modeling in Reacting Flows
ME5280	3	Hypersonic and High Temperature Aerodynamics

1. PG only

23.2 MTech in IDM (2022)

Code	Credits	Course Title
Semester 1		
ME5010	3	Mathematical Methods for Engineers
ME5130	3	Finite Element Method

Code	Credits	Course Title
ME5020	1.5	Elasticity and Plasticity
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5210	3	Cad/cam
LAXXXX	1	English Communication
Semester 2		
ME5030	1.5	Fluid Mechanics and Heat Transfer
ME5040	1.5	Computational Fluid Dynamics Tools
ME5421	1	FEM Lab
ME5431	2	Integrated Design and Manufacturing Lab
MEXXXX	6	Department Electives
MEXXXX	1	Seminar
MEXXXX	1	Industry Lectures
Semester 3		
ME6005	12	Thesis Stage-1
Semester 4		
ME6505	12	Thesis Stage-2
Semester-2 Electives		
ME5200	1.5	Additive Manufacturing
ME5220	1.5	Material Removal Processes
ME5240	1.5	Metal Forming
ME5250	1.5	Design for Manufacturability and Assembly
ME5530	1.5	Industry 4.0
ME5720	1.5	Advanced Material Joining Processes
ME5440	1.5	Introduction to Machine Vision
ME5490	1.5	Circular Manufacturing

23.3 MTech in MAD (2022)

Code	Credits	Course Title
Semester 1		
ME5010[1]	3	Mathematical Methods for Engineers
ME5110	3	Advanced Mechanics of Solids
ME5120	3	Dynamics and Vibration
ME5011	0	Data Acquisition and Control Lab
MEXXXX	3	Department Elective
LAXXXX	1	English Communication
Semester 2		
MEXXXX	9	Department Electives
ME5021	1	Vibration Lab
MEXXXX	1	Seminar
MEXXXX	1	Industry Lectures
Semester 3		
ME6005	12	Thesis Stage-1
Semester 4		
ME6505	12	Thesis Stage-2
Semester-1 Electives		
ME5130	3	Finite Element Method

Code	Credits	Course Title
Semester-2 Electives		
ME7100	3	Advanced Topics in Mathematical Tools
ME5610	3	Fracture Mechanics
ME5650	3	Engineering Noise Control
ME5690	3	Advanced FEM
ME5670	3	Vehicle Dynamics and Modeling
ME6040	3	Machine Learning and Its Applications
ME5723	3	Experimental Solid Mechanics
ME5670	3	Vehicle Dynamics and Modeling
ME5630	3	Nonlinear Oscillation
ME5700	3	Analysis and Design of Composite Structures
ME5160	3	Nonlinear Mechanics of Slender Structures

1. PG only

23.4 MTech in Tfe (2022)

Code	Credits	Course Title
Semester 1		
ME5010[1]	3	Mathematical Methods for Engineers
ME5310	3	Incompressible Fluid Flow
ME5320	3	Advanced Heat Transfer
LAXXXX	1	English Communication
MEXXXX	3	Core Elective
Semester 2		
MEXXXX	9	Department Electives
ME5441	1	CFD Lab
ME5971	2	Thermo-fluid Engineering Core Lab II
MEXXXX	1	Seminar
MEXXXX	1	Industry Lectures
Semester 3		
ME6005	12	Thesis Stage-1
Semester 4		
ME6505	12	Thesis Stage-2
Semester-1 Electives		
ME5020	1.5	Elasticity and Plasticity
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5110	3	Advanced Mechanics of Solids
ME5120	3	Dynamics and Vibration
ME5130	3	Finite Element Method
ME5260	3	Continuum Mechanics
ME5330	3	Computational Fluid Dynamics
ME5340	3	IC Engine Combustion and Pollution
ME5480	3	Sustainable Energy Technology: Energy Sources, Energy Efficiency, Storage and Optimization
Semester-2 Electives		
ME7100	3	Advanced Topics in Mathematical Tools
ME5810	3	Advanced Computational Fluid Dynamics
ME5830	3	Compressible Flow and Its Computation
ME5860	1	Introduction to Combustion and Reactor Models
ME5870	2	Chemical Kinetics and Modeling in Reacting Flows
ME5270	3	Interfacial Phenomenon

Code	Credits	Course Title
ME5280	3	Hypersonic and High Temperature Aerodynamics
ME5470	3	Introduction to Parallel Scientific Computing
ME6040	3	Machine Learning and Its Applications
ME5820	3	Turbulence
ME5910	3	Combustion Technology

1. PG only

23.5 MTech in IDM (2020)

Code	Credits	Course Title
Semester 1		
ME5010[1]	3	Mathematical Methods for Engineers
ME5130	3	Finite Element Method
ME5020	1.5	Elasticity and Plasticity
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5210	3	Cad/cam
LAXXXX	1	English Communication
Semester 2		
ME5030	1.5	Fluid Mechanics and Heat Transfer
ME5040	1.5	Computational Fluid Dynamics Tools
ME5421	1	FEM Lab
ME5431	2	Integrated Design and Manufacturing Lab
MEXXXX	6	Department Electives
MEXXXX	1	Seminar
MEXXXX	1	Industry Lectures
Semester 3		
ME6005	12	Thesis Stage-1
Semester 4		
ME6505	12	Thesis Stage-2
Semester-2 Electives		
ME5200	1.5	Additive Manufacturing
ME5220	1.5	Material Removal Processes
ME5240	1.5	Metal Forming
ME5250	1.5	Design for Manufacturability and Assembly
ME5530	1.5	Industry 4.0
ME5720	1.5	Advanced Material Joining Processes
ME5690	3	Advanced FEM
ME6040	3	Machine Learning and Its Applications
ME5440	1.5	Introduction to Machine Vision

1. PG only

23.6 MTech in AE (2020)

Code	Credits	Course Title
Semester 1		
ME5010[1]	3	Mathematical Methods for Engineers
AE5010	3	Introduction to Flight
ME5130	3	Finite Element Method
AE5020	3	Aerospace Structural Mechanics

Code	Credits	Course Title
LAXXXX	1	English Communication
Semester 2		
AE5030	3	Flight Vehicle Aerodynamics
ME5700	3	Analysis and Design of Composite Structures
MEXXXX	1	Seminar
MEXXXX	6	Department Electives
MEXXXX	1	Industry Lectures
Semester 3		
ME6005	12	Thesis Stage-1
Semester 4		
ME6505	12	Thesis Stage-2
Semester-2 Electives		
ME5610	3	Fracture Mechanics
ME5690	3	Advanced FEM
AE5040	3	Aeroelasticity
ME5723	3	Experimental Solid Mechanics
ME6040	3	Machine Learning and Its Applications
ME5810	3	Advanced Computational Fluid Dynamics
ME5860	1	Introduction to Combustion and Reactor Models
ME5870	2	Chemical Kinetics and Modeling in Reacting Flows
ME5280	3	Hypersonic and High Temperature Aerodynamics

1. PG only

23.7 MTech in MAD (2020)

Code	Credits	Course Title
Semester 1		
ME5010[1]	3	Mathematical Methods for Engineers
ME5110	3	Advanced Mechanics of Solids
ME5120	3	Dynamics and Vibration
ME5011	0	Data Acquisition and Control Lab
MEXXXX	3	Department Elective
LAXXXX	1	English Communication
Semester 2		
MEXXXX	9	Department Electives
ME5021	1	Vibration Lab
MEXXXX	1	Seminar
MEXXXX	1	Industry Lectures
Semester 3		
ME6005	12	Thesis Stage-1
Semester 4		
ME6505	12	Thesis Stage-2
Semester-1 Electives		
ME5130	3	Finite Element Method
Semester-2 Electives		
ME7100	3	Advanced Topics in Mathematical Tools
ME5610	3	Fracture Mechanics

Code	Credits	Course Title
ME5650	3	Engineering Noise Control
ME5690	3	Advanced FEM
ME5670	3	Vehicle Dynamics and Modeling
ME6040	3	Machine Learning and Its Applications
ME5723	3	Experimental Solid Mechanics
ME5670	3	Vehicle Dynamics and Modeling
ME5630	3	Nonlinear Oscillation
ME5700	3	Analysis and Design of Composite Structures
ME5160	3	Nonlinear Mechanics of Slender Structures

1. PG only

23.8 MTech in Tfe (2020)

Code	Credits	Course Title
Semester 1		
ME5010[1]	3	Mathematical Methods for Engineers
ME5310	3	Incompressible Fluid Flow
ME5320	3	Advanced Heat Transfer
LAXXXX	1	English Communication
MEXXXX	3	Core Elective
Semester 2		
MEXXXX	9	Department Electives
ME5441	1	CFD Lab
ME5971	2	Thermo-fluid Engineering Core Lab II
MEXXXX	1	Seminar
MEXXXX	1	Industry Lectures
Semester 3		
ME6005	12	Thesis Stage-1
Semester 4		
ME6505	12	Thesis Stage-2
Semester-1 Electives		
ME5020	1.5	Elasticity and Plasticity
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5110	3	Advanced Mechanics of Solids
ME5120	3	Dynamics and Vibration
ME5130	3	Finite Element Method
ME5260	3	Continuum Mechanics
ME5330	3	Computational Fluid Dynamics
ME5340	3	IC Engine Combustion and Pollution
ME5480	3	Sustainable Energy Technology: Energy Sources, Energy Efficiency, Storage and Optimization
Semester-2 Electives		
ME7100	3	Advanced Topics in Mathematical Tools
ME5810	3	Advanced Computational Fluid Dynamics
ME5830	3	Compressible Flow and Its Computation
ME5860	1	Introduction to Combustion and Reactor Models
ME5870	2	Chemical Kinetics and Modeling in Reacting Flows
ME5270	3	Interfacial Phenomenon
ME5280	3	Hypersonic and High Temperature Aerodynamics
ME5470	3	Introduction to Parallel Scientific Computing
ME6040	3	Machine Learning and Its Applications

Code	Credits	Course Title
ME5820	3	Turbulence
ME5910	3	Combustion Technology

1. PG only

23.9 MTech in IDM (2019)

Code	Credits	Course Title
Semester 1		
ME5010	3	Mathematical Methods for Engineers
ME5130	3	Finite Element Method
ME5140	1.5	Process Modeling and Optimization
ME5383	1	Soft Computation Lab
ME5020	1.5	Elasticity and Plasticity
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5090	1.5	Mathematical Elements for Geometrical Modeling
ME5100	1.5	Computer Integrated Manufacturing
Semester 2		
ME5030	1.5	Fluid Mechanics and Heat Transfer
ME5040	1.5	Computational Fluid Dynamics Tools
ME5421	1	FEM Lab
ME5240	1.5	Metal Forming
ME5200	1.5	Additive Manufacturing
ME5250	1.5	Design for Manufacturability and Assembly
ME5230	1.5	Design and Analysis of Welded Joints
ME5431	2	Integrated Design and Manufacturing Lab
MEXXXX	3	Core Electives
Semester 3		
ME6106	1	Seminar
ME6005	11	Thesis (stage1)
Semester 4		
ME6505	12	Thesis (stage2)

23.10 MTech in MAD (2019)

Code	Credits	Course Title
Semester 1		
ME5010	3	Mathematical Methods for Engineers
ME5260	3	Continuum Mechanics
ME5110	3	Advanced Mechanics of Solids
ME5120	3	Dynamics and Vibration
ME5130	3	Finite Element Method
ME5451	1	Computational Mathematics Lab
MEXXXX	1.5	Core Electives
Semester 2		
MEXXXX	12	Core Electives
ME5911	2	Design Engineering Core Lab II
Semester 3		
ME6106	1	Seminar

Code	Credits	Course Title
ME6005	11	Thesis (stage1)
Semester 4		
ME6505	12	Thesis (stage2)
Semester-1 Electives		
ME5020	1.5	Elasticity and Plasticity
ME5030	1.5	Fluid Mechanics and Heat Transfer
ME5040	1.5	Computational Fluid Dynamics Tools
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5090	1.5	Mathematical Elements for Geometrical Modeling
ME5100	1.5	Computer Integrated Manufacturing
ME5360	1.5	Planar Multibody Dynamics
Semester-2 Electives		
ME5610	3	Fracture Mechanics
ME5630	3	Nonlinear Oscillation
ME5650	3	Engineering Noise Control
ME5670	3	Vehicle Dynamics and Modeling
ME5690	3	Advanced FEM
ME5700	3	Analysis and Design of Composite Structures
ME7100	3	Advanced Topics in Mathematical Tools

23.11 MTech in Tfe (2019)

Code	Credits	Course Title
Semester 1		
ME5010	3	Mathematical Methods for Engineers
ME5310	3	Incompressible Fluid Flow
ME5320	3	Advanced Heat Transfer
ME5451	1	Computational Mathematics Lab
MEXXXX	6	Core Electives
Semester 2		
MEXXXX	12	Core Electives
ME5441	1	CFD Lab
ME5971	2	Thermo-fluid Engineering Core Lab II
Semester 3		
ME6106	1	Seminar
ME6005	11	Thesis (stage1)
Semester 4		
ME6505	12	Thesis (stage2)
Semester-1 Electives		
ME5020	1.5	Elasticity and Plasticity
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5110	3	Advanced Mechanics of Solids
ME5120	3	Dynamics and Vibration
ME5130	3	Finite Element Method
ME5250	1.5	Design for Manufacturability and Assembly
ME5260	3	Continuum Mechanics
ME5330	3	Computational Fluid Dynamics
ME5340	3	IC Engine Combustion and Pollution

Code	Credits	Course Title
Semester-2 Electives		
ME5270	3	Interfacial Phenomenon
ME5280	3	Hypersonic and High Temperature Aerodynamics
ME5810	3	Advanced Computational Fluid Dynamics
ME5820	3	Turbulence
ME5830	3	Compressible Flow and Its Computation
ME5860	1	Introduction to Combustion and Reactor Models
ME5870	2	Chemical Kinetics and Modeling in Reacting Flows
ME7100	3	Advanced Topics in Mathematical Tools

23.12 MTech 3Year

- 3-Year M.Tech Curriculum: The course list and the total credits for 3-year MTech will be same as the 2-year MTech counterparts with the following variations:
- (a) Course work must be finished within 5 semesters. The student can plan the course distribution in consultation with the guide.
- (b) The student must be enrolled for at least three credits and at most 12 credits of course-work each semester till the end of his/her course work.
- (c) As the thesis credits are not fixed, but vary across the semesters, the following course numbers can be used for different semesters.

Code	Credits	Course Title
Semester 1		
ME5915	(variable)	M.tech (3-year) Thesis (semester-1)
Semester 2		
ME5925	(variable)	M.tech (3-year) Thesis (semester-2)
Semester 3		
ME6915	(variable)	M.tech (3-year) Thesis (semester-3)
Semester 4		
ME6925	(variable)	M.tech (3-year) Thesis (semester-4)
Semester 5		
ME7915	(variable)	M.tech (3-year) Thesis (semester-5)
Semester 6		
ME7925	(variable)	M.tech (3-year) Thesis (semester-6)

23.13 PhD in Mechanical Engineering

- Minimum 12 Credits needs to be completed. For January admits ME5010 course is not available in the first semester.
- Students hopeful for applying PMRF lateral entry are requied to take all courses as 3 credit course and preferrably complet all 12 credits in the first semester to get two chances for appliation for PMRF lateral enry
- Minmum 9 credits in the first semester helps in managing the comprehensive exam and Research proposal seminar timelines

Code	Credits	Course Title
Semester 1		
ME5010	3	Mathematical Methods for Engineers

Code	Credits	Course Title
MEXXXX	3 – 9	Core Electives
Semester 2		
MEXXXX	3 – 6	Core Electives

24 | Department of Materials Science and Metallurgical Engineering

24.1 MTech in MSME

Code	Credits	Course Title
Semester 1		
MS5010	3	Functional Properties of Materials
MS5030	3	Materials Synthesis and Characterization
MS5050	3	Advanced Physical Metallurgy
MS5011	1	Materials Lab -1 (synthesis/characterization/functional)
SS	1	Soft Skills
MS5XXX	3	Core Elective
Semester 2		
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
MS5410	1	Industry Lectures
XXXXXXX	3	Free Elective
MS5021	1	Materials Lab-ii (structural Materials)
Semester 3		
MS5715	12	Thesis: Stage I
Semester 4		
MS5725	12	Thesis: Stage II
List of Electives		
MS5020	3	Electron Microscopy
MS5040	3	Thermomechanical Processing of Materials
MS5080	3	Thin Films Technology
MS5090	3	Advanced Materials Synthesis
MS5100	3	Composite Materials
MS5110	3	Scientific Writing and Ethics in Research
MS5120	3	Materials for Green Energy
MS5130	3	Powder Metallurgy Manufacturing
MS5140	3	Introduction to Computational Methods in Materials Science
MS5150	3	Biomaterials- Materials in Medicine
MS5160	3	Polymer Science and Engineering
MS5170	3	Thermodynamics and Kinetics of Materials
MS5180	3	Applications of Electrochemistry in Materials Science and Engineering
MS5190	3	Soft Materials
MS5200	3	Phase Transformations
MS5210	1	Hierarchical Nanostructured Materials
MS5220	2	Nature Inspired Materials Engineering
MS5230	1	Nature Inspired Materials Engineering for Mechanical Applications
MS5240	1	Nature Inspired Materials Engineering for Wettability, Optical Tunability
MS5250	1	Phase Stability in Alloy Design

Code	Credits	Course Title
MS5270	3	2d Materials: Synthesis, Characterization and Applications
MS5280	1	Wear and Tribology of Materials
MS5290	3	Plasmonics: Fundamentals to Advanced Applications
MS5300	3	Microstructural Design for Advanced Manufacturing
MS5310	3	Functional Ceramics
MS5320	3	Solidification Processing

24.2 MTech in Semiconductor Material

Code	Credits	Course Title
Semester 1		
SD5010	3	Fundamentals of Semiconductor Materials
SD5020	2	Semiconductor Extraction, Purification and Growth
SD5011	1	Semiconductor Materials Characterization Lab
LA5180	1	English Communications
MSXXXX/SDXXXX	6	Department Electives
Semester 2		
SD5030	3	Semiconductor Devices
SD5040	3	Micro and Nanofabrication
SD5021	1	Semiconductor Devices Characterization Lab
SD5015	1	Industry Lecture
MSXXXX/SDXXXX	6	Department Electives
Semester 3		
SD5025	12	Thesis: Stage I
Semester 4		
SD5035	12	Thesis: Stage II
List of Electives		
SD5050	3	Electrochemical Processes in Semiconductors
SD5060	3	Flexible/plastic Electronics

24.3 MTech in Industial Metallurgy (

- Students have a choice to complete Online Industrial Metallurgy course from 1-8 semesters

25 | Department of Microelectronics V

25.1 MV Online

Code	Credits	Course Title
Semester 1		
EE5107	2	Semiconductor Physical Electronics
EE5117	1	Microelectronic Device Physics
EE5127	2	Analog IC Design
EE5128	1	Analog IC Design Lab
EE5137	1	Mixed Signal Circuit Design
EE5147	2	Digital IC Design
EE5148	1	Digital IC Design Lab
EE5157	1	CMOS Processing and Wafer Technology
EEXXXX	2	Electives
Semester 2		
EE5168	1	Embedded Systems: Hardware Languages
EE5158	2	Advanced Digital IC Design
EE5149	2	VLSI Technology
EE5129	1	Advanced Analog IC Design
EE5159	2	Microfabrication and Device Simulation Laboratory
EE5138	2	Chips to System Design Laboratory
EEXXXX	2	Elective
EEXXXX	3	Thesis Stage 1
Semester 3		
EE5136	2	IC Characterisation Laboratory
EEXXXX	9	Thesis Stage 2
Semester 4		
EEXXXX	12	Thesis Stage 3

26 | Department of Polymers and Bio Systems Engineering

26.1 MTech 2Year

Code	Credits	Course Title
Semester 1		
PB5010[1]	1	Physical Biology of Cells - I
PB5020[1]	1	Systems Biology - I
PB5030[1]	2	Concepts in Soft Matter Systems
PB5040[1]	2	Transport in Biological Systems
PB5050[1]	2	Introduction to Statistical Hypothesis Testing
PB5210[2]	2	Inter-molecular and Surface Science
PB5220[2]	2	Advanced Fabrionics
PB5230[2]	2	Basics and Applications of Ai/ml for Process Systems Engg. (km)
PB5240[2]	2	Adsorption and Kinetics
Semester 2		
PB5060[1]	2	Bio-macromolecular Engineering
PB5070[1]	1	Physical Biology of Cells - II
PB5080[1]	1	Systems Biology – II
PB5090[1]	2	Polymeric Biomaterials: Science and Applications
CH5030[2]	2	Molecular Thermodynamics
PB5250[2]	2	Characterization of Polymer and Bio Systems
PB5260[2]	2	Design of Experiments and Data Analysis
PB5270[2]	2	Polymer Processing and Rheology
PB5106	1	Industrial Lectures
Semester 3		
PB5305	12	Thesis Stage 1
Semester 4		
PB5405	12	Thesis Stage 2

1. Core course
2. Electives

27 | Department of Physics

27.1 MSc (2021 and Onwards)

Code	Credits	Course Title
Semester 1		
PH5130	3	Quantum Mechanics-i
PH5110	3	Classical Mechanics
PH5120	3	Mathematical Physics-i
XXXXXX	1	English Communication
PH5210	3	Electrodynamics
PH5240	3	Statistical Mechanics
PH5101	2	Lab

27.2 MSc (before 2021)

Code	Credits	Course Title
Semester 1		
PH5117	1	Wave Formalism of Qm
PH5127	1	Hydrogenic Atoms
PH5267	1	Symmetries in Qm
PH5147	1	Classical Mechanics
PH5167	2	Experimental Techniques
PH2177	1	Linear Vector Spaces
PH5187	1	Fourier Series and Integral Transforms
PH5197	1	Complex Analysis
PH5217	1	Classical Electromagnetism
PH6218	2	Electrodynamics
PH5237	1	Optics
PH6288	2	Analytical Mechanics
FEXXXX	2	Free Elective
PH5101	2	Lab
Semester 2		
PH5287	1	Special Functions and De
PH5297	1	Group Theory
PH5288	1	Digital Electronics
PH5257	1	Scattering Theory
PH5137	1	Approximation Methods in Qm
PH5277	1	Relativistic Qm
PH5337	1	High Energy Physics
PH5347	1	Crystal Structure
PH6247	2	Statistical Physics
PH6238	2	Photonics and Laser
PH5118	2	Electronics

Code	Credits	Course Title
PH5247	1	Thermal Physics
PHXXXX	2	Elective - I
PH5201	2	Lab
Semester 3		
PH6268	2	Solid State Physics
PH5257	1	Atomic and Mol. Physics
PH6278	2	Particle Physics
PH6327	1	Nuclear Physics
PH6258	2	Spectroscopy
PH6588	1	Computational Physics - I
PH6589	2	Computational Physics - II
PH6297	1	Classical Field Theory
PH6458	2	Gravitation and Cosmology
PHXXXX	2	Elective - II
PHXXXX	2	Elective - III
PHXXXX	2	Elective - IV
PH5315	2	Project
PH5211	2	Lab
Semester 4		
PHXXXX	2	Free Elective
PHXXXX	2	Elective – V
PHXXXX	2	Elective – Vi
PHXXXX	8	Project – (continued From Sem. Iii)

27.3 PhD

Code	Credits	Course Title
Semester 1		
PH7010	3	Classical Physics
PH7020	3	Quantum Physics
Semester 1 and 2		
PHXXXX[1]	6	Core Electives
Electives		
PH7080	3	Partcile Physics
PH7090	3	Computational Physics
PH7190	3	Laser Technology
PH7013	3	Advanced Optical Instrumentation
PH6140	3	Quantum Yang Mills Theory
PH3287	1	Atomic-molecular Physics
PH3338	2	Photonics and Laser
PH3358	2	Spectroscopy
PH5167	2	Experimental Techniques
PH6338	2	Advanced Functional Materials
PH6138	2	Plasma Physics and Applications
PH6297	1	Classical Field Theory
PH6458	2	Gravitation and Cosmology
PH6130	2	Statistical Data Analysis
PH6418	2	Quantum Field Theory

1. Electives can be chosen from any of the offered courses suggested by the Faculty Advisor the batch from the choices of listed electives

27.4 PhD (2021 Onwards)

Code	Credits	Course Title
Semester 1		
PH7010	3	Classical Physics
PH7020	3	Quantum Physics

28 | Department of Smart Mobility

28.1 MTech 2Year

Code	Credits	Course Title
Semester 1		
AI5000	3	Basics of Machine Learning
SM5013	1	Autonomous Navigation
EE5817	2	Random Variables
SM5033	1	Internet of Things (iot)
CS5060	3	Advanced Computer Networks
SM5083	2	Basics of Programming
SM5206	1	Industry Lectures
Semester 2		
LA5180[1]	1	English Communication Skills: Advanced
SM5043	3	Traffic Engineering and Intelligent Transportation Systems
SMXXXX[2]	8	Core Electives
SM5206	1	Industry Lectures
Summer		
SM6025[3]	2	Thesis Stage I
Semester 3		
SM6035	10	Thesis Stage II
Semester 4		
SM6045	12	Thesis Stage III
Electives		
CE8993	3	Topics in Transportation Planning
CC5520	1	Mobilities, Cities and Environment
CE6680	2	Mathematical Methods in Civil Engineering
CE6511	2	Hydraulic And Hydrologic Simulation Lab
CE6610	3	Remote Sensing and GIS Applications To Civil Engineering
CS6550	3	Scaling to Big Data
CS5553	3	Wireless Networks and Security
CS6260	3	Topics in Wireless Networks
CS5200	3	Approximation Algorithms
CS6360	3	Advanced Topics in Machine Learning
CS6140	3	Video Content Analysis
CS6170	3	Computer Vision for Autonomous Vehicle Technology
CS5060	3	Advanced Computer Networks
MA6040	3	Fuzzy Logic Connectives and Their Applications
ME5710	2	Design of EV
ME5670	3	Vehicle Dynamics and Modeling
ME5120	3	Dynamics and Vibration
ME5520	1.5	Measurement Science and Techniques
EE6650	2	Sensors for Autonomous Navigation

Code	Credits	Course Title
SM5123	2	Introduction to Drones
EE5440	1	Classical Control Techniques for Mimo Systems
EE5327	1	Optimization
EE5450	2	State Feedback Control
EE6327	3	Statistical Learning Theory
EE6640	2	Queuing Theory
EE5720	1	Game Theory
EE6320	3	Wireless Sensor Network
CS5370	3	Deep Learning for Vision
CS5020	3	Pattern Recognition

1. Soft Skills
2. Department Electives
3. Summer Semester

29 | Course Descriptions

29.1 Institute-wide Courses

29.2 Department of Biomedical Engineering

BM4190 **2**
Biofabrication

The aim of this course is to provide insight of prospects of 3D bioprinting and allied technologires in biomedical and pharmaceutical applications. It will provide the basics and mechanisms of 3D bioprinting, 3D design software, and 3D tissue/organ printing. In addition, it will also provide nitty gritty of various biofabrication processes, such as the selection and development of biomaterial formulation (bioinks), modulating properties of biomaterials, and controlling different processing conditions. Finally, it will provide state-of-the-art examples of translation of biofabricated products from bench towards the bedside.
In this elective course, students will be introduced to all topics within biofabrication and bioprinting to provide them with a broad basic knowledge on the theoretical background, current status and future perspectives of the field. Besides the theoretical parts, students will work in teams on literature presentations. They will also prepare, present and defend a short scientific presentation.
This course will cover the basics of various 3D bioprinting techniques used in biofabrication; processing of medical imaging data into printable CAD models, and fabricating models on a 3D bioprinter; development of suitable bioinks; critical parameters of bioink for biofabrication; various process parameters and their role in biofabrication; Various 3D bioprinted in vitro, in vivo and ex vivo research models and techniques; in vitro manipulation of cells and biomaterials with a bioprinter to engineer tissues for regenerative medicine or in vitro models; biofabrication-based strategy from bench-to-bed to address a specific clinical problem; ethical issue related to biofabrication.

BM5013 **2**
Sensors and Transducers in Healthcare

Generalized design of bioinstruments, noise suppression techniques, Bioinstrument characteristics – basics of regulatory processes. Amplifiers and filters. Sensors and signal conditioning circuits for displacement sensing, gas analyzers, pulse oximetry. Principles bioelectric transduction, ECG-origin, physiology, 12-lead system, instrumentation, rhythms, arrhythmias, pathology, diagnostics. Simulators for pacemaker, defibrillator, heart rate detection.

BM5020 **3**
Artificial Intelligence in Biomedical and Healthcare

The primary objective of this course is to provide fundamentals of artificial intelligence in healthcare, including nature of biomedical data and the use of machine learning (ML) approaches for disease progression modelling, diagnosis, subtype classification of diseases, and explain ability of ML

BM5023 **2**
Biomedical Devices

Overview of Medical Devices, Revised Medical device rules, Considerations for Developing a Regulatory Strategy , Overview of Medical Device Regulation, and medical device life cycle, medical device standards, quality control and risk analysis

BM5033 **2**
Statistical Inference Methods in Bioengineering

Theory: Data types and their representation, terminology: levels, dependant/independant measures, descriptive statistics including mean, median, mode, measures of variability, bootstrapping approaches to compute variability; correlation, central limit theorem, Types of errors, Sample vs population, p-value, Hypothesis testing, confidence levels, statistical power and sample size, t-test, chi-square test, ANOVA, non-parametric tests, normality test; Experimental designs including parallel, factorial, nested design, two-factor design etc.; Statistics in clinical trials - Contingency tables, sensitivity and specificity, linear regression, mixed modelling approaches, Logistic regression; Bayesian inference - Priors, computing posterior distributions, Bayes Factors.
Lab: Laboratory sessions will involve hands-on application of the aforementioned topics on biological data using different softwares such as Python, R, SPSS etc.

BM5040 **1**
Biomechanics

Introduction to concept of stress/strain and elasticity - Normal and Shear stress - Linear models - Isotropic and Anisotropic materials - Matrix formulation to solve problems of elasticity - Biomechanics of body joints (knee and ankle) - Soft tissue mechanics and Introduction to non - linear models

BM5060 **0.5**
Cell Physiology

Cell structure and its organelles; Cell membrane; Cell homeostasis; Nucleus structure and function of its different components

BM5070 **1.5**
System Physiology

Respiratory: anatomy, gas exchange, acid-base balance; Renal: anatomy, ion exchange, transport of metabolites; Gastro-intestinal tract: anatomy, absorption of micro-nutrients, dysfunction; Cutaneous system: anatomy, temperature regulation; Endocrine: basic function, major endocrine organs and their regulation, bone physiology

BM5080 **2**
Neurotechnology and Bci Theory

EEG, fNIRS and EMG will be used to implement BCI and discussed. Futhermore, lab component will include design of BMI system with real-time processing of electrophysiological signals along with feedback. Students are expected to implement basic acquisition, real-time processing and establish an interface with openBCI framework and perform experiments of brain control of external devices.

BM5081 **2**
Neurotechnology and Bci Lab

The neuroscientific concepts that help entrain subjects to learn from abstract cues and rewards will be discussed. Mathematical models and stochastic processes to capture the learning processes will be discussed. Various modalities to record the subject's intent such as EEG, MEG, fNIRS, EMG will be discussed. Futhermore, lab component will include design of BMI system with real-time processing of electrophysiological signals along with feedback. Students are expected to gain end-to-end knowledge of the field of neuroimaging, neuromodulation, BMI and how signal processing and machine learning concepts can be applied to build better BCI systems.

BM5090 **1**
Biomaterials

Introduction of different generations of biomaterials, Different class of materials used in medicine, Understanding the general properties of different classes of materials to be used as biomaterials, Familiarity with biological response to biomaterials, biocompatibility and hemocompatibility.

BM5093 **2**
Biofabrication Technology

Various 3D bioprinting techniques used in biofabrication; processing of medical imaging data into printable CAD models, and fabricating models on a 3D bioprinter; development of suitable bioinks; critical parameters of bioink for biofabrication; various process parameters and their role in biofabrication; Various 3D bioprinted in vitro, in vivo and ex vivo research models and techniques; in vitro manipulation of cells and biomaterials with a bioprinter to engineer tissues for regenerative medicine or in vitro models.

BM5110 **1**
Lab On Chip

Introduction to Micro Nano scale phenomena - Biochips and Microfluidic Technology - Analogy with electrical circuits - Simple modeling designs - Electrokinetic manipulation of cells and macromolecules (Proteins/DNA) - Introduction to Micro Nano fabrication - Applications of Immunoassay On Chip - Outline and overview of Single cell Nanobiology on Chip.

BM5141 **1**
Advanced Biomaterials

Application: Application cover, Cardiovascular, Dental, Orthopedic, Burn Dressing, Suture, Drug Delivery. Practical covering scaffolds fabrication, delivery system and their physical and biological characterization.

BM5160 **2**
Mechanics of Bio-fluids

This course will start with the basics of fluid mechanics and will cover specific examlpes from the biological systems. The specific topic include oscillatory flows, peristaltic flows, active biological fluids, fluid-structure interactions, emergence of non-Newtonian nature of bio-fluids due to their deformable components with application in microfluidics.

BM5170 **3**
Ultrasound in Medicine

Ultrasound and other diagnostic imaging modalities; Review of Fourier transform; Introduction to image processing and filtering; Ultrasound transducers; Propagation of ultrasound wave; Diagnostic ultrasound imaging modes; Imaging systems and applications; Bioeffects of ultrasound; Review of ultrasound literature; Presentations

BM5193 **1**
Product Design and Prototyping

The aim of this theory course is to provide insight of designing and prototyping of medical device. It will provide the basics and mechanisms of rapid prototyping, 3D design software, and 3D printing of prototype. In addition, it will also provide hands on training of various product designing and fabrication, such as the selection and development of material formulation, optimization of different processing conditions of the printing operation, and finally 3D printing of device prototype.

BM6006 **1**
Industry Lectures

Industry lectures are given by different experts in areas related to biomedical engineering. Students will be exposed to various technologies, and businesses, and help them connect their regular coursework to industry-implemented technologies. In addition, this course potentially sets up students for future internships as well.

BM6013 **1**
Adv Molecular Imaging

This course is intended to cover special imaging modalities like PET-CT, MRI, CT and MOLECULAR IMAGING from a clinical perspective. In this course, training will be given to the students in understanding the latest diagnostic modalities and state of art clinical imaging applications. Practical aspects in Clinical Radiology, Radiation Physics and working of instrumentation would be addressed as a part of this course by allowing the students to visit and attend hospital sessions. This will be useful for the students to understand the basic working principles of machines so that in future to develop/transform new applications for better use to the patients.

BM6023 **1**
Cell Technology

This course is intended for practical handling experience for students for culture of mammalian cells. They should learn detailed step-wise protocols in culturing, freezing, splitting of mammalian cells. In addition, they should be able to see the cells found in blood. In addition, they will be taught molecular biology techniques such as DNA isolation, RNA isolation, polymerase chain reaction, and transfection. They should also learn basic molecular biology methods and their interpretation with respect to cell culturing techniques.

BM6070 **2**
Biomicrofluidics

Lab on Chip Microfluidic theory, design, biological and biomedical applications

BM6080 **2**
Advanced Biomechanics

Soft tissue mechanics, Fung's and Holpzafel models, Artery blood flow modeling, transport in GI tract, Experiments on soft polymer/tissue characterization

BM6090 **2**
Biomedical Imaging

Introduction to Xrays, Tomography, CT,PET, SPECT, Introduction to Ultrasound imaging, MRI, Optical imaging modalities.

BM6110 **2**
Nanomedicine

This is a highly interdisciplinary course for graduate students (M. Tech, Ph. D) who are interested in learning about the emerging field of nanoscience and nanotechnology and its application in biology and medicine. To capture the excitement of this emerging field, in this coruse student will be familiarized with fundamentals of nanoscience and Nano-scale engineering, and their potential application in the human health care system. This course will emphasize emerging nanotechnologies and its biomedical applications including fundamental of nanomaterials and nanoengineering, notoxicology, nanotechnology for drug delivery, regenerative medicine, imaging, and diagnostic system and translating nano-medicines into clinical investigation.

BM6120 **2**
Tissue Engineering

The students will learn how to test the biomaterials along with a number of cell types in vitro and in vivo. He should learn how the physiological cues are combined together with biomaterials for regenerative medicine point of view. Syllabus: Tissue engineering: fundamentals and current status; Stem cells: embryonic and mesenchymal stem cells; cell differentiation; Extra-cellular matrix components and their regulation of cell behavior; In vitro and in vivo testing of biomaterials. Bioreactor; Cell migration; Growth factors; Different approaches for angiogenesis and its importance.

BM6123 **3**
Tissue Engineering Lab
▷BM6120

Various scaffolds fabrication techniques used in tissue engineering; preparing hydrogel and processing, and fabricating scaffolds by various techniques; characterization of scaffolds; isolation of cells; characterization of cells; differentiation of cells on the scaffolds; characterization of cell-attached scaffolds

BM6125 **2**
Indepedent Research Proposal

This course enables students to work on mini-projects to build solutions around healthcare needs and drive productization of the prototypes.

BM6126 **1**
Regenerative Medicine
▷BM6120

The students will learn in a seminar-based manner about a number of tissue-specific regenerative medicine and various approaches to achieve this. Syllabus: Tissue-specific regenerative medicine: Bone, cartilage. Regulation and ethics of tissue engineering. Advanced methods applied in regenerative medicine field.

BM6140 **2**
Theor. and Comp. Neuroscience

Genesis of electrical activity in cells, resting membrane potentials; Neuron equivalent circuits and passive propagation in neurons; Hodgkin-Huxley equations and conductance based models; Ion channels and their diversity; Simple neuron models and analysis using dynamical systems concepts; Chemical and electrical synapses and their models; Neuronal networks and techniques for mathematical analysis; Models of learning and memory in the neuron and the network; Neural coding (Rate, temporal, population)

BM6146 **1**
Clinical Immersion

In this course, there will be presentations by physicians working in various hospitals. Students will also interact with physicians to better understand their perspectives. A

short report is required to be submitted as a course evaluation, which is aimed to encourage students to think innovatively about biomedical engineering.

BM6163 **1**
Molecular Technology
▷BM6023

This course is intended for practical handling experience for students for molecular biology techniques such as DNA isolation, RNA isolation, polymerase chain reaction, and transfection. They should also learn basic molecular biology methods and their interpretation with respect to cell culturing techniques. Prior knowledge of mammalian cell culture is mandatory for this course.

BM6243 **2**
Neuromechanics

Physics of the Musculoskeletal system; Anatomy of the musculoskeletal system; Quantitative Muscular physiology; Spinal circuits of movement; Cortical Control of movement; Modulation of movement; Measurement in NeuroMechanics; Introduction to the NEUROiD simulation platform; Simulation in neuromechanics

BM6246 **1**
Biodesign

Students will visit some hospitals and observe patient experiences and interactions with medical devices. They will also interact with physicians to better understand their perspectives. The curriculum aims at exposing the students to unmet needs in the clinic and introduce a systematic design process thinking to arrive a solution to the problems. The course will have detailed case studies and problem-based learning sessions on Biodesign. A short report is required to be submitted as a course evaluation, which is aimed to encourage students to think innovatively about biomedical engineering.

BM7080 **3**
Biophotonics
▷BM6090

This course is intended to introduce the concepts of biophotonics and interaction of light with biological matter. Biophotonics play a leading role in modern diagnostics, imaging and therapy. This course introduces principles of various biomedical optical imaging devices and techniques, lasers for biomedical applications, light-activated and light-guided therapy and biophotonic devices. This course is offered to newcomers and researchers interested in biophotonics and nanobiophotonics. This is offered as a core for Phd students in dept of Biotechnology/Biomedical Eng as well as an elective for Btech/Mtech students interested in this area. Topics include Biophotonics Topic introduction, Multidisciplinary nature, and role of photonics in biomedical engineering. Fundamentals of Light and Matter , Photobiology, Photodynamic Therapy

BM7106 **3**
Special Topics in Microscopy
▷BM6090

This course is an advanced research level course aimed at preparing freshers for a proper literature survey and appreciation of the research areas of advanced microscopy. The course consists of lectures, literature survey, group discussions and seminars on the advanced microscopic techniques. For this purpose, certain landmark journal papers in the area of microscopy have been identified, which would be discussed and presented by students in each lecture followed by discussions. Since, it is impossible to summarize the research literature with a few representative articles, students would be encouraged to collect all the related references and bring them up for discussions. The student contributions would be evaluated during each presentation and the question session every day and a minor project report on assigned topic. This is an advanced course offered for PhD students working in the area of biomedical imaging and microscopy. syllabus include the following topics: Fourier optics introduction, lens as a Fourier transformer, Fresnel Fraunhoffer Approximations: Phase contract technique, Fourier imaging principles (lectures): Coherent Optics: Interferometry, Interferometers applications, Basic ray optics, Wave Optics, E. M waves Maxwells Equations, Principles of holography, digital holography and digital holographic microscopy. Coherence imaging, Optical coherence tomography. (lectures)Optical microscopy techniques, Bright light, Phase contrast, Low coherence microscopy, Fluorescence microscope, Confocal microscopy, Nonlinear Multiphoton microscopy. (Lectures): Advanced microscopy techniques: Fluorescence correlation spectroscopy (FCS), Total internal reflection fluorescence (TIRF) microscopy, Fluorescence resonance energy transfer (FRET), Fluorescence recovery after photobleaching (FRAP), Fluorescence Lifetime Imaging Microscopy (FLIM), Two photon fluorescence microscopy (TPFM), Second harmonic generation microscopy (SHGM), Coherent anti-Stokes Raman scattering (CARS) microscopy, Near-field scanning optical microscopy (NSOM), Stimulated emission depletion microscopy (STED), Nonlinear structured illumination microscopy Super-localization: STORM/PALM/fPALM , Photoacoustic microscopy (PAM) (seminars/ class project)

BM7180 **3**
Modern Optics for Enginers and Physcists

Geometrical optics, Ray optics postulates, Wave optics and Maxwells equations, propagation of light, dual nature of light, Optical components. Scalar diffraction theory, Fresnel, Fraunhofer diffraction, diffraction from single, multiple slits, circular apertures. Fourier optics and applications, optical imaging system, point spread function and transfer function, Lens as a Fourier transformer, Concepts of Optical information processing: spatial filtering, Abbe Porter Experiment, Phase contrast, Optical correlators. Coherence, Interference of light, interferometers and applications, concepts of

holography, holographic recording and reconstruction, types of holograms. Wave propagation in anisotropic media, Polarization of light, Uniaxial crystals, polarizing components, waveplates. Liquid crystals Spatial light modulators and applications. Lasers Einstein's Equations, two-three four level systems, practical laser system examples.

29.3 Department of Biotechnology

BT4020 **1**
Essential Fatty Acids-biochemistry, Physiology and Clinical Significance

Course objective: The objective of this course is to make the students aware about how the Bioactive lipids play an important role in energy homeostasis, cell proliferation, metabolism, inflammatory homeostasis, and process regulation. Course content: Essential fatty acids (EFAs) Essential fatty acids (EFAs) and their metabolism, Metabolites formed from EFAs and their role in inflammation, Relationship between cytokines and eicosanoids, EFAs and free radicals and nitric oxide, EFAs and eicosanoids in chronic inflammation, Eicosanoids in cancer, Role of eicosanoids in the shift from acute inflammation to chronic inflammation, Immune check point inhibitors and eicosanoids and EFAs, Tumoricidal action of EFAS and other metabolite Reference: 1. DasUN. Clinical laborator tools to diagnose inflammation. Adv Clin Chemistry 2006; 41: 189-229. 2. Poorani R, Bhatt AN, Dwarakanath BS, Das UN. COX-2, aspirin and metabolism of arachidonic, eicosapentaenoic and docosahexaenoic acids and their physiological and clinical significance. Eur J Pharmacol 3. Das UN. Current and emerging strategies for the treatment and management of systemic lupus erythematosus based on molecular signatures of acute and chronic inflammation. J Inflammation Res 2010: 3: 143–170. 4. Das UN. Lipoxins, resolvins, protectins, maresins and nitrolipids: Connecting lipids, inflammation, and cardiovascular disease risk. Current Cardiovascular Risk Reports 2010; 4: 24–31. 5. Das UN. Lipoxins, resolvins, protectins, maresins and nitrolipids and their clinical implications with specific reference to cancer: Part I. Clin Lipidol 2013; 8: 437–463.

BT5010 **3**
Biochemistry

Course objective: This course aims to provide fundamental concepts of biochemistry, starting from simple building blocks to complex metabolism.
Course content: Basic principles: Biomolecules, Stereoisomers and life, thermodynamics of biochemical reactions; Structural biochemistry: Protein Structure, Protein Folding, Learning Pymol, Enzyme Catalysis, Enzyme Kinetics, Lipid structure and membrane assembly, Carbohydrate structure; Bioenergetics: Glycolysis, Glycolysis of red blood cells and liver, Bacterial Energetics, The citric acid cycle, Electron transport, ATP synthesis, Regulation of blood sugar; Tissue-specific metabolism: Liver metabolism, Muscle metabolism, Brain Metabolism; Synthesis and degradation of Biomolecules: Nucleic acid metabolism, Carbohydrate metabolism, Fatty acid metabolism, Protein metabolism.
Text Books: 1. Lehninger Principles of Biochemistry (WH Freeman, 7th Edition, 2017) by David L. Nelson and Michael M. Cox 2. Voet's Principles of Biochemistry (John Wiley and Sons, 5th Edition, 2018) by Donald Voet, Judith G. Voet, Charlotte W. Pratt

BT6020 **3**
Immunology

Course content: The learning outcome of this course is an overview of vertebrate immune system and detailed knowledge of the essential components of the immune system. Overview of contents Overview of Immunology; Innate and adaptive immunity; Antigen and antibody: Structure and function; Antigen-antibody interactions as tools for research; Generation of antibody diversity: Immunoglobulin genes; Presentation of antigen by major histocompatibility complex molecules, cytokines; complement; Effector mechanisms; T-cell development; B-cell development; AIDS and the immune system; Vaccines. Special topics on advances in immunology.
Text Book: ● Goldsby, Kindt, and Osborne. Kuby Immunology 6th ed. Freeman, 2007. ● Roitt's Essential Immunology. 12th Edition.Peter J. Delves,Seamus J. Martin, Dennis R. Burton,Ivan M. Roitt Reference book: ● David Male, Jonathan Brostoff, David Roth, Ivan Roitt, Immunology; Mosby Publisher, 7th ed. 2006 ● Recent articles

BT6023 **3**
Cell Technology

Course Objective: The course will give an overview of eukaryotic cell, describe the structure and functions of the cellular organelles, and review current research techniques used to post-graduate students.
Course Content: Cells and Organelles; Microscopy Techniques; Cell Membranes; Membrane Transport; Electrical Signaling; Signal Transduction; Extracellular Structures; Intracellular Compartments and Trafficking; Chromosomes and the Nucleus; Cell Cycle; Cytoskeleton; Cell Motility; Methods in mammalian Cell Culture; Transfection; Transient and stable Cell-line generation.
Text book: ● Molecular Cell Biology; Authors: Harvey Lodish, Arnold Berk, Chris A. Kaiser, Monty Krieger, Matthew P. Scott, Anthony Bretscher, Hidde Ploegh, Paul Matsudaira, 6th Edition 2008; W.H. Freeman and Company. ● Current Protocols in Cell

Biology; John Wiley and Sons, Inc. 2012. Reference: ● Molecular Biology of The Cell -by B. Alberts, 5th edition, Garland Science, New York 2010.

BT6033 **3**
Protein Technology

Course Objective: The course aims at providing required knowledge of advances in protein research for industrial and medical applications to post graduate students.
Course content: Over-view of Protein structure and function. Recombinant protein expression systems: E.coli, Pichia, Insect-cells, cell-free protein expression systems. Protein purification techniques: Ion-exchange chromatography; Gel-filtration; Affinity chromatography; FPLC; HPLC. Small and large scale purification; Protein characterization: Two-dimensional Gel electrophoresis; Mass spectrometry; Proteomics; Fluorescence Spectrometery; Circular Dichroism, Isothermal Titration Calorimetry. Protein folding-misfolding; Inclusion bodies; Mutant design and site-directed mutagenesis; Therapeutic proteins.
Text book: ● Introduction to Protein Structure; Carl brendon and John Tooze2nd edition, Garland Publishing; 1999. ● Molecular Biotechnology Bernard R. Glick, Jack J. Pasternak; 4th Edn; 2010. ● The protein protocol handbook; John M Walker, Humana press; 2009. Reference book: ● Introducing Proteomics; Josip Lovric Wiley press; 2011. ● Therapeutic Proteins: Methods and Protocols (Methods in Molecular Biology) C. Mark Smales David C. James Edn; Humana Press; 2005. ● Exploring proteins: Nick Price and Jacqueline Narin; Oxford University Press; 2009.

BT6035 **12**
Thesis

Research

BT6040 **1**
Industrial Lecture

The course is taught by the leaders of the Research and Development of Biotech indusry. In this course students learn latest trends in industrial biotech research directly from the scientists.

BT6043 **3**
Gene Technology

Course Objective: Gene technology course is designed to provide details of methods used in molecular biotechnology as well as insights into trends and techniques used in genomics. The course involves class room teaching of the principles and techniques, hands-on learning of the same in laboratory and presentation of selected articles from literature by students.
Course Content: Genetic manipulation: isolation, cloning, sequencing, annotation and mutagenesis of genes. Expression systems: plasmids and their features for heterologous expression of protein and RNA; in vitro and cellular expression systems. Genetic libraries: Genomic library, cDNA Library: generation and analysis. DNA sequencing: Principles of conventional, automated and high throughput sequencing. Microarrays and gene expression profiling. DNA microarray: design, fabrication, analysis. Genetically modified organisms: Generation, analysis and usage of transgenic organisms.
Text books: ● From genes to genomes: concepts and applications of DNA technology / Jeremy W. Dale, Malcolm von Schantz, and Nick Plant. 3rd Edition. Published by Chichester, West Sussex: John Wiley and Sons. 2011. ● Molecular biotechnology: principles and applications of recombinant DNA, 4th edition. / Bernard R. Glick and Jack J. Pasternak, Cheryl L. Patten. Published by Washington, DC: ASM Press, 2010 Reference books: ● Principles of Gene manipulation and Genomics, 7th edition/S. B. Primrose, Richard M. Twyman. Published by Blackwell, 2006. ● Molecular Cloning, a laboratory Manual, 3rd edition/ Joseph Sambrook and David W. Russell. Published by Cold Spring Harbor, N.Y.: Cold Spring Harbor Laboratory Press, 2001.

BT6045 **12**
Thesis

Research

BT6050 **2**
Circadian Clocks: Mechanisms and Functions

Course content: Introduction to biological oscillators, A brief history of circadian time keeping, Circadian clocks – the rhythms of life, Clock circuits in different organisms, Adaptive significance of rhythms, Molecular mechanisms of transcriptional and non-transcriptional circadian oscillations, Multidimensional regulation of the circadian rhythms, Master and peripheral clocks in mammalian systems, Metabolic oscillations, Timeseries analysis of rhythms - concepts and methods, Physiological functions and importance of time-keeping machinery, Circadian clocks and sleep, Circadian clocks in health and diseases, Human circadian disorders, Clock-infection biology, Chrononutrition- effects of diet on circadian rhythmicity, Chronomedicine, Modulation of daily rhythms for therapeutic benefit.

BT6053 **2**
Advanced Microscopy and Image Processing

Course content:Basics of fluorescence microscopy; microscope optics and design of a fluroescence microscope; fluorescent proteins, organic dyes and labelling strategies; illumination strategies (wide-field, confocal, TIRF/HILO, light-sheet, two-photon);

live-cell imaging; time-lapse imaging; FRET; FRAP; Immunofluorescence (IF); Immunocytochemistry (ICC); Immunohistochemistry (IHC); Fluorescence In-situ Hybridization (FISH); Super-Resolution Microscopy (Structured Illumination (SIM), Stimulated Emission Depletion (STED), Stochastic Optical Reconstruction (STORM); Single-Molecule Imaging; High Content Imaging; Spatial mapping of gene expression (RNAscope, MerFISH); Optical Tweezers and Traction Force Microscopy; Camera technologies for microscopy; digital image properties; intensity measurements and background subtraction; thresholding and image segmentation; colocalization; quantification and visualization of 3D images; deconvolution; 3D rendering and reconstruction; introduction to Fiji/Imagej; application of artificial intelligence/machine learning and virtual reality in image analysis. The practical component of this course includes computational image processing (using ImageJ/FIJI) and data analysis using various image processing software.

BT6060 **2**
Protein Misfolding in Neurodegenerative Diseases

Course contents: Protein folding and misfolding, Amyloidogenicity, Molecular biology of protein misfolding in : Alzheimer's disease, Parkinson's disease, Huntington's disease, Amyotrophic Lateral Sclerosis(ALS), Creutzfeldt Jacob's disease(Prion disease), and non-neuropathic systemic amyloid diseases. Mechanism of amyloid toxicity. Prion formation, transmission and pathogenesis. Role of Chaperones and other cellular factors in modulating amyloid formation and toxicity. Role of mitochondrial damage in pathogenesis of neurodegenerative diseases. Eukaryotic yeast cell models of neurodegenerative diseases. Therapeutics of neurodegenerative diseases.
Reference Books: 1. Prion Biology and Diseases, Stanley B. Prusiner Second Edition; Cold Spring harbour; 2004 2. Protein Misfolding Diseases: Current and Emerging Principles and Therapies. Marina Ramirez-Alvarado, Jeffery W. Kelly, Christopher M. Dobson; John Wiley and Sons inc. 2010. Review articles: 1. Huang Y., and Mucke L (2012) Alzheimer Mechanisms and Therapeutic Strategies. Cell, 148, 1204-1222. 2. Khurana V and Lindquist S. (2010) Modelling neurodegeneration in Saccharomyces cerevisiae: why cook with baker's yeast? Nat Rev Neurosci11: 436-449. 3. Rossi, S., Cozzolino, M. and Teresa Carri, M. (20160 Old versus new mechanisms in the pathogenesis of ALS. Brain Pathol.26, 276-286. 4. Selkoe DJ.,and Hardy J. (2016) The amyloid hypothesis of Alzheimer's disease at 25 years. EMBO Molecular Medicine Vol 8 (6), 595-608 5. Jahn, TR., Radford, S.E. (2008) Folding versus aggregation: Polypeptide conformations on competing pathways. Archives of Biochemistry and Biophysics 469, 100–117 6. Liebman SW, Chernoff YO (2012). Prions in yeast. Genetics. 191(4):1041-72. 7. Bates GP, Dorsey R, Gusella JF, Hayden MR, Kay C, Leavitt BR, Nance M, Ross CA, Scahill RI, Wetzel R, Wild EJ, Tabrizi SJ. (2015) Huntington disease. Nat Rev Dis Primers.23; 15005

BT6063 **1**
Animal Models in Medical Research

The learning outcome of this course is knowledge about use of animal models in medical research. This course has a hands on module. Overview of contents 1. Various animals as models and their advantages and disadvantages 2. Animal research in medicine: modelling heart damage, autoimmune diseases, tuberculosis, Parkinson's 3. Upcoming vertebrate animal model: zebrafish 4. Practical session using animal model zebrafish Textbooks 1. Animal models in cardiovascular research. David Gross, Springer 2009 2. The laboratory zebrafish. Claudia Harper and Christian Lawrence. CRC Press. Dec 2010. Reference literature 1. Animal models of human cardiovascular disease, heart failure and hypertrophy. Gerd Hasenfuss. Cardiovasc Res (1998) 39 (1):60-76. 2. Classic and New Animal Models of Parkinson's Disease. Javier Blesa, Sudarshan Phani, Vernice Jackson-Lewis,and Serge Przedborski. Journal of Biomedicine and Biotechnology. Volume 2012 (2012). 3. Animal Models in Autoimmune Diseases: Lessons Learned from Mouse Models for Sjögren's Syndrome. Byung Ha Lee,1 Adrienne E. Gauna,1 Kaleb M. Pauley,2 Yun-Jong Park,1 and Seunghee Cha. Clin Rev Allergy Immunol. 2012 Feb; 42(1): 35–44. 4. Various recent articles

BT6083 **2**
Programming for Biomacromolecular Data Analysis

Course objective: This course is designed to provide knowledge about the interdisciplinary approach to address biological problems. Course Content: Linux commands: ls, vim, emacs, grep, sed, awk etc., shell scripting: if condition, while loop etc. and their application in editing, organizing and transferring Protein Databank (PDB) files towards modeling and analyses of biomacromolecular structures. Python scripting for genomic/proteomic sequence analysis.
Text Books: • Computational Biology: Unix/Linux, Data Processing and Programming by Röbbe Wünschiers, 2004, Publisher: Springer. • A practical guide to Linux, Commands, Editors and Shell programming by Mark G Sobell, 2014, Pearson • Learning python (5th Edition) by Mark Lutz, O'Reilly Media, Inc. Reference Books: • Beginning Linux Programming by Neil Matthew, Stones Richard, 2004, Publisher: New Delhi Wiley Dreamtech India Pvt. Ltd.

BT6113 **2**

Course objective: The overall aim of this course is to provide an outline of the

Structural Bioinformatics

biomacromolecular structures that are the major therapeutic targets and various algorithms used for biomolecular structure prediction.
Course Content: Biomolecular Structure and Dynamics: Stereochemistry: configurational and conformational isomers - Internal parameters - Forces stabilizing biomolecular structures - Biomolecular structure visualization tools - Structure and dynamics of nucleic acids: architecture of nucleic acids – analyses of nucleic acids secondary structures - DNA origami - Modeling nucleic acids for biological applications using 3D-NuS - Sequence alignment: Pair-wise alignment method, Dynamic programming: Needleman-Wunsch method; Smith Waterman method - Multiple sequence alignment method - Scoring matrices: PAM and BLOSUM - Heuristic method: BLAST. Construction of phylogenetic tree - Introduction to protein structure prediction: homology modeling and threading.
Text Books: ● Martin Egli, Wolfram Saenger, Principles of Nucleic Acid Structure, Springer, 1983 ● David L. Nelson, Michael M. Cox, Lehninger Principles of Biochemistry, W. H. Freeman, 5th edition, 2008 ● David W Mount, Bioinformatics sequence and genome analysis, CBS publishers and Distributors, Second edition, 2004 Reference Books: G.E. Schulz and R.H. Schirmer, Principles of protein structure, Springer, 1979

BT6143 3
Gene Technology

Course Objective: Gene technology course is designed to provide details of methods used in molecular biotechnology as well as insights into trends and techniques used in genomics. The course involves class room teaching of the principles and techniques, hands-on learning of the same in laboratory and presentation of selected articles from literature by students.
Course Content: Genetic manipulation: isolation, cloning, sequencing, annotation and mutagenesis of genes. Expression systems: plasmids and their features for heterologous expression of protein and RNA; in vitro and cellular expression systems. Genetic libraries: Genomic library, cDNA Library: generation and analysis. DNA sequencing: Principles of conventional, automated and high throughput sequencing. Microarrays and gene expression profiling. DNA microarray: design, fabrication, analysis. Genetically modified organisms: Generation, analysis and usage of transgenic organisms.
Text books: ● From genes to genomes: concepts and applications of DNA technology / Jeremy W. Dale, Malcolm von Schantz, and Nick Plant. 3rd Edition. Published by Chichester, West Sussex: John Wiley and Sons. 2011. ● Molecular biotechnology: principles and applications of recombinant DNA, 4th edition. / Bernard R. Glick and Jack J. Pasternak, Cheryl L. Patten. Published by Washington, DC: ASM Press, 2010 Reference books: ● Principles of Gene manipulation and Genomics, 7th edition/S. B. Primrose, Richard M. Twyman. Published by Blackwell, 2006. ● Molecular Cloning, a laboratory Manual, 3rd edition/ Joseph Sambrook and David W. Russell. Published by Cold Spring Harbor, N.Y.: Cold Spring Harbor Laboratory Press, 2001.

BT6150 2
Molecular Basis of Cancer

Course objective: This course is designed to give molecular level understanding of cancer to post-graduate students.
Course Content: Etiology of cancer, oncogenes, Signaling pathways in cancer, Tumor suppressor genes, Cell cycle control and cancer, DNA Damage, and Cell Cycle Checkpoints, Immune system and cancer, Multistep process of carcinogenesis.
Textbooks: 1. The Biology of Cancer (3rd edition). Robert Weinberg; Garland Science; 2017 2. Molecular Biology of Cancer: Mechanisms, Targets, and Therapeutics (3rd edition); Lauren Pecorino, Oxford University Press; 2016

BT6180 1
Macromolecular Crystallography

Course objective: This course is designed to give insights on macromolecules crystallization and resolving their structure by X-ray crystallography.
Course content: Art of macromolecules crystallization: The course deals with the rational approaches and methods in protein-protein and protein-nucleic acids crystallization. X-ray Crystallography: Crystal symmetry and systems. X-ray diffraction, Structure factors and Phase problem in crystallography. Electron density equation and Phasing methods in crystallography. Model building and Refinement. Use of Ramachandran plots and other tools for structure validation. Graphics tools to visualize and analyze atomic structure of macromolecules. Case study for understanding biological phenomena with structures.
Text Book 1. Protein crystallography : T. L. Blundell, L. N. Johnson (1976), Academic Press 2. Outline of Crystallography for Biologists: D. Blow (2002), Oxford University Press Reference book 3. Biomolecular Crystallography: Principles, Practice, and Application to Structural Biology: B. Rupp (2009) 1st edition, Garland Science

BT6183 2
Molecular Biotechnology

Objective: The objective of this course is to provide fundamental concepts of the advances in the biotechnology field including methodologies, applications and the ethical issues involved.
Course content: Introduction to biomolecular organization. Recombinant DNA technology-methodologies and applications. Genetic methodologies and applications of bacterial and yeast cells in biotechnology. Application of biotechnology in small and large

scale production of biopharmaceuticals. Genetically modified plants and application of plant systems for production of medically important biomolecules. Biotechnology-based diagnostic and therapeutic strategies. Ethical issues in genetically modified plant and animal systems.
Reference Book: Molecular Biotechnology by Bernard R. Glick, and Jack J. Pasternak, 5th Edition, 2017.

BT6223 2
Pharmaceutical Biotechnology

Course objective: Deals with the principles of biotechnology are applied to the development of drugs.
Course contents: Introduction and history of biologics and biopharmaceuticals; Macromolecular structure relevance to biologics/biosimilars; Stereoisomers and drugs, Biotechnology in rational biodrug design; Role of Biotechnology in vaccine design: Virus like particles and protein nanocages; Synthesis and downstream processing of bioformulations; determining the product shelf life, stability, toxicity and immunogenicity and product analysis; Pharmacogenetics and chemical genetics in drug discovery; Effect of protein post translational modifications on protein formulations and methods/technology for their production in the laboratory.
Text books 1. Pharmaceutical biotechnology: concepts and applications, gary walsh, wiley publications, 2007 Biopharmaceuticals biochemistry and biotechnology, second edition, gary walsh, wiley publications, 2003

BT6303 2
Proteomics: Techniques and Applications

Course content: Introduction to proteomics, Transition from genomics to proteomics - prospects and challenges, Protein purification and separation technologies, Two-dimensional gel electrophoresis (2-DE), Difference in-gel electrophoresis (DIGE), Fundamentals of mass spectrometry, Soft ionization methods [Matrix assisted laser desorption/ionization-Time of Flight (MALDI-TOF), and Electro-spray ionisation (ESI)], Tandem Liquid Chromatography-Mass spectrometry (LC-MS/MS), Next-generation ultra-high resolution mass-spectrometry, Label-based (SILAC, iTRAQ, and TMT) and label-free (LFQ) quantitative proteomics, Applications of proteomics-studying disease pathogenesis, host-pathogen interactions, biomarker discovery, elucidating mechanism of drug actions, analysis of biomolecular interactions, analysis of post-translational modifications (phosphorylation and glycosylation), and study of biological rhythms and sleep. Practical component: Mass spectrometry data visualization, Database search and analysis of quantitative proteomics data (MASCOT and MaxQuant), Interpretation of MaxQuant analysis output files, Statistical analysis of MS-MS data.

BT6330 2
RNA Biology and Therapeutics

Objective: The course aims to bridge fundamental aspects with the cutting-edge new discoveries in the field of RNA Biology. Due to ongoing rapid advances in the field, the course will integrate classroom teaching with discussions and will rely heavily on discussing scientific papers critically.
Content: The course will cover metabolism and functions of RNA including synthesis, structure, processing, function and degradation of mRNAs, miRNAs, snoRNAs, rRNAs, tRNAs and long noncoding RNAs. A significant portion of the course will focus on the recent advances in RNA biology field including RNA interference, the role of RNAs in human diseases and RNA-based therapeutics. The course will also cover the role of long noncoding RNAs and RNA modifications in regulating gene expression.
Reference Books: 1. Molecular Biology of Cell, Bruce Alberts (2014) 6 th edition. Garland Science 2. RNA Worlds: From Life's Origins to Diversity in Gene Regulation, by John F. Atkins (Editor), Raymond F. Gesteland (Editor), Thomas R. Cech (Editor) 1 st edition.

BT6390 3
Advanced Cell Biology

Objective: The course is designed to help learners develop a broad understanding of the fundamental and advanced concepts of cell biology from a human-centred perspective. A major emphasis of the course will be on the recent advances in cell biology and its importance to human health and disease.
Content: Introduction to cell biology, Biogenesis and functions of plasma membrane, Cytoskeletal elements, Cell Division: Mitosis and Meiosis, Mitochondrial biogenesis and function, Protein import, Biosynthesis of ER and Golgi, Trans-Golgi Network, Vesicular trafficking, Lysosome biogenesis and pathophysiology, Nucleus- structure and biogenesis of nuclear envelope, Nuclear import and export, Cell cycle and Cell death, Regulation of signalling pathways, Physiological methods to characterize and understand cellular processes.
Suggested reading: 1. Molecular Biology of Cell, Bruce Alberts (2014) 6 th edition. Garland Science 2. Cell Biology, Pollard TD, Earnshaw WC, Schwartz JL. (2016) 3rd Edition Elsevier Publishing Co.

BT6670 2
Stem Cell Biology and Regenerative Medicine

Objective: The course aims at providing students a solid foundation in stem cell biology and human diseases connected to stem cell biology. The course will also cover the stem cell therapies that are currently being used in clinics and discuss the future treatments

that lie on the horizon. Due to the ongoing advances in the field, students will be expected to read and present seminal research literature on stem cell biology.
Contents: The course will include basics of stem cell biology, induced pluripotent stem (iPS) cells, biochemistry of pluripotency, stem cell epigenetics, embryonic and adult stem cells, tumor stem cells, cloning and stem cell reprogramming, stem cell research methodologies and clinical applications of stem cell research. The course will also cover ethical and legal issues raised by embryonic stem cell work.
Suggested reading: 1. Lanza R et al. Essentials of Stem Cell Biology. Elsevier Inc. 2. Marshak DN et al. Stem Cell Biology. Cold Spring Harbor Laboratory Press 3. Rex Turner. Stem Cells: Biology and Diseases

BT7280 2
Pharmacology and Physiology of Receptors

The learning outcome of this course is detailed knowledge about membrane receptors in biological systems and how they have been exploited in the biological and biomedical research.
Overview of contents ● Receptor classification ● Fundamental principles of pharmacology, Pharmacodynamics, Pharmacokinetics, Metabolism and toxicity ● Techniques used for receptor studies (ranging from old to advanced) ● Protein targeting and trafficking in mammalian cells, Imaging of receptor trafficking, ● Voltage gated ion channel superfamily, Ion channels as drug targets, indirect and direct assay technologies available like patch clamp techniques, SICM etc , ● Channelopathies, ● Heart failure overview and Principles of cardiovascular pharmacology, Beta adrenergic concept and paradox in heart failure.
Textbooks 1.Voltage gated ion channels as drug targets-David J. Triggle,Murali Gopalakrishnan,David Rampe, Wei Zheng- John Wiley and Sons-2006. 2.Principles of Pharmacology: The Pathophysiologic Basis of Drug Therapy-David E. Golan, Armen H. Tashjian, Ehrin J. Armstrong- Lippincott Williams and Wilkins-2011. Reference material 3. Recent articles in various journals. 4.Signal Transduction: Principles, Pathways, and Processes. Lewis C. Cantley, Tony Hunter, Richard Sever, Jeremy Thorner. Cold Spring Harbor Laboratory Pr (31 May 2014) 5.Receptors: Models for Binding, Trafficking, and Signaling: Models for Binding, Trafficking, and Signaling.Douglas A. Lauffenburger and Jennifer Linderman. Oxford University Press (5 August 1993)

29.4 Department of Climate Change

CC5003 1
Field Visit

None

CC5010 1
Earth's Evolution and Paleo Climate

Solar system and earth's evolution; Solar radiation; Precambrian glaciations; Late paleozoic ice ages; Cenozoic cooling; Northern hemisphere glaciation; Pleistocene ice ages; Last glacial period; The Holocene; Earth's atmosphere; Composition of the modern atmosphere, Atmosphere layers, Horizontal and vertical mixing, Pressure, Temperature, Precipitation, Clouds, Aerosols, Hydrological cycle, Carbon cycle, Tropospheric ozone, Ozone Depleting Substances, Ozone-protocols and policies, Photochemical smog, Green House System (GHS)

CC5020 1
Atmosphere

None

CC5030 1
Climate Dynamics - 1

None

CC5040 2
Climate Dynamics - 2

None

CC5050 2
Waste Management and Climate Change

Contents: Basics of wastewater treatment : unit operations and processes, material balance, kinetics of biodegradation of organic wastes. Estimation of GHG Emissions from Wastewater Treatment Plants (Biological Processes). Basics of municipal solid waste management. Estimation of GHG Emissions from Solid Waste Management Facilities (Landfill) References: Environmental Biotechnology: Principles and Applications by Rittman and McCarty (McGraw-Hill). Wastewater Engineering: Treatment and Reuse by Metcalf and Eddy (McGraw-Hill). Integrated Solid Waste Management: Engineering Principles and Management Issues by George Tchobanoglous (McGraw-Hill). Course Objective: Understand the basics of wastewater treatment systems and solid waste

		management systems. Estimation of greenhouse gas emissions from the biological processes involved in the above-mentioned systems. Justification: Direct emission from the waste management sector is only about 3% of the total global emissions. However, proper waste management practice can positively affect other sectors (industrial, agricultural, mining, transportation etc.) resulting in lesser emissions and more effective utilization of non-renewable resources.
CC5060 Entrepreneurship Opportunities in Climate Change	**1**	None
CC5070 Space Weather Impacts On Climate Climate Change	**1**	None
CC5080 Climate Change Sciences	**1**	None
CC5090 Climate Change Impacts and Implications - Engineering, Technology, Society and Health	**1**	None
CC5100 Climate Monitoring, Modeling and Variability	**2**	None
CC5110 Earth's Climate and Atmospheric Sciences	**3**	Solar system and earth's evolution; Solar radiation; Precambrian glaciations; Late paleozoic ice ages; Cenozoic cooling; Northern hemisphere glaciation; Pleistocene ice ages; Last glacial period; The Holocene; Earth's atmosphere; Composition of the modern atmosphere, Atmosphere layers, Horizontal and vertical mixing, Pressure, Temperature, Precipitation, Clouds, Aerosols, Hydrological cycle, Carbon cycle, Tropospheric ozone, Ozone Depleting Substances, Ozone-protocols and policies, Photochemical smog, Green House System(GHS).
CC5120 Climate Monitoring and Variability	**3**	Elements of the climate system, Energy balance in the climate system, General Circulations in the Atmosphere and Oceans, Natural variability, Teleconnection patterns, Climate Sensitivity feedback, Monitoring climate from the ground and from space
CC5130 Atmospheric Electricity	**2**	Fair weather electricity, Global electric circuit (GEC), Thunderstorms and Lightning discharge, Earth-Ionosphere waveguide, Surface and satellite-based observations, Seasonal variations and cosmic ray modulation, Changes in global electric circuit and Paleoclimate, Impact of Climate change on GEC.
CC5140 Climate Governance	**2**	The course offers an advanced introduction for the unique challenges anthropogenic climate change presents for policy and governmental actors. It introduces students to key international conventions to address climate governance, the work of the IPCC in particular, and some of the unique challenges and opportunities for India in this context.
CC5150 Cutting Carbon From Transportation	**2**	Policies, Carbon Budget, Carbon Burden, Vehicular Carbon Emissions, Reductions of Carbon Emission
CC5160 Industry Lecture	**1**	None
CC5180 Statistical Methods in Climate Sciences	**2**	None
CC5190	**1**	None

Climate Change Mitigation

CC5200 Rs, GIS and Climate Change	**3**	None
CC5210 Climate Change and Design Innovation	**1**	Climate change is the fundamental design problem of our time. The threat climate change poses is existential, and design of ”things” are hugely complicit in this global phenomenon. A responsible design approach with innovation for achieving efficiency in manufacturing, processes and system is the need of hour. The course intends to deliver on systemic design climate innovation steps for designing and implementing the process, drawing on various foresight and strategic planning approaches.
CC5220 Climate Mitigation	**2**	Global temperature variation – greenhouse gases and global energy balance, global temperature model, isotopes and temperature, recent climate change scenarios. Climate change mitigation – low emission techniques, carbon capture, storage, sequestration and conversion techniques, Environmental aspects - terrestrial carbon sequestration, ecological sequestration, case studies. Climate change adaptation – categories and approaches for climate change adaptation, adaptation to adaptive capacity, vulnerability reduction, case studies. Challenges and opportunities for climate change adaptation and mitigation. References Joel B Smith, Richard J T Klein, Saleemul Huq , Climate Change, Adaptive Capacity And Development, Imperial College Press Wei-Yin Chen Toshio Suzuki Maximilian Lackner, Handbook of Climate Change Mitigation and Adaptation, Springer reference. IPCC assessment reports on climate change mitigation and adaptation
CC5230 Renewable Energy Technology	**2**	Introduction to Renewable Energy Types. Solar, Wind, Hydro, Geothermal, Biomass Energy. Energy Storage. Fuel Cells.
CC5240 Data Modeling in Atmospheric Sciences	**1**	Statistical Models - Statistical Forecasting - Time Series - Machine learning models - ANN - RNN - Demonstration on applications from atmospheric sciences
CC5310 United Nations Sustainable Development Goals (un Sdgs)	**2**	UN SDGs are a roadmap for bringing a paradigm shift in prevalent economic model. The course tries to establish the underlying understanding behind this UN led initiative and value of sustainable development, how it touches our lives and the efforts required to achieve them. The course intends to elaborate on the evolution of scope under dynamic concept of sustainability and UN SDGs led cohesive societal framework to evolve a resilient community across the world. The course elaborates on seventeen UN SDGs, their systemic perspectives mapping and need for tomorrow. It talks about interconnectedness of planet, products, processes wrt SDGs. It touches the Paris agreement on climate-change, India’s participation in it and commitment towards SDGs. It also shows a glimpse of innovation led design processes to undertake challenges in its path.
CC5513 Human Dimensions of Climate Change	**1**	This course engages with climate as lived experience. It asks how people are understanding and experiencing climate change in their everyday lives, and how they are adapting to the implications that climate change has for them. The course introduces students to basic orienting concepts and research methodologies in the anthropology and sociology of climate change. Students will also get an opportunity to apply these concepts and methods by undertaking a brief collective research project that engages with everyday manifestations of otherwise abstract ideas such as climate change.
CC5520 Mobilities, Cities and Environment	**1**	None
CC5533 Advanced Computing	**1**	Serial programming: Introduction to Interpreters and Compilers; Recap of input and output operations, decision control structure, loop control structures, arrays, strings, functions, file operations in a low-level programming language (C/Fortran/C++); Introduction to scripting environments (Python/Matlab/shell). Basics of scientific computing: root finding, linear system solver, differentiation and integration; Parallel programming: Shared memory (OpenMP) and Distributed memory (MPI) parallelism: basics of theory and application to scientific computing.
CC6005 MTech Thesis Stage-i	**2**	None

CC6015 MTech Thesis Stage-ii	**12**	None
CC6025 MTech Thesis Stage-iii	**10**	None
CC6080 High Performance Computing in Weather Research and Forecast/gcm	**1**	Introduction to Parallel Programming; Task/data-based parallelism; shared/distributed memory systems; Weak and strong scaling; Measures of parallel performance. Parallelizing common numerical algorithms in shared memory systems using OpenMP and distributed memory systems using MPI; Running idealized simulations using WRF or GCMs.
CC6210 Climate Modeling	**2**	Historical background of atmospheric and ocean models; Primitive equations and their simplification; Coupled climate models; Fundamentals of the Global Climate Models and regional models; Parameterization of physical processes in the atmosphere; Numerical representation of atmosphere and ocean processes; GCMs' and regional models' simulations; Coupled Model Intercomparison Project (CMIP); Practical climate modeling.
CC6901 MTech Thesis Stage 1 (2020 Batch)	**12**	None
CC6902 MTech Thesis Stage 2 (2020 Batch)	**12**	None

29.5 Department of Civil Engineering

CE5110 Physico-chemical Processes	**3**	Chemistry of natural waters-redox chemistry, acid-base chemistry, reactions and energetics. Water and Wastewater quality; water purification in natural systems, Collection and Distribution system of water and wastewater – design and construction, screening, coagulation and flocculation, sedimentation, filtration ion exchange and adsorption, water stabilization, disinfection, aeration and gas transfer, Membrane processes: Reverse osmosis, ultrafiltration, electrodialysis, desalination, emerging contaminants
CE5120 Air Pollution and Control	**3**	Introduction, Atmosphere and its characteristics, sources and effects of air pollution, meteorological aspects of air pollutant dispersion, air pollution sampling and measurement, air pollution control methods and equipment, control of particulate and gaseous pollutants, atmospheric chemistry – stratospheric chemistry, chemistry of ground-level air pollution, indoor air pollution.
CE5130 Environmental Impact Assessment and Sustainability	**3**	Principles of EIA, baseline studies, methodologies in EIA, uncertainties in EIA, impact identification, public participation in EIA, prediction and assessment of impact on environment, monitoring and auditing of impacts, reviewing EIA, case studies. Overview and need of sustainable development - SDGs, impact assessment as a tool for sustainable development - indicators of sustainable development, Energy and environmental problems, water-energy-food nexus, mass balance and the footprint concept, waste management and material life cycles (3R concepts), ecological design, circular economy concepts, challenges and opportunities for sustainable development
CE5210 Bio-chemical Processes in Water and Wastewater Engineering	**3**	Basics of microbiology, stoichiometry and bacterial energetic, microbial kinetics, wastewater and water treatment microbiology. Material balance, flow models and reactors; enzyme kinetics; aerobic suspended growth processes, aerobic attached growth processes, anaerobic processes; lagoons and natural treatment systems; nutrient removal; effluent reuse/disposal; sludge processing and application of bio-solids; drinking water treatment using biological processes
CE5211 Advanced Environmental Lab	**2**	Full introduction to sophisticated lab equipment; Fundamentals behind measurements; Clean practices; Quality assurance and quality control; Students perform experiments independently on each instrument under faculty supervision.
CE5220	**2**	Introduction-Integrated solid waste management, municipal solid waste characteristics

Solid Waste Management

and quantities, refuse collection system, refuse processing, material separation, energy recovery, biochemical processes. Landfill-planning, design, and operation. Special wastes- batteries, computer, and other electronic wastes.

CE5230 3
Industrial and Hazardous Waste Management

Types of industries and industrial waste characteristics; management strategies for pollution prevention and waste minimization; waste water treatability assessment; treatment of industrial wastewater-equalization, neutralization, solids separation and handling, removal of FOG, removal of organic and inorganic constituents; process instrumentation and control. Principles of hazardous waste management, identification of hazardous waste, policy and regulatory requirement, treatment and disposal, hazardous waste site clean-up technologies.

CE5240 3
Environmental Chemistry and Microbiology

Chemistry of natural waters - redox chemistry, acid-base chemistry, water quality parameters, pollution and purification of water, emerging contaminants. Atmospheric chemistry - stratospheric chemistry, chemistry of ground level air pollution. Soil chemistry - solution-solid phase equilibrium, sorption, ion-exchange processes; acidity, salinity, and sodicity of soil. Instrumental techniques in environmental chemical analysis. Basics of microbiology, stoichiometry and bacterial energetic, microbial kinetics, wastewater and water treatment microbiology.

CE5300 3
Advanced Foundation Engineering

Limit state design and working stress design; ultimate limit state; tolerable foundation movement; limit bearing capacity; bearing capacity of footings resting on saturated clay and sand; bearing capacity failure modes- general shear, local shear and punching shear; foundations subjected to eccentric loading; pile foundations: types and their installation; axial pile capacity (from fundamental soil variables, CPT and SPT results); axial deformation of piles; laterally loaded piles; vertically loaded pile groups; piled rafts; laterally loaded pile groups

CE5302 3
Design Studio

Stability of Slopes-Slope stability problem primarily to show how to utilize the entry and exit method and Grid and Radius slip surface to search for the critical slip surface, Improvement of slope stability using Anchors, Geosynthetic Reinforcement using SLOPE/W. Retaining walls- Analyzing the stability of the gravity retaining wall using fully specified slip surfaces using SLOPE/W, Design of Reinforced Soil Retaining walls using MSEW (following design guidelines of AASHTO and FHWA-NHI-00-043). Design of Embankment and Dams-Drawdown pore-water pressures of the embankment with a SEEP/W transient analysis and rapid drawdown of an embankment with SLOPE/W using the effective stress approach, Computation of Settlements and stresses beneath the loaded regions using PLAXIS software package. Earth retention systems- Computation of Consolidation settlements of soft soils due to Embankments and demonstration of consolidation settlement control techniques using PLAXIS 2D software, Design of earth retention systems: Braced excavations and sheet pile walls using PLAXIS 3D software.

CE5310 3
Advanced Soil Mechanics

Stresses and strains in soils; dilatancy angle; Mohr's circle of stress and strain; zero-extension line; stress paths (p'-q' space, s-t space); failure theories- Tresca criterion, Mohr-Coulomb criterion; Caquot's principle; slip surface; stress-strain-volume change curves; sources of shear strength; critical state friction angle; factors affecting drained shear strength; Bolton's correlation for friction angle; undrained shear strength; small-strain stiffness; drained and undrained shear strength of clays; Hvorslev's cohesion and friction; critical-state, residual, and design strengths.

CE5320 1
Introduction To Railway Engineering

Introduction; Structure of railway track; Ballasted and Slab tracks; Track gauges; Curves and gradients; Rail fastening; Joints; Switches and crossings; Rolling stock; Axle loads; Coning of wheels; Wheel-rail interface; High-speed tracks; Defects in track; Noise and vibration

CE5323 3
Experimental Soil Mechanics

Fundamentals of experimental studies of soil behavior, soil properties and their laboratory test methods which include consolidation, direct shear, static triaxial, cyclic triaxial, resonant column, bender elements and other advanced geotechnical laboratory tests, instrumentation and measurement techniques.

CE5330 3
Soil Dynamics

Introduction -fundamentals of vibration; single degree of freedom systems; free and forced vibrations; damping- elastic stress waves in a bar; equation of motion in an elastic medium; stress waves in elastic half-space; laboratory tests to determine dynamic soil properties; field test measurements; dynamic behavior of foundations, ultimate dynamic bearing capacity, seismic bearing capacity and settlement in granular soil-dynamic behavior of retaining walls; liquefaction of soils.

CE5340 3
Ground Modification Techniques

Introduction-Mechanical modifications, compaction methods, stone columns, blasting-Hydraulic methods, sand drains, wick drains-Chemical methods, shallow and deep soil mixing, lime/cement stabilization-Thermal modifications, freezing, thawing,

	Vitrification and-Reinforcement methods, geosynthetic reinforcement
CE5350 3 Railway Geotechnics	Introduction to Railway Engineering; Railway superstructure; Track substructure: Ballast, Sub-ballast, Subgrade, and Embankment Fill; Railway loading: Static, Cyclic and Dynamic loads; Load transfer mechanisms in track foundations; Analytical models for track and subgrade; Ballasted railway track design; Slab track foundations; Track transitions and design principles; Railway embankment slopes: stability analysis and stabilization; Water effects on track substructure; Track drainage design; Geotechnical railway site characterization; Track inspection and maintenance; Geosynthetic applications in railroads
CE5352 3 Design Of Earth Structures	Limit equilibrium methods of slope stability; slope stability for analyses for rapid drawdown; design charts for slope stability; design of embankments; seepage principles; Darcy's law; flow nets; seepage forces and uplift; seepage in earth dams; at-rest earth pressure; Rankine's and Coulomb's active and passive earth pressures; retaining wall design; reinforced retaining walls; gabion retaining walls; cantilever and anchored sheet piles; open cuts; trenching; braced excavations; excavation support; nailing; anchoring; basal heave
CE5360 3 Geotechnical Earthquake Engineering	Introduction-seismology and earthquakes; Strong ground motion; Seismic hazard analysis; Dynamic soil properties; Ground response analysis; Liquefaction of soils.
CE5370 3 Soil-structure Interaction	Introduction, Contact Pressure, Modeling soil structure interaction for rational design of foundations, Brief Review of the Foundation Models, Elastic half-space method: Closed form solutions, Soil – structure interaction equations, Infinite Beam on Elastic Foundation, Finite Beams on Elastic Foundations, Solution using Method of Initial Parameters (MIP) for General loads, Solution using Method of Undetermined Parameters, Solution using Finite Difference Method (FDM), Analysis of Rectangular and circular plates on elastic foundations by Navier's and Levy's Solutions, Design of pile foundations and Laterally loaded piles in elastic media.
CE5390 3 Pavement Geotechnics	Introduction: History of pavements and road construction; Pavement materials: Material properties, laboratory tests (modulus, stability, fatigue), effect of moisture, temperature and age; Drainage Issues: Concepts, drainage design, effects of drainage on pavement performance; Pavement design and construction: Mechanistic pavement design aspects, Construction aspects, quality control and quality assessment (QA/QC) studies, field instrumentation and performance monitoring.
CE5392 3 Designing With Geosynthetics	Geosynthetics and Reinforced Soil Structures: Types and functions; Materials and manufacturing processes; Testing and evaluations; Principles of soil reinforcement; Design and construction of geosynthetic reinforced soil retaining structures – walls and slopes; Codal provisions; Bearing capacity improvement; embankments on soft soils; Indian experiences; Geosynthetics in Pavements: Geosynthetics in roads and railways; separations, drainage and filtering in road pavements and railway tracks; overlay design and construction; AASHTO and other relevant guidelines; french drains; Geosynthetics in Environmental Control: Liners for ponds and canals; covers and liners for landfills – material aspects and stability considerations; Landslides – occurrences and methods of mitigation; Erosion – causes and techniques for control.
CE5410 3 In Situ Testing	Planning of subsurface exploration, methods, sampling, samplers, in-situ tests, bore log. SPT and CPT testing and its correlations with soil properties. Plate load testing and interpretation. Vane shear testing. Pressure meter testing. Dilatometer Testing. Seismic survey. GPR and ERT surveys. In situ instrumentation of geostructures.
CE6002 2 Design Studio	Planning, Analysis and Design of structures with specific applications in Structural or Geotechnical Engineering. Structural Engineering applications include Multi storied buildings, Bridges, Towers, Storage structures. Geotechnical aspects in foundation design of spread footings, combined footings and pile foundations, design of retaining walls and slopes. Special emphasis on Earthquake resistant design. Design, detailing and preparation of drawings. Use of software for analysis and design.
CE6006 0 Seminar	None
CE6007 0 Seminar In EWRE	None

CE6011 **2**
Computer Methods In Civil Engineering

Introduction to computer programming, Matrix operations, Eigenvalues and Eigenvectors in matrices.
Solution to linear, non-linear, and ordinary differential equations, Application of finite differences to partial differential equations, Principles of curve fitting and optimization, Development and application of computer programming to case studies derived from Civil engineering

CE6110 **3**
Advanced Structural Mechanics

Fundamentals of elasticity, Unsymmetrical bending, Shear center, Torsion, Thin walled sections, Beam on elastic foundation, Fundamentals of buckling, Stress concentrations, thin-wall circular cylinders; Force and displacement method of analysis, computer implementation, static condensation and sub-structuring.

CE6111 **1.5**
Structures Lab

Strain gauges, strain and force measuring devices, Principles of non-destructive testing - basics of wave propagation and stress wave propagation techniques. Optical techniques for displacement and strain measurements, application of strain gauges and data acquisition system, Principles of closed-loop testing Closed-loop testing of concrete in compression and flexure, Load testing of Reinforced Concrete beams, Measurements using stress-wave based techniques on concrete and steel structures, Demonstration of optical techniques for discs, stress concentration and deep beams.

CE6120 **3**
Applied Elasticity And Plasticity

Tensor Algebra, Analysis of Stress, Analysis of strain, Stress-strain relations, 2-D problems in elasticity, Axisymmetric stress analysis, Plastic behavior of materials, Yield/Failure theories, Plastic stress-strain relations.

CE6130 **3**
Finite Element Analysis

Introduction, Mathematical preliminaries- Linear function spaces, operators and functionals. Continuity and differentiability. Inner products, norms and completeness. Background on variational calculus. Galerkin methods, Collocation methods, Least-squares methods. Variational methods of approximation- Rayleigh-Ritz method, variational theorems. Compatibility and completeness of admissible spaces. Basic element shapes in one, two and three dimensions. Polynomial shape functions. Area coordinates. The concept of isoparametric mapping. Computer implementation. Application to elliptic parabolic and hyperbolic differential equations.

CE6131 **1.5**
Finite Element Lab

Introduction to ANSYS/ABAQUS. Structural and stress analysis using ANSYS/ ABAQUS- linear static, 1D, 2D, and 3D. Intermediate tutorials on dynamic analysis and nonlinearities. Advanced tutorials on sub structuring, optimization, multi material systems, and user prescribed functions. Post processing tutorials. Introduction to programming the Finite element methods using MATLAB.

CE6140 **3**
Structural Dynamics

Free and forced dynamic response of Single and multi-degree-of-freedom systems; Numerical Evaluation of Dynamic Response; Modal Analysis; Fundamentals of Earthquake Engineering; Concepts of response spectrum, Earthquake Response of Linear Systems; Structural dynamics and Building codes.

CE6150 **3**
Structural Stability

Stability - General Principles, Equilibrium Analysis of Stability, Beam Columns; Stability Analysis of frames by Equilibrium Analysis; Dynamic Analysis of Stability; Energy Methods: General Principles, Variational Analysis, Ritz and Galerkin Methods; Beam on Elastic Foundation; Lateral Torsional Buckling; Design Implications

CE6160 **3**
Theory Of Plates And Shells

Introduction- Mathematical preliminaries, energy principles and variational methods, Classical theory of plates, Analysis of circular and rectangular plates, Bending, Buckling and Free vibration analysis of plates. Shear deformation theories- First order and third order plate theories. Theory and analysis of shells, thin cylindrical and circular shells, Free vibration and buckling analysis of shells. Introduction to composite plates- Classical laminate plate theory. Finite element analysis of plates, Nonlinear finite element models.

CE6170 **1**
Mathematical Methods In Civil Engineering

Stability - General Principles, Equilibrium Analysis of Stability, Beam Columns; Stability Analysis of frames by Equilibrium Analysis; Dynamic Analysis of Stability; Energy Methods: General Principles, Variational Analysis, Ritz and Galerkin Methods; Beam on Elastic Foundation; Lateral Torsional Buckling; Design Implications

CE6200 **3**
Condition Assessment And Strengthening

Damage mechanisms in reinforced concrete and steel structures, specifically, cracking (both load induced and environmentally assisted), corrosion of steel, Fire damage in concrete and steel, Sulfate-attack and Alkali-silica reaction in concrete structures; Laboratory and field techniques for detecting the various damage mechanisms and the theoretical background behind different techniques; Basics of wave propagation and review of non-destructive test techniques; Estimation of load carrying capacity of structural members with damage; Repair and Rehabilitation strategies used in the field to repair existing damage and rehabilitate and strengthen structures.

CE6212 Advanced Reinforced Concrete	**3**	Mechanical properties of concrete and steel, Behavior of concrete under uniaxial and multiaxial states of stress; effect of creep of concrete, Basic Design philosophies, Probabilistic load theory, ultimate strength design methodology, comparison of working stress and ultimate load method; Moment-curvature and load-deflection relationships. Behavior and design of columns subjected to biaxial bending, Analysis and design of slender columns - under sway and non-sway conditions, Behavior and design of reinforced concrete structures for combined shear and torsion, Design of flat slabs and two way slabs, Design of special reinforced concrete structures - Deep beams and corbels.
CE6222 Prestressed Concrete Design	**3**	Introduction to concept of prestressing, types of prestressing, systems and devices, review of short and long-term behavior of concrete and prestressing steel, losses in prestress., Stress analysis of flexural members, flexural and shear design of statically determinate beams, analysis and design for shear and torsion, codal provisions, Anchorage zone stresses for post-tensioned members; design of anchorage zone, Analysis and design of statically indeterminate structures - continuous beams and frames, determination of cable profile, concepts of linear transformation and concordancy. Composite construction with precast, prestressed beams and cast in-situ reinforced concrete slab; Analysis and design of post-tensioned slabs.
CE6232 Advanced Steel Design	**3**	Review of Beam Design, Plastic Design of Beams, Plate Girders (Built-Up Sections), Steel-Concrete Composite Beams, Review of Column and Tension Members, Review of Basic Welded and Bolted Connections, Bracing and Connections. Design of Bunkers and silos
CE6500 Engineering Hydrology And Hydrologic Systems	**3**	Governing equations for Hydrologic processes; Occurrence, distribution, measurement, analysis, and interpretation of various components of hydrologic system (includes precipitation, abstractions from precipitation, run-off, stream flow, groundwater); Hydrologic analysis (including distributed and lumped systems); Hydrologic statistics; Analysis of extreme events.
CE6501 Applied Computational Laboratory	**3**	Summary measures; Graphical data analysis; Probability; Probability distributions; Uncertainty Description; Hypothesis tests; Correlation; Linear regression; Introduction to time series modeling, principal component analysis and artificial neural network; Hands on R.
CE6510 Open Channel Hydraulics and Sediment Transport	**3**	Conservation of mass, momentum and energy; critical flow; channel transitions; uniform flow; compound channels; gradually varied flow; spatially varied flow; rapidly varied flow; wave propagation and surge; boundary layer theory; flow in curved channels; hydrodynamic drag and lift; physical properties of sediment; sediment mixture; terminal fall velocity; sediment threshold; stable channel design; bedload transport; suspended load transport; total load transport
CE6511 Hydraulic And Hydrologic Simulation Lab	**2**	Working with open source hydraulic and hydrologic softwares. Hydrologic simulation with SWAT, Groundwater simulation using MODFLOW (flow and transport modeling), Design of water distribution system using EPANET, Flood simulation and inundation mapping using HEC HMS
CE6520 Irrigation And Watershed Management	**3**	Sustainable irrigation strategies, soil-water-crop interactions, methods for estimation and partitioning of evapotranspiration, eddy covariance principles, water use efficiency at plant, ecosystem, and regional scales, modeling crop water and yield requirements, case studies, carbon-water interactions in crop lands, measures for improving crop water efficiency, discussion of research papers in agricultural water management
CE6530 Groundwater Modeling	**3**	Governing equations for groundwater flow; Boundary conditions; Estimation of source and sink components; Model execution and calibration process; Special needs for transient simulations; Introduction to particle tracking of groundwater flow; Groundwater recharge estimation: techniques
CE6540 Contaminant Hydrology And Remediation	**3**	Introduction, types of contaminants, point and non-point sources, and basics of contaminant transport phenomena in natural systems such as diffusion, dispersion, advection, adsorption, sources and sinks. Governing equations for flow and transport in surface and subsurface waters, physical, chemical and biological process models, simplified models for lakes, streams, and estuaries. Numerical models: FDM and Finite volume techniques, explicit vs. implicit methods, numerical errors, and stability. Introduction to remediation technologies, principles of remediation, site characterization, soil vapour extraction, Soil Flushing, Stabilization/Solidification, electrokinetic remediation, thermal desorption, vitrification, bioremediation, Phytoremediation, pump and treat system, Solvent Vapor Extraction, Air, Funnel and Gate Systems, permeable treatment walls, natural attenuation, remedy selection and risk assessment.
CE6610	**3**	None

Remote Sensing and GIS Applications To Civil Engineering

CE6620 **3**
Water Resources Systems Planning And Management
Books: Industrial Water Pollution Control, Eckenfelder

CE6630 **3**
Water Quality Modeling
Water quality standards, Reaction kinetics, Mathematical modeling of completely and incompletely mixed systems, Steady state and transient solutions, numerical methods, Modeling water quality in rivers, lakes, estuaries and groundwater systems, modeling dissolved oxygen and pathogen transport

CE6640 **3**
Multiphase Flow in Porous Media
REV concept, Capillarity, Governing equations of multiphase flow, numerical schemes, Buckley-Leverett theory, 1D and 2D simulation of two-phase flow and transport Course objective: To learn the fundamental concepts of multiphase flow and transport in porous media

CE6650 **3**
Hydraulic Transients
Design of pipelines, pumps, and valves, Governing equations for transient flows, rigid and elastic theories, pressure wave propagation, solution strategies: method of characteristics, numerical solutions, boundary conditions - applications and case studies; surge analysis, controlling transients, column separation

CE6660 **3**
Hydro-climatology
Atmosphere; Ocean; Hydrologic cycle; Spatial and temporal variations; Atmospheric circulations; Tropical weather and climate systems; Monsoons; Teleconnections; Floods; Droughts; Introduction to Principal Component Analysis and Cluster analysis;

CE6670 **3**
Advanced Statistical Methods in Hydrology
Parametric - and non-parametric methods; Probability distributions; Time series modeling; Principal Component Analysis; Cluster analysis; Neural Networks; Ensemble Forecasting techniques

CE6680 **3**
Fluvial Hydraulics
Turbulence in fluvial systems; Reynolds-averaged Navier–Stokes equations; shear-stress in steady-uniform flow; Prandtl's mixing length theory; classification of flow field; velocity distribution; turbulence intensity; secondary currents; isotropic turbulence; Kolmogorov hypotheses; turbulence induced sediment transport; fluvial bedforms; mathematical models; bed features in gravel bed streams; concepts of meandering and braiding; local scour; model studies.

CE6690 **3**
Integrated River Basin Management
Introduction to integrated approach; land drainage schemes; surface and subsurface drainage in coastal and interior basins; design of water conservation and harvesting structures; determination of design storm and design flood for spillways and other outlet structures; flood routing; flood control through single and multipurpose reservoir operation; soil erosion and salinity; control measures for erosion.

CE6691 **3**
Design of Water Distribution and Sewerage Systems
Hydraulics of pipes and sewers, Analysis and design of water distribution systems, quantity and quality, wastewater collection and conveyance systems, design of sewerage network.

CE6700 **1**
Intelligent Transportation Systems
Introduction to Intelligent Transportation Systems (ITS), Highway ITS, City ITS, Active Traffic Management Systems, Advanced Transportation Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), ITS for highway safety, Connected Vehicle Technology and Applications, ITS Standards and Architecture, Introduction to IOT, Communications for ITS.

29.6 Department of Chemical Engineering

CH5010 **3**
Advanced Numerical Methods
Review of computer programming; Solutions of simultaneous linear/nonlinear equations; Newton's interpolation formula; Quadrature formula; Systems of first order ordinary differential equations (ODEs), Stability analysis; Variable step size algorithms (Gear's algorithm etc.), Finite Difference Methods for ODEs (IVPs and BVPs) and PDEs (hyperbolic, parabolic, elliptic). Numerical solutions of Chemical engineering problems e.g. separation processes, reaction engineering, fluid mechanics, process control, thermodynamics etc

CH5030 **2**
Molecular Thermodynamics
Quick Recap of Basic Thermodynamics, Introductory Probability, Extremum Conditions, Statistical Interpretations of Free Energy and Entropy, 3rd Law and Boltzmann

		Distribution, Simple Gases, Temperature and Heat Capacity, Solutions, Different Ensembles, Fluctuations, Example Applications
CH5036 Industry Lectures	**1**	Eminent perosons from various industries are invited to deliver letucures on different topics.
CH5050 Heterogeneous Catalytic Reaction Engineering	**3**	Review of heterogeneous reaction; Classification of catalysts; Overview of catalyst preparation and characterization; transport processes with reaction in porous catalyst and multiphase reactor system; Kinetics and parameter estimation of heterogeneous catalytic reactions; Design of heterogeneous catalytic reactors; Multiphase (or dispersed phase) flow reactors; Catalyst deactivation; catalyst deactivation-diffusion interaction; Regeneration kinetics of deactivated catalyst.
CH5060 Advanced Process Control	**3**	Process models and discretization, fundamentals of discrete time stochastic processes, Identification of ARX, ARMAX models, Multi-loop control, Interactions, Decoupling, State Estimation, Kalman Filter, Particle Filter, Linear Quadratic Regulator, Linear Quadratic Gaussian, Model Predictive Control.
CH5080 Advanced Transport Phenomena	**3**	Vectors and tensor analysis, Momentum transport, Governing equations and Boundary conditions: equations of continuity and motion, Steady, Unidirectional flows, Non-dimensionalisation (Reynolds number, Schmidt number, Prandtl number etc), Time dependent flows, method of similarity solutions (combination of variables), Sturm-Liouville problems (separation of variables, infinite series), Two-dimensional flows: Stream function, limiting cases: creeping flow, inviscid flow, potential flow, velocity potential, Boundary layer theory, Turbulent flow, transition to turbulence, turbulence models, Analogy of Energy and Mass transport with Momentum transport (with examples).
CH5091 Process Engineering Lab	**2**	Introduction to chemical process design (Aspen Plus), Design of process equipment, Process simulation - steady state and dynamic simulation, Economic analysis, Project on process design
CH5101 CFD Lab	**2**	Applications of CFD, Introduction to CFD software (FLUENT/STAR-CCM), Balance equations: mass, momentum, energy and expression in Cartesian coordinates, Solution of simple flow problems using CFD Software (Flow in a pipe with and without wall heating, Lid-driven cavity problem), Review of solution of Linear algebraic equations: Gauss Jordan, Thomas algorithm, Discretization of derivatives, Finite difference formulae, Truncation vs Round-off error, Consistency, Stability (time-marching), Application to Wave equation: Euler explicit, Lax method, Leap-frog method, Lax-Wendorff method, Application to Heat equation: Simple-Explicit method, Crank-Nicolson method, Application to Inviscid Burger's equation: Lax-Wendorff method
CH5120 Advanced Biochemical Engineering	**2**	This course introduces advance biochemical engineering aspects in terms of mathematical modelling and simulation for cell growth and enzyme kinetics. Cell free and Immobilization kinetics; screening, isolation and identification of fungal and bacterial organisms. Problem solving on diffusion limitation, rate limiting for porous and non-porous material, effectiveness factor for intra particle diffusion, oxygen transfer rates and volumetric mass transfer rates. Comparison studies on submerged and solid state fermentation bioreactors i.e. batch, continuous, chemostat recycle and fed batch studies. Recombinant monoclonal technology and marine-derived biomaterial application.
CH5180 Viscous Fluid Flow	**2**	Properties of Fluids, Fundamental equations of fluid flow: Derivation of Navier-Stokes, continuity and energy equations, Boundary conditions for viscous flow, Some discussion on potential flows: stream function, potential function, Flow separation, Dimensionless parameters, Laminar boundary layers, similarity solutions: Blasius velocity profile for flow over a flat plate, Transition to turbulence: linear stability analysis, Introduction to Turbulence
CH5190 Molecular Modelling of Catalytic Reactions	**3**	Introduction to molecular modeling, Catalytic cycle and Sabatier Principle, Potential energy surface, Density functional theory, D-band theory, Chemical kinetics, Introduction to Vienna Ab-initio Simulation Package (VASP), EXAFS and XANES, Ab-initio thermodynamics, Electro-catalysis.
CH5200 Passive Microrheology	**2**	(I) Introduction to Brownian Motion – Kinetic Theory, Equipartition Theorem, Fluctuation Dissipation Theorem, Motion in Continuous Media (II) Passive Microrheology – Langevin Equation, Derivation and Physics of Generalized Stokes Einstein Equation, Solutions for Model Materials, Interconversions and Validity (III) Particle Tracking Microrheology – Video Microscopy, Image Analysis for Particle Detection and Tracking, Light Scattering Methods (IV) Application of Passive Microrheology for Complex Fluids Characterization

CH5220 **2**
Multiphase Flow Reactors

Multiphase reactors hydrodynamics and flow regimes. Transport effects in multiphase reactors, interplay of length and time scales. Multiphase Interactions: Drag, lift, buoyancy, virtual mass force, etc., one way, two way, three-way and four-way coupling and their mathematical formulation. Limitations of models. Process parameters of interest. Effectiveness and enhancement factors in gas-solid, liquid-solid, and gas-liquid-solid reactors. Introduction to multiphase reactors and their applications, classification of multiphase reactors. Mechanically agitated reactors, bubble column/slurry bubble column reactors, fluidized bed, packed bed, trickle bed reactor reactors.

CH5230 **2**
Colloids, Emulsions and Foams

General introduction to Colloids, Emulsions and Foams; Microscopic interactions in colloids; Suspension and Granular rheology; Emulsions: Formation, Stability and Interactions; Emulsifiers: HLB, PIT, CER, Packing and Pickering Emulsions; Emulsions: Creaming, Sedimentation, Ostwald Ripening, Flocculation and Coalescence; Foam Morphology; Foams: Drainage, Ripening, Coalescence; Foam Rheology

CH5240 **2**
Multi-objective Optimisation Under Uncertainty

Multi-objective optimisation, Evolutionary Algorithms, Optimization under uncertainty, Chance Constrained programming, Robust Optimization, Bayesian optimisation.

CH5250 **2**
Food Rheology

Food rheology and structure, Rheological models for fluid foods, Rheology and Rheometry, Rheology of food gum and starch dispersions, Fluid and semi-solids rheology, Rheological behaviour of food gels, Relationship between rheology and sensory assessment of foods and swallowing, Applied rheology: Fluid handling and Processing.

CH5260 **2**
Concepts of Biorefinery

Overview of petroleum refinery and petrochemical industry, energy and chemical scenario, needs for renewable feedstock, biorefinery - analogy with petroleum refinery and petrochemical industry, types and chemistry of biomass, types of biorefinery and their opportunities and challenges, platform chemicals, fuels and chemicals from vegetable oils, bioethanol and biobutanol - production and application as biofuels and chemicals, thermochemical conversion processes – gasification, liquefaction and pyrolysis, hydrocarbon biorefinery.

CH5290 **2**
Linear and Nonlinear Stability of Fluid Flows
▷CH2190 OR Basic course in fluid mechanics

1) Introduction, 2) Temporal stability theory, 3) Kelvin-Helmholtz instability, 4) Capillary instability, 5) Orr-Sommerfeld equation, 6) Spatio-temporal stability, 7) Rayleigh-Benard convection, 8) Thermocapillary instability, 9) Weakly nonlinear stability

CH5300 **3**
Light Scattering Methods for Complex Fluids
▷MA1140 AND MA1150 (Or any equivalent course on basic linear algebra and calculus)

(I) Fundamental theory: Introduction to light, scattering vector, Maxwell's equations, dipole scattering, Rayleigh-Gans-Debye Scattering, Form Factor for Spheres and Aspherical Objects, Mie Scattering, Structure Factor for polymers and colloidal crystals, Dynamic structure factor, Pair correlation function, Diffraction, Mean free path and Multiple Scattering (II) Instrument Design – Dynamic light scattering, Depolarized light scattering, Static multi-angle light scattering, Diffusing Wave Spectroscopy and Small-angle diffraction (III) Case Studies in (a) single particle sizing, Zimm plots and polymer molecular weight measurement (b) structure of colloidal gels and colloidal crystals, structural color, polymer solutions, (c) measurement of single particle Brownian dynamics, dynamics in concentrated suspensions, arrested dynamics in gels, microrheology, (d) open problems in light scattering by polymers and colloidal materials.

CH5320 **2**
Fundamentals of Droplet Drying
▷CH2190, CH2180 and CH3110 (or any equivalent courses on fundamental fluid mechanics, Basic heat and mass Transfer)

(i) Overview on Surface Tension and Wetting Phenomena: Surface energy and Capillary force, Laplace pressure, Measurement of surface tensions, Spreading, Wetting criteria, Contact angle (ii) Evaporation of Droplets: Sessile vs spherical droplet drying, Theoretical background, Diffusive evaporation, Spalding model, Evaporative flows-convective flow, Marangoni flow etc. (iii) Drying complex fluid drops and its Applications: Colloidal drops, Droplets of Ionic solutions, Surfactant droplets, Droplets of polymers, Biological fluid drops etc.(iv) Influence of fields in drying pure and complex fluid drops: Gravity, Sonic vibration, Electric field, and Magnetic field.

CH5390 **1**
Microfluidic Platform for Cell Culture and Diagnostics

Microfluidic chips for 2D and 3D cultures, Transport models, Controlled microenvironment, POC diagnostic toolkits, Diagnostics – fabrication, application protocols, Commercial devices

CH5460 **1**
Process Integration

Process Integration is a holistic approach to process design with a focus on unification. The emphasis will be on thermal pinch analysis for energy integration by integrating hold/cold streams. A material recovery pinch analysis will be discussed by the way of reducing waste materials to improve recycle and reuse. The course will be extended to

		discuss the development of radical intensifying techniques in chemical processes. In particular, applicability of the intensifying techniques to various practical applications will be discussed. Both the theoretical and conceptual phenomena pertaining to intensification will be covered.
CH5520 Physicochemical Fundamentals for Chemical Engineers	**2**	Random Walk, Brownian Motion, Fluctuation Dissipation Theorem, Langevin Equation; Equipartition Theorem and Related Aspects; Kinetic Theory of Gas; Osmosis, Osmotic Pressure and Calculations; Scattering Fundamentals
CH6003 Microreactors Design and Fabrication ▷CH6340 or CH6890	**3**	1. Design strategies for microfluidics, mixing in microflows and design for mixing, 2. Fabrication of master patterns using – photolithography, 3D printing, laser cutting, machining. Electrode deposition on substrates using - physical and chemical vapor deposition, etching, 3D printing. Soft lithography and rapid prototyping, assembly (series and parallel) of integrated microfluidic devices and systems. 3. Scale out issues and design considerations. 4. Experimental setup and analysis – single and multiphase flows. 5. Cell culture techniques – 2D and 3D cultures
CH6020 Sustainable Energy	**1**	It covers basics of renewable/nonrenewable and sustainable energy, global consumption of energies; includes different types of energy utilization. Advance of sustainable energy towards fossils; conventional energy resources; inexhaustible and environmental application.
CH6040 Process Intensification	**1**	History of Chemical engineering: evolution of chemical processes and process equipment; Process intensification: a paradigm shift in design, role of disruptive innovation; Process integration: heat and mass integration, reactive separations; Processing under centrifugal fields– HIGEE, spinning disk reactors, POD; Alternatives to stirred-tank mixers and reactors –Oscillatory baffle, Couette flow, 'custom-shaped' channel (Corning) mixers and reactors; Monolith (Structured) reactors and adsorbers; Micro devices: mixers, separators, heat exchangers, reactors for desk-top manufacture in Pharmaceuticals and fine chemicals.
CH6080 Introduction to Cardiovascular Mechanics	**1**	Need for knowledge of mechanics in healthcare interventions; Instances of structure-function relationship in the human body; Cardiovascular System; Heart: anatomy and physiology, cardiac cycle, mechanics and models; Blood: composition, rheology and models; Vasculature: structure and function, pressure regulation, mechanics and models; Hemostasis: causes and mechanism; Cardiovascular diseases (CVDs) and treatments
CH6090 Advanced Mineral Processing	**2**	This course is a full details and comprehensive knowledge of advance aspects of mineral processing, designing and selection of processing equipment and machinery. The following topics are explained in this course: Comminution theory; Models of comminution process; Grinding mills, designs and modeling; Screening and classification; Dense medium separation; Gravity separations; Froth flotation
CH6100 Electrochemical Engineering	**3**	Overview of electrode processes. Thermodynamics: Chemical Potential and Electrochemical Potential, Nernst equation. Electrode Kinetics: Heterogenous electrode reactions, Models for electrode kinetics. Potential step methods. Potential sweep methods: Cyclic voltammetry. Electrochemical Impedance Spectroscopy. Applications to fuel cells and batteries.
CH6120 Fluidization Technology	**2**	Fundamentals of gas-solids fluidization, Application of fluidization-based processes in the industry, Regimes of fluidization, Geldart classification of solids, Minimum fluidization velocity, Bubbling fluidization, Hydrodynamics of the fluidized bed, Bubble coalscence models, Pressure profile along the fluidized bed reactor, Gas distribution to Fluidized beds, K-L flow model, Entrainment characteristics, Elutriation, Gas solids movements, Circulating fluidized bed (CFB) reactors, Fluidized reactor designs, Comparison of BFB, CFB and ICFB systems, Heat and mass transfer processes in fluidized beds, Overview of modern fluidized bed-based industrial processes
CH6140 Petroleum Refinery	**2**	Overview of petroleum refinery, chemistry of petroleum, properties of crude oil, desalting of crude oil, atmospheric and vacuum distillation of crude oil, properties, specification and testing methods of petroleum products, secondary processing of petroleum, such as hydrotreatment, catalytic reforming for high-octane gasoline and aromatic feedstock, coking, visbreaking, fluid catalytic cracking, hydrocracking, and lube oil base stock.
CH6170 Interfacial Chemistry	**1**	None

CH6180 **1**
Statistical Design and Analysis
▷CH6310 Introduction to statistical hypothesis testing

Factorial Experiments, Full Factorial Designs, Blocking and Confounding in Factorial Designs, Fractional Factorial Designs, Introduction to Multivariate Analysis

CH6190 **3**
Modern Probability Theory

Sigma Algebra, Monotone Class Theorem, Random Variables, Expectation, Convergence of Random Variables, Monotone and dominated convergence theorems, Independence, Conditional Probability and Conditional Expectation, Product measures, Uniform Integrability, Discrete time martingales, Stopped Martingales, Doobs upcrossing Lemma, Convergence Theorems, L2 and UI martingales, Option Pricing, Black-Scholes Formula, KalmanFilter References: 1) Probability with Martingales, David Williams, Cambridge University Press, 1991 2) Probability, Leo Breiman, SIAM Classics in Applied Mathematics, 1992

CH6220 **2**
Advanced Soild-liquid Separations

Characterization of particles in liquids; Particle sizing techniques; Particle drag and settling rates; Rheology of slurries; Efficiency indices of separation of particles; Coagulation and flocculation; Gravity clarification and thickening; Classification by cyclones; Gravity separations; Separation by centrifugal methods; Filtration-fundamentals, cake washing, cake growth concepts; Pressure filtration; Vacuum filtration; Membrane separations; Latest developments of Solid-liquid flows.

CH6250 **1**
Engineering Materials

None

CH6270 **1**
Introduction to Nanotechnology

Evolutionary perspective of Nanomaterials, Physical aspects of Nanosciences, Synthesis, Design and Characterization of Nanomaterials, Nanofabrication methods and Product form of Nanomaterials.

CH6300 **3**
Cardiovascular Mechanics

Mechanics and Human Health, Preliminaries, Anatomy and Physiology of Cardiovascular system, Preliminaries of Continuum Mechanics, Problems and solutions in cardiovascular mechanics

CH6310 **2**
Introduction to Statistical Hypothesis Testing

Basic definitions, Data presentation, Numerical summary measures Probability recap, Some discrete probability distributions, Normal/Gaussian distribution and z-scores, Sampling distribution of the mean, Confidence intervals, t-test, Hypothesis testing, Comparison of means and variances, One-way and two-way analysis of variance (ANOVA) and associated designs.

CH6330 **1**
Systems Biology

Mathematical representation of biochemical system in time and space, Simulation of spatio-temporal dynamics of intra-cellular molecules and physiological activities (MATLAB), Examples from cell growth, cell death, bacterial infection and cell migration, Biological signals and systems, Overview of system properties, Ultra sensitivity, Amplification, Oscillations, Network model formulation and motifs, Introduction to disease models

CH6340 **2**
Introduction to Microfluidics and Microreactors

Physics of miniaturization – forces and scaling laws, Hydrodynamics in microsystems (surface tension, inertial effect, capillarity, drops-bubbles), Mixing – (diffusive, Taylor dispersion, chaotic advection), Multi-phase systems (droplets), Microreactors, Lab on chip devices and specific applications

CH6370 **2**
Statistical Computing

Introduction: Basics of random process, random sampling, probability density functions, Gamma /Weibull/lognormal distributions, computation of expectation, joint probability distributions, Statistical modeling: Expectation maximization, maximum likelihood, parameter estimation using MLE, Estimator for relative quality of statistical modeling, gaussian mixture model, Akaike information criterion, distance between two probability distributions, computation of KS distance, model ranking and model selection. Monte Carlo method: MC simulation using various probability density functions, numerical schemes for embedding statistical processes in system of non-linear ODEs, examples from chemical/biological processes. Computation of distance between data: types of distances, distance matrix, covariance matrix, correlation matrix, time series data, autocorrelation, cross-correlation

CH6420 **2**
Non-newtonian Fluid Mechanics

Definition of non-Newtonian behavior, Examples with underlying mechanisms, Flow problems and solutions for i) Single-phase non-Newtonian models, ii) Multi-phase non-Newtonian models (mixture theory and correlation-based), and iii) Particulate suspensions

CH6450 **1**

Linear Time Invariant systems, Sampling, Transfer Functions, Frequency Response,

Introduction to System Identification

Periodograms, Signal Spectra, Basic Probability review: Random Variables, Expectation, Variance, Covariance, Independence, Conditional Expectation, Quasi stationary signals, Spectra for random signals Prediction, one-step ahead Prediction, Observers Models for LTI systems: Equation Error, ARMAX, Output Error, Box Jenkins, General Family of Model Structures, Linear Regression Nonparametric methods : Correlation Analysis, Frequency Response Analysis, ETFE, Spectral Analysis Introduction to Prediction Error Methods Basics of Compressive Sensing and Model Validation.

CH6460 2
Bio-process Technology

Fundamentals of bioprocess engineering, Kinetics for growth and enzyme analysis. Process optimization through statistical techniques 2K, CCD, BBD, upstream development, fermentation and downstream technology by purification of biomolecules, large scale production of enzymes and byproducts. Solid state fermentation and Sub-merged fermentation process.

CH6470 2
System Identification Theory

Bias, Consistency of parameter estimates, Convergence of Random Variables, Analysis of the Least Squares Estimate, Best Linear Unbiased Estimate, Maximum Likelihood Estimator, Cramer-Rao Lower Bound Properties and Smoothing of ETFE, Weighting Functions Model Structures, Identifiability, Input Signals, Persistent Excitation, PRBS, Optimal Prediction, State Space Models, Kalman Filter, Theoretical Properties of Prediction Error Methods : Asymptotic distribution of parameter estimates, Instrumental Variable Methods and Analysis of Estimates, Recursive Identification, Identification in Closed Loop, Subspace Identification: Deterministic and Stochastic Systems, Identification in Continuous LTI systems, SRIVC, Generalized Smoothing Approaches.

CH6480 2
Principles of Heterogeneous Catalysis

History of Catalysis and Its Industrial Applications; Adsorption processes: Physical, chemical and dissociative adsorption; Desorption process; Kinetics and mechanism of catalytic reactions; Transport processes in catalysis: Mass and heat transfer in catalysis; Types of catalytic material and brief overview of their synthesis procedure; Poisoning, promotion, Deactivation and Selectivity of catalysts; Catalyst surface characterization: Physical and Chemical methods; Case Studies of Catalytic Applications.

CH6550 2
Chemical Reactor Modeling

Evaluation of thermodynamic properties using NASA polynomials; Calculation of equilibrium composition of a reacting mixture; Kinetics of gas-phase reactions; Kinetics of surface reactions; Adsorption isotherms; Development of governing equations for chemical reactors; solution of governing equations using numerical solvers.

CH6580 2
Advanced Mineral Processing

Introduction to mineral processing; Minerals and Mineralogy; Mineral circuits; Metallurgical Balances; Comminution theory and limitations; Models of comminution process; Rock breakage characterization; Grinding mills, designs and modeling; Classification; Dense medium separation; Gravity separations; Froth flotation.

CH6610 2
Fuel Cell Technology

Types of fuel cells, advantages and disadvantages of different fuel cell types, fuel cell thermodynamics, electrode kinetics, charge transport, fuel cell characterization, modeling of electrochemical processes.

CH6620 1
Intermolecular Forces

Thermodynamics of Inter-molecular Forces; Variety of forces between the molecules (Ionic, Polar, Induced Polar, Dispersion and H-bonding); Calculations and analysis.

CH6630 2
Membrane Separation Process
▷CH1050, CH3022

An overview of membrane separation process, membrane classification, chemistry, structure and characteristics and preparation; various membrane separations technology such as microfiltration, ultrafiltration, reverse osmosis, dialysis, electrodialysis, gas permeation, pervaoration, liquid membrane, and their applications in chemical, biotechnology, food, and biochemical industry.

CH6640 2
Optimization Techniques - I

Concepts of optimization, formulation of optimization problems, unconstrained optimization, necessary and sufficient conditions, convexity, single and multi-variable optimization, constrained optimization, KKT conditions, numerical optimization, one dimensional area elimination and interpolation based methods, multi dimensional Newton's / Quasi - newton methods, evolutionary optimization, genetic algorithms, solving practical problems.

CH6650 1
Introduction to Stochastic Differential Equations

Brief review of Modern Probability Theory, Stochastic Processes, Examples of SDE, Ito Integal, Ito Formula, Solutions to SDEs, Numerical Methods for solutions.

CH6670 2
Theory Of stochastic Differential Equations

Construction of Wiener Process (Brownian Motion), Continuous Time Martingales, Martingale Convergence Theorem, Wiener Martingales, Supermartingale Decomposition, Local Martingales, Stochastic Integrals for square integrable martingales, Ito Integral, Ito Formula and its applications, existence and uniqueness of solutions to SDEs, strong and

	weak solutions, linear SDEs, Markov and Diffusion processes. Pre-Req: Real Analysis, Probability Theory and some amount of Topology, Function spaces / Consent of instructor
CH6680 1 Drug Delivery Systems	Principles of drug delivery (diffusion, barriers, permeability, availability, effective dose); design of vehicles (matrix and reservoir systems); polymer-drug formulations; approaches for site-specific and targeted drug delivery; challenges in the delivery of sensitive biomolecules; routes of administration; introduction to pharmacokinetics and ADMET analysis.
CH6690 2 Energy Storage Systems	Introduction to energy storage, power density vs. energy density, electrochemical energy storage including batteries, supercapacitors and fuel cells, chemical energy storage including hydrogen storage and biofuels, thermal energy storage including phase change materials and cryogenics, mechanical energy storage including flywheels and compressed gas, discussion of viable technologies for commercialization with emphasis on environmental impact, cost and efficiency, advantages, disadvantages and applicability of various technologies.
CH6710 2 Concepts in Soft Matter Systems	Introduction to Soft Matter-Polymer, colloids, gels, surfactants and liquid crystals. Soft Matter Solutions - Thermodynamics and Phase transition. Elastic Soft Matter - Networks and Gels. Soft Matter Surfaces - Surface tension, wetting, surfactants, interaction between surfaces, polymer grafted surfaces. Liquid Crystals - structures and phase transitions. Soft Matter Dynamics - introduction to concepts.
CH6720 2 Basics of Nanosciences and Nanotechnology	Physical aspects of Nanosciences, Introduction to Nanomaterials, Synthesis of Nanomaterials, Carbon Nanomaterials, Nanofabrication Methods, Characetrization of Nanomaterials, Applications of Nanotechnology, Health, social, ethical concerns of nanotechnology.
CH6730 2 Nature Inspired materials engineering	Nature inspired material engineering and design for applications such as environment, energy and healthcare applications, bottom up assembly techniques and production, gap between natural and nature inspired materials.
CH6760 2 Molecular Theory of Polymeric Fluids ▷Statisitical Thermodynamics, Transport Phenomena	Introduction to Polymers: History, Synthesis, Polymer architecture. Single Molecule Conformations: Models for representing long chain molecules, Model Predictions- radius of gyration, end-to-end distribution, Effect of excluded volume on chain conformation (SAW model), Free energy of a chain, Ideal and real chains under tension and compression, Experimental measurements - Light Scattering. Single Molecule (Chain) Dynamics: Unentangled Dynamics: Rouse and Zimm model , Entangled Dynamics: Tube model - phenomenological mean field, Conclusions: From molecules to macroscopic properties: Structure-property relationships in systems with long chain molecules.
CH6770 2 Introduction to Applied Statistical Mechanics	Review of probability theory; concepts and significance of energy; postulates of statistical mechanics; statistical interpretation of thermodynamics; microcanonical, canonical and grand canonical ensembles; Statistics for various problems (of complex fluids and molecular fluids); Response of complex fluids under external forces; non-Newtonian behavior, concept of complex viscosity, stochastic force and Langevin equation, free and constrained Brownian motion etc.
CH6780 1 Soft Computing in Process Modeling	Evolution of soft computing techniques; Detailed discussion on components of soft computing e.g. Neural networks (NN), Support Vector Machines (SVM), Fuzzy logic (FL), Evolutionary computation (EC), Meta-heuristic and Swarm Intelligence; Formal implementation of soft computing techniques on real life data in the form of projects.
CH6810 2 Computational Fluid Dynamics	Philosophy of CFD, Governing equations of fluid flow, Mathematical behavior of partial differential equations, Discretization, Transformation, Numerical solutions, Some simple CFD Techniques, CFD solutions of some simple flows.
CH6820 2 Nature Inspired Optimization	Basics of optimization, objective functions, constraints, principles of optimality, single and multi-objective optimization, Pareto optimality, nature inspired optimization techniques e.g. genetic algorithms, differential evolution, simulated annealing, ant colony optimization, artificial bee colony optimization, particle swarm optimization etc., comparison with classical methods, hands on using standard test functions and practical projects.
CH6830 1 Surface Interactions ▷CH6620 Intermolecular Forces	Applying the intermolecular forces to the surfaces and geometries, DLVO forces, Polymer Forces, Self Assembly

CH6840 **2**
Biomaterials Science and Engineering

Properties, design and applications of metals, ceramics, polymers, hydrogels; Mechanical testing of biomaterials; Viscoelasticity; Maxwell/Kelvin-Voigt models; Surface properties of biomaterials; Protein adsorption and isotherms; Cell-ECM interactions; Cell adhesion on biomaterials; Cell migration models; Inflammation and immune response

CH6860 **1**
Data Analysis Tools for Experimental Research

Probability density function, analysis of variance: One way and Two-way ANOVA, Non-parametric testing, correlation, regression, computation of distances, clustering and validation, introduction to principal component analysis

CH6870 **1**
Machine Learning in Process Systems Engineering

Introduction to Supervised and Unsupervised Machine Learning, Multilayered Perceptron (MLP) Neural Networks, Optimization methods for training MLPs, Regularization, ANN Surrogate assisted Optimization, Recurrent Neural Networks (RNNs), System Identification of dynamical systems using RNNs, Hyper-parameter optimization.

29.7 Department of Computational Mechanics

ME5139 **3**
Finite Element Method

Theory and implementation of finite element methods for solving boundary value problems in solid mechanics. Mathematical foundations (Calculus of Variation), review of energy theorems, theory and implementation of 1D, 2D, and 3D elasticity problems. Introduction to FEM softwares.

ME5339 **3**
Computational Fluid Dynamics

Introduction to numerical solutions of PDEs; importance of CFD; various methods; Taylor Series; Finite-difference of first, second and third derivatives; Order of accuracy; finite-differences on non-uniform grids; time-stepping; explicit and implicit time-stepping of 1D unsteady heat conduction equation; Boundary and Initial conditions; tri-diagonal solver; Explicit and Implicit schemes for 2D unsteady heat conduction equation; Gauss-Seidel method; Convergence; iterative vs direct methods; Types of PDEs, and their IC and BCs; the well-posed problem; Methods of Elliptic PDE; False-transient method; Hyperbolic PDEs; 1st order wave equation: characteristics; Methods: Lax, McCormack etc; modified equation; dissipative and dispersive errors; systems of hyperbolic equations; diagonalization; Finite-volume method; Convection-Diffusion equation; Convective schemes: Upwind, 2nd upwind, Quick, etc; Vorticity-stream function formulation: Explicit, Implicit and Semi-Implicit schemes; coupled temperature equation; segregated and coupled solution methods; SMAC method for Navier-Stokes equations.

ME5429 **1**
Finite Element Method Lab

Finite element methods for solving boundary value problems in solid mechanics. Introduction, Spatial Modelling, Geometric discretization, Element Library, Material Modelling, Loading and Boundary Conditions, Constraints, Surface/Interfaces modelling, Step and job handling and Post-processing. FEA Implementation and Visualization of 1D Problems, Truss Problem, Beam bending, Plane and axisymmetric Problems and 3D problems. Various analysis such as, Static, Transient, Harmonic, Modal, Dynamics and Multi Physics (Thermomechanical, etc).

ME5449 **1**
Computational Fluid Dynamics Lab

Introduction and concepts of finite volume methods, Integral form of Navier-Stokes equations. Concepts of pressure and density-based solvers. Introduction to Ansys Workbench, basics of Design Modeler, Structured and unstructured meshing, Ansys fluent setup, solution and post processing. Laminar and turbulent viscous incompressible flow problems (2D and 3D Analysis). Compressible flow problems, Combustion modelling. Introduction to OpenFOAM solver.

ME5769 **1.5**
Applied Solid Mechanics

Introduction to basic solid mechanics, various strain measures and stress tensors, Balance laws, constitutive relations (commonly used energy density functions), special cases through simplification (incompressibility, plane stress and strain, hydrostatic loading, isotropy, linear elasticity), problems in Cartesian and other curvilinear coordinates.

ME5779 **1.5**
Applied Fluid Mechanics

Tensors; Lagrangian and Eulerian frames of reference; Derivation of continuity equation and Navier-Stokes Equations; Elliptic and parabolic equations; Analytical solutions of NS equations; Boundary-layer theory; Turbulence; RANS equations; Introduction to turbulence modelling; Non-dimensionalization and non-dimensional parameters

ME5789 **3**
Computational Dynamics and Vibrations

Governing equation and Generalized method: Newton's method, Virtual work principle, Euler-Lagrange method. Newton Raphson method, Runge kutta method, numerical tolerances and its control. Basics of linear vibration: 1 DOF linear vibration equation under free, forced and arbitrary forcing, Extension to MDOF system, Methods to solve linear equations. Basics of nonlinear vibration: 1 DOF nonlinear equation, Method to solve the equation: Perturbation methods.

ME5799 **3**
Topics in Computational Mechanics

A collection of modules (equivalent to 0.5 or 1 credit each) focusing on specialized multidisciplinary topics such as Impact Mechanics, Fluid-Structure Interaction, Parallel Computing.

ME5819 **3**
Advanced Computational Fluid Dynamics

Finite-volume method; pressure problem for incompressible Navier-Stokes equations; Pressure-velocity decoupling; Staggered and collocated grids; semi-explicit (SMAC) method on staggered grids; Convective schemes; Implicit SIMPLE method; higher-order accuracy implementations; Non-orthogonal grids: problems with staggered grids; collocated grid; implementation of semi-explicit and implicit schemes on rectangular collocated grids; generalization to collocated non-rectangular hexahedral grids; Boundary conditions and their implementation; adaptation of schemes to tetrahedral grids, general hybrid grids; advanced linear equations solvers; algebraic multigrid methods.

ME5899 **2**
Structural Optimization

Overview of size, shape and topology optimisation; constrained and unconstrained finite-variable optimization; KKT conditions; sufficiency conditions; analytical size optimization of bars and beams for stiffness, flexibility, strength, and stability criteria in the framework of variational calculus; gradient-based computational optimization of trusses, frames, and continuum structures; sensitivity analysis for parameter, shape, and topology variables; shape optimization; topology optimization; design parameterization for topology optimization of coupled structural problems involving multi-physics domains.

ME5909 **2**
Additive Manufacturing Technology

Overview of Rapid Product Development: Product Development Cycle, virtual prototyping, physical prototyping, Solid Modelling: Data formats, conversion, checking, repairing and transmission. Synergic integration technologies, Part slicing and Build Orientation, Area-filling strategies, applications and limitations of RPM. Classification of RPM processes: Sheet Lamination, Material Extrusion, Photo-polymerization, Powder Bed Fusion, Binder Jetting, Direct Energy Deposition. Popular RPM processes. Selection of rapid prototyping, tooling and manufacturing systems based on product requirements. Energy sources and their interactions with feedstock.

29.8 Department of Computer Science and Engineering

CS5020 **3**
Pattern Recognition

Basics of pattern recognition, Bayesian decision theory, Classifiers, Discriminant functions, Decision surfaces, Parameter estimation methods, Hidden Markov models, dimension reduction methods, Fisher discriminant analysis, Principal component analysis, Non-parametric techniques for density estimation, non-metric methods for pattern classification, unsupervised learning, algorithms for clustering: K-means, Hierarchical and other methods

CS5030 **3**
Advanced Topics in Data Management

Parallel and distributed database systems. Advanced query processing and optimization - Volcano optimizer, decorrelation techniques, holistic optimization of database applications. Adaptive query processing. Streaming databases. Data warehousing and OLAP. Spatial databases and indexing of spatial data. XML.

CS5040 **3**
Linear Optimization

Linear programming, linear algebra, geometry of polyhedra, the simplex method, duality, primal dual algorithms, opt: applications to integer linear programs.

CS5060 **3**
Advanced Computer Networks

Basics of Computer Networking, TCP/IP protocol stack, Local Area Networks (Ethernet, Wi-Fi), Network Management, Network Security, Multimedia Transport, Next generation Internet architectures, Green Communication Networks, and Data Center Networking. Performance studies using QualNet simulator and lab assignments using Seattle GENI testbed.

CS5120 **3**
Probability in Computing

Basic probability, random variables, expectation, concentration inequalities, with algorithmic applications, Markov chains, random walks, applications to sampling and approximate counting.

CS5130 **3**
Cryptography

Basic cryptanalysis, perfect secrecy, number theory - Euclid's algorithm, Chinese remaindering, private key encryption (DES), linear cryptanalysis, public key cryptography, Diffie-Hellman protocol, RSA, secret sharing, hash functions, authentication, digital signatures, zero knowledge proofs.

CS5190 **3**
Soft Computing

Competitive learning models: Principle Component Analysis (PCA); Self-organizing maps (SOM); Information theoretic methods: Entropy, mutual information, K-L divergences; Independent component analysis (ICA), Maximum entropy method; Pulsed neural networks: Spiking neuron model, Integrate-and-fire neurons; Fuzzy Logic and

Fuzzy systems, Fuzzy neural networks, Fuzzy K-means algorithm; Genetic Algorithms: Evolutionary computation, Genetic operators

CS5200 3
Approximation Algorithms

NP-hardness and approximation, approximation ratios and schemes, greedy algorithms, set cover, linear programming and rounding, primal-dual method, FPTAS for knapsack problem, bin packing, Euclidean TSP, introduction to hardness of approximation.

CS5230 3
Visual Recognition

Introduction to Representation, Learning, Detection, Recognition of objects, activities and their interactions from images and videos; Human visual recognition system; Recognition methods:
Low-level modeling (e.g. features), Mid-level abstraction (e.g. segmentation), High-level reasoning (e.g. scene understanding); Detection/Segmentation methods; Context and scenes, Importance and saliency, Large-scale search and recognition, Egocentric vision systems, Human-in-the-loop interactive systems, 3D scene understanding.

CS5290 3
Computer Vision

Students successfully completing this course will be able to apply a variety of computer techniques for the design of efficient algorithms for real-world applications, such as optical character recognition, face detection and recognition, motion estimation, human tracking, and gesture recognition. The topics covered include image filters, edge detection, feature extraction, object detection, object recognition, tracking, gesture recognition, image formation and camera models, and stereo vision.

CS5300 3
Parallel and Concurrent Programming
▷CS2233, CS3523

This course will provide an introduction to parallel and concurrent programming. It will focus both on correctness and efficiency of multi-threaded programs.
Introduction; Mutual Exclusion; Concurrent Objects; Foundations of Shared Memory; Consistency condition for concurrent objects: Sequential consistency, Linearizability; Consensus; Universality; Spin Locks; Multi-thread Linked Lists; Queues and Stacks; Counting; Hash Sets; Futures and Work-Stealing; Barriers; Transactional Memory; Parallel Graph and Marix Algorithms

CS5310 1
Advanced Operating Systems for Pervasive Computing
▷CS3523

- Introduction to Advanced OS Systems and Architecture
- Linux Kernel Frameworks and Infrastructure
- File-System Interface and Implementation
- Linux I/O Systems

CS5311 2
Pervasive Computing Lab
▷CS3523

- Linux Kernel Frameworks and Infrastructure
- Multimedia Framework Architecture
- Network Framework
- Graphics and UI Frameworks
- Web Framework
- Application Development
- Introduction to IoT

CS5320 3
Distributed Computing
▷CS2233, CS3510

Termination Detection Algorithms; Reasoning with Knowledge; Distributed Mutual Exclusion Algorithms; Deadlock Detection Algorithms; Global Predicate Detection; Distributed Shared Memory; Checkpointing and Rollback Recovery; Consensus and Agreement; Failure Detectors; Distributed file servers; Distributed programming environments: Communication primitives, selected case studies. (Note: Some topics may be added/deleted to suit specific offerings of the course)

CS5330 2
Introduction to Statistical Natural Language Processing

Probability Theory : Probability space, Random variables, probability distributions, joint and conditional distributions. Information Theory : Entropy, mutual information, divergences, Hypothesis testing.
N-gram and continuous space language models, distributed representations, probabilistic taggers and sequence labeling (HMM, maximum entropy models, conditional random fields), probabilistic parsing and structured prediction, probabilistic topic models, statistical machine translation.

CS5343 3
Computer and Network Security
▷CS3543, CS3523

It covers foundations of cryptography, system security, network security, Wi-Fi security, web security, mobile platform security with hands-on assignments and projects.

CS5350 2
Bayesian Data Analysis
▷Any basic course in Probability

Course Outline: Bayesian data analysis fits a probability distribution over the data and summarize the results by a probability distribution on the parameters of the model and on unobserved quantities. Bayesian models allow the incorporation of prior information and domain knowledge which helps to better model the data and observations. This is especially useful for applications such as healthcare and computational biology with limited data availability.
The course will cover various topics on bayesian data analysis such as single and multi-parameter models, regression models, hierarchical models, generalized linear

models, spatio-temporal models, bayesian decision theory, Model selection, Bayesian inference algorithms based on Monte Carlo methods, variational inference, quadrature and expectation propagation, Bayesian non-parametric approaches such as Gaussian processes and Dirichlet processes, Point processes, Bayesian optimization and Bayesian deep learning.

CS5360 3
Advanced Computer Architecture

This course will cover several state-of-the-art and emerging topics in computer architecture, including multicore processor architecture, GPUs, CPU-GPU heterogeneous system, multi-core cache/memory architectures and resource management techniques, emerging memory technologies, processor power management techniques. The students are also expected to review and critique one recent research paper during the course.

CS5560 3
Probabilistic Models for Machine Learning

The course includes studying basic probabilistic models that are often used in machine learning set-ups, and methods of estimating parameters of such models from data. The course ends with an introduction to a very rich class models known as probabilistic graphical model

CS5570 3
Algebra for Computer Science

Groups, rings, fields; applications in RSA, polynomial factorization, secret sharing, error-correcting codes etc.

CS5580 3
Convex Optimization - Theory

Convex Analysis: Convex Sets, Convex Functions, Calculus of convex functions, Dual characterizations of convex sets, convex functions. Optimality of Convex Programs: 1st order nec. and suff. conditions, KKT conditions Duality: Lagrange, Conic and Fenchel duality Standard Convex Programs and Applications: Linear and Quadratic Programs, Conic Programs: QCQPs, SOCPs, SDPs

CS5700 3
Text Processing and Retrieval

N-gram and continuous space language models, distributed representations, probabilistic taggers and sequence labeling, probabilistic parsing and structured prediction, probabilistic topic models, Indexing document collections, Query-document scoring using Vector space model, Language Model, Evaluation metrics for ranking, Document classification.

CS5803 3
Natural Language Processing
▷Machine Learning

Basics of NLP, Laanguage model, Sequence labeling, POS Tagging, Named Entity recognition, Topic modeling, Parsingm Word representation Learning, Discourse

CS6013 3
Advanced Data Structures and Algorithms

Dictionaries – Binary search trees, Probabilistic analysis of BST, Balanced search trees, Skip lists; Universal hash family, Hash tables; Heaps, Priority queues, Algorithmic Design Paradigms- Greedy algorithms, Dynamic programming, Divide and conquer, sorting, Randomized algorithms, Average case analysis, Lower bounds, Amortized Analysis, Graph algorithms- DFS, BFS, Topological sorting, Spanning trees, Shortest paths, Bipartite matching, online algorithms.

CS6140 3
Video Content Analysis

Introduction to video content analysis, feature extraction, video structure analysis -shot and scene segmentation, content based video classification, video abstraction - skimming and summarization, event detection and classification, indexing for retrieval and browsing, Applications -Movie and sports video analysis, news video indexing and retrieval etc.

CS6180 3
Systems Security

Understand the fundamental principles of access control models and techniques, authentication and secure system design. Have a strong understanding of different cryptographic protocols and techniques and be able to use them. Apply methods for authentication, access control, intrusion detection and prevention.
Introduction Motivating examples, Basic concepts: confidentiality, integrity, availability, security policies, security mechanisms, assurance.Access to the System, Discretionary Access Control, Passwords for File Access, Capability List, Owner/Group/Other, Access Control Lists, Trojan Horse Threats, Mandatory Access Control, Security Models, Role of a Security Model , Practical Applications of a Model, Types of Security Models, Characteristics of a Security Model, State-Machine Models, Examples of a State Machine Model, Adding Constraints to State-Machine Access Models, The Bell and La Padula Security Model, Information-Flow Models, Informal Model-to-System Correspondence. Mapping the Functions, Mapping the Variables, Unmapped Functions and Variables Firewalls and Web Security - Packet filters, Application level gateways, Encrypted tunnels, Cookies, Web security problems Introduction to cryptography, Secret key cryptosystems, Modular Arithmetic and Public key cryptosystems, Public key cryptosystems, Diffie-Hellman and RSA Message digests, digital signatures, Identification and authentication, Passwords, Biometrics, One-time passwords and challenge response schemes, Kerberos, Kerberos, SSL, SSH.

CS6190 **3**
Advanced Topics in Cryptology

Reading research papers in the area of cryptology and understanding the state of the art in the subject.

CS6200 **3**
Advanced Topics in Formal Methods

This course will involve a reading of important papers in the area of formal methods. It will be preceded by a review of pre-requisite concepts in logic, verification, model checking and automata theory.

CS6210 **3**
Advanced Machine Learning

Generative models for discrete data, Gaussian Models, Bayesian Statistics, Linear Regression, Logistic Regression, Directed graphical models (Bayes nets), Mixture models and the EM algorithm, Sparse linear models. Kernels: Kernel functions, kernel trick, Support vector machines (SVMs), Kernels for building generative models. Markov and hidden Markov models, State space models, Undirected graphical models (Markov random fields), Monte Carlo inference, Markov chain Monte Carlo (MCMC) inference, Graphical model structure learning, Deep learning, Boosting, On-Line learning, Decision Trees, Ranking. Compressive Sensing and Dictionary Learning: Pursuit algorithms and applications for imaging and vision.

CS6220 **3**
Computer Vision

This course aims for students to (1) understand and apply fundamental mathematical and computational techniques in computer vision and (2) implement basic computer vision applications. Students successfully completing this course will be able to apply a variety of computer techniques for the design of efficient algorithms for real-world applications, such as optical character recognition, face detection and recognition, motion estimation, human tracking, and gesture recognition. The topics covered include image filters, edge detection, feature extraction, object detection, object recognition, tracking, gesture recognition, image formation and camera models, and stereo vision.

CS6230 **3**
Optimization Methods in Machine Learning
▷see syllabus

Introduction to Optimization, Convex Sets, Convex Functions, Lagrange Duality, Convex Optimization Algorithms, Second-order cone models, Semi-definite programming, Semi-infinite programming, Minimax, Sublinear algorithms, Interior Point Methods, Active set, Stochastic gradient, Coordinate descent, Cutting planes method, Applications to Image/Video/Multimedia Processing
Pre-Req: Basic Machine Learning or Soft Computing course

CS6300 **3**
Topics in Compiler Optimizations
▷CS3020, CS6240, CS6250

This advanced graduate level course will focus on a melange of selected topics in Compiler Optimizations. It is mostly a research based course where the registrants will focus on studying state-of-the-art algorithms, in a traditional setting or in the polyhedral compilation: studying and improving the existing algorithms published in top compiler conferences or the ones implemented in LLVM, Polly, PPCG, Pluto, etc.

CS6310 **1**
Quantum Computing I
▷BTech CSE 3rd year+

Introduction to Quantum Mechanics—the mathematics and physics; Quantum Circuits; Deutsch and Deutsch Jozsa algorithms

CS6320 **1**
Quantum Computing II
▷CS6310

Quantum Algorithms: Shor's Integer Factoring, Grover's unordered search, Hidden Subgroup Problem for various groups, Other Quantum Algorithms

CS6330 **1**
Quantum Computing III
▷CS6310, CS6320

Quantum Error Correction, Quantum Information Theory and Quantum Cryptography

CS6350 **3**
Topics in Combinatorics
▷see syllabus

This advanced graduate level course on combinatorics will focus on selected topics such as extremal combinatorics, probabilistic techniques, algebraic method in combinatorics etc.
Pre-Req: Self-assessment. Prior approval of the course instructor is needed

CS6360 **3**
Advanced Topics in Machine Learning
▷see syllabus

This advanced graduate level course on machine learning will focus on selected topics such as deep learning, probabilistic graphical models, optimization in machine learning, etc. The course assumes that the student has basic knowledge in machine learning, and will have a research focus. The objective of the course will be to get a deeper understanding of machine learning algorithms, especially those that are highly relevant for contemporary real-world applications.
Pre-Req: Self-assessment: Should have prior knowledge in machine learning, either through IIT-H or Coursera courses. Prior approval of the instructor is needed.

CS6370 **3**
Information Retrieval
▷see syllabus

- Storing, indexing and querying document data
- Scoring, term weighting document relevance estimation
- Text classification and clustering

• Probabilistic information retrieval
• Ranking in a Graph
Pre-Req: Data Mining / Machine Learning. Prior approval of the course instructor is needed.

CS6380 1
Introduction to Compiler Engineering
▷see syllabus

• Real-world compilers have complex algorithms and optimization strategies implemented in them, along with having various implementation techniques that are language/architecture independent as well as having language/architecture specific features. All the above makes engineering modern real-world compilers also a hard software-engineering problem.
• This 1 credit course will focus on understanding these issues, taking the popular LLVM compiler as a case-study.
• The following are some of the areas that we plan to study:
• Analyses/Transformations in LLVM.
• Methods of adding new FrontEnds and BackEnds to LLVM.
• Introduction to Pass-manager of LLVM. Adding new passes.
Pre-Req: CS2430 (Principles of Programming Languages 2) or Equivalent for B.Techs. An advanced compiler course for M.Techs and PhDs. An aptitude for large software. Prior consent of the instructor.

CS6390 1
Enabling Large Scale Data Analytics: From Theoretical Foundations to Practice
▷see syllabus

Small-Space Algorithms, Estimating Statistical Properties, Distance Estimation, Clustering and Ranking, Algorithms over Massive Networks, Learning Algorithms
Pre-Req: Data Structures and Algorithms, Any course on Probability and Statistics

CS6400 1
Constraint Solving
▷see syllabus

Many real world problems reduce to solving a set of constraints. From time table scheduling to inventory management and fault localization to efficient resource utilization, it all ultimately boils down to expressing these problems as a set of constraints. Not only it is at the heart of most of the problems in operation research but constraint solving has applications ranging from computational biology to program analysis. These applications use the constraint solvers mostly as a black box. However, one can gain tremendously from the study of constraint solvers and the techniques they employ so as to adapt them to the problem at hand.
This course will attempt to study the underlying techniques employed by modern day constraint solvers. In particular, solving techniques behind SAT, MaxSAT, Pseudo-Boolean constraint solving will be studied. In addition, this course will also attempt to take a look at SMT (Satisfiability Modulo Theories) solving.
Pre-Req: Data Structures, Object-oriented programming, Theory of computation, Discrete mathematics, Algorithms

CS6410 3
Software Verification
▷see syllabus

Course Outline: Software has penetrated almost every aspect of our lives. From banking applications to air traffic control, from pacemakers to smart cars uses some software component. It is therefore of paramount importance that these software work correctly. In this course, we will study various ways to formally analyze and reason about software systems.
The course may cover topics such as Hoare logic, abstract interpretation, abstraction refinement, k-induction, symbolic execution, variants of bounded model checking for sequential as well as concurrent programs such as loop bounding, context bounding and reorder bounding. Use of formal techniques for software testing and reasoning about termination can also be covered
Pre-Req: Data Structures, Object-oriented programming, Theory of computation, Discrete mathematics, Algorithms, Compilers

CS6430 3
Computational Number Theory and Algebra
▷Discrete maths, Algorithms

Finite fields, quadratic residues, primality testing, polynomial factorization, applications in cryptography/coding theory. Optional topics: Integer factoring, lattices.

CS6440 2
Advanced Computer Architecture
▷CS2323

This course will cover several state-of-the-art and emerging topics in computer architecture, including multicore processor architecture, GPUs, CPU-GPU heterogeneous system, multi-core cache/memory architectures and resource management techniques, emerging memory technologies, processor power management techniques. The students are also expected to review and critique one recent research paper during the course.

CS6450 3
Advanced Topics in Computer Vision
▷see syllabus

This course will discuss advanced topics and current research in computer vision. Students are expected to read papers selected from various subareas such as deep learning, segmentation and grouping, object and activity recognition, scene understanding, and vision and language. Approaches for learning from image and video

data will be covered and include topics from convolutional neural networks, recurrent neural networks, structured predictions and others. The course will be a mix of lecture, student presentation and discussion.
Pre-Req: Undergraduate- or graduate-level machine learning or computer vision; A good working knowledge of C/C++, Java, Python or Matlab

CS6460 **1**
Introduction to Deep Learning for Vision
▷see syllabus

This course will introduce students into the complex, abstract world of computer vision and deep neural networks. Topics covered will include: Basics of deep learning and its history, State-of-the-art deep neural net models in computer vision; Specific tools and packages to train these deep nets; and what it takes to train and run these models in the real-world.
Pre-Req: Basic knowledge of machine learning and computer vision; Linear Algebra, Probability; A good working knowledge of C/C++, Java, Python or Matlab

CS6483 **3**
Constraint Programming

This course will study the underlying techniques employed by modern day constraint solvers. In particular, solving techniques behind SAT – such as chronological and non-chronological backtracking, conflict-driven clause learning. Various encoding techniques for cardinality constraints as well as analysis of size of the encodings for MaxSAT and Pseudo-Boolean constraint solving will be studied. In addition, this course may also attempt to take a look at SMT (Satisfiability Modulo Theories) solving. (Note: Some topics may be added/deleted to suit specific offerings of the course)

CS6490 **3**
Hardware Architecture for Deep Learning
▷an introductory course on computer architecture or an introductory course on machine/deep learning

Approximate computing and storage, low-precision deep-learning (DL) accelerators, FPGA-based DL accelerators, GPU-based DL accelerators, memristor-based DL accelerators, addressing memory-bottleneck in DL accelerators, deep learning on embedded system platforms such as Jetson, hardware-acceleration of cognitive tasks such as autonomous driving, differences in hardware requirements for DL training and inference, DL on virtual machine and containers, architectural review of some recently-proposed DL accelerators (e.g., TPU).

CS6510 **3**
Applied Machine Learning

Classification (Naive Bayes, k-NN, SVM, Neural Networks, Decision Trees, Logistic Regression, Ensemble Methods), Regression (Linear, Non-linear, k-NN, SVR), Clustering (k-means, DBSCAN, hierarchical), Dimensionality Reduction (PCA, MDS, Isomap), Gaussian Mixture Models, EM, Feature Selection, Model Selection and Performance Evaluation (Cross-Validation, Bootstrap, ROC), Time series analysis methods

CS6660 **3**
Mathematical Foundations of Data Sciences

Matrices, Vectors and Properties; Vector Spaces, Norms, Basis, Orthogonality; Matrix Decompositions: Eigen decomposition, Singular Value Decomposition; Differential Calculus: Derivatives and its significance, Partial derivatives; Optimization of single variable and multiple variable functions: Necessary and sufficient conditions; Real problems as optimization problems: Formulation and analytical solutions; Finding roots of an equation: Newton Raphson Method; Optimization via gradient methods; Probability basics, density function, counting, expectation, variance, independence, conditional probability, Poisson process, recurrences, Markov chains

CS6670 **3**
Topics in Data Mining
▷CS3560, CS3140

Data Preprocessing, Data Warehousing and OLAP, Mining Frequent Patterns and Associations, Classification, Cluster Analysis, Mining Complex Types of Data (Sequence Data, Graphs, Social Networks, etc.), Text Mining, Stream Data Mining

29.9 Department of Chemistry

CY5010 **3**
Stereochemistry, Reaction Mechanism, Rearrangements

Stereochemistry: Introduction to molecular symmetry and point groups. Topicity and prostereoisomerism, nomenclature of stereotopic ligands and faces, stereoheterotopic ligands and NMR spectroscopy. Centre of chirality, assignment of absolute stereochemistry, CIP rules, axial chirality, planar chirality and helicity, descriptors for absolute stereochemistry. Conformational analysis: acyclic systems, cyclic systems,cyclohexane and decalins, conformation and reactivity with examples from molecular rearrangements, neighbouring group participation, elimination reactions, formation and cleavage of epoxides, quantitative correlation between conformation and reactivity, Winstein-Eliel equation, Curtin-Hammett principle. Stereoselectivity: Classification, terminology, principle of stereoselectivity, examples of diastereoselectivity and enantioselectivity including few examples from pericyclic reactions. Circular dichroism, ORD, cotton effect, application of ORD and CD in steriods, examples illustrating the usefulness of Cotton effect. Reaction mechanisms: Definition of reaction mechanism, transition state theory, kinetics, qualitative picture. Substituent effects, linear free energy relationships, Hammett equation and related modifications. Basic mechanistic concepts like kinetic vs thermodynamic control, Hammond postulate, Curtin-Hammett principle, isotope effects, general and specific acid-base catalysis, and nucleophilic

catalysis. Nucleophilic substitution: various types, stability and reactivity of carbocations, nucleophilicity and basicity, neighbouring group participation and rearrangements, steric effects in substitution reactions, classical and non-classical carbocations. Rearrangements: neighboring group participation, ring expansion, carbocation, pinacol, dienone-phenol, benzilic, Favorskii, Baeyer-Villiger and Beckmann rearrangements.

CY5011 2
Organic Chemistry Practicals

Advanced Organic Chemistry Practicals

CY5020 3
Advanced Organic Chemistry of Multiple Bonds

Alkenes and alkynes synthesis; Alkenes and alkynes applications; Pericyclic reactions; Carbonyl compounds

CY5030 3
Spectroscopy and Applications

Nuclear Magnetic Resonance Spectroscopy: NMR phenomenon, spin 1/2 nuclei, 1H, 13C, 19F and 31P, Zeeman splitting, Boltzmann distribution, effect of magnetic field strength on sensitivity and resolution. 1H-NMR, chemical shift, anisotropic effects, chemical and magnetic equivalence, coupling constants. Karplus relationship of J on dihedral angle, first order splitting patterns and structure correlation. Second order effects on the spectrum, AB, AMX, AA'BB' spin systems, simplification of second order spectra. High field NMR, double irradiation, selective decoupling, chemical shift reagents. 13C satellites. - 13C-NMR, natural abundance, sensitivity. Introduction to FT technique, relaxation phenomena, NOE effects, 13C chemical shifts and structure correlations, off-resonance spectrum. - Dynamic processes by NMR, restricted rotation (DMF, DMA, biphenyls, annulenes), cyclohexane ring inversion, degenerate rearrangements (bullvalene and related systems), examples from few organometallic systems. Significance of coalescence temperature. - Introduction to 31P and 19F NMR. Infrared and Raman spectroscopy: Vibrational modes, group frequencies of organic, inorganic and organometallic systems, factors affecting the group frequencies, study of hydrogen bonding effects, vibrational spectra of ionic, coordination and metal carbonyl compounds. Mass spectrometry: Basic principle, ionization methods, isotope abundance, molecular ions, fragmentation processes of organic molecules and deduction of structural information, high resolution MS, introduction to soft ionization techniques and illustrative examples in macromolecular and supramolecular chemistry. Electronic spectroscopy: Electronic levels and types of electronic transitions in organic, inorganic and organometallic systems, solvent effects, effect of extended conjugation, Woodward-Fieser rules for calculation of absorption maximum, stereochemistry and electronic absorption.

CY5110 3
Concepts in Inorganic Chemistry

Atomic structure, wave-particle duality, Schrodinger equation, hydrogen atom energy levels, wavefunction and orbitals, multi-electron atoms, the periodic table and periodicity in properties: ionization potential, electron affinity, ionic radii and electronegativity. Lewis structures, formal charge and resonance, the shape of molecules, VSPER theory, valence bond theory and hybridization, molecular orbital theory, thermodynamics- bond and reaction enthalpies, chemical equilibrium, solubility and acid-base theory, acid-base equilibrium, salt Solutions and Buffers, acid-base titrations, oxidation-reduction and electrochemical cells, chemical and Biological oxidations, transition metals chemistry, crystal field theory, kinetics rate laws, magnetism and spectrochemical theory, nuclear chemistry and chemical kinetics.

CY5111 2
Inorganic Chemistry Practicals

Advanced Inrganic Chemistry Practicals

CY5120 3
Solid State Chemistry

X-ray diffraction, principles of inorganic crystal structures, crystal chemistry and bonding in solids; preparative methods, characterization of inorganic solids: application of physical techniques, thermal analysis, electronic properties and band theory: metals, semiconductors, inorganic solids, colour, electrical, magnetic, thermal, and optical properties

CY5130 3
Advanced Inorganic Chemistry

Objectives: A detailed look at coordination, electronic spectra and reaction mechanism of transition metals Topics to be tentatively covered: Coordination chemistry: Derivation of term symbols, nephelauxetic effect, Orgel and Tanabe-Sugano diagrams, Chiral complexes, ORD, CD, MCD. Reaction Mechanism: Trans effect, substitution reactions of octahedral and square planar complexes; Atom transfer and electron transfer reactions; Taube complex. Organometallics: History of organometallic chemistry, structure of TM complexes, ligands, hepaticity, "18-electron rule", bonding and orbital theory, cluster and

		M-M bonds, reaction mechanisms, synthesis of metal carbonyls and complexes, metal alkyl and hydride complexes, metal carbene complexes, multiple bonding between TMs, pi-complexes, metallocenes, main group OM chemistry. Carbonylation of alcohols, hydrogenation of alkenes, hydrofirmulation, alkene and alkyne metathesis. oligomerization and polymerixation of alkenes and alkynes.
CY5210 Electrochemistry and Chemical Kinetics	**3**	Basic electrochemistry (Nernst equation, concentration cells), Debye-Huckel theory, Debye-Huckel-Onsager equation, ion transport in solution: migration, convection and diffusion: Fick's laws of diffusion, ion-solvent interactions, ion-ion interactions, electrode-electrolyte interface phenomena, problems based on diffusion and DH theory, the Helmholtz-Perrin, Guoy-Chapman and Stern models, polarization and overpotential, Butler-Volmer Equation, systems of technological interest (e.g. Electrolytes for Electrochemical Cells).
CY5211 Physical Chemistry Practicals	**2**	Experiments in Physical Chemistry covering First order and second order kinetics, activation energy, Freundlich adsorption, conductometric and pHmetric titrations, distribution coefficient and equilibrium constant determination, phase diagram of a three component system, viscosity determination, study of systems with lower and upper CSTs, and mini-projects based on electro- and chemical- polymerization of aniline, study of the redox reactions and the different forms of PANI by cyclic voltammetry and UV-vis spectrscopy or preparation of silver nanoparticle colloids, and understanding the dependence of band ga on particle size using UV- vis spectroscopy, electrodeposition of Ni / NiOx films and study of their elecrochemical and optical properties.
CY5230 Statistical Thermodynamics and Surface Science	**3**	Surface Science: Interaction of radiation with matter, electronic transitions, Frank-condon principle, Jablonski diagram, basics of fluorescence (Stern Volmer equation, quenching etc), phosphorescence, delayed fluoresence (temperature effect, E and P, TADP), lifetime, applications of fluorescence, block diagram of spectrofluorometer, basics of photochemistry (with examples like C-H bond activation), photochemical reactions with examples, basics of lasers, theory of laser action, types of lasers (solid, liquid and gas, with detailed examples on their working), application of lasers, surface spectroscopy: XPS, AES and UPS. Types of statistics: Maxwell Boltzmann, Bose-Einstein, Fermi-Dirac statistics, Partition Functions: translational, rotational, vibrational, electronic and nuclear, Thermodynamics properties of monoatomic, diatomic gases considering distinguishable and indistinguishable particles, molar partition function of a system, partition function of a real gas, equilibrium constant of an ideal gas reaction, Einstein and Debye Theory of heat capacities, phase space, Ensembles, Entropy, Gibbs Paradox, Introduction to Quantum statistical mechanics.
CY5240 Quantum Chemistry and Molecular Spectroscopy (phd)	**3**	Introduction: importance, historic background, quantum mechanics vs classical mechanics, Failure of classical mechanics, wave particle duality, uncertainty principle. Postulates, Schrödinger equation: wave function and interpretation, time dependent and time independent Schrödinger equation, eigenvalue problem. Quantum mechanics of some simple systems: free particle, particle in a box, harmonic oscillator, Angular Momentum: rigid rotor, orbital and spin angular momentum. Hydrogen and hydrogen like atoms, Approximate methods: perturbation theory, variational method, some simple examples. Many electron, atom: Pauli anti symmetry principle, Slater determinant, He atom, Li atom, Vibrational and Rotational spectroscopy. Reference Books: (1) I. N. Levine, Quantum Chemistry, (2) D. A. McQuarrie, Quantum Chemistry, (3) D. A. McQuarrie, J. D. Simon, Physical Chemistry: A molecular approach, (4) P. W. Atkins, Molecular Quantum Mechanics
CY5250 Chemical Binding and Molecular Symmetry	**3**	Review of basic principles of quantum theory and atomic structure. Electronic structure of many electron atoms and variation principle. Electronic structure of diatomic molecules. Born-Oppenheimer approximation, H2+ ion, electronic term symbols, valence bond(VB) theory of diatomic molecules, comparison of VB and MO theories. Hartree-Fock theory of atoms and extension to molecules. Self Consistent Field (SCF) wavefunctions for diatomic molecules, configuration interaction(CI) wave functions. Electronic structures of polyatomic molecules. Basis functions. SCF-MO treatment of simple molecules, Koopmans theorems. Introduction to electron correlation. Mller-Plesset (MP) perturbation theory and CI calculations. Virial and Hellmann Feynman theorems. Huckel theory applied to conjugated molecules. Electron density theory, Semi-empirical methods, Molecular mechanics and Force fields, Operations and symmetry elements, The symmetry classification of molecules, Some immediate consequences of symmetry, Applications to molecular orbital theory and spectroscopy, Character tables and symmetry, labels, Vanishing integrals and orbital overlap, Vanishing integrals and selection rules.
CY6010	**3**	Basic retrosynthetic analysis: Basic principles and terminology of retrosynthesis,

Synthetic Methodology in Organic Chemistry	synthesis of aromatic compounds, one group and two group C-X disconnections, one group C-C and two group C-C disconnections, amine and alkene synthesis, important strategies of retrosynthesis, functional group transposition, important functional group interconversions. Nucleophilic C-C bond forming reactions: organometallic reagents of lithium, magnesium, copper, chromium and iron. Umpolung reagents, definition of umpolung, acyl anion equivalent, equivalents of ketene, RCOCH2+, RCOCH2CH2CH2+, RCOCH2CH2CH2□ etc. C-C bond formation via free radicals and carbenes: methods of generation of free radicals and carbenes, reactions of free radicals, coupling, addition, substitution, fragmentation and rearrangements. C-C bond formation using tin reagents: Protecting groups, protection of hydroxyl, carboxyl, carbonyl, amino groups. Protection of carbon-carbon multiple bonds. Illustration of protection and deprotection in synthesis. Protecting groups: Protection and deprotection of hydroxy, carboxyl, carbonyl, carboxy amino groups and carbon-carbon multiple bonds; chemo- and regioselective protection and deprotection; illustration of protection and deprotection in synthesis.
CY6015 **0** MSc Project	Research project with a Thesis, where a student works (experimental or theoretical) on a topic from Organic or Inorganic or Physical Chemistry
CY6016 **12** MSc Project 2	Research project with a Thesis, where a student works (experimental or theoretical) on a topic from Organic or Inorganic or Physical Chemistry
CY6110 **3** Metals in Biological Systems	Metal ions in biology: metallo-proteins and enzymes containing Mg, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo and W ions. heme and non-heme systems, Peptide and nucleotide hydrolytic enzymes, Metal environment, electronic, magnetic and redox properties; fixation of N2, water-oxidation reactions, Synthetic models for the structure and function of the above enzymes, syntheses of ligand-metal complexes, reactivity of O2, CO, NO, N2; mechanistic aspects, high-valent metal-oxo (Fe-, Mn- and Cu) systems, Interaction of metal ions with nucleotides and peptides, hydrolysis of phosphate and amide groups, Metal based drugs, environmental applications and toxic effects.
CY6211 **3** Advance Laboratory Techniques in Chemistry	This course is an intensive introduction to the advanced techniques of experimental chemistry and gives master students an opportunity to learn and master the basic chemistry lab techniques for carrying out experiments. Designated experiments for the development of synthesis, purification, analytical, characterization, spectral and electrochemical aspects skills with diverse areas of Inorganic Chemistry such as Coordination Chemistry, Organometallic Chemistry and Bioinorganic Chemistry etc. Measurements of superconducting properties of Oxides and Chalcogenides compounds. Multistep synthesis of a natural biomolecule: Retrosynthesis analysis, development of synthetic strategy, characterization and investigation of functional properties. Quantitative measurements of experimental parameters, such as rate constants, critical micelle concentration, redox potentials etc. using UV-VIS, Fluorescence, FT-IR spectroscopic methods and cyclic voltammetry. Text References Lab. Manuals/Instrument Manuals of Equipment's available in the Department.
CY6220 **3** Physical Methods in Chemistry	Rotational spectroscopy, Vibrational Spectroscopy, Selection rules, Vibrational-Rotational spectra, Morse Potential. Raman spectroscopy, electrical and magnetic properties of molecules, NMR, FT-NMR, Relaxation processes in NMR, ESR spectroscopy, Kramers degeneracy, Mossbauer spectroscopy.
CY6XXX **3** Free Elective	None

29.10 Department of Design

DS5013 **3** Design Fundamentals	The course will look at the building blocks of design such as space /point / line/ shape / value / texture / form. To understand perceivable and non-Perceivable elements of design with explorations on individual elements. It will offer an overview of principles of design basics such as balance, rhythm, harmony, contrast, symmetry, emphasis, scale, proportion, size, plane, volume, pattern, materials, drawing, color, composition and geometry. Understanding form and functionality correlation. Also an overview of Design Process with Basics of Design Methods. Basic colour theories and application of color modes such as additive and subtractive colours, and different colour models. Application of colour and colour mixing. (Hands-on course)
DS5020 **3**	The course is an attempt to look at the history of design and major turning points that

History of Art and Design		lead to what it is today. It also deals with the history of art from prehistoric to present. Understanding of design schools and key contributors for the evolution of design education and system. This will also give an overview of Semiotics, Aesthetics, Material Culture, theoretical approach to Image making and contemporary concerns and communication studies.
DS5033	**3**	A course about various methods, morphology and stages in design process - user studies, conceptual design, embodiment, detailing, functional, innovation and creative methods. Also an overview of Design Process with Basics of Design Methods, Design Issues, Various theoretical insights on methods, empirical and visual methods, methodology for documenting collective activity, design research and its argumentative grammar.
Design Process and Methodology		
DS5064	**1**	This course will give an overview of different types and techniques of drawing methods and visualization. Understanding various art materials, usage and visualization techniques. The course looks at intervention through design drawing tools, getting to understand observation and conveying through drawings in a systematic way.
Design Drawing and Sketching		
DS5076	**1**	Lectures from the industry experts.
Design Lecture Series		
DS5086	**2**	None
Internship		
DS5103	**3**	This course will deal with all the basics of Graphic Design and Information Design - Typography, Publication design, Branding and Identity, environmental graphics, information and data visualization. Basic Graphics introduces abstracting visual information in the form of pictograms, icons, symbols and together with typography how it creates a visual experience. Extending the exposure in typography and graphics to create strong publications in print media in the form of magazines, newspapers and books. While in Branding, the objective is to understand brand strategies, market and to learn how to create strong identity design/ logos, print ads, stationery, business cards, that support and enhance the brand with the aid of various graphic applications and communicate the brands message to a larger audience. Information and Data Visualization is to understand the increasing quantity and complexity of data and information produced, to filter information, organize, represent, establish relationships and discern patterns, to develop inspiring and stimulating solutions to contextualize information that simultaneously inspire, inform, entertain and even encourage critical thinking.
Graphics and Information Design		
DS5153	**3**	An introductory course in interactive media and its possibilities to students of any background. How content can be generated, effectively create the information architecture and user experience in the digital medium. It will also deal with Micro interactions, web and interactivity.
Interaction Design, Ai, Virtual Environments		
DS5173	**3**	The course introduces you to the powerful medium of photography, the technical aspects related to the equipment and delivery of the content. It introduces studio photography using artificial lights and street photography in natural light. It also introduces composition and various storytelling techniques in photography. Analog photography, historic practices, digital photography, tools, techniques, contemporary photographic practices, GIS.
Photography and Imaging		
DS5183	**3**	The course introduces the elements that make up the film such as creating script, storyboarding, art direction, cinematography, lighting, sound, editing etc. It introduces the technical aspects through hands-on experience in each of these elements. Understanding cinematic language and practicing it through making a film.
Film Making		
DS5233	**2**	The course aims to equip students in Design with tools and frameworks to think/reflect on images. Critical theory and popular media, social media and the circulation of images, images via production of space, performance theory, aesthetics, immersive media, film theory, architectural theory, theories of practice, theory vs practice in Design, creative labour, customer /audience/client.
Contemporary Visual Culture		
DS5253	**3**	The course introduces the principle of sustainability in design, the prevalent issues (world / India), approaches towards addressing sustainability, models, methods and tools to analyze and intervene. It uses lifecycle analysis methods and tools to understand simple and complex issues involved in designing of products, components, packaging, and their disposal, etc. Each decision made for any products has certain impact on the environment and alters ecological balance in some degrees. The course intends to deliver a sensitivity of responsibility, accountability and ownership while being a designer and
Strategies for Sustainable Design		

architect. Course is developed to how ecological design and planning strategies can be developed in a responsive manner for human needs and biosphere. The design for sustainability offers learning opportunities to enrich design process with ecological sensitivities, working along with nature, stimulate natural systems for design and development of resilient, responsive, and regenerative designs.

DS5313 3
Moving Images and Animation

This course introduces the principles of animation and how to physically achieve it using classic animation methods. The participant is also introduced to diverse techniques and materials in animation such as claymation, sand animation, stop motion etc. The course can extend to designing characters for animation. This course deals with 12 Principles of Animation, Squash and Sketch, Anticipation, Staging, Straight Ahead Action and Pose to Pose, Follow Through and Overlapping Animation, Slow-In and Slow-Out, Arc, Secondary Action, Timing, Exaggeration, Solid Drawing, Appeal. Oil on Glass, Sand Animation, Charcoal on Glass, Stop Motion, Clay Animation, Puppet Animation, White Board Animation, Paper Cut Out Animation, Light Animation and Pixilation. Film language, Elements of Video, multimedia, sound, editing, narrative theory, script writing and storytelling.

DS5323 3
Space Design

Designing a conscious, pleasant environment in public and private spaces considering all aspects of sustainable practices in Space, Architecture and horticulture.

DS5333 3
Product Semantics

The course intends to introduce the basics of product semantics with other elements like semiotics, aesthetics, cultural and emotional dimensions of product design. The development of form in relation to meaning making. Affordance, Color, Shape and Form, Gestalt, and analysis of product in the context of product semantics principles.

DS5343 3
Advanced Materials Design

This course aims to teach students knowledge of advanced materials and processes from a design perspective. With a theoretical and hands-on experimental approach, students comprehend all the different possibilities that the industry provides to transform matter. Materials Overview, Classification, Properties and usage of thermoplastics, thermosetting plastics. Process of selection and applications of plastics for engineering and consumer products. Design Limitations and specific advantages of plastic modelling processes. Concepts of structure and costing. Significance of form in structural strength of products. Influence of materials and processes on product aesthetics. Industrial finishes for plastic, wood and metals. Properties and use of rubber, ceramics and glass. Overview of natural materials- wood, bamboo, cane, leather, cloth, jute and paper and their use at craft and industrial levels

DS5353 3
Ergonomics for Industrial Designers

Overview of ergonomics and design relevance; Man- the prime system component; Man machine- environment interaction system and user-friendly design practice; Human compatibility, comfort and adaptability; Fundamentals of ergonomics: Physical (anthropometrics, human body- structure and function, posture, movement and biomechanics), Physiological (work physiology) and Psychological aspects (behavior, cognitive aspects and mental workload); Information processing, human error and risk perception; Visual performance and visual displays; environmental factors influencing human performance; Occupational stress; safety and health issues; Ergonomics criteria/check while designing; Design process involving ergonomics check and ergonomic design evaluation and Participatory ergonomics aspects.

DS5363 3
Curating Design

This course shall provide skills and opportunities to conceptualise and string together artefacts, practices and discourses to create newer, alternative narratives of Design in the global south.

DS5373 3
Inhabitants, Users, Subjects

Constructing the user, Couplings of the user and objects/systems, co-evolution, cultural impact, Commodities and cultural exchange, Interactive systems and Objects, Design systems and it's subjects, habitus and affordance.

DS5383 3
Technology and Experience

This course intends to take the participants through the philosophical issues, conflicts and discourse around art, technology and its experience: The intermediate space of art, technology and its' experience, history, contemporaneity, intertwinedness, the rise of the Experience economy, philosophical problems in the zone between Technology and Experience.

DS5403 3
Digital Storytelling

How information can be represented and narrated in the age of digital experience for a variety purposes from education to journalism. Convergence of media in digital platforms have made it challenging for designers to create sustaining story experiences in digital media. The course intends to create compelling narratives using possibilities of multimedia in digital world.

DS5413 3

The course introduces to various types of user interfaces and its user experiences. The

UI and UX		course allows the students to ideate and create newer models of user interfaces for usability, accessibility and sensory experience.
DS6076 Design Research Seminar	**2**	The course focuses on the research methodologies understanding in design studies. Students will explore research techniques in different domains of design and present the outcome as a seminar series. The peculiarities of research in understanding and practising design - the heuristic, creative and systematic approaches to doing research both in and through Design. Introduction to Design Research Methodology, Qualitative and quantitative approach, Statistical techniques for design research, Research Clarification, Descriptive Study I, Prescriptive Study, Descriptive study II. Theories and Models in Design, Proto theory, FBS and other models.
DS6080 Entrepreneurship Skills	**2**	The course will give an overview of Best practices in the industry, Accounting, IPR, proposal making and budgeting to turn budding designers into successful entrepreneurs. Essentially deals with the management of a design firm. Course looks at how the design industry works and process and logistics can be managed keeping in mind the peculiarities of this creative industry. It intends to provide a glimpse of the business aspect of design. The aim is to equip the students with the skill of drawing up and proposing business plans and start-ups.
DS6115 Final M.des Project	**12**	Independent project which involves meta-level system design component. It's the culmination of all the theoretical and practical learning applied to a final project for which the output could be in the chosen specialised area by the student. There will be a thesis component and final product / prototype based on the chosen medium.
DS6205 Specialization Project 2	**3**	This independent project in the third semester is oriented towards encouraging the student to design a final output in terms of a product, film, book, etc showing their understanding of the earlier courses.
DS6225 Specialization Project 1	**3**	Independent project that encourages the student to make an artefact based on the methods and materials explored in the first and second semester course work involving film-making, photography, product, graphic project and form exploration.
DS6245 Design Studies Project	**5**	This is a research based project in which the student takes up a research topic and explores the design dimensions. They are expected to submit an exclusively written thesis as opposed to an Artefact-based project.

29.11 Department of Design by Practice

DS5019 Design Fundamentals	**3**	Through a project-based teaching and learning, the course will look at the building blocks of design such as space /point / line/ shape / value / texture / form / color. It will help in the overall understanding of perceivable and non-Perceivable elements of design with explorations of individual elements. The course will also offer an overview of principles of design basics such as balance, rhythm, harmony, contrast, symmetry, emphasis, scale, proportion, size, plane, volume, pattern, materials, drawing, colour, composition and geometry. Understanding form and functionality correlation.
DS5029 History of Design	**3**	The course is an attempt to look at the history of design and the major turning points that lead to what it is today. It also deals with the history of art from prehistoric to the present. Understanding of design schools and key contributors to the evolution of design education and system. This will also give an overview of Semiotics, Aesthetics, Material Culture, theoretical approach to Image making and contemporary concerns and communication studies.
DS5039 Design Process and Methodology	**3**	A course about various methods, morphology and stages in the design process - user studies, conceptual design, embodiment, detailing, functional, innovation and creative methods. Also an overview of the Design Process with Basics of Design Methods, Design Issues, Various theoretical insights on methods, empirical and visual methods, methodology for documenting collective activity, design research and its argumentative grammar.
DS5069 Design Drawing and Sketching	**1**	This course will give an overview of different types and techniques of drawing methods and visualization. Understanding various art materials, usage and visualization techniques. The course looks at intervention through design drawing tools, getting to understand observation and conveying through drawings in a systematic way.
DS5079 Design Lecture Series	**1**	The course aims to connect students with industry professionals and design domain experts to learn about industry work culture, needs and expectations.

DS5109 3 Graphics and Information Design	This course will deal with all the basics of Graphic Design and Information Design - Typography, Publication design, Branding and Identity, environmental graphics, information and data visualization. Basic Graphics introduces abstracting visual information in the form of pictograms, icons, symbols and together with typography how it creates a visual experience. Extending the exposure in typography and graphics to create strong publications in print media in the form of magazines, newspapers and books. While in Branding, the objective is to understand brand strategies, market and to learn how to create strong identity design/ logos, print ads, stationery, business cards, that support and enhance the brand with the aid of various graphic applications and communicate the brands message to a larger audience. Information and Data Visualization is to understand the increasing quantity and complexity of data and information produced, to filter information, organize, represent, establish relationships and discern patterns, to develop inspiring and stimulating solutions to contextualize information that simultaneously inspire, inform, entertain and even encourage critical thinking.
DS5159 3 Interaction Design, Ai, virtual Environments	An introductory course in interactive media and its possibilities to students of any background. How content can be generated, effectively create the information architecture and user experience in the digital medium. It will also deal with Micro interactions, web and interactivity.
DS5179 3 Photography and Imaging	The course introduces you to the powerful medium of photography, the technical aspects related to the equipment and delivery of the content. It introduces studio photography using artificial lights and street photography in natural light. It also introduces composition and various storytelling techniques in photography. Analog photography, historic practices, digital photography, tools, techniques, contemporary photographic practices, GIS.
DS5189 3 Film Making	The course introduces the elements that make up the film such as creating script, storyboarding, art direction, cinematography, lighting, sound, editing etc. It introduces the technical aspects through hands-on experience in each of these elements. Understanding cinematic language and practicing it through making a film.
DS5239 2 Contemporary Visual Culture	The course aims to equip students in Design with tools and frameworks to think/reflect on images. Critical theory and popular media, social media and the circulation of images, images via production of space, performance theory, aesthetics, immersive media, film theory, architectural theory, theories of practice, theory vs practise in Design, creative labour, customer /audience/client.
DS5259 3 Strategies for Sustainable Design	Discusses sustainability principles and concepts from across places. Elaborates on sustainability definitions, aspects, dynamic nature of it, and its application in everyday life. Further, it discusses global efforts from UNFCCC and other agencies for developing context-based solutions. Involves field visits, real-life case studies, and assignments. Includes study on building technologies to improve on thermal, light, wind performances. Focusses basic scientific principles underlying the environmental performance of the built environment and designing for efficiency. Focuses on improving the ambient atmosphere in the built environment using design techniques.
DS5319 3 Moving Images and Animation	This course introduces the principles of animation and how to physically achieve it using classic animation methods. The participant is also introduced to diverse techniques and materials in animation such as claymation, sand animation, stop motion etc. The course can extend to designing characters for animation. This course deals with 12 Principles of Animation, Squash and Sketch, Anticipation, Staging, Straight Ahead Action and Pose to Pose, Follow Through and Overlapping Animation, Slow-In and Slow-Out, Arc, Secondary Action, Timing, Exaggeration, Solid Drawing, Appeal. Oil on Glass, Sand Animation, Charcoal on Glass, Stop Motion, Clay Animation, Puppet Animation, White Board Animation, Paper Cut Out Animation, Light Animation and Pixilation. Film language, Elements of Video, multimedia, sound, editing, narrative theory, script writing and storytelling.
DS5329 3 Space Design	Designing a conscious, pleasant environment in public and private spaces considering all aspects of sustainable practices in Space, Architecture and horticulture.
DS5339 2 Product Semantics	The course is intended to build a broad understanding of the interactions and behaviour of the users with products through which they explore the associated meanings. By understanding this process, the designers can craft unique experiences.
DS5349 3 Advanced Materials in	This course aims to teach students knowledge of advanced materials and processes from a design perspective. With a theoretical and hands-on experimental approach, students

Design

comprehend all the different possibilities that the industry provides to transform matter. Materials Overview, Classification, Properties and usage of thermoplastics, thermosetting plastics. Process of selection and applications of plastics for engineering and consumer products. Design Limitations and specific advantages of plastic modelling processes. Concepts of structure and costing. Significance of form in structural strength of products. Influence of materials and processes on product aesthetics. Industrial finishes for plastic, wood and metals. Properties and use of rubber, ceramics and glass. Overview of natural materials- wood, bamboo, cane, leather, cloth, jute and paper and their use at craft and industrial levels

DS5369 **3**
Experimental Typography

Typography is a constant evolving discipline. Apart from the conventional two-dimensional printed form, designers have explored it in three-dimension with texture, perspective and motion (kinetic) to make it expressive and impactful. The course will start with basic understanding about the letterforms and its use. Further, it will advance towards psychological, semantic and expressive value of typography and its applications. This will encourage students to break from the conventional typography and help them to experiment and innovate to understand the Experiential and Spirited aspects of typography.

DS5379 **3**
Data and Information Visualization

We are living in the age of information explosion. Designers can play an active role in making the huge volume of information intelligible to users. The objectives of the course are to understand the increasing quantity and complexity of data and information produced, to filter information, organize, represent, establish relationships and discern patterns, to develop inspiring and stimulating solutions to contextualize information that simultaneously inspire, inform, entertain and even encourage critical thinking.

DS6079 **3**
Design Research Seminar

The course focuses on the research methodologies understanding in design studies. Students will explore research techniques in different domains of design and present the outcome as a seminar series. The peculiarities of research in understanding and practising design - the heuristic, creative and systematic approaches to doing research both in and through Design. Introduction to Design Research Methodology, Qualitative and quantitative approach, Statistical techniques for design research, Research Clarification, Descriptive Study I, Prescriptive Study, Descriptive study II. Theories and Models in Design, Proto theory, FBS and other models.

DS6089 **2**
Entrepreneurship Skills/startups

The course will give an overview of Best practices in the industry, Accounting, IPR, proposal making and budgeting to turn budding designers into successful entrepreneurs. Essentially deals with the management of a design firm. Course looks at how the design industry works and process and logistics can be managed keeping in mind the peculiarities of this creative industry. It intends to provide a glimpse of the business aspect of design. The aim is to equip the students with the skill of drawing up and proposing business plans and start-ups.

DS6119 **12**
M.des Thesis Part II

Independent project which involves meta-level system design component. It's the culmination of all the theoretical and practical learning applied to a final project for which the output could be in the chosen specialised area by the student. There will be a thesis component and final product / prototype based on the chosen medium.

29.12 Department of Electrical Engineering

29.13 Department of Entrepreneurship and Management

EM5020 **1**
Innovation Management
▷Students who have registered for Minor in Entrepreneurship and MTech Techno-Entrepreneurship Students

Module 1: Introduction to Innovation Management Topics: What is Innovation? why is it important to innovate?, innovation process, types of innovation, innovation and strategic intent; sustainable competitive advantage through innovation Module 2: Sources of Innovation Topics: Sources of Innovation and Role of Information, Technology and Knowledge Transfer for Innovation, Innovation and Entrepreneurship Module 3: Systems Thinking and Innovation Topics: Concept of Systems Thinking, Role of Systems Thinking in Innovation, Using Systems Thinking to Innovate Module 4: Design Thinking and Innovation Topics: Concept of Design Thinking, Design Thinking Vs Design/Designing, Role of Design Thinking in Innovation, Using Design Thinking to Innovation Module 5: Chaos and Innovation Topics: Introduction to Chaos Theory, Concept of Fractals, Identifying Opportunities in Chaos to Innovate, Chaos and Entrepreneurship, Chaos and Innovation Module 6: Diffusion of Innovation Topics: Uncertainty matrix, stages in diffusion of innovation, adoption of innovation, Role of innovation in emerging markets

EM5040 **1**

History and Importance of Game Theory for Entrepreneurship; The theory of rational

Game Theory for Startups ▷Students who have registered for Minor in Entrepreneurship and MTech in Techno-Entrepreneurship Students.	choice; Introducing popular games and pay off matrices: Prisonner's Dilemma, Bach or Stravinsky, Matching Pennies, Stag Hunt; Nash Equilibrium; Best response functions, Pure and Mixed Strategies, Perfect and Imperfect games
EM5080 1 Introduction to Marketing	Introducing Marketing and Marketing Process, Executing Marketing Research, Understanding the Marketplace and Customer Value, and Creating and Managing Customer Value – Driven Strategy and Mix
EM5090 3 Accounting and Finance for Entrepreneurs	Basics of Financial Accounting, Cost Accounting and Management Accounting; Entrepreneurial Environment: Entrepreneurial process, Role of finance in Entrepreneurship, Fundamentals, Sources, and principles of entrepreneurial finance, Financial testing of the Business Model, Venture capital cycle, Financing through VC cycle, Developing the business idea. Organizing and Operating the Venture: Progressing through the business life cycle, Forms of business organization, Choosing the form of organization financing a new venture, Intellectual property rights, Preparing and using financial statements, and evaluating operating and financial performance-cash burn rates, Liquidity ratios, conversion period ratios, Leverage ratios, Profitability ratios, and Industry comparable ratios. Venture Valuation Methods: Financial planning throughout the venture life cycle, Types and costs of financial capital, Securities Law considerations when obtaining venture financing. Myths About New Venture Valuation, Discounted Cash Flow Valuation, The Relative Value Method, Venture Capital valuation Method, CAPM Valuation with Discrete Scenarios. Structuring Financing for the Growing Venture: Organizing new fund, soliciting investments in the new fund, other financing alternatives: Foreign investor funding sources, small business administration programs (SBAs), Vendor financing, Mortgage lending, Security structures, and Determining enterprise value. Exit and Turnaround strategies: Planning an exit strategy: Harvesting the business venture investment, Valuing the equity or valuing the Enterprise, Systematic liquidation, Going Public (IPOs). Turnaround opportunities and strategies, Troubled venture and financial distress Resolving financial distress situations (Insolvency), Private workouts, and Liquidations.
EM5110 1 Foundations of Techno-entrepreneurship	Module 1: Introduction to Techno Entrepreneurship - Meaning and Context of Techno Entrepreneurship; Understanding Entrepreneurship in High Technology domain; Opportunities for Techno Entrepreneurship; Need for Techno Entrepreneurship; Techno Entrepreneurship in India. Module 2: Understanding Entrepreneurial Mindset Entrepreneur, Enterprise and Entrepreneurship; Entrepreneurial journey, engineer/scientist to entrepreneurship, Risks and rewards in Entrepreneurship, Traditional Vs. New Age Approaches of Entrepreneurship. Module 3: Need Assessment and Opportunity Identification - Need, Want and Demand; Need Assessment Process, Invention to Innovation, Select Cases in Information and Communication Technology, Healthcare, Electronics. Module 4: Basics of Competition and Cooperation Meaning of competition; defining competitive set; competition Vs. cooperation; need for cooperation; modes of cooperation; coopetition and entrepreneurship Module 5: Managing Techno Entrepreneurship - Basics of Business Model; Business Model Canvas; Introduction to Need for understanding Marketing, Finance, Human Resource Management, Operations Management for Entrepreneurship.
EM5120 1 Economics for Technocrats	Module I: Introduction to Managerial Economics. The problem of what, how and for whom to produce; Basic economic concepts and their uses in business decision making – Opportunity Cost, Marginal/Incremental principle, Discounting principle - NPV, Equi-Marginal Principal; Markets, Price and Equilibrium; Case on Tax on Fast Food Containers Module 2: Consumer behavior. Theory of Demand, Demand Function, Elasticity of Demand – Types - Price, Income, Cross and Promotional –Measurement of elasticity. Demand Forecasting- techniques and its use in business planning and decision-making Module 3: Production and Costs – Total, marginal and average product, Production in the short run - Law of Variable Proportions. Types of production functions- Theory of Cost and Revenue- Cost concepts- Accounting and Economic costs. Module 4: Markets: Perfect and Imperfect- price output determination, Perfect Competition, Imperfect Competition - Monopolistic Competition, Ologopoly, Duoploly; Monopoly Module 5: Macro economic environment and impact on business; National Income and Related Aggregates – Consumption, Investment and Savings, Concepts and Measurement of National Income and issues in computing NI. Practical Applications of Macro Economic Aggregates in Business
EM5130 1	The Context of Leadership, Managers Vs Leaders, Leadership and entrepreneurship,

HR and Leadership	Self-leadership, followership, empowerment, building positive work culture and trust and power dynamics.
EM5650 **1** Introduction to Sales and Marketing	Marketing, sales, needs/wants/demand; What is value? How to define value proposition?;Segmentation, Targeting Positioning; Pricing Strategies; Primer on Digital Marketing. How is it different?; Go-To-Market Strategies; What is Customer-Centricity?
EM6010 **3** Strategic Management ▷EM PG Students, MTech Techno-Entrepreneurship Students	Module 1: Introduction to Strategic Management - Topics: Introduction to Strategy and Strategic Management, Process and Content of Strategy, Introduction to Competitive Advantage and Sustainable Competitive Advantage and Introduction to Strategic Intent - Vision and Mission. Module 2: External and Internal Analysis - Topics: Understanding the General Environment, Analysing the Industry Environment and Competitor Analysis, Need for Internal Analysis, Tools for Internal Analysis – BCG Matrix, SWOT Analysis, Value Chain Analysis and Balanced Scorecard Module 3: Strategy Formulation: Business-Level Strategy; Topics: Concept of Business unit, Corporate and Conglomerate, orter's Generic Strategies, Cost Leadership and its Pitfalls, Differentiation and its Pitfalls, Quick Response/Focus and its Pitfalls and Combination Strategy. Module 4: Strategy Formulation: Corporate-Level Strategy and International Strategy; Topics: Introduction to Corporate and Conglomerate; Ansoff Matrix; Levels of Diversification; Types of Diversification; Adjacency Strategy; Modes of Diversification – Organic and Inorganic; Divestiture, Liquidation and Termination, Motives and Risks of Internationalization, Diamond Model, CAGE Analysis and Uppsala Model, Born Global Firms and Ethical Issues in Internationalization. Module 5: Blue Ocean Strategy Topics: Red Ocean Vs. Blue Ocean, Concept of Value Innovation, Value Creation Vs. Value Capture, Creating uncontested market space, Blue Ocean Strategy and Entrepreneurship and Value Net Framework Module 6: Strategy Implementation and Control Topics: Strategy Implementation Vs. Strategy Execution, Organizational structure; Matching Structure to Strategy; Balanced Scorecard; McKinsey's 7 S framework, Strategic Control
EM6040 **3** Operational Entrepreneurship ▷EM PG Students, MTech Techno-Entrepreneurship Students	Introduction to Operations Management and Operational Entrepreneurship, Opportunities in Operations - Project Management, Process capability and statistical quality control, Facility Layouts, Capacity Planning, Facility Layouts, Just In time and Lean systems, Forecasting, Aggregate Planning, Inventory Control, Materials requirement planning, Lot Sizing, Scheduling, Theory of Constraints
EM6080 **1** Marketing for New Ventures	Marketing in New Ventures, Developing Entrepreneurial Marketing Strategies and Plan, Product Life Cycle, Creating customer demand and market for innovative new products, Competitive and Market Consideration, Adoption, diffusion and understanding lead customers, Marketing capability for new venture survival and its growth.
EM6085 **12** Project Stage I- Problem Definition and Business Plan Development and Mentoring	None
EM6090 **1** Customer Acquisition	None
EM6095 **12** Project Stage 2 – Developing a Prototype Or Proof of Concept	None
EM6096 **1** Industry Lecture	None
EM6130 **1** Introduction to Intellectual Property Rights	None
FC4658/EM4010 **1** Hr and Leadership	The Context of Leadership, Managers Vs Leaders, Leadership and entrepreneurship, Self-leadership, followership, empowerment, building positive work culture and trust and power dynamics.

LA1260 **1**
Fundamentals of Organizational Structure

Defining organizations, Dimensions of organizational structure, System perspective, life-cycle perspective, Types of structures, early stages of organizations

29.14 Department of E-Waste Resource Engineering and Management

CH5010 **3**
Computational Methods for Chemical Engineers

Review of computer programming; solutions of simultaneous linear/ non-linear equations; Newton's interpolation formula ; Quadratic formula; Systems of first order ordinary differential equations (ODEs), Stability analysis; Variable step size algorithms (Gear's algorithm etc.), Finite difference methods for ODEs (IVPs and BVPs) and PDEs (hyperbolic, parabolic, elliptic). Numerical solutions of chemical engineering problems e.g. separation processes, reaction engineering, fluid mechanics, process control, thermodynamics etc.

EW5010 **3**
Introduction to Waste Management

None

EW5100 **2**
Design Concepts of Project Capacity to a Viable Scale

Concept of Technology Readiness Levels (TRL); Project Management; Technology Commercialization: Role of Incubator, Cluster, Research Park and Consortia; Intellectual Property Protection and Management; Technology Assessment: Valuation and Pricing; Technology Development and Management; Measuring Commercialization Capability: Capital expenses, Revenue calculation; Building Commercialization Capability; Technology fusion; Sustainable Production Technologies; Case Study: Spent PCB recycling, Scale-up to Commercial Scale Recycling, Case Study: Rare Earth Recovery from Spent Permanent Magnets; Case Study: Recycling of Li ion Batteries; Availability of Raw Material and Consistency

EW5120 **2**
Swot Analysis and Risk Management

SWOT Analysis: Steps for Success with The SWOT Analysis; Influencing Factors; SWOT analysis of E-Waste sector in India; Strength: Statistics of E-Waste Generation, Demand and Need of Recycled Materials, Business Opportunities; Weakness: E-waste channelization, consumer unawareness, lack of research, poor implementation of E-waste management rules, high capital expenses for setting-up recycling facilities; Opportunity: Environment Friendly E-waste recycling, Difference between E-waste generated and recycled, start-ups in various fields of E-waste management, formalization of informal sectors; Threats: lack of E-waste awareness, Illegal processing of E-waste, health hazard and unhygienic working conditions, cost competence with informal route recycling, Effluents Management Risk Management: Risk Assessment Standards and Definitions; Risk Assessment Fundamentals; Fundamental Hazard Analysis and Risk Management: Informal Methods, Formal Methods; Industrial Hygiene Risk Assessment: Occupational Health Risk, Health Risk Assessment and Prioritization; Machine Risk Assessment: Machine Safety Standards, Machine Safeguarding, Assessment of Machine Maintenance and Service

LA5180 **1**
English Communication Skills:advanced

None

MS5390 **3**
Electrometallurgy

(A) Fundamental aspects of Electrometallurgy: Introduction (Electrometallurgy, Electrochemical principles and basic concepts, Evolution of electrometallurgy), Pourbaix diagrams, Transport properties of electrolytes (aqueous, molten and ionic solutions), Solution models (Debye-Hückel-aqueous, Temkin-molten salts), Electrode-electrolyte interface, Equilibrium electrode potential, and Potential Applications (Electronics, Automotive, Aerospace, Biomaterials and Medical Devices) (B) Electrochemical Kinetics: Electrochemical reaction kinetics and mechanism of electrodeposition, Mass transport and interfacial processes, Aspects of cementation, electrocrystallization and surface morphology of metal electrodeposits (through mathematical approach, physical model, and a realistic system), Current distribution in electrochemical cells, Electrodeposition at a periodically changing rate, Effects of additives (C) Various Electrometallurgical Processes: Electrowinning (melts electrolysis and aqueous solution electrolysis), Electrorefining (from impure metal anodes), Electroplating (metals, alloys and composites) from aqueous electrolytes, ionic liquids, and molten salts, Electroforming, Surface finishing (Electropolishing, Electromachining) (D) Electroless Deposition (Displacement deposition, Contact deposition and Autocatalytic deposition) (E)

Structure, Properties and Characterization of Electrodeposits (F) Case Studies, Industrial Practices and Challenges (energy utilization, chemical stability, productivity, and safety), Materials and Environmental issues, Industrial/Electrochemical Effluents/Wastewater Treatment (G) Electroplating: Numerical Modelling and Simulation (H) New age Electrodeposits (nanostructures, multilayers, multicomponent, etc)

MS5640 **3**
Advanced Concepts in Process Metallurgy

Principles of extraction, unit operations, material and heat balance of processes, thermodynamics of processes; introduction to laws, thermochemistry, thermodynamic equilibrium; Genesis, construction and analysis of Ellingham diagram, predominance area diagram, Eh-pH diagram and its application in extraction of various metals. Introduction to chemical kinetics and rate processes, Process kinetics: Heterogeneous kinetics, gas-solid reactions (progressive conversion, shrinking core, shrinking particle model), liquid-liquid reactions (mass transfer models), concepts of reactor design. Structure and properties of aqueous solution and molten melts (metals, slags, salts, and matte). Unit processes in pyro and hydrometallurgy. Ore Dressing; Fine separation technologies, Dry beneficiation techniques, Ironmaking; RIST model for BF and DRI, Steelmaking; concept of physical modelling and simulations, inclusion engineering in steels, construction, and analysis of inclusion stability diagram, flux design for liquid steel refining. Sustainable metallurgy; Novel use of hydrogen and CO2 in metallurgical processes, Thermodynamics and Kinetics of hydrogen and CO2 reactions, Hydrogen plasma smelting and other novel reactors, strip casting and challenges. Lunar metal/material processing; molten oxide electrolysis; thermodynamics, kinetics, and challenges in development of inert anode. Solar metallurgy; Concept, design and principle of solar concentrator/furnace and simulator for material processing. Introduction to life cycle analysis of metallurgical processes and case study.

29.15 Department of Energy Science and Technology

CH5030 **2**
Molecular Thermodynamics

None

CH5080 **3**
Advanced Transport Phenomena

None

CH6140 **1**
Petroleum Refinery

None

CH6610 **2**
Fuel Cell Technology

None

CH6860 **1**
Data Analysis Tools in Experimental Research

None

ET5010 **2**
Fundamentals of Electrochemistry

Galvanic cells, redox potential, electromotive force, electrochemical series, Nernst equation, thermodynamics of reversible electrodes/cells, concentration cells reversible to electrode/electrolyte, liquid junction potential, Faraday's laws, Electrical double layer: Helmholtz-Perrin, Guoy-Chapman and Stern models, polarization and overpotential, diffusion, electrolytic conductance and transport number, electrolytes for electrochemical cells, electroanalytical methods (cyclic voltammetry and chronoamperometry). References: 1. Modern Electrochemistry 1: Ionics, by J.M. Bockris and A.K.N. Reddy 2. Principles of Physical Chemistry, by B.R. Puri, L.R. Sharma, M.S. Pathania. 3. Physical Chemistry by P Atkins and J De Paula 4. Electrochemical Methods: Fundamentals and Applications, by Allen J. Bard and Larry R. Faulkner 5. Solid State Chemistry and its Applications, by A. R. West

ET5020 **3**
Electrochemical Energy Storage Systems: Batteries, Fuel Cells and Supercapacitors

Principles of Operation of Cells and Batteries; Electrochemical Principles and Reactions; Factors Affecting Battery Performance; Battery Design; Primary Batteries; Secondary Batteries: Advanced Lead-acid, Ni-based and lithium ion batteries (Fundamentals, Materials, Electrode preparation, Battery Assembly, Testing, Failure Analysis, Safety issues); Flow Batteries; Next Generation Batteries; Fuel cells, Supercapacitors, Selection and Application of energy storage systems for UPS, Solar, Telecom, Aerospace, Grid and

Electric Vehicle Systems.

References

1. Kirby W. Beard. Linden's Handbook of Batteries, Fifth Edition (McGraw-Hill Education: New York, Chicago, San Francisco, Athens, London, Madrid, Mexico City, Milan, New Delhi, Singapore, Sydney, Toronto, 2019). 2. Vladimir S. Bagotsky, Alexander M. Skundin and Yury M. Volfkovich (A.N. Frumkin Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Science, Russia) Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors" By, John Wiley and Sons Inc, New Jersey, USA, 2015, 372 pages, ISBN: 978-1-118-46023-6. 3. Ying-Pin Chen, Sajid Bashir, Jingbo Louise Liu, Nanostructured Materials for Next-Generation Energy Storage and Conversion: Advanced Battery and Supercapacitors, Springer Nature, 10-Oct-2019 - Technology and Engineering - 472 pages. 4. D. Pavlov, Lead-Acid Batteries: Science and Technology, Elsevier 31-May-2011 - Technology and Engineering - 656 pages. 5. C. Vincent, Bruno Scrosati, Modern batteries, Elsevier, 26-Sep-1997 - Technology and Engineering - 368 pages.

ET5030 2
Non-conventional Energy Sources and Environment

• Green energy resources: Introduction to non- conventional energy resources, overview of current developments. overview solar cell technology, solar thermal energy, geothermal energy, wind energy, wave energy/tidal energy, hydrogen production, biomass and biofuel production. • Solar cells: overview of solar cell technology, principles of solar cell technology, Silicon based solar cells, fabrications and latest development, Non-Si solar cells i.e. chalcogenide solar cells, dye sensitized solar cells and organic solar cells • Concentrated solar thermal energy and geothermal energy: introduction to working principles of concentrated solar thermal energy systems, type of solar concentrators and their components, types of heat storage systems and mechanisms of heat storage, thermodynamics aspect of heat exchange systems and steam generators. Overview of geothermal technology • Wind Energy: advantages and challenges of wind energy, fundamentals mechanisms of electricity generation from wind energy, geographical estimation and prediction of wind energy potential, type of wind energy systems, life cycle analysis and economical aspects of wind energy systems

References 1) Handbook of Photovoltaic Science and Engineering, Antonio Luque, Steven Hegedus, John Wiley and Sons, 2011, 1162 pages 2) Advances in Concentrating Solar Thermal Research and Technology, Manuel Blanco,

ET5040 1
Energy Management

Energy generation, Energy storage, Generation-side management, Network operation, Demand-side management, Design example of the autonomous power supply using solar PV and battery to study energy management, Energy management smart parking lot with EVs.

ET5060 2
Bio-energy

Overview of Bio Energy; Biomass sources, classification and properties; Biomass pre-treatment and processing; Biomass Conversion processes; Biofuels; Biohydrogen; Biogas, Biofuels Economics, Sustainability, Environmental and Policy

References: 1. Yebo Li, Samir Kumar Khanal, Bioenergy: Principles and Applications, Wiley 2016 2.Vaughn C. Nelson, Kenneth L. Starcher, Introduction to Bioenergy, CRC press, 2017 3. Anju Dahiya, Bio Energy: Biomass to Biofuels and Waste to Energy, 2nd Ed, Academic press, 2020 4. Francesco Dalena, Angelo Basile and Claudio Rossi, Bioenergy systems for the future: Prospects for Biofuels and Biohydrogen, Woodhead publishing (Elsevier), 2017.

ET5210 3
Power Systems Engineering and Converters for Renewable Applications

Basic concept of power plants, types of power plants, thermal power stations, various components of thermal power stations, power plant cycles, fuel handling, combustion, waste disposal methodologies, economizers, turbo alternators, heat transfer/balance and efficiencies, hydroelectric power plant, various components, capacity calculation, design methodologies, operation and maintenance methodologies, elements of nuclear power stations, reactor design, fuel, moderator, coolant control and safety, waste disposal, Need for power conversion, Concept of MPPT, Introduction to Power Electronic switches, Power electronic converters - basics of dc to dc converters (non-isolated), dc to ac converters (Inverters), ac to dc converters (rectifiers). Modelling of basic dc to dc converters

ET5211 2
Energy Conversion and Storage Devices (lab-2)
▷ET5020 Electrochemical Energy Storage Systems: Batteries, Fuel Cells and Supercapacitors mandatory

Material Synthesis, Electrode Preparation, Lead-acid and Li-ion cell assembly, Battery charge-discharge, life-cycle studies, CV, EIS, Chronoamperommetry and potentiommetry, LSV, Solar cell testing.

ET5212 Laboratory Methods in Electrochemistry and Related Analysis ▷ET5010 Fundamentals of Electrochemistry mandatory	**1**	Electrochemical methods will include the following: Cyclic Voltammetry, Chrono-amperometry, Chrono-coulometry and Electrochemical Impedance Spectroscopy (EIS) studies on standard analytes (ferricyanide/ferrocyanide redox couple), and on electroactive films of conducting polymers (e.g., poly(aniline)), nickel oxide, Prussian Blue), which will be fabricated over conducting substrates by electro-oxidation/reduction methods. Analysis will include the determination of useful parameters (e.g., diffusion coefficient, charge transfer resistance, exchange current density, capacitance etc) from the experimental data.
ET5220 Photovoltaic (pv) Technology	**2**	Characteristics of the photovoltaic cell; Semiconductor Basics; Silicon solar cells; Thermodynamic limit to efficiency, Light management, electrical losses, thin-film silicon solar cells; Advanced strategies for high-efficiency solar cells; Chalcogenides and III-V Technologies; Organic Photovoltaics; Hybrid Technologies; PV modules.
ET5230 Energy Audit	**1**	Concept, types of audit, energy index, cost index, pie charts, Sankey diagrams, load profiles, Energy efficiency in electrical utilities, Energy performance assessment for utility systems, building energy audit, campus energy audit.
ET5240 Hydrogen Economy	**2**	Hydrogen-based energy carrier and storage, Sustainable application, high-efficiency hydrogen conversion devices, Production and storage of hydrogen, Hydrogen Storage in Advanced Solid State and Liquid Materials
ET5260 Electric Vehicles ▷ET5020 Electrochemical Energy Storage Systems: Batteries, Fuel Cells and Supercapacitors mandatory	**1**	Introduction, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design, Vehicle Dynamics, drive train design methodology and control principles, Battery-fuel cell-supercapacitor requirements, BMS, Advantages and disadvantages of EVs.
ET5280 Industry Lecture Series	**1**	Industry lecture given by the industry experts on various aspects of Energy Science and Technology
LA5180 English Communication	**1**	Offered by LA dept.
MS5030 Material Synthesis and Characterization (including Lab 1.0)	**3**	None

29.16 Department of Electronic Vehicles

CH6610 Fuel Cell Technology	**2**	None
DS4013 Automobile Design Explorations	**2**	None
DS5253 Strategies for Sustainable Design	**3**	None
DS5343 Advanced Materials in Design	**3**	None
DS5353 Ergonomics for Industrial Designers	**2**	None
DS5403	**2**	None

Form and Parametric Digital Surfacing		
DS5413 Fundamentals of Design for EV	**2**	None
DS5423 Design Thinking for EV	**2**	None
DS5443 Life-cycle Analysis for EV	**2**	None
DS5463 Product System and Service Design for EV	**2**	None
EE5167 Embedded System Hardware and Design	**2**	None
EE5210 Power Converter Design	**3**	None
EE5240 Electrical Machines and Analysis Control	**3**	None
EE6360 Introduction to Drones	**2**	None
ET5020 Electrochemical Energy Storage Systems: Batteries, Fuel Cells and Super Capacitors	**3**	None
ET5040 Energy Management	**1**	None
ET5220 Photovoltaic (pv) Technology	**2**	None
ET5230 Energy Audit	**1**	None
ET5260 Electric Vehicles	**1**	None
IS5033 Embedded Programming	**3**	None
ME5040 Computational Fluid Dynamics Tools	**1.5**	None
ME5340	**3**	None

IC Engine Combustion and Pollution

ME5421 **1** None
FEM Lab

ME5480 **3** None
Sustainable Energy Technology: Energy Sources, Energy Efficiency, Storage and Optimization

ME5650 **3** None
Engineering Noise Control

ME5670 **3** None
Vehicle Dynamics and Modeling

ME5700 **3** None
Analysis and Design of Composite Structures

ME5710 **2** None
Design of EV

ME5800 **1** None
Testing and Certification of EV

SM5013 **1** None
Autonomous Navigation

SM5033 **1** None
Internet of Things (iot)

SM5043 **3** None
Traffic Engineering and Intelligent Transportation

29.17 Department of Integrated Sensor Systems

BM4190 **0** None
Biofabrication

BM6110 **0** None
Nano Medicine

CH5290 **0** None
Introduction to Microfluidics and Micro Reactors

CH5390 **0** None
Microfluidic Platform for Cell Culture and Diagnostics

CH6720 Basics of Nanosciences and Nanotechnology	**0**	None
CH6730 Nature Inspired Materials Engineering	**0**	None
CH6770 Introduction to Applied Statistical Mechanics	**0**	None
CH6840 Biomaterials Science and Engineering	**0**	None
CH6890 Introduction to Microfluidics	**1**	None
CS6230 Optimization Methods in Machine Learning	**0**	None
CS6510 Applied Machine Learning	**0**	None
CY5220 Solid State Chemistry	**0**	None
CY5230 Statistical Thermodynamics and Surface Science	**0**	None
CY7040 Organic Electronics and Photonics	**0**	None
CY7230 Nanochemistry and Applications	**0**	None
CY8938 Modern Molecular Simulation Methods	**0**	None
CY8998 Applications of 3d Printing in Chemistry	**0**	None
EE5107 Semiconductor Physical Electronics	**2**	None
EE5110 Semiconductor Device Modeling	**0**	None
EE5127	**0**	None

Analog IC Design

EE5128 **0** None
Analog IC Design Lab

EE5139 **0** None
Power Management
Integrated Circuit Design

EE5147 **0** None
Digital IC Design

EE5148 **0** None
Digital IC Design Lab

EE5158 **0** None
Advanced Digital IC Design

EE5159 **0** None
Microfabrication and Device
Simulation Laboratory

EE5167 **0** None
Embedded System Hardware
and Design

EE5168 **0** None
Embedded Systems:
Hardware Languages

EE5170 **0** None
Thin-film Transistors

EE5300 **0** None
Digital Signal Processing

EE5607 **0** None
ML – Hardware
Implementation

EE5611 **0** None
Machine Learning
Applications for Wireless
Communications

EE6120 **0** None
Nanoelectronics: Principles
and Devices

EE6140 **0** None
Introduction to Biosensor
Technology

EE6150 **0** None
Nanophotonics and
Metamaterials

EE6151 Topics in Nanophotonics	**2**	None
EE6160 Mesoscopic Carrier Transport	**0**	None
EE6180 Biomedical IC Design	**0**	None
EE6410 Biomedical IC Design	**0**	None
EE7110 More Than Moore Electronics	**0**	None
EE7120 CMOS Sensors	**0**	None
IS5010 Smart Material and Transducers	**2**	Introduction to Smart materials, Equilibrium properties of the systems, Ferroelectricity, Piezoelectricity. Si photodetectors, III-V group semiconductors (Epitaxy, DBG andamp; Quantum well and dot), Nano-photonics (Optimum drop of metal, localized surface plasmon resonance sensing), Metamaterials (Introduction to energy ε and μ, -ve refractive index). Different types of sensors and their sensing mechanisms (Temperature sensors, Metal oxide sensors, Potentiometric sensors, Chemical sensors), Introduction to smart systems and their applications. Electrochemical sensors. Scaling Laws, Overview of MEMS design and fabrication issues, Modelling of mechanical deflection, frequency, electrostatic forces, Electromechanical effects and fluid flow in MEMS and its effect. Performance analysis of a MEMS gyroscope device.
IS5013 Fabrication Technology and Characterization	**3**	Fabrication methods for MEMS: Microstereolithography, Lithography, Galvanoformung, Abformung (LIGA), Micromachining, etc., Surface micromachining, Bulk micromachining, Dry bulk micromachining, Deep reactive Ion Etching (DRIE), Wet chemical-based micromachining. Thin film, 3-D ICs Fabrication, Modelling challenges, Material, Mechanical and Electrical characterization
IS5015 Thesis Stage -1	**12**	None
IS5020 Physics of Low Dimensional Systems and Quantum Devices	**3**	Phonons and lattice dynamics, Free electron theory and Band theory of solids, Density of states, 1D, 2D and 3D, Effective mass tensors in low dimensions Heterostructure concepts and low dimensional systems such as quantum wells, nanowires and quantum dots. Quantum physics applied to such systems. Optical properties of low dimensional systems (transition rules, polarization etc). Transport properties of 2D and 1D systems. Quantized conductance with Landauer-formalism. Scattering phenomena in 1D. Devices based on quantum phenomena and Coulomb blockade. Magnetic nanowires, Domain wall motion devices, Magnetic nanoparticles and applications to data storage, the dielectric function and optical absorption • Excitons and plasmonics, Raman scattering and photoluminescence.
IS5023 Circuits and Packaging	**3**	RLC circuits, Amplifier, OPAMP/OTA, Comparator, Data Converter, Clock generation. MOSFET Fundamentals, CMOS logic Circuits, Memory, RTL coding, Die-bonding, Chip Packaging, SiP/SoP
IS5025 Thesis Stage -2	**12**	None
IS5030 Computational Modelling Techniques	**2**	Review of computational linear algebra, numerical methods for ordinary and partial differential equations, concepts of modeling across length and time scales, thermodynamic and kinetic models, Basic electronic structure methods - applications in thermodynamics of phase transitions, determination of physical properties Atomistic simulations: Molecular Dynamics and Monte Carlo methods and their applications in materials modelling; Applications of Finite Element Method in Multiphysics Modeling Multiphysics Simulations

IS5033 Embedded Programming	**3**	Introduction to Embedded Systems, Architectures of embedded processors, Memory hierarchy and its management Basics of Microcontrollers –timers, interrupts, analogy to digital conversion, bootloaders Interaction with devices -buses, memory management, device drivers and wireless comm., Interfacing sensors, actuators and peripherals. Real-time principles -multi-tasking, scheduling, synchronization Building low-power high-performance systems –code profiling and optimization Architecture, Case Studies of Real time. Microcontrollers/Microprocessor: Arduino, Raspberry-pi, ARM, FPGA, ESP32, RL78etc)
IS5035 Thesis Stage -1	**0**	None
IS5040 Intelligent Signal Processing Using Ai/iot	**2**	Algorithms, IC Design Perspective. Different types of signal processing techniques, Traditional Signal Processing algorithms vs. Practical Constraints; Need of an holistic view of Algorithm and VLSI Architecture, Hardware complexity analysis of resource constrained system; Computational Delay analysis of resource constrained system; Trade-off analysis : Arithmetic complexity vs Signal parameters; Wireless Sensor Networks, Network characteristics, Network Design and Challenges, Wireless Sensor Node Architecture and Design, Wireless Sensor Network Architecture, Data Aggregation, Sensor Data storage, Data Management and Processing, Time Synchronisation, Wireless Sensor and Actuator Networks, Network design, Control on Sensor Networks. Role of AI and ML in overall data aggregation, management and processing.
IS5045 Thesis Stage -2	**0**	None
IS5050 Industry Lecture Series	**1**	None
IS5055 Thesis Stage -3	**0**	None
IS5065 Thesis Stage -4	**0**	None
LA5180 English Communication Skills: Advanced	**1**	This course aims to familiarize the student with varieties of methodological and technical approaches to communication in English language. The course proposes to develop skills such as oral and written presentation, argumentation, composition, and technical reporting in students. Further, it seeks to help the student learn effective strategies and skills for academic and professional written and oral communication.
ME5010 Mathematical Methods for Engineers	**0**	None
ME5080 Scaling Laws and Multi-scale Manufacturing	**0**	None
ME5130 Finite Element Method	**0**	None
ME5660 Applied Micro and Nanomechanics in Engineering	**0**	None
MS5010 Properties of Materials	**0**	None
MS5030 Materials Synthesis and	**0**	None

Characterization

MS5080 **0** None
Thin Films Technology

MS5140 **0** None
Introduction to Computational Methods in Materials Science

MS5270 **0** None
2d Materials: Synthesis, Characterization and Applications

MS5290 **0** None
Plasmonics: Fundamentals to Advanced Applications

PB5220 **0** None
Advanced Fabrionics

PH4268 **0** None
Solid State Physics

PH6168 **0** None
Spintronics

PH6198 **0** None
Organic Electronics

PH6317 **0** None
Physics and Applications of Functional Materials

PH6438 **0** None
Fundamentals of Semiconductors Physics and Devices

PH6448 **0** None
Microfabrication Techniques

PH7013 **0** None
Advanced Optical Instrumentation

XXXX **0** None
Any Suitable Course As Per Advice of Your Guide

29.18 Department of Liberal Arts

29.19 Department of Mathematics

MA3120 **3** Polynomials, factorization, Inequalities for roots, The resultant and the discriminant,

Theory of Polynomials		Lagrange's series, Irreducibility criteria, Hilbert's irreducibility theorem, The cyclotomic polynomials, Chebyshev polynomials, Bernoulli polynomials, Hilbert's Seventeenth Problem
MA3140 Statistical Inference	**3**	Point estimation: Methods of moments and maximum likelihood estimation; Unbiasedness, Sufficiency, Efficiency, Completeness; UMVU estimators, Fisher-Information, Cramer-Rao; Confidence Interval Estimation; Hypothesis testing: Neyman-Pearson, Likelihood Ratio Tests, Chi-Square Tests, t-tests, F-tests
MA3143 Statistical Analysis Using R ▷MA2110, MA2140	**1**	Data organization, Data import–export, Data production and manipulation, Graphical techniques, Conditional statements, Functions. Random variables, Distributions and simulation, Descriptive statistics, Confidence intervals and hypothesis testing, Basic regression analysis (linear and logistic), Analysis of variance
MA3163 Computational Algebra I - Mathematical Computing With Mathematica	**2**	Computations in Number Theory, Calculus, Linear Algebra; and modeling, Visualization and Geometry
MA3310 Basic Cryptography	**3**	Elliptic Curves, Weierstrass and Edwards curves, Factoring using elliptic curves, Primality testing, discrete logarithm problem, Anamalous curves, A Cryptosystem based on the Weil and Tate-Lichtenbaum pairings, Miller's algorithm, Hyperelliptic curves, divisors, Cantor's algorithm
MA3320 Diophantine Equations	**3**	Lattices, quadratic forms, algebraic numbers, class group, class numbers, Diophantine aspects of elliptic curves, analytic tools.
MA3610 Variational Calculus ▷MA1220	**1**	Extrema of functionals, Variation of a functional and its properties, Euler's equation, Field of extremals, Sufficient conditions for the Extremum of a Functional, Conditional extrema, Moving boundary problems, Ritz method
MA3620 Some Special Functions in Mathematical Analysis	**1**	Exponential and Logarithmic function. The Trigonometric functions. The Gamma function. The characterization of Gamma function. Introduction to Fourier Series and Fourier transform.
MA4010 Analysis of Functions of a Single Variable ▷	**3**	•Real number system: Field properties, ordered properties, completeness axiom, Archimedean property, subsets of $\mathbb{R}$, infimum, supremum, extended real numbers. Finite, countable and uncountable sets, decimal expansion. Sequences of real numbers, Subsequences, Monotone sequences, Limit infimum, Limit Supremum, Convergence of Sequences. Metric spaces, limits in metric spaces. Functions of single real variable, Limits of functions, Continuity of functions, Uniform continuity, Continuity and compactness, Continuity and connectedness, Monotonic functions, Limit at infinity. Differentiation, Properties of derivatives, Chain rule, Rolle's theorem, Mean-value theorems, L'Hospital's rule, Derivatives of higher order, Taylor's theorem. Definition and existence of Riemann integral, properties, Differentiation and integration. Revision of Series, Sequences and Series of functions, Pointwise and uniform convergence, Uniform convergence of continuous functions, Uniform convergence and differentiability, Equicontinuity, Pointwise and uniform boundedness, Ascoli's theorem, Weierstrass approximation theorem, Fourier series
MA4020 Linear Algebra	**3**	• System of Linear Equations, Elementary Operations, Row-Reduced Echelon Matrices, Gaussian Elimination. • Vector Spaces, Subspaces, Direct Sums, Bases and Dimension, Linear Maps, Rank-Nullity Theorem, The Matrix of a Linear Map, Invertibility. • Eigenvalues and Eigenvectors, Invariant Subspaces, Upper-Triangular Matrices, Diagonal Matrices. • Inner Products, Norms, Orthonormal Bases, Gram-Schmidt process, Schur's theorem, Orthogonal Projections and Minimization Problems, Linear Functionals and Adjoints. • Self-Adjoint and Normal Operators, The Spectral Theorem for finite dimensional operators. • Generalized Eigenvectors, The Characteristic Polynomial, Cayley-Hamilton Theorem, The Minimal Polynomial, Jordan Form.
MA4030 Ordinary Differential Equations ▷	**3**	Introduction: Mathematical modeling using ODE's, Definition of Linearity, Classification of ODE's, Notion of solutions, Methods of solution for first order linear differential equations: Separation of variables, integrating factor. Second order linear differential equations: Homogeneous and non homogeneous differential equations. Series solutions.

Initial Value Problem (IVP): Notion of solutions, wellposedness of IVP in the sense of Hadmard. Some examples on unique solution, infinitely many solutions and no solution of IVP – Lipschitz continuity, Gronwall's inequality and uniqueness of the solution of IVP. Picard's existence and uniqueness theorem for IVP. Peano existence theorem. Continuous dependence of solution on initial data. Continuation of solution and maximal interval of existence.
Linear System Theory: Reduction of nth order scalar differential into a system of n first order ODE's. Fundamental matrix solution, space of all solutions as n-dimensional vector space Transition matrix and solution of IVP. Peano-Baker series for computation of transition matrix. Autonomous systems and matrix exponential. Computation of matrix exponential for diagonal matrices, Jordan blocks and other special matrices. Solution of nonhomogeneous IVP by Duhamel's principle.
Stability Theory: Stability theory for 2×2 systems, canonical form, equilibrium points, node, center and focus. Classification of equilibrium points of nonlinear systems. Lyapunov stability, asymptotic stability and exponential stability Poincaŕe-Bendixson theorem, Lienard's theorem.
Boundary value problems: Introduction to boundary value problems. Regular Sturm-Liouville problems. Green's function. Existence of eigen functions. Zeros of solutions. Oscillation results. Comparison theorems

MA4040 3
Probability Theory
▷

• Probability Space, Independence and dependence, Random variables and distribution functions
• Random variables and joint distributions, Functions of random variables
• Expectation and moments, Conditional expectation, Characteristic functions, Sequences of random variables
• Modes of Convergence, Weak and Strong laws of large numbers, Central Limit Theorems.

MA4051 3
Basics of Programming

Structure of a program, Input and Output Variables and Types, Arithmetic and Relational Operators, Control Structures, Functions, Arrays and Pointers, File Handling.

MA4053 1
Searching in Metric Spaces
▷MA4010

Basics: Introduction to metric spaces - Nearest Neighbour Searches - Some applications.

Efficacy of Searching in Metric Spaces: Interplay of different properties, like triangle inequality, order-invariance, etc. on the obtained search results. Role of separable metric spaces in 1-NN search

Efficiency of Searching in Metric Spaces: Computationally efficient search algorithms in metric spaces like Burkhard–Keller Tree, Bisector Trees, Geometric Near-Neighbour Access Trees, etc.

MA4060 3
Complex Analysis

• Spherical representation of extended complex plane, Analytic Functions, Harmonic Conjugates, Elementary Functions, Cauchy Theorem and Integral Formula, Homotopic version
• Linear fractional transformations, Power Series, Analytic Continuation and Taylor's theorem, Zeros of Analytic functions, Hurwitz Theorem, Maximum Modulus Theorem, Laurent's Theorem, Classification of singularities
• Residue theorem and applications, Argument Principle, Theorem of Rouche, Schwarz-Christoffel Transformation.

MA4070 3
Algebra I - Groups and Rings

•Binary operation and its properties, Definition of Groups, Examples and basic properties. Subgroups, Coset of a subgroup, Lagrange's theorem. Cyclic groups. Normal subgroups, Quotient group. Homomorphisms, Isomorphism theorems. Permutation groups, Cayley's theorems. Direct and semidirect product of groups. Group actions and Sylow theorems.
Definition of Rings, Examples and basic properties, Zero divisors, Integral domains, Fields, Characteristic of a ring, Quotient field of an integral domain. Subrings, Ideals, Quotient rings, Isomorphism theorems. Ring of polynomials. Prime, Irreducible elements and their properties, Unique Factorization Domains, Principal Ideal Domains, and Euclidean domains. Prime ideal, Maximal ideal, Prime avoidance theorem, Chinese remainder theorem.

MA4080 3
Measure and Integration
▷MA4010

• Sigma-algebra of measurable sets. Completion of a measure. Lebesgue Measure and its properties. Non-measurable sets.
• Measurable functions and their properties. Integration and Convergence theorems. Lebesgue integral, Functions of bounded variation and absolutely continuous functions. Fundamental Theorem of Calculus for Lebesgue Integrals.
• Product measure spaces, Fubini's theorem.
L^p-spaces, duals of L^p spaces. Riesz Representation Theorem for $C([a, b])$.

MA4090 **3**
Multivariable Calculus
▷MA4010
Functions of several-variables, Directional derivative, Partial derivative, Total derivative, Jacobian, Chain rule and Mean-value theorems, Interchange of the order of differentiation, Higher derivatives, Taylor's theorem, Inverse mapping theorem, Implicit function theorem, Extremum problems, Extremum problems with constraints, Lagrange's multiplier method.
Multiple integrals, Properties of integrals, Existence of integrals, iterated integrals, change of variables. Curl, Gradient, div, Laplacian cylindrical and spherical coordinate, line integrals, surface integrals, Theorem of Green, Gauss and Stokes.

MA4110 **1**
Applied Galois Theory
Revision of concepts from field theory, normal extensions, separable extensions, fundamental theorem of Galois theory, cyclotomic extensions, impossibility of solving quintic equations

MA4113 **1**
Field and Coding Theory
Field extensions, degree of a field extension, algebraic closure of a field, introduction to finite fields and coding theory

MA4120 **1**
Advanced Linear Algebra
Vector spaces, multilinear maps, tensor product of vectors, exterior product, tensor algebra and exterior algebra

MA4133 **3**
Computational Algebra On Polynomials and Ideals
The Division Algorithm. Polynomial Rings. Basic Operations with Monomial Ideals and Modules. Term Orderings and Leading Terms. Gröbner Bases of Ideals and Modules, Buchberger's Algorithm. Computation of Colon Ideals and Annihilators, Computation of Intersections of ideals. Elimination. Diophantine Systems and Integer Programming. Systems of Polynomial Equations

MA4140 **1**
Homological Algebra I
Categories, Functors, Chain complexes, Derived functors, Left/Right Exactness, Tor and Ext. Group homology and cohomology

MA4143 **3**
Time Series Analysis
▷MA2110, MA2140, MA2142
Test for trend, seasonality test; Estimation and elimination of trend and seasonality, moving average smoothing, Holt-Winter's method, least squares method, method of differencing; Mathematical formulation of time series; Weak and Strict stationary, stationary up to order m, covariance stationary; Auto Covariance and Auto correlation functions of stationary time series and its properties; AR, MA, ARMA, seasonal, non-seasonal and mixed models; ARIMA models; Auto covariance generating function; Parameter estimation of AR, MA and ARMA models-LS approach, Model identification with ACF and PACF. ARCH, GARCH models, Multivariate Time series models.

MA4145 **2**
Design of Experiments
▷MA2110, MA2140
Linear Models, One-way and two-way classification models. Standard designs such as CRD, RBD, LSD, BIBD. Confounding. Fractional factorial deigns. A brief introduction to mixed effects models. Cross-over and cluster designs. Response surface methodology

MA4150 **3**
Homological Algebra II
Category Theory: Categories, Functors, Natural Transformations, Abelian Categories, Limits and Colimits, Adjoint Functors. Chain complexes, Homological Dimension, Spectral Sequences

MA4170 **1**
Linear Algebra Over Commutative Rings
Commutative rings, modules and their homomorphisms, sub-modules and quotient modules, tensor product

MA4210 **2**
Algebraic Curves and Integer Factorization
Ideals in polynomial rings, Hilbert's nullstellensatz, projective varieties, algebraic curves. elliptic curve in projective plane, integer factorization using elliptic curve

MA4220 **2**
Geometry of Complex Numbers
Holomorphic and meromorphic functions, compact Riemann surfaces, holomorphic maps, coverings, projective space and complex projective curves

MA4230 **2**
Advanced Calculus
Differentiation, integration, inverse function theorem, implicit function theorem, manifolds, differential forms, Stokes' theorem

MA4310 **3**
Topics in Number Theory
Basic congruences, division algorithm, quadratic reciprocity, Chinese remainder theorem, primitive roots, Fermat's little theorem, Pythagorean triplets, primality testing, arithmetic functions, prime number theorem, Riemann-zeta function

MA4320 **2**
Representation of finite groups, complete reducibility, Schurs lemma, characters,

Representation of Finite Groups	projection formulae, induced representation, Frobenius reciprocity.
MA4340 3 Probability Theory in Finance ▷MA4040	Review of basic probability theory; Money, Interest rates, Market, stochastic processes, call options, hedging and arbitrages, martingales (discrete and continuous), martingale convergence, stochastic integration, the convergence of random variables, stochastic Riemann integral, Ito integral, Ito's lemma, Black-Scholes formula.
MA4510 1 Finite Fields and Their Applications	Review of basics of finite fields, Roots of unity and cyclotomic polynomials over finite fields, Irreducible polynomials over finite fields, Primitive polynomials over finite fields. Equations over finite fields: Outlines of some classical results and recent developments. A finite field "Nullstellensatz." Application to Cryptography: Linear feedback shift registers (LFSRs), Word oriented LFSRs, Splitting Subspace Conjecture, Outline of some recent developments. Application to coding theory: Reed-Muller codes, their basic parameters, and some open problems.
MA4520 3 Positive Definite Matrices ▷MA4020	Positive matrices, characterizations, some basic results, block matrices, Schur product, Monotonicity, convexity.Positive linear maps: Representations, positive maps, properties, applications, tensor product of matrices, some applications, positive maps on operator systems. Completely positive maps: Basic examples, Choi-Krauss theorem, Stinespring's theorem, Arveson's extension theorem, Schwarz inequalities, positive completions and Schur product, the numerical radius, Applications.
MA4540 2 Non-parametric Inference	Order statistics, Tests of randomness and Goodness of fit, one-sample and paired sample procedures, general two-sample problems, linear rank tests for location and scale problem, k-sample problem, measures of association for bivariate samples, asymptotic relative efficiency, concepts of Jackknife and Bootstrap methods
MA4550 3 Introduction to Modern Number Theory ▷MA1250, MA4020, MA4070	Divisibility, Arithmetic functions and applications, Congruences, Counting primes and their distribution, Arithmetic of quadratic extensions (units and prime factorization), Structure of units, Dirichlet L-functions, Finite fields, Equations over finite fields, Quadratic Reciprocity law.
MA4560 3 Introduction to Analytic Number Theory ▷MA1250	Averages of Arithmetical functions, Distribution of prime numbers, Congruences, Dirichlet's theorem on primes in Arithmetic progressions, Zeta function, Dirichlet Series, Partitions.
MA4570 3 Algebraic Coding Theory	Group codes, Polynomial codes, Hamming codes, Finite fields and BCH codes, Error-Correcting codes, Linear codes, Cyclic codes, Classical Goppa codes, Bounds on codes, Self-dual codes, Quadratic residue codes, Maximum distance separable codes, Hadamard matrices and Hadamard codes, Codes on curves.
MA4580 3 Coding Theory On Algebraic Curves	Error-Correcting codes: Linear codes and their parameters, Bounds on codes, Examples and constructions, Finite fields, Counting points on curves over finite fields. Algebraic curves: Varieties, non-singular curves, divisors, Riemann-Roch theorem. Codes on Algebraic curves: Geometric Goppa codes, algebraic geometric codes: Construction and properties, codes on higher dimensional varieties.
MA4610 1 Classical Results in Analysis and Applications ▷MA1110, MA1220	Implicit function theorem. Inverse function theorem. Stone-Weierstrauss theorem. Banach-Stone theorem. Arzela-Ascoli theorem. Mazur-Ulam theorem
MA4710 1 Topology and Its Applications	Topological spaces, quotient topology, separation axioms, connectedness and compactness. (If time permits:) Brief introduction to topological data analysis
MA4740 3 Introduction to Bayesian Statistics	Basics of point estimation, maximum likelihood estimators, hypothesis testing, likelihood ratiotests, confidence intervals, Bayes rule, prior distributions, posterior distributions, conjugateprior, techniques of posterior inference, highest posterior density interval, predictivedistributions, Bayesian inference for one-parameter models: Binomial, Poisson, Normal,Bayesian inference for the mean of the multivariate normal distribution, Hierarchical models,Model-checking, posterior predictive checking, Bayes factor, Bayesian hypothesis testing,Bayesian computation, Markov Chain Monte Carlo, Gibbs sampling.
MA5010 3 Combinatorics and Graph	• Basic counting: Bijections, Counting objects with repetitions, de Bruijn-Erdos theorem, Listing combinatorial objects.

Theory

• Permutations: Combinatorial representation of a permutation, Descents and Eulerian polynomial, Tree representation for permutations.
• Inclusion-Exclusion principle: Use of Rook polynomial, Some arithmetic and Mobius functions.
• Parity: Parity in Graph theory, Eulerian circuits in graphs, digraphs and de Bruijn circuits, Hypercubes and Gray codes, Parity of a permutation, Quadratic reciprocity.
• Pigeonhole principle: Ramsey theorem, The infinite case.
• Geometry: Regular polytopes and tessellations of plane, triangulations and Sperner's lemma.
• Recurrence relations: Fibonacci recurrence relation, Linear homogeneous recurrence relations with constant coefficients, Case of repeated roots, Difference tables and sums of polynomials, Other types of recurrence relations.

MA5020 3
Functional Analysis
▷MA4010, MA4020

• Normed linear spaces. Non-compactness of the unit ball in infinite dimensional normed linear spaces. Product and quotient spaces. Banach spaces, Hilbert spaces.
• Linear maps. Boundedness and continuity. Linear isometries, linear functionals. Examples.
• Hahn-Banach extension theorem, applications. Banach-Steinhaus theorem, closed graph theorem, open mapping theorem and bounded inverse theorem, Spectrum of a bounded operator.
• Gram-Schmidt orthogonalization. Bessel's inequality, Riesz-Fisher theorem. Orthonormal basis, Parseval's identity, Projection, orthogonal decomposition. Bounded linear functionals on Hilbert spaces.

MA5030 3
Partial Differential Equations
▷MA4030

Basic Concepts: Definition and order of a PDE. Classification of PDEs. Examples of some important equations and their significance. Classification into hyperbolic, parabolic, and elliptic equations, Canonical forms.
First order PDE's: Method of characteristics (Charpit's method). Existence and uniqueness results for the Cauchy problem for quasilinear and fully non- linear equations. Breakdown of classical solutions.
Wave Equations: d'Alembert's formula, uniqueness and stability of solutions to the initial value problem for one dimensional wave equation. Parallelogram identity, domain of dependence, range of influence, finite speed of propagation, conservation of energy. Inhomogeneous equation. Duhamel's formula. Characteristic triangle. Spherical means, Hadamard's method of descent. Huygens' principle. Duhamel's principle for solutions of non-homogeneous wave equation. Uniqueness using energy method.
Laplace Equations: Green's identities, Uniqueness of solutions, Green's function and Possion's formula, Harnack's inequality, Liouville's theorem, Weak maximum principle, Mean-value property, Strong maximum principle, Analyticity of harmonic functions. Dirichlet principle, Uniqueness using energy method for Dirichlet, Neumann, and Robin(mixed) boundary value problems, Hadamard's example illustrating non-uniqueness, instability of solutions to Cauchy problem for Laplace equation.
Heat Equations: Fundamental solution, Cauchy problem for homogeneous heat equation, infinite speed of propagation, Duhamel's principle for non-homogeneous heat equation, Uniqueness using energy method for initial boundary value problem, Maximum principle and uniqueness, Ill-posedness of backward heat equation.
Supplementary Topic: Fourier Series Method: Construction of Fourier series solutions to Laplace, Heat, and Wave equations using method of separation of variables and their convergence.

MA5040 3
Topology

• Definition of Topologies in terms of open sets, neighborhood system, closed sets and closure operations and their equivalence, points of accumulation, interior, exterior and boundary points.
• Base and subbase of a topology, subspace, product space, quotient space, continuous, open and closed maps, homeomorphism convergence of sequence and nets.
• Separation axioms, Urysohn's Lemma, Tietze extension theorem, separability.
• Compactness, local compactness, sequential and countable compactness, Tychonoff's theorem, Lindelof space. One point compactification
• Connectedness and local connectedness.
• Urysohn's metrization theorem.

MA5050 3
Mathematical Methods

• Integral Transforms: Laplace transforms: Definitions - properties - Laplace transforms of some elementary functions - Convolution Theorem - Inverse Laplace transformation - Applications.
• Fourier transforms: Definitions - Properties - Fourier transforms of some elementary functions - Convolution theorems - Fourier transform as a limit of Fourier Series - Applications to PDE.
• Integral Equations: Volterra Integral Equations: Basic concepts - Relationship between

Linear differential equations and Volterra integral equations - Resolvent Kernel of Volterra Integral equation - Solution of Integral equations by Resolvent Kernel - The Method of successive approximations - Convolution type equations, solution of integral differential equations with the aid of Laplace transformation.
• Fredholm Integral equations: Fredholm equations of the second kind, Fundamentals - Iterated Kernels, Constructing the resolvent Kernel with the aid of iterated Kernels - Integral equations with degenerate Kernels - Characteristic numbers and eigen functions, solution of homogeneous integral equations with degenerate Kernel - non homogeneous symmetric equations - Fredholm alternative.
• Calculus of Variations: Extrema of Functionals: The variation of a functional and its properties - Euler's equation - Field of extremals - sufficient conditions for the Extremum of a Functional conditional Extremum Moving boundary problems - Discontinuous problems - one sided variations - Ritz method.

MA5052 3
Advanced Mathematical Methods
▷MA4030, MA4060, MA 5050

Introduction: Ordering symbols, 'O and o' notation, Asymptotic Sequence, Asymptotic Analysis, Applications.

Basic Complex Analysis: Singularities of complex functions, Cauchy's residue and other important theorems, Jordan's lemma, Plemlj formulae.

Series Solution: Singular points – classification, Properties near ordinary and regular singular points, Frobenius solution for ordinary differential equations, Behaviour near irregular singular points, Method of dominant balance and some special functions: Airy functions, Gamma Function.

Matched Expansions, Boundary Layer Theory: Regular and singular perturbation theory, uniform approximations, Interior boundary layer analysis with examples. Generalised Functions: Introduction, derivatives of generalised functions, applications to singular integrals.

Integral Transforms: Fourier Transform, Laplace Transform, Mellin Transform, Riemann-Lebesgue Lemma and analytic continuation of Mellin Transforms.

Asymptotic Expansion of Integrals: Use of Mellin transform for asymptotic expansion of integrals, Laplace method, stationary phase, method of steepest and decent. Weiner-Hopf Method: Conformal mapping, critical points, Schwartz-Christoffel formula, Bilinear maps-Mobius transformation, Riemann-Hilbert problems and the Wiener-Hopf method.

MA5060 3
Numerical Analysis

• Floating point representation of numbers, floating point arithmetic, errors, propagation of error.
Solution of nonlinear equations: Iterative methods, Fixed point iteration method, convergence of fixed point iteration, Newton-Raphson method, complex roots and Muller's method.
Interpolation: Existence and uniqueness of interpolating polynomial, error of interpolation - interpolation of equally and unequally spaced data - Inverse interpolation - Hermite interpolation.
Approximation: Uniform approximation by polynomials, data fitting, Least square, uniform and Chebyshev approximations.
Solution of linear systems: Direct and iterative methods, ill-conditioned systems, Eigen values and eigen vectors: Power and Jacobi methods.
Integration: Newton-cotes closed type methods; particular cases, error analysis - Romberg integration, Gaussian quadrature; Legendre, Chebyshev formulae.
Solution of Ordinary differential equations: Initial value problems: Single step methods; Taylor's, Euler method, modified Euler method, Runge-Kutta methods, error analysis

MA5070 3
Modules and Fields

Review of Rings, Modules, Free modules, Cartesian products and direct sums of modules, quotient modules, Simple and semisimple modules, isomorphism theorems. Modules over principal ideal domains and applications. Noetherian and Artinian rings/Modules, Hilbert basis theorem. Jordan-Holder theorem. Projective/Injective modules.
Field extensions. Algebraic/transcendental elements, Algebraic extensions. Finite fields, Cyclotomic fields. Splitting field of a polynomial. Algebraic closure of a field, Uniqueness. Normal, separable, purely inseparable extensions. Primitive elements, simple extensions. Fundamental theorem of Galois theory. Solvability by radicals - Solutions of cubic and quartic polynomials, Insolvability of quintic and higher degree polynomials. Geometric constructions

MA5080 3
Advanced Programming

Mathematical background, Model - What to Analyze.
Abstract Data Types (ADT's), The List ADT, The Queue ADT, The Stack ADT, Preliminaries, Binary Trees, The Search Tree ADT, Binary Search Trees, AVL Tree, Preliminaries, Insertion Sort, Shell Sort, Merge Sort, Quick Sort,

Definitions, Topological Sort and Minimal Spanning Tree.

MA5090 3
Sets, Logics and Boolean Algebra

Sets and Relations: Types of relations, Peano Axioms and Mathematical Induction, Cardinality, Recursion.
Boolean Algebra: Partially Ordered Sets, Lattices, Subalgebras, Direct Product, Homomorphisms, Boolean Functions, Representation and Minimization of Boolean functions.
Mathematical Logic: Connectives, Normal Forms, Theory of Inference for the Statement Calculus.

MA5100 3
Introduction to Algebraic Topology
▷MA5040

Homotopy, Fundamental group, The Fundamental group of the circle, Retractions and fixed points, Application to the Fundamental Theorem of Algebra, The Borsuk-Ulam theorem, Homotopy equivalence and Deformation retractions, Fundamental group of a product of spaces, and Fundamental group the torus, Sphere, and the real projective n-space.
Free Products of Groups, The Van Kampen Theorem, Fundamental Group of a Wedge of Circles, Definition and construction of Cell Complexes, Application to Van Kampen Theorem to Cell Complexes, Statement of the Classification Theorem for Surfaces, Fundamental groups of the closed orientable surface of genus g.
Introduction to Covering spaces, Universal Cover and its existence, Unique Lifting Property, Galois Correspondence of covering spaces and their Fundamental Groups, Representing Covering Spaces by Permutations - Deck Transformations, Group Actions, Covering Space Actions, Normal or Regular Covering Spaces.

MA5110 3
Fourier Analysis and Applications
▷MA4010

• Definition, Examples, Uniqueness of Fourier series, Convolution, Cesaro summability and Abel summability of Fourier series, Mean square convergence of Fourier series, A continuous function with divergent Fourier series. Some applications of Fourier series, The isoperimetric inequality, Weyl's equidistribution theorem.
• Fourier transform on the real line and basic properties, The Schwartz space, Approximate identity using Gaussian kernel, Solution of heat equation, Fourier inversion formula, L^2-theory .
• Some basic theorems of Fourier Analysis, Poisson summation formula, Heisenberg uncertainty principle, Hardy's theorem, Paley-Wiener theorem, Wiener's theorem, Shannon sampling theorem.
• The class of test functions, Distributions, Convergence, differentiation and convolution of distributions, Tempered distributions, Fourier transform of a tempered distribution.

MA5120 3
Numerical Linear Algebra
▷MA4020

Gaussian elimination and its variants. Sensitivity of system of linear systems. QR factorization and The least squares. The singular value decomposition. Computing Eigenvalues and Eigenvectors. Iterative methods for linear systems.

MA5130 3
Theory of Computation

• Regular Languages: Finite Automata, Non-determinism, Regular Expressions, Nonregular Languages.
• Context-Free Languages: Context-free Grammars, Pushdown Automata, Non-context-free Languages
• The Church-Turing Thesis: Turing Machines and Variants.
• Decidability: Decidable Languages, The Halting Problem.
• Reducibility: Undecidable Problems, Example, Mapping Reducibility
• Time Complexity: Measuring Complexity, The classes of P and NP

MA5140 3
Introduction to Stochastic Processes
▷MA4040, MA4080

Basics of probability, Definition, Classification and properties, Markov processes, Gaussian process, Stationary processes, Discrete and continuous-time Markov chains, Classification of states, Limiting distribution, Poisson process, Steady-state and transient distributions, Queuing models.

MA5142 3
Elliptic Curve Cryptography
▷MA4060, MA4070

Elliptic curves, the group law, Weierstrass and Edwards curves, Efficient computation. Integer arithmetic, Finite field arithmetic.

The Discrete logarithm problem, the Index calculus, General attacks on discrete logs, Attacks with pairings, Anamalous curves, Diffie-Hellman key exchange, Massey-Omura encryption, ElGamal public key encryption, ElGamal digital signatures.

The Digital signature algorithm, Public key scheme based on factoring, A Cryptosystem based on the Weil pairing, Factoring using elliptic curves, Primality testing. The Weil and Tate-Lichtenbaum pairings, Miller's algorithm, Hyperelliptic curves, divisors, Cantor's algorithm

MA5150 3
Algebraic Number Theory
▷MA4070, MA5070

Localisation, Integral ring extensions, Dedekind domains, discrete valuation rings, unique factorisation of ideals, ideal class groups, finiteness of class number, some class number computations, valuations and completions of number fields, Hensel's lemma, norm, trace, discriminant, different, Ramification theory of p-adic fields, Decomposition

groups, Inertia groups, cyclotomic fields, Gauss sums, quadratic reciprocity, geometry of numbers, Ostrowski's theorem, Dirichlet's unit theorem.

MA5160 3
An Introduction to Modular Forms
▷MA4060, MA4070

Modular group, congruence subgroups, modular forms, examples, Eisenstein series, lattice functions, Some number theoretic applications, space of modular functions, expansions at infinity, zeroes and poles using contour integrals, Hecke operators, Theta functions, Atkin-Lehner theory, Petersson inner product, Eigenforms, L-functions and some properties, relation between Modular forms and Elliptic curves.

MA5170 3
Basic Introduction to Algebraic Geometry
▷MA4070, MA5070

Algebraic curves in the plane, Singular points and tangent lines, local rings, intersection multiplicities, Bezout's theorem for plane curves, Max Noether's theorem and some of its applications. Affine spaces, Projective spaces, Affine and projective varieties, coordinate rings, morphisms and rational maps, local ring of a point, function fields, dimension of a variety, Zariski's main theorem.

MA5180 3
Advanced Measure Theory
▷MA5030

• Revision on Radon-Nikodym Theorem, Radon-Nikodym derivative and their applications.
• Complex measure and its various properties, Complex analogue of Radon-Nikodym
• Theorem. Dual of $C^0(X)$, the space of all complex valued continuous functions vanishing at infinity on a locally compact Hausdorff X.
• A revision on the spaces $L^p(\mu)$ for a σ finite measure μ. Dual of $L^p(\mu)$. Dense subclasses of $L^p(\mu)$.
• Modes of convergence: pointwise convergence, convergence in measure, convergence almost uniformly. Egoroff's Theorem.
• Fundamental Theorem of Calculus for Lebesgue Integrals. Derivative of an integral.
• Derivative of a measure: The Lebesgue Differentiation Theorem. Functions of Bounded Variation and Rectifiable curves in the plane. Absolutely continuous functions.

MA5190 3
Advanced Partial Differential Equations
▷MA4080, MA5030

Review: Quasi-linear PDE, Cauchy problem, higher order PDE, classification, wave equation, heat equation, Laplace equation.
Introduction to non-linear waves: 1-D linear equation, basic non-linear equations, expansion wave, centered expansion wave, breaking and examples. Shock waves, discontinuous shocks, equal area rule, asymptotic behavior, shock structure, Burgers equation, Thomas equation.
Second order systems: the equations of shallow water theory, method of characteristics, waves on a sloping beach, linear and nonlinear theory, conservation equations and boundary value problems,, exact solutions for certain nonlinear equations.

MA5220 3
Applied Functional Analysis

Review of normed linear spaces, Banach and Hilbert spaces. Orthogonal systems in Hilbert spaces, Representation through harmonic and nonharmonic bases, Redundant representations, Sampling theorems, Issues with under-sampling and over-sampling, Applications in signal analysis

MA5240 3
Mathematical Introduction to Elliptic Curves
▷MA4070

Plane curves, Bezout's theorem, Basic Theory of Elliptic Curves. Reduction modulo p, Torsion points. Elliptic curves over the complex numbers, Lattices and bases, Doubly periodic functions. Heights, Mordell-Weil theorem, rank of E(Q), Neron-Tate pairing, Nagell-Lutz Theorem, Elliptic curves over finite fields and local fields, Elliptic Curves and it's relation with modular forms.

MA6010 3
Topics in Analysis

Real Analysis: Review of real numbers, sequences and series.
Basic topology, continuity, differentiation, Riemann-Stieltjes integral, Sequence and series of functions.
Complex Analysis: Analytic functions, Harmonic conjugates, Cauchy theorems and consequences, Power series, Maximum modulus theorem, Phragmen Lindelof theorem, Singularities, Laurent series, Residues. Mobius transformations.

MA6020 3
Topics in Algebra

Review of vector spaces, bases, dimension, Linear transformations, The rational and Jordan forms, Inner product spaces, Bilinear forms.
Review of Group Theory, Jordan Holder theorem, Rings, Modules and Fields.

MA6040 3
Fuzzy Logic Connectives and Their Applications

Fuzzy Logic Connectives: T-norms : Classes and their generation process, Algebraic and analytical properties, related conjunctions.
Fuzzy implications: Classes and their generation process, Algebraic and analytical properties.
Fuzzy Measures and Integrals: An Introduction.
Applications: Including but not limited to :Approximate Reasoning, Clustering and Data Analysis, Image Processing

MA6050 3
Wavelets and Applications

Fourier transform - Continuous wavelet transform, frames - Multiresolution analysis, discrete wavelets, - Spline, orthogonal and biorthogonal wavelets - Applications in Image processing, Numerical analysis

MA6060 **3**
Redundant and Sparse Representation Theory

Redundant representations, Orthogonal, nonorthogonal and frame type bases, Sparsity, Coherence, Uncertainty Principle , L1 minimization, Probabilistic and deterministic approaches, Convex and iterative methods, Applications in analog-to-digital conversion, Nyquist sampling theory, Low-rank matrix recovery, Dictionary design, Recent develop

MA6070 **3**
Approximation Theory

The Theorems of Weierstrass, Bernstein, Fejer, and Korovkin, Stone's Approximation Theorem and the Stone-Weierstrass Theorem, Some applications, Best approximation in normed spaces: some basic notions and results, Degree of uniform approximation by algebraic and trigonometric polynomials - Modulus of continuity and modulii of smoothness - Jackson's theorems - Bernstein's inequality for trigonometric polynomials - Inverse theorems for uniform trigonometric approximation, Bernstein and Markov inequalities for algebraic polynomials, Characterizations of best uniform approximants - Theorems of Collatz and Schewdt, Collatz and Kolmogorov - Haar systems and the Haar-Kolmogorov Theorems - Chebyshev's Alternation Theorem and some applications.

MA6080 **3**
Measure Theoretic Probability

Classical Probability and Preliminaries: Discrete Probability, Conditional Probability, Expectation, Theorems on Bernoulli Trials. Basic definitions of algebraic structures, few facts about Banach Spaces; Measure Theory: Sigma Algebra, Measurable functions, Positive and Vector valued measures, Total Variation of a measure, Spaces of measures, Lebesgue Measure on R, Completion, Caratheodory's theorem, • Lebesgue Integration: Abstract Integral, Convergence theorems of Lebesgue and Levi, Fatou's Lemma, Radon-Nikodym Theorem, Modes of convergence of measurable functions; Product Spaces: Finite Products, Fubini's Theorem, Infinite Products, Kolmogorov's Extension Theorem; Independence: Random Variables, Distributions, Independent Random Variables, Weak and Strong Law of Large Numbers, Applications.

MA6090 **3**
Operator Theory

Operators on Hilbert spaces: Basics of Hilbert spaces; Bounded linear operators, Adjoint of operators between Hilbert spaces; Self-adjoint, normal and unitary operators; Numerical range and numerical radius; compact operators, Hilbert-Schmidt operators. Spectral results for Hilbert space operators: Eigen spectrum, approximate eigen spectrum; Spectrum and resolvent; Spectral radius formula; Spectral mapping theorem; Riesz-Schauder theory; Spectral results for normal, self-adjoint and unitary operators; Functions of self-adjoint operators. Spectral representation of operators: Spectral theorem and singular value representation for compact self-adjoint operators; Spectral theorem for self-adjoint operators. Unbounded Operators: Basics of unbounded closed Operators in Hilbert spaces, Cayley transform, Spectral theorem for unbounded self-adjoint operators.

MA6100 **3**
Mathematics Behind Machine Learning

Data Representation: Eigenvalues - Eigenvectors - PCA - SVD - Fischer Discriminant; Functionals - Hilbert Spaces - Riesz Representation Theorem - Kernel Trick - Kernel PCA - Kernel SVM; Norm Minimization - LLE - Sparse Representation Theory - Dimensionality Reduction
Supervised Learning: Convex Optimisation - Primal-Dual Transformations - Karush-Kuhn-Tucker Conditions - SVM; Probability and Measures - Types of Convergences - Statistical Learning Theory - VC dimension and Capacity - Some bounds
Unsupervised Learning: Expectation Maximization - EM-based Clustering - C-means clustering - Fuzzy CM clustering; Operator Theory - Decomposition of Operators and Subspaces - Subspace Clustering

MA6110 **3**
Convex Functions and Their Applications

Basic properties of convex functions; Convex functions on a normed linear spaces; Various notions of differentiability of a convex function on a normed linear space; Monotone operators, Asplund spaces and Radon Nikodym property; A smooth variational principle and more on Asplund spaces.

MA6116 **3**
Commutative Algebra
▷MA4070

Modules, ideals, prime ideals, maximal ideals. Noetherian rings; Hilbert basis theorem. Minimal primes. Localization. Polynomial rings and algebraic sets. Weak Nullstellensatz. Nilradical and Jacobson radical; strong Nullstellensatz. Integral extensions. Prime ideals in integral extensions. Noether Normalization Lemma. Krull dimension; dimension of an affine algebra.

MA6120 **3**
An Introduction to Operator Algebras

Banach Algebras: Banach Algebras and invertible group; spectrum; multiplicative linear functionals; Gelfand transform and applications; maximal ideal spaces; Non-unital Banach Algebras.
C*-algebras: C*-algebras; commutative C*-algebras; the spectral theorem and applications; polar decomposition; positive linear functional and states; The GNS Construction; non unital C*-algebras
von Neumann Algebras: Topologies on B(H); Existence of projections; the Double Commutant Theorem; the Kaplansky density theorem; the Borel functional calculus; Abelian von Neumann algebras; the La functional Calculus; equivalence projections; Type decompositions

MA6126 **3**
Combinatorial Commutative Algebra
▷MA4070

Monomial ideals and simplicial complexes. The theory of Gröbner bases. Hilbert functions. Resolutions of monomial ideals. Multigraded Betti numbers. Cellular resolutions. Alexander duality. Toric varieties and lattice ideals.

MA6130 **3**
Banach Space Theory

Basic properties of Banach spaces; Classical Banach spaces and their various properties; Linear operators in Banach spaces; Schauder bases; Convexity and smoothness.

MA6140 **1**
Compressive Sensing

Nyquist Sampling Theorem, Under-determined linear systems, Classical solution techniques, l0, l1 and l2 norm minimization problems, Theoretical guarantees for sparse recovery, Greedy and Convex optimization techniques, Dictionary Learning, Applications in Signal Processing.

MA6150 **3**
Discrete Dynamical Systems
▷MA4010, MA4060, MA5040

Phase portraits, Topology of the Real numbers, periodic points and stable sets, Sarkovskii's theorem, Families of dynamical systems, bifurcation, The logistic function, Cantor sets and chaos, topological conjugacy. period-doubling cascade. Symbolic dynamics. Newton's method. Complex dynamics, quadratic family, Julia sets, Mandelbrot set.

MA6160 **3**
Banach Algebras
▷MA4010, MA4020, MA4060, MA5020, MA5040

Preliminaries on functional analysis, Banach spaces and Hilbert spaces.
Banach algebras: Definition, homomorphism, spectrum, basic properties of spectra, Gelfand-Mazur theorem, spectral mapping theorem, group of invertible elements.
Commutative Banach algebras and Gelfand theory: Ideals, maximal ideals and homomorphism, semi-simple Banach algebra, Gelfand topology, Gelfand transform, involutions.
Banach*-algebras, Gelfand-Naimark theorem, applications to non-commutative Banach algebras. A characterization of Banach*-algebras.

MA6170 **3**
Topics in Differential Equations

• Ordinary Differential Equations: Existence and uniqueness of solutions of first order ODE, system of first order equations and the nth order ODE. The method of successive approximations.
• Variations of solutions with respect to initial conditions and parameters. Linear Differential equations and asymptotic behaviour of the solutions of certain linear systems problem.
• Linear systems with isolated singularities: Singularities of the first kind and singularities of the second kind.
• Partial Differential Equations:
• First order PDE: Pfaffian differential equation, Quasi-linear PDE's, Cauchy Problem, Compatible systems, non-linear PDE's, Monge Cone Method.
• Higher order PDE: Classification, canonical form, Heat equation, Wave equation, Laplace equation, Uniqueness theorems.

MA6180 **3**
Topics in Computational Mathematics

• Basics of Programming: Structure of a Program - Variables and Data Types - Conditional Statements -Loops - Functions - Arrays.
• Boolean Logic:
• Propositional Logic: Syntax of PL - Semantics of PL - Normal Forms - Some Applications - Resolution Proof Procedure - Proofs in PL - Axiomatic System of Predicate Calculus - Soundness and Completeness of PL
• First Order Logic: Syntax and Semantics - Proofs in FL - Axiomatic System of First Order Calculus - Soundness and Completeness of FL
• Recurrence Relations: Growth of Functions - Asymptotic Notations - The Substitution Method - The Recursion-Tree Method - The Master Method.

MA6190 **3**
Transcendental Number Theory
▷MA4010, MA4060, MA4070, MA5070.

Irrational Numbers: Decimal representation of real numbers, repeating decimals and rational numbers, irrationality of k-th root of an integer, irrationality of e, π, irrationality of various trigonometric functions at rational arguments, irrationality of $\zeta(3)$.
Transcendental Numbers: Liouville's construction of transcendental numbers, transcendence of e and π, Lindemann's theorem on algebraic independence of exponentials of algebraic numbers and its corollaries, Gelfond - Schneider theorem on transcendence of algebraic exponents of algebraic numbers and its corollaries, linear forms in logarithms - Baker's theorem with application to the Catalan's conjecture, Mahler's construction of transcendental numbers.

MA6200 **3**
Topics in Differential Equations

None

MA6210 **3**

Curves in two and three dimensions, curvature and torsion for space curves,

Curves and Surfaces	Serret-Frenet formula for space curves, Surfaces in R3, Tangent spaces and derivatives of maps between manifolds, geodesics, first fundamental form, orientation of a surface, Second fundamental form and the Gauss map
MA6220 **3** Distribution Theory and Sobolev Spaces	Distributions: Test functions and Distributions, Convolution of Distributions, Fundamental solutions, The Fourier transforms, The Schwartz space $\mathscr{S}$, Tempered Distributions. Sobolev spaces: Definition and basic properties, Approximations by smooth functions, Traces, Sobolev inequalities, Compactness, Other spaces of functions, Dual spaces, Fractional order spaces and trace spaces. Weak solutions of elliptic boundary value problems: Definitions of weak solutions, Existence, The Lax-Milgram theorem, Regularity, Galerkin method, Maximum principle, eigenvalue problems, Introduction to finite element methods.
MA6230 **3** An Introduction to Variational Methods	Preliminaries: Differential calculus, The local and the global inversion theorems, Function spaces, Nemitski operators, Elliptic equations. Topological methods: Bifurcation results, The Lyapnov-Schmidt reduction, Bifurcation from the simple eigenvalue. Brouwer degree and its properties, The LeraySchauder degree, Some applications to elliptic equations, The Krasnoselski bifurcation theorem, The Rabinowitz global bifurcation theorem. Critical points and extrema: Functionals and critical points, Gradients, Existence of extrema, Differentiable manifolds, an outline, Constrained critical points, Manifolds of codimension one, Natural constraints. Deformations and the PalaisSmale condition: Deformations of sublevels, The steepest descent flow, The PalaisSmale condition, Existence of constrained minima, The mountain pass theorem, Applications.
MA6240 **3** Differential Geometry	Differentiable manifolds and smooth maps, Tangent spaces, vector fields, Riemannian metrics, Riemannian connections, Geodesics, Sectional and Ricci Curvatures, Tensors, Jacobi fields, The second fundamental form, Complete manifolds, Hopf-Riniw theorem. Spaces of constant curvature. Cartan Theorem, Hyperbolic Spaces. Liouville Theorem. Formulas for the first and second variation of energy. The Rauch comparison theorem
MA6260 **3** Algebraic Geometry I	Sheaves, Schemes and morphisms, First properties of schemes, Finiteness conditions on morphisms, Separated and proper morphisms, Sheaves of modules, Coherent sheaves, Divisors, Projective morphisms, Blowing up, Differentials, Tangent and normal bundles.
MA6270 **3** Algebraic Geometry II	Derived Functors, Cohomology of sheaves, Cohomology of noetherian affine schemes, Cech cohomology, Cohomology of projective space, Ext groups and sheaves, Serre duality theorem, Higher direct images of sheaves, Flat morphisms, Smooth morphisms.
MA7020 **3** Commutative Algebra II	Regular sequences and depth: Regular sequences, Grade and depth, Depth and projective dimension, Free resolution. Torsion-free and reflexive modules, Ideal of minors, Acyclicity criterion, Graded rings and modules, The Koszul complex. Cohen-Macaulay rings: Cohen-Macaulay rings and modules, Regular rings and normal rings, complete intersections, Gorenstein rings, Injective resolution. Hilbert functions: Hilbert functions over homogeneous rings, Macaulay's theorem on Hilbert functions, Regularity, Hilbert functions over graded rings.
MA7040 **3** Differential Topology ▷MA4090	Differentiable manifolds and maps, Inverse and implicit function theorem, Sub-manifolds, immersions and submersions. Differential forms, Exterior differential, closed and exact forms, Poincare's lemma, Integration on manifolds, Stokes theorem. Tangent space, Vector bundles, Tangent and Cotangent bundle as a vector bundle, Vector fields, flows, Lie derivative, De-Rham cohomology.
MA7140 **3** Statistical Reliability Theory	Coherent Systems - structural properties and reliability, bounds on system reliability, notion of ageing and stochastic orders, parametric families of life distributions, life distributions of coherent systems, poisson process and shock models, mixture of distributions, partial orderings of life distributions, reliability bounds.

29.20 Department of Medical Device Innovation

BM5023 **2** Biomedical Devices	This course teaches the instrumentation of medical devices, electronics and circuits and interfaces required for building medical devices.
MD5520 **3** Physio-anatomy and Patho-physiology of Diseases	Physio-Anatomy of Respiratory, Cardiovascular, GIT, Neuro, Renal, Endocrine systems and related diseases.

MD6116 **2**
Design Thinking

This course focuses on a design process thinking for Innovations in healthcare. The course will teach the students how to make the best use of clinical immersion before starting the clinical immersion. The main goal is to develop a design thinking process to empathize with the healthcare community and patients and help the students to identify the needs that are faced by various stakeholders in a healthcare scenario. This methods trains the students to carry out clinical immersions in an effective manner.

MD6155 **2**
Clinical Immersion (stage I)
▷MD 6116,MD 5520

Students undergo clinical immersions, where they will be shadowing clinicians, nurses, paramedics and patients, observing the procedures, and treatment modalities. The main goal of clinicla imersions is to understand the problems that the stakeholders face and empathize with them. Ultimately these observations take the shape of unmet needs as they learn the biodesign process thinking. tudents will visit the AIG group of hospitals accompanied by doctors to note down all unmet needs of patients. They will observe the operating theatre, procedures, patients and all parts of hospital to find the problems associated with proper patient care delivery. They will learn by a discussion based method of all the problem scenario acquired from the hospitals.

MD6193 **3**
3-d Rapid Prototyping and Modelling

This theory plus lab course aims to provide a basic understanding of CAD modeling and 3D rapid prototyping technologies. The basics and mechanisms of various rapid prototyping technologies with parameters optimization, 3D design software, and 3D printing prototypes will be covered. It will also provide an overview of various product designing and fabrication requirements, such as the selection and development of material formulation, optimization of different processing conditions of the printing operation, and finally, 3D printing of device prototype. Students need to present and discuss a case study related to rapid prototyping and modeling from recent literature in this course. They also work in teams on a mini-project, where they would select one medical device from the market, reverse engineer that, and build a prototype of the same device. They also prepare, present, and defend a short scientific presentation based on their mini-projects.

29.21 Department of Mechanical and Aerospace Engineering

AE5010 **3**
Introduction to Flight

Aerodynamics of flight vehicles under different speed regimes, Basics of propulsion systems in flight vehicles, Flight vehicle performance in steady and accelerated flight, Systems of axes and notation, Static equilibrium and trim, Equations of motion of flight vehicles, Longitudinal dynamics, Lateral Dynamics, Stability and control

AE5020 **3**
Aerospace Structural Mechanics

Aircraft structural components and loads, Aircraft materials, Concept of stress and strain in structures, Kinetics and Kinematics of structures, Constitutive behavior of materials, Plane stress/strain problems in elasticity. Three-dimensional beam theory, Euler-Bernoulli beam theory, Timoshenko beam theory, Bending and Torsion of Thin-walled beams. Classical Kirchhoff-Love theory of plate, First order shear deformation plate theory, Introduction to composite laminate theory. Energy and variational methods, Principle of minimum potential energy, Strain energy of beams and plates, Rayleigh-Ritz method, Mixed-variational principles. Structural analysis of beams and plates, Energy formulation of beams and plates, Bending analysis, Buckling analysis.

AE5030 **3**
Flight Vehicle Aerodynamics

Flow characteristics in subsonic, transonic, supersonic and hypersonic flow regimes, Estimation of aerodynamic coefficients and derivatives for flight vehicles, Quasi-1D analysis of compressible flow, Introduction to numerical methods for aerodynamics, Basics of experimental aerodynamics

AE5040 **3**
Aeroelasticity

Review of Mechanics fundamentals, Structural dynamics, Static aeroelasticity of wind-tunnel models, Aeroelasticity of uniform lifting surface, Aileron reversal, Divergence, Aeroelastic tailoring, Classical flutter analysis, Flutter analysis using assumed modes, Introduction to numerical simulation of aeroelasticity

ME5010 **3**
Mathematical Methods for Engineers
▷PG Only

Vectors, operations and operators, identities; Cartesian tensors: definition, notation, transformation matrix, orthogonal properties, order of a tensor, operations, contraction, quotient rule, vector identities and theorems in tensor form.
First and second order ODEs, linear ODEs with constant coefficients; Laplace transforms; Second order linear homogenous differential equations and their solutions; Sturm-Liouville problem; orthogonal functions; Gram-Schmidt procedure
PDEs: Classification of PDEs, analytical solution of linear PDEs, Fourier series, and Fourier transforms transformation of PDEs between different coordinate systems.
Linear algebraic equations: matrix form, matrix operations, determinants, Cramer's rule,

Inverse, singularity, inconsistent equations, Gauss elimination, Gauss-Seidel, LU decomposition, finding inverses, echelon form, general solution for under-determined systems, generalized inverses, least-squares solution for over-determined systems, eigen-values and eigenvectors, orthogonalization, singular value decomposition (without proof)
Introduction to Integral equations, classifications, solution methodology. Function, functional and an introduction to integral of calculus, Euler-Lagrange equation.
Pre-Req: The student should have done GATE level Math courses in his/her undergraduate

ME5011 0
Data Acquisition and Control Lab

List of Experiments: (1) Elevator control using PLC (2) Conveyor belt control and object categorization using PLC (3) Unipolar and bipolar stepper motor actuation using Arduino board (4) On/Off temperature control using Arduino board (5) Introduction to LabView (6) Unipolar and bipolar stepper motor actuation using LabView

ME5020 1.5
Elasticity and Plasticity
▷PG Only

Elastic and Plastic Behaviour of Metals; Stress: Introduction, Invariants, Deviatoric stress and equilibrium equations; Strain: Introduction, Compatibility, Strain Invariants and Deviatoric Tensor; Stress and Strain Relations (Elastic and Plastic); Yield and Flow: Yield Condition, Isotropic Yield Criteria (von-Mises, Tresca and Hill), Experimental Verification of Yield Criteria, Anisotropy and Anisotropic Yield Criteria.

ME5021 1
Vibration Lab
▷ME5120

List of Experiments: Exp1: Vibration Fundamental Trainer ; Exp2: Damping Measurement using Oberst Beam Method ; Exp3: Whirling of Shaft ; Exp4: Experimental Modal Analysis ; Exp5: Shaft Alignment

ME5030 1.5
Fluid Mechanics and Heat Transfer
▷PG Only

Introduction to Fluid flow; Lagrangian and Euler frames of reference; Material derivative; streamlines, streamlines and path lines; velocity potential and stream function; Conservation of mass and momentum; continuity equation; potential flows; Elliptic equations; boundary conditions; Euler equations; Newton's law of viscosity; Navier-Stokes equations; boundary conditions; Boundary layers; Turbulence; Turbulence modelling; Heat conduction; transient and steady heat conduction equation; Natural convection; Forced Convection; Non-dimensionalization, and non-dimensional parameters; Turbulent convection.

ME5040 1.5
Computational Fluid Dynamics Tools
▷PG Only

Introduction to Navier Stokes equation, basics of discretization methods, finite volume formulation of convection-diffusion equation, pressure-velocity coupling, boundary condition implementation, mesh generation techniques in CFD, CFD applications in manufacturing processes through examples - heat removal during machining process, laser welding process, casting, spray coating process.

ME5050 1.5
Material Science and Material Selection
▷PG Only

Phase and Phase diagrams, Diffusion in Solids, Fundamentals of dislocations and strengthening mechanisms, Mechanical behavior of materials. Materials and design, Evolution of Engineering Materials and their Properties, Materials selection charts, Selection of Engineering materials and their Shape, Selection of Manufacturing Processes, Examples and Case studies.

ME5080 1.5
Scaling Laws and Multi-scale Manufacturing

Introduction to Macro and micro-manufacturing, Importance of Scaling Laws. Scaling Laws in Mechanics, fluids , thermodynamics, Electromagnetism, tribology and Examples. Trimmer force scaling vector. Micro-Fabrication - Fundamentals of Micro-fabrication and Materials, Micro Manufacturing Processes (Additive, Formative and Removal) and their scientific and technological details, Applications. Sensing (measurement) and Control.

ME5090 1.5
Mathematical Elements for Geometrical Modeling

Introduction to computer aided design, fundamentals of computer graphics; geometric modelling of synthetic curves: Hermite, Bezier, B-spline, NURBS. Parametric representation of surfaces: plane, ruled, revolution; Part modelling techniques: wireframe, surface and solid modelling, data representation and exchange formats, geometry and topology. Three-dimensional transformations and projections.

ME5100 1.5
Computer Integrated Manufacturing
▷ME5090/ME3040

Current developments in CAD- feature based modeling, design by feature, function, feature linkages, application of feature based models, parametric modeling; Computer Aided Manufacturing: fundamentals of part programming, path generation, post processing and verification; Group Technology, Computer aided process planning (CAPP), computer aided inspection and reverse engineering, manufacturing process simulation, virtual and distributed manufacturing, computer integrated manufacturing.

ME5110 3
Advanced Mechanics of Solids

Introduction; Stress definition and stress-traction relations; Deformation, strain definition, strain-displacement relation; Constitutive equations; Equilibrium and compatibility equations; Two dimensional problem solutions – Plane stress and Plane strain; Advanced two dimensional problems – Plate with a hole, Rotating disk, Disk under diametral compression; Axisymmetric problems; Torsion – Prandtl stress function; membrane analogy; Special problems – Wedge with boundary tractions, concentrated

force on half plane.

ME5120 **3**
Dynamics and Vibration

Analytical dynamics, degrees of freedom, equations of motion using Newton's laws and Lagrange equations, constrained motion, free and forced vibration of single degree of freedom damped and undamped systems, vibration isolation, Jeffcott rotor, free and forced vibration of multi-degree of freedom systems, modal decoupling, free and forced vibrations of continuous systems (vibrations of rods, strings, beams, and plates).

ME5130 **3**
Finite Element Method

Theory and implementation of finite element methods for solving boundary value problems in solid mechanics. Mathematical foundations (Calculus of Variation), review of energy theorems, theory and implementation of 1D, 2D, and 3D elasticity problems. Introduction to FEM softwares.

ME5140 **1.5**
Process Modeling and Optimization

Introduction to Processes and Variation, Probability Models of Manufacturing Processes, Statistical modeling and control in manufacturing processes, Sampling Distributions and Statistical Hypotheses, Statistical Process Control. Design of Experiments, ANOVA. Use of experimental design and response surface modeling to understand manufacturing processes. Multi criteria optimization. Case studies.

ME5150 **1.5**
Computational Intelligence

Function approximation and Pattern recognition: Statistical modelling, Neural Network, Fuzzy system and Classification, Principal Component Analysis; Evolutionary computation: Genetic algorithms; Meta-heuristic methods: Simulated annealing, Ant colony optimization, Tabu search; Monte-Carlo simulation, Design and analysis of experiments.

ME5160 **3**
Nonlinear Mechanics of Slender Structures

Review of tensor algebra, Introduction to classical beam, plate and shell theories, Applications of large deformations in rods, plates and shells, problems on instabilities, Kirchhoff rods: analytical solutions, theory of Cosserat rods, Von Karman plates, Cosserat plates and shells, current research topics.

ME5190 **2**
Manufacturing Processes

Classification, operating parameters, and throughputs of manufacturing processes - Generative, Additive, and Removal Processes; Conventional and Non-conventional process; Contact and Non-contact processes; Hybrid manufacturing processes. Characterization of manufactured products: Form and Surface features, Residual stress, Mechanical properties, Corrosion resistance; Process control and feedback: Electrical, hydraulic, pneumatic, and optical sensors; open and closed loop control.

ME5200 **1.5**
Additive Manufacturing
▷PG Only

Overview of Rapid Product Development: Product Development Cycle, virtual prototyping, physical prototyping, Solid Modelling: Data formats, conversion, checking, repairing and transmission. Synergic integration technologies, Part slicing and Build Orientation, Area-filling strategies, applications and limitations of RPM. Classification of RPM processes: Sheet Lamination, Material Extrusion, Photo-polymerization, Powder Bed Fusion, Binder Jetting, Direct Energy Deposition. Popular RPM processes. Selection of rapid prototyping, tooling and manufacturing systems based on product requirements.

ME5220 **1.5**
Material Removal Processes

Conventional and non-conventional machining operation; Machine tools; Cutting Tool: Tool material, Tool geometry, Tool wear; Metal working fluids; Machinability. Mechanics of Machining Operation, Dynamometry in machining operations. Surface Integrity; Precision machining; Machining Economics; Environmentally friendly machining, Machining of difficult to cut materials.

ME5230 **1.5**
Design and Analysis of Welded Joints

Modern welding process: GMAW (Robotic, CMT, and STT), Micro plasma welding, EBW, LBW, Diffusion bonding, Ultrasonic welding, Pulsed current welding, Friction stir welding, Magnetic Pulse welding. Analysis of heat sources for material joining, 2D and 3D heat flow in welds, Residual stress analysis. Weldment design for static and fatigue loading, Failure of welds, NDT of welds, Welding symbols.

ME5240 **1.5**
Metal Forming
▷ME5020

Overview of Plasticity; Metal Forming- Bulk Processes: Rolling, Extrusion, Drawing and Forging (Each Process will be analysed using Force Equilibrium, Slip-line and Upper Bound Methods), Tool Design, Defects and Remedies; Sheet Metal Forming: Shearing, Bending, Deep Drawing (all its variants) and other processes; Hydro Forming, Explosive Forming, Electro-Magnetic Forming, Electro-Plasticity. Scaling laws in Plasticity, Micro-Forming; Analysis of Forming Processes including defects using Finite Element Analysis.

ME5250 **1.5**
Design for Manufacturability and Assembly
▷If UG: ME2030/ME2230, ME3010

Introduction to design for manufacturing concepts; importance of product specification and standardization, selection of materials and shapes, design rules for various manufacturing processes, design for assembly, design for reassembly, design for automated assembly, design for ergonomics, design for quality and reliability, design for X concepts. Materials selection charts, Selection of Engineering materials and their Shape, Selection of Manufacturing Processes, Examples and Case studies.

ME5260 **3**
Continuum Mechanics

Tensor Algebra and Analysis - Review properties of a vector space. Tensors as linear transformations. Tensor product of vectors. Symmetric tensor related to dot product. Scalar and regular product of tensors. Trace, Determinant, Inverse, Orthogonality, Positive Definiteness. Eigen vectors/values and Spectral theorem, Cayley-Hamilton theorem and principal invariants, Polar decomposition. Derivatives as a linear map. Compute derivative by this definition. Derivative of determinant/ square root/ simple functions. Product rule and Chain rule. Gradient/Divergence/Curl. Divergence theorem, Stokes' theorem.
Kinematics - Body as a subset of a Euclidean space. Motion, deformation, deformation gradient, Polar decomposition. Lagrangian and Eulerian descriptions. Properties of deformation gradient and left/right stretch tensors. Examples of deformation: homogeneous, isochoric, rotations. Assumptions of small deformation. Motion, Velocity, Acceleration, Material time derivative, velocity gradient. Transport theorem
Balance Laws - Conservation of mass, linear and angular momenta. Global and local statements. Cauchy's theorem and its proof. Surface/body forces. Principle of virtual work. States of stress: tensile, shear, hydrostatic etc. Examples of various stress tensors.
Constitutive Modelling - Motivation of the general constitutive law s=g(n). Hyperelasticity and energy-density function. Material symmetry and various symmetry groups. Invariance on change of observer. Special consequences of isotropy.

ME5270 **3**
Interfacial Phenomenon

Introduction to interfacial flows Governing equations and boundary conditions - Laplace Pressure - Minimal surfaces Young's law - Fluid statics - Hydrodynamics of Interfaces: Thin films, RayleighTaylor instability, Plateau-Rayleigh instability, Drop oscillations, coating flows, Marangoni effects - Contact line hysteresis - Dynamic wetting phenomenon.

ME5280 **3**
Hypersonic and High Temperature Aerodynamics

(1) Review of fundamental gas dynamics, introduction to hypersonic flow regimes; (2) Inviscid hypersonic flows: applicability, hypersonic shock and expansion relations, surface pressure distribution relations, hypersonic aerodynamic theory, numerical solution techniques (3) Viscous hypersonic flows: Navier Stokes and boundary layer equations, Friction drag and aerodynamic heating, hypersonic-viscous interactions, numerical modelling of viscous hypersonic flows, shock-boundary layer interactions in hypersonic flows, numerical modelling of viscous hypersonic flows. (4) High Temperature Gas Dynamics: Introduction to high temperature flows, thermodynamics of reacting gases, Statistical thermodynamics and Boltzmann distribution, kinetic theory of gases, energy, mass and momentum transport, chemical and vibrational reaction rates, inviscid high temperature flows, viscous high temperature flows, radiative gas dynamics. Applications.

ME5290 **1**
Stability of Time Delayed Systems

Stability theory of ordinary differential equations, Stability of maps, introduction to delay differential equations (DDEs), quasi-polynomials, method of semi-discretization, Galerkin approximation, Floquet theory, stability of DDEs with time periodic delays and time periodic coefficients

ME5300 **2**
Variational Methods in Mechanics

Introduction to functional; simple fixed end point variational problem and its Euler equation; generalized variational problem; Legendre transformation; Noether's Theorem; Principle of least action and conservation laws; Second variation and sufficient condition for extremum; application to continuous mechanical systems.

ME5310 **3**
Incompressible Fluid Flow

Tensors, Lagrangian and Euler frames of reference; Material derivative; Reynolds Transport Theorem; Derivation of conservation of mass; Fluid kinematics; Conservation of angular momentum; Derivation of Navier-Stokes equations (Newton's law of viscosity); Elliptic and Parabolic equations; boundary conditions; Analytical solutions of NS equations (both steady and unsteady); velocity potential and stream function; potential flows; Euler equations; Stokes equations and their applications; Lubrication approximation; Boundary layer Theory; Similarity solutions; Approximate methods; Introduction to turbulence.

ME5320 **3**
Advanced Heat Transfer
▷ME3110

Introduction - Review of fundamentals of heat transfer. Conduction: General heat conduction equation, Analytical solutions of two dimensional steady state heat conduction; Transient conduction. Convection: Governing equations, boundary layer equations, Forced convection over external surfaces and internal ducts; Similarity solutions. Free and Mixed convection flows, Conjugate heat transfer analysis. Radiative Heat Transfer: Thermal radiation, Emissive Power, Solid Angles, Radiative Intensity, Heat Flux, Pressure and Characteristics, Radiative transport equation.

ME5330 **3**
Computational Fluid Dynamics

Introduction to numerical solutions of PDEs; importance of CFD; various methods; Taylor Series; Finite-difference of first, second and third derivatives; Order of accuracy; finite-differences on non-uniform grids; time-stepping; explicit and implicit time-stepping

of 1D unsteady heat conduction equation; Boundary and Initial conditions; tri-diagonal solver; Explicit and Implicit schemes for 2D unsteady heat conduction equation; Gauss-seidel method; Convergence; iterative vs direct methods; Types of PDEs, and their IC and BCs; the well-posed problem; Methods of Elliptic PDE; False-transient method; Hyperboilc PDEs; 1st order wave equation: characteristics; Methods: Lax, McCormack etc; modified equation; dissipative and dispersive errors; systems of hyperbolic equations; diagonalization; Finite-volume method; Convection-Diffusion equation; Convective schemes: Upwind, 2nd upwind, Quick, etc; Vorticity-stream function formulation: Explicit, Implicit and Semi-Implicit schemes; coupled temperature equation; segregated and coupled solution methods; SMAC method for Navier-Stokes equations.

ME5340 **3**
IC Engine Combustion and Pollution

Introduction: Engine types and their operation, Engine design and operating parameters, Thermochemistry of fuel-air mixtures; Combustion in Spark-Ignition Engines: Essential features of process, Thermodynamic analysis of SI engine combustion, Flame structure and speed, cyclic variations in combustion, partial burning and misfire, Spark ignition, Abnormal combustion: Knock and surface Ignition; Combustion in Compression-Ignition Engines: Essential features of process, Types of Diesel combustion Systems, Phenomenological model of CI engine combustion, Analysis of cylinder pressure data, Fuel spray behavior, Ignition delay, Mixing-controlled combustion; Modeling real engine flow and combustion processes: Purpose and classification of Models, Governing equations for open thermodynamic system, Intake and exhaust flow models, Thermodynamic-based In-Cylinder models, Fluid-mechanics based multidimensional models; Pollutant formation and control: Nature and extent of problem, Nitrogen oxides, Carbon monoxide, unburned hydrocarbon emissions, Particulate emissions, Exhaust gas treatment; Nonconventional Engines: Common rail diesel injection, Dual fuel and multi-fuel engine, Free piston engine, Gasoline direct injection engine, Homogenous charge compression ignition engine, Lean burn engine, Stirling engine, Stratified charge engine, Variable compression ratio engine, Wankel engine.

ME5350 **1.5**
Introduction to Hydrodynamic Stability
▷ME5310 or ME2240

Introduction to hydrodynamic stability theory - relevance and applications - Linear Inviscid stability analysis - Rayleigh's stability equation - temporal stability analysis and spatial stability analysis - convective and absolute instabilities - Initial value problems - Viscous stability analysis - Orr Sommerfeld and Squire's equation - Stability of density and thermally stratified flows - Capillary instabilities - Solve stability problems with Matlab.

ME5360 **1.5**
Planar Multibody Dynamics

Introduction to kinematics and dynamics of planar rigid bodies - vector and matrix notation - degrees of freedom, constraint equations and constraint forces, kinematic joints - formulation of kinematics in body coordinates, joint coordinates, and point coordinates; formulation of dynamics in body coordinates, joint coordinates, and point coordinates; kinematic analysis - forward dynamic analysis - inverse dynamic analysis.

ME5370 **2**
Impact Mechanics
▷ME3150 or ME5110 or ME5020

Propagation of 1D stress pulse, coaxial collision of bars, reflection and superposition, review of continuum mechanics, dilatational and shear waves, Rayleigh and Lamb waves, longitudinal, torsional and flexural vibrations of rods, Pochhammer equations for cylindrical bars, design of a split hopkinson bar for high strain rate characterization, propagation of 1D stress pulse in elasto-plastic material, Taylor impact test, one dimensional impact on metal foams, plastic deformation of beams subjected to impact.

ME5380 **2**
Robot Manipulators: Kinematics and Dynamics

Introduction to robot manipulators – common kinematic arrangements of manipulators – rigid motion and homogeneous transformations – forward kinematics – inverse kinematics – velocity kinematics – Jacobian – singularities; Dynamics – Euler-Lagrange formulation – Newton-Euler formulation

ME5400 **2**
Sustainable Energy Technology 1: Energy Sources

(a) Introduction:- Review of thermodynamics; Energy Demand and Supply Outlook; Climate Change: projections and risks (b) Non-renewable Energy sources (Coal, Oil, Natural Gas, Nuclear) and their impact on the environment (climate change , atmospheric pollution, radioactive waste); (c) Renewable Energy Sources - Wind, Solar PV, Solar-Thermal, Geo-thermal, Hydropower – technology and deployment; (d) Carbon Neutral Fuels – biomass to fuel conversion, biofuel combustion technology, hydrogen as fuel, CO2 to fuel conversion, fuel cell technology;

ME5410 **1**
Sustainable Energy Technology 2: Energy Efficiency, Storage and Optimization

(a) Energy Storage Technology – chemical storage and battery technology, electro-mechanical storage, thermal storage; (b) Energy Efficiency and Emission Reduction – Use of Exergy to optimize energy use, Clean Combustion Technology, Carbon Capture and Storage, Energy efficient buildings, Life Cycle Assessment (LCA), Distributed and Smart Grid systems.

ME5420 **1**

3D rigid body kinematics – representation of rotation – rotation matrix – Euler angles –

Aerial Robotics: Dynamics of Drones	Tait-Bryan angles – Euler parameters – axis-angle representation – quaternions – rigid body dynamics – angular momentum – moment of inertia tensor – equations of motion – under-actuated motion
ME5421 **1** FEM Lab ▹ME5020, ME5130	Finite element methods for solving boundary value problems in solid mechanics. Introduction, Spatial Modelling, Geometric discretization, Element Library, Material Modelling, Loading and Boundary Conditions, Constraints, Surface/Interfaces modelling, Step and job handling and Post-processing. FEA Implementation and Visualization of 1D Problems, Truss Problem, Beam bending, Plane and axisymmetric Problems and 3D problems. Various analysis such as, Static, Transient, Harmonic, Modal, Dynamics and Multi Physics (Thermomechanical, etc).
ME5431 **2** Integrated Design and Manufacturing Lab	Job preparation using CNC machining, Robotic welding, 3D printing, EDM, Injection molding. Measurements of parts using CMM; Form measurement; Digitization using 3D scanner, surface roughness testing. Deep drawing using forming machine. Cutting force measurement using dynamometer. Sample preparation and characterization using Optical Microscope. Lab project.
ME5440 **1.5** Introduction to Machine Vision	Overview, cameras and selection, lenses and selection, illumination, image acquisition, sampling, quantization and digitization, transforms, filtering, image restoration and enhancement, image segmentation techniques, object identification, application to automatic inspection and identification, optical character recognition, bar code, robot guidance
ME5441 **1** CFD Lab	Mesh generation techniques, experiment using commercial CFD solver - turbulent mixing and heat transfer, external flow, combustion, two-phase flow, turbo-machines.
ME5451 **1** Computational Mathematics Lab	Introduction to MATLAB - variables, structures, arrays, operators, conditional statements, loops; root finding using Newton-Raphson method, optimization, solving ODEs and PDEs, event detection; graphics; simulink based simulations.
ME5470 **3** Introduction to Parallel Scientific Computing	Almost all computing devices today employ multiple processing units that work at the same time (in parallel). As a result, parallel programming finds application in several engineering domains. This course will introduce parallel programming as applied to a subset of scientific computing applications, focused on solving partial differential equations. Parallel algorithms for sparse and dense linear solvers and fast Fourier transforms will be discussed. Basics of parallel thinking, measures of parallelism and parallel performance will be introduced. Shared memory (using OpenMP) and distributed memory (using MPI) paradigms will be described. The need to understand hardware aspects to achieve scaling will be emphasized. Students will get experience with practical aspects of building, debugging, and profiling parallel applications through exercises. Since the examples used will focus on solution of partial differential equations, this course will be beneficial for students in Mechanical and Aerospace, Civil, and Chemical Engineering departments. Ideally, students taking this course should have some exposure to implementing (serial) numerical algorithms. This course will be useful to students using scientific computing for their research needs as well as to those aspiring to work in industry focused on numerical algorithms.
ME5480 **3** Sustainable Energy Technology: Energy Sources, Energy Efficiency, Storage and Optimization	Introduction:- Review of thermodynamics; Energy Demand and Supply Outlook; Climate Change: projections and risks. Non-renewable Energy sources (Coal, Oil, Natural Gas, Nuclear) and their impact on the environment (climate change , atmospheric pollution, radioactive waste); Renewable Energy Sources - Wind, Solar PV, Solar-Thermal, Geo-thermal, Hydropower – technology and deployment; Carbon Neutral Fuels – biomass to fuel conversion, biofuel combustion technology, hydrogen as fuel, CO2 to fuel conversion, fuel cell technology; Energy Storage Technology – chemical storage and battery technology, electro-mechanical storage, thermal storage; Energy Efficiency and Emission Reduction – Use of Exergy to optimize energy use, Clean Combustion Technology, Carbon Capture and Storage, Energy efficient buildings, Life Cycle Assessment (LCA), Distributed Energy and Smart Grid systems.
ME5505 **3** Special Topics in Manufacturing	This is a project oriented course where the students are expected to work on a research subject with the guidance of the individual faculty. This will be accompanied by regular assessment of the progress through weekly presentation/seminars.
ME5510 **1.5** Industrial Automation and Robotics	Automation principles and strategies, basic elements of an automated system, levels of automation, sensors, actuators, and control system components; automation in manufacturing processes, material handling, inspection and assembly.

	Robotics fundamentals - workspace, forward kinematics, inverse kinematics, dynamics and control algorithms
ME5520 **1.5** Measurement Science and Techniques	Introduction to Measurement, Errors in Measurement, Calibration and Basic Statistics, Displacement Measurement: Intrusive and non-Intrusive methods, Measurement of Temperature: Contact and non-contact, Measurement of Pressure: Various principles of measurement, Different gauges, Vibration and Acoustic Measurement: Velocity and Acceleration Measurement, Sound pressure level measurement, Measurement of Force Torque and Power: Load cells, Torque cells, Dynamometers, Stress Strain Measurements using Strain gauges
ME5530 **1.5** Industry 4.0	[1] Introduction to Industry 4.0: The various industrial revolutions; Comparison of industry 4.0 factory and today's factory; Trends of industrial big data and predictive analytics for smart business transformation; Drivers, enablers, compelling forces for Industry 4.0. [2] Concepts of the factory of the future: Flexible production; Crowdsourcing; Interoperability of data; movement from mass production to mass customization; integration of enterprise IT and operations technology. [3] Local Initiatives and Case-Studies: US- Industrial Internet of Things (IIoT), Japan- e-Factory, Germany- Industrie 4.0, China- Intelligent Manufacturing; case studies. [4] Enabling Technologies: Machine-to-machine communication; Cloud-based application infrastructure and middleware; Data analytics; Integrated product-production simulation; Additive manufacturing/3D printing.
ME5610 **3** Fracture Mechanics	Review of elements of solid mechanics, analysis of stress-strain-constitutive equations, introduction to fracture mechanics, crack growth mechanisms, fracture mechanism, Inglis solution, Griffith's realization, energy principles, energy release rate, linear elastic fracture mechanics, stress intensity factor, SIF for general cases - analytical/numerical/experimental, multi-parameter stress field equation, elastic plastic fracture mechanics, J-integral definition, fatigue crack propagation and evaluation of testing standards.
ME5620 **3** Mechatronic Systems	Overview of mechatronic systems - mathematical modeling of systems - introduction to control - sensors and transducers - signal conditioning - amplification, filtering, analog-to-digital converters and digital-to-analog converters - data presentation systems - actuators - electrical, mechanical, pneumatic, hydraulic - analog electric circuits, operational amplifiers - digital logic circuits, microprocessors, microcontrollers, DSPs, Programmable Logic Controllers - programming in assembly and C - communication interfaces - RTOS - machine vision systems - robotics.
ME5630 **3** Nonlinear Oscillation	Review of dynamical systems, solution methodology, phase space and different stability analysis, different types of nonlinear systems and its classification based on the nature of nonlinearity, modeling of single/multi-degree of freedom dynamical systems with single/multiple inputs, evolution equations obtained from continuous systems, existence of nonlinear resonances, regular perturbation, singular perturbation methods, multiple scales method, equilibrium stability vs orbital stability of periodic and quasiperiodic systems, local bifurcation theory and center manifold theorem, application of techniques to do nonlinear analysis of mechanical systems under external/parametric excitation.
ME5640 **3** Multibody Dynamics	Review of kinematics and dynamics of point mass and rigid body - types of constraints - constraints for revolute joints, translational joints, composite joints - formulation of planar multi-body systems, kinematics and dynamics in point coordinates, body coordinates, and joint coordinates - numerical methods for solution - analysis of planar multi-body systems, kinematic analysis, inverse dynamic analysis, forward dynamic analysis, constraint stabilization - case studies, McPherson strut suspension, Double A-arm suspension, planar robot manipulator - Spatial multi-body systems.
ME5650 **3** Engineering Noise Control	Introduction to noise control: definition of sound, acoustic wave equation, sound level and spectra, octave and 1/3 octave bands, weighting networks (a, b, c and linear), hearing, psychological response to noise, loudness interpretation, NC curves, masking, sound propagation, plane wave, spherical wave, sound power, its use and measurement, sound power and sound pressure level estimation procedure, characteristics of noise sources, source ranking, passive noise control methods, sound absorption coefficient measurement, transmission loss, room acoustics, sound in enclosed spaces, basics of muffler design, lined plenum absorption, pipe wrapping, vibration isolation, vibration damping.
ME5660 **3** Applied Micro and Nanomechanics in Engineering	Review of different physical domains and their coupling in the design of micro and nanomechanics based senors and actuators. Scaling laws - length and time scale. Inter and intra-molecular forces, constitutive relationships in solids and fluids. Electrostatic potential, and capacitance, pull-in phenomena, static and dynamic analysis. Application

of the numerical techniques through standard multidomain analysis softwares such as COMSOL multiphysics/Intellisuite/Coventorware/ANSYS, etc.

ME5670 **3**
Vehicle Dynamics and Modeling

Vehicle Mechanics - Forces under static and dynamic equilibrium. Free body diagram of different vehicle components. Simple linearized rigid models of different components. Dynamic stability and the vehicle performance under different operating conditions such as understeering, neutral steering, and oversteering. Concept of vehicle ride comfort. Vehicle stability controls. Driveline models, Performance characteristics of a comfortable vehicle ride. Introduction to the development of vehicle model using different software such as MATLAB Simulink, MAPLESIM, System Modeller, ADAMS, CarSIM.

ME5680 **1.5**
Fatigue and Damage Tolerance Evaluation

Introduction to fatigue of structures and material; fatigue phenomenon in material; stress intensity factors; fatigue properties; fatigue strength of notched specimens; fatigue crack growth - analysis and predictions; fatigue testing; fatigue tolerant structure.

ME5690 **3**
Advanced FEM
▷ME5130

Theory and implementation of finite element methods for solving non-linear boundary value problems in solid mechanics. Review of fem and continuum mechanics, nonlinear bending of beams and plates, nonlinear analysis of time dependent problems, material non-linearity, and solution procedures for linear and nonlinear algebraic equations.

ME5700 **3**
Analysis and Design of Composite Structures

Introduction to composite materials, Concepts of isotropy vs. anisotropy, Micro-mechanics of composite lamina, Macro-mechanics of composite laminate, Classical Lamination Plate theory (CLPT), Failure criteria, Bending and buckling analysis of laminated composite plates, Inter-laminar stresses, First Order Shear Deformation Theory (FSDT), Delamination models, Composite tailoring and design issues.

ME5720 **1.5**
Advanced Material Joining Processes

Modern welding process: GMAW (Robotic, CMT, and STT), Micro plasma welding, EBW, LBW, Diffusion bonding, Ultrasonic welding, Pulsed current welding, Friction stir welding, Magnetic Pulse welding. Analysis of heat sources for material joining, 2D, 3D heat flow in welds, residual stress analysis, Arc physics.

ME5723 **3**
Experimental Solid Mechanics

Introduction to stress analysis; Optical Methods for whole field measurement; Strain gauges – Principle, measurement; Introduction to Interferometry technique; Photoelasticity - Principle, measurement; Moiré - Principle, measurement; Holography - Principle, measurement; Speckle pattern interferometry - Principle, measurement; Digital Image Correlation - Principle, measurement; Recent advancements in experimental techniques; Sensitivity and data interpretation; Practical measurements using photoelasticity, strain gauges, DIC including specimen preparation, testing and analysis.

ME5750 **3**
Micro-mechanics of Defects
▷ME5110

Review of Elasticity, Theory of Eigen strains, the theory of elastic inclusions (Isotropic and Cubic), the theory of cracks and dislocation. Interaction of defects. Review of plasticity, Theory of elastoplastic inclusions.

ME5810 **3**
Advanced Computational Fluid Dynamics

Finite-volume method; pressure problem for incompressible Navier-Stokes equations; Pressure-velocity decoupling; Staggered and collocated grids; semi-explicit (SMAC) method on staggered grids; Convective schemes; Implicit SIMPLE method; higher-order accuracy implementations; Non-orthogonal grids: problems with staggered grids; collocated grid; implementation of semi-explicit and implicit schemes on rectangular collocated grids; generalization to collocated non-rectangular hexahedral grids; Boundary conditions and their implementation; adaptation of schemes to tetrahedral grids, general hybrid grids; advanced linear equations solvers; algebraic multigrid methods.

ME5820 **3**
Turbulence

Turbulence: Introduction, nature, origin, length and time scales in turbulent flows, Kolmogorov energy spectrum. RANS equations, Closure problem, Turbulent transport of momentum and heat. Dynamics of Turbulence: Kinetic energy of the mean flow, Kinetic energy of turbulence, Vorticity dynamics, Dynamics of temperature fluctuations. Free-shear flows, Wall bounded shear flows. CFD modelling of Turbulence: Algebraic models, One-equation models, Two-equation models: Wall bounded flows; Wall functions and Low Reynolds number effects, Beyond RANS for turbulence modelling; LES and DNS.

ME5830 **3**
Compressible Flow and Its Computation

Basics: Introduction and review of Thermodynamics; Integral form of conservation equations; One-dimensional Flow - Area-Velocity Relations and Isentropic Relations, Wave Propagation, Speed of Sound, Shock Waves, Normal Shock Waves; Flow Through Nozzles and Duct, Flow with Heat addition and friction; Two - dimensional Compressible Flow: Oblique Shocks, Expansion Waves, Shock Interactions, Detached Shocks, Shock-Expansion Technique; Unsteady Wave Motion; Analytic Methods: Method of Characteristics;
Computation: Mathematical nature of Euler equations: Various forms of Euler equations; Hyperbolic Equations; Riemann Problem. Basic Numerical Methods: Centred and

upwind discretisation. Artificial Viscosity, CFL condition and Numerical stability. Brief Historical Evolution of the computational methods for compressible flow and their classification. Central Schemes, First and Second order upwind scheme. Roe and MacCormack methods. Flux-Vector Splitting, Godunov Methods, High Resolution Schemes: TVD and Flux-limiters. Boundary Conditions: Treatments for physical and numerical Boundary Conditions. Modern Compressible Flow and Current Research; Numerical Methods available in commercial and open source software.

ME5840 1
Introduction to Open CFD

Open source CFD software distribution; Meshing, Initialization, Boundary conditions, Selecting models, Mesh conversion; Examples - Incompressible Flows, Compressible Flows, Multiphase flows; Post-processing tools and visualization, Running in parallel, Programming new transport and turbulence models.

ME5850 1
Introduction to Molecular Solvers

Introduction to Continuum and Molecular Theories, Direct Simulation Monte Carlo Method, Open source molecular solvers with applications to hypersonic, rarefied and microscale gas flows; external aerodynamics; Molecular Dynamics Method, Applications to nano liquidics.

ME5860 1
Introduction to Combustion and Reactor Models

Combustion background; 1st and 2nd law of thermodynamics applied to chemical reaction, Gibbs free Energy, equilibrium temperature and composition; Arrhenius law, reaction rate for single step and multistep reactions; PSR, PFR, const. pressure and const. volume reactor models and their applications to simulate practical combustion systems.

ME5870 2
Chemical Kinetics and Modeling in Reacting Flows

Chemical Kinetics - elementary and global reactions, collision theory, rate of reaction in multistep mechanisms, chemical time scales and partial equilibrium; Simplified conservation equations applied to reaction systems, concept of conserved scalar; Laminar flames - premixed and diffusion; Turbulent flames - premixed and diffusion; detonations and deflagration, liquid and solid fuel combustion reaction modeling.

ME5880 3
Combustion and Flow Diagnostics

Detailed review of optical diagnostic techniques - PIV, PLIF, CARS, Raman and Rayleigh scattering, interferometry, schlieren and shadowgraph; experimental applications to flow field diagnostics; liquid fuel spray atomization characterization, combustion and pollutant formation; optical measurements in direct injected diesel and gasoline engines; advanced developments - Infrared laser-induced fluorescence imaging, novel flow-tagging velocimetry approach, new diode laser sources for combustion diagnostics and control, CO2 interferences in engine diagnostics.

ME5910 3
Combustion Technology

Thermo-Chemistry of Combustion, Combustion Kinetics, Simple Chemical Reactors, Conservation Equations for Reacting Flows, Laminar Premixed Flames, Laminar Non-Premixed Flames, Droplet Combustion, Turbulent Premixed Flames, Turbulent Non-Premixed Flames, Solid Combustion.

ME5911 2
Design Engineering Core Lab II

Experimental stress analysis lab: Strain measurement involving strain gages for tensile, torsion and bending applications,Thick cylinder under internal pressure, Gage factor determination for a strain gage, Introduction to photoelasticity, Material stress fringe value determination, Tardy method of compensation for fringe order determination, Photoelasticity applications, Beam under four point bending, Bending study of a diaphragm under pressure load Vibration Lab: Vibration Fundamental Trainer, Whirling of Shaft, Experimental Modal Analysis, Laser alignment system Mechatronics Design Lab: Traffic control using Programmable Logic Controller, Magnetic levitation system, Stepper motor control through digital input/output (DIO) using Labview, Temperature measurement through ADC using LabView.

ME5971 2
Thermo-fluid Engineering Core Lab II

Introduction about Subsonic Wind tunnel; Measurement of static and dynamic pressure; Calibration of pressure transducers; Measurement of aerodynamic forces and flow characteristics: Cylinder, flat plate, symmetric and asymmetric airfoils.
Thermal conductivity of fluids: water and air; Fluidized bed heat transfer; Pool boiling and Condensation.

ME6010 2
Mechanics of Composite Materials
▷ME5110

Introduction to composite materials, Concepts of isotropy vs. anisotropy, Micro-mechanics of composite lamina, Macro-mechanics of composite laminate, Classical Lamination Plate theory (CLPT), Failure criteria, Bending and buckling analysis of laminated composite plates, Inter-laminar stresses, First Order Shear Deformation Theory (FSDT), Delamination models, Composite tailoring and design issues.

ME6020 2
Theory of Dislocations

Introduction to Dislocations and Disclinations. Glissile dislocations: Velocity of dislocations, Glide, Climb, and Plastic strain due to dislocation movement. Elastic Properties of Dislocations (Straight and curved): Stress fields, Strain Energy, Dislocation Interactions (with other dislocation, crack, free surface and grain boundary). Dislocations in FCC: Full and Partial dislocations, Stacking faults. Dislocations in other structures: BCC, HCP, Polymer crystals and Graphene. Intersection of dislocations.

Nucleation of dislocations: Sessile dislocations, Homogenous nucleation, in-homogenous nucleation. Dislocation Arrays and Crystal Boundaries and twinning: Plastic deformation, recovery and Recrystallization. Plasticity and Dislocation Dynamics: Strain rate dependence of the flow stress, Peierls stress lattice resistance, Work hardening, flow stress for random array of obstacles, dislocation fracture.

ME6040 **3**
Machine Learning and Its Applications
▷PG Only

Overview, supervised learning – linear regression, logistic regression and classification, regularization; feedforward neural network and backpropagation training algorithm; Support Vector Machines; unsupervised learning – clustering, dimensionality reduction; anomaly detection; advanced concepts in machine learning; application case studies

ME6106 **1**
Seminar

Thesis writing, research paper writing, delivering technical seminars, group discussion, technical interview, text processing using LaTeX.

ME7100 **3**
Advanced Topics in Mathematical Tools
▷ME5010

Classical Optimization, stochastic optimization, Neural and Fuzzy system, FFT, Wavelets, monte carlo simulations, design of experiments, Taguchi method. Introduction to linear and nonlinear dynamical system, fixed points and stability, phase plane analysis, Limit cycles, Bifurcations in 1D and 2D of systems, Lyapunov stability, Deterministic chaos, Strange attractors, Regular and singular perturbation, Boundary layer theory, Matched asymptotic expansions, and Method of multiple scales.

ME7110 **1**
Introduction to Impact Mechanics

Elastic impact: Propagation of 1D stress pulse, coaxial collision of bars, reflection and superposition, Navier's equations, dilatational and shear waves, Rayleigh and Lamb waves.
Plastic impact: lower and upper bound theorems of plasticity, applications to static plastic deformations in beams, propagation of 1D stress pulse in elasto-plastic material, Taylor impact test, one dimensional impact on metal foams, plastic deformation of beams subjected to impact, dynamic buckling of beams.

29.22 Department of Materials Science and Metallurgical Engineering

MS5010 **3**
Functional Properties of Materials

Solids and bonding:Introduction to types of bonding – classification of solid types, metals, ionic crystals, covalent crystals Electrical Properties:Introduction, Basic concept of electric conduction, Free electron and Band theory, Classification of materials, Insulator, Semiconductor, Metal, Superconductor etc. novel materials, some recent trends.
Magnetic properties:Introduction, Origin of magnetism, Units, Types of magnetic ordering: dia-para-ferro-ferri and antiferro-magnetism, Soft and Hard magnetic materials, examples of some magnetic materials with applications Dielectric and ferroelectric properties:Dielectric constant and polarizability, temperature and frequency effects, electric breakdown, structural phase transitions, Ferroelectric crystals, Classification of ferroelectric materials: piezo-pyro and anti-ferroelectric materials.

MS5020 **3**
Electron Microscopy

Principles of electron microscopy-scattering mode and transmission mode. SEM, TEM, electron diffraction and X-ray, Resolution and magnification, Instrumentation (electron gun, acceleration, magnification, etc), Aberration, distortion and mitigation, Applications of SEM: Surface morphology, qualitative and quantitative phase analysis, Applications of TEM: Bright Field and Dark Field imaging, diffraction, resolution and magnification, Limitations of electron microscopy, Recent developments in electron microscopy

MS5029 **3**
Electron Microscopy

Principles of electron microscopy-scattering mode and transmission mode. SEM, TEM, electron diffraction and X-ray, Resolution and magnification, Instrumentation (electron gun, acceleration, magnification, etc), Aberration, distortion and mitigation, Applications of SEM: Surface morphology, qualitative and quantitative phase analysis, Applications of TEM: Bright Field and Dark Field imaging, diffraction, resolution and magnification, Limitations of electron microscopy, Recent developments in electron microscopy

MS5030 **3**
Materials Synthesis and Characterization

Crystal Structure: Crystalline solids, crystal systems point groups: methods of characterizing crystal structure - Powder x-ray diffraction; types of close packing - hcp and ccp, packing efficiency, radius ratios; structure types with examples. Basics of Solid State Synthesis: Powder synthesis and compaction- precipitative reactions, sol-gel route, precursor method, ion exchange reactions, intercalation/deintercalation reactions, powder metallurgy; Bulk synthesisSolidification from melt (amorphous and crystalline), electrodeposition, thin film preparation. Characterization Techniques: Thermal analyses (differential scanning calorimetry, thermogravimetric), microscopy (light, X-ray, electron) and spectroscopy. Crystal Structure: Crystalline solids, crystal systems point groups: methods of characterizing crystal structure - Powder x-ray diffraction; types of close packing - hcp and ccp, packing efficiency, radius ratios; structure types with

examples. Basics of Solid State Synthesis:Powder synthesis and compaction- precipitative reactions, sol-gel route, precursor method, ion exchange reactions, intercalation/deintercalation reactions, powder metallurgy; Bulk synthesisSolidification from melt (amorphous and crystalline), electrodeposition, thin film preparation. Characterization Techniques: Thermal analyses (differential scanning calorimetry, thermogravimetric), microscopy (light, X-ray, electron) and spectroscopy.

MS5040 **3**
Thermomechanical Processing of Materials

Introduction to thermo mechanical processing, Hardening mechanisms, Static and dynamic softening processes, Crystallographic texture development during thermo mechanical processing,Different thermo mechanical processing techniques, Residual stress in thermo mechanical processing, Defects in thermo mechanical processing Case studies: Thermo mechanical processing of steel, aluminum, magnesium, titanium and other advanced alloy systems, Recent trends in thermo mechanical processing

MS5049 **3**
Thermomechanical Processing of Materials

Introduction to thermo mechanical processing, Hardening mechanisms, Static and dynamic softening processes, Crystallographic texture development during thermo mechanical processing,Different thermo mechanical processing techniques, Residual stress in thermo mechanical processing, Defects in thermo mechanical processing Case studies: Thermo mechanical processing of steel, aluminum, magnesium, titanium and other advanced alloy systems, Recent trends in thermo mechanical processing

MS5050 **3**
Advanced Physical Metallurgy

General Introduction, Structure of solids, Characterization techniques- X-ray and Electron Diffraction, Imperfections in solids including fundamentals of dislocations, Strengthening mechanisms, Phase and phase diagrams, Diffusion in solids, Phase transformation in materials Mechanical behavior of materials, Materials degradation and corrosion, Important Engineering materials

MS5059 **3**
Advanced Physical Metallurgy

General Introduction, Structure of solids, Characterization techniques- X-ray and Electron Diffraction, Imperfections in solids including fundamentals of dislocations, Strengthening mechanisms, Phase and phase diagrams, Diffusion in solids, Phase transformation in materials Mechanical behavior of materials, Materials degradation and corrosion, Important Engineering materials

MS5080 **3**
Thin Films Technology

Introduction to thin films: Definition of thin films - Formation of thin films (sticking coefficient, formation of thermodynamically stable cluster - nucleation) - Environment (Gas phase and plasma) for thin film deposition; Deposition parameters and their effects on film growth, Substrates – overview of various substrates utilized. Vacuum technology: Concept of different vacuum pumps: rotary, diffusion, Turbo molecular pump, Cryogenic-pump, Ti-sublimation pump, Concept of different gauges: pirani, penning, Pressure Control – Mass flow controllers. Physical vapor deposition (PVD) techniques: Evaporation- Thermal evaporation, Electron beam evaporation; Laser ablation; Ion beam evaporation and Cathodic arc deposition, Molecular Beam Epitaxy. Glow discharge Sputtering- DC and RF Sputtering; Magnetron sputtering; Ion beam sputtering – Reactive sputtering Chemical vapor deposition techniques: Advantages and disadvantages of Chemical vapor deposition (CVD) techniques over PVD techniques, Different kinds of CVD techniques: Metallorganic (MO) CVD, Thermally activated CVD, Plasma enhanced CVD, Atomic layer deposition (ALD)-Importance of ALD technique. Epitaxy – Introduction: Epitaxial growth- Growth kinetics of epitaxy, Growth modes – illustration of crystallographic relations with thin film to substrate, characterization of epilayers (insitu and exsitu) – RHEED – XRR, Utilization of various methods to grow epilayers (PVD and CVD) Thickness Determination techniques: Thickness determination methods in thin film (insitu and exsitu) – Non Destructive Techniques - quartz crystal monitoring technique, optical interferometry, Ellipsometry, profilometric techniques. Destructive Techniques – depth profiling and cross sectional electron microscopy Characterization of Thin films: Structural characterization of thin films - Advanced X-ray characterization of epilayers - compositional characterization - surface sensitive photoemission techniques (UPS, XPS).

MS5090 **3**
Advanced Materials Synthesis

Crystal Structure Crystalline solids, crystal systems point groups: methods of characterizing crystal structure - Powder x-ray diffraction; types of close packing - hcp and ccp, packing efficiency, radius ratios; structure types with examples. Basics of Solid State Synthesis and its Characterization techniques Solid state chemistry reaction: precipitative reactions, sol-gel route, precursor method, ion exchange reactions, intercalation / deintercalation reactions, glasses, thin film preparation and solidification from melts. Thermal analysis, microscopy and spectroscopy as tools of characterization. Functional Materials Low dimensional Materials, Electronic and Magnetic Materials, Superconductors, Mott insulators, Bethe Slater Curve, Thermoelectric Materials, Optical Materials, PbMo6S8, NiO, La2CuO4. Biomaterials Introduction; Requirements (Mechanical Properties, Biocompatibility, High corrosion and wear resistance,

		Osseointegration); Currently used metallic biomedical materials and their limitations; Ti alloys (thermomechanical processing, microstructure and properties, wear, corrosion behavior, surface modification); Ti alloys used in Dentistry; Next generation biomaterials â€“ Nanophase materials Energy Conversion and Energy Storage Materials Energy Conversion Materials (Thermoelectric materials, Piezoelectric materials, Solar cells); Energy Storage Materials (Li-ion Batteries, Fuel Cells and Nickel-MH batteries, Hydrogen storage)
MS5100	**3**	General Introduction, Classification of composites Strengthening mechanism in composite Mechanics of composite materials Types of reinforcements- particles, whiskers, fibers Dispersion hardened composites Fiber reinforcement composites- continuous and discontinuous fiber reinforcement composites Metal matrix composite, Metal matrix composite, carboncarbon composites, molecular composites, multilayer composites, ceramic matrix composites polymer matrix composites, thermoelastic and thermoplastic composites, biocomposites Liquid metal route, powder metallurgy route and in-situ composites Production of diamond tools and cermets, composite coatings, electrodeposition techniques, spray forming, characterization of composites Effect of orientation and adhesion, interfaces and interphases Effect of reinforcement materials size and shapes on properties Mechanical behaviour of composites, stress-strain relations, elastic properties, thermal stresses, strength, fracture, toughness, fatigue, creep and wear.
Composite Materials		
MS5109	**3**	General Introduction, Classification of composites Strengthening mechanism in composite Mechanics of composite materials Types of reinforcements- particles, whiskers, fibers Dispersion hardened composites Fiber reinforcement composites- continuous and discontinuous fiber reinforcement composites Metal matrix composite, Metal matrix composite, carboncarbon composites, molecular composites, multilayer composites, ceramic matrix composites polymer matrix composites, thermoelastic and thermoplastic composites, biocomposites Liquid metal route, powder metallurgy route and in-situ composites Production of diamond tools and cermets, composite coatings, electrodeposition techniques, spray forming, characterization of composites Effect of orientation and adhesion, interfaces and interphases Effect of reinforcement materials size and shapes on properties Mechanical behaviour of composites, stress-strain relations, elastic properties, thermal stresses, strength, fracture, toughness, fatigue, creep and wear.
Composite Materials		
MS5110	**3**	A journey from writing a manuscript till sending it to the journal Introduction to the journal formats related to science and engineering streams Arrangements of research outcomes into journal format; Basic English grammar skills for writing manuscripts Rules of manuscript writing like tables, equations, figures, references, cover letter, etc To reaffirm the right human morals while performing research, ethics of correct scientific practices will be taught in details
Scientific Writing and Ethics in Research		
MS5120	**3**	Green energy resources Introduction to non- conventional energy resources, overview of current developments Sustainable Energy resources Overview of fuel cell technology and introduction to various type of fuel cell i.e. solid oxide fuel cell (SOFC), proton exchange membrane fuel cell (PEM), phosphoric acid fuel cell etc SOFC Principles of SOFC, types of fuel, reforming reactions, components of SOFC, Typical component materials and their characteristics, commercial fabrications processes, current trends and future outlook SOFC technology. PEM Fuel Cell Typical component materials and their characteristics, commercial fabrications processes, current trends and future outlook for PEM fuel cell technology. Energy harvesting Overview of wind energy, solar energy technology Solar cells : Overview of solar cell technology, principles of solar cell technology, Silicon based solar cells, fabrications and latest development, Non-Si and organic solar cells Energy Storage : Li-ion battery technology: basics of Li-ion battery, battery components, current trends and challenges Hydrogen storage materials : Overview of various hydrogen storage materials including porous materials, metal hydrides, organic materials etc., storage mechanism and latest development in hydrogen storages
Materials for Green Energy		
MS5130	**3**	Introduction to powder metallurgy manufacturing, historical perspective, scope of powder metallurgy industries Techniques of near net shape manufacturing, techniques of powder manufacturing Characterization of powders, relation between powder production method and powder characteristics, powder compaction methods powder injection moulding Introduction to sintering, driving forces of sintering, stages of sintering, solid state sintering, liquid phase sinterin, pore morphology, sintering of mixed powders, Sintering techniques, sintering atmosphere, post-sintering operations Problems of nano-powders during compaction and sintering, sintering mechanisms, sintering diagrams Powder metallurgy products: bearings, filters, friction parts, electrical contact materials, porous parts, functionally graded materials.
Powder Metallurgy Manufacturing		
MS5139	**3**	Introduction to powder metallurgy manufacturing, historical perspective, scope of

Powder Metallurgy Manufacturing

powder metallurgy industries Techniques of near net shape manufacturing, techniques of powder manufacturing Characterization of powders, relation between powder production method and powder characteristics, powder compaction methods powder injection moulding Introduction to sintering, driving forces of sintering, stages of sintering, solid state sintering, liquid phase sinterin, pore morphology, sintering of mixed powders, Sintering techniques, sintering atmosphere, post-sintering operations Problems of nano-powders during compaction and sintering, sintering mechanisms, sintering diagrams Powder metallurgy products: bearings, filters, friction parts, electrical contact materials, porous parts, functionally graded materials.

MS5140 3
Introduction to Computational Methods in Materials Science

Tensors in Materials Science, Computational linear algebra, Nonlinear algebra, Random numbers (MC simulations, Random walk model), Fourier series and Fourier transforms, PDEs and ODEs, IVP, BVP (Mesoscale methods)

MS5149 3
Introduction to Computational Methods in Materials Science

Tensors in Materials Science, Computational linear algebra, Nonlinear algebra, Random numbers (MC simulations, Random walk model), Fourier series and Fourier transforms, PDEs and ODEs, IVP, BVP (Mesoscale methods)

MS5150 3
Biomaterials- Materials in Medicine

Application of materials in medicine Introduction to structure and biological properties of cardiovascular, orthodontic, ophthalmic and soft tissues and requirement of implant materials Metallic Implants Physical, mechanical properties and corrosion behavior of metallic materials, surface modification, Implant design and processing, examples of bone, stents and surgical implants Ceramic and composite implants materials Chemical and structural and biological properties of ceramic materials, synthetic methods for ceramic and composite materials, Biomimetic approach towards composite design and bioresorbable implants, examples of ceramic and composite materials in orthodontic implants Polymeric materials Synthetic and biopolymers, chemical properties, thermomechanical behaviour, examples of polymeric materials in cardiovascular, ophthalmic and other soft tissue implant applications. Practical aspects of Implant materials Host tissue response, implant failure

MS5160 3
Polymer Science and Engineering

The objective is to teach basics in polymer physics, relate it to polymer structure, processing and applications. This course also aims to introduce conventional characterisations techniques in context of polymers.
Introduction to polymers- synthetic and natural (wood, silk) , structure (states and configuration) of polymers- spring dash pod models - relaxation behaviour, structure - properties relationship and application, processing techniques and product development (eg fibre spinning), introduction to functional polymers (eg liquid crystalline polymers), characterisation- XRD, SAXS, SEM, TGA, DSC, flow in polymers- rheology, composites (natural and synthetic), networks and hydrogels

MS5170 3
Thermodynamics and Kinetics of Materials

Concepts of classical and statistical thermodynamics - extensive and intensive properties - heat capacity, enthalpy, entropy and Gibbs free energy; Partial molar quantities - chemical potential, Gibbs-Duhem relations; Phase equilibrium in single component systems; Ideal and nonideal behavior of solutions; Gibbs free energy composition diagrams; Phase diagrams; Multicomponent phase equilibria; Irreversible thermodynamics - diffusion in continuum – continuity equation; Concepts of fields, fluxes and gradients; Fick's laws of diffusion – steady state and nonsteady state; Solutions to the diffusion equation; Atomic mechanisms of diffusion – random walk; Interstitial and substitutional diffusion; Solutions to diffusion equations; Interdiffusion – Kirkendall effect, Darken relations; Diffusion in multicomponent systems.

MS5180 3
Applications of Electrochemistry in Materials Science and Engineering

Fundamental concepts of Electrochemistry, Electrical double layer and it's importance, concepts of electrode potential, over potential and it's practical implications, The Butler-Volmer equation, introduction to electrochemical analytical techniques like cyclic voltametry, electro chemical polarization and electrochemical impedance spectroscopy; Examples of applied electrochemistry: Batteries, Fuel Cells, the Lithium Ion Battery, applications in extractive metallurgy - electrowinning and other techniques like electrochemical deposition

MS5190 3
Soft Materials

Introduction to 'soft' materials in terms of structure, property- Colloids, foams, gels, liquid crystals, soft biological materials such as DNA, and polymers (synthetic and natural) Structure (states and configuration) of polymers, synthesis, effect of temperature (glass transition and melting), branching, cross-linking on properties, crystallisation in polymers (types and mechanism), mechanical behaviour – viscoelasticity -spring dash

		pod models – relaxation behaviour (time and temperature effect) Self-assembly and Supramolecular organisation with reference to cellulose, silk, collagen and biological macromolecules
MS5200 Phase Transformations	**3**	Phase transformations and microstructure formation; different classifications: first order vs higher order, diffusional vs diffusionless, discontinuous vs continuous; free energy-composition diagrams; nature of interfaces in crystalline materials and their role in phase transformations; thermodynamics and kinetics of nucleation; solid state precipitation: phase diagram, stable and metastable/intermediate phases, solvus temperatures, growth forms and kinetics, discontinuous precipitation; spinodal decomposition and disorder-order transformations; eutectoid transformation; massive transformation; martensitic transformation and shape memory effect.
MS5210 Hierarchical Nanostructured Materials	**1**	Natural hierarchical materials - bone, nacre, butterfly wing and so on, Advantages of hierarchical nanostructural organisation - mechanical, colours, and other functional benefits
MS5220 Nature Inspired Materials Engineering	**2**	Nature inspired material engineering and design for applications such as environment, energy and healthcare applications, bottom up assembly techniques and production, gap between natural and nature inspired materials
MS5230 Nature Inspired Materials Engineering for Mechanical Applications	**1**	Design and Fabrication methods for producing nature inspired materials with enhanced mechanical properties, including optimisation of toughness and strength like in nacre or bone, introduction to materials and their synthesis for actuation properties like muscle, selection and design of materials for regenerative medicine
MS5240 Nature Inspired Materials Engineering for Wettability, Optical Tunability	**1**	Introduction of top down and bottom up fabrication techniques; Usage of combination of approaches to achieve tunability in wettability (similar to hydrophobicity of lotus) and optical properties such as reflection, colours (similar to peacock or moth's eye) and interaction (adhesive properties of gecko's foot)
MS5250 Phase Stability in Alloy Design	**1**	Alloy thermodynamics, Analysis of phase stability, metastable and non-equilibrium transformations, phase stability in design of complex alloys
MS5270 2d Materials: Synthesis, Characterization and Applications	**3**	This course will cover the latest advances development of 2D materials. Specifically, we will study the new materials along with their potential for different applications. A non-trivial part will also be dedicated to learning about special characterization techniques required to study such materials. For example, a group of materials expected to be studied include Graphene and other 2D materials (MoS2, TeS2, WSe2 etc.). These materials have significant potential for future applications.
MS5280 Wear and Tribology of Materials	**1**	Introduction to trobological systems and their characteristic features; analysis and assessment of surface; techniques of surface examination, friction and measurement, mechanism of wear, types of wear, quantitative laws of wear, measurement of wear, wear resistance materials.
MS5289 Wear and Tribology of Materials	**1**	Introduction to trobological systems and their characteristic features; analysis and assessment of surface; techniques of surface examination, friction and measurement, mechanism of wear, types of wear, quantitative laws of wear, measurement of wear, wear resistance materials.
MS5290 Plasmonics: Fundamentals to Advanced Applications	**3**	Introduction to nano-optics and plasmonics, Restrictions on materials for plasmonics, Localized plasmons, Effect of shape, size and material, Multiple particle assemblies - Analogy to molecular hybridization, Biosensing and molecular recognition (SERS/SEIRA), Molecular modification of nanoparticle surfaces, Nanofabrication using localized plasmons, Characterization techniques - Far-field techniques (BF/DF microscopy, Fourier plane imaging), near-field techniques (near-field scanning optical microsope), Propagating surface plasmons, Thin film plasmons: Special excitation geometries (Otto, Kretschmann, Sarid geometry), Biosensing - determination of binding constant, Surface plasmon imaging, Optical interconnects and plasmonic waveguides, Characterization techniques, Nano- and micro-fabrication techniques for realizing plasmonic nanostructures will also be covered.
MS5300 Microstructural Design for	**3**	Concepts of microstructural elements and texture; microstructure-texture control strategies during manufacturing; severe plastic deformation processing, aspects of

Advanced Manufacturing	strength-ductility synergy; metastability and TRIP phenomena; stacking fault engineering and TWIP phenomenon; segregation engineering, heterogeneous microstructures, processing and mechanical behavior; microstructural design of multicomponent alloys; processing-microstructure-texture-properties landscape in 3-D printing of advanced alloys
MS5309 3 Microstructural Design for Advanced Manufacturing	Concepts of microstructural elements and texture; microstructure-texture control strategies during manufacturing; severe plastic deformation processing, aspects of strength-ductility synergy; metastability and TRIP phenomena; stacking fault engineering and TWIP phenomenon; segregation engineering, heterogeneous microstructures, processing and mechanical behavior; microstructural design of multicomponent alloys; processing-microstructure-texture-properties landscape in 3-D printing of advanced alloys
MS5310 3 Functional Ceramics	Special structures: Zinc blende, Rock salt, fluorites, perovskites, double perovskites, layered perovskites, pyrochlores and polymorphs, Transition metal oxides: Gas sensors, varistors, wide bandgap oxides, solid state electrolytes, ionic conductors. Piezoelectric ceramics: lead based and lead free piezoelectrics, piezoelectric coefficients, measurements and devices, Ferroelectric ceramics: ferroelectricity, domain theory, phenomenological and atomistic theory of ferroelectricity
MS5320 3 Solidification Processing	Types of casting processes and heat transfer fundamentals for casting; Stefan problem for heat transport with phase change; thermodynamic and atomistic treatment of nucleation; directional binary alloy solidification with planar interface: equilibrium, macrosegregation, and steady state; constitutional supercooling and breakdown of planarity; G-V maps for microstructure selection; welding processes and weld thermal cycle; heat transfer models for welding; weld solidification and microstructure development.
MS5380 3 Interdiffusion in Solids	Recap of basic thermodynamics and crystal defects, Fick's laws of diffusion, Solution to thin film condition and homogenization, Development of Interdiffusion zone in different systems, Interdiffusion in binary alloys – Matano Boltzmann analysis, Den Broeder and Wagner's approach, The Kirkendall effect, Darken analysis, Intrinsic diffusion coefficients, Vacancy wind effect, Phase growth in line compounds and phases with narrow homogeneity range, Concept of integrated and average diffusion coefficients, Interdiffusion in multicomponent alloys, Determination of phase diagrams using diffusion couple technique
MS5400 3 Advanced Thermodyanmics of Materials	Revisiting basic terminologies – thermodynamic system, surroundings, etc., Laws of Thermodynamics, Thermodynamic relations and functions, Equilibrium in Thermodynamics systems, Statistical Thermodynamics, Unary Heterogeneous systems, Multicomponent homogenous non-reacting systems: solutions, Multicomponent heterogeneous systems, Thermodynamics of Phase Diagrams, Multicomponent multiphase reacting systems, Capillary effects in thermodynamics, Defects in crystals, Thermodynamic effects of external fields
MS5459 1 High Entropy Materials	The Concept of Alloy Design and High Entropy alloys (HEAs), Multi-component Glasses vs. HEAs, Predicting Phase formation in HEAs, Synthesis routes of HEAs, Variety of HEAs and High Entropy Materials, Properties of HEAs
MS5469 3 Metal Additive Manufacturing	• Introduction to Metal Additive Manufacturing: Nomenclature, Additive Manufacturing vs. Conventional Manufacturing, Advantages and Limitations of Metal Additive Manufacturing; Direct and Indirect Approaches to Metal Additive manufacturing: Classification of Metal Additive Manufacturing Processes, • Direct Metal Additive Manufacturing: Directed Energy Deposition (Laser–Powder/Wire, Electron Beam–Wire, Electric Arc–Wire/Powder processes), Powder-Bed Fusion (Laser and Electron Beam Processes); Solid-State Metal Additive Manufacturing Processes (Ultrasonic Additive Manufacturing, Friction Deposition (Meld), Friction Stir Welding); Fusion vs. Solid-State Additive Manufacturing; Hybrid (Additive + Subtractive) and Emerging Techniques for Metal Additive Manufacturing; Defects and Post-Processing of Additive Manufactured Parts; Use of Additive Techniques for Repair, • Indirect Metal Additive Manufacturing: Binder Jetting, Extrusion, Sheet Lamination, and Other Processes; Post-Processing Methods and Procedures; Direct vs. Indirect Metal Additive Manufacturing, • Commercially Available Equipment and Materials for Metal Additive Manufacturing; Process Development, Parameters and Control; Microstructures and Mechanical Properties of Additive Processed Metals; Post-Processing of Additive Manufactured Metallic Parts, • Recent Developments and Progress in Metal Additive Manufacturing; Selection of Metal Additive Manufacturing Processes, Application Case Studies
MS5479 3	Metallurgy of welding and additive manufacturing

Metallurgy of Welding and Additive Manufacturing

MS5509 **3**
Deformation Behaviour of Materials

Continuum description of stress, strain, constitutive relations, Elasticity and Plastic deformation in metallic materials; Defects in crystalline materials, Theory of dislocations, Strengthening mechanisms in metals and alloys; Flow behavior under quasistatic loading, Cyclic loading; Room temperature fracture, High temperature deformation, creep and superplasticity

MS5519 **3**
Applied Phase Equilibria and Phase Transformations

Basic concepts of phase equilibrium in unary, binary and multicomponent systems – specific heat, thermodynamic processes and variables, laws of thermodynamics, thermodynamic potentials, equations of state, solutions – ideal, regular and Redlich-Kister solution models – chemical reactions – Ellingham and predominance area diagrams, CALPHAD tools for calculation of free energy vs. composition diagrams and phase diagrams – assessment of metastability, Kinetics – Fick's laws and their applications to carburization, nitridation, decarburization, homogenization – temperature dependence of diffusivity – basics of interdiffusion, Phase Transformations – driving force for phase transformations – nucleation, growth and coarsening – TTT diagrams – T0 curves for massive and martensitic transformations, Applications of kinetic databases and tools for carburization, homogenization processes, precipitation, TTT curves

MS5529 **2**
Engineering Alloys

Introduction to engineering alloys; Fundamental metallurgical principles; Strengthening mechanisms, Alloy design considerations; Ferrous and non-ferrous alloys, Common engineering alloys: Steels, Cast irons, Stainless steels, Copper alloys, Aluminum alloys, Titanium alloys, Magnesium alloys, Nickel alloys, Cobalt alloys, and others – Classification, Physical metallurgy, Heat treatment, Properties, and Applications

MS5539 **3**
Corrosion Science and Engineering

Basics of Electrochemistry and Corrosion, Fundamentals of Electrochemistry, Electrochemical Reactions, Electrochemical Methods and Applications, Types of corrosion (Uniform and localized corrosion, Galvanic, Intergranular, Crevice, Pitting, Erosion etc.) Corrosion protection – prevention and economic considerations, Introduction to High-temperature oxidation, examples of oxidation in high-temperature alloys, superalloys, mechanisms and prevention from a metallurgical perspective

MS5549 **3**
Diffusion Analysis in Materials Engineering

A brief introduction - Phase Diagrams, Thermodynamic variables, Gibbs phase rule, Free Energy Composition Diagrams, Point Defects, Fick's laws of diffusion, solution of diffusion equations – applications to carburization, decarburization, homogenization, Atomic Mechanisms of diffusion – Interstitial diffusion, Vacancy mechanism, Temperature effects, diffusion in ordered intermetallics, Basics of interdiffusion – Chemical potential as driving force, development of interdiffusion zone in various systems, Kirkendall effect, Application in developing products, Experimental techniques – Radiotracer diffusion, Secondary ion mass-spectrometry (SIMS), Electron probe microanalysis (EPMA), High diffusivity paths – Diffusion along grain boundaries – Fisher's model, Kinetic regimes of GB diffusion, Dislocation diffusion, Diffusion in nanocrystalline materials, Applications of diffusion analysis – Microstructure development at the interface, High-throughput alloy design using diffusion-couple experiments, Determination of phase diagrams, Composition-structure property relations, Thermal oxidation, atomic transport in semiconductors and ionic materials

MS5559 **3**
Welding Processes

Introduction to Welding: Fundamental Concepts; Classification of Welding Processes; Evolution of Fusion and Solid-State Welding Processes; Weld Thermal Cycles, Fusion Welding Processes: Gas welding; Flux- and Gas-shielded Arc Welding; Arc Physics; Laser and Electron Beam Welding; Other Processes, Solid-State Welding Processes: Friction Welding; Friction Stir Welding; Explosive Welding; Ultrasonic Welding; Diffusion Bonding; Resistance Welding; Other Processes, Weld Defects and Control; Selection of Welding Processes; Brazing and Soldering

MS5569 **3**
Casting and Solidification

Types of casting processes; Casting design fundamentals; Heat transfer fundamentals for casting; Thermodynamic and atomistic treatment of nucleation; Stefan problem for heat transport with phase change; Directional binary alloy solidification with planar interface: equilibrium, Gulliver-Scheil segregation, and steady state; Constitutional supercooling and breakdown of planarity; Microsegregation; G-V maps for microstructure selection; Eutectic solidification; Casting and solidification of engineering alloys

MS5579 **3**
Structure and Characterization of Materials

Structure of materials at various length-dimension scale (atom, crystal, nano, micron, bulk); Structure (length and dimension scale)-property relationship; Optical Microscopy: Basics, Imaging (contrast, resolution), illumination modes, polarized light, metallographic analysis through case studies; Electron Microscopy (Scanning, Transmission): Basics, Instrument details, Imaging, Composition Analysis and

		Diffraction techniques, Application through various case studies; X-ray Diffraction: Basics (interactions with matter, diffraction from perfect and imperfect crystals); Instrument details (X-ray sources and optics); Techniques (imaging, small angle scattering, tomography); Analyses (Crystal structure and size-grain and particle; Orientation; Phase diagram; Order-disorder transformations; Chemical analysis; Stress measurement) through various case studies; Thermal Analyses: Differential Scanning calorimetry, Differential Thermal Analysis, Thermogravimetric Analysis
MS5589 Non-destructive Testing of Materials	**2**	Introduction to non-destructive testing (NDT) of materials, Scope of NDT, Visual testing, Liquid penetrant methods for NDT, Magnetic NDT methods, Ultrasonic NDT, X-ray radiographic testing, Electromagnetic wave-based NDT, Leak testing, Thermal NDT method
MS5599 Metallurgical Failure Analysis	**2**	Introduction to Failure Analysis: Purpose and end; Qualities of a failure analyst; Ethics in failure analysis, Tools and techniques in failure analysis; Fracture analysis; Determination and classification of damage, Deficiencies in materials selection and design; Manufacturing defects; Operational and maintenance defects, Case studies: Failures due to fatigue, creep, embrittlement, corrosion, and wear in automotive, aerospace, power, petrochemical, and other sectors
MS5609 Role of Microstructure in Materials Selection and Design	**3**	• Basics of microstructure-property-processing correlations for structural and functional applications. Materials selection principles • Basics of microstructure-based materials design criteria • Materials processing for microstructure control • Non-equilibrium materials processing for the development of nano and ultrafine grained materials • Design of microstructure for room temperature structural applications – optimization of strength, ductility and toughness • Microstructural design for cryo and high temperature applications • Microstructural design improved wear, oxidation and corrosion resistant applications • Design of microstructure for functional applications such as magnetic, thermoelectric materials. • Design philosophy behind advanced materials such as bulk metallic glasses, high entropy alloys, in-situ composites, superalloys, nanostructured materials, etc.
SD5010 Fundamentals of Semiconductor Materials	**3**	Introduction to Theory of metals - crystals - Bravais lattices - Reciprocal lattice - Energy band formation - Semiconductor crystals - tight binding approach and Band formation in semiconductors - Direct and Indirect Band gap semiconductors - Concept of holes - Hall Effect - Effective mass - heavy and light
SD5011 Semiconductor Materials Characterization Lab	**1**	XRD (Bulk and thin film), Microscopy (Optical, SEM, TEM, SPM), UV-Visible spectroscopy, Photoluminescence, Raman spectroscopy
SD5020 Semiconductor: Extraction, Refining and Crystal Growth	**3**	Principles of extraction, pyrometallurgical processes, material and heat balance of processes, thermodynamics of processes; introduction to laws, thermodynamic equilibrium, thermochemistry, Ellingham diagram. Process kinetics; introduction to chemical kinetics and rate processes, heterogeneous kinetics, kinetics of liquid-liquid reactions, concepts of reactor design. Structure and properties of molten liquids. Production of metallurgical grade (MG) Si: Carbothermic reduction, principle, operation and practice of sub-merged arc furnace, energy and process calculation, refining and impurities control in molten MG Si. Production of electronic grade (EG) Si: Concept of fluidized bed reactor, Siemens Process (Chlorine based), Schumacher's Process (Bromine based), Silane process, Fluoride process, solvent refining, slag refining. Crystal Growth: Crystal growth processes (Bridgman and its variants, Czochralski), heat and species transfer during non-steady and steady state plane-front growth, interface instability and effect of convection on interface stability.
SD5021 Semiconductor Devices Characterization Lab	**1**	Sheet resistance and Hall effect measurements of semiconductor films, determination of resistivity and conductivity, measuring I-V characteristics of p-n junction diodes, MOSFETs, thin film transistors, and determination of field-effect mobility and transconductances of devices.
SD5030 Semiconductor Devices	**3**	Fundamentals of semiconductors, Carrier transport phenomena, Recombination and generation, Physics of PN Junction diodes (Ohmic and Schottky contacts) MOSFET modelling, MOS capacitors, MOSFET Operation and modeling, Short and narrow channel effects, Radiation and hot-carrier effects, Bipolar junction transistors,Bipolar device Design and Modeling, Small and large signal models, Non-ideal effects, breakdown voltage, charge storage, Multidimensional effects, Bipolar Device optimization and performance factors for digital and analog circuits, Future technologies
SD5040	**3**	Lithography – Photolithography, E-beam lithography, Focussed ion beam lithography,

Micro and Nanofabrication	Etching (Dry and wet etching techniques, selectivity, directionality), Deposition techniques (PVD (sputtering and evaporation) and CVD (PECVD, LPCVD, APCVD), Chemical planarization, Oxidation, Ion implantation and Diffusion (for doping)
SD5050 3 Electrochemical Processes in Semiconductors	Fundamentals of Electrochemical Processes: Introduction (Electrochemical principles and basic concepts, Evolution of electrometallurgy), Pourbaix diagrams, Transport properties of electrolytes (aqueous, molten, and ionic solutions), Solution models (Debye-Hückel-aqueous, Temkin-molten salts), Electrode-electrolyte interface, Equilibrium electrode potential Electrochemical Kinetics: Electrochemical reaction kinetics and mechanism of electrodeposition, Mass transport and interfacial processes, Aspects of cementation, electrocrystallization and surface morphology of metal electrodeposits, Current distribution in electrochemical cells, Butler-Volmer equation, Tafel plot, Electrodeposition at a periodically changing rate, Effects of additives Electrochemical Characterization: Current-Voltage measurements, voltammetry, photocurrent measurements, rotating ring disk electrodes, scanning electrochemical microscopy, measurements of surface recombination and minority carrier injection, impedance measurements, spectroscopic methods, In situ surface microscopy (STM and AFM) Applications: Electrodeposition of metals for semiconductor devices (interconnects, electromagnetic shields, bond wires), electrodeposition of Semiconductors (elemental semiconductors, binary semiconductors, ternary semiconductors), etching of semiconductors, electrochemical e-waste management Failures of devices under fields: Electromigration, oxidation, corrosion, electronic charge induced damage
SD5060 3 Flexible Electronics and Processing	Introduction, fundamentals and applications of flexible electronics, mechanics of flexible and stretchable devices, stress-strain analysis, failure modes of films, mechanical testing methods, organic and inorganic materials, substrates, barrier films, flexible electronic devices (thin film transistors, memory devices, sensors), processing (physical vapor deposition techniques, different printing, and coating techniques). Lab component: thin film deposition, mechanical testing of thin films, and stress-strain analysis.

29.23 Department of Microelectronics V

EE5107 0 Semiconductor Physical Electronics	None
EE5117 0 Microelectronic Device Physics	None
EE5127 0 Analog IC Design	Two port parameters, nonlinearity, large-signal and small-signal analysis, incremental y-parameters of MOSFET; common-source amplifier: biasing, signal coupling, swing limits; negative feedback: Bode plot, stability; MOSFET biasing schemes, common-drain and common-gate amplifiers; differential pair, single-stage and two-stage op-amp; frequency response of amplifiers; bipolar transistors.
EE5129 0 Advanced Analog IC Design	CMOS process: mismatch, variation, active and passive components; MOSFET small signal model; controlled-sources; noise in electrical circuits; op-amp design: frequency compensation, noise, mismatch, slew-rate; fully differential op-amp design, common-mode feedback; analog system example: band-gap, PLL etc.
EE5137 0 Mixed Signal Circuit Design	None
EE5147 0 Digital IC Design	Two port parameters, nonlinearity, large-signal and small-signal analysis, incremental y-parameters of MOSFET; common-source amplifier: biasing, signal coupling, swing limits; negative feedback: Bode plot, stability; MOSFET biasing schemes, common-drain and common-gate amplifiers; differential pair, single-stage and two-stage op-amp; frequency response of amplifiers; bipolar transistors.
EE5149 0 VLSI Technology	Environment for VLSI Technology : Clean room and safety requirements, Single crystal growth (Technique), Crystal defects, Wafer cleaning processes and wet chemical etching techniques; Impurity incorporation : Solid State diffusion modelling and technology; Ion Implantation modelling, technology and damage annealing; characterisation of Impurity

profiles; Oxidation : Kinetics of Silicon dioxide growth both for thick, thin and ultrathin films; Oxidation technologies in VLSI and ULSI; Characterisation of oxide films; High k and low k dielectrics for ULSI; Lithography :Photolithography, E-beam lithography and newer lithography techniques for VLSI/ULSI; Mask generation; Chemical Vapor Deposition techniques : CVD techniques for deposition of polysilicon, silicon dioxide, silicon nitride and metal films; Epitaxial growth of silicon; modelling and technology; Metal film deposition : Evaporation and sputtering techniques. Failure mechanisms in metal interconnects; Multi-level metallisation schemes; Plasma and Rapid Thermal Processing: PECVD, Plasma etching and RIE techniques; RTP techniques for annealing, growth and deposition of various films for use in ULSI; Process integration for NMOS, CMOS and Bipolar circuits; Advanced MOS technologies.

EE5157 0
CMOS Processing and Wafer Technology

None

EE5158 0
Advanced Digital IC Design

None

EE5168 0
Embedded Systems: Hardware Languages

None

29.24 Department of Polymers and Bio Systems Engineering

CH5030 2
Molecular Thermodynamics

Quick Recap of Basic Thermodynamics, Introductory Probability. Extremum Conditions, Free Energy and Entropy, 3rd Law and Boltzmann Distribution, Simple Gases, Temperature and Heat Capacity, Solutions, Different Ensembles, Fluctuations, Example Applications

PB5010 1
Physical Biology of Cells - I

Components of eukaryotic cells and cell function, protein expression, DNA, RNA, ion channels, transcription factors, receptors and other components of signalling pathway, structure of biopolymers.

PB5020 1
Systems Biology - I

Introductory biology, differential equations and probability, system level reasoning for biomolecular pathway and networks, single cell and population-level systems biology, Population-level systems include models of pattern formation and cell-cell communication, programming in python or MATLAB.

PB5030 2
Concepts in Soft Matter Systems

Introduction to Soft Matter-Polymer, colloids, gels, surfactants and liquid crystals. Soft Matter Solutions – Thermodynamics and Phase transition. Elastic Soft Matter – Networks and Gels. Soft Matter Surfaces – Surface tension, wetting, surfactants, interaction between surfaces, polymer grafted surfaces, self-consistent field theory. Liquid Crystals – structures and phase transitions. Soft Matter Dynamics – introduction to concepts.

PB5040 2
Transport in Biological Systems

Introduction; Vectors and tensor algebra and calculus; Conservation and Balance Laws; Dimensional analysis, Scaling, Continuity equation; Navier-Stokes equations; Boundary conditions; Constitutive equations; Fundamentals and applications of mass transport - Diffusion with convection, transport in porous media, fluid flow in circulation and tissues; transvascular transport; gas transfer in biological systems; renal modeling; drug transport in cells/tissues

PB5050 2
Introduction to Statistical Hypothesis Testing

Basic definitions, Discrete probability distributions, Normal distribution and z-scores, Sampling distribution of the mean, Confidence intervals, Hypothesis testing, Comparison of means (T-testing), Comparison of variances, One-way and Two-way ANOVA

PB5060 2
Bio-macromolecular Engineering

Introduction to design and engineering of biological macromolecules, rational and evolutionary methods for the design of biological macromolecules, aptamers, protein and RNA-based switches, unnatural amino acids and nucleotides, genome engineering, DNA assemblies, protein engineering, therapeutic antibodies and their integration via synthetic biology, application of these technologies address pressing problems in medicine and bioengineering

PB5070 1
Physical Biology of Cells - II

Biomembrane, Transportation of ions, action potential, biomolecule motors, Cell-virus interactions, thermodynamic modeling of molecular interactions in cells, mathematical

modeling of biomolecular diffusion, random walk model, intracreaction dynamics.

PB5080 **1**
Systems Biology – II

Mathematical modeling of genetic networks, cell-cell interactions, and evolutionary dynamics [Single cell systems include genetic switches and oscillators], analysis of network motifs, genetic network evolution, and cellular decision-making.

PB5090 **2**
Polymeric Biomaterials: Science and Applications

Introduction, Types and properties, Hydrogels and viscoelasticity, Biomimetic materials, Complexity in biomaterial design, Self-assembly and biological membranes, Protein adsorption, Applications (e.g., tissue engineering, drug delivery).

PB5106 **1**
Industrial Lectures

Few lectures from related industrial experts will be arranged. It will be mandatory for the students to attend those lectures. Later a comprehensive viva and/or seminars will be conducted to evaluate students on their experiences gained from the expert's lectures.

PB5210 **2**
Inter-molecular and Surface Science

General Aspects, Background Thermodynamics, Strong intermolecular forces, Polar Interactions, Induced Interactions, Definition of van der Waals Forces, Special Interactions: H-bonding, Hydrophobic and Repulsive Interactions, Surfaces, Self-assembly, Ionic forces on particles and surfaces, Forces in Neutral and Ionic Polymers, Biological Applications

PB5220 **2**
Advanced Fabrionics

Microfabrication: Deposition (physical and chemical vapor deposition), etching, photo lithography, soft lithography and 3D printing (Stereolithography, fused deposition moulding). Nanofabrication: Sol-gel, electrospinning, Self-assembly, Directed self-assembly and Surface modification.

PB5230 **2**
Basics and Applications of Ai/ml for Process Systems Engg. (km)

Basics of Machine learning, Supervised learning (classification and regression), Unsupervised learning (clustering), Theory and algorithms, Optimization in Machine Learning, Multi-objective optimization, Genetic Algorithms, Artificial Neural Networks, Fuzzy Logic, practical problem solving with examples from optimal control, surrogate optimization, time series modeling.

PB5240 **2**
Adsorption and Kinetics

Introduction to adsorption, Adsorption on surfaces, Thermodynamics and kinetics of surfaces; adsorption and desorption kinetics; Cell adhesion, ligand-receptor interactions and enzyme kinetics, Case studies on biological surface adsorption including internalization of nanoparticle in cells, gene delivery and virus internalization in eukaryotic cells.

PB5250 **2**
Characterization of Polymer and Bio Systems

Mechanical characterizations (toughness, strength), rheological measurements (elastic and viscous modulus, time, frequency, amplitude sweep), thermal analysis , scanning and transmission electron microscopy, optical microscopy, basics of fluorescence microscopy and laser scanning confocal microscopy, multicolor sequential imaging

PB5260 **2**
Design of Experiments and Data Analysis

Factorial Experiments, Full Factorial Designs, Blocking and Confounding in Factorial Designs, Fractional Factorial Designs, Advanced designs, Introduction to Multivariate Analysis Non-parametric testing methods,Correlation, Regression, Clustering

PB5270 **2**
Polymer Processing and Rheology

Introduction to structure of polymers - molecular weight, tacticity and branching. Polymer characterization. Introduction to rheology and constitutive relations. Viscometric flows. Linear and non-linear viscoelasticity in polymeric systems. Relation between rheology and molecular structure of polymers. Role of rheology in melt processing.

29.25 Department of Physics

PH3257 **1**
Numerical Methods

Linear Systems: Gauss elimination, LU-Factorization, Eigenvalues by iterations
Numerical differentiation and integration
Interpolation, Splines, Solution of equations by iterations
Numerical methods for differential equations

PH3417 **1**
Elasticity

Displacement vector, strain tensor, dilation and shear, stress tensor, translational and rotational equilibrium, elastic free energy, elastic moduli, linear response, isotropic solid, elastic wave propagation, seismic wave.

PH4268 **2**
Solid State Physics

Crystalline Solids -different types of crystal binding-Free electron gas in 3D- Thermal and transport properties - Hall Effect - Introduction to Band theory of solids, Lattice Vibrations-Mono atomic and di-atomic lattices - Phonon frequencies and density of states - Phonon dispersion curves - Thermal expansion and thermal conductivity, Magnetic properties of solids.

PH5118 **2**

Introduction, Thevenin's Theorem, Norton's Theorem, Diode Theory, Rectifiers,

Electronics		Optoelectronics devices (LED, Photodiode, Laser Diode), Transistors and their frequency response (BJT, JFET, MOSFET,), Voltage and Power amplifiers, Differential Amplifiers, Operational amplifiers
PH5147 Classical Mechanics	**1**	Constraints, D'Alembert's principle, Lagrange's equation of first kind, generalized coordinates, Lagrange's equation of second kind, Hamilton's equation, connection to Newtonian physics.
PH5167 Experimental Techniques	**2**	Vacuum Techniques, Spectroscopic Techniques, Charged Particle Optics, Data Analysis, Error Analysis
PH5288 Digital Electronics	**1**	Binary digits, logic operations, number systems, logic gates, Boolean algebra, K-maps, combinational logic gates, functions of logic gates (adder, comparator etc), Flip flops and its applications (counters, shift registers, memory and storage)
PH5327 Fluid Mechanics ▷for honors students	**1**	Conserved quantities and continuity, Euler's equation, hydrostatics, streamline flow, vortices, Bernoulli's equation, energy and momentum flux, incompressible fluids, flow past bodies, viscous fluids - Navier Stokes equation, energy dissipation, Stoke's formula.
PH5338 Computational Physics	**2**	Introduction to programming in C++/C/Fortran/MATLAB Numerical differentiation and integration Gauss elimination, LU-Factorization, Eigenvalues by iterations Numerical methods for differential equations
PH6018 Laser Spectroscopy	**2**	Lasers Overview; Spectroscopic instrumentation; Doppler-limited Absorption and Fluorescence spectroscopy; nonlinear optics and Spectroscopy; Laser spectroscopy of Molecular Beams; Time resolved laser spectroscopy; coherent spectroscopy; THz spectroscopy
PH6027 Accelerator Physics	**1**	Charged Particle Motion in Static Fields, Linear Transverse Motion, acceleration and longitudinal motion; Examples of Cyclotron, Linear Collider and Synchrotron, applications of accelerator physics.
PH6028 Accelerator Physics-ii ▷PH2218	**2**	Accelerator magnets, Particle Dynamics, Steady state Electric and Magnetic fields, Modifications of Eand B fields by Materials, Electric and Magnetic field Lenses, Focusing Fields, LINAC, Betatrons, Phase Dynamics; effects of linear magnet errors; chromatic effects and their correction; effects of nonlinearities; basic beam manipulations; RF systems, diagnostic systems; and introduction to accelerator lattice design. Other topics such as synchrotron radiation excitation and damping; beam-beam interaction; collective effects and instabilities; linear accelerators
PH6038 Laser Technology ▷PH3338	**2**	Atomic Radiation - line shape and broadening of spectral lines; Laser oscillations and amplification - gain saturation in homogenous and inhomogenous broadened transitions; General characteristics of Lasers; Methods of generating short and ultrashort pulses – Q switching and Mode locking; Laser systems; Frequency multiplication of laser beam - introduction to nonlinear optical phenomena, second harmonic generation, optical parametric oscillation and implication.
PH6048 Ultrafast Optics ▷PH3338	**2**	Laser basics; Pulsed Optics; Principle of Mode-locking-Active and Passive; Femtosecond laser pulses; Ultrafast-pulse measurement methods; dispersion and dispersion compensation; ultrafast nonlinear optics; manipulation of ultrashort pulses; application of ultrashort pulses: time resolved and THz spectroscopy, coherent control; attosecond pulses.
PH6058 Feynman Diagram Techniques in Condensed Matter Physics	**2**	Second quantization; Zero and Finite temperature Green functions; Feynman rules; Homogeneous electron gas; Strongly correlated systems, Linear response theory
PH6068 Computational Solid State Physics	**2**	Electronic structure methods; density functional framework; Tight binding theory; computations of band structure and electronic states; electronic structure of semiconductor, magnetic and dielectric materials.
PH6078 Physics of Surfaces and Interfaces	**2**	Electronic surface states, Surface phonons, Scattering from surfaces and thin films, Statistical thermodynamics of surfaces, Metal-semiconductor junctions, semiconductor heterostructures, Oxide surfaces, Collective phenomena at interfaces
PH6088	**2**	Mean field theory, symmetry and order parameter, Ginzburg-Landau theory,

Theory of Phase Transitions

Ferromagnet-paramagnet transition, liquid-gas transition: critical point, coexistence curve, multicritical points, nematic-isotropic transition, liquid-solid transition - classical density functional theory, variational mean field theory; breakdown of mean field theory and construction of field theory, self-consistent field approximation, critical exponents, universality and scaling, ideas of renormalization group.

PH6098 2
Statistical Physics of Fields

Collective behaviour from particles to fields, continuous symmetry breaking and Goldstone modes, fluctuations and scattering, correlation functions and susceptibilities, lower critical dimension, Gaussian integrals - fluctuation corrections to saddle point, Ginzburg criterion, scaling hypothesis:
homogeneity assumption, divergence of correlation length, critical self-similarity, Gaussian model, the renormalization group (RG), perturbative RG: 1st order and 2nd order, the epsilon-expansion,
irrelevant variables; XY model, topological defects, Kosterlitz-Thouless type transitions, phase diagram from RG flow.

PH6108 2
Fractal Concepts in Physics

Scaling concepts, roughening, dynamic scaling, self-similarity and fractals, fractal dimensions, self-affinity, physical examples: surface growth, interfaces, polymers; Linear theory - Edward-Wilkinson equation, Kardar-Parisi-Zhang equation: scaling and exponents, re-scaling in momentum space, RG-flow equations for KPZ, phase transitions in KPZ, dynamic RG: introduction, perturbation expansion, renormalization procedure, calculation of integrals

PH6110 1
Black Holes I: Static Black Holes
▷PH 6887 or PH 6458 or PH 4258

- Gravitational Collapse: TLV equation, Neutron stars, Chandrasekhar limit
- The Schwarzschild solution of vacuum Einstein Equations
- Geodesics and trajectories, Horizons, Black holes and white holes
- Kruskal coordinates, Carter-Penrose diagrams, Eternal black hole
- Charged Black holes: Reissner-Nordstrom (RN) solutionExtreme RN solution, multicenter solutions.

Pre-Req: Static black holes, PH6887 (Introduction to General Relativity) or a course at the same level

PH6118 2
Classical Theory of Fields

Special theory of relativity and relativistic kinematics, Covariant (Lagrangian) formulation of electrodynamics, interaction between particles and fields: dynamics of charges and electromagnetic field.

PH6120 2
Introduction to Astrophysics
▷Modern Physics (or equivalent). Also Electromagnetism and quantum Mechanics

Introduction to astronomical and astrophysical nomenclature and concepts. Coordinate systems, celestial orbits, radiation, stars, stellar structure and evolution, galaxies and galaxy clusters, Cosmology

PH6128 2
Group Theory for Physicists

Continuous groups/ algebras: SU(2), SU(3), SO(N), SU(N), representations and applications in modern physics. Lorentz Group and applications, Discrete groups: S3, S4, A4... etc. and applications.

PH6130 2
Statistical Data Analysis
▷Basic Probability and Statistics

Measurement, analysis; Probability distributions; Parameter Estimation; Hypothesis testing; Model Comparison; Confidence Intervals; Bayesian Analysis; Markov Chain Monte Carlo techniques; Dimensionality Reduction; Time-series analysis

PH6138 2
Plasma Physics and Applications

Introduction, Motion of charged particles in fields, Waves in plasmas, Methods of plasma production, Ionization and equilibrium models in a plasma, Radiation from plasmas and diagnostics, Absorption processes and instabilities in plasmas, Laser Plasma Interaction.

PH6140 3
Quantum Yang Mills Theory
▷see syllabus

This elective course will provide to the PhD students the fundamentals of the framework on which our current understanding of particle physics is based. Here they will learn about non-abelian (Yang-Mills) gauge theories and how to quantize them. This course will teach how to calculate 1-loop Feynman diagram, and furthermore how to renormalize these theories. This course, which is a core course for any PhD student pursuing PhD in theoretical particle physics will equip students with the necessary tools to carry out cutting edge research in various fields of particle physics.
Course contents:
Gauge Invariance, Basics of Lie Algebras, Yang-Mills Lagrangian, Gauge Fixing, Ghosts and Unitarity, Feynman Rules, One loop divergences, TheBeta function, Asymptotic Freedom.
Pre-Req: Quantum phi-4 theory, quantization of Dirac fields, tree and one-loop Feynman diagram calculations.

PH6148 **2**
Advanced Solid State Physics

Introduction of Many body techniques; Electron gas; Quantum theory of magnetism, Plasmons, Polaritons, Polarons, Excitons; optical processes in solids, Semi-classical and quantum transport in solids, BCS theory of superconductivity

PH6150 **1**
Magnetohydrodynamics
▷PH2218

Modes of description of a plasma . Collisional plasma. The one-fluid description .The two-fluid description. Collisionless plasma. The guiding center limit of the Vlasov equation. The double adiabatic theory .Consequences of the MHD description . Conservation relations. Flux frozen in plasma

PH6158 **2**
Superconductivity

Introduction to superconductivity, electrodynamics of superconductors, type II superconductors, critical magnetic fields, pinning, the critical state model, superconducting materials, and microscopic theory of superconductivity. The London equations, Ginzburg-Landau theory, The Josephson effect, BCS theory and the energy gap, London's model, flux quantization, Josephson Junctions, superconducting quantum devices, equivalent circuits, high-speed superconducting electronics, and quantized circuits for quantum computing. Unconventional super-conductors and super-conducting technology.

PH6160 **2**
Techniques in Particle Physics
▷see syllabus

We will explore different techniques to calculate different physical observables, viz. cross-sections, decay widths, differential distributions for different systems in particle physics. It will involve different numerical packages.
Particle physics at the era of LHC also require to learn some simulations in order to have predictions closer to the experimental observations. Our aim is to learn PYTHIA, SARAH, micrOmegas, CaclHep, AlpGen etc. At the end we should be able to address various beyond Standard Model phenomenology. The course also require to have 'hands on' sessions, where we solve some problems using different tools.
Pre-Req: Fortran, C, C++, Mathematica, basic knowledge of Standard Model, QFT

PH6168 **2**
Spintronics

Overview of spin electronics; Classes of magnetic materials; Quantum Mechanics of spin; Spin-orbit interaction; Exchange interaction; Spin relaxation mechanisms; Spin-dependent transport; Spin transfer torques; Current-driven switching of magnetization and domain wall motion; Spin injection, Silicon based spin electronic devices, Spin photo electronic devices, Nanostructures for spin electronics, Spintronic Biosensors, Spin transistors, Quantum Computing with spins.

PH6170 **1**
Introduction to Ads/cft Duality
▷PH 6140, PH 6458, Perturbative String theory

Review of superstring theory, D-branes I: via (super)gravity, D-branes II: via (super)Yang Mills theory, Decoupling limit: AdS/CFT duality, Field -Operator mapping: Extracting Correlation functions, Holographic Renormalization,Wilson loops, Entanglement Entropy
Pre-Req: Quantum Field Theory (Yang Mills), General Relativity (Charged Black holes, Multicenter solutions), Basic perturbative string theory.

PH6178 **2**
Micromagnetics

Introduction to micromagnetic equilibrium, solutions of micromagnetic equations, finite difference micromagnetics, finite element micromagnetics, micromagnetics of domain pattern, micromagneitcs of dynamic magnetization process, application of micromagnetics in modern magnetism

PH6180 **1**
Black Holes Ii: Stationary Black Holes
▷PH 4110 or PH 6110

- Rotating black holes: Kerr solution
- Ergosphere and Ring Singularity
- Penrose Process, Superradiance
- Uniqueness theorems
- Energy and Angular momentum (ADM, Komar)
- Laws of black hole mechanics.

Pre-Req: Static black holes, PH6887 (Introduction to General Relativity) or a course at the same level

PH6188 **2**
Physics of Solar Cell

Basic principles of Photovoltaics; characteristics of the photovoltaic cell; Semiconductor physics: generation and recombination of electrons and holes, junctions; analysis of junctions; Silicon solar cells; thin film solar cells; third generation solar cells; managing light; Thermodynamic limit to efficiency-The Shockley-Queisser limit; Advanced strategies for high efficiency solar cells;

PH6198 **2**
Organic Electronics

Organic semiconductor device physics; Semiconducting polymer Physics; Organic Transistors; Advanced materials for organic electronics; Organic Photovoltaics; Organic light emitting diodes; Fabrications techniques for organic electronics.

PH6278 **2**
Particle Physics

Classification of particles, Quark contents of Hadrons, Particle quantum numbers, Gell-Mann Nishijima formula, Relativistic kinematics, scattering amplitudes, Cross sections, decay rate and life-time. Breight-Wigner formula, Continuous symmetries and conservation laws. Discrete symmetries. CPT theorem, Weak processes, pion decay, GIM

		mechanism, Parity violation, CP violation, Quark mixing, CKM matrix, Neutrino Physics, Elements of Quantum Chromodynamics, Electroweak interaction, Symmetry breaking and Higgs mechanism, Standard Model of Particle Physics and Physics beyond the standard model.
PH6317 Physics and Applications of Functional Materials	**1**	Introduction to Functional Materials, Structure of typical materials, Ferroelectricity, Piezoelectricity, magnetoresistance (GMR, CMR etc) magnetocaloric materials.
PH6318 Physical Biology of the Cell	**2**	The cell and subcellular components, cell division, motility, force generation, signalling; Physical principles: noise, diffusion, random walk in biology, Langevin and Fokker-Planck, first passage problems, polymers and membranes; F-actins, microtubules, cell membranes, motor proteins, chromosome, DNA to protein: translation and transcription.
PH6327 Nuclear Physics	**1**	Alpha decay: Tunnelling effect and probability, Geiger-Nuttall law, Electron and positron spectra, Neutrino mass, Kurie plot, Fermi theory of beta decay, Gamma decays, Nuclear models, Nuclear reactions, Direct reactions, Compound nucleus reactions.
PH6328 Non-equilibrium Statistical Mechanics	**2**	Brownian motion, Langevin and Fokker-Planck equations, Zwanzig formalism, Master equations, Kramers problem, first passage time, energy diffusion, kinetic models, H-theorem, hydrodynamics, static and dynamics response.
PH6338 Advanced Functional Materials	**2**	Introduction to Functional Materials, Processing methods (Bulk and Thin films) and Characterization techniques (XRD, SEM, etc.) in brief, Concept in dielectric , introduction to Impedance spectroscopy, magnetoresistive and magnetocaloric materials, Spintronics, thermoelectric materials, Nano-X (X = materials, wires, tubes, dots , magnetism, etc).
PH6348 Crystallography	**2**	Point symmetry operations, crystal systems (lattice, unit cell, crystal structure), Lattice directions , planes and reciprocal lattice, Bravais lattices, point groups, space groups, methods to resolve structure by using XRD pattern, Practice to read International Tables of crystallography.
PH6358 Nonlinear Dynamics and Chaos	**2**	Introduction to nonlinear dynamics, application to physics and engineering, one dimensional system, bifurcations, phase plane, nonlinear oscillators, Lorentz equations, Chaos, strange attractors, fractals, iterated mappings, periodic doubling.
PH6418 Quantum Field Theory	**2**	Canonical quantization, Complex scalar fields, Charge conservation, Charge conjugation, Feynman propagator, Dirac Equation, Quantization of Electromagnetic fields, Gauge invariance, Elements of quantum Electrodynamics. Feynman rules and Feynman diagram for spinor electrodynamics. Lowest order cross sections for electron-electron, electron-positron and electron-photon scattering. Elementary treatment of self-energy and radiative corrections, divergence and renormalization.
PH6428 Quantum Optics	**2**	Quantization of radiation filed, Coherent states, Quantum theory of Laser, Photon coherence, Statistical optics of Photons, Photon distribution of coherent and chaotic light, Quantum mechanical photon counting Distribution, Super radiance, Quantum beats, Squeezed states of light
PH6438 Fundamentals of Semiconductors Physics and Devices	**2**	Classification of materials, Basic Semiconductor: energy bands, donors and acceptors, carrier concentration, carrier transport, generation recombination processes, basic equations for device operation, P-N junctions: electrostatics, space charge, abrupt and linearly graded, current-voltage and capacitance-voltage characteristics, junction breakdown, Metal-Semiconductor contact: Ohmic and non-ohmic, Schottky effect, current-voltage characteristics, Bipolar Transistor: transistor action, current gain, static characteristics, frequency response, transient behaviour, junction breakdown, metal-insulator-semiconductor (MIS), Metal-Oxide-Semiconductor (MOS) diode, C-V characteristics of MOS, Charge couple devices (CCD). Field Effect Transistor, MISFET, MOSFET, CMOS.
PH6448 Microfabrication Techniques	**2**	Crystal Structures, Crystal Growth, wafer fabrication, Oxidation, Diffusion, Ion Implantation, Metallization, Lithography, Wet Etching, Dry Etching, Chemical Mechanical Lapping and Polishing (CMP), Wafer bonding, Evolution of MEMS, Fabrication methods of MEMS: Microsteriolithography, Lithographie, Galvanoformung, Abformung (LIGA), Micromachining, etc. Bulk micromachining, Deep reactive Ion Etching (DRIE), Wet chemical based micromachining, Surface Micromachining, Stiction problems in surface micromachining.
PH6458	**2**	Review of Special Relativity, General relativity, Equivalence principle, tensor Analysis,

Gravitation and Cosmology	Curvature of Space-time, Einstein's equation, The Schwarzschild solution, action principle, Black Holes, Gravitational radiation, Isometries, Symmetric spaces, Cosmology.
PH6468 2 Advanced Particle Physics	Symmetries and Conservations laws, Noether's theorem, QED processes, Self energy corrections, Renormalization, QCD, Parton model, Electroweak theory, Spontaneous symmetry breaking, Grand Unified Theories,, Symmetries and Conservations laws, Noether's theorem, QED processes, Self energy corrections, Renormalization, QCD, Parton model, Electroweak theory, Spontaneous symmetry breaking, Grand Unified Theories,, Beyond the Standard Model, Gravitation and Cosmology.Beyond the Standard Model, Gravitation and Cosmology.
PH6478 2 Quantum Computation and Quantum Information	Classical logic gate operations, Single and multiple qubit quantum gates, Bell states and entanglement, Schmidt decomposition, EPR and Bell inequality, Idea of quantum teleportation, Deutsch algorithm, Shor's factoring algorithm, Principles of quantum search algorithm, Grover's algorithm, NMR and Computing, Classical Information theory, Shannon's coding theorem, Von Neumann entropy, Entropy of entanglement, Quantum noise, Elements quantum tomography and quantum cryptography
PH6488 2 Particle Astrophysics	Special Theory of Relativity, General Relativity, Elementary Standard model of particle physics, Standard model of Cosmology, Particle kinematics in FRW metric, Friedmann Equation, Dynamics of FRW Universe, Red-shift, Thermodynamics in early Universe, Boltzmann distribution, Neutrino decoupling temperature, Big-Bang Cosmology, Nucleosynthesis and baryon to photon ratio, Dark matter and its relic abundance, Baryogenesis, Phase transitions in early Universe, Inflationary Cosmology, Dark Energy, CMBR
PH6588 1 Computational Physics - I	Interpolation; Least square and spline approximation; numerical differentiation and integration; Numerical methods for matrices; Extremes of a function; Non-linear equations and roots of polynomials; Applications of numerical methods in Physics
PH6589 2 Computational Physics - II	Numerical methods for ordinary differential equations; Numerical solution of Sturn-Liouville and Schrodinger equation; Discrete and fast Fourier transforms; Molecular dynamics and Monte Carlo simulations; Numerical methods for partial differential equations; Applications of numerical methods in Physics
PH6592 2 Plasma Physics and Magnetohydrodynamics (mhd)	Plasma and its occurrence in nature, Concept of Temperature, Debye Shielding, Plasma Parameter, Criteria for Plasmas, Applications of Plasma Physics, Motion of charged particles in fields, Waves in plasmas Methods of plasma production, Ionization and equilibrium models in a plasma, Radiation from plasmas and diagnostics, Absorption processes and instabilities in plasmas, Laser Plasma Interaction Modes of description of a plasma, Collisional plasma, The one-fluid description, The two-fluid description. Collisionless plasma, The guiding center limit of the Vlasov equation, The double adiabatic theory, Consequences of the MHD description. Conservation relations, Flux frozen in plasma
PH6593 1 Optical Engineering	Basics of Geometrical Optics and Diffraction Theory, Optical Components: Mirrors, Lens, Prisms, Thin lens theory, Aberrations, Basic Optical Instruments, Lens Design and evaluation, Introduction to Optical Instrument design.
PH6887 1 Introduction to General Relativity ▷Undergraduate Mathematical Physics and Classical Physics	Newton's theory of Gravitation and Mechanics: Failures and inconsistencies, Special Relativity: Minkowski Geometry, Curved Space-time: Riemannian geometry, Einstein Field Equations: Gravitation as curvature of space-time, Linearized approximation: Gravitational waves, Non-linear solution: Schwarzschild case, Cosmology Pre-Req: Courses on Mathematical Physics and Classical Physics
PH6888 2 Introduction to String Theory ▷Undegraduate Mathematical Physics, Relativity. Quantum Mech.	Motivation for Strings, Relativistic Point particle: Classical and quantum, Bosonic strings: Nambu-Goto action, Old Covariant Light Cone quantization, Conformal Field Theory, RNS Superstrings, Compactification and T-duality: D-branes, Heterotic Strings, S-Duality and M-theory. Pre-Req: Courses on Mathematical Physics, Relativity and Particle Physics
PH7010 3 Classical Physics ▷Classical Mechanics, Electromagnetism (PhD core course)	Problem oriented review of mechanics and methods of mathematical physics: vector analysis, tensors, special functions, linear vector spaces, matrices, complex variables, particle mechanics, system of particles, rigid body motion, Lagrangian and Hamiltonian formulation, special relativity, Problem-oriented review of electromagnetism, optics and thermodynamics: electric fields, potentials, Gauss's law, dielectrics, magnetic fields, Ampére's law, Faraday's law, Maxwell's equations, electromagnetic waves, interference, diffraction, polarization
PH7013 3	Basics Optics overview; Optical Instrumentations: Optical materials and components,

Advanced Optical Instrumentation
▷PH3338

Alignment of Optical systems, Design considerations of interferometer and spectrometers; Optical modulators;
Time-resolved spectroscopy Detectors for advanced spectroscopy techniques, Apparatus for Charged particle optics; Optical imaging techniques.

PH7017 **1**
Advances in Atomic and Molecular Imaging

Charged Particle Imaging in Chemical Dynamics; Velocity Map Imaging: Experimental Aspects; Reconstruction Methods (Abel and Hankel Inversion); 3-D Imaging

PH7020 **3**
Quantum Physics
▷Core Ph.D course and Hons

Intro to Quantum Physics, SHM, Spin system, Perturbation theory, Scattering, Dirac eqn, Lie groups and algebra.

PH7080 **3**
Partcile Physics

Classification of particles, Quark contents of Hadrons, Particle quantum numbers, Gell-Mann Nishijima formula, Relativistic kinematics, scattering amplitudes, Cross sections, decay rate and life-time. Breight-Wigner formula, Continuous symmetries and conservation laws. Discrete symmetries. CPT theorem, Weak processes, pion decay, GIM mechanism, Parity violation, CP violation, Quark mixing, CKM matrix, Neutrino Physics, Elements of Quantum Chromodynamics, Electroweak interaction, Symmetry breaking and Higgs mechanism, Standard Model of Particle Physics and Physics beyond the standard model.

PH7190 **3**
Laser Technology
▷PH3338

Introduction to lasers; Stability issues of optical cavities; Gaussian Beams -TEM00 and higher order modes, ABCD law for Gaussian beams; Resonant optical cavities; Atomic Radiation - line shape and broadening of spectral lines; Laser oscillations and amplification - gain saturation in homogenous and inhomogeneous broadened transitions; General characteristics of CW and pulsed Lasers; Generation and characterization of ultra-short pulses; Frequency multiplication of laser beam - introduction to nonlinear optical phenomena, second harmonic generation, optical parametric oscillation and implication; Different laser systems - gas, rare-earth doped solid-state, semiconductor, Ti: Sapphire, fiber, free electron lasers; Applications of laser in science, medicine, defense and biology etc.

29.26 Department of Smart Mobility

AI5000 **3**
Foundations of Machine Learning

Overview of Machine learning, Basic probabilistic and non-probabilistic model, Supervised learning, non-parametric modelling, Unsupervised learning, Representation learning, online learning, Reinforcement learning, ensemble methods, learning with sequential data

CS5060 **3**
Advanced Computer Networks

Basics of Computer Networking, TCP/IP protocol stack, Local Area Networks (Ethernet, Wi-Fi), Network Management, Network Security, Multimedia Transport, Next generation Internet architectures, Green Communication Networks, and Data Center Networking. Performance studies using QualNet simulator and lab assignments using Seattle GENI testbed

EE5817 **3**
Random Variables and Stochastic Processes

Introduction to Probability; Definitions, scope and history; limitation of classical and relative-frequency-based definitions, Sets, fields, sample space and events; axiomatic definition of probability , Combinatorics: Probability on finite sample spaces, Joint and conditional probabilities, independence, total probability; Bayes' rule and applications, Random variables, Definition of random variables, continuous and discrete random variables, cumulative distribution function (cdf) for discrete and continuous random variables; probability mass function (pmf); probability density functions (pdf) and properties, Jointly distributed random variables, conditional and joint density and distribution functions, independence; Bayes' rule for continuous and mixed random variables, Function of random a variable, pdf of the function of a random variable; Function of two random variables; Sum of two independent random variables, Expectation: mean, variance and moments of a random variable, Joint moments, conditional expectation; covariance and correlation; independent, uncorrelated and orthogonal random variables, Random vector: mean vector, covariance matrix and properties, Some special distributions: Uniform, Gaussian and Rayleigh distributions; Binomial, and Poisson distributions; Multivariate Gaussian distribution, Vector-space representation of random variables, linear independence, inner product, Schwarz Inequality, Elements of estimation theory: linear minimum mean-square error and orthogonality principle in estimation, Moment-generating and characteristic functions and their applications, Bounds and approximations: Chebysev inequality and Chernoff

	Bound, Sequence of random variables and convergence, Almost sure (a.s.) convergence and strong law of large numbers; convergence in mean square sense with examples from parameter estimation; convergence in probability with examples; convergence in distribution, Central limit theorem and its significance, Random process: realizations, sample paths, discrete and continuous time processes, examples, Probabilistic structure of a random process; mean, autocorrelation and autocovariance functions, Stationarity: strict-sense stationary (SSS) and wide-sense stationary (WSS) processes, Autocorrelation function of a real WSS process and its properties, cross-correlation function, Ergodicity and its importance, Spectral representation of a real WSS process: power spectral density, properties of power spectral density ; cross-power spectral density and properties; auto-correlation function and power spectral density of a WSS random sequence, Linear time-invariant system with a WSS process as an input: sationarity of the output, auto-correlation and power-spectral density of the output; examples with white-noise as input; linear shift-invariant discrete-time system with a WSS sequence as input, Spectral factorization theorem, Examples of random processes: white noise process and white noise sequence; Gaussian process; Poisson process, Markov Process.
LA5180 **1** English Communication Skills: Advanced	None
SM5013 **1** Autonomous Navigation	An Introduction to Navigation systems: History, System architecture, Application; Modes of Navigation – Land, Aerial, Underwater, Aeronautic; Sensors for autonomous navigation: Radar, Inertial Navigation system (INS), LiDAR, GNSS; Introduction to Simultaneous Location and Mapping (SLAM); Case study: Route and Flight path planning for UAVs for autonomous flying
SM5033 **1** Internet of Things (iot)	Introduction: Concept, Importance, Interdisciplinary, Challenges, Various applications/smart objects, Major Players/Industry, Iot Node and Network architecture, Communication technologies, Smartness, Handson with Iot platforms
SM5043 **3** Traffic Engineering and Intelligent Transportation Systems	Traffic Operations:Traffic stream components, Theories of traffic flow,traffic studies,design of control strategies for simple systems..Intelligent transportation system:goal of ITS, ITS design, Highway ITS, concepts of operation,ITS system architecture,ADAS, ITS in India
SM5083 **2** Basics of Programming	Math Computing Matrix/Vector arithmetic, Simulation of Random Variables in Probability; Optimization - solvers for linear, semi-definite and quadratic programming; Embedded Programming - HDL for FPGAs, Microcontroller programming for IoT applications; 3D printing- CAD design and applications
SM5206 **1** Industry Lectures	None
SM6025 **2** Thesis Stage I	None
SM6035 **10** Thesis Stage II	None
SM6045 **12** Thesis Stage III	None