Courses of Study

Masters & PhD

Contents

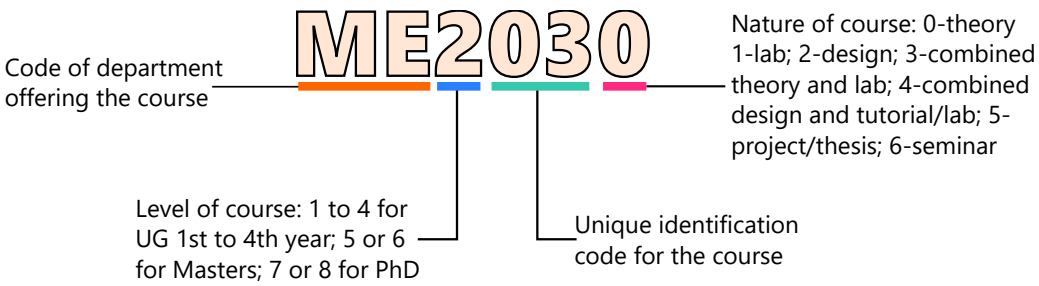
1 | Introduction

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

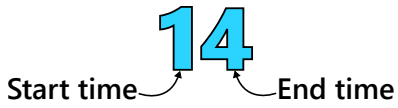
1.2 Course Numbering Scheme

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

- At least 3 credits must be taken from the Core AI and ML basket.
- Any equivalent or related course can also be taken as an elective
- At least 3 credits must be taken from the Applied AI and ML basket.

Code	Cred.	Course Title
Semester 1		
AI5000	3	Basics of Machine Learning
AI5001	1	Introduction to Modern AI
AI5002	2	Probability and Random Variables
AI5003	1	Stochastic Processes
AI5005	3	Advanced Data Structures and Algorithms
MA4020	3	Linear Algebra
Semester 2		
AI5100	3	Deep Learning
AI/EE/CS/MA	8	AI and ML Electives (baskets Below)
AI5301	2	MTech Thesis (ta) Stage - I
Summer		
AI5302	2	MTech Thesis (ta) Stage - II
Semester 3		
AI5303	10	MTech Thesis (ta) Stage - III
Semester 4		
AI5304	10	MTech Thesis (ta) Stage - IV
Electives: Core AI and ML		
EE5603	1	Concentration Inequalities
EE5604	1	Introduction to Statistical Learning Theory
EE5605	1	Kernel Methods
CS6230	3	Optimization Methods in Machine Learning
EE5606	2	Convex Optimisation
EE5327	1	Optimization
MA5120	3	Numerical Linear Algebra
CS6510	3	Applied Machine Learning
EE5601	1	Representation Learning
EE5602	1	Probabilistic Graphical Models
EE5390	1	Source Coding
EE6317	1	Channel Coding
Electives: Applied AI and ML		
CS5290	3	Computer Vision
CS5330	2	Introduction to Statistical Natural Language Processing
EE6307	3	Speech Systems

Code	Cred.	Course Title
EE6310	3	Image and Video Processing
CS6370	3	Information Retrieval
AIXXXX	0	Data Analytics/big Data
CS6460	1	Introduction to Deep Learning for Vision
AIXXXX	0	Applications of AI in Healthcare
EE5607	1	ML – Hardware Implementation
CS5600	0	Data Mining
CS6370	3	Information Retrieval

2.2 MTech ACM

- At least 5 credits must be taken from the Core AI and ML basket.
- Any equivalent or related course can also be taken as an elective
- At least 5 credits must be taken from the Applied AI and ML basket.

Code	Cred.	Course Title
Semester 1		
AI5000	3	Basics of Machine Learning
AI5001	1	Introduction to Modern AI
AI5002	2	Probability and Random Variables
AI5003	1	Stochastic Processes
AI5005	3	Advanced Data Structures and Algorithms
MA4020	3	Linear Algebra
AI/EE/CS/MA	2	AI and ML Electives (baskets Below)
Semester 2		
AI5100	3	Deep Learning
AI/EE/CS/MA	9	AI and ML Electives (baskets Below)
FEXXXX	3	Free Electives
Summer		
AI/EE/CS/MA	3	AI and ML Electives (baskets Below)
FEXXXX	3	Free Electives
Electives: Core AI and ML		
EE5603	1	Concentration Inequalities
EE5604	1	Introduction to Statistical Learning Theory
EE5605	1	Kernel Methods
CS6230	3	Optimization Methods in Machine Learning
EE5606	2	Convex Optimisation
EE5327	1	Optimization
MA5120	3	Numerical Linear Algebra
CS6510	3	Applied Machine Learning
EE5601	1	Representation Learning
EE5602	1	Probabilistic Graphical Models
EE5390	1	Source Coding
EE6317	1	Channel Coding
Electives: Applied AI and ML		
CS5290	3	Computer Vision
CS5330	2	Introduction to Statistical Natural Language Processing
EE6307	3	Speech Systems
EE6310	3	Image and Video Processing
CS6370	3	Information Retrieval
AIXXXX	0	Data Analytics/big Data

Code	Cred.	Course Title
CS6460	1	Introduction to Deep Learning for Vision
AIXXXX	0	Applications of AI in Healthcare
EE5607	1	ML – Hardware Implementation
CS5600	0	Data Mining
CS6370	3	Information Retrieval

2.3 MTech 3Year

- At least 3 credits must be taken from the Core AI and ML basket.
- Any equivalent or related course can also be taken as an elective
- At least 3 credits must be taken from the Applied AI and ML basket.

Code	Cred.	Course Title
Semester 1		
AI5000	3	Basics of Machine Learning
AI5001	1	Introduction to Modern AI
AI5002	2	Probability and Random Variables
AI5003	1	Stochastic Processes
MA4020	3	Linear Algebra
Semester 2		
AI5100	3	Deep Learning
AI/EE/CS/MA	3	AI and ML Electives (baskets Below)
Semester 3		
AI5005	3	Advanced Data Structures and Algorithms
AI/EE/CS/MA	2	AI and ML Electives (baskets Below)
AI5311	2	MTech Thesis (ra) Stage - I
Semester 4		
AI/EE/CS/MA	3	AI and ML Electives (baskets Below)
AI5312	6	MTech Thesis (ra) Stage - II
Semester 5		
AI5313	8	MTech Thesis (ra) Stage - III
Semester 6		
AI5314	8	MTech Thesis (ra) Stage - IV
Electives: Core AI and ML		
EE5603	1	Concentration Inequalities
EE5604	1	Introduction to Statistical Learning Theory
EE5605	1	Kernel Methods
CS6230	3	Optimization Methods in Machine Learning
EE5606	2	Convex Optimisation
EE5327	1	Optimization
MA5120	3	Numerical Linear Algebra
CS6510	3	Applied Machine Learning
EE5601	1	Representation Learning
EE5602	1	Probabilistic Graphical Models
EE5390	1	Source Coding
EE6317	1	Channel Coding
Electives: Applied AI and ML		
CS5290	3	Computer Vision

Code	Cred.	Course Title
CS5330	2	Introduction to Statistical Natural Language Processing
EE6307	3	Speech Systems
EE6310	3	Image and Video Processing
CS6370	3	Information Retrieval
AIXXXX	0	Data Analytics/big Data
CS6460	1	Introduction to Deep Learning for Vision
AIXXXX	0	Applications of AI in Healthcare
EE5607	1	ML – Hardware Implementation
CS5600	0	Data Mining
CS6370	3	Information Retrieval

3 | Department of Biomedical Engineering

3.1 MTech 2Year

Code	Cred.	Course Title
Semester 1		
BM5013	2	Sensors and Transducers in Health Care
BM5023	2	Biomedical Devices
BM5030	1	Scientific Computing and Data Analysis
BM5040	1	Biomechanics
BM5050	1	Introduction to Brain and Neuroscience
BM5060	0.5	Cellular Physiology
BM5070	1.5	Systems Physiology
BM5090	2	Biomaterials: Materials in Medicine
BMXXXX	1	Elective 1
BMXXXX	2	Elective 2
BMXXXX	3	Elective 3
Semester 2		
BM6013	1	Advances in Molecular Imaging
BM6023	2	Cell Technology
BM6146	2	Biodesign
BM6086	1	Seminars in Biomedical Engg.
BM6125	2	Independent Research Proposal
BM6060	1	Digital Signal Processing
BMXXXX	2	Elective 1
BMXXXX	2	Elective 2
BMXXXX	3	Elective 3
Semester 3		
BM5105	12	Thesis Stage 1
Semester 4		
BM6105	12	Thesis Stage 2

3.2 MTech ACM

- The following are the additional summer courses for ACM students on top of the regular Mtech list

Code	Cred.	Course Title
Summer		
BM****	1	Biostatistics
BM6160	2	Biomedical Toxicology

3.3 PhD

- The following is the basket of courses available for PhD

Code	Cred.	Course Title
Jul		
BM4190	2	Biofabrication
BM5013	2	Sensors and Transducers in Health Care
BM5023	2	Biomedical Devices
BM5030	1	Scientific Computing and Data Analysis
BM5040	1	Biomechanics
BM5050	1	Introduction to Brain and Neuroscience
BM5060	0.5	Cellular Physiology
BM5070	1.5	Systems Physiology
BM5090	2	Biomaterials: Materials in Medicine
BM5110	1	Lab On Chip
BM5193	2	Product Design and Prototyping
BM5141[1]	1	Advanced Biomaterials
Jan		
BM6023[2]	2	Cell Technology
BM6070	2	Biomicrofluidics
BM6080	2	Advanced Biomechanics
BM6090	2	Biomedical Imaging
Jul		
BM6100	2	Bio-nanotechnology
Jan		
BM6110	2	Nanomedicine
BM6120	2	Tissue Engineering
BM6123	1	Advances in Molecular Imaging
BM6126[3]	1	Regenerative Medicine
BM6140	2	Theoretical and Computational Neuroscience: From Cell to Systems
BM6146	2	Biodesign
BM6150	2	Mathematical Physiology and Modeling
BM6163	1	Molecular Technology
BM7106	2	Special Topics in Microscopy
BM5150	2	Neurophysiological Signal Processing
BM1130	1	Healthcare

1. Pre-req: BM5090
2. Pre-req: BM5060
3. Pre-req: BM6120

4 | Department of Biotechnology

4.1 MTech 2Year

Code	Cred.	Course Title
Semester 1		
BO6113[1]	2	Structural Bioinformatics
BO6120[1]	2	Advanced Immunology
BO6143[1]	2	Gene Technology
BO7390[1]	2	Cellular and Molecular Neuroscience
BO6060[2]	0	Protein Misfolding In Neurodegerative Diseases
BO6150[2]	2	Molecular Basis of Cancer
BO6240[2]	2	Structural Biology
BO6670[2]	2	Stem Cell Biology And Regenerative Medicine
Semester 2		
BO6123[1]	2	Cell Technology
BO6133[1]	2	Protein Technology
BO6330[1]	2	RNA Biologyandtherapeutics
BO5050[2]	1	Gene Editing
BO6163[2]	1	Modern Techniques In Neuroscience
BO6290[2]	2	Molecular Machines: DNA Interacting Proteins
BO7053[2]	2	Biomolecular NMR
BO7280[2]	2	Pharmacology and Physiology of Receptors
Semester 3		
BO6025	0	Thesis-2
Semester 4		
BO6035	12	Thesis Stage 2

1. Core
2. Elective

4.2 PhD

- The following is the basket of courses available for PhD

Code	Cred.	Course Title
Semester 1 and 2		
BO6240	2	Structural Biology
BO6143	2	Gene Technology
BO6113	2	Structural Bioinformatics
BO6120	2	Advanced Immunology
BO7390	2	Cellular and Molecular Neuroscience
BO6670	2	Stem Cell Biology and Regenerative Medicine

Code	Cred.	Course Title
BO6060	2	Protein Misfolding in Neurodegenerative Diseases
BO6150	2	Molecular Basis of Cancer
BO6123	2	Cell Technology
BO6133	2	Protein Technology
BO6330	2	RNA Biology and Therapeutics
BO7053	2	Biomolecular NMR
BO7280	2	Pharmacology and Physiology of Receptors
BO6290	2	Molecular Machines: DNA Interacting Proteins
BO6163	1	Modern Techniques In Neuroscience
BO5050	1	Gene Editing

5 | Department of Civil Engineering

5.1 MTech 2Year in EWRE

Code	Cred.	Course Title
Semester 1		
CE6500	3	Engineering Hydrology And Hydrologic Systems
CE6510	3	Water And Wastewater Engineering
CEXXXX	3	Elective-1
CEXXXX	3	Elective-2
CE6011	2	Computer Methods In Civil Engineering
CE6006	0	Seminar
Semester 2		
CE6520	3	Air Pollution
CE6530	3	Groundwater Modeling
CE6511	2	Soft Computing Lab (environmental and Water Resources)
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	3	Environmental Chemistry and Microbiology
CE6560	3	Physico-chemical Process
CE6570	3	Environmental Impact Assessment
CE6580	3	Solid and Hazardous Waste Management
CE6590	3	Industrial Waste Management
CE6610	3	Remote Sensing and GIS Applications To Civil Engineering
CE6620	3	Water Resources Systems Planning And Management
CE6630	3	Open Channel Hydraulics
CE6640	3	Irrigation And Watershed Management
CE6650	3	Hydrogeology
CH5020	1	Numerical Methods - II

5.2 MTech 2Year in Geotech

Code	Cred.	Course Title
Semester 1		

Code	Cred.	Course Title
CE6310	3	Advanced Soil Mechanics
CE6330	3	Soil Dynamics
CEXXXX	3	Elective I
CEXXXX	2	Elective II
CE6011	2	Computer Methods In Civil Engineering
Semester 2		
CE6300	3	Advanced Foundation Engineering
CEXXXX	3	Elective III
CEXXXX	3	Elective IV
CEXXXX	2	Elective V (dept./free)
Semester 3		
CE6015	13	Master's Thesis
Semester 4		
CE6025	12	Master's Thesis
Electives		
CE6323	3	Experimental Soil Mechanics
CE6352	3	Design Of Earth Structures
CE6370	0	None
CE6392	0	None
CE6410	0	None
CE6340	0	Ground Modification Techniques
CE6360	0	None
CE6390	0	None
CE6130	3	Finite Element Analysis
ME5010	3	Mathematical Methods for Engineers
CH5050	2	Non-isothermal Reactors
CE6002	2	Design Studio
CE5390	2	Geothermics

5.3 MTech 2Year in Structural

Code	Cred.	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

5.4 MTech ACM in EWRE

Code	Cred.	Course Title
Semester 1		
CE6500	3	Engineering Hydrology And Hydrologic Systems
CE6510	3	Water And Wastewater Engineering
CE6540	3	Contaminant Hydrology And Remediation
CE 6011	2	Computer Methods in Civil Engineering

5.5 MTech ACM in Geotech

Code	Cred.	Course Title
Semester 1		
CE6310	3	Advanced Soil Mechanics
CE6330	3	Soil Dynamics
CE6352	3	Design Of Earth Structures

5.6 MTech ACM in Structural

Code	Cred.	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

5.7 MTech 3Year in Structural

Code	Cred.	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		

Code	Cred.	Course Title
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	2	Non-isothermal Reactors

5.8 PhD

- Four courses in the first two semester

6 | Department of Chemical Engineering

6.1 MTech 2Year

Code	Cred.	Course Title
Semester 1		
CH5010	2	Numerical Methods - I
CH5030	2	Chemical Engineering Thermodynamics - I
CH5040	1	Chemical Engineering Thermodynamics - II
CH5070	2	Transport Phenomena - I
CH5091	2	Simulations Lab - I
CHXXXX	5	Electives
Semester 2		
CH5020	1	Numerical Methods - II
CH5050	2	Non-isothermal Reactors
CH5060	1	Heterogeneous Reaction Engineering
CH5080	1	Transport Phenomena - II
CH5101	2	Simulation Lab II
CHXXXX	5	Electives
CH5015	3	Thesis Stage I
Semester 3		
CH5025	9	Thesis Stage II
Semester 4		
CH5035	12	Thesis Stage III

6.2 MTech ACM

Code	Cred.	Course Title
Semester 1		
CH5010	2	Numerical Methods - I
CH5030	2	Chemical Engineering Thermodynamics - I
CH5040	1	Chemical Engineering Thermodynamics - II
CH5070	2	Transport Phenomena - I
CH5090	1	Bioprocess Technology
CH5140	1	Pinch Analysis
CH5091	2	Simulations Lab - I
CHXXXX	2	Electives (basket -1)
CHXXXX	2	Electives (basket -2)
Semester 2		
CH5020	1	Numerical Methods - II
CH5050	2	Non-isothermal Reactors

Code	Cred.	Course Title
CH5060	1	Heterogeneous Reaction Engineering
CH5080	1	Transport Phenomena - II
CH5100	2	Advanced Process Control
CH5120	1	Process Intensification
CH5101	2	Simulation Lab II
CHXXXX	2	Electives (basket-3)
CHXXXX	2	Electives (basket-4)
CHXXXX	1	Electives (basket-5)
Semester 3		
CHXXXX	6	Electives
Basket-1: Electives for Semester 1		
CH6720	2	Basics of Nanosciences and Nanotechnology
CH6840	2	Biomaterials Science and Engineering
CH6480	2	Principles of Heterogeneous Catalysis
Basket-2: Electives for Semester 1		
CH6630	2	Membrane Separation Process
CH6580	2	Advanced Mineral Processing
Basket-3: Electives for Semester 2		
CH6810	2	Computational Fluid Dynamics
CH5180	2	Viscous Fluid Flow
CH6420	2	Non-newtonian Fluid Mechanics
CH6850	0	Particulate and Multiphase System (2 Credit)
Basket-4: Electives for Semester 2		
CH6640	2	Optimization Techniques - I
CH6550	2	Chemical Reactor Modeling
Basket-5: Electives for Semester 2		
CH6400	1	Biorefinery
CH6610	1	Fuel Cell Technology
CH6880	0	Introduction to Energy Storage (1 Credit)

6.3 MTech ACM Thesis

Code	Cred.	Course Title
Semester 1		
CH5010	2	Numerical Methods - I
CH5030	2	Chemical Engineering Thermodynamics - I
CH5040	1	Chemical Engineering Thermodynamics - II
CH5070	2	Transport Phenomena - I
CH5090	1	Bioprocess Technology
CH5140	1	Pinch Analysis
CH5091	2	Simulations Lab - I
CHXXXX	2	Electives (basket -1)
CHXXXX	2	Electives (basket -2)
Semester 2		
CH5020	1	Numerical Methods - II
CH5050	2	Non-isothermal Reactors
CH5060	1	Heterogeneous Reaction Engineering
CH5080	1	Transport Phenomena - II

Code	Cred.	Course Title
CH5100	2	Advanced Process Control
CH5120	1	Process Intensification
CH5101	2	Simulation Lab II
CHXXXX	2	Electives (basket-3)
CHXXXX	2	Electives (basket-4)
CHXXXX	1	Electives (basket-5)
Semester 3		
CHXXXX	12	Thesis Stage-i
Semester 4		
CHXXXX	12	Thesis Stage-ii
Basket-1: Electives for Semester 1		
CH6720	2	Basics of Nanosciences and Nanotechnology
CH6840	2	Biomaterials Science and Engineering
CH6480	2	Principles of Heterogeneous Catalysis
Basket-2: Electives for Semester 1		
CH6630	2	Membrane Separation Process
CH6580	2	Advanced Mineral Processing
Basket-3: Electives for Semester 2		
CH6810	2	Computational Fluid Dynamics
CH5180	2	Viscous Fluid Flow
CH6420	2	Non-newtonian Fluid Mechanics
CH6850	0	Particulate and Multiphase System (2 Credit)
Basket-4: Electives for Semester 2		
CH6640	2	Optimization Techniques - I
CH6550	2	Chemical Reactor Modeling
Basket-5: Electives for Semester 2		
CH6400	1	Biorefinery
CH6610	1	Fuel Cell Technology
CH6880	0	Introduction to Energy Storage (1 Credit)

6.4 PhD

- Can be taken anytime before the end of 2nd semester

Code	Cred.	Course Title
Semester 1		
CHXXXX	6	5th and Higher Level Courses
Semester 2		
CHXXXX	6	5th and Higher Level Courses

7 | Department of Computer Science and Engineering

7.1 MTech 2Year

- Total Credit Requirement in Semester 1 and 2 is 24 Credits.
- In Semester 1 and 2, the total credits that the students can register is Min-9 and Max-12.
- 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.

Code	Cred.	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
CS6035[1]	4	Thesis (stage-1)
Semester 3		
CS6045	8	Thesis (stage-2)
Semester 4		
CS6055	12	Thesis (stage-3)

1. Summer Semester

7.2 MTech 3year

- Total Credits Requrement in semesters 1, 2, 3, and 4 is 24 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 12 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

Code	Cred.	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
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)

7.3 MDS

Code	Cred.	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

Code	Cred.	Course Title
CS5300	3	Parallel and Concurrent Programming
CS5360	3	Advanced Computer Architecture
CS5560	0	None
CS5580	3	Convex Optimization - Theory
CS5700	3	Text Processing and Retrieval
CS6270	0	None
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
CS6530	0	None
CS6550	0	None

7.4 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 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 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.

Code	Cred.	Course Title
Semester 1		
CS6013	3	Advanced Data Structures and Algorithms
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
Semester 2		
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CS7005	3	Research Project

7.5 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 3, 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 6 credits in mathematics or other engineering department with the permission of DPGC.
- The curriculum for the students who register in 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.

Code	Cred.	Course Title
Semester 1		

Code	Cred.	Course Title
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
Semester 3		
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CSXXXX	3	Core Elective
CS7005	3	Research Project

8 | Department of Chemistry

8.1 MSc

Code	Cred.	Course Title
Semester 1		
CY5010	3	Stereochemistry, Reaction Mechanism, ...
CY5110	3	Concepts in Inorganic Chemistry
CY5210	3	Electrochemistry and Chemical Kinetics
CY5220	3	Solid State Chemistry
CY5240	3	Quantum Chemistry and Molecular Spectroscopy
CY5011	2	Organic Chemistry Practicals
CY5111	2	Inorganic Chemistry Practicals
Semester 2		
CY5020	3	Advanced Organic Chemistry of Multiple Bonds
CY5120	3	Advanced Inorganic Chemistry
CY5230	3	Statistical Thermodynamics and Surface Science
CY5250	3	Chemical Binding and Molecular Symmetry
CY7410	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
CYXXXX	3	Elective
CY6015	0	MSc Project
Semester 4		
CYXXXX	3	Elective
CYXXXX	3	Elective
CYXXXX	3	Elective
CY6016	15	MSc Project

8.2 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	Cred.	Course Title
CYXXXX	3	Elective
CYXXXX	3	Elective
CYXXXX	3	Elective
CYXXXX	3	Elective

9 | Department of Design

9.1 MDes

Code	Cred.	Course Title
CA1024	1	Action Drawing
DS3014	1	Immersion, Movement Art, Technology
DS1014	1	Let's Make a Graphic Novel
DS3033	1	Creative Product Design
DS3024	2	Principles of Animation and Moving Images
DS3017	1	Digital Heritage
DS3053	2	Visual Communication and Digital Imaging
DS3062	2	Built-environment/ Urban Space Design
DS3072	1	Special Topics On Design
DS3082	1	Word and Image
DS3016	2	Environmental Installations and Performances
DS3043	1	Film Appreciation
DS3064	2	Drawing: Taxanomy Understanding and Exploration
DS4013	2	Automobile Design Explorations
DS4023	1	Calligraphy
DS4033	1	Life Cycle Analysis
DS5013	3	Elements of Visual Design
DS5020	3	Evolution of Visual Design
DS5030	3	Design Methods
DS5103	3	Graphic Design
DS5153	3	Information and Experience Design
DS5173	3	Digital Imaging and Photography
DS5183	3	Film Making
DS5193	3	Typography
DS5204	3	Form Explorations
DS5205	3	Project II
DS5213	3	Semiotics
DS5225	3	Project 1
DS6013	3	Moving Images
DS6033	3	Word and Image
DS6050	3	Design for Education
DS6076	3	Design Research Seminar
DS6095	3	Project 3
DS6115	12	Thesis
DS6116	3	Dissertation

9.2 PhD

Code	Cred.	Course Title
DS7010	3	Design Research

Code	Cred.	Course Title
DS7024	3	Research Project 1
DS7050	3	Research Methodologies

10 | Department of Electrical Engineering

10.1 MTech 2Year in Csp

Code	Cred.	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

10.2 MTech 2Year in Micro (Aug Entry

Code	Cred.	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

Code	Cred.	Course Title
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

10.3 MTech 2Year in Micro (Jan Entry

Code	Cred.	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

10.4 MTech 2Year in PEPS

Code	Cred.	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

Code	Cred.	Course Title
EE5277	2	Analysis of AC Machines
EEXXXX	6	Departmental Electives
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

10.5 MTech 2Year in SysCon

Code	Cred.	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		

10.6 MTech ACM in Csp

Code	Cred.	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

Code	Cred.	Course Title
EE5811	2	Fpga Lab
Semester 3		
EEXXXX	3	Core Electives
XXXXXX	3	Free Electives

10.7 MTech ACM in Micro

Code	Cred.	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

10.8 MTech ACM in PEPS

Code	Cred.	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

Code	Cred.	Course Title
EE5287	1	Basics of Power System Protection
EE5297	2	Advanced Power System Protection
EEXXXX	6	Departmental Electives
XXXXXX	3	Free Electives
Semester 3		
EEXXXX	2	Departmental Electives
EE6201	2	Power System Lab
EE6211	2	Power Electronics Lab

10.9 MTech 3Year in Csp (Aug entry)

Code	Cred.	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

10.10 MTech 3Year in Csp (Jan entry)

Code	Cred.	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

Code	Cred.	Course Title
EE5801	3	Csp Lab
Semester 3		
EE5847	1	Information Theory
EEXXXX	3	Core Electives
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

10.11 MTech 3Year in Micro (Aug Entry

Code	Cred.	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

10.12 MTech 3Year in Micro (Jan Entry

Code	Cred.	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

10.13 MTech 3Year in PEPS (Aug entry)

Code	Cred.	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

Code	Cred.	Course Title
EE6201	2	Power System Lab
Semester 4		
EEXXXX	4	Departmental Electives
EE6225	4	Thesis Stage 1
Semester 5		
EE6211	2	Power Electronics Lab
EE6235	8	Thesis Stage 2
Semester 6		
EE6245	12	Thesis Stage 3

10.14 MTech 3Year in PEPS (Jan entry)

Code	Cred.	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

10.15 MTech 3years in SysCon

Code	Cred.	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

Code	Cred.	Course Title
EE5606	2	Convex Optimisation
Semester 2		
EE5221	2	Advanced Control Lab
EEXXXX	3 – 5	Electives
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	2	Numerical Methods - I

10.16 PhD

- Regular PhD entry candidates need to take 12 credits.
- For candidates joining PhD directly from BTech, 27 credits of course work is required.
- The load distribution is flexible and can be discussed with the faculty adviser.

11 | Department of Liberal Arts

11.1 MA

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

Code	Cred.	Course Title
Semester 1		
LA5070	3	Rural and Urban Development Policy
LA5050	3	Social Research Methods
LA5110	3	Principles of Economics
LA5030	3	Basic Econometrics And Forecasting
LA6090	3	Contemporary India
Semester 2		
LAXXXX	3	Gender and Development
LA5020	3	Industrial Organization
LAXXXX	3	Elective 1
LAXXXX	3	Elective 2
LAXXXX	3	Free Elective
Summer		
LAXXXX	6	Summer Project
Semester 3		
LA5010	3	Macroeconomics
LAXXXX	3	Elective 1
LAXXXX	3	Elective 2
LAXXXX	3	Free Elective
Semester 4		
LAXXXX	12	Dissertation
Semester 2nd Semester Electives		
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
Semester 3rd Semester Electives		
LA6240	3	Sociology Of Globalization
LA6270	3	Chronic Disease Management
LA5060	3	Environment and Sustainability
LA6440	3	Visual Anthropology

11.2 PhD

- A total of four courses in the first two semesters for the degree of PhD

Code	Cred.	Course Title
Semester 1 and 2		
LA2080	3	Introduction To Western Art: From Cave Art To Middle Age
LA2100	3	Language, Cognition, And Computation
LA3010	3	Financial Institutions And Markets
LA4100	3	Natural Language And Natural Meaning
LA4060	3	Indian Economic Development
LA4200	3	Gender and Society
LA6010	3	Qualitative Research Methods
LA6020	3	Advanced Health Psychology
LA6040	3	Theories On Culture
LA5030	3	Basic Econometrics And Forecasting
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 Behvaioral Sciences
LA6160	3	American Trancendentalism
LA6170	3	American Fiction After 1945
LA6190	3	Continental Aesthetics: From The Eighteenth Century to The Present
LA6200	3	Advanced Econometrics
LA6210	3	Special Topics In Economic Research
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
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 and Practice
LA6015	3	Advanced Topics in Xxxx 1
LA6065	3	Advanced Topics in Xxxx 2

12 | Department of Mathematics

12.1 MSc

Code	Cred.	Course Title
Semester 1		
MA4010	3	Analysis of Functions of a Single Variable
MA4020	3	Linear Algebra
MA4030	3	Ordinary Differential Equations
MA4040	3	Probability Theory
MA4051	3	Basics of Programming
Semester 2		
MA4060	3	Complex Analysis
MA4070	3	Groups and Rings
MA4080	3	Measure and Integration
MA4090	3	Analysis of Functions of Several Variables
MA****	3	Elective I
Semester 3		
MA5010	3	Combinatorics and Graph Theory
MA5020	3	Functional Analysis
MA5030	3	Partial Differential Equations
MA****	3	Elective II
MA****	6	Thesis I
Semester 4		
MA****	3	Advanced Course - I
MA****	3	Advanced Course - II
MA****	3	Elective III
MA****	3	Elective IV
MA****	6	Thesis II

12.2 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.

13 | Department of Mechanical and Aerospace Engineering

13.1 MTech 2Year in IDM

Code	Cred.	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)

13.2 MTech 2Year in MAD

Code	Cred.	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

Code	Cred.	Course Title
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
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

13.3 MTech 2Year in TFE

Code	Cred.	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

Code	Cred.	Course Title
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
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

13.4 MTech ACM in IDM

Code	Cred.	Course Title
Semester 1		
ME5010	3	Mathematical Methods for Engineers
ME5130	3	Finite Element Method
ME5140	1.5	Process Modeling and Optimization
MEXXXX	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		
ME5510	1.5	Industrial Automation and Robotics
ME5505	3	Special Topics in Manufacturing
ME5520	1.5	Measurement Science and Techniques
ME5530	1.5	Industry 4.0

13.5 MTech ACM in MAD

Code	Cred.	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		
MEXXXX	9	Core Electives
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

13.6 MTech ACM in TFE

Code	Cred.	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		
MEXXXX	9	Core Electives
Semester-1 Electives		
ME5020	1.5	Elasticity and Plasticity
ME5080	1.5	Scaling Laws and Multi-scale Manufacturing
ME5110	3	Advanced Mechanics of Solids

Code	Cred.	Course Title
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
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

13.7 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	Cred.	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)

13.8 PhD in Mechanical Engineering

Code	Cred.	Course Title
Semester 1		

Code	Cred.	Course Title
ME5010	3	Mathematical Methods for Engineers
MEXXXX	5 – 8	Core Electives
Semester 2		
ME7100	3	Advanced Topics in Mathematical Tools
MEXXXX	2 – 5	Core Electives

14 | Department of Materials Science and Metallurgical Engineering

14.1 MTech 2Year

Code	Cred.	Course Title
Semester 1		
MS5010	3	Properties of Materials
MS5030	3	Materials Synthesis and Characterization
MS5050	3	Advanced Physical Metallurgy
MS5611	2	Materials Synthesis And Characterization Lab
MS5XXX	3	Core Elective
Semester 2		
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
XXXXXXX	3	Free Elective
MS5621	2	Materials Lab
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	Cred.	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

14.2 MTech ACM

Code	Cred.	Course Title
Semester 1		
MS5010	3	Properties of Materials
MS5030	3	Materials Synthesis and Characterization
MS5050	3	Advanced Physical Metallurgy
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
Semester 2		
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
XXXXXXX	3	Free Elective
Summer		
MS5XXX	3	Core Elective/free Elective
MS5XXX	3	Core Elective/free Elective

14.3 MTech ACM Thesis

Code	Cred.	Course Title
Semester 1		
MS5010	3	Properties of Materials
MS5030	3	Materials Synthesis and Characterization
MS5050	3	Advanced Physical Metallurgy
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
Semester 2		
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
XXXXXXX	3	Free Elective
Semester 3		
MS5715	12	Thesis: Stage I
Semester 4		
MS5725	12	Thesis: Stage II

14.4 PhD

- PhD student should obtain 12 credits

Code	Cred.	Course Title
Semester 1		
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective
Semester 2		
MS5XXX	3	Core Elective
MS5XXX	3	Core Elective

15 | Department of Physics

15.1 MSc

Code	Cred.	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
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
PHXXXX	2	Elective - II
PHXXXX	2	Elective - III
PHXXXX	2	Elective - IV
PH5315	2	Project

Code	Cred.	Course Title
PH5211	2	Lab
Semester 4		
PHXXXX	2	Free Elective
PHXXXX	2	Elective – V
PHXXXX	2	Elective – Vi
PHXXXX	8	Project – (continued From Sem. Iii)

15.2 PhD

Code	Cred.	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

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

16 | Course Descriptions

16.1 Department of Biomedical Engineering

BM1040 **1**
Neuromuscular Physiology

This course is intended for basic understanding of human physiology with respect to peripheral neurons and muscles in the engineers' perspective. The students need to understand the cellular and physiological systems with respect to peripheral neurons, neuromuscular junction and skeletal muscles. Action potential and electrical conductivity of peripheral neurons will be covered.
Syllabus: Peripheral neurons and their function, Skeletal muscle and their functions, Action potential and electrical conductivity, Neuro-muscular junction

BM1050 **1**
Brain Machine Interface

This course is intended for understanding the emerging field of Brain Machine Interfaces (BMI). After the completion of this course the students will have working knowledge of what BMIs are, how they are designed, implemented and tested. The core modules of BMI are data acquisition, decoding and application. Each of these modules will be expanded in detail. The students are expected to choose a specialized topic and write a term paper towards the final week.
Syllabus: Neural Data Acquisition, Neural Decoding, Applications of Brain Machine Interfaces, Challenges and opportunities in BMIs.

BM1060 **1**
Introduction to the Brain and Neuroscience

This course is an undergraduate's introduction to the fascinating world of the brain and its study. The course will give an overview of the structure and function of the brain along with the nervous system using interesting case studies and descriptions of experiments. Students will be introduced to various disciplines that go under the umbrella term of neurosciences like Cognitive, behavioral, network, cellular, developmental or computational neurosciences. The course will emphasize on the interdisciplinary nature of modern neuroscience and opportunities for people from various backgrounds to contribute to it. Towards the end of the course students pick a landmark paper or case study and present the same in class.
Syllabus: Introduction, Organization of the brain and its function, Behaviour and cognition, Systems: Motor, sensory and learning, Regions, Networks, Neuron, Ion channels. Neural development and disease, Role of experiments and computation in neuroscience, Methods in neuroscience, The interdisciplinary nature of neuroscience.

BM1130 **1**
Healthcare

None

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 Health Care	This course is intended to understand the origin of signals in biosystems and living organisms, their sensing, detection and meaningful processing for practical diagnostic sensing applications. Various engineering aspects of the detection, acquisition, processing, and display of signals, biomedical sensors for measurements of biopotentials, ECG, force, displacement, blood pressure and temperature sensors, will be addressed in this course. The course includes work involving circuits, electronics, sensor design and interfaces for building complete biomedical instrumentation. Displacement sensors: Resistive sensors, strain sensors, bridge circuits, Inductive, capacitive, piezo-electric sensors Temperature sensors: thermoelectric, radiation thermometry, thermistors, fiber-optic sensors Biopotentials: Origin of biopotentials, Cell, nerve and muscle protentials, Action potential, resting potential, Membrane structure and Nernst Equation, Nerve cell, Biopotential electrodes and biopotential amplifiers, ECG principle, sensing, 12-Lead ECG PQRS characteristics.
BM5023 2 Biomedical Devices	This course will cover the various biomedical devices and diagnostics in health care. Electrochemical devices for biosensing: blood glucose monitoring: Principle and working, cholesterol sensing, microfluidic devices, and Lab on a chip. (lectures + Lab) Blood pressure monitoring, Audiometry, Optical Pulse oximetry. (lectures+ Lab) Electromyography principle, ECG and holter monitor devices, Arrythmia and Defibrillation and telemetry systems for health care (lectures + Lab) Therapeutic instrumentation such as pacemakers, defibrillators and prosthetic devices will be reviewed.
BM5030 1 Scientific Computing and Data Analysis	The course intends to introduce the students of first year interdisciplinary masters programs to scientific computing and tools for the same. This course will be compulsory for students with basic degree in Life sciences and others not exposed to quantitative sciences. The main contents of the course are: • Matrices, matrix operations, factorisations, eigen values, transforms, Linear equations • Coding in MATLAB and Python using matrices as elementary structures • Probability and random variables • Statistical hypothesis testing
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
BM5050 1 Introduction to Brain and Neuroscience	• Introduction • Organization of the brain and its function: • Behaviour and cognition • Systems : Motor, sensory and learning • Regions • Networks • Neuron • Ion channels • Neural development and disease • Role of experiments and computation in neuroscience • Methods in neuroscience • The interdisciplinary nature of neuroscience
BM5060 0.5 Cellular Physiology	• Cell structure and its organelles • Cell membrane • Cell homeostasis • Nucleus structure and function of its different components
BM5070 1.5 Systems 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

BM5090 **2**
Biomaterials: Materials in Medicine

The primary objective of this course is to teach the fundamental properties of different type of materials and their use in the human body. Student will learn the different material properties necessary for the use in biomedical application of the verities of materials. This course will help student to design a novel biomaterial for the specific application.

BM5093 **1**
Biofabrication Technology

The aim of this laboratory course is to provide insight of methods and protocols of biofabrication technology and allied technologies. It will provide the basics and mechanisms of 3D bioprinting, 3D design software, and 3D tissue/organ printing. In addition, it will also provide hands on training of various biofabrication processes, such as the selection and development of biomaterial formulation (bioinks), modulating properties of biomaterials, controlling different processing conditions and biofabrication of 3D structures. In this elective course, students will be introduced to all topics within biofabrication technology to provide them with a broad knowledge on the practical background, operation, and applications. Besides this, students will work in teams on experimental work. They will also prepare, present and defend a short scientific presentation. Syllabus: 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
▷BM5090

This course is a laboratory based practical course for PhD and M.Tech students where student will prepare biomaterials for tissue engineering and drug delivery. In this course we will emphasize on the preparation of different type of scaffold and nanocarrier for tissue engineering and drug delivery application respectively. Students also learn the physical and biological characterization technique of these biomaterials. The biological characterization techniques include stem cells/cells base evaluation of these biomaterials.

BM5150 **2**
Neurophysiological Signal Processing

The course is to introduce the origin of neurophysiological signals such as local field potentials (LFP), electro-corticogram (ECoG), electroencephalogram (EEG) and magnetoencephalogram (MEG) will be covered. Origin and biophysics of LFP, ECoG, EEG and MEG signals, mathematical models; Signal processing basics, Spectral decomposition methods - Fourier analysis, Hilbert transform, wavelet transform, multitapering; Neurophysiological signals - Acquisition, artefacts, artefact suppression and data processing algorithms; Neurophysiological rhythms, spectral bands of physiological interest–theta, alpha, beta, gamma activity; Evoked fields, time-frequency representation of neurophysiological signals, value of spectral analysis; Source localization methods – beamformer, distributed localization methods – mathematical framework and application; Motor evoked potentials - nerve stimulation; Applications in clinical setting: Unit activity, Motor evoked fields, nerve stimulation in intra-operative neurophysiological monitoring; Nerve conduction tests for diagnosis of neurological disorders; ECoG and MEG/EEG for epilepsy diagnosis and surgical planning

BM5193 **2**
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. In this elective course, students will work in teams on a mini-project. They will select one medical device from the market, reverse engineer that and build a prototype of the same device. They will also prepare, present and defend a short scientific presentation.

BM6023 **2**
Cell Technology
▷BM5060

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. They should also learn basic molecular biology methods such as DNA, RNA isolation from cultured cells and running a polymerase chain reaction. Syllabus:
- Cell culture, splitting
- Cell freezing and thawing

	• Identification of cells in blood smear • DNA, RNA isolation • PCR reaction
BM6070 **2** Biomicrofluidics ▷	Introduction to Micro Nano scale fluid flows and Mass transport - Navier Stokes equation, Convection Diffusion equation and analytical solutions for flows in rectangular channel cross sections - Flow field fractionation using Dielectrophoresis - Separaion and concentration of Cells on Chip using Acoustic, Magnetic and Optical fields - Microfabrication - materials - thin film deposition and patterning techniques - Bonding techniques - 3D/Multilayer fabrication of microfluidic Chips - Applications - Drug screening - SERS on Chip using magnetic nanoparticles - Single Cell trapping techniques on Chip - Stem Cell differentiation studies on Chip - Microfluidic PCR - Biochips for studies on Protein Folding.
BM6080 **2** Advanced Biomechanics ▷	Isotropic and Anisotropic models of elasticity - Nonlinear models for soft tissue mechanics - Biofluid mechanics - Newtonian and Non-Newtonian fluids -Effect of constituents of blood and synovial fluid on viscosity - Navier Stokes equation and analytical solutions for flows in different geometries - Non-Newtonian flow modeling - Arteial Blood flow - Pulsatile flows in arteries and analytical solutions for transient velocity field and shear stress - Oscillatory wall shear stress and its significance - modeling of Spherical Aneurysms
BM6090 **2** Biomedical Imaging	Medical imaging systems: Ultrasound, Photoacoustic imaging, MRI, X rays and CT, Nuclear imaging techniques: PET, SPECT, Optical imaging and microscopy, Molecular and Cellular imaging, Contrast agents (6 Lectures + Lab)
BM6100 **2** Bio-nanotechnology	The course will introduce Bio-nanotechnology from material's viewpoint. The course content will deal with various types of nanomaterials (zero dimentional, one dimentional, two dimentional and special nanomaterials) used in biology/medicine. The course will also introduce various characterization techniques in nanotechnology and the principles behind them. Students will be exposed to various applications of nanomaterials in medicine and biology through lectures and seminar discussions. • Introduction: About the course; Nanotechnology for biology and biomedical field (2) • Emergence of Bio-nanotechnology (2) • Bottom up and Top down approaches (2) • Challenges in Bio-nanotechnology (2) • Zero Dimentional Nanostructres (2) • One Dimentional Nanostructures (2) • Two Dimentional Nanostructures (2) • Special Nanomaterials (2) • Characterization and properties of Nanomaterials (2) • Applications of Nanomaterials in biology (10)
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 **1** Advances in Molecular Imaging	This course is intended to cover special imaging modalities like PET-CT, MRI, CT and MOLECULAR IMAGING. 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.

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.

BM6136 **1**
Clinical Health Care

Positive patient experience is a key aspect of designing medical products. Does this product ensure patient safety? Does this medical instrument make the patient feel more comfortable using it? Does this machine reduce error and increase accuracy, thereby increasing patients' trust and psychological well-being? Questions such as these are asked not only by end-users, but also by science and engineering. Considering human factors, i.e. human interaction with systems, is quickly gaining importance where technology is increasingly user-centered. This course will first introduce psychology, highlight the role psychology plays in health both from a patient and doctor perspective, elaborate on human factors in medical device design, and how one tests for usability. Following this, 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. A short report is required to be submitted as a course evaluation, which is aimed to encourage students to think innovatively about biomedical engineering and psychology.

BM6140 **2**
Theoretical and Computational Neuroscience: From Cell to Systems

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
• Models of cognition, decision making and psychophysical models
• Systems (sensory and motor systems) and their modeling
• Neural coding (Rate, temporal, population)
• Neuronal data analysis techniques (Pre-processing, Spike detection and sorting techniques.

BM6146 **2**
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. A short report is required to be submitted as a course evaluation, which is aimed to encourage students to think innovatively about biomedical engineering.

BM6150 **2**
Mathematical Physiology and Modeling

This course for senior undergraduates and postgraduates will introduce the principles of physiology and its mathematical characterisation. The course will cover the important elements of physiology like Cellular function, Growth, Homoeostasis and metab, Characterisation of some systems. E.g. Cardiovascular, Respiratory, Endocrine.

BM6163 **1**
Molecular Technology

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.
Syllabus:
• DNA, RNA isolation
• PCR reaction
• Transfection
• Western blotting

BM7106 **2**
Special Topics in Microscopy

None

16.2 Department of Biotechnology

BO1010 **1**
Introduction to Life Sciences

Relevance of Biological Principles to Engineering undergraduates. Water and its special properties: Relevance to life. Building blocks of life: Bio-molecules and their structure-function aspects. Cell structure and organelles, cell membrane, cellular transport and signaling. How does a cell sustain life? Cell metabolism and its regulation; Cell energetic: harvesting chemical and solar energy. Cell division and cancer. DNA structure and packing. its replication, damage and repair: Consequences of unrepaired

		DNA damage. Dogma in Molecular Biology: Transfer of information from DNA to protein synthesis. Biotechnology.
BO5050 Gene Editing	**1**	Basic understanding of the cell and how it functions (role of gene to protein to function). Principles of gene expression and regulation and the idea of gene mutations and associated diseases. Fundamentals of DNA damage and repair process and their mechanisms. Introduction to gene editing strategy with regard to the principles of gene regulation and DNA repair process. Overview of gene editing techniques including, zinc finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs) and Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)-Cas9. Application of gene editing tools with strong emphasis on Crisper-Cas9 system in understanding gene function, disease modeling, and therapeutic potential for genetic diseases including cancer and sickle cell anemia.
BO6015 Thesis-1	**15**	Independent research project leading to an M.Tech thesis. Students will learn to think creative, design and perform research projects independently under the guidance of a faculty mentor.
BO6025 Thesis-2	**0**	Independent research project leading to an M.Tech thesis. Students will learn to think creative, design and perform research independently under the guidance of a faculty mentor.
BO6060 Protein Misfolding In Neurodegerative Diseases	**0**	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.
BO6063 Animal Models in Medical Research	**1**	The learning outcome of this course is knowledge about use of animal models in medical research. This course has a hands on module. • Various animals as models and their advantages and disadvantages • Animal research in medicine: modelling heart damage, autoimmune diseases, tuberculosis, Parkinson's • Upcoming vertebrate animal model: zebrafish • Practical session using animal model zebrafish
BO6083 Programming for Bio Macromolecular Data Analysis	**2**	This course is designed to provide knowledge about interdisciplinary approach in addressing 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 and organizing Protein Databank (PDB) files towards modeling and analysis of biomacromolecular structures and python scripting for Pymol software.
BO6113 Structural Bioinformatics	**2**	The overall aim of this course is to provide an outline of the structure of biomacromolecules that are major target for therapeutics and various algorithms used for biomolecular structure prediction. Biomolecular Structure and Dynamics: Stereochemistry: configurational and conformational isomers - Internal parameters - Forces stabilizing biomolecular structure - Structure and dynamics of nucleic acids: base pair geometry, sugar puckering and phase angle of pseudo rotation, secondary structures of nucleic acids - Structure and dynamics of proteins: primary, secondary, tertiary and quaternary structures of proteins, Ramachandran diagram and conformation of proteins - Carbohydrate structure. Sequence alignment: Pair-wise alignment method, Dynamic programming: Needleman-Wunsch method; Smith Waterman method - Multiple sequence alignment method - Scoring function: BLASUM matrices - Heuristic method: BLAST. Structure prediction: RNA secondary structure prediction: Nussinov Algorithm - Protein secondary structure prediction - protein tertiary structure prediction.
BO6120 Advanced Immunology	**2**	The learning outcome of this course is detailed knowledge of advanced Immunology with recent advances in immunology including few clinical focuses.Quick overview of 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, Effector mechanisms; AIDS and the immune system; Vaccines. Special topics on advances in immunology.
BO6123	**2**	This course is intended to provide practical handling experience of culturing of human

Cell Technology	cells. Human cell culture media, growing cells, counting cells, cell cryopreservation, cell transformation with DNA, methods of DNA, RNA isolation from cultured cells; cell based assays with fluorescence microscopy; cell staining and cell survival analysis.
BO6133 **2** Protein Technology	This course aims to provide knowledge of advances in protein research for industrial and biomedical applications to post graduate students. Recombinant protein expression systems: E.coli, Yeast, Pichia, Insect-cells, cell-free protein expression. Protein purification techniques: Ion-exchange chromatography; Gel-filtration; Affinity chromatography; FPLC; HPLC. Proteomics: 2-D Gel Electrophoresis, Mass spectrometry, Protein microarrays. Protein characterization: Fluorescence Spectrometry; Circular Dichroism, Isothermal Titration Calorimetry. Mutant design and site-directed mutagenesis. Therapeutic proteins.
BO6143 **2** Gene Technology	Gene technology course is designed to provide details of methods used in molecular biology, particularly PCR based cloning and mutagenesis for over expression of genes. The course involves students independently performing the following in the class room: Retrieval of nucleotide and amino acid sequences of genes from NCBI database, components of cloning vectors, features of expression vectors, elements of prokaryotic and eukaryotic genes, analysis of restriction sites in genes and vectors, designing of primers for PCR amplification and directional cloning of genes, confirmation of insert sequence in ligated plasmid, primer design of achieving expression in multiple versions of expression vectors, requirement for generation of site directed mutants, creation of restriction sites for scoring of mutation, quantification of copies of mRNA or DNA fragments in clinical samples using qPCR.
BO6150 **2** Molecular Basis of Cancer ▷Basic knowledge of Biology	This course aims to provide a detailed understanding of biological pathway leading to cancer and molecular understanding of anti-cancer therapy.
BO6160 **1** Next Generation Sequencing Technologies and Application	Next-generation sequencing (NGS) technologies have revolutionized our understanding of complex diseases and allowed identification of newer targets for therapeutic intervention. The primary aim of the course is to cover the current and developing next generation sequencing technologies with emphasis on the scientific and medical applications of these technologies. Introduction to next generation sequencing (NGS) technology, basic principles of NGS, introduction to various NGS platforms; their advantages and limitations, single-cell sequencing technology, basic and advanced biological applications of various sequencing technologies, clinical applications. The course will also provide an overview of the various tools available to analyze the sequencing data. In addition, the course will also cover the recent scientific breakthroughs made using NGS technology.
BO6163 **1** Modern Techniques In Neuroscience	This course is designed to introduce theoretical knowledge and some practical aspects of recent techniques in understanding neurobiology at molecular, cellular, circuit and behavioral levels. Viral vector based neural circuit tracing, Optogenetics to control circuit activity and behavior, Calcium imaging by genetically encoded sensors (GCaMP, RCaMP), pH Sensitive Fluorescence reporter (pHluorin), Molecular Profiling by TRAP approach, Brainbow multicolor imaging, Functional MRI for brain imaging, Ex Vivo slice culturing, Primary Culturing in Neural and Glial Cells, Biochemical Techniques.
BO6180 **1** Macromolecular Crystallography	This course is designed to give insights on macromolecules crystallization and resolving their structure by X-ray crystallography. 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 phenomenon with structures.
BO6240 **2** Structural Biology	The course emphasis on techniques used to determine and analyze the macromolecules organization and interactions. The course aims on case studies which enable students to use the information obtained from macromolecular structures and interactions studies for understanding a biological process. Quantification and characterization of interactions, involving proteins with other molecules termed as ligands (proteins, nucleic acids, carbohydrate, peptide, inorganic molecules etc), using appropriate biophysical techniques. Characterization of macromolecular assembly using principal techniques.

Principles of protein and nucleic acid structures: Three-dimensional conformations of proteins and nucleic acids. Covalent, non-Covalent and van der Waals interactions role in protein and nucleic acids structure and folding. Bioinformatics tools for analyzing motifs and folds. Protein and nucleic acids folding problem. Case study for understanding biological phenomenon with structures.

BO6250 2
RNA Biology and Therapeutics

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.
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 the role of RNAs in human diseases and RNA-based therapeutics. The course will also cover role of long noncoding RNAs and RNA modifications in regulating gene expression.

BO6290 2
Molecular Machines: DNA Interacting Proteins

In this advanced course, the students get to learn about aspects involved in interaction of a protein with DNA, such as, pathways for recognizing a specific sequence in genome, ways to access the nitrogen bases in the double helix, relation between binding and activity of the proteins, molecular mimicry, role of non-specific DNA, etc. The analysis and interpretation of current literature, followed by, design of experiments to probe activity of a protein on DNA form the core of the course.

BO6340 2
Epigenetics

This course is intended to provide the students with importance of epigenetics in modern biology. Histone modifications, chromatin structure and modifications; Overview of epigenetic mechanisms and their link to chromatin dynamics. Link between epigenetic mechanisms and DNA dependent activities. Structural and biochemical basis of covalent histone and DNA modifications reading, writing and erasing. RNAi: discovery, mechanisms, biological functions; Roles of micro-RNAs in gene regulation and embryonic development; epigenetic regulation of gene expression; variations in gene expression profiles during cellular differentiation.

BO6350 1
Membrane Biophysics

The course will focus on physical principles governing biological membranes, including lipid and transporter structures and dynamics as well as their mechanical characteristics and their effect in cellular transport.
Introduction to lipids and their structures, membrane protein motifs, molecular and ionic membrane transporters: passive and active, electrochemical gradient and diffusion, case studies of membrane protein transport mechanisms, role of transmembrane proteins in infectious diseases, modeling as a tool in studying membrane…transporter interaction dynamics.

BO6670 2
Stem Cell Biology And Regenerative Medicine

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.

BO7053 2
Biomolecular NMR

Objective of the course is to provide the fundamental concepts of NMR and applications of NMR in understanding the biomolecular structure and dynamics.
Properties of electromagnetic radiation - Magnetic properties of nuclei - The nucleus in a magnetic field - Spin populations at thermal equilibrium and the NMR phenomenon - The classical vector model - Chemical shift - T1andT2 Relaxation - FID - A simple one-pulse experiment - Inversion-recovery method - J coupling - Polarization transfer - NOE - INEPT - The spectrophotometer - Introduction to product operator formalism - 2D NMR - 3D experiments and Sequential assignment strategies - Structure calculation protocol.

BO7280 2
Pharmacology and Physiology of Receptors
▷Basic knowledge of biology

- Receptor classification
- Fundamental principles of pharmacology: drug receptor interactions.
- Techniques used to study receptor localization, trafficking and signaling.
- Principles of cardiovascular pharmacology.
- Voltage gated ion channels: assay technologies available,
- Channelopathies.

BO7390 2
Cellular and Molecular Neuroscience

Basic understanding of the nervous system development and function. To understand generation and architectural organization of brain cells. Basic cell biology, biochemistry and molecular biology of neuron, how neurons are electrically excitable, role of ion channels, surface receptors and synapse formation and synapse plasticity. Principles of neural circuit formation and function and ways to manipulate them. Introduction to

nonneuronal cells (glial cells- astrocytes, oligodendrocytes and microglia) of the brain and their emerging role in controlling neuronal function. Overview of innovative experimental tools including optogenetics and CLARITY in uncovering neural circuit assembly at cell and molecule level. Concept of neurodevelopmental and neurodegenerative diseases and possibility of development of new tools to better understand disease mechanism.

16.3 Department of Civil Engineering

CE5390 **2**
Geothermics

Heat transfer - conduction, convection, radiation, heat flow measurements; Natural hydrothermal systems, hydrothermal solutions, chemical and isotopic signatures; Utilization of geothermal energy. Economics and management of geothermal energy - CO2 mitigation strategy; Case histories - Indian and world examples.

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 **3**
Advanced Reinforced Concrete

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 **3**
Prestressed Concrete Design

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 **3**
Advanced Steel Design

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

CE6300 **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

CE6310 **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.

CE6323 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.
CE6330 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.
CE6340 0 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
CE6352 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
CE6500 3 Engineering Hydrology And Hydrologic Systems	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.
CE6510 3 Water And Wastewater Engineering	Introduction - chemical and biological concepts, reactions, material balance, flow models and reactors, wastewater characteristics. Screening and shredding, grit removal, flow equalization, coagulation, flocculation, sedimentation. Aerobic suspended growth processes, aerobic attached growth processes, anaerobic processes. Advanced wastewater treatment, disinfection processes, effluent reuse/disposal, sludge processing and land application of biosolids.
CE6511 2 Soft Computing Lab (environmental and Water Resources)	Hydrologic simulation using ArcSWAT (watershed modeling and pesticide modeling), Groundwater simulation using GMS (flow and transport modeling), Hydro-geologic simulation using HGA (analysis of bore hole and pumping information), EPANET(Design of water distribution networks), Strom CAD, Sewer CAD, HEC-HMS, HEC-RAS, Stream quality modeling using QUAL2Kw
CE6520 3 Air Pollution	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.
CE6530 3 Groundwater Modeling	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 3 Contaminant Hydrology And Remediation	Introduction, types of contaminants, point and nonpoint 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 vapor 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.
CE6550 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.
CE6560	**3**	Water and Wastewater quality, Water purification in natural systems, process dynamics, reactions and energetics, kinetics and reaction rates and catalysis, surface and colloidal chemistry. acid-base equilibria, solubility, oxidation reduction. Coagulation and flocculation, sedimentation, filtration ion exchange and adsorption, water stabilization, disinfection, aeration and gas transfer. Membrane process: Reverse osmosis, ultrafiltration, electro dialysis, desalination.
Physico-chemical Process		
CE6570	**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.
Environmental Impact Assessment		
CE6580	**3**	Introduction - Integrated solid waste management, municipal solid waste characteristics 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. Principles of hazardous waste management, identification of hazardous waste, policy and regulatory requirement, treatment and disposal, hazardous waste site clean-up technologies.
Solid and Hazardous Waste Management		
CE6590	**3**	Types of industries and industrial waste characteristics; management strategies for pollution prevention and waste minimization; wastewater 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; hazardous waste management; removal of industrial air contaminants.
Industrial Waste Management		
CE6610	**3**	Principles of remote sensing; Introduction to LiDAR technology; Integration of remote sensing and GIS; Spatial, statistical, and raster analysis in GIS; Urban land use/cover classification and characterization; Surface runoff modeling and analysis; Quality assessment and monitoring; GIS solutions to urban transportation sector; GIS framework to disaster management
Remote Sensing and GIS Applications To Civil Engineering		
CE6620	**3**	Systems concept in water resources; Optimization systems; Constrained optimization principles; Applications of linear and dynamic programming principles to water resource management; Introduction to multi objective optimization using Fuzzy, ANN, and Genetic algorithm approaches; Economic considerations for water resources planning.
Water Resources Systems Planning And Management		
CE6630	**3**	Energy and momentum principles; Energy-depth relations; Analysis of uniform and varied flows; Sediment transport through open channels; Design principles of hydraulic structures; hydrologic routing principles; Spatially varied flows; Introduction to un-steady open channel hydraulics; Numerical solutions to un-steady flow equations.
Open Channel Hydraulics		
CE6640	**3**	Soil-water-crop relations; Hydraulics of open channels; Management of canal irrigation; Design principles of canal regulating structures and cross-drainage works; Watershed inventory; Estimation of watershed model parameters; Principles of watershed modeling; Cost, legal, and administrative concerns of water resources management of a region
Irrigation And Watershed Management		
CE6650	**3**	Occurrence and movement of groundwater; Principles of groundwater flow; Well hydraulics; Design of wells; Water chemistry; Groundwater contamination - principles; Surface geophysical exploration - methods, analysis, interpretation; Geophysical well logging; Hydro-geologic site evaluation; Develop pre-processing tools to groundwater models.
Hydrogeology		
CE6700	**1**	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.
Intelligent Transportation Systems		

16.4 Department of Chemical Engineering

CH3580	**1**	Evolutionary perspective of Nanomaterials, Physical aspects of Nanosciences, Synthesis, Design and Characterization of Nanomaterials, Nanofabrication methods and Product form of Nanomaterials.
Introduction to Nanotechnology		

CH5010 **2**
Numerical Methods - I

Review of computer programming; simultaneous linear algebraic equations, Gauss elimination, partial pivoting, LU decomposition, matrix inverse, Gauss-Seidel method, relaxation, Eigen value calculations, roots of nonlinear equations, successive substitution, Newton's method, single variable / multiple variable methods, functional approximation, curve-fitting, linear and nonlinear regression, Newton's forward and backward difference interpolation, Lagrangian interpolation, Pade and cubic spline approximations, numerical differentiation and integration.

CH5020 **1**
Numerical Methods - II

Ordinary differential equations, First-order ODEs, explicit Adam Bashforth methods, implicit Adam Moulton methods, multi-step methods, predictor-corrector methods, Runge-Kutta methods; step size controls, estimation of errors, stability of algorithms, stiff ODEs; system of first-order ODEs; higher-order ODEs.

CH5030 **2**
Chemical Engineering Thermodynamics - I

Recap for Thermodynamics of Laws, Allied postulates, Different definitions and related aspects, Entropy Balance, Single Phase, Pure Fluid Industrial Applications, Behavior of Mixtures, Liquid Models, Vapor-Liquid and Liquid-Liquid Equilibria Chemical Equilibria.

CH5040 **1**
Chemical Engineering Thermodynamics - II

High-pressure phase equilibrium, Osmotic equilibrium, Introduction to Electrochemical Thermodynamics, Partition of solute among two solvents, Advanced Liquid Models, Introduction to Intermolecular forces, Introduction to Statistical Mechanics.

CH5050 **2**
Non-isothermal Reactors

Overview of reaction engineering and emerging challenges, stoichiometric table, reaction network analysis, effect of pressure drop on performance of plug flow vessels, energy balance and non-isothermal reactors design, optimal design for exothermic reversible reactions, stability and multiplicity of steady states in CSTR.

CH5060 **1**
Heterogeneous Reaction Engineering

Adsorption kinetics, kinetics of catalytic reaction, External diffusion effects on heterogeneous reactions, reaction and diffusion in porous catalysts, catalyst deactivation, design for deactivating catalysts, Kinetics and reactor design of fluid-fluid and Fluid-particle system , Design of heterogeneous catalytic reactor: fixed bed reactor, slurry reactor, trickle bed reactor and fluidized bed reactor.

CH5070 **2**
Transport Phenomena - I

Vectors and tensor algebra and calculus. Momentum transport - Viscosity, stress tensor, mechanisms of momentum transport; shell momentum balances, boundary conditions; governing equations: equations of continuity and motion, applications to steady, unidirectional flows; Energy transport - Thermal conductivity, mechanisms of energy transport; shell energy balances; equations of change for nonisothermal systems; Mass transport - Diffusivity, mechanisms of mass transport; shell mass balances, concentration distributions in laminar flow. Analogy between the three transport phenomena.

CH5080 **1**
Transport Phenomena - II

Dimensional analysis of the equations of change; Momentum Transport - Time dependent flows: method of similarity solutions, Sturm-Liouville problems; 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. Energy Transport - Forced and free convection: Boussinesq equation of motion; temperature distributions with more than one independent variable: unsteady heat conduction, steady heat conduction in laminar flow; boundary layer theory for nonisothermal flows. Mass Transport - equations of change for multicomponent systems; concentration distributions with more than one independent variable.

CH5091 **2**
Simulations Lab - I

Simulation concepts, Aspen Plus - Introduction, Reactor models, Distillation models, Process simulation - Steady State and Dynamic, Process Control, Economic Analysis. Introduction to molecular dynamics (MD) and monte carlo (MC) simulations.

CH5101 **2**
Simulation Lab II

Applications of CFD, Balance equations in CFD (mass, momentum, energy), Solution of simple flow problems using ANSYS FLUENT (CFD software), Programming assignments for solution of linear algebraic equations, Discretization of derivatives, Conditions for consistency, stability, and convergence of a Finite Difference scheme. Introduction to Monte Carlo and Molecular Dynamics simulation, Introduction to LAMMPS (Molecular Dynamics Simulator), Example simulations: visualize trajectories and calculate thermodynamic properties.

CH5180 **2**
Viscous Fluid Flow

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
CH6020 Sustainable and Energy Options	**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.
CH6120 Fluidization Technology	**1**	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, Pressure profile along the fluidized bed reactor, Solids inventory, 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.
CH6220 Advanced Soild-liquid Separations	**2**	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.
CH6310 Cardiovascular Mechanics	**3**	Mechanics and Human Health, Preliminaries, Anatomy and Physiology of Cardiovascular system, Preliminaries of Continuum Mechanics, Problems and solutions in cardiovascular mechanics
CH6420 Non-newtonian Fluid Mechanics	**2**	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 Introduction to System Identification	**1**	Linear Time Invariant systems, Sampling, Transfer Functions, Frequency Response, 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 Bio-process Technology	**2**	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 System Identification Theory	**2**	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 Principles of Heterogeneous Catalysis	**2**	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.

CH6560 **1**
Mineral Processing

Overview of mineral processing in terms of separation methods for minerals; introduction, mineral processing overview, metals vs minerals; metallurgical accounting, mineral liberation, comminution and classification, dense medium separations, gravity separation, froth flotation.

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 **1**
Fuel Cell Technology

Types of fuel cels, advantes and disadvantages of differen fuel cell types, fuel cell thermodynamics, electrode kinetics, charge transport, fuel cell charanterization, 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
▷see syllabus

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

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, Charactetrization 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.

CH6750 **2**
Applied Statistics in Experimental Research

Data presentation (histograms, box/scatter plots, bar/line graphs, distributions); Sampling distribution of the mean; Confidence intervals; Hypothesis testing; Comparison of means (T-testing, One-way and two-way ANOVA); Multivariate analysis; Non-parametric testing methods (Sign, Wilcoxon); Theoretical probability distributions ; (Normal/Poisson/ Binomial/ Gamma/ Lognormal/ Exponential/ Beta); Regression analysis; Concepts of clustering techniques (K-means, Fuzzy); Feature extraction (Principal component analysis)

CH6760 **2**
Molecular Theory of Polymeric Fluids
▷CH5030,CH5070

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

16.5 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.

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.

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

This advanced graduate level course on combinatorics will focus on selected topics such as extremal combinatorics, probabilistic techniques, algebraic method in combinatorics

▷see syllabus	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

16.6 Department of Chemistry

CY5010 **3**

Stereochemistry: Introduction to molecular symmetry and point groups. Topicity and

Stereochemistry, Reaction Mechanism, ...	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
CY5110 **3** Concepts in Inorganic Chemistry	Periodicity in Properties: Ionization potential, electron affinity, ionic radii and electronegativity. Chemical Bonding: Ionic solids, Born-Haber cycle, covalent bonds, dipole moment, resonance, hybridization, geometry and shape of simple molecules. Coordinate Bond, Hydrogen bond.Introduction to Transition Elements: oxidation states and their stabilities, colour (excluding the details of electronic transitions) and calculation of spin-only magnetic moment; Coordination compounds: nomenclature of mononuclear coordination compounds, cis-trans and ionisation isomerisms, hybridization and geometries of mononuclear coordination compounds (linear, tetrahedral, square planar and octahedral), acid-bases concepts, Isolation of Metals, Extraction of commonly occurring ores and minerals of iron, copper, zinc, silver and gold. Chemical principles and reactions of extractive metallurgy, Carbon reduction method (Iron), Self-reduction method (Copper), Cyanide process (silver and gold).
CY5111 **2** Inorganic Chemistry Practicals	Advanced Inrganic Chemistry Practicals
CY5120 **3** Advanced Inorganic Chemistry	None
CY5210 **3** Electrochemistry and Chemical Kinetics	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 **2** Physical Chemistry Practicals	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.
CY5220 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
CY5230 3 Statistical Thermodynamics and Surface Science	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 3 Quantum Chemistry and Molecular Spectroscopy	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 3 Chemical Binding and Molecular Symmetry	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 Synthetic Methodology in Organic Chemistry	None
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 15 MSc Project	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.

CY6210 3
Separation Techniques And Dynamic Electrodics

Extraction methods, super critical fluids, Electrophoresis- theory and applications. Chromatography, Identification of trace elements: DCP and ICP, Flame Emission and Atomic Absorption Spectrometery Neutron diffraction methods. Electrode-electrolyte interface phenomena (kinetics of electrode reactions), the Helmholtz-Perrin, Guoy-Chapman and Stern models, Butler-Volmer Equation, Electroanalytical methods: Controlled Potential Sweep Methods, Controlled Potential Step Methods, Polarography, Pulse Voltammetry, Electrochemical Impedance Spectroscopy, Controlled Current Methods and Bulk Electrolysis Methods, Application to Electroactive layers and other coupled characterization methods.

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.

CY7010 3
Chemistry of Natural Products and Biomolecules

None

CY7020 3
Drug Discovery, Design and Development

Introduction to the molecular basis of disease; identification and validation of drug target; History of Drug Discovery and Identification of Lead Compounds; Strategies for Organic Drug Synthesis; Combinatorial Chemistry; Structure-Based Drug Design; Use of chemoinformatics in drug design, Physiochemical Properties of Drugs (Absorption, Distribution, Metabolism); Drug Receptor interactions; enzymes as drug targets, Prodrugs and drug delivery systems, Illustration of drug development through specific examples, Drug resistance, Drug synergism and combination therapy.

CY7030 3
Asymmetric Synthesis

1.Introduction to asymmetric synthesis Asymmetric synthesis – Definition, importance of asymmetric synthesis, Principals of Assymetric Synthesis , strategies for asymmetric synthesis- advantages and limitations of each strategy, analytical methods for determining enantiomeric excess. Resolving agents and resolution of common functional groups. Resolution of priviledged chiral ligands- BINOL, trans 1,2-diaminocyclohexane 2.Substrate and reagent control of stereoselectivityAsymmetric synthesis with chiral substrate: Nucleophilic addition to α –chiral carbonyl compounds, Electrophilic addition to α – chiral olefins - epoxidation, cyclopropanation, hydroboration – oxidation, alkylation of enolates of β-chiral carbonyl compounds. Asymmetric synthesis using chiral reagents: Chiral organo boranes, Chiral lithium aluminium hydride applications , chiral organo cuprates, chiral lithium amides. 3. Reaction between chiral substrate and chiral reagent Double stereo differentiation Matched pair and mismatched pair example from aldol reaction and hydroboration reactions. Kinetic resolution 4. Asymmetric synthesis using chiral auxiliaryes 5. Asymmetric synthesis using chiral catalyst Organometallic catalysts , Organo caltalysts, Biocatalysis.

CY7040 3
Organic Electronics and Photonics

Introduction to organic semiconductors; Band-gap engineering; Synthetic approaches for semiconducting polymers and small molecules; Mechanisms of charge transport; Importance of molecular ordering on charge-transport and luminescence; Large area processing; Organic field-effect transistors (OFETs); Organic solar cells (OPVs); Transient absorption; Singlet fission; Organic electroluminescence; Organic light-emitting diodes (OLEDS); Thermally activated delayed fluorescence; Time-resolved photoluminescence.

CY7110 3
Organolanthanide Chemistry

Course syllabus: Intrinsic Properties of the Lanthanide Elements (Electronic Features, Steric Features). Synthesis of Organolanthanide Compounds (Thermodynamic and Kinetic Guidelines, Inorganic Reagents, Metalorganic Reagents, Thermal Stability). Ligand Concepts (Steric Bulk and Donor Functionalization, Ancillary Ligands, Immobilization – "Supported Ligands". Reactivity Pattern of Organolanthanide Complexes (Donor-Acceptor Interactions, Complex Agglomerization, Ligand Exchange and Redistribution Reactions, Insertion Reactions, Elimination Reactions– Ligand Degradation, Redox Chemistry, Reaction Sequences – Catalytic Cycles, Side Reactions. Lanthanide Triflate-Catalyzed Carbon-Carbon Bond-Forming Reactions in Organic Synthesis. Lanthanide - and Group 3 Metallocene Catalysis in Small Molecule Synthesis. Ref. Books. (1) Principles in Organolanthanide Chemistry, Reiner Anwander, Topics in Organometallic Chemistry, Vol 2, Springer, Germany, 1999. (2) Lanthanide and Actinide

Chemistry, Simon Cotton, John Wiley andamp; Sons Ltd, The Atrium, Southern Gate, Chichester, England, 2 nd Ed, 2006.

CY7111 3
Bio Inspired Catalysis in Modern Research

Basic Concepts: Chemical challenges and opportunities in energy research; New trends in transition metal coordination chemistry; Metal-Ligand Multiple Bonds; Electronic structures of oxo-metal complexes; Water Splitting: thermodynamics; water oxidation catalysts and mechanisms for O-O bond formation; Proton Coupled Electron Transfer (PCET); Hydrogen Production; Hydrogenases: models; small molecule catalysts and photocatalysts; Heterogeneous catalysts and electrode materials; O2 reduction; CO2 reduction: thermodynamics; mechanisms: enzymatic CO2 reduction, homogeneous catalysis and electrocatalysis; Metal Organic Frameworks and their applications. Inorganic complexes as MRI contrast agents.

CY7112 3
Bioinspiration and Biomimicry in Chemistry

Basic Concepts: Energy parameters, basic principles and chemical transformations; Energy Carriers; Fossil Fuels: Oil, Gas and Coal; H2, H2O2, HCO2H and MeOH; New trends in transition metal coordination chemistry: Photochemistry and photo physics of transition metal complexes; Supramolecular Chemistry; Photosynthesis: Overview: light reactions, Z scheme and Calvin cycle; Photosystem II and the Oxygen-evolving center (OEC); Photosystem I and the Ferredoxin-NADP(+) reductase; Artificial photosynthesis and water splitting; Overview: Catalysts for the production of solar fuels; Catalyzed water oxidation to O2; Catalyzed production of H2O2; Catalyzed reduction of H2O to H2; Catalyzed reduction of CO2 to hydrocarbons; Light-harvesting complexes and charge separation systems; H2 production; Catalytic hydrocarbon and NOx combustion.

CY7120 3
Advanced Organometallic Chemistry

Structure of TM complexes , ligands, hapticity, 18- electron rule, Clusters and M-M bonds, Reaction mechanisms, Metal alkyl and hydride, Metal-carbene complexes, Fischer/Schrock carbenes, NHC's, olefin metathesis, multiple bonding between TMs and heteroatoms - p-complexes (olefins, dienes, alkynes, allyls, arenes) - Metallocenes - structures, syntheses, properties - OM complexes of alkali metals, Grignard reactions - Main group OM chemistry (group 13-16), Carbonylation of Alcohols- Hydrogenation of Alkenes- Hydroformylation - Alkene and Alkyne Metathesis. Oligomerization and Polymerization of Alkenes and Alkynes. C-C Coupling Reactions, C-Heteroatom Coupling: Aminationof Arenes, Hydroamination, Hydroboration, and Hydrosilation.

CY7130 3
Main Group Organometallic Chemistry

Classes of Organometallic Compounds, Stability of Organometallic Compounds, Main Group Metal-Carbon Bond Formation, Organolithium Compounds and their application, Organosodium and potassium compounds and their application, Organoberyllium Compounds, Organomagnesium Compounds and Grignard Reagent, Organo alkaline earth metal compounds, Organoboron Compounds, Organo Aluminum Compunds, Organo Silicon Compunds, Organotin Compunds etc.

CY7140 3
Fundamentals and Applications of Small Molecule X-ray Crystallography

Introduction of Crystallographic programs such as SHELXTL, JANA, FullProf, Olex2, Diamond, Crystal Maker etc.; Crystallographic Symmetry, Derivation of Point Groups, Laue Groups, Plane and Space Groups, Miller Indices, Crystallographic Directions, Crystal Lattices, Reciprocal Lattices, and Systematic Absences;Fundamentals of X-ray, Neutron Diffraction, Electron Diffraction, and Elements of Electron Microscopy: Scattering by Electrons, Atoms, and Unit Cells, Atomic Form Factors, Structure Factors, and Extinction Rules;Data Collection and Processing Strategies, Types of Detectors, and X-ray Sources;Phase Problem in Crystallography, Patterson, and Direct Methods; Refinement of Crystal Structures, Correction Factors such as Temperature Factor, Absorption Factor, Multiplicity Factor, and Lorentz Polarization Factor.; Crystal Structure Description of Important Molecular and Inorganic Structures, Bonding, etc.

CY7150 3
Functional Inorganic Solids for Energy Applications

Bonding in Solids and Electronic Properties (electronic band structure, Linear Combination of Atomic Orbitals Approach).
Descriptive Crystal Chemistry (Structure of solids, homologue series, intergrowth structures, defects and non-stoichiometry).
Ionic, Covalent, and Metallic Bonding, Pauling's Three Rules for Predicting New Structures, Electronegativity, Hybridization, and Bond Valence Concept.
Translational symmetry, Bravais lattices, and Basic Concepts of Diffractions (X-ray and Neutron).
Crystals Chemistry of Superconductors: Intermetallic Superconductors, Cuprate Superconductors, Chevral Phases, Magnesium Diboride, and Iron based Pnictide Superconductors.
Basic Concepts of Superconductivity: Critical Temperature, Cooper-pair wavefunction, types of Superconductors, Meissner Effect, Flux-Quantization, Coherence Length, The Josephson Effects, Isotope Effect, Critical Current, and Critical Magnetic Fields.
Fundamentals of Thermoelectric Materials: Electrical Resistance, Thermal Conductivity, Thermopower (Seebeck Coefficient), and Thermoelectric Figure of Merit.

Classes of Inorganic Structures with Potential Thermometric Properties: Zintl Phases (role of hypervalent bonding in thermal conductivity), Clathrate structures, and Metal Chalcogenides of Heavy Metals (chalcogen-chalcogen bonding).
Structural Requirements for the Design of New Thermoelectric materials: Type of elements, Anion-Anion bonding, Superstructures, Role of Defect Chemistry for achieving Low Thermal Conductivity, and High Density of States.

CY7220 3
Chemical and Electrochemical Energy Systems

Brief overview of Electrochemical Techniques and their application to Real Systems, Electrochemical Cells: Batteries, Supercapacitors, Fuel Cells, Solid Electrolytes and Photoelectrochemical Cells (Dye Sensitized Solar Cells, Quantum Dots solar cells, Water Splitting), Perovskite Solar Cells, Photocatalysis, steam reforming, petroleum refining, coal reforming, hydrogen production, decomposition of N2O, dry reforming.

CY7230 3
Nanochemistry and Applications

Introduction to Nanoscience: classification of nanomaterials - zero dimensional , one dimensional nanostructures - nanowires and nanorods, two dimensional nanostructures - films, nanotubes and biopolymers, three dimensional nanostructures - fullerenes and dendrimers, quantum dots and their properties, synthesis and application of nanomaterials-dye-sensitized solar cells, photocatalysis etc, basic instrumentation and imaging techniques. Intermolecular Interactions, Principles of self-assembly, supramolecular chemistry, soft lithography, nano/micro-contact printing-stamps and tips, layer by layer assembly, meso-structures from soft building blocks, nanocrystals-synthesis and self-assembly, templating methods, photonic crystals, nanorods-, nanotubes-, nanowires- self-assembly.

CY7240 3
Batteries

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; Selection and Application of Batteries for UPS, Solar, Telecom, Aerospace, Grid and Electric Vehicle Systems.

CY7250 3
Molecular Modeling of Complex Chemical Systems

Ab initio methods, Empirical force fields, Molecular dynamics techniques, Concepts, Algorithms, and Tools to perform and analyze molecular simulations, Trajectory Ananlysis, Visualization, Project component based on lectures

CY7260 3
Principles of Mass Spectrometry and Its Applications

Basic concept: quasi-equilibrium theory (QET), ionization energy - concept and measurement, ionization efficiency and cross section, internal energy of ions, rate constants from QET, isotope effects and calculation of isotopic distributions.
Ion source and ionization methods: electron impact ionization (EI), chemical ionization (CI), field ionization (FI), photo ionization (PI), fast atom bombardment (FAB), secondary ion mass spectrometry (SIMS), field desorption (FD), plasma desorption (PD), laser desorption (LD and MALDI), and electrospray ionization (ESI).
Analyzer and detector: quadrupole, ion trap, orbit trap, time-of-flight instruments, discrete dynode electron multipliers, channel electron multipliers, microchannel plates and conversion dynode.
Other techniques: chromatography coupled (GC-MS and LC-MS), tandem mass spectrometry, FT-ion cyclotron resonance, etc.
Application: analysis of biomolecules, proteins, peptides, lipids, oligonucleotides, oligosaccharides and mass spectrometry of aerosols

CY7270 3
Advanced Molecular Spectroscopy

Absorption and emission of radiation, fluorescence, phosphorescence, Einstein's coefficients, transition moment integral, time-dependent perturbation theory, types of transitions and selection rules, energy levels, electronic transitions and spectral broadening. Hund's coupling cases, Franck-Condon principle, Herzberg-Teller vibronic coupling, Renner-Teller and Jahn-Teller effects, population inversion, frequency and spatial properties of laser radiation, continuous wave lasers, Q-switching and mode locking, generation of short pulses and harmonic generation. He-Ne, rare-gas ion, CO2 and excimer, Nd:YAG, dye laser systems, Ti:sapphire laser systems, semiconductor diode lasers, non-linear crystal and OPO/OPA lasers. Laser spectroscopy: cavity ring-down spectroscopy, laser induced fluorescence, multiphoton absorption and ionization spectroscopy, photoelectron spectroscopy, double resonance spectroscopy, stimulated emission pumping spectroscopy, two dimensional (2D) fluorescence, 2D-IR spectroscopy and rotational coherence spectroscopy.

CY7410 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.

CY7990 3
Chemical Handling and Safe Laboratory Practices

Risk assessments in the chemistry laboratory. SDS, MSDS. Regulations that govern chemist's activities. Guidelines for use of compressed gases and cryogenic materials. Demonstration and usage of protective equipment available for chemical exposure. Respond to laboratory accidents, such as spills, fires, and cuts, and clean up a mercury spill. Recognize fire hazards and put out a fire using an ABC fire extinguisher. Radiological safety, including biosafety levels, management of solid and liquid wastes, lasers, and radionuclides. Chemical hazard classes and administrative guidelines to work safely in a laboratory environment. Proper storage and disposal of chemicals.

CY7995 3
Data Analysis in Inorganic Chemistry

Introduction to the data interpretation in FT-IR, NMR, ESR, CD, TGA, DSC, UV-vis, GC-MS and single crystal X-ray diffraction techniques. Hands on training to software and data analysis.

CY7998 3
Scientific Writing in Chemical Research

Research Methodology : The Role of Paradigms in Scientific research , Art of Scientific Story telling , Various genre of scientific writting and their components , Basics Guidelines for Maniscruipt Preparation , Writting an abstract (MMRC) , Pedagogy for Academic Writting : Mind Mapping Technique as a tool , Mind Mapping for Litrature Review , Basics of covering letter for persuading Editorial Board and peer reviewers for various scientific writtings.

CY8938 3
Modern Molecular Simulation Methods

Molecular dynamics and Monte Carlo methods, Coarse-graining and multiscale methods, Free energy algorithms, Advanced sampling strategies, Rare events algorithms, Algorithms for computing thermodynamic and kinetic behavior, Modern analysis techniques and visualization packages, Coding languages, Mathematical software, Project component based on lectures

CY8998 3
Applications of 3d Printing in Chemistry

3D printing, Basics of 3D-printing technologies currently available, Process of additive manufacturing (3D-printing, Up-to-date usage of 3D-printing for chemistry applications, Organs on chips, 3D bioprinting.

CY8999 3
Principles of Single Crystal X-ray Diffraction

This course offers the practical aspects of crystal structure determination from data collection strategies to data reduction along with basic and advanced refinement problems of organic and inorganic molecules. Single crystal X-ray diffraction-single crystal X-ray diffraction techniques-crystal growth-crystal handling-crystal mounting-goniometer-crystal systems-space group-data collection-absorption correction-data reduction-structure determination-refinement-atom labeling-CIF file analysis-structural alerts-structural plots-structural disorder-twin crystals.

16.7 Department of Design

CA1024 1
Action Drawing

The body as tool and the surface as canvas. Explorations and experiments with the body and its interaction with the surface. Drawing as an action intensive act. Theatre, performance, art.

DS1014 **1** Let's Make a Graphic Novel	The course aims to provide exposure to making and constructing visual narratives. Concept, plot, story-telling, visualizing and building of a character will be conveyed through hands-on exercises.
DS3014 **1** Immersion, Movement Art, Technology	A creative exploration of space, object and some technological component.
DS3016 **2** Environmental Installations and Performances	This course shall expose students to the practice of putting forth and exhibiting poetic installations in public/community space. The course touches upon aspects of public art, creative writing, display typography, exhibition design and layout.
DS3017 **1** Digital Heritage	This course deals with fully practice based learning, Digital imaging and techniques for digital heritage conservation, History of the location, Photography, Approaches in documentation and imaging, Creating Photo stories, Introduction to 3-D laser scanning.
DS3024 **2** Principles of Animation and Moving Images	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. Pixilation.
DS3033 **1** Creative Product Design	This course deals with Design philosophy, Products, Product Design Process. Morphology of Design, Phases in Design cycle, Identification of needs-Techniques-User interviews, questionnaires, Group feedback, conceptual design - idea generation creative methods, Lateral thinking, Brainstorming exercise, Design by analogy methods, Innovation in Design, detail design, idea generation - brainstorming, analogical reasoning, Theory of Inventive problem solving (TRIZ), Design for manufacturing and Assembly (DFMA), Failure Modes Effects Analysis, Product Planning and Marketing.
DS3043 **1** Film Appreciation	This course intends to practically help participants to read a film beyond its on-screen meaning to understand its creative structure through the intentions of its makers and their effort. The course will give them a first-hand introduction on cinematic elements such as narrative, mise-en-scene, editing, cinematography and sound to help them understand how their sum contributes to the whole experience.
DS3053 **2** Visual Communication and Digital Imaging	This course deals with visual communication photography and design practice, Graphic Design, Studio Photography, Printing and Digital Processing, Idea of an Image, Creation of Photo book, Understanding of a Visual Narrative, Photography/Sketching, basics of visual design, Research (Visual and Historical), Story-telling (Script and Story Board), Product (Book making, Slideshows, Exhibitions).
DS3062 **2** Built-environment/ Urban Space Design	This course aims to provide a hands-on experience in designing a built-environment. The intent is to introduce the course participants to various aspects associated with built form: site, context, conceptualization, behavior, spatial scales, planning and construction. Conceptualizing Space - Early stage conceptualization for a real site, reading and interpreting space through drawing, diagrams, photographs/images and proposing interpretations that could be built. Planning - Schemes and strategies for constructing and executing the proposed design. Scale models and testing. Construction - Executing the planned design on a real site.
DS3064 **2** Drawing: Taxanomy Understanding and Exploration	The course looks at intervention through design drawing tools, getting to undderstand observations and conveying through drawings in a systematic way.
DS3072 **1** Special Topics On Design	Each semester and expert practitioner from the field will offer a course in design. The content of the course will depend on the expertise of the expert who is coming for the teaching in consultation with the design department. The subject expert will be from the area of Visual Design.
DS3082 **1** Word and Image	This course deals with creative thinking process of association of words and images, Elements of 2D form and logo design, Semiotics, semantics and visual culture, Building a narrative and creating meaning for images, Visual pun, Principles of advertising. Composition.
DS4013 **2**	The course intends to deliver skills of visualization and design delivery for the need of

Automobile Design Explorations		mobility. Utilizing core subject knowledge competence with creative blend for automobile design and development of mobility solutions across personal to mass transportation. Elements of engineering, anthropometry, ergonomics, alternative energy systems, materials and styling would be used to amalgamate and come up with innovative ideas to address complex requirements. The course embraces the design and development process by user research, scenario study, applying new materials, utilizing cutting edge technologies to address the changing paradigm. Explorations and design process would be emphasized to come up with fresh ideas in initial stage. Further student would move to solve comfort, functional, safety and technical requirements and refine the design in physical and digital mediums for a final design solution. It is a challenging process to achieve good design and would require in-depth attention towards development of form, function and innovation for achieving future-ready rewarding mobility solutions. Lectures would be supported by hands-on exercises, field study, research and model making.
DS4023 Calligraphy	**1**	The course intends to deliver calligraphy as a quick but effective art form to express by words or art. It helps students, in writing skillfully by careful attention to shape, figure, strokes and structure of letters and learning its techniques with fineness. Learn to sync drawing movement by fingers while balancing the coherence of the typeface. Learn to draw using artistic inspirations, free but controlled flow and the rhythm which creates the sense of exotic lyricism in the text and art form.
DS4033 Life Cycle Analysis	**1**	Like a living entity; every manufactured entity has various life-stages. It starts with the collection of raw materials or ingredients, processing / manufacturing, use, maintenance and after-life disposal. The LCA devises quantitative analysis of environmental impact, defragments all life stages, calculates embodied energy, analyzes impact on ecosystem of particular product / service / system in its entirety. It encompasses a holistic view of the chosen entity from sourcing to decomposition and all intermediate stages. LCA offers insights of the phases and interpretations of it provide feedback loop for the improvement. The course intends to deliver understanding of LCA and capacity to implement it for a given product / service / system. The course intends to undertake real life case studies for LCA. The areas could be based on student's background and interest such as buildings, industrial products, 3D printers, building materials (cement, concrete, bricks, steel, rubble, etc.), metals, civic waste, sewage, solid waste, landfills, electronic materials and components, semiconductors, chemicals (pharmaceutical, drug, dyes, lead, mercury, high toxicity compounds, heavy metals), medical waste, tannery, distillery, paper and pulp, food waste, bye-products, pollutants, VOCs, fertilizers, GHGs, SOx, NOx, Coal, hydrocarbons, etc., with biotic and abiotic resources.
DS5013 Elements of Visual Design	**3**	Form explorations, Color, Composition, Drawing, Design language, Artistic expressions, Design and Society
DS5020 Evolution of Visual Design	**3**	History of Art, History of Design, Semiotics, Aesthetics, Material culture, theoretical approach to image making and contemporary concerns and communication studies
DS5030 Design Methods	**3**	Morphology of Design process, stages in design process– user studies, conceptual design, Embodiment, detailing, functional innovation and creative methods
DS5103 Graphic Design	**3**	Illustration, typography, printing technology, packaging
DS5153 Information and Experience Design	**3**	Information design, user-experience design, data visualization, Human-Computer interaction, usability, visual ergonomics
DS5173 Digital Imaging and Photography	**3**	Analog photography, historic practices, digital photography, tools, techniques, Contemparory photographic practices, GIS
DS5183 Film Making	**3**	Understanding cinematic language and practicing it through making a film.

DS5193 **3**
Typography
The course deals with understanding character of fonts in detail to create new fonts for a variety of media and in different languages and its application in a variety of media.

DS5204 **3**
Form Explorations
To explore the three-dimensional physicality of a certain idea through materials and techniques of production

DS5205 **3**
Project II
This independent project in the second sem is oriented towards encouraging the student to design and make a product

DS5213 **3**
Semiotics
This course intends to sensitise the students to the fact that our environment is composed of signs and signals of various kinds which we process and interact with. The exercises are printed towards creative sign-making

DS5225 **3**
Project 1
Independent project that encourages the student to make an artefact based on the methods and materials explored in the first semester coursework involving film-making, photography and form exploration.

DS6013 **3**
Moving Images
Film language, elements of video, multimedia and animation, sound, editing, narrative theory, script writing, story telling

DS6033 **3**
Word and Image
A visual and philosophic grasp of the complex interconnections and relationships between the sound, physical form and mental image of an idea.

DS6050 **3**
Design for Education
The course looks at intervention through design tools, thinking and pedagogical methods to improve education. Creating innovative methods to make education fun for all. Analogue and digital methods are explored.

DS6076 **3**
Design Research Seminar
The course foucses 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.

DS6095 **3**
Project 3
Independent project oriented towards a complex product or artefact.

DS6115 **12**
Thesis
Independent project which invovles meta-level system design component.

DS6116 **3**
Dissertation
To examine and reflect on any dimension of design closely through seminars and essays.

DS7010 **3**
Design Research
Introduction to Design Research Methodology, Research Clarification, Descriptive Study I, Prescptive Study, Descriptive study II. Theories and Models in Design, Proto theory, FBS and other models.

DS7024 **3**
Research Project 1
The Project primarily focuses on the research methods and techniques applied to design domains.

DS7050 **3**
Research Methodologies
Research Methodologies, qualitative and quantitative approach. Statistical techniques for design research.

16.8 Department of Electrical Engineering

EE5110 **3**
Semiconductor Device Modeling
Lattice structure, Band diagram and transport phenomenon of Semiconductor, Physics of Schottky, homo- and hetero-junction junctions semiconductor, Compact modelling of P-N diode, BJT and HBT, MOS Capacitance, MOS transistors and its modelling, Introduction on SOI and SiGe, Layout and Parasitics.

EE5120 **3**
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
EE5127	**2**	Review of CMOS Process Device Modelling, CMOS Amplifier Basics, Current and Voltage Sources, CMOS Operational Amplifiers, Noise in MOS Circuits, Data Conversion Circuits, Switched Capacitor Techniques, Continuous Time Filters, Clock Generation for Mixed Signal System ICs
Analog IC Design		
EE5128	**1**	See EE5127, Analog IC Design
Analog IC Design Lab		
EE5139	**2**	Part-1: Introduction to PMIC, Motivation, Linear Regulators, Switching Regulators. Part-2: Different analog linear regulator architectures, analysis, design, layout. Digitally controlled regulator architectures, analysis, design, layout and testing. Part-3: Different switching regulator architectures (Current mode, Voltage mode, and Hysteretic, analysis, design, layout. Part-4: MIMO regulators, battery chargers. Part-5: Design of pA load DC-DC converters.
Power Management Integrated Circuit Design		
EE5147	**2**	Basic of Digital Design: Introduction to digital system, Synchronous and asynchronous system design, Finite State Machine with case studies, ASIC Design: Introduction to RTL (HDL) coding, Test bench writing, Combinational and Sequential circuit using HDL with examples., Methodology for Digital Design: Synthesis, Timing analysis and verification, Introduction to Physical design, Computer Arithmetic for data path design: Fast adders, multipliers, dividers. CORDIC, Basic of DSP and Digital Communication systems architecture.
Digital IC Design		
EE5148	**1**	See EE5147, Digital IC Design
Digital IC Design Lab		
EE5155	**1**	Basic semiconductor properties, semiconductor materials - heterojunctions, quantum wells, quantum dots, optical processes in semiconductors, selection rules, fundamentals of LEDs, semiconductor diode lasers, single/multijunction solar cells and photodetectors.
Semiconductor Optoelectronics		
▷EE1140, EE2180, Elementary Quantum Mechanics		
EE5167	**2**	Processors: ISA, Pipelining and Hazards, Optimisations. RISC-V and ARM architectures. Memory: Hierarchy, Cache, Virtual Memory. System and peripheral buses. AMBA and AXI. Peripherals: I/O, Interrupts, JTAG. Sensors: characteristics, useful circuits, PID control basics. Operating Systems: RTOSes, Monolithic and Microkernels. Task scheduling: algorithms and resource sharing.
Embedded System Hardware and Design		
EE5168	**1**	Overview of Verilog. Overview of PICORV32. Implementation of simple custom extensions and co-processors.
Embedded Systems: Hardware Languages		
EE5170	**3**	• Device physics for thin-film transistors • Thin film transistors structures and performance • Poly-Si TFTs: Technology, performance, and architecture • Amorphous Si-TFTs: technology, performance, and architecture • Organic TFTs: Materials, fabrication, architecture, performance, and instability factors. • Amorphous metal oxide TFTs: Materials, fabrication processes, characteristics, architecture and performance. • TFTs on flexible substrates.
Thin-film Transistors		
EE5191	**1**	Wave optics, scalar diffraction theory, Fresnel and Fraunhofer diffraction, types of holograms, numerical reconstruction, recording of digital holograms with image sensors, applications of digital holography in microscopy.
Digital Holography		

EE5200 **3**
Steady State Power System

Steady- state Modeling of the Power Network: Understanding the basic architecture of a transmission network, three-phase modeling of the different elements of a transmission network, formation of three-phase impedance and admittance matrices, review of the theory of sequence transformation, equivalent single-phase representation of the transmission network. Performance Analysis of an AC Transmission Line: Voltage and current profiles over a transmission line, loadability, shunt compensation, series compensation. Power System Load Flow Analysis: Numerical methods for solving non-linear algebraic equations, reference concepts in the context of power flow analysis, load modeling, lumped slack power flow analysis,
distributed slack power flow analysis, linearized representation of system's loss characteristics, DC power flow analysis, loss-compensated DC power flow analysis and the concept of power flow accuracy, three-phase load flow analysis, introduction to the optimal power flow analysis. Unit Commitment: Principle of unit commitment, constraining factors of unit commitment, a brief overview of different methods for solving unit commitment problem. Power System Short Circuit Analysis: Thevenin's equivalent of the power network, balanced short circuit analysis, unbalanced short circuit analysis. Power System State Estimation: Review of basic statistics, philosophy of state estimation, least square based method for power system state estimation, constrained state estimation, bad data detection, introduction to network observability analysis, introduction to network topology processor. Modeling and Analysis of Distribution Network: Understanding the basic architecture of a distribution network, modeling of the different components of a distribution network, distribution system power flow analysis, distribution system fault analysis.

EE5207 **1**
Steady State Modelling of Power Systems

Modeling of synchronous generators, transformer modeling, transmission line modeling, modeling of shunt elements, load modeling, modeling of single phase and three phase power systems, symmetrical components

EE5210 **3**
Power Converter Design

Characteristics of power electronic switches, Drive circuits, AC to DC rectifiers (single phase/three phase), analysis and performance with passive loads, Basics of DC-DC converters, Basic principles of cycloconverter (AC to AC Conversions) operation, DC/AC inverters (single phase and three phases) and PWM Control techniques.

EE5217 **2**
Computer Aided Power System Analysis

Numerical methods for solving system of nonlinear equations, Single phase and three phase power flow analysis, short circuit analysis, Analysis of distribution systems

EE5220 **3**
Advanced Control Systems

Introduction to Multivariable systems, Why Multivariable systems are important?, Interaction dynamics and its role on control system, design, Multivariable control-classical approaches, Structure, selection - variable pairing, tuning single loop controllers for MIMO, systems, Transmission zeros and transmission zero direction, Advanced control approach, State space representation, Conversion from SS to/from TF, Controllability, Observability, State transfer problem, solution to state transfer problem, pole placement controller design, Design of observer, Kalman filter design, Model (observer) based predictive controllers, LQR/LQG, various MPC schemes.

EE5221 **2**
Advanced Control Lab

Design and implementation of advanced control strategies on experimental systems: i) Twin Rotor MIMO system, ii) 2dof robotic manipulator, iii) Ball balancer system.

EE5227 **1**
Basics of Power Electronic Converters

Characteristics of power electronic switches, Drive circuits, AC to DC rectifiers (single phase/three phase), analysis and performance with passive loads, Basics of DC-DC

EE5230 **3**
Power System Dynamics and Control

A brief introduction to nonlinear dynamics, Numerical methods for solving differential equation, dynamic modeling of power system components, simulation of power system dynamics, power system stabilizer design, direct methods for transient stability assessment, sub-synchronous resonance, introduction to voltage stability, introduction to electro-magnetic transient simulation

EE5237 **2**
Analysis and Design of Power Electronic Converters

Characteristics of power electronic switches, Drive circuits, AC to DC rectifiers (single phase/three phase), analysis and performance with passive loads, Basics of DC-DC converters, Basic principles of cycloconverter (AC to AC Conversions) operation, DC/AC inverters (single phase and three phases) and PWM Control techniques.

EE5240 **3**
Electrical Machines and

Basic principles of electric machines, magnetically coupled circuits, machine windings and air-gap MMF, Winding inductances and voltage equations, DC machines - Theory of

Analysis Control		DC machines, voltage and torque equation (DC Machine) in machine variables and Block diagrams . Reference Frame theory - equations of transformation, commonly used reference frames, transformation between reference frames, transformation of a balanced set. Induction machine Voltage and torque equation in machine variables, arbitrary reference frame equivalent circuits, voltage and torque equations in arbitrary reference frame variables, dynamic performance of induction motor, Vector control of induction motor. Synchronous machine - Voltage and torque equations in machine variables, equivalent circuits of 3-phase synchronous machine in arbitrary reference frames.
EE5247 Dynamics of Power System Components	**2**	State-space modeling of a dynamical system, equilibrium analysis, d-q transformation, generator dynamics, excitation control system, speed control system, load dynamic, network dynamics, OLTC dynamics
EE5257 Power System Stability Analysis	**1**	Simulation of power system dynamics, model reduction, classification of power system instability phenomena, power system stabilizer design, overview of energy function method for the transient stability assessment, introduction to the SSR problem
EE5267 Analysis of DC Machines and Reference Frame Theory	**1**	Basic principles of electric machines, magnetically coupled circuits, machine windings and air-gap MMF, Winding inductances and voltage equations, DC machines - Theory of DC machines, voltage and torque equation (DC Machine) in machine variables and Block diagrams . Reference Frame theory - equations of transformation, commonly used reference frames, transformation between reference frames, transformation of a balanced set. Induction machine Voltage and torque equation in machine variables, arbitrary reference frame equivalent circuits, voltage and torque equations in arbitrary reference frame variables, dynamic performance of induction motor, Vector control of induction motor. Synchronous machine - Voltage and torque equations in machine variables, equivalent circuits of 3-phase synchronous machine in arbitrary reference frames.
EE5277 Analysis of AC Machines	**2**	Basic principles of electric machines, magnetically coupled circuits, machine windings and air-gap MMF, Winding inductances and voltage equations, DC machines - Theory of DC machines, voltage and torque equation (DC Machine) in machine variables and Block diagrams . Reference Frame theory - equations of transformation, commonly used reference frames, transformation between reference frames, transformation of a balanced set. Induction machine Voltage and torque equation in machine variables, arbitrary reference frame equivalent circuits, voltage and torque equations in arbitrary reference frame variables, dynamic performance of induction motor, Vector control of induction motor. Synchronous machine - Voltage and torque equations in machine variables, equivalent circuits of 3-phase synchronous machine in arbitrary reference frames.
EE5287 Basics of Power System Protection	**1**	Various scientific disciplines requiring image analysis: medical fields including ophthalmology and radiology, surveillance and navigation, biological sciences including live cell/tissue dynamics, and so on; unique image analysis challenges arising in various fields; basic image analysis tools such as histogram, contrast enhancement, edge and other feature detection, elementary segmentation, wavelet analysis, basic morphological processing; strategies towards tackling practical challenges: case studies.
EE5297 Advanced Power System Protection	**2**	Numerical Relaying: An Introduction, Sampling Theorem, Algorithms for Phasor Estimation-II; Current and Voltage Transformers: Introduction to CT, CT Saturation and DC Offset current, Introduction to VT, performance issues of current and voltage transformers Digital protection schemes for transmission lines, generators, and transformers: Overcurrent protection, Directional overcurrent protection, Distance protection, Differential protection, Out-of-Step protection. Additional topics of protection: Adaptive relaying, integrated substation protection and control, new relaying principles based on AI techniques, ANN approach and Fuzzy logic (FL) methods for fault detection and fault location, wide area monitoring, protection and control systems
EE5300 Digital Signal Processing	**3**	Review of LTI systems and their properties, Convolution sum, Sampling of continuous-time signals, Discrete-time Fourier transform (DTFT) and its properties, Sampling in frequency domain, Discrete Fourier transform (DFT) and its properties, Z-transform and its inverse, region of convergence, pole-zero locations and frequency response, stability analysis, implementation of discrete-time systems, design of FIR filters and IIR filters, linear phase filters, group delay, response of first and second order filters, Computational issues in DFT, FFT algorithm, Applications of DSP.
EE5307 Complex Analysis in Electrical Engineering	**1**	Properties of Analytic functions, Cauchy's integral formula, applications in Fourier, Laplace, Z transforms and probability theory.

EE5310 **3**
Probability and Random 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.

EE5317 **1**
Optimization

Convex functions, Linear Programming, Semi-Definite Programming, Karush–Kuhn–Tucker conditions, Solvers, Applications in Research.

EE5320 **3**
Digital Communications

Basebad Digital Transmission:PAM, PWM, PPM,PCM,DM. Digital Transmission: BPSK, QPSK, QAM, BER Analysis, Performance in Rayleigh, Rician and Nakagami Fading

EE5328 **1**
Introduction to Submodular Functions

Definition, examples and properties; modeling discrete optimization problems using submodular functions; Lovasz extension and minimization, discrete and randomized algorithms for maximization; selected applications among machine learning (active/semi supervised learning, feature selection, regularization using structured sparsity, clustering), inference and learning for graphical models, circuit design and network analysis, social networks and computer vision.

EE5330 **3**
Information Theory and Coding

Measures of information: Entropy, mutual information, differential entropy, Kullback Leibler distance, role of convexity, information inequalities, Source coding without loss: prefix codes, Kraft's inequality, Shannon, Huffman, arithmetic coding, Channel coding: Hamming codes, concept of Reed Solomon codes, convolution codes, turbo codes and LDPC codes, Method of types: universal source coding, Lempel-Ziv Coding, Lossy source coding: rate distortion theory via type-covering, Rate-distortion functions for the binary hamming and the Gaussian, mean-squared error problems, Channel coding: Shannon capacity via sphere-packing, Capacity of binary symmetric and Gaussian channels, Rate allocation in Gaussian source and channel coding: Reverse waterfilling and waterfilling, Application to signal compression and wireless communication.

EE5340 **3**
Detection and Estimation

Elements of hypothesis testing: Bayesian, minimax, Neyman-Pearson, composite; Gaussian hypothesis testing; Discrete-time signal detection: models and detector structures, performance evaluation - direct computation, Chernoff and related (large-deviation) bounds, asymptotic relative efficiency, sequential detection, nonparametric and robust detection; Parameter estimation: Bayesian, nonrandom,

		maximum likelihood; Signal estimation: Kalman-Bucy filtering, linear estimation, Wiener-Kolmogorov filtering; Continuous-time signal detection: Grenander's theorem and Karhunen-Loéve expansion, detection of deterministic signals in Gaussian noise, detection of random signals in Gaussian noise, estimator-correlator representation; Continuous-time signal estimation: Linear innovation process, continuous-time Kalman-Bucy filter, Optimum nonlinear filtering, practical approximations; Application to communication systems: DSB-AM, DSB-SC, SSB-SC.
EE5342	**1**	Binary Detection Rule single observation, Maximum likelihood, Neyman-Pearson, Minimum Probability of Error, Bayes Risk, Min-max, Multiple observations, M-ary Detection rule, Composite and non-Parametric detection Theory
Detection Theory		
EE5343	**1**	Fundamentals of Estimation, Maximum likelihood, Bayes Cost, Relationship of Estimators, Linear minimum variance and Least Squares, Estimation with Gaussian Noise, Properties of Estimators, State Estimation, Kalman Filter.
Estimation Theory		
EE5350	**3**	This course deals with the design, structure and decoding of Linear Block Codes, G Fields, Cyclic Codes, BCH, Convolution Codes, TCM, TURBO and LDPC codes.
Error Correcting Codes		
EE5360	**3**	Various scientific disciplines requiring image analysis: medical fields including ophthalmology and radiology, surveillance and navigation, biological sciences including live cell/tissue dynamics, and so on; unique image analysis challenges arising in various fields; basic image analysis tools such as histogram, contrast enhancement, edge and other feature detection, elementary segmentation, wavelet analysis, basic morphological processing; strategies towards tackling practical challenges: case studies.
Practical Challenges in Image Analysis		
EE5366	**1**	Introduction to Wireless Systems. (0.5 hours), Wireless Channel Model, Review principles of digital communications, Single user point-to-point fading channel detection, Multi-access schemes, Capacity of point-to-point Wireless Channels.
Fundamentals Wireless Communications		
EE5368	**2**	ISI and need for equalization in wireless channels, Review of capacity of point-to-point channels, Coding for Wireless channels, Adaptive Modulation and coding
Advanced Wireless Communications		
EE5370	**1**	Unsupervised learning - clustering, latent variable models, supervised learning - classification, regression, multilayer perceptrons
Introduction to Machine Learning		
EE5410	**3**	Why Nonlinear Control?; Phase plane analysis; Fundamentals of Lyapunov Theory; Advanced stability theory; Describing Function analysis; Feedback Linearization; Sliding Control; Adaptive control
Nonlinear Control Theory		
EE5440	**1**	Introduction to Multivariable systems, Why Multivariable systems are important?, Interaction dynamics and its role on control system design, Multivariable control - classical approaches, Structure selection - variable pairing, Tuning single loop controllers for MIMO systems, Transmission zeros and transmission zero direction
Classical Control Techniques for Mimo Systems		
EE5450	**2**	Introduction to advanced control approaches, State space representation, Conversion from SS to/from TF, Controllability, Observability, State transfer problem, Solution to state transfer problem, Pole placement controller design, Design of observer, Kalman filter design, Model (observer) based predictive controllers, LQR/LQG, various MPC schemes.
State Feedback Control		
EE5460	**2**	Why Nonlinear Control?; Phase plane analysis; Fundamentals of Lyapunov Theory; Advanced stability theory; Describing Function analysis; Input-output stability; Notion of passivity;
Analysis of Nonlinear Systems		
EE5470	**1**	Feedback Linearization;
Nonlinear Control Techniques		
EE5480	**1**	Pontryagin's Principle; Linear Quadratic Regulator; Time Optimal Control; Fuel Optimal Control
Optimal Control		
EE5490	**2**	Why robust control? What is robust control: Problem definition; Youla parameterization; H-infinity control.
Robust Control Techniques		

EE5600 Introduction to AI and ML	**1**	Classification and regression using linear and nonlinear models, Bayes decision theory, risk minimization, multilayer perceptron and support vector machines (SVM).
EE5601 Representation Learning	**1**	Clustering and latent variable models, auto-encoders, energy based models, manifold learning, and deep networks.
EE5602 Probabilistic Graphical Models	**1**	Bayesian networks, undirected graphical models and their temporal extensions, exact and approximate inference methods, parameter estimation.
EE5603 Concentration Inequalities	**1**	Markov inequality, Chebyshev inequality, Jensen's inequality, Han's inequality, Hoeffding's inequality, Bernstein's inequality, Stein's inequality
EE5604 Introduction to Statistical Learning Theory	**1**	Consistency, uniform laws of large numbers, VC dimension, entropy integrals, Rademacher complexity, statistical consequences
EE5605 Kernel Methods	**1**	Reproducing kernel Hilbert spaces (RKHS), Fourier properties and analysis, randomized and low-rank approximations
EE5606 Convex Optimisation	**2**	Convex sets and functions (definitions, operations preserving convexity, separating and supporting hyperplane theorems, Jensen's inequality, epigraphs, quasi convexity and other properties), convex optimisation (subtypes: LP, QP, QCQP, SOCP, SDP, Geometric programs: definitions and properties; transformation techniques; using CVX), KKT conditions and duality, interpretation of dual variables, gradient descent, convex relaxation and examples.
EE5607 ML – Hardware Implementation	**1**	0. Overview of the ML Hardware implementation 1. ML Hardware on FPGA - theory, and practice 2. High-Level Synthesis - will help non-VLSI guys to get the RTL using theseapproaches. 3. Hardware-software co-design 4. ChaiDNN demo - practical approach: Here people will learn how to dump their codes from Caffe platform to the FPGA boards. They will have the prerequisite of hw-sw co-design already by that time. Here, theflow from caffe to ChaiDNN will be demonstrated by considering a small example and demonstrate the outcomes, resource consumption etc.. This session may last for 1- 1.5 hours. It will be followed by a Practical Session. This may take another 1.5 hours. So total duration of this session will be tentatively 3 hours. 5. Network On Chip and GPU based designs of ML Hardware- Duration will be tentatively for 3 hours. First 1.5 to 2 hours on NOC and rest on GPU. This may include the state of the ML hardware - literature review and their brief description. Bit of research insights will also be provided 6. Case Studies – Indigenously designed and developed hardware designs of our recently proposed Rehab-NET, Amputee-NET and RIM-NET: Rehab-NET - Its hardware implementation using the Modified Distributed Arithmetic (MDA) approach will be presented. Reference: Our IEEE ECCTD paper. Amputee-NET - Its hardware design will be presented with a bit of description of the algorithm and its novelty. RIM-NET – Its GPU (Jetson TX2) based implementation will be presented and novelty will be explained. 7. DNN and Hardware Compression technique for the Deep Net
EE5608 Sequence Modelling	**1**	Markov models, Hidden Markov models, Kalman filters, Linear Dynamical Systems, Recurrent and Recursive Neural Networks (RNNs), LSTMs, BLSTMs, Sequence-to-Sequence learning
EE5609 Matrix Theory	**3**	1. Modeling using matrices: Basic examples, graph theory (adjacency/Laplacian), probability and statistics (Covariance matrices, Markov matrices), signal processing (Fourier matrices, convolution/filtering), communication (Linear codes, MIMO, STBC), machine learning (clustering, dimensionality reduction), basic linear dynamical systems etc 2. Row/column spaces and rank, basic matrix operations (multiplication, transpose, determinant, trace, inverse, etc), matrix types, rank-nullity, underdetermined/overdetermined systems of linear equations, block matrices 3. Matrix decompositions - eigenvalues, SVD and applications like PCA, LU and Cholesky decomposition, QR and Schur decomposition, non-negative matrix factorization, Quadratic forms 4. More on determinants - its algebraic properties, how to compute determinants 5. Characteristic polynomial and its properties 6. Solving Ax=b, least

squares and its many variants, min norm solutions for underdetermined systems of linear equations, other optimization problems framed using matrices; pseudo inverse, matrix norms 7. Special matrices: Toeplitz, Circulant, Fourier etc. 8. Generalized eigenvectors and Jordan form 9. Solutions to systems of ordinary differential equations, matrix exponent 10. Numerical issues and common matrix algorithms, linear algebra in MATLAB/python 11. Intro to random matrices and context in which they are useful.

EE5611 2
Machine Learning Applications for Wireless Communications
▷EE5600, EE5320 or EE3320, EE6337 or equivalent

Introduction to Machine Learning, Supervised, Unsupervised learning, Online learning techniques including Reinforcement learning techniques such as Q-Learning, Post Decision State Learning, Markov Decision Processes, Multi-armed bandits and Deep Learning techniques. Applications in various wireless communications problems and design of enhanced wireless communications systems and mobile networks using the above tools. Each class includes an introduction to a certain type of tools, and is followed by introducing various problems in wireless communications/ networks and how those tools can be used for the same. The students have to work on a project using a tool of their choice and solve a relevant problem or implement a relevant recent paper where ML is used to solve a wireless communications problem.

EE5815 2
MTech Thesis Stage 1

Thesis Work

EE5817 2
Random Variables

Review of probability, introduction to random variables; pmf, pdf and cdf; Mean, variance and moments; Markov and Chebyshev inequalities, Chernoff bounds; convergence of random variables, weak law of large numbers and the central limit theorem; Introduction to estimation, MMSE and LMMSE.

EE5825 2
MTech Thesis Stage 2

Thesis Work

EE5827 1
Random Processes

Random processes, mean and autocorrelation, Stationarity and ergodicity, Filtering random processes; Markov chains, transience and recurrence; Poisson point processes; examples and applications.

EE5835 10
MTech Thesis Stage 3

Thesis Work

EE5845 10
MTech Thesis Stage 4

Thesis Work

EE5848 2
Topics in Information Theory and Coding
▷EE2340 or EE5847, recommended EE5350 and EE6317

Review MDS codes and relation to polynomials. Introduction to straggler mitigation using coded computation. Reducing communication bandwidth through coded data shuffling. Distributed matrix multiplication using entangled polynomial codes, PolyDot codes, MatDot codes and product codes. Lagrange coded computing for robustness, privacy and secrecy. Coded gradient descent using fractional repetition codes, MDS codes, expander graphs and overcomplete representations. Coding for approximate gradient descent. Coded Fourier transform.

EE6010 2
Applied Algebra

This is a basic subject on matrix theory and (linear) algebra. Topics to be covered include, groups, systems of equations, vector spaces, determinants, eigenvalues, similarity, and positive definite matrices, linear transformations, symmetry groups, bilinear forms, and linear groups.

EE6120 3
Nanoelectronics: Principles and Devices

Introduction to the principles of quantum mechanics, quantum operators, wave-particle duality, wavefunctions and Schrödinger's equation; Quantum-mechanical origin of the electrical and optical properties of materials and nanostructures, absorption, luminescence, transport including tunneling in low-dimensional semiconductors, transport in nanoMOSFET, velocity saturation; ballistic transport, single-electron devices, calculation methods, thermal transport in nanostructures, emerging nanomaterials and structures including graphene, graphene nanoribbons, carbon nanotubes; properties and applications in electronics, photonics, bioelectronics, energy harvesting.
Nanostructure devices- Introduction, Resonant-tunneling diodes, Field-effect transistors, Single-electron-transfer devices, Potential-effect transistors, Light-emitting diodes and lasers, Nano-electromechanical system devices, Quantum-dot cellular automata.

EE6140 3
Introduction to Biosensor Technology

Silicon microfabrication, Cantilever biosensors, Surface Micromachining, Bulk Micromaching, Soft lithography, Nano Imprint Lithography, Dip-Pen lithography, Application of Nanotechnology for surface modification, Self Assembled Monolayers,

Polyelectrolyte multilayers, Functionalization of Carbon Nano tubes, Electrochemical sensors, chronoamperometry, cyclic voltammetry, differential pulse voltammetry, Electrochemical Impedance spectroscopy, Optical Sensors, colorimetry, fluorescence, Surface Plasmon Resonance, Immunoassay detection, antibody-antigen interactions, lateral flow immunoassay, integrated lab on chip devices, Enzyme linked immunosorbent assay (ELISA).

EE6150 3
Nanophotonics and Metamaterials
▷Fundamentals of Classical Electrodynamics, Device Physics and Vector Calculus

1. Light-matter interaction 2. Introduction to Photonic Crystals 3. Plasmonics and Metamaterials 4. Silicon Photonics 5. Nanofabrication of optical meta-devices 6. Application of meta-devices in imaging, information processing, sensing, medicine and energy

EE6160 2
Mesoscopic Carrier Transport
▷EE5107, EE5117

Boltzmann transport, semi-classical diffusive transport, Quasi-ballistic and ballistic carrier transport physics in nano-scale electronic devices, Non- equilibrium carrier transport, Quantum transport formalisms, Quantum coherence processes, Quantum corrections to charge electrostatics, Quantum conductance, Landauer transport, Wigner function formalism.

EE6170 3
Mesoscopic Device Electronics

Introduction to Mesoscopic Systems, Quantization of observables and reduced dimensionality of electronic states, Mesoscopic physics of nano-scale MOSFETs, Carrier transport in mesoscopic systems, Conductance viewed as transmission and conductance channels, Ballistic and quasi-ballistic transport, Carrier transport in nanowires, Quantum dots and coulomb blockade, Quantum well and super-lattices, Resonant tunneling Diodes, Quantum Hall effect, Superconducting electronics, and Graphene physics.

EE6180 3
Biomedical IC Design

Part 1: BIOSIGNAL-SENSING: Technology and Design Perspective: Introduction to Bio-Sensing and Bio-Sensors:- focusing on what is bio-sensing, why is it necessary, what are different bio-sensors, how to design these, what are the state-of-the art techniques, what is the future, and then link it to the chapters under this part. Biosensor fabrication technology:- The objective is to give a thorough understanding of basic fabrication technologies for making sensors and surface modification and detection methodologies which enables the use of these sensors for selective biomolecule detection. Surface modification methodologies and Characterization techniques:- The objective is to give a thorough understanding of characterization techniques necessary to develop biosensors, modification methodologies which help in preconcentration, isolation, amplification of bioanalyte of interest and methods to eliminate interferences. Detection methodologies:-Electrochemical detection, Immunoassay detection, Bio-Photonics and Optical detection, Micro Analytical Systems, Biopotential measurements. Miniaturized instruments for biosensors:- Potentiostat, Galvanostat, Measuring electronics based on off the shelf components; Reflectance measurements, Fluorescence microscopy, Handheld instrumentation.
Part-2: BIOSIGNAL-PROCESSING: AlgorithmS and IC Design Perspective: Introduction :-Role of Signal processing in healthcare-Case studies (1. Foetal ECG separation from maternal ECG, 2. ECG feature extraction, 3. EEG analysis); Different types of signal processing techniques, Remote healthcare: technology driven next-generation healthcare: Need of remote healthcare, Overview of remote healthcare architecture; Role of Technology Signal processing for remote healthcare: Potential Challenges. Fundamentals of biomedical signal processing: signal pre-processing, denoising, artifact separation, filtering signal compression-decompression:- Overview of Biomedical signal processing techniques; Detailed discussion with various case-studies on the real life problems. Constraints for applying traditional signal processing techniques in remote healthcare - low-energy issue:- Traditional Signal Processing algorithms vs. Practical Constraints; Need of an holistic view of Algorithm and VLSI Architecture; Technology for next generation bio-medical signal processing. Arithmetic complexity and trade-off analysis for biomedical signal processing processes:- Hardware complexity analysis of resource constrained system; Computational Delay analysis of resource constrained system; Trade-off analysis : Arithmetic complexity vs Signal parameters.
Part-3: BIOSIGNAL-COMMUNICATION: Practical Design Perspective: Wireless Sensor Networks for Healthcare:-Overview of wireless sensor networks, Network characteristics, Network Design and Challenges, Some applications and WSN requirements for specific applications. Wireless Sensor Network Protocol Stack, algorithms and design:- Wireless Sensor Protocol Stack, Physical Layer, Medium Access Control, Network Layer, Transport and Application Layer, Cross Layer. Data Aggregation and some Advanced Topics:- Sensor Data aggregation techniques, Sensor Data storage, Data Management and Processing; Time Synchronisation in WSN: Need and Techniques; Sensor Node localisation: Need and Techniques; Security and Privacy - Authentication and

		Cryptography; Wireless Sensor and Actuator Networks - Bidirectional Network design, Control on Sensor Networks - design challenges and solutions. Healthcare on Mobile Platforms:-Need for mobile platforms for healthcare applications; Mobile application development for Healthcare: Wireless Sensor Data collection (Bluetooth, WiFi, 3G..), Data Processing and Alert generation; Some examples on Android Application development for mobile platforms.
EE6197 Digital Chip Design for Futuristic Cardio-vascular Health monitoring	**1**	Cardio Vascular Disease overview, current status, challenges and future directions including 2 European funded long-term research Projects: CHIRON and HEARTMAN and how these can be viewed from a Medico- engineering perspective, Next generation Technology requirement in remote CVD monitoring, Low power hardware design for CVD monitoring, Diagnostic Features and their effects on human health, Importance of ICT for patients with Hypertrophy, Heart Failure and other major heart related diseases. Areas of interest to improve patient reported outcomes in CHF patients: physical activity, medication and nutrition; Hardware and softwares needed for up-to-date telemedicine in CHF, IOT based technology platform design for remote healthcare, Importance of real time fragmentations detection from the ECG and On-chip Signal processing for detection of fragmentation, Bridging the gap between medical science and technology with Demo and hands on.
EE6201 Power System Lab	**2**	Introduction to sparse matrix computation, introduction to optimization in GAMS, introduction to steady-state analysis in PSS/E, introduction to transient analysis in PSCAD.
EE6210 Switched Mode Power Conversion	**1**	Linear dc to dc Power Converters, Non-idealities in Reactive Elements, Design of Inductors, Design of Transformers, Operating Principle of Non-isolated dc to dc Power Converters (buck, boost, buck-boost, Cuk) Equivalent Circuit Model of the non-isolated dc-dc converters. State Space Averaged Model of dc-dc Converters. Isolated converters (Forward, Flyback, Half/Full Bridge Converters). Closed Loop Control of Switching Converters, Resonant converters, zero current switching (ZCS) and zero voltage switching (ZVS).
EE6211 Power Electronics Lab	**2**	None
EE6220 Hvdc and Facts Applications	**3**	HVDC transmission: Principle of operation of HVDC transmission, components and structure of an HVDC link, transformer organization, basic control characteristics, ac-dc load flow analysis, multi-terminal HVDC transmission. FACTS devices: Operating principles and basic control characteristics of SVC, STATCOM, TCSC, UPFC and SPST. HVDC and FACTS applications: Control circuit design, small signal stability improvement, transient stability improvement, voltage stability improvement, power quality improvement.
EE6230 Electrical Drivers and Control	**3**	Introduction, Electrical Machines, Power Converters, Controllers, Modeling of DC Machines, State space modeling, Electro-mechanical model Phase controlled DC motor drives: Steady state analysis of the three phase converter controlled dc motor drive, two-quadrant, three phase converter controlled Dc motor drive, field weakening, four-quardrant dc motor drive, converter selection and characteristics, simulation Chopper controlled dc motor drive Polyphase induction motor drives: steady state equivalent circuit, dynamic modeling and simulation, slip energy recovery scheme, speed control of inductor motor Vector-controlled induction motor drives: principles of vector control, direct vector control, indirect vector control scheme, tuning of vector controller.
EE6240 Power System Protection	**3**	Introduction to power system protection (Evolution in protection systems, introduction to computer relaying, software tools for digital simulation of relaying signals, apparatus protection, system protection, desirable attributes of protection); Sequence Components and Fault Analysis (Sequence components, sequence modeling of power apparatus); Numerical Relaying (Signal conditioning, sampling and analog to digital conversion, real-time considerations, hardware design concepts - microcontroller/DSP based, single/multiprocessor based, relaying algorithms, software considerations); Current and Voltage Transformers (Introduction to CT, CT Saturation and DC Offset current, Introduction to VT, performance issues of current and voltage transformers); Digital protection schemes for transmission lines, generators, and transformers (Overcurrent protection, Directional overcurrent protection, Distance protection, Differential protection, Out-of-Step protection); Additional topics of protection (Adaptive relaying, integrated substation protection and control, new relaying principles based on AI techniques, ANN approach and Fuzzy logic (FL) methods for fault detection and fault location, wide area monitoring, protection and control systems)

EE6247 **1**
Introduction to Smart Grids

Introduction to Smart Grid, Smart Grid Conceptual Overview, Interoperability in power sector, Architectures for Smart Grids, Standards, Smart Tranmission System, Smart Distribution System, Smart Prosumer, Distributed Generation.

EE6257 **2**
Smart Grid Design and Implementation Aspects

Cost Benefit Analysis of Smart Grid Projects, Regulatory and Policy Issues, Indian Scenario, Information and Communication Technologies for Smart Grid, Demand Response, Smart Grid as foundation for Smart Cities, Smart Grid Design and Implementation Aspects, Student Projects on Smart Grids

EE6260 **2**
Control of Power Converters
▷Basic Power Electronics

Course contents: 1. Review of Modelling procedures of the power converters 1.1. State space averaging 1.2. Linearization 2. Designing of the close loop control of a power converter 2.1. Single input single output control 2.2. Multiple loop control 2.3. Instantaneous current control 2.4. Formulation of control strategy 3. Studying the performance of power converters in close loop 3.1. Simulation and verification of control strategy 3.2. Importance of feedback and feedforward loops 3.3. Effect of disturbances on the performance of power converters 3.4. Effect of perturbation / variation in elements of power converters 3.5. Impact on start-up transients 3.6. DC and AC type input references and controller performance 4. Significance of close loop responses of a power converter with respect to change in close loop bandwidth and phase margin 5. Demonstration and Experimental verification of some of the modules 5.1. SMPS response and control 5.2. DC bus voltage control of DC-DC converter

EE6270 **1**
Grid Integration of Pv Systems

Equivalent circuit representation of a PV array, different configurations of a PV system (i.e., battery-backed, non-battery backed, single level power conversion, two-level power conversion, centralized configuration, string configuration, multi-string configuration), MPPT control, LPPT control, issue of partial shading.

EE6297 **2**
Modeling and Analysis of Electromagnetic Transients

Principles of transient modeling of lumped circuits, Computer methods for solving electromechanical transients, traveling wave phenomena, modeling of transmission lines, frequency dependent transmission line modeling, modeling of transformers, Transients in 3 phase circuits,transient models for electrical machines, analysis of switching and fault transients, development of electromagnetic transients program (EMTP)

EE6300 **3**
Speech Signal Processing

Speech signal production, acoustic phonetic characterization, classification of sounds based on place and manner of articulation, source-filter model of speech production, short-term spectral analysis of speech, linear prediction analysis, cepstral analysis, spectral distortion measures, vector quantization, Gaussian mixture modelling, dynamic time-warping, hidden Markov models, development of speaker and speech recognition systems, speech enhancement.

EE6307 **3**
Speech Systems
▷Basic Calculus, Probability and Random Processes, Digital Signal Processing and Machine Learning

Feature Extraction: Acoustic theory of speech production and parametric representation of speech signal Automatic Speech Recognition: Template matching approaches, hidden Markov models, deep acoustic modeling, language modeling Speaker Recognition: Gaussian mixture modeling, universal background models, minimum divergence criteria, probabilistic LDA, system building Speech Synthesis: Text analysis, Pronunciation, prosody, waveform generation using unit selection, HTS and wavenets, voice building and modification.

EE6310 **3**
Image and Video Processing

Review of linear algebra, 2D Fourier transform, 2D sampling and reconstruction, 2D DTFT, Human visual perception — spatial properties: physics, biology, empirical understanding, and image fidelity criterion, Image scanning and display: half-toning, dithering, error diffusion; RGB and CMYK systems, Image enhancements — Point operations: display calibration, dynamic range compression, histogram equalization, color mapping, (changing color coordinates, pseudo-color, false color), Edge enhancements, filtering, Image restoration: degradation modeling, Inverse filtering, Wiener filtering, cleaning of additive and multiplicative noise, Image compression: lossless, Image compression: lossy — predictive coding, transform coding, Karhunen Loeve transform, Discrete cosine transform, wavelet transform, quantization, subband coding, JPEG standards, Human visual perception — temporal properties: spatio-temporal modulation transfer function, and fidelity criterion for video, Analog and digital television, video conferencing, Video restoration, Video compression: Motion estimation and compensation, MPEG standards.

EE6320 **3**
Wireless Sensor Network

Introduction to WSN, History and Applications Wireless Sensor Node Architecture-System level - Main components with detailed description, Microcontroller, Communication (RF) module, Sensors (depending on application) and signal conditioning, Memory, Power Supply, Battery Management, Energy Harvesting Wireless Sensor Network Architecture-Topology/Network Structure, Power Management, Physical, MAC, Routing, IEEE802.15.4 Standard and ZigBee,Synchronization, Localization, Data Aggregation and Data base management, Sensor Network Platforms

and Testbeds-Operating Systems: Tiny OS, Contiki, Hardware testbeds, Libelium WASP motes, Crossbow Motes, Weather monitoring Systems and eKo motes, System Level discussion on specific applications, Environment monitoring, Green buildings, smart micro grids, green ICI, Health care - BAN

EE6327 3
Statistical Learning Theory
▷Basic Calculus, Probability and Random Processes and Machine Learning

Classification and kernel methods: reproducing kernel Hilbert spaces, Fourier properties and analysis, randomized and low-rank approximations Uniform convergence: uniform laws of large numbers, VC dimension, entropy integrals, Rademacher complexity Concentration and risk bounds: Concentration inequalities and applications, Statistical consequences

EE6330 3
Advanced Cellular Communications

Introduction to cellular networks. Link budget, propagation models, statistical channel models, Spatial MIMO channel model, SINR distribution in full frequency reuse-1 network; OFDM transmitter and receiver, Coding for multipath frequency selective channels, code rate diversity trade-off, DFT-precoded-OFDM (SC-FDMA) modulation, Frequency domain MMSE and MMSE-DFE equalizers for DFT-precoded-OFDM, Synchronization, channel estimation, frequency offset correction techniques for OFDM/DFT-precoded-OFDM systems; Capacity of single user MIMO channel, Transmitter diversity methods, Spatial multiplexing (SM), Capacity of MU MIMO in downlink: ZF/MMSE transmit precoding, vector perturbation techniques; Interference channels: Degree-of-freedom for K-user interference channel, interference alignment, multi-antenna MMSE; Distributed MIMO network architectures: Co-ordinated multi point transmission (COMP) with full channel state feedback, limited feedback techniques; Opportunistic scheduling in cellular networks. Proportional fair multi user scheduling in noise and interference limited networks. Best-band scheduling, Traffic modeling, scheduling with QOS constraints, cross-layer optimization; Miscellaneous topics: Channel quality (CQI) computation, Pilot design, CQI stability, Control channel design, power control, Hybrid ARQ, Energy efficiency, Link and system simulation methodologies.

EE6337 1
Deep Learning

Deep feedforward networks, regularization for deep networks, optimization for training deep models, convolutional neural networks, practical methodology and applications Prerequisites: Optimization Theory, Machine Learning, Linear algebra

EE6340 3
Cooperative Communications

Introduction to Amplify and Forward (AF) and Decode and Forward (DF) cooperative systems, dual hop and multihop systems, variable and fixed gain relays for AF, receivers for AF and DF systems, BER and outage analysis for cooperative and multihop systems, MIMO Relay systems

EE6347 1
Advanced Random Processes
▷Random processes, Information science

Point processes, Markov processes, Hidden Markov models, Gaussian processes, Gauss-Markov processes, Maximum entropy, KL expansion and other properties, Gaussian scale mixtures and Spherically invariant random processes, Applications.

EE6350 3
Multiple Antenna Systems

MIMO: Single user MIMO link capacity, Capacity of multi-user MIMO, Degrees-of-freedom for interference channels. Open-Loop MIMO: Design criterion and performance analysis of space-time codes, STBCs, delay diversity, phase-offset diversity, transmit antenna switching Closed Loop MIMO: Equal gain transmission, Antenna selection, eigen mode trans-mission, beam forming with quantized feedback, code books based beam-forming, Multi-user MIMO, ZF and vector perturbation methods Spatial Multiplexing: Maximum likelihood and MMSE receivers, Successive cancellation, Reduced state sequence estimation, BER analysis, SM for ISI channels, generalized MIMO MMSE-DFE Co-channel Interference Suppression: Maximum ratio combining, interference rejection combining, Bit error rate (BER) bounds, interference channels, interference alignment Opportunistic Scheduling: Proportional fair scheduling in multi-user systems in white noise and interference. Traffic models Review of multiple antenna techniques adopted in 4G systems.

EE6357 1
Sparse Signal Processing
▷Linear algebra

Sparse signal models, L1 minimization, uncertainty and coherence, greedy and relaxation pursuit algorithms, MAP and MMSE Based interpretations, example applications to denoising and super resolution

EE6360 3
Multimedia Communication Systems

Video compression fundamentals: optical flow, motion estimation and compensation techniques. Video quality assessment algorithms: full reference, reduced reference and no-reference techniques in the context of packetized transport. The H.264 compression standard: tools for communication including scalable video coding, multiview coding, configurable video coding. Fundamentals of network programming :TCP, UDP, TCP sockets, clientserver examples. Protocols: Apple HTTP Live Streaming (HLS), Microsoft Smooth Streaming (SS), Dynamic Adaptive Streaming over HTTP (DASH), RTSP and related lower level protocols. Fundamentals of Android: Basics of application development on Android.

EE6380 **3**
Deep Learning

Course syllabus: Background for Pattern Recognition and Machine Learning; A short introduction to feed-forward neural networks and error backpropagation; Analysis of Hopfield networks, Hebbian learning, Lyapunov energy functions and basins of attractions; Boltzmann machines, restricted Boltzmann machines; deep belief networks, sigmoid belief networks, deep autoencoders; convolutional neural networks; Application of deep architectures to speech and image processing.

EE6390 **3**
Wavelets and Subband Coding

Wavelets, filter banks and multiresolution signal processing, Fundamentals of signal decompositions, Discrete-time bases and filter banks, Series expansions using wavelets and modulated bases, Continuous wavelet and short-time Fourier transforms and frames, Applications: signal compression, image restoration, compressive sensing.

EE6410 **3**
Biomedical IC Design

Role of Signal processing in healthcare - Case studies (1. Foetal ECG separation from maternal ECG, 2. ECG feature extraction, 3. EEG analysis, 4. EMG analysis; to help readers understand where signal processing is used), Different types of signal processing techniques; Remote healthcare: technology driven next-generation healthcare - Need of remote healthcare, Overview of remote healthcare architecture, Role of Technology; Signal processing for remote healthcare: Potential Challenges; Overview of Biomedical signal processing techniques; Detailed discussion with various case-studies (will address some of the well-known signal processing techniques in greater details and will also illustrate how these are used in the real life problems); Traditional Signal Processing algorithms vs. Practical Constraints; Need of an holistic view of Algorithm and VLSI Architecture ; Technology for next generation bio-medical signal processing; 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 for Healthcare; Wireless Sensor Node Architecture and Design, Wireless Sensor Network Architecture; Wireless Sensor Protocol Stack - Layered architecture: Physical, MAC, Network, Transport and Application; Physical Layer Technologies - RF Wireless communications, Modulations, Wireless channel effects, Channel coding, Error Control, Some example Transceivers; Medium Access Control - Design aspects, MAC protocols classification and analysis, MAC for healthcare; Network Layer - Routing in Sensor networks, Different protocol classifications and analysis, Routing for healthcare; Transport and Application Layer- Algorithms ; Cross Layer Solutions - MAC and PHY, MAC and Network, PHY and Network, cross layer modules.; Sensor Data aggregation techniques, Sensor Data storage, Data Management and Processing; Time Synchronisation in WSN: Need and Techniques; Sensor Node localisation: Need and Techniques; Security and Privacy - Authentication and Cryptography; Wireless Sensor and Actuator Networks - Bidirectional Network design, Control on Sensor Networks - design challenges and solutions; Healthcare on Mobile Platforms

EE6640 **2**
Queuing Theory
▷Random Processes

Introduction to Queuing Systems, Analysis of a Simple Queue, Introduction to Markov Processes and Markov Chains,Birth-Death Processes,Flow Balance,Basics of Queuing(M/M- Type Queues),Kendall's Notation, Little's Result, PASTA,M/M/1/8,M/M/m/8, M/M/m/m, M/M/1/K Queues,Delay Analysis, Departure
Process,Burke's Theorem,Method of Stages,Batch Arrivals Problems, Residual Life Approach,Embedded Markov Chain Approach,Analysis of M/G/1 queue, Special Cases of the M/G/1 Queue, M/G/1 Queue with Multiple Vacations, M/G/1 Queue with Batch Arrivals, M/G/1/K- Finite Capacity G/M/1, G/G/1, G/G/m and M/G/m/m Queues Jackson's Theorem, Splitting and Combining Poisson Processes, Norton's Theorem, Mixed Networks, QNA, Introduction to Discrete Time Queues

EE7110 **3**
More Than Moore Electronics

3-D ICs Fabrication, Modeling andDesign Challenges, Molecular Electronics Fabrication, Modeling Challenges (Bottom up approach), Other Si electronics

EE7120 **2**
CMOS Sensors

Course Outline: Introduction to sensor technology, CMOS compatibility, Inertial sensors, Biosensors, Gas sensors, Acoustic sensors, magnetic sensors,ASIC design for sensors, design of application specific amplifier, noise considerations, low power, data conversion, layout issues for CMOS analog/mixed circuits
Brief Description: This focuses specifically focuses on the understanding of sensors and CMOS circuits. This understanding is necessary to integrate sensors onto a CMOS chip to achieved sensors with integrated electronics. The sensor input and output define the design consideration of circuits and the cmos circuits puts constraints on the choice of materials/ mechanism that can be used for designing sensors. An understanding of both domain gives an added advantage for both circuit engineer as well as sensor technologist.

EE7210 **3**

Part - I Smart Grid (SG) Core Concepts: SG Conceptual Model, SG Architectures, SG

Smart Grids	Standards, SG Regulatory Perspective, SG Technologies. Part - II Smart Grid Practical Aspects: Initiatives around the world, Initiatives in India, India Smart Grid Vision and Roadmap (2012 - 2027), SG standards development in India, SG Pilot Projects in India, Challenges and way forward.
EE7220 3 Microgrid Operation and Control	Motivation behind microgrid, ingredients and architecture of a microgrid, distinct features of a microgrid, V-I characteristics of photovoltaic and fuel cells, maximum power point tracking and limited power point tracking of photovoltaic plants, principle of operation of wind generators, introduction to doubly-fed induction generator, utilizations of energy storage devices and plug-in electric vehicles, voltage and frequency control, droop controller tuning, source power output control, islanded and grid connected modes of operation, transition from one mode to another mode, introduction to virtual synchronous generator.
EE7230 3 Wide Area Monitoring, Protection and Control ▷EE5247, EE5257	Concepts of static and dynamic phasors, time synchronization, time stamping, phasor estimation, frequency estimation, phasor concentration, PMU standard, WAMS architecture, online transient stability monitoring, state feedback control basics, classification of power system oscillations, WAC architecture, state feedback, output feedback, generator state estimation, treatment of communication delay, H_2 norm optimization, $H_{infinity}$ norm optimization, treatment of structural constraints.
EE7310 3 Cognitive Radio	This course provides an introduction to cognitive radios, a new type of radio that will be capable of cooperatively adapting transmission modes, channels, and protocols to make the best use of the available spectrum. Such radios will include wideband receivers and transmitters, with many of their functions implemented in software, rather than hardware, to enable greater flexibility. While the most commonly cited example of uses of such radios is sharing of under-used portions of the spectrum with licensed (primary) users, the basic technology also can lead to improved uses of the ISM bands. In addition, the cooperative and adaptive nature of the radios has large consequences for jamming/anti-jamming in military communications, representing both a threat to current systems and an opportunity for their evolution to more secure modes. The course provides a background in the technology that makes these radios possible as well as providing guidance on their benefits in multiple access systems.
EE7320 3 Immersive Multimedia	Camera modeling and calibration; Image stitching and mosaicing; Stereo vision and depth perception: parallel and non-parallel optical axes; Multicamera array: geometry and calibration; High-resolution image based on camera array; Self-configurable camera array; View-free video; 3-D Reconstruction based on multiple views: mathematical frameworks and algorithms; Compression and the compressive sensing approach; Basis selection: Finite element method, Proper orthogonal decomposition, Wavelets, Wavelet packets and derivatives; Architecture of 3-D video and telepresence system; Concept of space sharing in practical implementation; 3-D rendering and display with emphasis on light-field reconstruction;
EE7330 3 Network Information Theory	Probability basics and the weak law of large numbers, method of types and the strong law of large numbers, Sphere packing lemma, channel coding theorem, Type covering lemma, Distortion-abstracted source coding theorem, Lossless coding theorem, Rate-distortion theorem, Type covering with side information, Distortion-abstracted source coding with side information problem and coding theorem, Slepian-Wolf theorem for lossless coding with side information, Wyner-Ziv theorem, Two-terminal distortion abstracted problem with side information -Application of Markov lemma and modular construction, Slepian-Wolf theorem for multiterminal source coding, Wyner-Ahlswede-Korner theorem, Berger-Yeung theorem - without and with side information, General two-terminal source coding problem: unified structural view, multi-letter coding theorem - direct statement and converse, Special cases - Two-terminal Jointly Gaussian problem under MSE distortion (Oohama and Wagner-Tavildar-Viswanath solution), Two-terminal binary Hamming problem, Korner-Marton modulo-two sum problem with symmetric source distribution, Issues in network source coding - Information irrelevance at encoder, Vanishing error versus vanishing distortion, Potential entanglement between independent joint sources and other advanced topics, Channel coding as a game - Covert channel, data hiding capacity, Multiple access channel, Gelfand-Pinsker theorem for channel coding with state information, Relay channel, Degraded relay channel, Broadcast channel, Degraded broadcast channel, Writing on dirty paper, Gaussian broadcast channel, Interference channel, Issues in channels networks - Network capacity and advanced topics.
EE7340 2 Special Functions in Communications.	Course Description: Introduction to Gamma Functions, Beta Functions, Hypergeometric Functions, Orthogonal Polynomials, Bessel Functions. Contour integral representations of special functions. Special functions in communications: statistics of decision variables

encountered in fading channels and BER analysis.

EE7350 **3**
Adaptive Signal Processing

Fundamentals for adaptive systems, mean-square estimation, Wiener filters. Introduction to adaptive structures and the least squares method. State space models. Kalman filters. Search techniques: Gradient and Newton methods. LMS(least mean squares), RLS (recursive least squares). Analysis of adaptive algorithms: Learning curve, convergence, stability, excess mean square error, mis-adjustment. Generalizations of LMS and RLS.

EE7370 **2**
Markov Chains - MAC Modelling

Markov Chains - Discrete Time, Continuous Time, State classifications, Birth Death processes, Network of queues, MAC protocols - CSMA/CA, QoS parameters - Reliability, Latency, State diagram of CSMA, 2 Dimensional, Markov Model of CSMA, 3 Dimensional Markov Model of CSMA

EE7390 **3**
Pattern Recognition and Machine Learning

Introduction to PRML; General Notions: Parameter estimation, overfitting, model selection, curse of dimensionality, bias-variance tradeoff; Supervised Learning (Regression and Classification): Density estimation, Bayes decision theory, generative vs. discriminative models, Linear Methods: linear and logistic regression, generalized linear models, linear discriminant functions for classification, support vector machines etc., Nonlinear methods: kernel methods, nearest neighbor,
neural networks etc., Unsupervised Learning (Clustering and Density Estimations): K-means clustering, vector quantization, Gaussian mixture models, autoencoders, dimensionality reduction (linear and nonlinear) Handling Sequential Data: Hidden Markov models, and Linear Dynamical systems.

EE7710 **3**
Probabilistic Models of the Brain

Introduction: Brain under the hood: the neuron, ion and ion channels, cable theory, simple brain models. Perception: Bayesian modeling of visual perception including depth, velocity and motion, Information theoretic approaches to neural coding and parameter estimation. Neural function: Natural image statistics, probabilistic network model of population responses, models for spiking populations - sparse codes, restricted boltzmann machines, predictive coding.

16.9 Department of Liberal Arts

LA2010 **3**
Introduction To World Literature

Designed for the beginning student of literature, this course provides an introduction into the nature and functions of literature from different cultures and geographical regions across the world. It provides a historical overview of the major literary forms, viz. short stories, poetry, drama and novel with emphasis on techniques of understanding, evaluating and interpreting literature. It also helps the student understand the art of rhetoric and argument formation with the help of literary narratives.

LA2020 **3**
Principles Of Economics

- Ten Principles of Economics
- Thinking like an Economist
- The Market Forces of Supply and Demand
- Elasticity and Its Application
- Supply, Demand, and Government Policies
- Consumers, Producers, and Efficiency of Markets
- Externalities
- The Costs of Production
- Firms in Competitive Markets
- Monopoly, Oligopoly, Monopolistic Competition
- Measuring National Income
- Measuring the Cost of Living
- Saving, Investment and Financial System
- Money Growth and Inflation
- Open-Economy Macroeconomics: Basic Concepts
- Open-Economy Macroeconomics: Theory and Application
- Short-Run Tradeoff between Inflation and Unemployment

LA2060 **3**
Evolution Of Gender Question In India
▷Only PG

None

LA2080 **3**
Introduction To Western Art: From Cave Art To Middle Age

In this course, we will explore Western Art—especially painting and architecture—from European Cave Paintings to Medieval Art. After a series of introductory lectures on various periods in Western Art, we will concentrate on Cave Art, Egyptian Art, Greek Art, Roman Art, and Medieval Art, along with some aspects of Greek, Roman, and Gothic

▷Only PG

Architecture. We will explore different media and styles that evolved over the millennia, and develop a vocabulary for speaking about works of art. Since art always grows out of its social contexts, art's dialogue with society will also be of special interest. And, of course, we will study in detail magnificent paintings, buildings and sculptures!

LA2100 **3**
Language, Cognition, And Computation
▷Only PG

This course will address some of the fundamental problems in cognitive science from a linguistic angle. Some of the questions that will be raised and discussed are: (i) how is language represented in the mind? (ii) what is it about the nature of representation that it can mediate between language and the mind? (iii) what do linguistic structures reveal about the mind, and vice versa? and (iv) how do operations on linguistic structures relate to issues in computation?

LA3010 **3**
Financial Institutions And Markets
▷Only PG

Objectives: The aim of this course is to provide an overview of financial institutions, their role in the financial system, the products and services they provide and the manner in which they are regulated and managed, with special reference to the Indian context. The course also focuses on the major risks faced by financial institutions and the techniques used to manage these risks.
Topics:
- Role of financial markets and institutions
- Central Bank and monetary policy
- Debt security Market
- Equity market
- Derivative security markets
- Commercial banking
- Banking Institutions
- Non-Bank financial intermediaries
- Foreign exchange market

LA4017 **3**
Ethics And Modern Political Theory
▷Only PG

In this phase of human history the concept of 'ethics' delinked itself from religion/divine authority and became more pragmatic. Perceptions about 'human nature' changed and state is projected as merely a technical organ to aid the individual. Thus the state is demystified and lost its glory which it enjoyed from pre-Socratic, through Hellenistic to medieval periods (Ethical discourse during medieval period is omitted in this course because of its overwhelmingly religious inclinations). Human became crux of every discourse and apart from him/her no institution would enjoy any status. This has paved way for the formulation of several discourses based on strict individualism. This course would focus on: what this shift from state/church-centric ethical theories to human-centric theories mean, what are the broad changes this shift brought, its shift from subjectivism to staunch objectivism (for instance, most of these theories supported and benefited from positivism unlike the earlier ones), limitaions in such shifts etc. All this will be debated around their ethical implications.
European Enlightenment's conflict with religion and emphasis on reason; ethical theories of Rene Descartes; Baruch Spinoza, Jean-Jacques Rousseau (Theory of human nature), Geroge Edward Moore's refutation of idealism and solipsism (how Moore's views paved way for ethical relativism); Brief principles of Individualism, Marxism (excerpts from the writings of Karl Marx on human nature), Utilitarianism (Jermy Bentham theory of hedonism); Logical Positivism and Ethical Emotivism.

LA4020 **3**
Ethics In Political Theory
▷Only PG

First philosophical contemplations about abstract ethical notions like virtue, truth, valor, wisdom, love etc took place in ancient Greece in 6th century BC. This ancient Greece philosophy has created an epistemological base for all the later political theories despite their ideological moorings. The course covers theories from ancient Greece to 20th century:
Presocratic Period, Socratic Period (Athenian Period), Hellenistic Period: Major differences between Hellenistic and Pre-Hellenistic political theories and changes in their political system from participatory government to highly centralized state; Epicureans; Stoics; Skeptics; Neo-Platonism by Plotinus; European Enlightenment's conflict with religion and emphasis on reason; ethical theories of Rene Descartes; Baruch Spinoza, Jean-Jacques Rousseau (Theory of human nature), Geroge Edward Moore's refutation of idealism and solipsism (how Moore's views paved way for ethical relativism); Brief principles of Individualism, Marxism (excerpts from the writings of Karl Marx on human nature), Utilitarianism (Jermy Bentham theory of hedonism); Logical Positivism and Ethical Emotivism; Postmodernism and Post structuralism.
Postmodernism was started as a challenge to everything that underlies modern epistemology. It thus has raised complicated questions about all its basic assumptions ranging from human nature, truth, telos, norms and established ways of doing academics writing history and so on. Crux of this philosophy is extreme relativism and this implies great challenge to most of the normative codes and expected behaviors in a given system.

This philosophical trend reflects in the current culture in multiple ways. While postmodern philosophy has contributed to de-stigmatize several cultural/foundational connotations, it has also posed great threat to the very settled notions of 'morality'. Hence, the present course would try to analyze these theories and assess their applicability to rapidly changing current cultural scenario.

LA4027 **3**
Postmodern Theories And Ethics
▷Only PG

Postmodernism was started as a challenge to everything that underlies modern epistemology. It thus has raised complicated questions about all its basic assumptions ranging from human nature, truth, telos, norms and established ways of doing academics writing history and so on. Crux of this philosophy is extreme relativism and this implies great challenge to most of the normative codes and expected behaviors in a given system. This philosophical trend reflects in the current culture in multiple ways. While postmodern philosophy has contributed to de-stigmatize several cultural/foundational connotations, it has also posed great threat to the very settled notions of 'morality'. Hence, the present course would try to analyze these theories and assess their applicability to rapidly changing current cultural scenario.

LA4030 **3**
Popular Fiction
▷Only PG

This course explores various genres that constitute Popular Fiction. Through selected representative texts of science fiction, fantasy/children's fiction, detective fiction, thrillers, horror and satire this course intends to familiarize students with the basic features of popular writing and literature. Students would be trained in discussing and responding critically to both literary texts and their film adaptations while analyzing how such narratives address complex cultural phenomena.
Pre-Req: Only for UG and basic proficiency in English with primary background in literature.

LA4050 **3**
Personality Psychology
▷Only PG

Personality Psychology addresses questions about how individuals develop characteristics that make them unique from each other, why they act and behave the way they do, historical issues and controversies that personality psychologists have encountered, techniques used in assessing personality, and how the study of personality psychology may be applied to everyday life. Some of the most popular personality theories will be introduced. Since the organization of personality is a complex one, shaped by many influences such as genetics, environment, and internal conflicts, one may recognize that there is no one approach that would present an integrated picture of human personality. The aim of this course is to provide an overall perspective that includes a multitude of factors in understanding personality. This would help in application of concepts from personality psychology for both personal development as well as in understanding others.

LA4060 **3**
Indian Economic Development
▷Only PG

India as a Developing Economy: Nature and Basic Characteristics, Occupational structure and economic development, Human resource and economic development, Employment and unemployment Perspective, Economic planning - Rationale, features and objectives, Assessment of Indian planning: 1950-51 to 2007-12, Inclusive growth, The place of agriculture in the national economy, Industrial Development and Policies, Service in the Indian Growth Process, Information Technology (IT) Industry, Economic reforms and liberalization, Globalization and its impact on the Indian economy, Foreign Direct Investment in India, Foreign trade: issues and policies, Indian tax structure and fiscal policy, Global financial crisis.

LA4070 **3**
Organizational Behavior And Work Psychology
▷Only PG

- Organizational Behaviour - Introduction
- Role of Individual Perception at Work Place
- Learning at Work Place
- Individual Differences at Work Place
- Attitudes at Work Place
- Emotions at Work place
- Work Motivation
- Interpersonal Behaviour at Work Place
- Power and Leadership
- Group Dynamics
- Organizational Dynamics

LA4100 **3**
Natural Language And Natural Meaning
▷Only PG

Course Description:
This course will explore the territory of linguistic semantics and probe into the problems of linguistic meaning. The central questions to be addressed are: (i) how is meaning represented in natural language? (ii) why is there meaning in language at all? (iii) how can we represent meaning? and (iv) is meaning in language related to mental representations?
Course Contents:
- Foundations of Linguistic Semantics

	• Formal foundations of linguistic approaches to meaning • The relation between meaning and logic • The nature of the meaning-logic interface • Linguistic meaning and matters of mental representation • The connection between semantic representations and mental representations
LA4200 **3** Gender And Society ▷Only PG	This course is an introduction to the study of gender within sociology and social anthropology. The course aims to familiarise students to the ways in which social stratification, on the one hand, and social inequality on the other are part of the gender framework. The discussion will be centred on exploring the ways in which gender comes to be an important part of the family, workplace and social milieu. Through the study of other cultures and groups, the course aims to develop a more nuanced understanding of the dynamics involved in the social construction of gender. The objective of this course is to: • Introduce students to canonical texts within gender theory • Familiarize them to emerging concepts in the domain of gender and women's studies • Equip students to understand various facets of studying social structures and practices related to gender
LA5010 **3** Macroeconomics	This course is designed to create a solid background in macroeconomic theory and policy and its applications to economic problems. The course objectives are to provide a complete and comprehensive analysis of fluctuations in national income, output, and employment within the classical and Keynesian frameworks. The course also discusses various policy options and the extent to which these policies can affect the level of output and unemployment in the economy. Topics: • National Income Accounting • Money and Inflation • The Open Economy • Economic Growth • Economic Fluctuations • Stabilization Policy
LA5020 **3** Industrial Organization ▷Only PG	• Organizational form and motive of the firm • Market structure • Market Concentration, entry and exit • Diversification, Vertical Integration and Merger • Productivity, efficiency and their measurement • Competitiveness • Determinants of profitability • RandD Spillover and Productivity • Innovation • Technological Diffusion • Technology Transfer and Firm Performance, technology spillover • Spillover and Backward Linkage Effects of FDI • Globalisation and Technology based Growth
LA5030 **3** Basic Econometrics And Forecasting	• Two-variables Regression Analysis • Two-variables Regression Model: The Problem of Estimation • Classical Normal Linear Regression Model • Multiple Regression Analysis • Dummy Variable Regression Model • Multicollinearity • Heteroscedasticity • Autocorrelation • The Forecasting Perspective • Basic Forecasting Tools • Time Series Decomposition • Moving Averages Method • Exponential Smoothing • Box- Jenkins (ARIMA) Methodology
LA6010 **3** Qualitative Research Methods ▷Only PG	Introduction; Theoretical and philosophical premises of qualitative methodologies; Difference between quantitative and qualitative methodologies; New paradigms in the social sciences Qualitative methods of data collection: Ethnography; Participant and non-participant observation; Interviews (semi-structured and unstructured) and focus group discussions; Participatory research methods and action research

Qualitative methods of data analysis: Thematic analysis; Narrative analysis; Grounded theory technique; Discourse analysis; Quantifying qualitative data

LA6020 3
Advanced Health Psychology
▷Only PG

Health psychology studies the social, cognitive, behavioral and emotional factors that influence health, illness and well-being among individuals. This course will introduce different approaches to health in the social sciences, especially health psychology. The course will discuss advanced topics in health psychology, such as health behavior change models, relationship between chronic illnesses and psychological outcomes, perceptions of illness, health promotion and risk prevention. The course will describe new approaches in research in health psychology which shape the way the field is progressing today, e.g., salutogenic research, mixed-method approach for evaluating the effectiveness of interventions, multi-cultural comparison studies.

LA6040 3
Theories On Culture
▷Only PG

This course critically examines major theories in the field of Cultural Studies produced from and on South Asian history in general and Indian context. CS in India has taken a unique turn with the introduction of Subaltern Studies in early 1980s. Its main focus is to deconstruct the foundational theories of knowledge produced in the west and develop its own epistemology based on India's own history and realities. This course tries to focus on Subaltern Studies critic against western cultural theories, how far its claims for alternate historiography are feasible, its own potentials, limitations etc.

LA6060 3
Medical Anthropology
▷Only PG

This course aims to study the ways in which medicine, its practice, institutions and its principles are enmeshed in social relationships and structures. Drawing from an existing and emerging engagement in the field of science, technology and society studies and medical anthropology this course introduces students to the ways in which medicine and its practice comes to be marked by social negotiations. The course will also explore the ways in which cross-cultural notions of disease, pathology and the normal are constructed and debated within an overwhelming culture of Western medicine.
The focus will be on: folk medicine; the clinic; the abnormal-pathological; the idea of curing and prevention; the body; public health; the globalization of health

LA6070 3
Literary And Critical Theory
▷Only PG

This course provides an overview of modern methodologies in literary criticism and theory. Readings include key texts of literary theory from Marxism, Feminism and Psychoanalysis, Post-structuralism, Deconstruction, Postmodernism and Cultural and Postcolonial studies. While this course analyzes various modes of interaction between literature, culture and society, it also provides a basic understanding of concepts, techniques, and vocabularies used in contemporary literary analysis. In tandem with theoretical discourses covered in class, students will be required to examine and analyze select works of fiction according to established procedures of literary research

LA6080 3
Positive Psychology
▷Only Students From Psychology

Positive Psychology is a relatively new approach that focuses on positive psychological aspects as opposed to the clinical/psychopathological perspective of traditional psychology. This course will provide an outline to the basic concepts of positive psychology emphasizing specifically on well-being and strengths. The focus will primarily be on one's understanding of well-being and journey towards it. Answers to the questions raised, will be discovered through an integration of theory and research findings in the area. Relevant concepts will be introduced and their relation to well-being will be examined. These include character strengths and virtues, post traumatic growth, resilience, and positive relationships. Strategies in achieving a state of subjective well being and meaningful life would be explored.

LA6090 3
Contemporary India
▷Only PG

Agrarian issues; industrial labour; urbanization; transnational migration; globalization; environment and development; caste as a system and ideology; relationship between caste and class; the middle classes and consumption; media depictions; gender identities; education and employment; inequalities in access to resources. The course material will consist of chapters in edited volumes, ethnographies, and journal articles. Audiovisual resources will also be used in teaching.

LA6110 3
Critical Psychology

This is an advanced level course in psychology that is focused on training students to examine and analyze contemporary theory and research in psychology from a critical lens. Critical psychology emphasizes that the theories developed in psychology are not merely objective and neutral academic constructs but are produced in sociohistorical contexts. A re-reading of the history of psychology is required in order to understand the biases and assumptions that have subtly guided the development of the discipline. Alternate newer paradigms that are popular in contemporary research will be discussed, with illustrative cases from research studies.
Course Content :
What is critical psychology?; History of psychological thought (positivist and post-positivist); Limitations of mainstream psychology research and theory; New

paradigms in psychology from critical perspectives; Critical studies in health, illness, emotion, identity, development; Feminist psychology; Case studies of contemporary critical research in psychology; Importance of doing socially relevant research in the Indian context

LA6120 **3**
Advanced Theory In Sociology And Social Anthropology
▷Only PG

This course will take a look at theoretical developments in social anthropology from the 19080s, especially after the publication of the book 'Writing Culture'. By looking at some of the recent work by great scholars in the field, the course allows students in social sciences and humanities to grasp more recent developments in the field, such as the focus on discourse, power, governance and citizenship, globalisation, and the public sphere. This will be a seminar-style class where students are required to read ethnographies by reputed scholars, and participate in class discussions. They will write two papers, a mid-term and a final paper, which will long essays on topics chosen by them in consultation with the instructor.

LA6130 **3**
Issues In International Finance
▷Only PG

This course introduces major topics in international ?nance and provides an analytical framework for addressing issues in international monetary economics. This course mainly focuses on exchange rate determination and the effectiveness of the monetary and the fiscal policies of in the open economy.

LA6140 **3**
Quantitative Research Methods For Behvaioral Sciences
▷Only PG

Course Outline:
One of the primary objectives of Behavioural Sciences is to understand behaviour in controlled situations. Behavioural sciences rely heavily on quantitative research methods. Quantitative research methods are extensively used in studies in behavioural sciences. This course will help research scholars get an in-depth understanding of different quantitative research methods and the basic assumptions behind those methods.
Course Outline
- Introduction to Quantitative research methods
- Different types of data
- Ethical issues in behavioural research
- The research process, Defining the research problem
- Research and theory building
- Experimental method, Survey method and questionnaire design, Research Designs
- Determining the sample size, Sampling techniques, Measurement and scaling
- Descriptive and univariate statistics, Multivariate analysis.

LA6160 **3**
American Trancendentalism
▷Only PG

This course examines how America's national and cultural identity in the mid-nineteenth century was constructed largely by the literature and ideology propounded by a group of intellectuals from New England who were famously called the Boston Brahmins. By reading how this group, comprising of names such as Emerson, Thoreau, Whitman, Melville and Hawthorne, among others, exchanged dialogues with the European literary canons and strived to define a new identity that celebrated individualism, egalitarianism and progressivism as the guiding principles of the New World, this course proposes that nineteenth century literature has a profound impact on the national identity of America. By exploring some of the most famous literary works of this period, this course attempts to establish how the Transcendentalist movement has not only played a significant role in upholding the concept of American exceptionalism but also influenced the cultural and political transformations that define contemporary America.

LA6170 **3**
American Fiction After 1945
▷Only PG

This course explores landmark works of fiction in American Literature from 1945 to the present paying particular attention to issues such as history, gender, race, capitalism, the American Dream, and Modernism and Postmodernism in the American novel to examine the social, cultural and intellectual milieu of postwar America. Authors to be considered include Saul Bellow, Truman Capote, John Updike, Cormac McCarthy, Philip Roth, Toni Morrison, Marilynne Robinson, Maxine Hong Kingston, Joyce Carol Oates and Anne E Proulx. In reading these authors the course aims to develop discursive techniques for grasping the complex dynamics between literature and cultural change in contemporary America.

LA6190 **3**
Continental Aesthetics: From The Eighteenth Century to The Present
▷Only PG

Any attempt to create a theoretically dense framework for literary or cultural studies will have to be based on a firm grounding in Continental aesthetics. German and French philosophers of the 18th, 19th, and 20th centuries have dominated the field of aesthetics in the West, and their work has been tremendously influential in creating the tools with which cultural products are analyzed all over the world. In this course, we will read key texts on aesthetics by German Idealists and Romantics (Kant, Hegel, Schlegel, Fichte, Humboldt, Herder, Hamann, Nietzsche) the Phenomenologists (Heidegger, Merleau-Ponty, Levinas, and others), the Poststructuralists (Barthes, De Man, Derrida, Foucault, Lyotard, Baudrillard), Marxism and the Frankfurt School (Marx, Bloch, Sartre, Adorno, Benjamin, Marcuse, Habermas), and the Psychoanalytic and Feminist traditions.

LA6200 **3**
Advanced Econometrics
▷Only PG

Objectives: This course is designed to provide a practical exercise to advance econometrics tools that have been used in economic research. This course is taught primarily through lectures and presentation by students. The course is essential for a research scholar in economics to integrate their research objectives with the advance models to obtain robust outcome.
Course Contents:
• Review of basic econometrics
• Pooling cross section and time series data or Longitudinal model
• Fixed and Random effect model
• Dynamic panel data model
• Binary response models: Logit, Probit and Tobit
• Stochastic production frontier model
• Quantile Regression
• VAR Analysis
• Cointegration and Error-Correction Models
• ARDL model
• Modeling Volatility: ARCH and GARCH Processes

LA6210 **3**
Special Topics In Economic Research
▷Only PG

Course Description:
This course provides an overview of frontier research and recent policy developments in economics. This course will be taught through a mixture of lectures by the instructor and series of presentation by MPhil students. The course will be essential for a research scholar in economics to integrate their research topics with current issues that global economy facing.
Course Content:
• Why Does the Economy Fall to Pieces after a Financial Crisis?
• The Economic Crisis from a Neoclassical Perspective
• Rebalancing Growth in Asia
• Employment and Real macroeconomic stability: The Role of Financial Flows
• Financial Development and GDP Volatility
• The Governance of Financial Regulation: Reform Lessons from the Recent Crisis
• The Rise of Middle Kingdoms: Emerging Economies in Global Trade
• Currency Depreciation, Financial Transfers and Firm Heterogeneity
• The impact of the global financial crisis on business cycles in Asian emerging economies
• Innovation, competition, and growth: Schumpeterian ideas within a Hicksian framework
• The economic impact of technological and organizational innovations: A firm-level analysis
• North-South Technology Spillovers: The Relative Impact of Openness and Foreign RandD
• Productivity shocks, budget deficits and the current account

LA6220 **3**
Culture And Mental Health
▷Only PG

This course is an advanced level course that deals with the interface of culture and psychology in everyday life, focusing in particular on the area of mental health. Traditionally, theory and research in clinical psychology focusses on mental health from an individual biomedical perspective. The aim of this course is to emphasize that mental health and illness can never be studied solely in abstraction but have to be understood in relation to sociocultural contexts. Thus, even something as personal and private as the 'self' is located in a web of social reality. Readings will include contemporary research in transcultural psychiatry, cross-cultural psychology, and cultural psychology. The focus will be on understanding the cultural variations in manifestations of mental illness, with specific emphasis on South Asia in general and India in particular. Illustrations will be taken from studies of healing systems across cultures. Finally, students will learn about the skills in cultural sensitivity in practice.

LA6240 **3**
Sociology Of Globalization
▷Only PG

The objective of this course is to provide students with a sociological perspective on the set of processes commonly referred to as 'globalisation'. It will look at the ways in which social and cultural factors affect attitudes to family and kinship, education, employment, labour practices, migration, media images, and gender ideologies. Through in depth study of ethnographies from different parts of the world, the course aims to educate students on the effect of globalization processes in people's daily lives.

LA6260 **3**
Logical Foundations Of Language And Cognition
▷Only PG

Course Description:
This course will look at the formal foundations of linguistic theories that have a cognitive underpinning. The connections between logic, language and cognition will be traced to their philosophical roots. Questions such as the following are of paramount significance: (i) what is the logical basis of linguistic structures? (ii) how does the logical structure of language relate to cognition? and (iii) why does cognition matter to language at all?

Course Contents:
• Logical roots of linguistic structures and linguistic roots of logical structures
• Formal foundations of linguistic theories as they relate to logicality of language
• Cognitive roots of linguistic structures
• The cognitive basis of linguistic expressions
• Logical roots of cognitive structures
• The logical and linguistic scaffolding of current cognitive theories that bear on linguistic issues

LA6270 **3**
Chronic Disease Management
▷Only PG

This course aims to introduce students to what are chronic diseases and the various factors involved in their management. The course consists of two modules: 1) a theoretical, taught module that includes topics ranging from patient education to supportive care systems (2 credits), and 2) a practical module where students are expected to visit hospitals and conduct a study (1 credit)

LA6280 **3**
Psychological Resilience
▷Only PG

With the emergence of the positive psychology movement in 1998, the focus of psychology research has shifted considerably from the pathological model to the strengths model. This has led to several investigations in the area of resilience. This course aims to trace the history of resilience research through discussion of the concepts of vulnerability, risk and protective factors as proposed by researchers in an attempt to understand the "paradox of resilience." Conceptual issues and methodological constraints faced in resilience research will be presented. Some of the major resilience theories and research will be introduced, evaluated and critiqued. An outline of current research in the area including contributions by Indian researchers, and future directions in the area will be discussed. Assignments will include review of resilience research under specific adversities and with specific samples, and identifying and presenting case studies in resilience/conducting quantitative assessments.

LA6300 **3**
Anthropology And Popular Culture
▷Only Students From Psychology

The aim of this course is to understand the ways in which 'culture', said to be one of the most difficult words in English (Raymond Williams 1976), is expressed and consumed by the people, in popular forms such as music, dance, film and television. The readings for this course will deal with popular culture from different parts of the world- North America, Latin America, Africa, and South Asia. Audio-visual resources will be widely used in lectures and class presentations. This course will contain a project component that requires fieldwork.

LA6310 **3**
Films
▷Only PG

Concepts covered are: gaze, mirror, identification, scopophilia, voyeurism, essentialism, eurocentrism, postcolonialism, objectification, spectatorship, invisible guest, matrixial gaze, counter and parallel cinema, reception-encoding and decoding etc.
Methodology:
Excerpts of a few movies will be screened; You Tube comments (particularly on Indian films) will be put to discussion apart from regular instruction. A small survey on 'spectatorship' will also be conducted by the students. Seminars will be conducted.
Theories:
Film Theories around World War I and after WW II and their differences: Structuralist, Marxist, Screen, Formalist, Feminist, Auteur, Apparatus, Psychoanalytical, Surreal and Postmodern film theories. The course specially focuses on the theoretical contributions of Sergei Eisenstein, André Bazin, Jacques Lacan, Louis Althusser Gilles Deleuze and Stuart Hall.
Indian films:
History: Colonial and postcolonial background of Indian films; impact of the narratives of nationalism, nuclear family, socialism and reform; world acclaimed Indian directors like Satyajit Ray and feminist directors; Indian Art Movies; Feminist counter movies by Indian female directors- film as a political tool (sexual oppression to freedom/lesbian rights and uni-gender) Different popular genres- commercial, art, neo-classical.

LA6350 **3**
Advanced Introduction To Science, Technology And Society
▷Only PG

This course provides an advanced introduction to the interdisciplinary field of Science and Technology Studies (STS). The focus will be on different intellectual traditions through which scholars have conceptualized technoscience-society interactions. By the end of the course, students will have developed a broad understanding of different regional, thematic, and conceptual approaches to the study of science, technology, and society. Literatures introduced in the course will include, among others, social constructivism, actor network theory, feminist and postcolonial STS, as well as more regionally focused literatures such as South Asian, East Asian, Latin American, and African STS.

LA6370 **3**
Organizational Theory
▷Only PG

Organizational effectiveness is an interplay of macro and micro level factors. Macro level factors like organizational structure, strategy, technological process influence micro level factors like behavior of employees and vice versa. Researchers aim to understand

behavior in work places should be cognizant of the larger macro level factors which influence employee behavior like attitude, motivation and emotions and also the interplay between them. With this background this course aims to introduce theories and concepts related to these macro level factors to doctoral students who are planning to do research in the area of industrial psychology and work behavior.

LA6380 **3**
Advanced Theories In Social Anthropology II
▷Only PG

This course continues theoretical and methodological discussions initiated during the course LA 6120, Advanced Theories in Social Anthropology. Students enrolled for this course will be already familiar with broad transformations in disciplinary orientation in the wake of the "crisis of representation." This course aims to help students connect these ongoing discussions in the discipline of anthropology to their own research interests, engaging with additional theoretical and methodological texts and frameworks as they relate to students' particular research projects.

LA6400 **3**
Humor And Well-being
▷Only PG

The recent positive psychology movement has brought to attention the importance of humour in the context of well-being. Humour has been regarded as an intriguing part of behaviour by researchers; yet one often fails to acknowledge the functional aspects of humour in our everyday lives. This course attempts to illustrate that humour deserves to be "taken seriously". The course has been designed to provide students with a scientific understanding of the processes involved in the psychology of humour with the overall objective of linking it to well-being. This course will present discussions from evolutionary, developmental, and social standpoints while introducing theoretical perspectives on humour. Related concepts such as smiling and laughter, application of humour in everyday life, personality and individual differences in humour, and the effect of humour on health will be highlighted. Finally, findings from empirical investigations would be discussed in the process of gaining insight and understanding into humour experiences.

LA6440 **3**
Visual Anthropology
▷Only PG

The history of the discipline of anthropology is a history of its technologies of documentation and representations. Of these, the visual mode of engaging with and 'showing' the object of research has been the site for much debate with regard to its efficacy as a theoretical tool. Can the visual, like the text, generate a theoretically sound analysis? Or does engagement with the visual bring to surface the theoretical gaps in textual analysis? This course will dwell upon anthropology's history of visual documentation of the bodies, indigineity and cultures, and trace the entanglement of power and 'ways of seeing' embedded in the development of professional anthropology. Beginning with colonial 'showcases' and exhibitions, the course maps anthropology's affinity with photography and film, to understanding the nature of ethnography within new visual scapes of the Internet.

LA6450 **3**
Literature And Culture Of the Diaspora
▷Only PG

This course will examine diverse literatures of the diaspora from the Indian, Jewish/Palestinian, and African contexts to understand the body of anxieties that characterize diasporic cultural identity. With a focus on works by Bharati Mukherjee, Chitra Banerjee Divakaruni, and Shaun Tan (The Arrival), we will study how the themes of home and exile, dislocation and nostalgia, memory and history, feature in the literary-cultural structuration of diasporic experiences. We will undergird our readings with samplings of cinematic texts (Mira Nair, Gurinder Chadha) and extracts from postcolonial and diaspora theory (Homi Bhaba, Stuart Hall, Benedict Anderson).

LA6460 **3**
Scholarly Research and Writing in the Humanities: Pedagogy and Practice
▷Only PG

This course will offer an in-depth training and orientation in the methodologies of scholarly research and writing for advanced students in the humanities. Lectures and assignments will be aimed at guiding students through their current academic projects. Mid-Semester and End-Semester evaluations will require the submission of take-home essays that raw on class exercises.

16.10 Department of Mathematics

MA3120 **3**
Theory of Polynomials

Polynomials, factorization, Inequalities for roots, The resultant and the discriminant, Lagrange's series, Irreducibility criteria, Hilbert's irreducibility theorem, The cyclotomic polynomials, Chebyshev polynomials, Bernoulli polynomials, Hilbert's Seventeenth Problem

MA3140 **2**
Statistical Inference

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 **1**
Statistical Analysis Using R
▷MA 2110, MA 2140

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 **2**
Computational Algebra-i Mathematical Computing With Mathematica

Computations in Number Theory, Calculus, Linear Algebra; and modeling, Visualization and Geometry

MA3310 **3**
Basic Cryptography

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 **3**
Diophantine Equations

Lattices, quadratic forms, algebraic numbers, class group, class numbers, Diophantine aspects of elliptic curves, analytic tools.

MA3610 **0**
Variational Calculus
▷MA1220

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 **1**
Some Special Functions in Mathematical Analysis

Exponential and Logarithmic function. The Trigonometric functions. The Gamma function. The characterization of Gamma function. Introduction to Fourier Series and Fourier transform.

MA4010 **3**
Analysis of Functions of a Single Variable
▷

•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 **3**
Linear Algebra

• 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 **3**
Ordinary Differential Equations
▷

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.

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
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
Analysis of Functions of Several Variables
▷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 Advanced Linear Algebra	**1**	Vector spaces, multilinear maps, tensor product of vectors, exterior product, tensor algebra and exterior algebra
MA4133 Computational Algebra On Polynomials and Ideals	**2**	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 Homological Algebra I	**1**	Categories, Functors, Chain complexes, Derived functors, Left/Right Exactness, Tor and Ext. Group homology and cohomology
MA4143 Time Series Analysis ▷MA 2110, MA 2140	**1**	Testing randomness of a time series, test for trend, seasonality test; Estimation and elimination of trend and seasonality, moving average smoothing, 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; Invertibility of linear stationary processes; Auto covariance generating function; Parameter estimation of AR, MA and ARMA models-LS approach, Model identification with ACF and PACF. Some classical algorithms for model building
MA4145 Design of Experiments ▷MA 2110, MA 2140	**2**	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 Homological Algebra II	**2**	Category Theory: Categories, Functors, Natural Transformations, Abelian Categories, Limits and Colimits, Adjoint Functors. Chain complexes, Homological Dimension, Spectral Sequences
MA4170 Linear Algebra Over Commutative Rings	**1**	Commutative rings, modules and their homomorphisms, sub-modules and quotient modules, tensor product
MA4210 Algebraic Curves and Integer Factorization	**2**	Ideals in polynomial rings, Hilbert's nullstellensatz, projective varieties, algebraic curves. elliptic curve in projective plane, integer factorization using elliptic curve
MA4220 Geometry of Complex Numbers	**2**	Holomorphic and meromorphic functions, compact Riemann surfaces, holomorphic maps, coverings, projective space and complex projective curves
MA4230 Advanced Calculus	**2**	Differentiation, integration, inverse function theorem, implicit function theorem, manifolds, differential forms, Stokes' theorem
MA4310 Topics in Number Theory	**3**	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 Representation of Finite Groups	**2**	Representation of finite groups, complete reducibility, Schurs lemma, characters, projection formulae, induced representation, Frobenius reciprocity.
MA4610 Classical Results in Analysis and Applications ▷MA1110, MA1220	**1**	Implicit function theorem. Inverse function theorem. Stone-Weierstrauss theorem. Banach-Stone theorem. Arzela-Ascoli theorem. Mazur-Ulam theorem
MA4710 Topology and Its Applications	**1**	Topological spaces, quotient topology, separation axioms, connectedness and compactness. (If time permits:) Brief introduction to topological data analysis
MA5010 Combinatorics and Graph	**3**	• 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**
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.

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

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
▷MA 4070

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 **2**
Combinatorial Commutative Algebra
▷MA 4070

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 3
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.

MA6210 3
Curves and Surfaces

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

16.11 Department of Mechanical and Aerospace Engineering

ME5010 3
Mathematical Methods for Engineers
▷see syllabus

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

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.

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

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.

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

Overview of Rapid Product Development: Product Development Cycle, virtual prototyping, physical prototyping, Solid Modelling: Data formats, conversion, checking,

▷PG Only

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.

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
▷ME2030, ME3010, ME3040, ME3050

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
▷ME5310

Introduction to interfacial flows - Governing equations and boundary conditions - Laplace Pressure - Minimal surfaces - Young's law - Fluid statics - Hydrodynamics of Interfaces: Thin films, Rayleigh-Taylor 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; Newton's law of viscosity; velocity potential and stream function; Derivation of continuity equation; potential flows; Euler equations; Derivation of Navier-Stokes equations; Elliptic and Parabolic equations; boundary conditions; Analytical solutions of NS equations; Boundary layer Theory; Similarity solutions; Approximate methods; Turbulence; RANS equations; Introduction to Turbulence modelling; Non-dimensionalization, and non-dimensional parameters.

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

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

Propagation of 1D stress pulse, coaxial collision of bars, reflection and superposition, review of continuum mechanics, dilatational and shear waves, Rayleigh and Lamb waves,

▷ME3150 or ME5110 or ME5020	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** Aerial Robotics: Dynamics of Drones	3D rigid body kinematics – representation of rotation – rotation matrix – Euler angles – 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.
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.
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.

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 - elementary and global reactions, collision theory, rate of reaction in

Chemical Kinetics and Modeling in Reacting Flows	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.
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.
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.

16.12 Department of Materials Science and Metallurgical Engineering

MS5010 **3**
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

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

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

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**
Composite Materials

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.

MS5110 **3**
Scientific Writing and Ethics in Research

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

MS5120 **3**
Materials for Green Energy

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

MS5130 **3**
Powder Metallurgy Manufacturing

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.

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)

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 **3**
Phase Transformations

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.
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 Advanced Manufacturing	**3**	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 Functional Ceramics	**3**	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**	Types of casting processes and heat transfer fundamentals for casting; Stefan problem for

Solidification Processing	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.

16.13 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** Electronics	Introduction, Thevenin's Theorem, Norton's Theorem, Diode Theory, Rectifiers, Optoelectronics devices (LED, Photodiode, Laser Diode), Transistors and their frequency response (BJT, JFET, MOSFET,), Voltage and Power amplifiers, Differential Amplifiers, Operational amplifiers
PH5147 **1** Classical Mechanics	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 **2** Experimental Techniques	Vacuum Techniques, Spectroscopic Techniques, Charged Particle Optics, Data Analysis, Error Analysis
PH5288 **1** Digital Electronics	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 **1** Fluid Mechanics ▷for honors students	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 **2** Computational Physics	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 **2** Laser Spectroscopy	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 **1** Accelerator Physics	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 **2** Accelerator Physics-ii ▷PH2218	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 **2** Laser Technology	Atomic Radiation - line shape and broadening of spectral lines; Laser oscillations and amplification - gain saturation in homogenous and inhomogenous broadened transitions;

▷PH3338	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 2 Ultrafast Optics ▷PH3338	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 2 Feynman Diagram Techniques in Condensed Matter Physics	Second quantization; Zero and Finite temperature Green functions; Feynman rules; Homogeneous electron gas; Strongly correlated systems, Linear response theory
PH6068 2 Computational Solid State Physics	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 2 Physics of Surfaces and Interfaces	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 Theory of Phase Transitions	Mean field theory, symmetry and order parameter, Ginzburg-Landau theory, 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**

Introduction to micromagnetic equilibrium, solutions of micromagnetic equations, finite

Micromagnetics	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 1 Physics and Applications of Functional Materials	Introduction to Functional Materials, Structure of typical materials, Ferroelectricity, Piezoelectricity, magnetoresistance (GMR, CMR etc) magnetocaloric materials.
PH6318 2 Physical Biology of the Cell	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 1 Nuclear Physics	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 2 Non-equilibrium Statistical Mechanics	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 2 Advanced Functional Materials	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 2 Crystallography	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 2 Nonlinear Dynamics and Chaos	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 2 Quantum Field Theory	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 2 Quantum Optics	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 2 Fundamentals of Semiconductors Physics and Devices	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 2 Microfabrication Techniques	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 Gravitation and Cosmology	Review of Special Relativity, General relativity, Equivalence principle, tensor Analysis, 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**
Advanced Optical Instrumentation
▷PH3338

Basics Optics overview; Optical Instrumentations: Optical materials and components, 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.

Cover: The Fractal Academics at IIT Hyderabad is inspired by the fractals patterns that are self-similar across different scales. They are formed when similar patterns recur at progressively smaller & larger scales. The IITH logo seen on the cover is one such fractal curve formed through Hilbert filling of the space with variable densities.