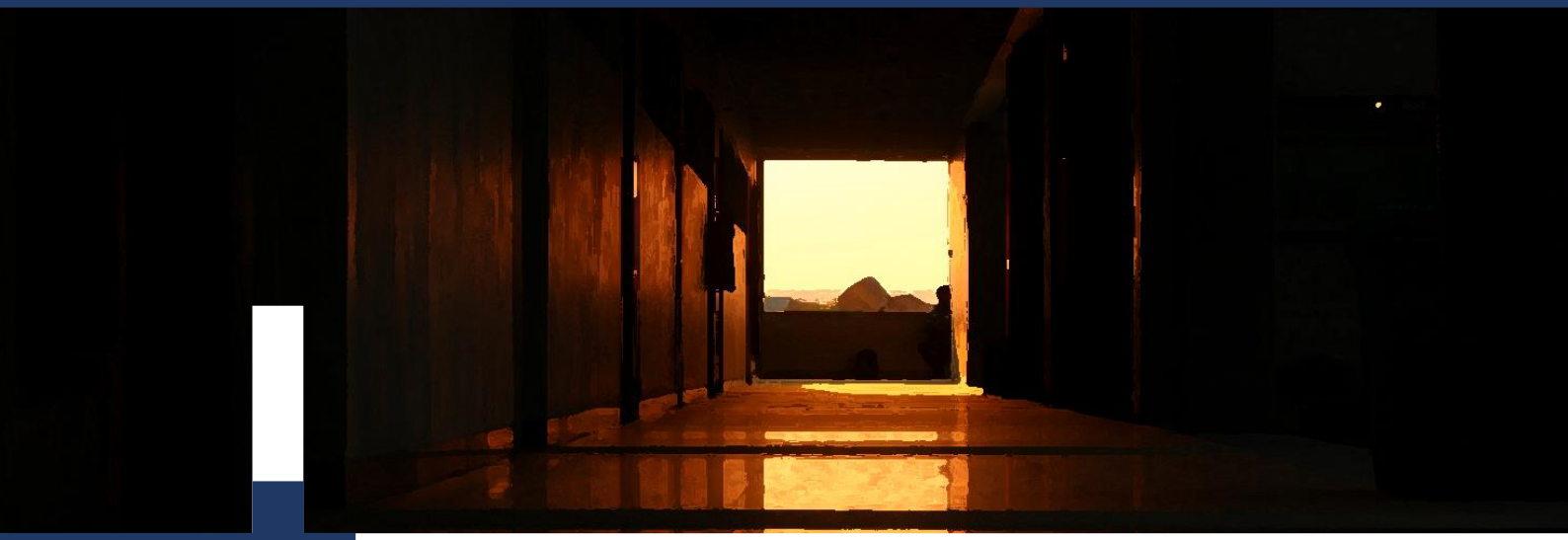
INDIAN INSTITUTE OF TECHNOLOGY
HYDERABAD



Fractal Academic Program

Course Booklet 2017-18

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

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Message from Director

Fractal Academics

At IITH we are exploring a new approach to structuring the academic curriculum. We grapple with many questions in educating our students: lack of motivations among students, low attendance and uneven student interest. Other challenges include: the gulf between theory and practice, breadth vs. depth, and the relevance of non-core subjects. How do we tailor the curriculum based on individual potential? How do we make the curriculum interdisciplinary? How do we increase industry interactions? How do we incorporate research in under graduate curriculum? This list of questions is by no means exhaustive, and each question, perhaps, begets a thesis.

In order to provide some resolution to these difficult questions, we first started with fractional credit courses. A typical 3-credit course has 42 contact hours; we developed courses with 0.5, 1.0, 1.5, 2.0, 2.5, and 3 credits having 7, 14, 21, and 28, 35 and 42 contact hours. The motivation was to atomize the teaching program and also involve industry partners in some aspects of academics. The student enthusiasm, their commitment, and their output was very high in these courses. Based on the overall success of fractional credit courses, we developed a complete 4-year curriculum, referred to as Fractal Academics. The core of fractal academics is that breadth courses are of 1 credit, while depth courses are typically of 1.5 to 2.5 credits. In essence, we are atomizing the academic program, providing a more holistic education, and in the long run giving students the choice to design their curriculum.

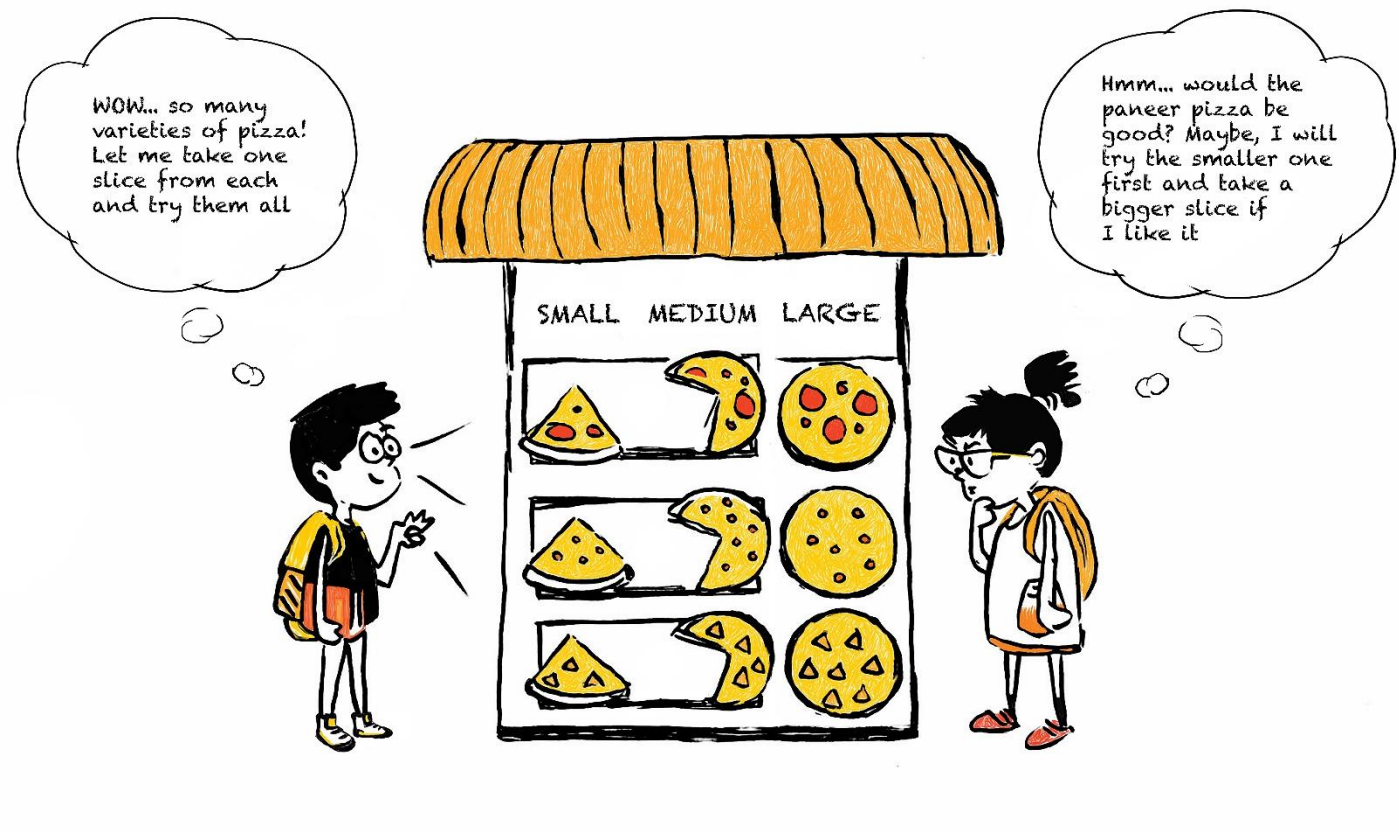
Fractal Academics was first implemented at IITH for the Electrical Engineering Department in Aug 2013. From Aug 2014 all engineering departments followed Fractal Academics. In 2016 Aug, Fractal Academics was also implemented at IIT Bhilai in Computer Science and Engineering, Electrical Engineering and Mechanical Engineering.

Fractal Academics was developed by the faculty of IITH and it is to them the novel academic program owes its success. Also, the students of IITH deserve a very special thanks for experimenting with and accepting this novel program.

Fractal Academics is constantly evolving based on feedback from students and faculty. We believe that it should evolve continuously and keep pace with changing times and changing aspirations of the students.

Contents

Introduction



The Fractal program at IITH atomizes the courses into breadth and depth, allowing the student to pursue interdisciplinary learning with a wide array of basic courses as well as pursue any subject in greater depth.

Perceived Role of Higher Education

- Convey knowledge
- Create knowledge
- Create and develop ideas
- Innovations
- Publish
- Develop future citizens
- Create a better society

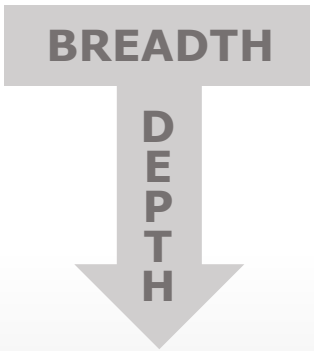
Some Questions

- Does the curriculum need complete overhaul?
- What are the right models of teaching and learning now that the traditional lecture seems obsolete?
- Which students should be targeted?
- Just as we've seen the forces of technology and globalization transform sectors such as media and communications or banking and finance over the last two decades, these forces may now transform higher education.
- The traditional university is being unbundled

Some More Questions...

- Why the lack of motivation among students?
- Why the low attendance?
- Why the uneven student interest?
- How do we bridge the gulf between theory and practice?
- How do we bridge the gulf between breadth and depth?
- What is the relevance of non-core subjects?
- How do we have a flexible curriculum?
- How do we space the curriculum based on individual potential?
- How do we make the curriculum interdisciplinary?
- How do we increase industry interactions?
- How do we incorporate research in under graduate curriculum?
- Has the 3 credit hour system outlived its utility?

Philosophy: The new program should capture



- T-Education
- Breadth with depth
- Flexibility
- Foster interdisciplinarity
- Wider choice of electives
- Foster research at the undergraduate level
- Synergy in projects – hopefully leading to products
- Students can pace their program
- Greater choice for knowledge acquisition and specialization
- Encourage creativity
    - | Bouquet of courses in Creative Arts (music, movie making, fine arts, photo journalism, performing arts, etc.)

Initial Attempts: Fractional Credit Courses

- Strong industry interaction
- A typical 3 lecture course has 3 credits leading to 42 lecture hours in a semester.
- Fractional credits can be 0.5, 1, 1.5, 2.0, 2.5, 3.0 having 7, 14, 21, 28, 35 and 42 lecture hours respectively.
- Some examples of fractional credit courses that were offered in the 2011-2012 and 2012-2013 academic years are:
    - | Trends in Storage Systems (by NetApp)
    - | Mobile Applications (by Adobe)
    - | Data Management and Computing on the Cloud
    - | Empowering Three Billion (taught by former President Dr. Kalam)
    - | Finance and Economy
    - | Sales and Marketing
    - | Photo Journalism
    - | Movie Making
    - | Drama (Performing Arts)
    - | Courses by Visiting Faculty in Math and EE from the USA

Fractal Academic Program

- A novel academic program implemented at IITH – we believe it is first of its kind
- Atomize the courses and programs
- 1 credit courses for breadth
  - | Core courses
- 1.5, 2, 2.5 credit courses for depth
  - | Specialized courses
  - | Electives
  - | Projects and building prototypes / products
  - | Bridging gulf between theory and practice

1 Credit Courses

- Form foundation for the core courses
- Help interdisciplinary education
- Open to all students – allows for greater breadth
- Students have the option of greater number of interesting courses
- Allow students to better tailor their coursework and choose across Departments
- Large basket of non-technical courses (Liberal Arts + Creative Arts)
- Better access to a wide variety of courses increases exposure and preparedness for research
- Synergy in projects - foundation for product development
- A balance is sought between technical and non-technical courses to reduce stress when students enter IIT Hyderabad
- The first two semesters expose students to all the basic tools required for the rest of their Bachelors program
- The curriculum potentially makes students ready for internship right after the first year

Concluding Remarks

- This is just the beginning; a lot more needs to be done
- Need to think creatively and out of the box
- Fractal Academics is an evolutionary program
  | Will need tuning with fast-changing times

Acknowledgements

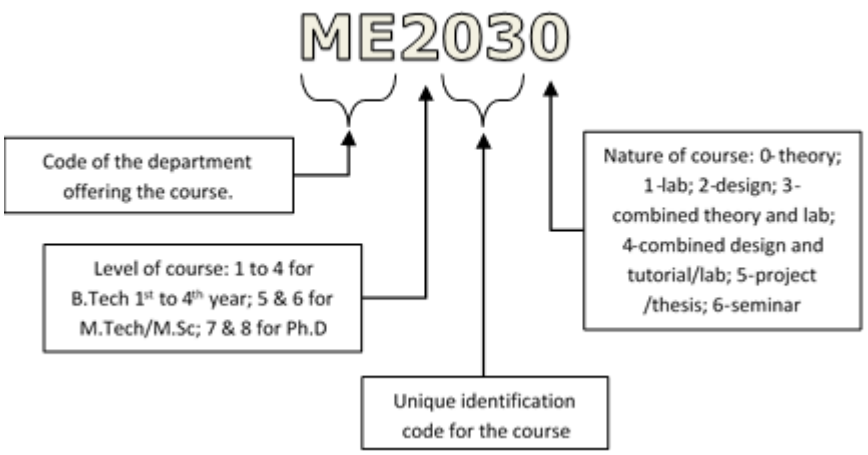
Special thanks to Prof. Raj Reddy of CMU for providing the core idea of 1 credit courses.

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 alphabets 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 * 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					

B.Tech Course Curriculum

The curriculum at IITH ensures larger scope for project component in each course. This would help in bridging the gulf between theory and practice and fostering research at UG level.

CHEMICAL ENGINEERING

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 1									
CH1010	Material & Energy Balance	2	14						
CH1030	Fluid Mechanics	2	36						
CH1050	Introduction to Mass Transfer	1	56						
ID1035	Independent Project	1	16						
ID1054	Digital Fabrication	2	16						
ID1171	Fabrication Lab - I	2	16						
MA1110	Calculus-I	1	12						
MA1220	Calculus-II	2	36						
PH1017	Classical Physics	1	34						
PH1031	Physics Lab	2	16						
	Total	*16*							
Semester 2									
CH1020	Introduction to Thermodynamics	2	14						
CH1021	Chemical Engineering Lab	1	16						
CH1040	Chemical Reaction Engineering-I	2	14						
CH1060	Heat Transfer	2	14						
CH1080	Separations Process - I	2	14						
CY1020	Dynamics of Chemical Systems-I	1	12						
ID4006	Professional Ethics	1							
LAxxxx	LA/CA Elective	1							
MA1130	Vector Calculus	1	12						
MA1140	Linear Algebra	1	34						
MA1150	Differential Equations	1	56						
PH1027	Electromagnetism and Maxwell's Equations	1	34						
	Total	*16*							
Semester 3									
CH2010	Mechanical Operations	2	14						
CH2011	Applied Chemistry Lab	1	16						
CH2030	Numerical Methods-I	2	14						
CHxxxx	Core Elective Basket: Biological Processes	3							
CY1030	Environmental Chemistry-II	2	36						
CY1017	Environmental Chemistry-I	1	12						
CY1031	Chemistry lab	2	16						
ID1041	Engineering Drawing	2	16						
ID1303	Introduction to Programming	2	36						
MA2120	Transforms	1	34						
	Total	*18*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 4									
CH2020	Basic Control Theory	1	12						
CH2021	Mechanical Operations Lab	1	16						
CH2040	Heat Transfer Equipment & Design	2	36						
CH2060	Numerical Methods-II	2	36						
CH2080	Chemical Reaction Engineering -II	2	14						
CH2100	Heterogeneous Reaction Engineering	2	36						
CH2120	Fluid Mechanics Lab	1	16						
CHxxxx	Core Elective Basket: Energy & Environment	3							
LAxxxx	LA-1/CA-1	2							
MA2130	Complex Variables	1	12						
	Total	*17*							
Semester 5									
CH3010	Separation Process II	2	14						
CH3011	HT Lab	1	16						
CH3030	Transport Phenomena-I	2	14						
CH3031	MT Lab	1	16						
CH3050	Control Design and Analysis	2	36						
CH3070	Chemical Engineering thermodynamics-I	2	14						
CH3090	Chemical Engineering thermodynamics-II	1	56						
CHxxxx	Core Elective Basket: Materials	3							
LAxxxx	LA-2/CA-2	2							
	Total	*16*							
Semester 6									
CH3020	Transport Phenomena-II	2	14						
CH3021	Reaction Engineering Lab	1	16						
CH3022	Mass Transfer Equipment Design	1	14						
CH3041	Process Control Lab	1	16						
CH3042	Plant Design -I	2	14						
CHxxxx	Core Elective Basket: Chemical Processes	3							
LAxxxx	LA-3/CA-3	2							
	Total	*12*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 7									
CH4010	Safety	1	56						
CH4011	Process Simulation Lab	2	16						
CH4012	Plant Design-II	1	56						
LAxxxx	LA-4/CA-4	2							
XXxxxx	Free Electives I	5							
	Total	11							
Semester 8									
CH4020	Optimization	2	14						
LAxxxx	LA-5/CA-5	2							
XXxxxx	Free Electives II	5							
	Total	9							
	Total Credits (without free electives)	115							
	Free electives (can be taken in any semester)	10							
	Total Credits	**125**							

Core Elective Basket: Biological Processes (Semester-3)									
CHXXXX	Systems Biology	1							
CHXXXX	Drug delivery systems	1							
CHXXX	Introduction to Biological Engineering	1							
CHXXX	Advanced Biochemical Engineering	2							
Core Elective Basket: Energy and Environment (Semester-4)									
CHXXXX	Energy Storage Systems	2							
CHXXXX	Sustainable and Energy Options	1							
CHXXXX	Introduction to Fuel Cells	1							
CHXXXX	Biorefinery	1							
CE3512	Environmental Engineering	1							
CE3522	Water and Waste Water Engineering	2							
CE3530	Air Pollution	2							
Core Elective Basket: Materials (Semester-5)									
CHXXXX	Engineering Materials	1							
CHXXXX	Concepts in Soft Matter Systems	2							
CHXXXX	Introduction to Nanotechnology	1							
CHXXXX	Interfacial Chemistry	1							
Core Elective Basket: Chemical Processes (Semester-6)									
CHXXXX	Chemical Technology	1							
CHXXXX	Petrochemical Industry	1							
CHXXXX	Petroleum Refinery	1							
CHXXXX	Process Intensification	1							
CH6550	Chemical Reactor Modeling	2							
CHXXXX	Fluidization Technology	1							
CHXXXX	Mineral Processing	1							

CIVIL ENGINEERING

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 1									
ID1035	Independent Project	1	16						
CY1017	Environmental Chemistry-I	1	12						
ID1041	Engineering Drawing	2	16						
ID1054	Digital Fabrication	2	16						
ID1100	Fluid Mechanics-I	2	46						
ID1130	Engineering Statics	2	13						
ID1171	Fabrication Lab - I	2	16						
ID1303	Introduction to Programming	2	36						
MA1110	Calculus-I	1	12						
MA1220	Calculus-II	2	36						
	Total	*17*							
Semester 2									
CE2020	Construction Materials	1.5	46						
CE3512	Introduction to Environmental Engineering	1	12						
CY1020	Dynamics of Chemical Systems-I	1	12						
EE1330	DSP	1	34						
ID1140	Thermodynamics - I	1	12						
ID1150	Thermodynamics - II	2	36						
ID1160	Solid Mechanics - I	2	13						
LAxxxx	LA/CA Elective	2							
MA1130	Vector Calculus	1	12						
MA1140	Linear Algebra	1	34						
MA1150	Differential Equations	1	56						
ME1030	Dynamics	2	46						
	Total	*16.5*							
Semester 3									
CE2021	Construction Materials Lab	2	16						
CE2030	Concrete Technology	1.5	13						
CE2031	Fluid Mechanics Lab	1	13						
CY1031	Chemistry lab	2	16						
EE1010	Electric Circuits	1	12						
ID1110	Fluid Mechanics - II	1.5	13						
ID2020	Solid Mechanics-II	2	46						
MA2110	Probability	1	12						
MA2120	Transforms	1	34						
PH1017	Classical Physics	1	34						
PH1031	Physics Lab	2	16						
	Total	*16*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 4									
BO1010	Introduction to Life Sciences	1	34						
CE2100	Introduction to Structural Analysis	1.5	13						
CE2101	Structural Mechanics Lab	2	46						
CE2110	Analysis of Indeterminate Structures	1.5	46						
CE3300	Geotechnical Engineering-I	1.5	13						
CE3301	Geotechnical Engineering Lab	2	16						
CE3310	Geotechnical Engineering-II	1.5	46						
LAxxxx	LA/CA Elective	2							
MA2130	Complex Variables	1	12						
MA2140	Statistics	1	34						
	Total	*15*							
Semester 5									
BM1030	Bio-Engineering	1	56						
CE2500	Engineering Hydrology	2	14						
CE3102	Introduction to Reinforced Concrete	1.5	13						
CE3122	Reinforced Concrete Design	1.5	46						
CE3312	Introduction to Foundation Engineering	1	12						
CE3322	Design of Foundations	2	36						
CE3500	Introduction to Hydraulic Engineering	1.5	13						
CE3501	Hydraulic Engineering Lab	1	56						
CE3522	Water and Wastewater Engineering	2	14						
CE3820	Highway Design and Materials	2	14						
CE3830	Railway and Airport Engineering	1	56						
XXxxxx	Core Electives / Projects	0-3							
	Total	*16.5-19.5*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 6									
CE3010	Fundamentals of GIS and Remote Sensing	2	14						
CE3011	GIS Lab	1	34						
CE3132	Design of Steel Structures	1.5	46						
CE3142	Introduction to Structural Steel Design	1.5	13						
CE3510	Open Channel Hydraulics	1.5	13						
CE3530	Air Pollution	2	14						
CE3821	Highway Materials Lab	1	56						
CE3840	Traffic Engineering and Planning	2	14						
CE3841	Traffic Engineering Lab	1.5	46						
LAxxxx	LA/CA Elective	2							
XXxxxx	Core Electives / Projects	0-3							
	Total	*16-19*							
Semester 7									
CE3020	Surveying	2							
CE3511	Environmental Engineering lab	2	16						
CE4500	Water Resources Engineering	2	36						
CE4900	Construction Management	2	16						
LAxxxx	LA/CA Elective	2							
XXxxxx	Core Electives / Projects	3-6							
	Total	*13-16*							
Semester 8									
CEXXXX	Environmental Impact Assessment	2	36						
ID4006	Professional Ethics	1							
LAxxxx	LA/CA Elective	2							
XXxxxx	Core Electives / Projects	3-6							
XXXXXX	Free Electives	6							
	Total	*16*							
	Total Credits	***128***							

COMPUTER SCIENCE AND ENGINEERING

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 1									
CS1310	Discrete Structures I	2	14						
CYXXXX	CY Electives	1							
EE1110	Applied Digital Logic Desgn	1	12						
EE1120	Digital Logic Design	1	34						
ID1035	Independent Project	1	16						
ID1054	Digital Fabrication	2	16						
ID1303	Introduction to Programming	2	36						
LAxxxx	LA/CA Elective	1							
MA1110	Calculus-I	1	12						
MA1220	Calculus-II	2	36						
PHXXXX	PH Electives	1							
	Total	15							
Semester 2									
BOXXXX	BO Electives	1							
CS1340	Discrete Structures II	2	36						
CS1353	Introduction to Data Structures	3	36						
CYXXXX	CY Electives	1							
EE1330	DSP	1	34						
LAxxxx	LA/CA Elective	2							
MA1130	Vector Calculus	1	12						
MA1140	Linear Algebra	1	34						
PHXXXX	PH Electives	2							
XXxxxx	Free Electives	1							
	Total	15							
Semester 3									
CS2233	Data Structures	3	16						
CS2323	Computer Architecture	2	14						
CS2400	Principles of Programming Languages I	1	56						
CS3510	OS I	1	56						
LAxxxx	LA/CA Elective	2							
MA2110	Probability	1	12						
PH1031	Physics Lab	2	16						
PHxxxx	PH electives	1							
XXxxxx	Free Electives	2							
	Total	15							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 4									
CS2410	Theory of Computation	2	14						
CS2420	Introduction to Complexity Theory	1	56						
CS2433	Principles of Programming Languages II	3	16						
CS2443	Algorithms	3	16						
CS3320	Compilers-I	1	56						
CS3523	OS II	3	16						
MAxxxx	MA Elective	1							
XXxxxx	Free Electives	2							
	Total	*16*							
Semester 5									
BMXXXX	BM Electives	1							
CS3423	Compilers-II	3	16						
CS3530	Computer Networks I	1	56						
CS3550	DBMS I	1	56						
CSxxxx	Dept Electives	3							
LAxxxx	LA/CA Elective	3							
XXXXXX	Free Electives	5							
	Total	*17*							
Semester 6									
CS3543	Computer Networks II	3	16						
CS3563	DBMS II	3	16						
CSxxxx	Dept Electives	5							
LAxxxx	LA/CA Elective	3							
XXXXXX	Free Electives	3							
	Total	*17*							
Semester 7									
CS4443	Software Engineering	3	16						
CSxxxx	Dept Electives	6							
LAxxxx	LA/CA Elective	3							
XXxxxx	Free Electives	3							
	Total	*15*							
Semester 8									
CSxxxx	Dept Electives	6							
ID4006	Professional Ethics	1							
LAxxxx	LA/CA Elective	2							
XXxxxx	Free Electives	6							
	Total	*15*							
	Total Credits	***125***							

ELECTRICAL ENGINEERING

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 1									
BM1030	Bio-Engineering	1	56						
EE1010	Electric Circuits	1	12						
EE1020	Magnetic Circuits	1	56						
EE1110	Applied Digital Logic Design	1	12						
EE1120	Digital Logic Design	1	34						
EE1310	Signals and Communications	1	56						
EE1320	Internet of Things (IOT)	1	12						
ID1035	Independent Project	1	16						
ID1054	Digital Fabrication	2	16						
LAxxxx	LA/CA Elective	1							
MA1110	Calculus-I	1	12						
MA1220	Calculus-II	2	36						
PH1017	Classical Physics	1	34						
	Total	*15*							
Semester 2									
EE1130	Analog Circuits	1	34						
EE1140	Semiconductor Fundamentals	1	12						
EE1150	Embedded programming	1	56						
EE1210	Basic Control Theory	1	12						
EE1330	Independent Project	1	16						
EE1330	DSP	1	34						
EE1410	Data Structures	2	34						
EE1510*	Matrix Analysis	1	34						
EE1520*	Data Analytics	2	36						
LAxxxx	LA/CA Elective	1							
MA1130	Vector Calculus	1	12						
MA1150	Differential Equations	1	56						
XXxxxx	Free Elective	1							
	Total	*15*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 3									
CY1017	Environmental Chemistry-I	1	12						
CY1031	Chemistry lab	2	16						
EE2015	EE Independent Project	1	16						
EE2110	Microprocessors	1	56						
EE2120	Device Physics	2	14						
EE2210	Transformers and DC Machines	2	14						
EE2220	AC Machines	1	56						
EE2230	Power Electronics	1	56						
EE2310	Random Processes	1	34						
EE2320	Digital Modulation Techniques	1	56						
LAxxxx	LA/CA Elective	2							
XXxxxx	Science Elective	1							
	Total	*16*							
Semester 4									
EE2025	EE Independent Project	1	16						
EE2140	CMOS Fabrication	1	56						
EE2150	Digital Electronics	1	12						
EE2160	Embedded Systems	1	12						
EE2170	Mixed Signal Electronics	1	34						
EE2211	Electrical Machines Lab	2	16						
EE2240	Control Systems	2	36						
EE2250	Renewable Energy and Power Systems	1	56						
EE2330	Antenna Design	1	56						
EE2340	Information Sciences	1	12						
LAxxxx	LA/CA Elective	2							
MA2130	Complex Variables	1	34						
PH1027	Electromagnetism and Maxwell's Equations	1	34						
	Total	*16*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 5									
EE3210	Smart grid	1	12						
EE3220	Power System Practice	2	36						
EE3310	Advanced DSP	2	36						
EExxxx	Core Electives	3							
IDxxxx	Independent Project	1	16						
LAxxxx	LA/CA Elective	2							
XXxxxx	Science Elective	2							
XXxxxx	Free Elective	3							
	Total	*16*							
Semester 6									
EExxxx	Core Electives	9							
IDxxxx	Independent Project	1	16						
LAxxxx	LA/CA Elective	1							
XXxxxx	Science Elective	1							
XXxxxx	Engineering Elective	2							
XXxxxx	Free Electives	3							
	Total	*17*							
Semester 7									
CAxxxx	Creative Arts Electives	1							
EE4015	EE Independent Project	3	16						
EExxxx	Core Electives	3							
LAxxxx	LA Elective	1							
XXxxxx	Science Elective	1							
XXxxxx	Free Electives	6							
	Total	*15*							
Semester 8									
CAxxxx	Creative Arts Electives	1							
EE4025	EE Independent Project	3	16						
EExxxx	Core Electives	3							
LAxxxx	LA Elective	1							
XXxxxx	Science Elective	1							
XXxxxx	Free Elective	6							
	Total	*15*							
	Total Credits	***125***							

ENGINEERING PHYSICS

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 1									
EE1010	Electric Circuits	1	12						
EE1020	Magnetic Circuits	1	56						
EE1110	Applied Digital Logic Design	1	12						
EE1120	Digital Logic Design	1	34						
ID1035	Independent Project	1	16						
ID1054	Digital Fabrication	2	16						
ID1303	Introduction to Programming	2	36						
MA1110	Calculus-I	1	12						
MA1220	Calculus-II	2	36						
PH1017	Classical Physics	1	34						
PH1567	Maths for Physics- I	1							
PH2217	Classical Electromagnetism	1							
EE1320	Internet of Things (IOT)	1	12						
XXxxxx	Free elective	1							
	Total	17							
Semester 2									
CS1353	Introduction to Data Structures	3	36						
CY1020	Dynamics of Chemical Systems-I	1	12						
EE1130	Analog Circuits	1	34						
EE1330	DSP	1	34						
EE1510	Matrix Analysis	1	34						
PH2827	Thermodynamics	1							
LAxxxx	LA/CA Elective	2							
PH1027	Electromagnetism and Maxwell's Equations	1	34						
PH1587	Tensors and differential forms	1							
PH2027	Quantum Physics	1	34						
PH2817	Modern Physics	1							
XXxxxx	Free elective	2							
	Total	*16*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 3									
EE2110	Microprocessor	1	56						
CS2233	Data Structures	3	16						
PH3288	Analytical Mechanics	2							
CY1031	Chemistry lab	2	16						
EE2230	Power Electonics	1	56						
XXxxxx	Free elective	1							
ID1041	Engineering Drawing	2	16						
ID1100	Fluid Mechanics	2							
PH1031	Physics Lab	2	16						
PH2017	Relativity	1							
PH2117	Photonics	1	56						
	Total	*18*							
Semester 4									
CS2440	Algorithms	3	16						
EE2140	CMOS Fabrication	1	56						
EE2150	Digital Electronics	1	12						
EE2170	Mixed Signal Electronics	1	34						
LAxxxx	LA/CA Elective	2							
PH2041	EP2 Lab	2							
PH2127	Astroparticle Physics	1							
PH2218	Electrodynamics	2							
XXxxxx	Free elective	2							
PH3317	Thermal Physics	1							
	Total	*16*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 5									
EE2120	Device Physics	2	14						
LAxxxx	LA/CA Elective	2							
PH2177	Linear Vector Spaces	1							
PH2187	Fourier Series and Integral Transforms	1							
PH2197	Complex Analysis	1							
PH3051	EP3 Lab	2							
PH3117	Wave formalism of Quantum Mechanics	1							
PH3127	Hydrogenic Atoms	1							
PH3227	Nonlinear Dynamics	1							
PH3267	Symmetries in Quantum Mechanics	1							
PH3588	Computational Physics I	1							
PH3367	Experimental techniques- I	1							
XXxxxx	Free elective	2							
	Total	*17*							
Semester 6									
PH2287	Special functions and Differential Eqn	1							
PH2297	Group theory	1							
PH3061	EP4 Lab	2							
PH4075	Project	3							
PH3237	Approx methods in Quantum Mechanics	1							
PH3257	Scattering Theory	1							
PH3277	Relativistic Quantum Mechanics	1							
PH3337	High Energy Physics	1							
PH3338	Photonics & Laser	2							
PH3347	Crystal Structure	1							
PH3348	Statistical Physics	2							
XXxxxx	Core elective	2							
	Total	*18*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 7									
LAxxxx	LA/CA Elective	2							
PHxxxx	Accelerator Physics	2							
PH3358	Spectroscopy	2							
PH3478	Particle Physics	2							
PH3537	Nuclear Physics	1							
PH4071	EP5 Lab	2							
PH4268	Solid State Physics	2							
PH3287	Atomic & Mol Phys	1							
PHxxxx	Core Elective	2							
XXxxxx	Free Elective	2							
	Total	*18*							
Semester 8									
ID4006	Professional Ethics	1							
LAxxxx	LA/CA	2							
PHxxxx	Core-Electives	2							
PHxxxx	Core-Electives	2							
XXxxxx	Free Elective	2							
	Total	*9*							
	Total Credits	***129***							

ENGINEERING SCIENCE

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 1									
CS1310	Discrete Structures I	2	14						
CY1017	Environmental Chemistry-I	1	12						
EE1110	Applied Digital Logic Design	1	12						
EE1120	Digital Logic Design	1	34						
EE1310	Signals and Communications	1	56						
EE1320	Internet of Things (IOT)	1	12						
ID1035	Independent Project	1	16						
ID1054	Digital Fabrication	2	16						
ID1303	Introduction to Programming	2	36						
LAxxxx	LA/CA Elective	1							
MA1110	Calculus-I	1	12						
MA1220	Calculus-II	2	36						
XXxxxx	Free Elective	1							
	Total	*17*							
Semester 2									
BO1010	Introduction to Life Sciences	1	34						
CS1353	Introduction to Data Structures	3	36						
CY1020	Dynamics of Chemical Systems-I	1	12						
EE1150	Embedded programming	1	56						
ID1140	Thermodynamics - I	1	12						
LAxxxx	LA/CA Elective	1							
MA1130	Vector Calculus	1	12						
MA1140	Linear Algebra	1	34						
MA1150	Differential Equations	1	56						
MS1050	Physics of Solids	1	56						
PH1027	Electromagnetism and Maxwell's Equations	1	56						
PH2027	Quantum Physics	1	34						
EE1140	Semiconductor Fundamentals	1	12						
	Total	*15*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 3									
BM1030	Bio-Engineering	1	56						
CH2450	Numerical Methods-1	2	14						
CS2233	Data Structures	3	16						
CY1031	Chemistry Lab	2	16						
EE1010	Electric Circuits	1	12						
EE2120	Device Physics	2	14						
ID1100	Fluid Mechanics-I	2	46						
LAxxxx	LA/CA Elective	1							
MA2110	Probability	1	12						
PH1017	Classical Physics	1	34						
PH2117	Photonics	1	56						
	Total	*17*							
Semester 4									
CS2443	Algorithms	3	16						
CS3220	Compilers-I	1	16						
EE2140	CMOS Fabrication	1	56						
EE2160	Embedded Systems	1	12						
EE1210	Basic Control Theory	1	12						
LAxxxx	LA/CA Elective	1							
MA2130	Complex Variables	1	12						
MA2140	Statistics	1	34						
ME1030	Dynamics	2	46						
ME2080	Introduction to Mathematical Modelling	1	12						
MS1050	Physics of Solids	1	56						
MS2090	Electronic Materials	1	56						
XXxxxx	Free Elective	1	16						
	Total	*16*							
Semesters 5-8									
	Core Engg Electives	33							
XXxxxx	Free Electives	9							
LAxxxx	LA/CA Elective	6							
	Project	12							
	Total	*60*							
	Total Credits	***125***							

MATERIALS SCIENCE AND METALLURGICAL ENGINEERING

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 1									
CY1031	Chemistry lab	2	16						
ID1035	Independent Project	1	16						
ID1054	Digital Fabrication	2	16						
ID1303	Introduction to Programming	2	36						
LAxxxx	LA/CA Elective	1							
MA1110	Calculus-I	1	12						
MA1220	Calculus-II	2	36						
MS1010	Science and Engineering of Materials	1	12						
MS1040	Materials Synthesis	1	12						
PH1017	Classical Physics	1	34						
PH1031	Physics Lab	2	16						
	Total	*16*							
Semester 2									
BO1010	Introduction to Life Sciences	1	34						
CY1021	Dynamics of Chemical Systems-II	2	36						
CY1020	Dynamics of Chemical Systems-I	1	12						
LAxxxx	LA/CA Elective	2							
MA1140	Linear Algebra	1	34						
MA2140	Statistics	1	34						
MS1011	Metallography Lab	1	13						
MS1021	Materials Synthesis Lab	1	46						
MS1050	Physics of Solids	1	56						
MS1060	Polymers	1	12						
MS1080	Computational Methods in Materials Science-I	1	12						
PH1027	Electromagnetism and Maxwell's Equations	1	56						
PH2027	Quantum Physics	1	34						
	Total	*15*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 3									
BM1030	Bio-Engineering	1	56						
CY1017	Environmental Chemistry-I	1	12						
EE1010	Electric Circuits	1	12						
EE1020	Magnetic Circuits	1	56						
ID1041	Engineering Drawing	2	16						
ID1171	Fabrication Lab - I	2	16						
LAxxxx	LA/CA Elective	2							
MS1020	Metallic Materials	1	12						
MS1030	Materials Characterization-I	1	12						
MS1070	Semiconductor materials	1	34						
MS2010	Soft Matter Science	1	56						
MS2020	Physical Metallurgy	2	36						
MS2040	Advanced Materials Synthesis	2	36						
	Total	*18*							
Semester 4									
ID1160	Solid Mechanics - I	2	13						
LAxxxx	LA/CA Elective	2							
MA1130	Vector Calculus	1	12						
MA1150	Differential Equations	1	56						
MS2011	Functional Properties Characterization Lab	2	16						
MS2021	Mechanical Behaviour Lab	2	16						
MS2030	Materials Characterization II	2	14						
MS2050	Mechanical Behaviour of Materials	2	14						
MS2060	Functional and Structural polymers	2	36						
MS2080	Process Metallurgy	1	34						
MS2090	Electronic Materials	1	56						
MS2100	Rate Phenomena in Process Modeling	1	56						
	Total	*19*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 5									
LAxxxx	LA/CA Elective	2							
ME1010	Manufacturing Technology	1	56						
MS3010	Magnetic Materials	1	34						
MS3020	Casting and solidification	2	14						
MS3021	Foundry and solidification Lab	1	46						
MS3030	Non-Ferrous extractive metallurgy	1	56						
MS3090	Phase Equilibria	1	12						
MS3100	Kinetics of Materials	2	36						
MS3270	Iron making & Steel Making	1	56						
MS3280	Powder Metallurgy Processing	1	34						
xxxx	Core Elective	2							
xxxx	Free Elective	1							
	Total	*16*							
Semester 6									
ME2030	Manufacturing Science -I	2	36						
MS3011	Heat Treatment Lab	2	16						
MS3015	Mini Project	2	16						
MS3040	Thin Films	2	36						
MS3080	Computational Methods in Materials Science II	2	36						
MS3110	Transport phenomena	2	14						
MS3120	Phase Transformations	2	14						
MS3140	Technical communication	1	56						
MS3150	Corrosion	1	12						
xxxx	Core Elective	2							
xxxx	Free Elective	1							
	Total	*19*							
Semester 7									
LAxxxx	LA/CA Elective	2							
MS3015	Mini Project	2	16						
MS4011	Metal Forming Lab	1	13						
MS4020	Research methodology	1	56						
MS4030	Materials Selection and design	1	34						
MSxxxx	Core Elective	4							
XXxxxx	Free Elective	1							
	Total	*12*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 8									
MS4016	Seminar	1	56						
MS4050	Fracture and Fatigue	2	14						
MS4060	Thermo-mechanical Processing	2	36						
MSxxxx	Core Elective	4							
XXxxxx	Free Elective	2							
	Total	*11*							
	Total Credits	***126***							

MECHANICAL ENGINEERING

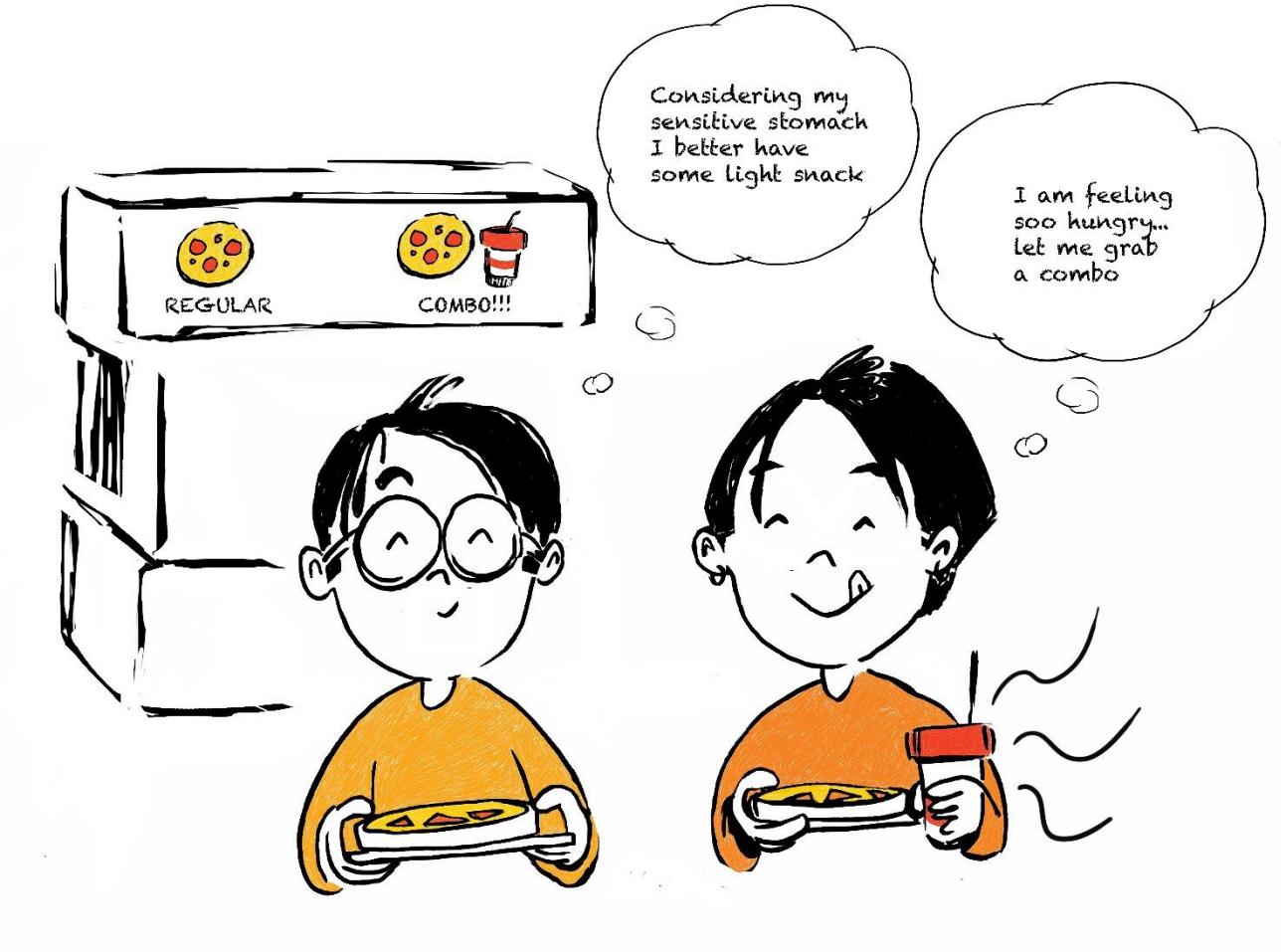
Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 1									
ID1035	Independent Project	1	16						
ID1041	Engineering Drawing	2	16						
ID1054	Digital Fabrication	2	16						
ID1100	Fluid Mechanics-I	2	46						
ID1130	Engineering Statics	2	13						
ID1171	Fabrication Lab - I	2	16						
LAxxxx	LA/CA Elective	1							
MA1110	Calculus-I	1	12						
MA1220	Calculus-II	2	36						
ME1010	Manufacturing Technology	1	56						
	Total	*16*							
Semester 2									
BO1010	Introduction to Life Sciences	1	34						
CY1021	Dynamics of Chemical Systems-II	2	36						
CY1020	Dynamics of Chemical Systems-I	1	12						
ID1091	Fabrication Lab - II	2	16						
ID1140	Thermodynamics - I	1	12						
ID1160	Solid Mechanics - I	2	13						
LAxxxx	LA/CA Elective	1							
MA1130	Vector Calculus	1	12						
MA1140	Linear Algebra	1	34						
MA1150	Differential Equations	1	56						
ME1030	Dynamics	2	46						
PH1027	Electromagnetism and Maxwell's Equations	1	56						
	Total	*16*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 3									
BM1030	Bio-Engineering	1	56						
CY1017	Environmental Chemistry-I	1	12						
EE1010	Electric Circuits	1	12						
EE1110	Applied Digital Logic Design	1	12						
ID1110	Fluid Mechanics - II	2	13						
ID1303	Introduction to Programming	2	36						
ID2020	Solid Mechanics - II	2	46						
LAxxxx	LA/CA Elective	1							
MA2110	Probability	1	12						
MA2120	Transforms	1	34						
MS1020	Metallic Materials	1	12						
MS2020	Physical Metallurgy	2	36						
PH1031	Physics Lab	2	16						
	Total	*17.5*							
Semester 4									
ID1150	Thermodynamics - II	2	36						
LAxxxx	LA/CA Elective	1							
MA2130	Complex Variables	1	12						
MA2140	Statistics	1	34						
ME2030	Manufacturing Science -I	2	36						
ME2040	Instrumentation	2	46						
ME2080	Introduction to Mathematical Modelling	1	12						
ME2090	Kinematics of Machinery	2	13						
ME2100	Dynamics of Machinery	2	46						
ME2421	Solid Mechanics Lab	1	13						
ME2431	Fluid Mechanics Lab	1	46						
XXxxxx	Free Electives	1							
	Total	*16.5*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 5									
LAxxxx	LA/CA Elective	1							
ME3010	Manufacturing Science - II	2	14						
ME3070	Power and Refrigeration System	2	13						
ME3080	Design of Machine Elements	2	13						
ME3090	Design of Transmission Elements	2	46						
ME3110	Heat & Mass transfer	3	16						
ME3150	Applied Elasticity	2	14						
ME3445	Finite Element Methods Lab	1	13						
ME3455	Computational Fluid Dynamics Lab	1	46						
MExxxx	Core-Electives	3							
	Total	*18.5*							
Semester 6									
LAxxxx	LA/CA Elective	1							
ME3060	Experimental Testing Techniques	1	56						
ME3100	Modeling & Simulation	2	14						
ME3140	IC Engines	3	16						
ME3413	Machine Drawing & Solid Modelling	2	16						
ME3425	Mini-project	3	16						
ME3465	Manufacturing Lab	1	13						
ME3475	IC Engines Lab	1	46						
ME4030	Operations Research	1	12						
ME4040	Industrial Engineering	1	34						
ME4050	Production Planning & Control	1	56						
	Total	17							
Semester 7									
LAxxxx	LA/CA Elective (total 3 for 7 & 8 sems)	0-1							
ME3040	Mathematical Elements for Geometrical Modeling	2	13						
ME3050	Computer Integrated Manufacturing	2	46						
ME4010	Control Systems	2	13						
ME4020	Turbo Machines	3	16						
ME4325	Elective Project / CoreElective	3							
ME4435	Dynamics lab	1	13						
ME4445	Heat Transfer lab	1	46						
MExxxx	Core-Electives (total 9 for 7 & 8 sems)	0-3							
XXxxxx	Free Electives (total 2 for 7 & 8 sems)	0-1							
	Total	*12.5-17.5*							

Course Number	Course Name	Credits	Segment	When it runs in a Semester					
				1	2	3	4	5	6
Semester 8									
ID4006	Professional Ethics	1							
LAxxxx	LA/CA Elective (total 3 for 7 & 8 sems)	2-3							
MExxxx	Core-Electives (total 9 for 7 & 8 sems)	6-9							
XXxxxx	Free Electives (total 2 for 7 & 8 sems)	1-2							
	Total	10-15							
	Total Credits	***129***							

Honors/Minors



In addition to satisfying the minimum credit requirement for obtaining a degree, a student can also take up additional basket of courses either from the same or different department in the form of Honors & Minors. Such additional efforts would also be reflected in the final Degree certificate

HONORS/MINORS

- In order to earn a minor, a student has to earn a minimum of 12 extra credits from a basket of courses prescribed for each minor stream.
- In order to earn honors, a student has to earn a minimum of 12 extra credits out of which six credits from project work and at least six credits are from courses offered by the student's major department.
- A student can enroll for both Minor & Honors or for two Minors.
- The final transcript will only show the basic CGPA corresponding to the minimum requirement for the degree. The Minors/Honors will be indicated by a separate CGPA. The additional courses taken will also find separate mention in the transcript. If a student drops (or terminated) from the Minor/Honors program, they cannot convert the earned credits into free or core electives; they will remain extra. These additional courses will find mention in the transcript (but not in the degree certificate). In such cases, the student may choose between the actual grade or a "pass(P)" grade and also choose to omit the mention of the course as for the following: All the courses done under the dropped Minor/Honors will be shown in the transcript None of the courses done under the dropped Minor/Honors will be shown in the transcript.
- Honors will be reflected in the degree certificate as "BTech (honors) in XYZ Engineering". Similarly, Minor as "BTech in XYZ Engineering with Minor in ABC". If a student has done both honors & minor, it will be acknowledged as "BTech (honours) in XYZ Engineering with Minor in ABC". And two minors will be reflected as ""BTech in XYZ Engineering with Minor in ABC and Minor in DEF".

Honors & Minors Details		
Department	**Honors**	**Minors**
Department of Biomedical Engineering		Yes
Department of Biotechnology		
Department of Civil Engineering	Yes	Yes
Department of Chemical Engineering	Yes	
Department of Computer Science Engineering	Yes	Yes
Department of Electrical Engineering	Yes	Yes
Department of Engineering Science		
Department of Materials Science and Metallurgical Engineering		
Department of Mechanical & Aerospace Engineering *(Honors in Mechanical Engineering)*	Yes	
Department of Mechanical & Aerospace Engineering *(Minor in Aerospace Engineering)*		Yes
Department of Liberal Arts *(Minor in Economics)*		Yes
Department of Chemistry		
Department of Mathematics		
Department of Physics		Yes
Minor in Entrepreneurship		Yes

FAQ

Q. What is the eligibility requirement for registration in terms of number of credits or projects?

A. No requirement

Q. What is the eligibility requirement for registration in terms of number of backlogs?

A. A student must have cleared all outstanding backlogs by the time of enrolment into Honors/Minors

Q. Is there a CGPA criterion for registration?

A. No CGPA criterion for Minor. However, a CGPA criterion for Honors can be set by the respective Departments.

Q. Department-wise course pre-requisites requirements? Please mention in detail all the courses semesters-wise with suitable credits here.

A. Table below in Double Major section.

Q. Department-wise maximum number of students (or a percentage of existing student strength) that can avail this option?

A. To avoid overloading, Departments offering Minors can put an upper limit on the number of Minor students they wish to take. The students have to understand that since the number of seats available for each of the Minor will always be limited, one has to compete for a place; he/she thus cannot ignore the basic CGPA.
A cap of 15% increase in the original batch strength of any department due to minor.

Q. When can one apply, in which semester?

A. A student can enrol for Minor in the fifth semester only. There is no CGPA criterion for enrolling into a Minor. A student can enrol for Honors in the fifth or sixth semester, depending on the policy of the department. The department can plan the Honors from the fifth or sixth semester. There is no CGPA criterion for enrolling into Honors at the institute level.

Q. Whom to inform/seek approval from (faculty advisor/ DUGC/ others?) in case the student from your department wants to pursue an option in another department?

A. Faculty advisor

Q. Whom to inform/seek approval from (faculty advisor/ DUGC/ others?) in case a student from another department wants to pursue an option in your department?

A. DUGC Convenor

Q. Should the concerned person make a list and inform acads or will it all be online?

A. It should be through AIMS.

Q. If a student would like to withdraw from major, minor or honors, what is the procedure and when can that be done, again whom to contact?

A. Through the faculty advisor

Q. Can a student be terminated from the program and under what circumstances?

A. After enrolling into Minors/Honors, if a student gets FS/FR grade in more than 3 credits his/her enrolment to the same will be terminated.

Q. If a student has done the required courses as free electives before, how does he/she make up for the lost credits?

A. Case by case basis on recommendation of the DUGC convenor.

Double Major

The Double Major program at IITH takes into cognizance the large overlap between various engineering streams and allows a student to graduate with two distinct degrees by doing a certain additional number of courses in the second stream in addition to the original.

DOUBLE MAJOR

Double Major Details	
Department	**Double Major**
Department of Biomedical Engineering	
Department of Biotechnology	
Department of Civil Engineering	Yes
Department of Chemical Engineering	Yes
Department of Computer Science Engineering	Yes
Department of Electrical Engineering	Yes
Department of Engineering Science	
Department of Materials Science and Metallurgical Engineering	Yes
Department of Mechanical & Aerospace Engineering	Yes
Department of Liberal Arts	
Department of Chemistry	
Department of Mathematics	
Department of Physics	Yes

FAQ

Q. What is the eligibility requirement for registration in terms of number of credits or projects?
A. No requirement

Q. What is the eligibility requirement for registration in terms of number of backlogs?
A. No backlogs

Q. Is there a CGPA criterion for registration?
A. No.

Q. What are the department-wise pre-requisites? Please mention in detail all the courses semesters-wise with suitable credits here.
A. Table above.

Q. Department-wise maximum number of students (or a percentage of existing student strength) that can avail this option?
A. We recommend a cap of 15% increase in the original batch strength of any department due to major.

Q. When can one apply, in which semester?
A. Starting from the 4th Semester

Q. Whom to approach if the student from one department wants to pursue an option in another department?
A. Faculty advisor. Further, the advisor should inform the academic section.

Q. Whom to approach if the student from another department wants to pursue an option in your department?
A. DUGC Convenor

Q. If a student would like to withdrawal from major what is the procedure and when can that be done, again whom to contact?

A. Faculty advisor

Q. Can a student be terminated from the program and under what circumstances?

A. After enrolling into Majors, if a student gets FS/FR grade in more than 3 credits his/her enrolment to the same will be terminated.

Q. If a student has done the required courses as free electives before, how to make up for the lost credits?

A. Case by case basis on recommendation of the DUGC convenor.

CHEMICAL ENGINEERING.

Course No.	Course Title	Semester	Credits
CH1050	Introduction to Mass Transfer	Jul	1
CH3010	Separation Process II	Jul	2
CH3070	Chemical Engineering thermodynamics-I	Jul	2
CH3030	Transport Phenomena-I	Jul	2
CH3050	Control Design and Analysis	Jul	2
CH2010	Mechanical Operations	Jul	2
CH3011	HT Lab	Jul	1
CH3031	MT Lab	Jul	1
CHXXXX	Sustainable and Energy Options	Jan	1
CHXXXX	Chemical Technology	Jan	1
CH1080	Separations Process - I	Jan	2
CH3070	Chemical Engineering thermodynamics-I	Jan	2
CH1060/CH3042	Heat Transfer/Plant Design -I	Jan	2
CH2020	Basic Control Theory	Jan	1
CH1021	Chemical Engineering Lab	Jan	1
CH3041	Process Control Lab	Jan	1
		Total	**24**

CIVIL ENGINEERING.

Course No.	Course Title	Credits
	Pre-requisites	
ID1100	Fluid mechanics I	2
ID1160	Solid Mechanics I	2
ID1110	Fluid mechanics II	1.5
ID2020	Solid Mechanics II	2
	Department Courses	
CE3300	Geotechnical Engineering I	1.5
CE3310	Geotechnical Engineering II	1.5
CE3312	Introduction to foundation Engineering	1
CE2020	Construction Material	1.5
CE2030	Concrete Technology	1.5

CE3102	Introduction to Reinforced Concrete	1.5
CE2110	Analysis of Indeterminate Structures	1.5
CE3112	Introduction to Structural Steel Design	1.5
CE4900	Construction Management	3
CE3512	Introduction to Environmental Engineering	1
CE3522	Water and Wastewater Engineering	2
CE3500	Introduction to Hydraulic Engineering	1.5
CE2500	Engineering Hydrology	2
CE3830	Railway and Airport Engineering	1
CE3840	Traffic Engineering and Planning	2
	Total	**24**

COMPUTER SCIENCE AND ENGINEERING

CSE Minor Program Curriculum: The following minor curriculum is applicable for students in non-CSE departments who started their B.Tech in the Aug 2015 semester or later.

Requirements: Any 12 out of the 23 credits listed in the table below, starting from 4th semester of the student from other departments. The student should ensure that the appropriate pre-requisites are met. It is up to the student to choose the courses and manage his/her schedule along with the courses in his/her home department.

CSE Secondary major (Double major) curriculum: The following curriculum for obtaining CS as the additional major is applicable for students in non-CSE departments who started their B.Tech in the Aug 2015 semester or later.

Requirements: 24 credits in the CSE department which must include any 15 out of the 23 credits listed in the table below, starting from 4th semester of the student from other departments. The student should ensure that the appropriate pre-requisites are met. It is up to the student to choose the courses and manage his/her schedule along with the courses in his/her home department.

Remarks:

- If any course in the basket is part of the student's primary major curriculum, then that course cannot be used to satisfy the CSE minor/secondary major requirements.
- The minor and secondary major students should enroll with the application process, which will be announced at an appropriate time before the 4th semester. The announcement will be through email, and it is the interested student's responsibility to apply before the announced deadline. Note that this application process is different from the registration on the AIMS portal.
- The seats for the minor and secondary major in CSE are limited to 10% of the CSE BTech program intake. The CGPA from the first and second semesters of the students would be used as a tiebreaker if there are more applicants than the number of seats available.

Course No.	Course Title	Pre-requisite	Credits
CS1353	Introduction to Data Structures	ID1303	3
CS2233	Data Structures	CS1353	3
EE1110	Applied Digital Logic Design		1
EE1120	Digital Systems and Design		1
CS2400	Principles of Programming Languages I	CS2233	1
CS2323	Computer Architecture	ID1303, EE2110	2
CS3510	Operating Systems I	CS1353, CS2323	1
CS2443	Algorithms	CS2233	3
CS3523	Operating Systems II	CS3510, CS2233	3
CS3530	Computer Networks I	CS1353	1

CS3550	Introduction to Database Management Systems I	CS3510	1
CS3563	Introduction to DBMS II	CS3510, CS3550	3
	Total		**23**

CAP on Double major students like Minor students, ES students
Senate Ruling:

- 10% of the strength
- Overall CGPA of 1st and 2nd semesters will be the qualifying mark

ELECTRICAL ENGINEERING

The following 24 credits are required for Double Major. In case some of the courses have been done as a part of their basic degree, the students can choose additional credits as electives from EE.

Course No.	Course Title	Credits
Student to choose 14 credits from the following list		
EE1110	Boolean Algebra	1
EE1010	Electrical Circuits	1
EE1020	Magnetic Circuits	1
EE2120	Computer Organization	1
EE1320	Signals and Communications	1
EE1310	Data Analytics	2
EE1300	DSP	1
EE2320	Digital Modulation Techniques	1
EE2520	Computer Networks	1
EE3310	Random Process	1
EE1220	Basic Control Theory	1
EE2220	Control Systems	1
EE2200	Transformer and DC machines	2
EE2210	Power Electronics	1
EE2260	AC Machines	1
EE1080	Semiconductor Fundamentals	1
EE2010	Device Physics	2
EE2020	Linear Electronics	1
EE2110	Digital System Design	2
EE2140	CMOS Fabrication	1
At-least 10 credits from level EE 3 and above courses.		
	Total	**24**

PHYSICS

Course No.	Course Title	Pre-requisite	Credits
Odd Semester			
PH5127/PH3127	Hydrogenic Atoms	PH2027 (1)	1
PH5117/PH3117	Wave formalism of QM	PH2027(1)	1
PH5137/PH3237	Approx. Methods in QM	PH2027(1)	1

PH5247/PH3317	Thermal Physics	No	1
PH6238/PH3338	Laser and Photonics	PH2117 and PH1027 (1)	2
PH6268/PH4268	Solid State Physics	PH3347 (1)	2
PH6278/PH3478	Particle Physics	PH2127 (1)	2
PHxxxx	Elective I	Yes	2
	Total		**12**
Even Semester			
PH5257/PH3257	Scattering theory	PH3117 (1)	1
PH5267/PH3267	Symmetries in QM	PH3117 (1)	1
PH5277/PH3277	Relativistic QM	PH3237 (1)	1
PH5347/PH3347	Crystal Structure	No	1
PH6248/PH3348	Statistical Physics	PH3317 (1)	2
PHxxxx	Elective II	Yes	2
PHxxxx	Elective III	Yes	2
PHxxxx	Elective IV	Yes	2
	Total		**12**

MATERIALS SCIENCE AND METALLURGICAL ENGINEERING

Course No.	Course Title	Credits
Odd Semester		
MS1020	Metallic Materials	1
MS1030	Materials Characterization-I	1
MS1040	Materials Synthesis	1
MS2010	Soft Matter Science	1
MS2020	Physical Metallurgy	2
MS1070	Semiconductor materials	1
MS3090	Phase Equilibria	1
MS3100	Kinetics of Materials	2
MS4030	Materials Selection and design	1
MS3021	Foundry and solidification Lab	1
Even Semester		
MS1050	Physics of Solids	1
MS2080	Process Metallurgy	1
MS2090	Electronic Materials	1
MS1011	Metallography Lab	1
MS1021	Materials Synthesis Lab	1
MS2011	Functional Properties Characterization Lab	2

Core Electives:

- Remaining MSME core courses and core elective courses, specified for regular B.Tech. Curriculum (main degree in BTech MSME), will be available as 'Core Electives' for the Double Major program. Elective theory courses will be level 3 or higher, i.e. MS3xx0, MS4xx0, MS5xx0, etc.
- If student has already credited any of the courses mentioned above, as a part of his/her parent department, then student is allowed to choose other elective courses of MSME for the equal credits.
- Courses to be chosen by consultation with faculty advisor of MSME

MECHANICAL ENGINEERING.

Course No.	Course Title	Credits
Pre-requisites		
ID1130	Engineering Statics	2
ID1100	Fluid mechanics I	2
ME1010	Manufacturing Technology	1
ID1160	Solid Mechanics I	2
ID1140	Thermodynamics-I	1
ID1150	Thermodynamics-II	2
ID1110	Fluid mechanics II	1.5
ID2020	Solid Mechanics II	2
Department Courses		
ME2060	IC Engines - I	1
ME2030	Manufacturing Science -I	2
ME2220	Kinematics & Dynamics of Machinery	4
CE2020	Construction Material	1.5
ME2421	Solid Mechanics Lab	1
ME2431	Fluid Mechanics Lab	1
ME3010	Manufacturing Science - II	2
ME3130	Design of Machine Elements	4
ME3110	Heat & Mass transfer	3
ME3465	Manufacturing Lab	1
ME4435	Dynamics lab	1
ME4445	Heat Transfer lab	1
MExxx0	Electives	3
	Total	**24**

Courses with External Collaboration

In addition to the various courses offered by the different departments, IITH also a vibrant set of courses with significant contribution from the external scientific & industrial community. The fractal academic structure of IITH makes such a collaboration particularly convenient as the instructor has flexibility in choosing the total credits and contact hours. Fractional credit courses, Creative Art Courses, GIAN Courses, Minor in Entrepreneurship are some of the means for such collaboration. Needless to say, these courses are very dynamic in nature and change from time to time. Hence, the following list is only indicative in nature.

FRACTIONAL CREDIT COURSES

S.No	Course	Instructor
1	Advanced Topics in Digital Circuit Design	Dr. Bhardwaj Amrutur
2	Architecture of Memories and Newer Technologies	Dr. Abesh Kumar Tirupati
3	Building Robust Software	Dr. Santosh Nagarkatte
4	Data Management and Computing on the Cloud	Dr. S Seshadri
5	Empowering 3 Billion	Dr. APJ Abdul Kalam
6	Fatigue and Damage Tolerance Evaluation	Dr. C M Manjunatha
7	Innovation, Entrepreneurship and Medical Device Industry	Dr. Sudhi Gautam
8	Introduction to Film Making	Ms. Pratima Jaidev
9	Managing and Analyzing Large Data	Prof. Seshadri
10	Mechanical Behaviour of Nano Structured Materials	Prof. Tsuji
11	Mobile Applications	Dr. Ramesh Srinivasa Raghavan
12	Molecular Symmatry and Its Chemical Applications	Prof. V Chandra Sekhar
13	Moving Images	Prof. Nina Sabnani
14	Opportunities & Challenges in Globalized Services Delivery	Mr. Pradeep Khanna
15	Phase Transformations in Metals and Alloys	Dr. Allan Hazotee
16	Photojournalism	Mr. Navrotze Contractor
17	Power Electronics in Aircraft	Dr. Sukumar
18	Smart Communications	Dr. Maduchadda
19	Software Driven Networking	Dr. Vijay Mann and Dr. Anil Kumar
20	Streaming Data and Pattern Analysis	Dr. Lakshmi Narayana Choudur
21	Systems and Resource Virtualization	Dr. Prasad Saripathi
22	Trends in Storage Systems	Dr. Preetam Patil

CREATIVE ARTS COURSES

Course No.	Course	Instructor
CA1010	Introduction to Theatre	MK Raina
CA1011	Introduction to Sculpture	Priti Kahar
CA1012	My City: A Course in Photography	Tomacz Sobecki
CA1013	Singing Kabir with Prahlad Tipaniya	Prahlad Tipaniya
CA1014	Exploring the Performance Spectrum	Jayachandran Palazhy
CA1015	Introduction to Hindustani Music	
CA1016	Visual Arts: A Dialogue between Material and Process	Sanchayan Ghosh
CA1018	Newspaper Design for Dummies	Amrith Lal
CA1019	Bollywood Calling: Introduction to Film	Sanu John Varughese
CA1020	Introduction to Pottery and Ceramics	Jagruti Dutta
CA1021	Understanding Cinema: Five Days at the Movies	Shubhra Gupta
CA1022	Rohi Rang: Sufi Music with Mukhtiyar Ali	Mukhtiyar Ali
CA1023	Introduction to Karnatic Music	Vasudev
CA1024	Indian Classical Dance	Purvadhanashree
CA1025	Madhubani Painting	Shalinee Kumari
CA1026	Kalamkari Painting	Viswanath Reddy
CA1027	Understanding Hyderabad and Its Heritage	Anuradha Reddy, Anuradha Naik

CA1028	Introduction to Creative Writing	Dr Karni Pal Bhati
CA1029	Initiation to Dhrupad for All	Ustad Wasifuddin Dagar
CA1030	Flamenco Dance Basics	Yuka Kataoka
CA1031	Music, Masti and More: Introduction to Film Music and Technology	Ramana Gogula
CA1032	Musics from the World	Arko Mukhaerjee
CA1033	Filmmaking for Beginners	Parikshit Suri
CA1034	Principles of Comedy	Vasu Primlani

GIAN COURSES

S.No	Course	Instructor
1	Advanced Optical Design at the Thermodynamic Limit	Prof. Jeffrey M. Gordon
2	Advanced Prestressed Concrete Design for Modern Buildings and Bridges	Prof. Sri Sritharan
3	Applied Financial Modelling	Prof. Paresh Kumar Narayan
4	Behavior and Design of Sturctural Systems in Extreme Thermal Loading Conditions including Fire Affects	Prof. Venkatesh Kodur
5	Biomaterials Engineering and Digital Manufacturing	Prof. Seeram Ramakrishna
6	Contemporary Radar System Design and Signal Processing	Prof. Amit kumar Mishra
7	Course on Finite Element Method	Prof. J. N. Reddy
8	Dislocation Theory for Mechanical Behavior of Metals	Prof. Nobuhiro Tsuji
9	Electron Microscopy: Basics and Applications	Prof. Emmanuel Bouzy
10	Enabling Large Scale Data Analytics: From Theoretical Foundations to Practice	Prof. Barna Saha
11	Environmental and Human Health Risk Assessment of Chemicals	Prof. Matthew MacLeod
12	Groundwater Flow and Transport Modeling Through Fractured Geologic Media	Prof. Walter Illman
13	Hydrological modelling using SWAT model	Prof. R. Srinivasan
14	Modeling and Design of Steel Concrete Composite structural Systems under Extreme Loading Conditions such as Seismic and Fire Efect	Prof. Amit H. Verma
15	Social Network Analysis	Prof. Israr Qureshi
16	Social Network Theory	Prof. Israr Qureshi
17	Spectrum Sharing in Next Generation Wireless Networks: Principles, Analysis & Case Studies	Prof. Sumit Roy
18	Structural upgrade and strengthening of civil engineering infrastructure using fiber reinforced polymer composites	Prof. Abdeldjelil Belarbi

*GIAN (Global Initiative of Academic Networks) is an initiative of MHRD, GoI.

MINOR IN ENTREPRENEURSHIP

Course No.	Course	Instructor
FC3651	Introduction to Finance and Economy	Mr. Srinagesh
FC3652	Introduction to Sales & Marketing	Mr. Y. Ravi
FC3653	Introduction to Entrepreneurship	Mr. Ajai Chowdary
FC3654	Strategic Innovative Entrepreneurship	Mr. Ramesh Loganathan
FC3655	Introduction to Business Plan	Mr. Srinivasa Addepalli
FC3656	Early Customer Acquisition and Relationship Management	Mr. Arun Chandran
EP4657	Business Plan Development(Project)	Mr. Murali Bukkapatnam
FC4658	HR and Leadership	Mr. B. V. R. Mohan Reddy
FC4659	Company Valuation	Mr. Rimpal Chawla
FC4660	Risk Management	Mr. Pradeep Mittal

Course Descriptions

COMMON (ID) COURSES

ID1035	**INDEPENDENT PROJECT**
Credits: 1 *Semester: Jul* *Segment: 16*	This course is envisioned to familiarize students with basic project work. The theme may be from a selection of broad engineering topics.

ID1041	**ENGINEERING DRAWING**
Credits: 2 *Semester: Jul* *Segment: 16*	Introduction to engineering drawing - lettering - coordinate axes and types of views - orthographic sketching - dimensioning - sectioning - isometric sketching - boolean operations on 3D sketches.

ID1054	**DIGITAL FABRICATION**
Credits: 2 *Semester: Jul* *Segment: 16*	Complete process chain for design and subsequent realization of concepts making use of 3D modelling and additive manufacturing (3D printing) processes: Familiarization with 3D solid modelling for creation of engineering and freeform geometries; 3D Scanning using CMM and laser scanners. 3D Printing concepts for conversion of CAD model into real part: slicing, effect of part orientation. Project involving ideation, design and final fabrication using 3D printing.

ID1091	**FABRICATION LAB- II**
Credits: 2 *Semester: Jan* *Segment: 16*	Machine Shop - Introduction to general machines, Facing, Step turning, Drilling, Knurling, Boring, Taper turning, Thread Cutting (only Demo): Welding - TIG Welding (Butt Joint with S.S.Plate), MIG welding (Butt Joint with M.S.Plate): Pneumatics Lab - Circuits and applications: Advance Electronics - Microprocessor Programming and Applications.

ID1100	**FLUID MECHANICS - I**
Credits: 2 *Semester: Jul* *Segment: 46*	Introduction - scope and relevance; Method of analysis - system vs control volumes - differential vs integral approach, Units and dimensions; Fluid properties - continuum, density, viscosity, surface tension, velocity, pressure, temperature; Fluid Statics - Hydrostatics, Fluid forces on planes and curved surfaces, submerged and floating bodies, Buoyancy and stability, Atmosphere as a fluid; Fluid Concepts - Streamlines, streaklines, pathlines, viscous vs inviscid flows, laminar vs turbulent flows, compressible vs incompressible flows; Engineering bernoulli equation; Control Volume analysis: Basic laws - Mass conservation law, thermodynamic laws, Newton's laws, Angular-Momentum principle; Buckingham Pi-theorem; Similitude and modeling - scaling effects; Flows in a pipes and channels - friction factor, flow measurement devices - Venturi meter, Orifice meter.

ID1110	**FLUID MECHANICS - II**
Credits: 1.5 *Semester: Jul* *Segment: 13* *Pre-Req: ID1100*	Differential analysis to fluid flow: Conservation of Mass - Coordinate systems, Kinematics - Translation, Rotation, Deformation, derivation of Governing equations of fluid flows - continuity, Euler equations, Potential flows - Bernoulli equation and applications to external aerodynamics, Navier-Stokes equations, Non-dimensional analysis; Exact solutions of Navier-Stokes equations; Internal flows; External flows - Prandtl's Boundary layer theory - flow over a flat plate, concept of similarity; Approximate methods - von Karman Integral analysis; (Thwaites method); Flow separation; Brief introduction to turbulence - characteristics of turbulence, drag crisis.

ID1130	**ENGINEERING STATICS**
Credits: 2 *Semester: Jul* *Segment: 13*	Particle, deformable and rigid bodies, statics, dynamics, fundamental laws of mechanics, parallelogram law and triangular law, vector operations; Resultant of coplanar and concurrent forces; Components of forces in space; Equilibrium of a particle and a rigid body. Trusses, Frames and Machines, analysis of forces in trusses using the method of joints and the method of sections; Special conditions in truss members: zero-force members; Condition of statically determinate system; Force analysis in frames and machines. Internal forces-normal or axial force, shear force, bending moment, torsional moment; Sign convention for different internal forces; Application of the method of sections to determine internal forces; Relationship between applied load, shear force, and bending moment; Method of superposition to obtain shear force diagram and bending moment diagram.

Friction: Introduction to the concept of dry friction, Equilibrium of rigid bodies subjected to dry friction; Examples demonstrating the application of frictions on wedges, screws, belts, and bearings; Concept of rolling resistance.
Center of gravity and centroid; Moment of inertia; Theorems of Pappus and Guldinus; Moment of inertia for simple geometries; Parallel-axis theorem; Perpendicular-axis theorem; Polar moment of area; Radius of gyration; Application to Composite areas; Mass moment of inertia.

ID1140 **THERMODYNAMICS - I**

Credits: 1
Semester: Jan
Segment: 12

State of a system, 0th law, equation of state; First law - Work, heat, Internal energy; Expansion work; quasi-static and reversible processes; Open and Closed systems, Enthalpy, Adiabatic changes; Carnot cycle; Second law - Entropy and the Clausius inequality; Entropy and irreversibility; Thermodynamic table and charts.

ID1150 **THERMODYNAMICS - II**

Credits: 2
Semester: Jan
Segment: 36
Pre-Req: ID1140

Statements of the second law, heat engines and refrigerators, absolute temperature scale; Entropy: theoretical development, second law in terms of entropy, the Gibbs equation, entropy for ideal gases, entropy change for reversible and irreversible processes, tabulation of entropy, adiabatic reversible processes for ideal gases, entropy of mixing, probabilistic approach; Second law analysis for control volumes: irreversible entropy production; Cycles: Otto, Diesel, Rankine, Brayton, refrigeration; Exergy; Maxwell relations, heat capacity, real gas behavior and non-ideal equations of state; Thermochemistry - Application of first and second laws to chemical reactions, Calorimetry.

ID1160 **SOLID MECHANICS - I**

Credits: 2
Semester: Jan
Segment: 13
Pre-Req: ID1130

Introduction - Mechanical behaviour of materials, tension, compression and shear stresses, axially loaded members, torsion, beam bending, transverse shear, combined loading, and impact loading.

ID1171 **FABRICATION LAB - I**

Credits: 2
Semester: Jul
Segment: 16

Fitting Shop - Dovetail Fitting, V-fitting, U T fit, Joining two pieces (male and female): Welding - Single V-butt joint, Double lap Joint, Corner joint, T- joint, Edge joint, Gas cutting (Demo): Machine Shop - Facing & Longitudinal turning, Step & taper turning, Chamfering & drilling: Electronics Shop - Diode characteristics, Bridge rectifier, LDR Circuit, Connecting resistors: Electrical Shop - Wiring basics, Stair case wiring, Switch circuits, Characteristics of DC motor.

ID1303 **PROGRAMMING IN C/C++ WITH LAB**

Credits: 2
Semester:
Segment:

Introduction to C and C++ programming. Problem solving and algorithms. Input and output operations, decision control structure, loop control structure, arrays, strings, etc.
Pointers, arrays, structures, functions, file operations, classes, object oriented programming.
Lab is also included in this course.

ID2020 **SOLID MECHANICS - II**

Credits: 2
Semester: Jul
Segment: 46
Pre-Req: ID1160

Deflections of beams, energy methods, analysis of stress and strain, stress transformation, applications of plane stress, pressure vessel, column buckling, and statically indeterminate structures.

ID4006 **ETHICS AND VALUES**

Credits: 2
Segment: 36

Course Description: The primary objective of this course is to sensitize students on the concept of Ethics and Values and make them understand the relevance of these ideas in their day to day personal and professional lives. The following is the outline of the course:

- Defining Values and Ethics
- Personal and social values
- Theories on Ethics
- Ethical decision making
- Managerial Ethics and Corporate Social Responsibility

BIOMEDICAL ENGINEERING

BM1047 **NEUROMUSCULAR PHYSIOLOGY**

Credits: 1
Semester:
Segment:

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 **BRAIN MACHINE INTERFACE**

Credits: 1
Semester:
Segment:

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 **INTRODUCTION TO THE BRAIN AND NEUROSCIENCE**

Credits: 1
Semester:
Segment:

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.

BM4190 **BIOFABRICATION**

Credits: 2
Semester: Jul
Segment: 36

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 **SENSORS AND TRANSDUCERS IN HEALTH CARE**

Credits: 2

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

Semester: Jul
Segment: 14

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 **BIOMEDICAL DEVICES**

Credits: 2
Semester: Jul
Segment: 36

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 **SCIENTIFIC COMPUTING AND DATA ANALYSIS**

Credits: 1
Semester: Jul
Segment: 12

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 **BIOMECHANICS**

Credits: 1
Semester: Jul
Segment: 34

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 **INTRODUCTION TO BRAIN AND NEUROSCIENCE**

Credits: 1
Semester: Jul
Segment: 12

- 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 **CELLULAR PHYSIOLOGY**

Credits: 0.5
Semester: Jul
Segment: 33

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

BM5070 **SYSTEMS PHYSIOLOGY**

Credits: 1.5
Semester: Jul
Segment: 46

- 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 **BIOMATERIALS: MATERIALS IN MEDICINE**

Credits: 2
Semester: Jul
Segment: 14

This course is for PhD and M. Tech students. 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.

BM5110 **LAB ON CHIP**

Credits: 1
Semester: Jul
Segment: 12

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 **ADVANCED BIOMATERIALS**

Credits: 1
Semester:
Segment:

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.

BM6023 **CELL TECHNOLOGY**

Credits: 2
Semester: Jul
Segment: 46
Pre-Req: 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 **BIOMICROFLUIDICS**

Credits: 2
Semester: Jan
Segment: 14
Pre-Req:

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 **ADVANCED BIOMECHANICS**

Credits: 2
Semester: Jan
Segment: 36
Pre-Req:

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	**BIOMEDICAL IMAGING**
Credits: 2 *Semester: Jan* *Segment: 14*	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	**BIO-NANOTECHNOLOGY**
Credits: 2 *Semester: Jul* *Segment: 14*	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	**NANOMEDICINE**
Credits: 2 *Semester: Jan* *Segment: 14*	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	**TISSUE ENGINEERING**
Credits: 2 *Semester: Jan* *Segment: 36*	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	**ADVANCES IN MOLECULAR IMAGING**
Credits: 1 *Semester: Jan* *Segment: 14*	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	**REGENERATIVE MEDICINE**
Credits: 1 *Semester: Jan* *Segment:56* *Pre-Req: 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 **CLINICAL HEALTH CARE**

Credits: 1
Semester: Jul
Segment:

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 **THEORETICAL AND COMPUTATIONAL NEUROSCIENCE: FROM CELL TO SYSTEMS**

Credits: 2
Semester: Jan
Segment: 36

- 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 **CLINICAL IMMERSION**

Credits: 1
Semester: Jan
Segment:

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 **MATHEMATICAL PHYSIOLOGY AND MODELING**

Credits: 2
Semester: Jan
Segment: 36

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 **MOLECULAR TECHNOLOGY**

Credits: 1
Semester: Jan
Segment: 56

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

BM6330 **THEORETICAL AND COMPUTATIONAL NEUROSCIENCE: FROM CELL TO SYSTEMS**

Credits: 3
Semester:
Segment:

This course is a first pass through the principles of working of the brain from the level of a single neuron to systems and behaviour. The course focuses on characterising the operating principles of the brain at various levels and the mathematical models used to represent them. The objective of the course is to develop in students an ability to convert concepts in neurophysiology into a mathematical model.

The course consists of lectures and programming assignments spread over the extent of the course.

Syllabus : 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).

BM7143 **NANOMEDICINE**

Credits: 3
Semester:
Segment:

This is a highly interdisciplinary course for M. Tech, and Ph. D students who are interested in learning about the emerging field of nanoscience and nanotechnology and its application in biology and medicine. The basic rationale is that the nanostructure materials have unique functional and structural properties which are discrete from their molecular or bulk counterpart. Recent advancement in the nanotechnology field allow us to develop various novel nanostructure materials such as quantum dots, nanofiber, nan-rod, dendrimer and many other nanostructure materials having comparable size with bio-macromolecules of the living system. The size comparability and further engineering of these nanostructure materials make them capable to interact and control human biological system at the molecular level and opened up a new emerging field called 'Nano-Medicine'. To capture the excitement of this emerging field I have plan to offer the special course, where 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.

BO6083 **PROGRAMMING FOR BIO MACROMOLECULAR DATA ANALYSIS**

Credits: 2
Semester:
Segment:

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 & organizing Protein Databank (PDB) files towards modeling & analysis of biomacromolecular structures and python scripting for Pymol software.

BO6110 **PHARMACOLOGY AND PHYSIOLOGY OF RECEPTORS**

Credits:2
Semester:
Segment:

- 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.

BIOTECHNOLOGY

BO1010	**INTRODUCTION TO LIFE SCIENCES**
Credits:1 *Semester: Jan* *Segment: 46*	Relevance of Biological Principles to Engineering undergraduates, Water and its special properties of relevance to life - Building blocks of life: Bio-molecules and their structure-function aspects - Cell structure and organelles, cell membrane, cellular transport and signaling, Cell metabolism and its regulation; Cell energetics: harvesting chemical and solar energy - Molecular genetics, Introduction to the molecular basis of human diseases

BO5050	**GENE EDITING**
Credits: 1 *Semester: Jan* *Segment: 12*	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**
Credits:15 *Semester: Jul* *Segment: 16*	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.

BO6016	**SEMINAR**
Credits: 2 *Semester: Jan* *Segment: 16*	The course is designed to impart smart presentation skills to the students with emphasis on Medical biotechnology research advances. The course is intended to help students understand and critically analyze and present seminal research papers in the field. Current advances in HIV-1 research: HIV-1 integration into human genome, pathogenesis and possible therapeutics; Role of UBC-13 in innate immunity & DNA repair; Cancer biology, Recent advances in gene therapy; Applications of molecular dynamics simulations and NMR techniques in understanding the biomolecular structure, dynamics & function; Molecular biology of Protein misfolding diseases: causes, mechanism and possible therapeutics.

BO6025	**THESIS-2**
Credits:15 *Semester: Jan* *Segment: 16*	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
Credits:2 Semester: Jan Segment:	Protein folding & 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**
Credits: 1 *Semester: Jan* *Segment:*	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

BO6113	STRUCTURAL BIOINFORMATICS
Credits: 2 *Semester: Jul* *Segment: 16*	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 & Dynamics: Stereochemistry: configurational & conformational isomers - Internal parameters - Forces stabilizing biomolecular structure - Structure & dynamics of nucleic acids: base pair geometry, sugar puckering & phase angle of pseudo rotation, secondary structures of nucleic acids - Structure & 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
Credits: 2 *Semester: Jul* *Segment: 16*	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	CELL TECHNOLOGY
Credits: 2 *Semester: Jan* *Segment:*	This course is intended to provide practical handling experience of culturing of human 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	PROTEIN TECHNOLOGY
Credits: 2 *Semester: Jan* *Segment:*	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	GENE TECHNOLOGY
Credits: 2 *Semester: Jul* *Segment: 16*	Gene technology course is designed to provide details of methods used in molecular biotechnology as well as insights into trends and techniques used in genomics. The course involves class room teaching of the principles and techniques, hands-on learning of the same in laboratory and presentation of selected articles from literature by students. 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.

BO6160	NEXT GENERATION SEQUENCING TECHNOLOGIES AND APPLICATION
Credits: 1 *Semester: July* *Segment:*	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 **MODERN TECHNIQUES IN NEUROSCIENCE**

Credits: 1
Semester: Jan
Segment:

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 **MACROMOLECULAR CRYSTALLOGRAPHY**

Credits: 1
Semester:
Segment:

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 **STRUCTURAL BIOLOGY**

Credits: 2
Semester: Jul
Segment: 16

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 **RNA BIOLOGY AND THERAPEUTICS**

Credits: 2
Semester: Jan
Segment:

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 **MOLECULAR MACHINES: DNA INTERACTING PROTEINS**

Credits: 2
Semester:
Segment: 16

The course provides detailed view of nature engineering a multicomponent system. The students will understand the processes carried out by the molecular machines, structural details of components making up the system, coordination of functions among the components and techniques available to characterize the microscopic machines.

Introduction: DNA-protein interactions; DNA polymerase: A multifunctional molecular machine; Endonuclease: Mechanisms of cleaving DNA; DNA repair: Recognition and rectification; Recombination: Homologous and non-homologous; Transposition: Jumping genes;

BO6340 **EPIGENETICS**

Credits: 2
Semester: Jan
Segment:

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 **MEMBRANE BIOPHYSICS**

Credits: 1
Semester: Jan
Segment:

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.

BO7053 **BIOMOLECULAR NMR**

Credits: 2
Semester:
Segment: 16

Objective of the course is to provide the fundamental concepts of NMR and applications of NMR in understanding the biomolecular structure & 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 - T1&T2 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 & Sequential assignment strategies - Structure calculation protocol.

BO7280 **PHARMACOLOGY AND PHYSIOLOGY OF RECEPTORS**

Credits: 2
Semester: Jan
Segment: 16

- 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 **CELLULAR AND MOLECULAR NEUROSCIENCE**

Credits: 2
Semester: Jan
Segment: 16

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.

CHEMICAL ENGINEERING

CH1010	MATERIAL & ENERGY BALANCE
Credits: 2 *Semester: Jul* *Segment:*	Review of basic concepts: units and dimension, material properties, process variables and stoichiometry; Techniques for problem solving; Steady state material balances for processes involving no reaction; Steady state material balances for processes involving reaction: species and elemental balances, combustion of fuels; Recycle, bypass and purge calculations; Steady state material balances involving multiple units; Steady state material balances in multiphase systems ; Steady state energy balances for processes with and without reaction; De-Coupled and coupled mass and energy balances; Analysis of degree of freedom in a steady state process ; Unsteady state material and energy balances.

CH1020	INTRODUCTION TO THERMODYNAMICS
Credits: 2 *Semester: Jan* *Segment:*	Basics of Thermodynamics: Laws, Allied postulates, Different terms and related aspects; Equations and Relations; Single Component Phase changes and related phenomenon; Basic Definitions; Thermodynamic Cycle (Carnot, Rankine, Refrigeration, Auto & Diesel Cycles etc); Definition of non-equilibrium; Need of Statistical Mechanics.

CH1021	CHEMICAL ENGINEERING LAB
Credits: 1 *Semester: Jan* *Segment:*	A laboratory course designed to introduce the wider aspects of Chemical Engineering (a multi-scale approach) in today's perspectives. It includes experiments related to basic chemical engineering thermodynamics, process control to state-of the-art topics such as surface and interfacial sciences to advanced materials. Objective of this laboratory course is to spark the young students with multi-directional facets of Chemical Engineering right in the beginning.

CH1030	FLUID MECHANICS
Credits: 2 *Semester: Jul* *Segment:*	Scope & Applications, Definition of Fluid, Concept of Continuum, Dimensions & Units. Fluid Properties: Velocity & Stress field, Density, Viscosity, Surface Tension, Pressure, Temperature. Fluid Statics: Basic equations, Pressure variation in static fluid, Manometers & Hydraulics, Fluid force on plane/curved submerged surface, Buoyancy and Stability. Fluid Dynamics: 1D, 2D, & 3D Flows; Timelines, Pathlines, Streamlines; Streaklines; Viscous & Inviscid Flows, Laminar & Turbulent flows, Compressible & Incompressible flows, Internal & External flows. Basic equations in Integral form/Differential form: Mass conservation, Momentum conservation, Energy conservation, Angular momentum principle. Incompressible Inviscid flow: Euler's equation, Bernoulli's equation, Irrotational flow. Dimensional Analysis; Similitude. Internal Incompressible Viscous flow: Fully developed laminar flow in channel; pipe, flow measurement devices.

CH1040	CHEMICAL REACTION ENGINEERING-I
Credits: 2 *Semester: Jan* *Segment:*	Elementary/non-elementary reaction; reaction order, molecularity, Mathematical modeling of reaction mechanism, polymerization/biochemical reaction, Rate data analysis, Variable volume reaction system. Isothermal reactor design: Batch, Mixed and Plug flow reactors, multiple reactor system, multiple reaction system, series/parallel/complex reaction, reaction network, Residence time distribution (RTD); RTD in ideal reactors; Reactor modeling using RTD: Segregation model, maximum mixedness model; RTD and multiple reaction.

CH1050	INTRODUCTION TO MASS TRANSFER
Credits: 1 *Semester: Jul* *Segment:*	Definition of Mass Transfer, Examples; Classes of Mass Transfer operations; Methods of Mass Transfer Operation; Principles of equipment design; Basics: Diffusion, Mass Transfer Coefficients.

CH1060	HEAT TRANSFER
Credits: 2 *Semester: Jan* *Segment:*	Conduction: Fourier Law; Steady state conduction in 1D; Critical and optimal thickness of insulation; Steady state conduction in multiple dimensions; Numerical heat conduc on; Convection: Energy equation on boundary layer; Thermal boundary layer; Reynolds's and Colburn analogy;

Free convection; Radiation: View factors; square of the distance effect; radiation between black surfaces; infinite parallel planes; radiosity, irradiation and surface resistance.

CH1080 **SEPARATIONS PROCESS - I**

Credits: 2
Semester: Jan
Segment:

Theory of Interphase Mass Transfer (Equilibrium between phases, Henry's Law, Raoult's Law; Gas and Liquid Phase resistances); Absorption Operations and Equipment used (Concepts of Operating and equilibrium lines, co-current, counter-current flows, different methods of calculating stages, application, Tray design concept, Design parameters, Design for Packed Towers); Overview of Distillation (Thermodynamics of Distillation, Basic Operation and Basics of Design Parameters)

CH2010 **MECHANICAL OPERATIONS**

Credits: 2
Semester: Jul
Segment:

Principles of mechanical separations involved in the fluid- particulate solid systems, flow through porous media (packed beds), fluidization, gravity settling operations, centrifugal separations, gas - solid separation processes, filtration theory and equipment, separations involved in froth flotation, electrostatic and magnetic separation.

CH2011 **APPLIED CHEMISTRY LAB**

Credits: 1
Semester: Jul
Segment:

Determination of Total Organic Carbon from Wastewater sample; Measurement of Surface/Interfacial Tension of Liquid-Liquid system; Measurement of pH and conductivity of Polymer Solution; Preparation and Characterization of Langmuir Blodgett Thin films; Determination of Flash and Fire Point of Fuel; Determination of Water hardness; Measurement of Contact Angle of Solid samples; Determination of Calorific value of fuel; Proximate analysis of coal; Measurement of Viscosity of Polymer Solution; Determination of Cloud and Pour Point of Lubricant; Determination of melting and boiling point of polymers.

CH2020 **BASIC CONTROL THEORY**

Credits: 1
Semester: Jan
Segment:

First order systems; response of first order systems to different forcing functions. Second order systems. Underdamped, critically damped and overdamped systems. Servo and regulator problem. Block diagrams. PD, PI, and PID controllers.

CH2021 **MECHANICAL OPERATIONS LAB**

Credits: 1
Semester: Jan
Segment:

Estimation of Power draw/Work-index of mineral rock in the Ball Mill/Rod Mill; Measuring the size reduction ratio & power draw for Jaw crusher using Comminution laws; Determining the filter medium and cake resistance of plate and frame filter press; Particle classification through a hydrocyclone; Identifying the settling zone and estimation of particle hindered settling velocity in sedimentation; Coal washability characterization using sink-float method; Fine Coal/Mineral separation using Froth Flotation; Magnetic particle separation using WHIMS/Davis tube.

CH2030 **NUMERICAL METHODS-I**

Credits: 2
Semester: Jul
Segment:

Review of computer programming; errors in numerical calculations; roots of nonlinear equations, bracketing and open methods, bisection, false-position, and secant methods, Newton's method, multiple roots, roots of polynomials; linear algebraic equations, Gauss elimination, partial pivoting, LU decomposition, matrix inverse, Gauss-Seidel method, relaxation; curve-fitting, least-squares regression, linear and polynomial regression.

CH2040 **HEAT TRANSFER EQUIPMENT & DESIGN**

Credits: 2
Semester: Jan
Segment:

Boiling and condensation; heat exchangers: types and classification; logarithmic mean temperature difference (LMTD); overall heat transfer coefficients from individual heat transfer coefficients; heat transfer coefficient in shell and tube exchangers; LMTD correction; effectiveness and number of transfer units (NTU); Evaporators: single effect and multiple effect; methods of feeding; enthalpy balance. Process design of shell & tube and double pipe heat exchangers; Process design of single effect and multiple effect evaporators.

CH2060 **NUMERICAL METHODS-II**

Credits: 2
Semester: Jan
Segment:

Numerical differentiation and integration; ordinary differential equations, First-order ODEs, Euler's methods, predictor-corrector methods, Runge-Kutta methods; adaptive Runge-Kutta Methods,

multi-step methods, stiff ODEs; system of first-order ODEs; higher-order ODEs, initial- and boundary-value problems, shooting method, finite-differences.

CH2080 **CHEMICAL REACTION ENGINEERING -II**

Credits: 2
Semester: Jan
Segment:

Models for non-ideal reactors: tank-in- series model, dispersion model; modeling of real reactors with combinations of ideal reactors; stoichiometric table, reaction network analysis, effect of pressure drop on performance of plug flow vessels. Steady state non-isothermal reactor design,energy balance on batch, plug flow and CSTR reactors, optimal design for exothermic reversible reactions, stability and multiplicity of steady states in CSTR; unsteady state non isothermal reactor design: unsteady state energy balance, unsteady operation of batch, plug flow and CSTR.

CH2100 **HETEROGENEOUS REACTION ENGINEERING**

Credits: 2
Semester: Jan
Segment:

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.

CH2120 **FLUID MECHANICS LAB**

Credits: 1
Semester: Jan
Segment:

Fluid Mechanics: Measurement of fluid properties; Pressure measurement using U-tube and inclined manometers; Measurement of discharge using notches; Impact of water jet; Flow measurement using venturimeter, orifice meter, rotameter; Measurement of friction losses.

CH3010 **SEPARATION PROCESS II**

Credits: 2
Semester: Jul
Segment:

Flash distillation, Column Distillation: (Binary),Column Distillation (Multi-component); Liquid-liquid extraction principles; Solid liquid extraction, phase rule and phase diagram, tie lines, co-current and counter-current operation; Leaching; Adsorption; Introduction to chromatography, crystallization principles; Drying; Humidification.

CH3011 **HT LAB**

Credits: 1
Semester: Jul
Segment:

Heat Transfer experiments: Temperature measurement and calibration; Measurement of thermal conductivity of solids; Shell and tube heat exchanger in parallel and counter flow configurations- Determination of emissivity and Stefan-Boltzmann constant - Measurement of convective heat transfer coefficient: Free and forced convection; heat transfer coefficient in vertical condenser and horizontal condenser.

CH3020 **TRANSPORT PHENOMENA-II**

Credits: 2
Semester: Jan
Segment:

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.

CH3021 **REACTION ENGINEERING LAB**

Credits: 1
Semester: Jan
Segment:

Chemical reaction engineering: Selected laboratory experiments based on performance of batch, plug flow, continuous stirred tank reactors (CSTR), adiabatic reactor, packed bed reactor, residence time distribution (RTD), polymerization reaction, biochemical reaction and kinetics of homogeneous and heterogeneous reaction.

CH3022 **MASS TRANSFER EQUIPMENT DESIGN**

Credits: 1
Semester: Jan
Segment:

Review of Vapor Liquid Equilibrium: Chemical Potential, Gibbs Phase Rule, Fugacity, Activity Coefficients, Predicting VLE equilibrium constants and Henry's Law. Design of flash distillation units: Binary and Multicomponent Distillation, Calculating flow rates, compositions and energy requirements, Rachford-Rice equation, sequential and simultaneous solution methods. Design of

distillation columns: Binary Distillation, Dynamic mass and energy balances, Tray hydraulics, Empirical correlations for column pressure drop, efficiency calculations, estimating flooding and weeping, Column sizing, Dynamic control configurations and methods, Control using RGA, Multicomponent Distillation, Alternating convergence method for solution, Multistage Batch Distillation. Design of absorption columns: Equilibrium curve, operating line, number of ideal stages, Efficiency (Murphree and tray efficiency), design analysis for dilute and concentrated systems, Kremser equation, Packed tower: Mass transfer coefficients, height and number of transfer Unit (HTU-NTU). COCO simulator will be used in hands-on sessions for automatic solution of flowsheets with a combination of these unit operations.

CH3030 **TRANSPORT PHENOMENA-I**

Credits: 2
Semester: Jul
Segment:

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.

CH3031 **MT LAB**

Credits: 1
Semester: Jul
Segment:

Mass Transfer experiments: Basic Mass transfer experiments with simple calculations: Packed-bed Absorption, Packed-bed Extraction, Distillation (batch & continuous), Adsorption, Vapor-liquid equilibrium.

CH3041 **PROCESS CONTROL LAB**

Credits: 1
Semester: Jan
Segment:

Control Valve Trainer: Understand various types of control valves, Quick opening, Linear, Equal Percentage by changing the pressure signal to the valves and measuring the flow using the provided rotameter; Pressure Control System: Perform open loop step testing and obtain a model relating pump- speed, opening of a solenoid valve and pressure. Implement PID control of the pressure in the process vessel using pump- speed and the solenoid valve; Four- Tank System: Perform open loop step testing and obtain a model relating liquid level in each of the tanks to the flow rates. Implement level control in various configurations; Heat Exchanger: To perform open loop testing and obtain a model relating hot, cold water flows and the temperature. Implement PID control of temperature using the hot and cold water flow rates. Heater Board: Developing a first order model and Implementing temperature control of the plate by regulating the power to the heater. Distillation Column: Obtaining continuous steady state in a Distillation column, Perform step tests in reboiler power, reflux ratio, feed pump power (feed flow rate) and developing a lower order model.

CH3042 **PLANT DESIGN -I**

Credits: 2
Semester: Jan
Segment:

Process Synthesis, Materials & Energy Balance, Computer Aided Design, Flow-sheet Development, Aspects of Instrumentation-Control-Storage-Materials.

CH3050 **CONTROL DESIGN AND ANALYSIS**

Credits: 2
Semester: Jul
Segment:

Modelling of Dynamic Processes, Linear Time Invariant (LTI) systems, Stability of Linear and Non-Linear systems, Dynamics of sensing elements, Frequency Response of LTI systems, Bode stability criterion, Gain and Phase Margins, Nyquist plot, Cauchy's Principle, Nyquist stability, Root Locus (Asymptotes, Break-Away points), Review of P, PI, PID controllers, Cohen-Coon Method, Ziegler Nichols Method, Smith Predictor, Feed-forward control, Cascade control, Multi-Input Multi-Ouput (MIMO) systems, Loop interactions, Controller Design using Relative Gain Array (RGA), Model Predictive Control (MPC), Demonstration of MPC for Distillation Column control. Additional topics that may be covered : Inverse Response, Pole Placement, Sensitivity Functions, Internal Stability, Robust Stability Theorem, Fundamental Limitations on Feedback Control structure, Effect of NMP/ LHP zeros on control Design, Sensitivity Bounds.

CH3070	**CHEMICAL ENGINEERING THERMODYNAMICS-I**
Credits: 2 *Semester: Jul* *Segment:*	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.
CH3090	**CHEMICAL ENGINEERING THERMODYNAMICS-II**
Credits: 1 *Semester: Jul* *Segment:*	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.
CH4010	**SAFETY**
Credits: 1 *Semester: Jul* *Segment:*	Basic concepts relating to chemical hazards, risk, and ethics, Layers of Plant Safety, General Protocol and Scope Identification, Chemical Hazards classification, Handling and storage of hazardous chemicals, HAZAN, HAZOP, fault tree analysis, Case Studies with regard to inadequate process design, improper process modification, and disregard for ethical decision making, plant layout and environmental impact.
CH4011	**PROCESS SIMULATION LAB**
Credits: 2 *Semester: Jul* *Segment:*	Usage of programming environment e.g. MATLAB to solve engineering problems that are expressed by ordinary differential equations boundary value problems (ODEBVP) & Partial differential equations (PDEs) - Usage of MATLAB to solve engineering optimization problems.
CH4012	**PLANT DESIGN-II**
Credits: 1 *Semester: Jul* *Segment:*	Role of Safety in Design, Economic Analysis & Feasibility, Depreciation Methods, Economic evaluation (NPV, DCFROR etc.), case studies relating process, equipment, plant design, from concepts to product (concept, lab scale, prototype/ pilot scale, further scale-up)
CH4020	**OPTIMIZATION**
Credits: 2 *Semester: Jan* *Segment:*	Formulation of optimization problem - Analytical and numerical techniques - Single / multi-variable optimization - Unconstrained / constrained optimization - Nonlinear programming - Solving real life problems using Numerical Optimization.
CH5010	**NUMERICAL METHODS-I**
Credits: 2 *Semester: Jul* *Segment:*	Review of computer programming; errors in numerical calculations; roots of nonlinear equations, bracketing and open methods, bisection, false-position, and secant methods, Newton's method, multiple roots, roots of polynomials; linear algebraic equations, Gauss elimination, partial pivoting, LU decomposition, matrix inverse, Gauss-Seidel method, relaxation; curve-fitting, least-squares regression, linear and polynomial regression.
CH5020	**NUMERICAL METHODS-II**
Credits: 2 *Semester: Jan* *Segment:*	Numerical differentiation and integration; ordinary differential equations, First-order ODEs, Euler's methods, predictor-corrector methods, Runge-Kutta methods; adaptive Runge-Kutta Methods, multi-step methods, stiff ODEs; system of first-order ODEs; higher-order ODEs, initial- and boundary-value problems, shooting method, finite-differences.
CH5030	**CHEMICAL ENGINEERING THERMODYNAMICS-I**
Credits: 2 *Semester: Jul* *Segment:*	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	**CHEMICAL ENGINEERING THERMODYNAMICS-II**
Credits: 1 *Semester: Jul* *Segment:*	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	**NON-ISOTHERMAL REACTORS**
Credits: 2 *Semester: Jul*	Overview of reaction engineering & emerging challenges, stoichiometric table, reaction network analysis, effect of pressure drop on performance of plug flow vessels, energy balance and non-

Segment: isothermal reactors design, optimal design for exothermic reversible reactions, stability and multiplicity of steady states in CSTR.

CH5060 HETEROGENEOUS REACTION ENGINEERING

Credits: 2
Semester: Jan
Segment:

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 TRANSPORT PHENOMENA-I

Credits: 2
Semester: Jul
Segment:

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 TRANSPORT PHENOMENON-II

Credits: 2
Semester: Jan
Segment:

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 SIMULATIONS LAB - 1

Credits: 2
Semester: Jul
Segment:

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.

CH5180 VISCOUS FLUID FLOW

Credits: 2
Semester:
Segment:

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.

CH6220 ADVANCED SOILD-LIQUID SEPARATIONS

Credits: 2
Semester:
Segment:

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 & 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.

CH6420 NON-NEWTONIAN FLUID MECHANICS

Credits: 2
Semester:
Segment:

Definitions, Newtonian vs Non-Newtonian (NN) Fluids, NN behavior examples, NN Fluids in Engineering Practice. Structure and Rheology: Examples in NN fluids. Basics: Balance equations, Axioms in Constitutive Modeling, NN model examples. Single phase fluids: Generalized Newtonian, Bingham Plastic, Differential (Grade 2), Rate-type (Maxwell, Oldroyd-B), and Integral models (Lodge-Rubberlike, K-BKZ). Multi-phase fluids: Gas-Liquid flows, Solid-Liquid flows. Particulate systems: Spheres in Shear-thinning and Viscoplastic fluids, Fluid drops in Non-Newtonian fluids.

CH6450	**INTRODUCTION TO SYSTEM IDENTIFICATION**
Credits: 2 *Semester:* *Segment:*	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**
Credits: 2 *Semester:* *Segment:*	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**
Credits: 1 *Semester:* *Segment:*	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.
CH6580	**ADVANCED MINERAL PROCESSING**
Credits: 2 *Semester:* *Segment:*	This course is a full details and comprehensive knowledge of advance aspects of mineral processing, designing and selection of processing equipment and machinery. The following topics are explained in this course: Comminution theory; Models of comminution process; Grinding mills, designs & modeling; Screening and classification; Dense medium separation; Gravity separations; Froth flotation.
CH6620	**INTERMOLECULAR FORCES**
Credits: 1 *Semester:* *Segment:*	Thermodynamics of Inter-molecular Forces; Variety of forces between the molecules (Ionic, Polar, Induced Polar, Dispersion and H-bonding); Calculations and analysis.
CH6630	**MEMBRANE SEPARATION PROCESS**
Credits: 2 *Semester:* *Segment:* *Pre-Req: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.
CH6650	**INTRODUCTION TO STOCHASTIC DIFFERENTIAL EQUATIONS**
Credits: 1 *Semester:* *Segment:*	Brief review of Modern Probability Theory, Stochastic Processes, Examples of SDE, Ito Integal, Ito Formula, Solutions to SDEs.
CH6670	**THEORY OF STOCHASTIC DIFFERENTIAL EQUATIONS**
Credits: 2 *Semester:* *Segment:* *Pre-Req: 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

CH6710 **CONCEPTS IN SOFT MATTER SYSTEMS**

Credits: 2
Semester:
Segment:

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 **BASICS OF NANOSCIENCES AND NANOTECHNOLOGY**

Credits: 2
Semester:
Segment:
Pre-Req:

Physical aspects of Nanosciences, Introduction to Nanomaterials, Synthesis of Nanomaterials, Carbon Nanomaterials, Nanofabrication Methods, Characetrization of Nanomaterials, Applications of Nanotechnology, Health, social, ethical concerns of nanotechnology.

CH6730 **NATURE INSPIRED MATERIALS ENGINEERING**

Credits: 2
Semester:
Segment:

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 **APPLIED STATISTICS IN EXPERIMENTAL RESEARCH**

Credits: 2
Semester:
Segment:

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 **MOLECULAR THEORY OF POLYMERIC FLUIDS**

Credits: 2
Semester:
Segment:

Introduction to Polymers: History, Polymerization (synthesizing large molecules), Polymer architecture (linear, branched and rings), Applications. Single Molecule Conformations: Ideal Chain: Models for representing long chain molecules, Model predictions (radius of gyration, end-to-end distribution), Real Chain: Effect of excluded volume on chain conformation (SAW model), Model Predictions, Free energy of a chain, Ideal and real chains under tension and compression, Experimental measurements (relationship to the models). Single Molecule (Chain) Dynamics: Unentangled Dynamics: Rouse chain (beads connected by springs) and Zimm model (effect of hydrodynamic interactions), Entangled Dynamics: Tube model - phenomenological mean field (relaxation of a long polymer chain confined in a tube), Conclusions: From molecules to macroscopic properties: Structure-property relationships in systems with long chain molecules.

CH6770 **INTRODUCTION TO APPLIED STATISTICAL MECHANICS**

Credits: 2
Semester:
Segment:

Review of probability theory; concepts & 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 **SOFT COMPUTING IN PROCESS MODELING**

Credits: 1
Semester:
Segment:

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.

CH6820 **NATURE INSPIRED OPTIMIZATION**

Credits: 2
Semester:
Segment:

Basics of optimization covering formulation, definition of objective function, constraints, basic principles of optimality. Basics of single and multi-objective constrained optimization. Nature inspired optimization techniques under this category. Difference of these methods with classical methods. Discussion on working principles of several such techniques e.g. Genetic algorithms,

simulated annealing, ant colony optimization etc. Performance judgement of these techniques using standard test functions as well as practical projects.

CH6840	**BIOMATERIALS SCIENCE AND ENGINEERING**
Credits: 2 *Semester:* *Segment:*	Properties, design and applications of metals, ceramics, polymers, hydrogels; Mechanical testing of biomaterials; Viscoelasticity; Maxwell/Kelvin-Voigt models; Biomaterial degradation; Surface properties of biomaterials; Protein adsorption and isotherms; Cell-ECM interactions; Cell adhesion on biomaterials; Cell migration models; Immune response; Introduction to drug delivery; Pharmacokinetics.

Chemical Processes

CHXXXX	**PETROCHEMICAL INDUSTRY**
Credits: 2 *Semester: Jan* *Segment:*	Motivation & Socio-Economic Spread, Definition & Categories of Petrochemicals, Petrochemical Production: Steam Cracking, Fluid Catalytic Cracking, C4- C5- Stream Processing, Production & Product Profiles for Syngas/ Olefins / Aromatics, Product Profile of lesser known Petrochemicals.

CHXXXX	**PETROLEUM REFINERY**
Credits: 2 *Semester: Jan* *Segment:*	Evaluation and characterization of crude oil: TBP and other distillation tests. Petroleum products, their properties, specification and testing different properties like flash point, fire point, smoke point, aniline point, carbon residue, kinematic viscosity, pour point, freezing point etc. Petroleum refinery distillation-pre- fractionation and atmospheric distillation of crude. Stabilization of naphtha. Vacuum distillation of RCO. Reforming of naphtha. Other secondary processes like Vis-breaking, FCC unit. Hydrotreatment processes in refining: hydro-desulfurisation, hydrofinishing, Hydrocracking. Production of lube oil base stock.

CH6550	**CHEMICAL REACTOR MODELING**
Credits: 2 *Semester: Jan* *Segment:*	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.

CHXXXX	**CHEMICAL TECHNOLOGY**
Credits: 1 *Semester: Jan* *Segment:*	Introduction to chemical technology; Overview of various chemical process industries including petroleum refinery, petrochemical industries, inorganic chemical industries (chlor-alkali industries, mineral acids, and ammonia), fertilizers industries, pulp, paper, and rayon industries, and soap and detergents industries.

CHXXXX	**FLUIDIZATION TECHNOLOGY**
Credits: 1 Semester: Jan Segment:	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, Terminal velocity for a single solid particle, 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.

CHXXXX	**PROCESS INTENSIFICATION**
Credits: 1 *Semester: Jan* *Segment:*	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.

CHXXXX	**MINERAL PROCESSING**
Credits: 1 Semester: Jan Segment:	This course briefs the knowledge 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.

Energy and Environment

CHXXXX **ENERGY STORAGE SYSTEMS**

Credits: 2
Semester:
Segment:

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.

CHXXXX **SUSTAINABLE AND ENERGY OPTIONS**

Credits: 1
Semester: Jan
Segment:

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.

CHXXXX **INTRODUCTION TO FUEL CELLS**

Credits: 1
Semester: Jan
Segment:

Types of fuel cells; Advantageous and Disadvantageous of different fuel cell types; Potential and thermodynamics of cells; Electrode kinetics; Characterization of fuel cells; Modeling of electrochemical processes.

CHXXXX **BIOREFINERY**

Credits: 1
Semester: Jan
Segment:

Overview of petroleum refinery and petrochemicals, Scenario of energy and chemicals and need for renewable feedstock; introduction and overview of bio-refinery, fuels and chemicals from vegetable oils; bio-alcohol as feedstock for fuels and chemicals; synthesis gas from biomass, overview of gasification, pyrolysis, and reforming; fuels and chemicals from synthesis gas; fuels and chemicals from biomass.

Biological Engineering

CHXXXX **SYSTEMS BIOLOGY**

Credits: 1
Semester: Jul
Segment:

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

CHXXXX **DRUG DELIVERY SYSTEMS**

Credits: 1
Semester: Jul
Segment:

Principles of drug delivery (diffusion, barriers, permeability, availability, effective dose); design of vehicles (matrix & reservoir systems); polymer-drug formulations; approaches for site-specific and targeted drug delivery; challenges in the delivery of sensitive biomolecules; routes of administration; introduction to pharmacokinetics and ADMET analysis.

CHXXXX **INTRODUCTION TO BIOLOGICAL ENGINEERING**

Credits: 1
Semester: Jul
Segment:

This course introduces the field of biological engineering, where the principles of engineering are used to solve problems in medicine and biology. Topics covered include an introduction to biological systems, application of industrial fermentation, microbial metabolism and biochemistry approach to understand the cloning, genetically modified products, bio-molecules, vitamins and enzymes. Studies on bioreactors systems on upstream, production and downstream, operation, control towards engineering approach to biological systems.

CHXXXX **ADVANCED BIOCHEMICAL ENGINEERING**

Credits: 2
Semester: Jul
Segment:
Pre-Req: Introduction to

This course introduces advance biochemical engineering aspects in terms of mathematical modelling and simulation for cell growth and enzyme kinetics. Cell free and Immobilization kinetics; screening, isolation and identification of fungal and bacterial organisms. Problem solving on diffusion limitation, rate limiting for porous and non-porous material, effectiveness factor for intra particle diffusion, oxygen transfer rates and volumetric mass transfer rates. Comparison studies on

Biological Engineering	submerged and solid state fermentation bioreactors i.e. batch, continuous, chemostat recycle and fed batch studies. Recombinant monoclonal technology and marine-derived biomaterial application.

Materials

CHXXXX	**ENGINEERING MATERIALS**
Credits: 1 *Semester:* *Segment:*	Properties of water; Synthesis and properties of Lubricants; Fuels; Polymers; Explosives; Cement; Adhesives; Nanomaterials.
CHXXXX	**CONCEPTS IN SOFT MATTER SYSTEMS**
Credits: 2 *Semester:* *Segment:*	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.
CHXXXX	**INTRODUCTION TO NANOTECHNOLOGY**
Credits: 1 *Semester: Jul* *Segment:*	Physical aspects of Nanosciences, Synthesis of Nanomaterials, Characterization of Nanomaterials, Nanofabrication methods.
CHXXXX	**INTERFACIAL CHEMISTRY**
Credits: 1 *Semester:* *Segment:*	Introduction to Colloids and Interfaces; Forces in Colloidal Systems; Stability of Colloids; Surface Forces, Adhesion and Wettability

CHEMISTRY

CY1017 **ENVIRONMENTAL CHEMISTRY-I**

Credits: 1
Semester: Jul
Segment: 12

Know our environment (atmosphere composition and behavior, ecosystem, flow of energy and nutrient cycles, sustainability), Know about global warming (greenhouse gases, results of global warming), concise overviews of ozone depletion and atmospheric pollutants. Organic and Inorganic chemicals in environment (toxicity, polychlorinated hydrocarbons like DDT, polymers, detergents) and their impact on environment, a project on environment related topic.

CY1020 **DYNAMICS OF CHEMICAL SYSTEMS-I**

Credits: 1
Semester: Jan
Segment: 12

Introduction to Chemical kinetics, Basics in Electrochemistry: Electrochemical Principles and Reactions, Basic concepts of electrochemical cells and batteries, Historical background of quantum hypothesis, Wave equation, Postulates, Schrodinger equation and introduction to simple solvable problems

CY1021 **DYNAMICS OF CHEMICAL SYSTEMS-II**

Credits: 2
Semester: Jan
Segment: 36

Advanced insights into chemical kinetics including Collision theory of reaction rates, Transition State Theory, Energy Storage Systems (e.g. Lead-Acid, Lithium Ion Batteries, Fuel Cells and Supercapacitors): fundamentals to applications, detailed understanding of Corrosion, electroplating, electroless plating, Particle in box, Harmonic Oscillator, Rigid rotor, Vibrational and rotational spectroscopy, Approximate methods, Atomic and molecular orbitals, Hybrid orbitals, Chemical bonding.

CY1030 **ENVIRONMENTAL CHEMISTRY-II**

Credits: 2
Semester: Jul
Segment: 36

More about environment (chemistry of lithosphere, energy balance, sustainability and recycle), More on global warming (infrared absorption, molecular vibration, atmospheric window, residence time of greenhouse gases, evidences and effects of global warming), Deeper analysis of atmospheric pollution (Chemistry of CO, NO_x, VOCs, SO_2, Industrial smog, photochemical smog), Ozone depletion (production, catalytic destruction), Fate of organic/inorganic chemicals in natural and engineered systems (fate of polymers after use, detergents, synthetic surfactants insecticides, pesticides etc. after use), impact on physical-chemical properties of environmentally relevant compounds, Aspects of transformations in atmosphere (microbial degradation of organics-mechanism of action of DDT or analogues, environmental degradation of polymers, atmospheric lifetime, toxicity), Future challenges (CO_2 sequestering, Nuclear energy), a project on environment related topic.

CY6220 **SEPARATION TECHNIQUES AND DYNAMIC ELECTRODICS**

Credits: 3
Semester:

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 Processes, Potential Sweep Methods, Polarography, Pulse Voltammetry, Impedance Spectroscopy, Controlled Current and potential Methods, Application to Electroactive layers, Spectroelectrochemistry and other coupled characterization methods.

CY7020 **DRUG DISCOVERY, DESIGN AND DEVELOPMENT**

Credits: 3
Semester:

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.

CY7111 **BIO INSPIRED CATALYSIS IN MODERN RESEARCH**

Credits: 3
Semester: Jan

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; O_2 reduction; CO_2 reduction: thermodynamics; mechanisms: enzymatic CO_2 reduction, homogeneous catalysis and electrocatalysis; Metal Organic Frameworks and their applications. Inorganic complexes as MRI contrast agents.

CY7112 **BIOINSPIRATION AND BIOMIMICRY IN CHEMISTRY**

Credits: 3
Semester:

Basic Concepts: Energy parameters, basic principles and chemical transformations; Energy Carriers; Fossil Fuels: Oil, Gas and Coal; H_2, H_2O_2, HCO_2H 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 O_2; Catalyzed production of H_2O_2; Catalyzed reduction of H_2O to H_2; Catalyzed reduction of CO_2 to hydrocarbons; Light-harvesting complexes and charge separation systems; H_2 production; Catalytic hydrocarbon and NOx combustion.

CY7130 **MAIN GROUP ORGANOMETALLIC CHEMISTRY**

Credits: 3
Semester: Jan

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 **FUNDAMENTALS AND APPLICATIONS OF SMALL MOLECULE X-RAY CRYSTALLOGRAPHY**

Credits: 3
Semester: Jan

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.
Powder X-ray diffraction (PXRD): Rietveld Refinement of Powder X-ray Data.
Crystal Structure Description of Important Molecular and Inorganic Structures, Bonding, etc.
Role of Symmetry in Predicting New Structures.

CY7150 **FUNCTIONAL INORGANIC SOLIDS FOR ENERGY APPLICATIONS**

Credits: 3
Semester:

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 **CHEMICAL & ELECTROCHEMICAL ENERGY SYSTEMS**

Credits: 3
Semester:

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 N_2O, dry reforming.

CY7230 **NANOCHEMISTRY & APPLICATIONS**

Credits: 3
Semester:

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 & 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.

CY7260 **PRINCIPLES OF MASS SPECTROMETRY AND ITS APPLICATIONS**

Credits: 3
Semester:

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

CY7260 **BATTERIES**

Credits: 3
Semester:

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.

CY7270 **ADVANCED MOLECULAR SPECTROSCOPY**

Credits: 3
Semester:

Basic concepts: 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.
General spectroscopy: rotational and vibrational selection rules, classification of electronic states, vibrational coarse structure, rotational fine structures, diatomic and polyatomic molecules, Hund's coupling cases, Franck-Condon principle, Herzberg-Teller vibronic coupling, Renner-Teller and Jahn-Teller effects.

Fundamentals of lasers: population inversion, frequency and spatial properties of laser radiation, continuous wave lasers, Q-switching and mode locking, generation of short pulses and harmonic generation.
Examples of lasers: He-Ne, rare-gas ion, CO_2 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.

CIVIL ENGINEERING

CE2020	**CONSTRUCTION MATERIALS**
Credits: 1.5 *Semester: Jan* *Segment: 46*	Structure and properties of materials, Production of ferrous metals and characteristics; Types of major rolled steel shapes; Properties of Structural Steel, Cold-formed steel and its properties; steel and aluminium, masonry and mortar, polymers and plastics, Composites and wood.
CE2021	**CONSTRUCTION MATERIALS LAB**
Credits: 2 *Semester: Jul* *Segment: 16*	Physical tests on cement, fine and coarse aggregate; tests for workability; tests on hardened concrete; compression tests on cubes and cylinders; modulus of rupture test on concrete beams; rebound hammer and UPV test on hardened concrete; Testing of bricks for efflorescence, water absorption and compressive strength; Tension Tests on Steel/ Wood/Composite Coupons.
CE2030	**CONCRETE TECHNOLOGY**
Credits: 1.5 *Semester: Jul* *Segment: 13*	Manufacture and chemical composition of cement; Hydration of cement and products of hydration; Influence of temperature and water to cement ratio on hydration of cement; Admixtures for improving properties of fresh and hardened concrete; properties of aggregate; concrete mix design; Properties of fresh and hardened concrete; durability and long-term performance of concrete; special concretes and self-consolidating concrete.
CE2031	**FLUID MECHANICS LAB**
Credits: 1 *Semester: Jul* *Segment: 13*	Flow in open channel. Fluid friction. Hydro-statistics and properties of fluids. Impact of jets. Notches. Pressure measurements. Flow measurement.
CE2100	**INTRODUCTION TO STRUCTURAL ANALYSIS**
Credits: 1.5 *Semester: Jan* *Segment: 13*	Types of Structures and Supports; Free - Body Diagram; Forces and Moments; Analysis of Various statically - determinate structures; Cables, Arches, Beams; Influence Lines and Energy Methods.
CE2101	**STRUCTURAL MECHANICS LAB**
Credits: 2 *Semester: Jan* *Segment: 46*	Flexural Stresses and Deflection in a Simply Supported Steel Beam; Symmetrical and Unsymmetrical Bending of Steel Sections; Compression Test on Composite Column; Tension Test on Steel Sections, Column Buckling Test, Indeterminate Beam testing, Torsion testing, Pin jointed frame work analysis, Three and Two hinged Arches.
CE2110	**ANALYSIS OF INDETERMINATE STRUCTURES**
Credits: 1.5 *Semester: Jan* *Segment: 46*	Introduction to Statically Indeterminate Structures; Flexibility for Analysing Statically Indeterminate Structures. Slope deflection method, Moment distribution method, Force method, Stiffness method for truss, beams and frames.
CE2500	**ENGINEERING HYDROLOGY**
Credits: 2 *Semester: Jul* *Segment: 14*	Measurement, analysis, and interpretation of various components of hydrologic system (precipitation, infiltration, runoff, evapotranspiration); Rainfall - Runoff correlations; Hydrograph analysis; Groundwater hydrology and wellhydraulics.
CE3010	**FUNDAMENTALS OF GIS AND REMOTE SENSING**
Credits: 2 *Semester: Jan* *Segment: 14*	Principles of electromagnetic radiation; Data analysis and image interpretation; Coordinate system and map projections; Spatial data management; Map overlay and geo processing; Spatial, geo-statistical, Network tools in GIS; Introduction to model building with GIS.
CE3011	**GIS LAB**
Credits: 1 *Semester: Jan* *Segment: 34*	Working with ERDAS -> Data interpretation and geo referencing; Image classification; Image interpretation techniques Working with ArcGIS -> Spatial joins and geo processing; Editing and geocoding algorithms; Vector and Raster analysis; GIS networking

CE3020	**SURVEYING**
Credits: 2 *Semester: Jul* *Segment:*	Geo-informatics, Principles of surveying, Errors in measurements, Maps, Linear Measurements, Measurement of Directions, Bearings and angles; Compass surveying- magnetic bearings, declination, local attraction errors and adjustments; Theodolites, Traversing, Triangulation and Trilateration, Purpose and classification of each; Compass and theologize traverses, Triangulation, Adjustment Computations.
CE3102	**INTRODUCTION TO REINFORCED CONCRETE**
Credits: 1.5 *Semester: Jul* *Segment: 13*	Mechanical properties of reinforced concrete materials including shrinkage, and creep; Load displacement behavior under pure compression and pure tension; Basic Bending Theory; Moment-curvature and load-deflection relationships; Shear Behavior of RC Members; Torsional Behavior of RC Members.
CE3122	**REINFORCED CONCRETE DESIGN**
Credits: 1.5 *Semester: Jul* *Segment: 46*	Probabilistic load theory; Design Philosophies; Difference between strength and limit state design; Introduction to cods of design -- IS 456 and IS 875; Design for Flexure and Shear; Design of Columns subjected to axial load and uniaxial bending; Introduction to Design of slabs; Introduction to Design one-way and isolated footings.
CE3132	**DESIGN OF STEEL STRUCTURES**
Credits: 1.5 *Semester: Jan* *Segment: 46*	Types of Beam Buckling Failures; Design of beams and beam-columns, Connections - Bolted Connections Welding and Welded Connections -Bolt Group, Weld Group; Beam and Column Splices.
CE3142	**INTRODUCTION TO STRUCTURAL STEEL DESIGN**
Credits: 1.5 *Semester: Jan* *Segment: 13*	Mechanical Properties of Steel; Effect of Corrosion; Fire and Fatigue; Limit State Design - Analysis procedures and Design Philosophy; Design of Tension Members; Compression Members - Elastic Buckling, Strength Curves, Strength of Compression Members, Concept of Effective Lengths, Types of Column Sections, Design of Axially Loaded Columns.
CE3300	**GEOTECHNICAL ENGINEERING - I**
Credits: 1.5 *Semester: Jan* *Segment: 13*	Introduction to Geotechnical engineering, Rock cycle, Clay Mineralogy, Phase Relationships, Grain-Size analysis, Plasticity and Soil Classification, Compaction, Standard/Modified Proctor Test, Field Compaction, Permeability, Seepage.
CE3301	**GEOTECHNICAL ENGINEERING LAB**
Credits: 2 *Semester: Jan* *Segment: 16*	Visual Soil Classification and Water Content, Sieve Analysis, Liquid Limit and Plastic Limit, Hydrometer Analysis, Standard Proctor Test, Field Density Test, Constant and Variable Head Permeability Test, Oedometer Test, Unconfined Compression Test, Direct Shear Test, Unconsolidated and Undrained Test.
CE3310	**GEOTECHNICAL ENGINEERING - II**
Credits: 1.5 *Semester: Jan* *Segment: 46*	Effective Stress Principle, In situ Stresses, Mohr's Circle, Vertical Stresses, Boussinesq's and Westergaard's Theories, Terzaghi 1D Consolidation Theory, Compressibility, Secondary Consolidation, Settlement Calculations, Shear Strength, Direct Shear and Triaxial Shear Tests, Drained and Undrained behavior of sands and Clays.
CE3312	**INTRODUCTION TO FOUNDATION ENGINEERING**
Credits: 1 *Semester: Jul* *Segment: 12*	Foundation Design - Limit State and Working Stress, Tolerable Foundation Movements, Site Investigations, In-Situ Testing (SPT and CPT) and their Interpretation, Field vane Shear Test, Foundation Types and their Installation (Shallow and Deep), Shallow Foundation Settlement.
CE3322	**DESIGN OF FOUNDATIONS**
Credits: 2 *Semester: Jul* *Segment: 36*	Limit Bearing Capacity and Design of Shallow Foundations, Analysis and Design of Axially and laterally Loaded single piles, Under-reamed Piles, Pile Groups; Retaining Walls, Earth Pressure Theories and Design, Reinforced Earth Structures, Slopes, Limit Equilibrium Methods- Method of Slices, Sheet Pile Wall and Braced Excavations.

CE3500	INTRODUCTION TO HYDRAULIC ENGINEERING
Credits: 1.5 *Semester: Jul* *Segment: 13*	Analysis and design of water distribution system; Steady and Unsteady flows in closed conduits; Design principles of hydraulic structures; Introduction to Hydraulic Machinery.

CE3501	HYDRAULIC ENGINEERING LAB
Credits: 1 *Semester: Jul* *Segment: 56*	Impact of jet on fixed vanes; Developing characteristic curves for axial / radial flow turbines, and centrifugal pumps; Experimental investigation of sediment movement in open channels; Analysis of flows in fixed bed and tilting channels.

CE3510	OPEN CHANNEL HYDRAULICS
Credits: 1.5 *Semester: Jan* *Segment: 13*	Application of energy and momentum principles in open channels; Uniform flow; Concept of specific energy; Gradually varied flow analysis; Rapidly varied flow; Hydraulic jump analysis.

CE3511	ENVIRONMENTAL ENGINEERING LAB
Credits: 2 *Semester: Jul* *Segment: 16*	Determination of physical contaminants: solids, turbidity, pH, electrical conductivity, Jar test; acidity and alkalinity of water; hardness of water; dissolved oxygen content of water; chemical oxygen demand; biochemical oxygen demand; chlorine and bleaching, MPN Test, demonstration of advanced equipment.

CE3512	INTRODUCTION TO ENVIRONMENTAL ENGINEERING
Credits: 1 *Semester: Jan* *Segment: 12*	Concept of environmental pollution: air pollution, water pollution, solid waste, special waste; sources, measurement techniques and criteria; fate and transport of contaminants; treatment technologies; key concepts, examples and case studies will be presented. Important lab instruments will be introduced, along with field visit.

CE3522	WATER AND WASTE WATER ENGINEERING
Credits: 2 *Semester: Jul* *Segment: 14*	Chemical and biological concepts, reactions, material balance, flow models and reactors, water quality, wastewater characteristics. Screening and shredding, grit removal, flow equalization, coagulation, flocculation, sedimentation, filtration, disinfection. Aerobic suspended growth processes, aerobic attached growth processes, anaerobic processes. Sludge processing and land application of biosolids.

CE3530	AIR POLLUTION
Credits: 2 *Semester: Jan* *Segment: 14*	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, Air (Prevention and Control of pollution) Act.

CE3820	HIGHWAY DESIGN AND MATERIALS
Credits: 2 *Semester: Jul* *Segment: 14*	History of highway development, Surveys and classification of roads, Highway elements, Geometric design of highway, Advanced highway geometric design, Pavement materials and testing; Material characterization for design; Design of highway; Highway construction, maintenance and rehabilitation.

CE3821	HIGHWAY MATERIALS LAB
Credits: 1 *Semester: Jan* *Segment: 56* *PreReq: CE3820*	Laboratory testing of road aggregates, bituminous binders and mixes for their suitability in road construction with reference to IRC/BIS specifications. Sub grade evaluation - California bearing ratio, resilient modulus, modulus of sub grade reaction; Pavement evaluation studies -measurement of pavement distresses, deflection studies.

CE3830	RAILWAY AND AIRPORT ENGINEERING
Credits: 1 *Semester: Jul* *Segment: 56*	Railway Engineering: Railway location surveys and alignment, Permanent way, Gauges, Functions and requirements, Geometric design, Track Junctions, Points and crossings, design and layout, Railway stations and yards. Railway track drainage

Airport Engineering: Aircraft characteristics, Airport obstructions and zoning, Runway, taxiways and aprons, Terminal area planning, Airport site selection; Geometric design of railway and airfield elements.

CE3840	**TRAFFIC ENGINEERING AND PLANNING**
Credits: 2 *Semester: Jan* *Segment: 14*	Traffic Engineering: Traffic stream components and characteristics; Theories of traffic flow; Traffic studies; Design of control strategies for simple systems like intersections, roundabouts, freeways, etc.; Capacity and level of services of various transportation facilities. Multilane highways capacity and LOS, Introduction to Intelligent Transportation Systems. Transportation Planning: Introduction to urban and regional transportation planning; Urban transportation planning process; Activity based travel demand modeling.

CE3841	**TRAFFIC ENGINEERING LAB**
Credits: 1.5 *Semester: Jan* *Segment: 46* *PreReq: CE3840*	Traffic studies, Volume studies, Speed studies, Intersection studies, Gap acceptance studies, Parking studies, Origin-destination studies.

CE4330	**GEOLOGY I**
Credits: 1 *Semester:* *Segment: 12*	The Earth: surface and internal structure; thermal gradient, earthquakes, isostacy, ocean ridges, magnetism, continental drift and age. Geological history, Weathering processes; rock forming minerals; igneous, sedimentary and metamorphic rocks. Faults, folds and unconformities, Engineering properties of rocks; Law of superposition.

CE4500	**WATER RESOURCES ENGINEERING**
Credits: 2 *Semester: Jul* *Segment: 16*	Reservoir planning and operation; Seepage theories; Design of gravity dams; Analysis of earthdams, Spillways and energy dissipaters; Soil-crop-water relations; Methods and types of irrigation; Crop water requirement.

CE4510	**ENVIRONMENTAL IMPACT ASSESSMENT**
Credits: 2 *Semester: Jan* *Segment: 36*	Introduction to Environmental Impact Assessment (EIA), need, limitations, stages & types of EIAs, matrices, cost-benefit analysis, assessment of impact on land, water, air, people and culture, flora and fauna, case studies.

CE4900	**CONSTRUCTION MANAGEMENT**
Credits: 2 *Semester: Jul* *Segment: 16*	Objectives, Construction planning, scheduling procedures and techniques, Cost control, monitoring and accounting, The cost control problem, The project budget, Financial, Accounting systems and cost accounts, Control of project cash flows, Schedule control, Quality control and safety during construction.

CE5390	**GEOTHERMICS**
Credits: 2 *Semester:* *Segment:*	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 - CO_2 mitigation strategy; Case histories - Indian and world examples.

CE6002	**DESIGN STUDIO**
Credits: 2 *Semester: Jan* *Segment: 16*	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	**SEMINAR**

CE6011	COMPUTER METHODS IN CIVIL ENGINEERING
Credits: 2 *Semester: Jul* *Segment: 16*	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	ADVANCED STRUCTURAL MECHANICS
Credits: 3 *Semester: Jul* *Segment:*	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	STRUCTURES LAB
Credits: 1.5 *Semester: Jan* *Segment:*	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	APPLIED ELASTICITY AND PLASTICITY
Credits: 3 *Semester: Jul* *Segment:*	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	FINITE ELEMENT ANALYSIS
Credits: 3 *Semester: Jan* *Segment:*	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	FINITE ELEMENT LAB
Credits: 1.5 *Semester: Jan* *Segment:*	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	STRUCTURAL DYNAMICS
Credits: 3 *Semester: Jan* *Segment:*	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	STRUCTURAL STABILITY
Credits: 3 *Semester: Jan* *Segment:*	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	THEORY OF PLATES AND SHELLS
Credits: 3 *Semester: Jul* *Segment:*	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.

CE6200	CONDITION ASSESSMENT AND STRENGTHENING
Credits: 3 *Semester: Jan* *Segment:*	Damage mechanisms in reinforced concrete and steel structures, specifically, cracking (both load induced and environmentally assisted), corrosion of steel, Fire damage in concrete and steel, Sulfate-attack and Alkali-silica reaction in concrete structures; Laboratory and field techniques for detecting the various damage mechanisms and the theoretical background behind different techniques; Basics of wave propagation and review of non-destructive test techniques; Estimation of load carrying capacity of structural members with damage; Repair and Rehabilitation strategies used in the field to repair existing damage and rehabilitate and strengthen structures.

CE6212	ADVANCED REINFORCED CONCRETE
Credits: 3 *Semester: Jan* *Segment:*	Mechanical properties of concrete and steel, Behavior of concrete under uniaxial and multiaxial states of stress; effect of creep of concrete, Basic Design philosophies, Probabilistic load theory, ultimate strength design methodology, comparison of working stress and ultimate load method; Moment-curvature and load-deflection relationships. Behavior and design of columns subjected to biaxial bending, Analysis and design of slender columns - under sway and non-sway conditions, Behavior and design of reinforced concrete structures for combined shear and torsion, Design of flat slabs and two way slabs, Design of special reinforced concrete structures - Deep beams and corbels.

CE6222	PRESTRESSED CONCRETE DESIGN
Credits: 3 *Semester: Jan* *Segment:*	Introduction to concept of prestressing, types of prestressing, systems and devices, review of short and long-term behavior of concrete and prestressing steel, losses in prestress., Stress analysis of flexural members, flexural and shear design of statically determinate beams, analysis and design for shear and torsion, codal provisions, Anchorage zone stresses for post-tensioned members; design of anchorage zone, Analysis and design of statically indeterminate structures - continuous beams and frames, determination of cable profile, concepts of linear transformation and concordancy. Composite construction with precast, prestressed beams and cast in-situ reinforced concrete slab; Analysis and design of post-tensioned slabs.

CE6232	ADVANCED STEEL DESIGN
Credits: 3 *Semester: Jan* *Segment:*	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	ADVANCED FOUNDATION ENGINEERING
Credits: 3 *Semester: Jan* *Segment:*	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 & 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	ADVANCED SOIL MECHANICS
Credits: 3 *Semester: Jul* *Segment:*	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	**EXPERIMENTAL SOIL MECHANICS**
Credits: 3 *Semester: Jul* *Segment:*	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	**SOIL DYNAMICS**
Credits: 3 *Semester: Jan* *Segment:*	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	**GROUND MODIFICATION TECHNIQUES**
Credits:3 *Semester: Jan* *Segment:*	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	**DESIGN OF EARTH STRUCTURES**
Credits: 3 *Semester: Jul* *Segment:*	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	**ENGINEERING HYDROLOGY AND HYDROLOGIC SYSTEMS**
Credits: 3 *Semester: Jul* *Segment:*	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	**WATER AND WASTEWATER ENGINEERING**
Credits: 3 *Semester: Jul* *Segment:*	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	**SOFT COMPUTING LAB (ENVIRONMENTAL & WATER RESOURCES)**
Credits: 2 *Semester: Jan* *Segment:*	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	**AIR POLLUTION**
Credits: 3 *Semester: Jan* *Segment:*	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	GROUNDWATER MODELING
Credits: 3 *Semester: Jan* *Segment:*	Governing equations for groundwater flow; Boundary conditions; Estimation of source and sink components; Model execution and calibration process; Special needs for transient simulations; Introduction to particle tracking of groundwater flow; Groundwater recharge estimation: techniques

CE6540	CONTAMINANT HYDROLOGY AND REMEDIATION
Credits: 3 *Semester: Jul* *Segment:*	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	ENVIRONMENTAL CHEMISTRY & MICROBIOLOGY
Credits: 3 *Semester: Jul* *Segment:*	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	PHYSICO-CHEMICAL PROCESS
Credits: 3 *Semester: Jul* *Segment:*	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.

CE6570	ENVIRONMENTAL IMPACT ASSESSMENT
Credits: 3 *Semester: Jul* *Segment:*	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.

CE6580	SOLID & HAZARDOUS WASTE MANAGEMENT
Credits: 3 *Semester: Jan* *Segment:*	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.

CE6590	INDUSTRIAL WASTE MANAGEMENT
Credits: 3 *Semester: Jan* *Segment:*	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.

CE6610	REMOTE SENSING & GIS APPLICATIONS TO CIVIL ENGINEERING
Credits: 3 *Semester: Jan* *Segment:*	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

CE6620	**WATER RESOURCES SYSTEMS PLANNING AND MANAGEMENT**
Credits: 3 *Semester: Jan* *Segment:*	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.

CE6630	**OPEN CHANNEL HYDRAULICS**
Credits: 3 *Semester: Jan* *Segment:*	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.

CE6640	**IRRIGATION AND WATERSHED MANAGEMENT**
Credits: 3 *Semester: Jul* *Segment:*	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

CE6650	**HYDROGEOLOGY**
Credits: 3 *Semester: Jul* *Segment:*	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.

COMPUTER SCIENCE & ENGINEERING

CS1310	DISCRETE STRUCTURES I
Credits: 2 *Semester:* *Segment:*	Concept of mathematical proof, logic, proof by contradiction, mathematical induction, constructive proofs, sets, relations. Illustration of proof techniques in various mathematical topics.

CS1340	DISCRETE STRUCTURES II
Credits: 2 *Semester:* *Segment:* *Pre-Req: CS1310*	Combinatorics. Basic counting principles, inclusion-exclusion, binomial/multinomial coefficients, bijections, double counting, pigeon-hole principle, recurrence relations. Introduction to graphs. Degree, isomorphism, diameter, connectivity, trees, matchings, colorings, planarity.

CS1353	INTRODUCTION TO DATA STRUCTURES
Credits: 3 *Semester:* *Segment:*	Abstract data types, Big-Oh notation, Basic data types - Stacks, Queues, Trees

CS2233	DATA STRUCTURES
Credits: 3 *Semester:* *Segment:* *Pre-Req: CS1353*	More data types. Dictionaries. Binary search trees, Balanced search trees, Hash tables; Heaps, Priority queues, Graphs

CS2323	COMPUTER ARCHITECTURE
Credits: 2 *Semester:* *Segment:* *Pre-Req: ID1303, CS1353*	The objective of the course is to teach the fundamentals of computer architecture to CSE undergraduate students. The course would cover the following topics: • Instruction set architecture • Micro architecture • Architecture and performance • Arithmetic operations in processors • Enhancing performance with pipelining • Memory subsystem - cache and virtual memory • Input/output organization

CS2400	PRINCIPLES OF PROGRAMMING LANGUAGES-I
Credits: 1 *Semester:* *Segment:*	Programming language syntax, basics of compilers, names, scopes and bindings, control flow, data types, subroutines and control abstraction. Various paradigms of programming languages.

CS2410	THEORY OF COMPUTATION
Credits: 2 *Semester:* *Segment:* *Pre-Req: CS1310, CS1340*	Alphabets, languages, finite state machines - deterministic and non-deterministic finite automata. Context Free Grammars, Context Free Languages, Parse trees, Push Down Automata, Pumping lemma for CFLs and applications, CYK algorithm Turing machines, Variants, Undecidability theory

CS2420	INTRODUCTION TO COMPLEXITY THEORY
Credits: 1 *Semester:* *Segment:* *Pre-Req: CS2410*	Time and Space bounded computation. Reductions, theory of NP completeness, Introduction to time and space complexity.

CS2433	PRINCIPLES OF PROGRAMMING LANGUAGES-II
Credits: 3 *Semester:* *Segment:* *Pre-Req: CS2400*	Functional programming, Object Oriented programming, Logic programming, Lambda calculus, Concurrency, Scripting languages, Programming language semantics.

CS2443	ALGORITHMS
Credits: 3 *Semester:* *Segment:* *Pre-Req: CS1310, CS1340, CS1353*	Algorithmic Design Paradigms, Divide and Conquer, Analysis for Divide and Conquer, Sorting, Greedy Algorithms. Dynamic Programming, Graph Algorithms (DFS, BFS, Topological Sort, Single Source Shortest Path, Spanning Trees, All Pair Shortest Path, Matching, Max Flow), FFT.

CS3303	SOFTWARE TECHNOLOGIES
Credits: 2 *Semester:* *Segment:* *Pre-Req: ID1303*	Latest technologies like Java Script, JSP, Python, Android, Perl, etc., to design software artifacts.

CS3320	COMPILERS I
Credits: 1 *Semester:* *Segment:*	Syntax directed translators, Finite automata, Regular Expressions, Lexical analysis, Context free languages and grammars, Syntactic analysis, Bottom-up and Top-down Parsing, Syntax directed translation, Lex and yacc as tools for lexical analysis and parsing.

CS3423	COMPILERS II
Credits: 3 *Semester:* *Segment:* *Pre-Req: CS3320*	Review of compilation process, semantic analysis, intermediate code generation, runtime, code generation, introduction to simple machine independent optimizations.

CS3510	OPERATING SYSTEMS I
Credits: 1 *Semester:* *Segment:* *Pre-Req: ID1303, CS1353*	History of OSs, Concurrency vs parallelism, Overview of Process management, Memory management, File systems

CS3523	OPERATING SYSTEMS II
Credits: 3 *Semester:* *Segment:* *Pre-Req: CS3510*	Process management: process states, process vs thread, scheduling algorithms, system calls, IPC. Process synchronization: Semaphores, Monitors, Deadlocks, Main memory: Paging system, File system; Virtual memory: demand paging and page replacement algorithms, File system implementation, Disk management, and I/O management; Case studies on Windows/Linux OSs. Programming assignments related to OS features and their implementation. Further, students enhance functionalities of open-source toy OS named Minix3 by Andrew S. Tanenbaurm as part of the group projects.

CS3530	COMPUTER NETWORKS-I
Credits: 1 *Semester:* *Segment:* *Pre-Req: CS3523*	Basics and History of Computer Networks, TCP/IP protocol stack, Application layer (WWW, Email, DNS), Protocols at Transport layer, Network layer and Data link layer. Lab: Client-Server Design using Socket programming in C/C++/Java; Wireshark assignments on DNS, HTTP, DHCP, TCP, UDP, IP, Ethernet, ARP, etc.

CS3543	COMPUTER NETWORKS-II
Credits: 3 *Semester:* *Segment: CS3530*	Network congestion, TCP vs UDP, IPv4 vs IPv6, Routing algorithms, Routing in Internet, ARQ protocols, Local Area Networks (Ethernet, Wi-Fi) and Multimedia Networking;

Implementation of multi-threaded Web Server/Web Proxy with Caching/Filtering features, Sliding Window protocol implementation, performance study of various TCP/IP variants. Hands-on with Cisco/HP routers.

CS3550 **INTRODUCTION TO DATABASE MANAGEMENT SYSTEMS**

Credits: 1
Semester:
Segment:

Purpose and evolution of database management systems, Relational model of data, Formal relational languages (relational algebra/calculus), SQL, Introduction to database design

CS3563 **DATABASE MANAGEMENT SYSTEMS (WITH LAB)**

Credits: 3
Semester:
Segment:
Pre-Req: CS3550

Advanced SQL (procedures/functions/triggers), Database design and normal forms, Database application development, Storage structures and indexing/hashing, Query processing and optimization, Transactions, Lock-based concurrency control.

CS4443 **SOFTWARE ENGINEERING (INCLUDES LAB)**

Credits: 3
Semester:
Segment:
Pre-Req: ID1303, CS2233

Introduction to Software Engineering: Importance, challenges, approaches. Software Processes. Requirements Engineering, Software Architecture, Planning, Design, Coding, Testing, Software Project Management, Advanced topics like Formal Methods in Software Engineering

CS5020 **PATTERN RECOGNITION**

Credits: 3
Semester:
Segment:

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 **ADVANCED TOPICS IN DATA MANAGEMENT**

Credits: 3
Semester:
Segment:

Parallel and distributed database systems. Advanced query processing & 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.

CS5060 **ADVANCED COMPUTER NETWORKS**

Credits: 3
Semester:
Segment:

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.

CS5190 **SOFT COMPUTING**

Credits: 3
Semester:
Segment:

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

MACHINE LEARNING

Credits: 3
Semester:
Segment:

Classification, clustering - fuzzy c-means and hierarchical, decision surfaces, parameter estimation methods, Bayesian decision theory, Markov models, HMMs, dimension reduction methods, principal component analysis, SVD, Fisher discriminant analysis, perceptrons, support vector machines, unsupervised learning and k--means clustering, non-parametric methods, applications in real world.

CS5200	**APPROXIMATION ALGORITHMS**
Credits: 3 *Semester:* *Segment:*	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	**VISUAL RECOGNITION**
Credits: 3 *Semester:* *Segment:*	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.
CS5300	**PARALLEL AND CONCURRENT PROGRAMMING**
Credits: 3 *Semester:* *Segment:* *Pre-Req: 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	**ADVANCED OPERATING SYSTEMS FOR PERVASIVE COMPUTING**
Credits: 1 *Semester:* *Segment:* *Pre-Req: CS3523*	• Introduction to Advanced OS Systems & Architecture • Linux Kernel Frameworks & Infrastructure • File-System Interface & Implementation • Linux I/O Systems
CS5311	**PERVASIVE COMPUTING LAB**
Credits: 2 *Semester:* *Segment:* *Pre-Req: CS3523*	• Linux Kernel Frameworks & Infrastructure • Multimedia Framework Architecture • Network Framework • Graphics and UI Frameworks • Web Framework • Application Development • Introduction to IoT
CS5320	**DISTRIBUTED COMPUTING**
Credits: 3 *Semester:* *Segment:* *Pre-Req: 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	**INTRODUCTION TO STATISTICAL NATURAL LANGUAGE PROCESSING**
Credits: 2 *Semester:* *Segment:*	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	**COMPUTER AND NETWORK SECURITY**
Credits: 3 *Semester:* *Segment:*	It covers foundations of cryptography, system security, network security, Wi-Fi security, web security, mobile platform security with hands-on assignments and projects.

Pre-Req: CS3543, CS3523

CS5380	**INTRODUCTION TO WIRELESS NETWORKS1**
Credits: 1 *Semester:* *Segment:* *Pre-Req: CS3530*	Fundamentals of Wireless Communication, Wired vs Wireless Networks, Overview of various wireless technologies: Wireless LANs, Cellular Systems, Mobile Ad hoc Networks, Bluetooth, Zigbee, etc.

CS6140	**VIDEO CONTENT ANALYSIS**
Credits: 3 *Semester:* *Segment:*	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	**SYSTEMS SECURITY**
Credits: 3 *Semester:* *Segment:*	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	**ADVANCED TOPICS IN CRYPTOLOGY**
Credits: 3 *Semester:* *Segment:*	Reading research papers in the area of cryptology and understanding the state of the art in the subject.

CS6200	**ADVANCED TOPICS IN FORMAL METHODS**
Credits: 3 *Semester:* *Segment:*	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	**ADVANCED MACHINE LEARNING**
Credits: 3 *Semester:* *Segment:*	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	**COMPUTER VISION**
Credits: 3	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.

Semester:
Segment:

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 **OPTIMIZATION METHODS IN MACHINE LEARNING**

Credits: 3
Semester:
Segment:
Pre-Req: 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 **TOPICS IN COMPILER OPTIMIZATIONS**

Credits: 3
Semester:
Segment:
Pre-Req: 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 **QUANTUM COMPUTING I**

Credits: 1
Semester:
Segment:
Pre-Req: BTech CSE 3rd year+

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

CS6320 **QUANTUM COMPUTING II**

Credits: 1
Semester:
Segment:
Pre-Req: CS6310

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

CS6330 **QUANTUM COMPUTING III**

Credits: 1
Semester:
Segment:
Pre-Req: CS6310, CS6320

Quantum Error Correction, Quantum Information Theory and Quantum Cryptography

CS6340 **QUANTUM COMPUTING IV**

Credits: 1
Semester:
Segment:
Pre-Req: CS6310, CS6320, CS6330

Topics in quantum computing and information; Latest advances in the field.

CS6350 **TOPICS IN COMBINATORICS**

Credits: 3
Semester:
Segment:
Pre-Req: see syllabus

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

CS6360 **ADVANCED TOPICS IN MACHINE LEARNING**

Credits: 3
Semester:
Segment:
Pre-Req: 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 **INFORMATION RETRIEVAL**

Credits: 3
Semester:
Segment:
Pre-Req: 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 **INTRODUCTION TO COMPILER ENGINEERING**

Credits: 1
Semester:
Segment:
Pre-Req: 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 **ENABLING LARGE SCALE DATA ANALYTICS: FROM THEORETICAL FOUNDATIONS TO PRACTICE**

Credits: 1
Semester:
Segment:
Pre-Req: see syllabus

Small-Space Algorithms, Estimating Statistical Properties, Distance Estimation, Clustering & Ranking, Algorithms over Massive Networks, Learning Algorithms

Pre-Req: Data Structures and Algorithms, Any course on Probability and Statistics

CS6400 **CONSTRAINT SOLVING**

Credits: 1
Semester:
Segment:
Pre-Req: 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 **SOFTWARE VERIFICATION**

Credits: 3

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.

Semester:
Segment:
Pre-Req: see syllabus

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

CS6420 BAYESIAN DATA ANALYSIS

Credits:
Semester:
Segment:
Pre-Req: 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.

CS6430 COMPUTATIONAL NUMBER THEORY & ALGEBRA

Credits: 3
Semester:
Segment:
Pre-Req: Discrete mathematics, Algorithms

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

CS6440 ADVANCED COMPUTER ARCHITECTURE

Credits: 2
Semester:
Segment:
Pre-Req: 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 ADVANCED TOPICS IN COMPUTER VISION

Credits: 3
Semester:
Segment:
Pre-Req: 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 INTRODUCTION TO DEEP LEARNING FOR VISION

Credits: 1
Semester:
Segment:
Pre-Req: 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

CS6660	MATHEMATICAL FOUNDATIONS OF DATA SCIENCES
Credits: 3 *Semester:* *Segment:*	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	TOPICS IN DATA MINING
Credits: 3 *Semester:* *Pre-Req: CS3560, CS3140*	Data Preprocessing, Data Warehousing & 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

FC5264	ADVANCED COMPILER OPTIMIZATION TECHNIQUES
Credits: 1 *Semester:* *Segment:*	The objective of this course is to learn basic and advanced compiler optimization techniques, either traditional or modern in their scope, or scalar-variable based or loop-optimization based in their application or machine independent or dependent in their variety. The initial part of the course would be devoted to a collection of traditional compiler analyses and optimizations that are primarily based on control flow and data flow analyses. This will be followed by studying more high-level optimizations that are based on the static single assignment intermediate representation as well as low-level optimizations like register allocation and instruction scheduling and software pipelining. The later part of this course would be devoted to a model named polyhedral compilation where for-loops can be transformed to run efficiently on advanced architectures like multi-core or GPU using rational and integer linear programming techniques. Here, the focus would be on basics of the three phase process of dependence analysis, affine scheduling and code generation.

FC5265	SOFTWARE-DEFINED NETWORKS
Credits: 2 *Semester:* *Segment:*	Software-Defined Networks is an active research topic to address the existing issues in the enterprise and global networks as well as to enable innovative networking that is not restricted by the traditional network architecture. This course conducts the analysis and solution development for the existing challenges in the computer networks. We introduce SDN for the solution development, system design and its implementation. The expected outcome of this course is the running source codes and systems that will be proposed and developed by the students as well as a writing for publishing such outcomes for public.

FC5268	INDEXING SPATIAL AND TEMPORAL DATA
Credits: 1 *Semester:* *Segment:* *Pre-Req: BTech CSE 3rd year+*	The course introduces indexing techniques for spatial and temporal data, covering even more abstract metric spaces. It describes a range of indexing techniques targeting different types of data, including their underlying principles and properties, as well as their support for queries and updates. The contents of this course are collected from state-of-the-art research papers (i.e., not found in textbooks). Below is a broad breakdown of the course: • Indexing low-dimensional data (1-5 dimensions) • E.g. Indexing Spatial Data with R-trees, R-tree variants, Space-Filling • Curves (Hilbert, Z-curves etc), Quad-trees etc. • Indexing high-dimensional data • E.g. Locality Sensitive Hashing (LSH), VA File • Indexing Metric Spaces • E.g. Metric Trees, GNAT, VP-Tree, iDistance • Indexing Time Series • E.g. TS tree, Chebyshev Polynomials, Wavelet-based indexing, MR Index

FC5269	HIGH PERFORMANCE COMPUTING USING R
Credits: 1 *Semester:* *Segment:*	• Introduction • The parallel R taxonomy • lappy and foreach-based parallelism • Map reduce based parallelism

DESIGN

CA1024	**ACTION DRAWING**
Credits: 1 *Semester: Jan* *Segment:*	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	**LET'S MAKE A GRAPHIC NOVEL**
Credits: 1 *Semester: Jan* *Segment:*	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.
DS3013	**CREATIVE PRODUCT DESIGN**
Credits: 1 *Semester: Jan* *Segment:*	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.
DS3024	**PRINCIPLES OF ANIMATION AND MOVING IMAGES**
Credits: 2 *Semester: Jan* *Segment:*	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.
DS3042	**DIGITAL HERITAGE**
Credits: 1 *Semester: Jan* *Segment:*	This course deals with fully practice based learning, Digital imaging & techniques for digital heritage conservation, History of the location, Photography, Approaches in documentation and imaging, Creating Photo stories, Introduction to 3-D laser scanning.
DS3053	**VISUAL COMMUNICATION AND DIGITAL IMAGING**
Credits: 2 *Semester: Jan* *Segment:*	This course deals with visual communication photography and design practice, Graphic Design, Studio Photography, Printing & Digital Processing, Idea of an Image, Creation of Photo book, Understanding of a Visual Narrative, Photography/Sketching, basics of visual design, Research (Visual & Historical), Story-telling (Script & Story Board), Product (Book making, Slideshows, Exhibitions).
DS3062	**BUILT-ENVIRONMENT/ URBAN SPACE DESIGN**
Credits: 2 *Semester: Jan* *Segment:*	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.
DS3072	**SPECIAL TOPICS ON DESIGN**
Credits: 1 *Semester: Jan* *Segment:*	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	WORD AND IMAGE
Credits: 1 *Semester: Jan* *Segment:*	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.

	INTRODUCTION TO ERGONOMICS AND HUMAN CENTERED DESIGN
Credits: 1 *Semester: Jan* *Segment:*	This course deals with anthropometric study, study of spaces, products and visual design, Human physical dimensions, posture and movements, Ergonomic design process and design interventions Communication and cognitive issues, Humanizing Design, Comfort compatibility and adaptability aspects.

ELECTRICAL ENGINEERING

EE1010 **ELECTRIC CIRCUITS**

Credits: 1
Semester: July
Segment:

- Mesh and node analysis
- Thevenin, Norton and other network theorems
- Two port Networks
- Sinusoidal Steady state analysis of R-L-C circuits
- Filters
- Transient Circuit analyses through Laplace transform techniques.

EE1020 **MAGNETIC CIRCUITS**

Credits: 1
Semester: July
Segment:

Coupled circuits, Transformers

EE1110 **APPLIED DIGITAL LOGIC DESIGN**

Credits: 1
Semester: July
Segment:

- Driving SSD segments using Arduino
- Displaying decimal digits on the SSD through the decoder IC and arduino.
- Decimal to binary conversion using arduino.
- Simulating the SSD decoder in arduino using Karnaugh maps and Boolean logic functions.
- State machine design for the decade counter
- Implementing the decade counter using flip flop ICs and arduino for combinational logic and testing it through the SSD.
- Simulating flip flops using arduino.
- Simulating the decade counter completely in arduino and testing through the SSD.

EE1120 **DIGITAL SYSTEM DESIGN**

Credits: 1
Semester: July
Segment:

Gate level design of Small Scale Integration (SSI) circuits, Modular combinational logic elements- Decoders, Encoders, Priority encoders, Multiplexers and Demultiplexers, Adders, Subtractors, Multipliers, division circuits, Complexity and propagation delay analysis of circuits, Programmable Read Only Memories (PROMs), Programmable Logic Arrays (PLAs), Programmable Array Logic (PAL) devices, Sequential circuits - Latches, Flip-flops, Master-slave flip flops, Edgetriggered flip-flops, Models of sequential circuits - Moore machine and Mealy machine, Flip-flops - Characteristic table, Characteristic equation and Excitation table, Analysis and Design of sequential circuits, Modular sequential logic circuits- Shift registers, Registers, Counters and Random access memories, Design using programmable logic sequencers (PLSs), Serial adder for integers, Design of control units for multipliers/dividers

EE1130 **ANALOG ELECTRONICS**

Credits: 1
Semester: July
Segment:
Pre-Req: EE1010, EE1020

Introduction to Analog Electronics and Application, Devices parameters: Analog perspective and significance, Macro-modelling: small signal & behavioral, Amplifiers: single stage & differential, Biasing: Voltage & current bias, Test board design

EE1140 **SEMICONDUCTOR FUNDAMENTALS**

Credits: 1
Semester:
Segment:

- Valence band and Energy band models of intrinsic and extrinsic semiconductors.
- Thermal equilibrium carrier concentration.
- Fermi-Dirac distribution
- Carrier transport by drift
- resistivity
- Excess carriers
- Lifetime
- carrier transport by diffusion
- Continuity equation
- P-N Junction

- structure, I-V characteristics
- Forward and Reverse bias. Bipolar junction transistor: Structure,DC input and Output characteristics, Application as amplifier and switch.
- MOSFET: Structure, DC input and Output Characteristics, Applications.

EE1150 EMBEDDED PROGRAMMING

Credits: 1
Semester:
Segment:

- Concepts of embedded programming.
- Concepts of assembly language
- Hardware-description language (VHDL/Verilog).
- High-level synthesis (using Synopsys Synphony C Compiler)
- Micro-controller programming: basic and advanced (concepts of firmware using ARM MBed kits), Field-Programmable Gate Array (FPGA) programming (XIlinx Spartan series), and practical hands-on experience in all the embedded programming languages covered above.

EE1210 BASIC CONTROL THEORY

Credits: 1
Semester:
Segment:

Course Content: Applications of controllers and control systems, basic building blocks of a control system, types of controllers, thumb rules for designing P/PI/PD/PID controllers, advantages of control system, stability analysis, time response analysis, frequency response analysis, introduction to modeling, controller design and implementation using MATLAB/SCILAB.

EE1310 SIGNALS AND COMMUNICATIONS

Credits: 1
Semester:
Segment:

Introduction: The communication process, Sources of information, Communication channels, Baseband and pass band signals, Representation of signals and systems, The modulation process, Information theory and coding, Analog versus digital communications Representation of signals and systems: Notation of energy and power, Dirac delta function, Continuous-time LTI systems and their properties, The Fourier transform and its properties, Transmission of signals through linear systems, Filters, Hilbert transform, Pre-envelope, Canonical representation of band-pass signals, Phase and group delay. Modulation: Amplitude modulation, Double sideband-suppressed carrier modulation, Single sideband modulation, VSB, Frequency modulation, Phase- locked loop.

EE1320 INTERNET OF THINGS

Credits: 1
Semester:
Segment:

Introduction: Concept, Importance, Interdisciplinary, Challenges, Various applications \smart objects, Major Players/Industry. Standards IoT Architecture: Node structure: Sensing, Processing, Communication Powering Networking: Topologies, Layer/Stack architecture Communication Technologies: Introduction to ZigBee, BLE, WiFi, LTE, IEEE 802.11ah, Discuss data rate, range, power, computations/bandwidth, QoS. Smartness - Signal Processing/Analytics: Impact on Power/Energy savings, dynamic networks, simple case studies. IoT Fabricator: Introduction to Embedded electronics, fabricating electronics, Communication Network requirements, Data processing challenges - recreation, IP/security, Challenges. Hands-on in IoT (Starts in the first week and goes on until end of course): Projects based on some Hardware (Raspberry pi, Arduino, Intel, IITH Mote, Smartphones), Software (Contiki, TinyOS, Android), IoT Fabricator

EE1330 DSP

Credits: 1
Semester:
Segment:

Sampling, continuous and discrete-time transforms, z-transforms, finite impulse response (FIR) and infinite impulse response (IIR) filter design, FFT algorithm.

EE1410 DATA STRUCTURES

Credits: 2
Semester: July
Segment:
Pre-Req

Data types, loops, conditions, functions, arrays, pointers, linked lists and trees.

EE1510 MATRIX ANALYSIS

Credits: 1
Semester:
Segment: 34

Matrices and vectors, determinants, singularity of matrices, rank, Eigen values, eigenvectors, and invariant subspaces, Vector norms and matrix norms.

EE1520	**DATA ANALYTICS**
Credits:2 *Semester:* *Segment:*	Statistical modeling of large data sets, correlation and regression analysis, time series analysis, elementary hypothesis testing, framework for probabilistic abstraction of data, 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.
EE2110	**MICROPROCESSORS**
Credits: 1 *Semester:* *Segment:* *Pre-Req: Applied Logic Design*	Microcontrollers: 8085/8051 Assembly programming: Arithmetic operations, logical operations, interrupt handling, interfaces for microcontrollers, ADC and DAC interfaces for microcontrollers, application project. Reading Materials: Microprocessor Architecture, Programming and Applications with the 8085 6/e, Penram International Publishing, 2013.
EE2120	**DEVICE PHYSICS**
Credits: 1 *Semester:* *Segment:*	PN Junction: Space Charge region, Poisson's Equations, Static analysis, Energy Band Diagrams, Biasing, Small signal analysis, Breakdown mechanism. Bipolar Junction transistor: Injection Efficiency, Current base current gain, Common emitter current gain, AC analysis, Impact Ionization, Punch through. Transit time, Charge control description. Theory of Field Effect Transistors: Static characteristics of JFETs, heterojunction bipolar transistors, MOS Capacitor analysis, C-V measurements, Drain Current, Small signal analysis.
EE2140	**CMOS FABRICATION**
Credits: 1 *Semester:* *Segment:*	Introduction to CMOS technology, Czochralski method, Thermal Oxidation, Lithography, Physical Deposition Techniques, Diffusion, Ion Implantation, Cleaning, Wet etching, Dry etching, Chemical Vapour deposition techniques, Complete CMOS process flow.
EE2150	**DIGITAL ELECTRONICS**
Credits: 1 *Semester:* *Segment:* *Pre-Req: EE1010, EE1020, Digital System*	Introduction to Digital Electronics, Logic Families, MOS Devices parameters: digital perspective and significance, Switching Properties of MOSFET. Analysis and design: CMOS Inverters, CMOS Static, Combinational and Sequential logic Circuits, Transmission gate logic circuits, Test board design.
EE2160	**EMBEDDED SYSTEMS**
Credits: 1 *Semester:* *Segment:*	An overview of the application areas. State charts for design. Overview of components of an embedded system with ARM architecture as an example (CPU, memory, buses, peripherals etc.), CPU internals. Hands on with a single board computer (LPC1768). Software issues: processes and their management, memory overview.
EE2170	**MIXED SIGNAL ELECTRONICS**
Credits: 3 *Semester:* *Segment:* *Pre-Req: EE1130, EE2150*	Introduction to Mixed signal Electronics, Power supply, mixed signal filters, OPAMPs and application, Data converters, Oscillator and Phase locked loop, Test board design
EE2210	**TRANSFORMER AND DC MACHINES**
Credits: 2 *Semester:* *Segment:*	Transformer: Ideal transformer, losses, equivalent circuit, open circuit test, short circuit test, polarity test, efficiency, voltage regulation, construction, transients, poly-phase transformer. D.C.

Machine: Armature windings, principle of operation, methods of excitation, equivalent circuit, generator characteristics, motor characteristics.

EE2211 **ELECTRICAL MACHINES LAB**

Credits: 2
Semester: July
Segment: 16

Exp. 1: OC, SC and load test on 1- Transformer; Exp. 2: Sumpner's (Back-to-Back) Test on single phase transformer; Exp. 3: Speed Control of a DC Shunt Motor by Armature voltage method (below base speed) and Field resistance method (above base speed); Exp. 4: Determination of voltage regulation of a synchronous machine using EMF method; Exp. 5: V and inverted V curves of an synchronous motor; Exp. 6: No load and blocked rotor test on a 3- Induction Motor; Exp. 7: Determination of the Critical Speed and Critical Resistance of a Self-Excited DC Shunt Generator; Exp. 8: To perform the load test on DC shunt generator.

EE2220 **AC MACHINES**

Credits: 1
Semester:
Segment:

Three Phase Synchronous Machine: Armature winding, MMF distribution, rotating MMF, equivalent circuit, open circuit test, short circuit test, operation on an infinite bus, synchronous condenser. Three Phase Induction Machine: Principle of operation, equivalent circuit, torque-slip characteristic, noload test, blocked rotor test. Fractional Horsepower Electric Machines: Basics of Linear induction motor, stepping motor, single phase induction motor.

EE2230 **POWER ELECTRONICS**

Credits: 1
Semester:
Segment:

The basics of power electronic switches, introduction to AC - DC (uncontrolled), Non-isolated DC - DC converters and single phase Inverters.

EE2240 **CONTROL SYSTEMS**

Credits: 2
Semester:
Segment: 36

Course Content: Classical control systems, optimal control systems, nonlinear systems, adaptive control, fuzzy logic control, neural networks.

EE2250 **RENEWABLE ENERGY AND POWER**

Credits: 1
Semester:
Segment:

Introduction to Renewable Energy, World wide scenario, Indian Scenario, Primary attributes of different renewable energy sources; Solar Thermal, Solar Photovoltaics, Wind energy, Bio Energy, Geo thermal energy, other renewable sources, integration of renewable energy to the grid.

EE2310 **RANDOM PROCESSES**

Credits: 1
Semester:
Segment:

Function of two random variables; Random vectors; Vector-space representation of random variables; Elements of estimation theory; Bounds and approximations; Sequence of random variables; Central limit theorem and its significance; Random processes; Spectral representation of a real WSS process; Linear time-invariant system with a WSS process as an input; Examples of random processes

EE2320 **DIGITAL MODULATION TECHNIQUES**

Credits:
Semester:
Segment:

Passband representation, Baseband equivalent AWGN Channel, Data Modulation and Demodulation, Synthesis of the Modulated Waveform, Discrete Data Detection, The Additive White Gaussian Noise (AWGN) Channel, Signal-to-Noise Ratio (SNR) Maximization with a Matched Filter, Error Probability for the AWGN Channel, MAP and ML detection, BPSK, FSK, QPSK, MPSK, PAM, QAM, DPSK, GMSK.

EE2330 **ANTENNA DESIGN**

Credits: 1
Semester:
Segment:

Radiation mechanisms, Fundamental parameters, Radiation integrals and vector potentials, linear dipoles and loop antennas, Yagi-Uda, Broadband antennas: Logperiodic, Helix; Impedance matching, Aperture antennas, Micro-strip Antennas.

EE2340 **INFORMATION SCIENCE**

Credits: 1
Semester:
Segment:

Information, discrete memoryless source, entropy, mutual information, capacity, source and channel coding theorems, shannon's capacity formula, rate-distortion theorem, differential entropy.

EE3210	**SMART GRID**
Credits: 1 *Semester:* *Segment:*	Components and organization of a power system; operational issues; different operating states; power flow modeling and analysis; state estimation; pricing of different services; power grid frequency control mechanism.
EE3220	**POWER SYSTEM PRACTICE**
Credits:2 *Semester:* *Segment:*	Architecture of a power system, Line parameter calculation, Performance analysis of an AC transmission line, Load flow analysis, Short circuit analysis, Stability analysis, Economic load dispatch, Introduction to the protection system.
EE3310	**ADVANCED DSP**
Credits: *Semester:* *Segment:*	Frequency Domain Analysis of LTI Systems, Implementation of FFT, algorithms, Filter Design: IIR and FIR filters, Multi-rate signal processing: sampling rate conversion.
EE5110	**SEMICONDUCTOR DEVICE MODELING**
Credits: *Semester:* *Segment:*	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	**VLSI TECHNOLOGY**
Credits: *Semester:* *Segment:*	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
EE5130	**ANALOG IC DESIGN**
Credits: *Semester:* *Segment:*	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
EE5140	**DIGITAL IC DESIGN**
Credits: *Semester:* *Segment:*	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.
EE5160	**EMBEDDED SYSTEMS DESIGN**
Credits: *Semester:* *Segment:*	ARM Processors: Brief history of ARM, ARM Architecture, Addressing modes, Instruction sets, Arm Thumb and instruction sets, Memory concepts, System Control Coprocessor, Introduction to Vector Floating Point Architecture Microcontrollers: Introduction to microcontrollers, 8051 architecture, Addressing modes and instruction set, Interrupts and serial communications, Programming Tools,

Applications using microcontrollers Digital Design: Introduction, Digitial design using Field Programmable Gate Arrays (FPGAs)

EE5170 THIN-FILM TRANSISTORS

Credits: 3
Semester:
Segment:

- 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.

EE5200 STEADY STATE POWER SYSTEM

Credits:
Semester:
Segment:

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.

EE5210 POWER CONVERTER DESIGN

Credits:
Semester:
Segment:

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.

EE5220 ADVANCED CONTROL SYSTEMS

Credits:
Semester:
Segment:

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 ADVANCED CONTROL LAB

Credits: 2
Semester:
Segment:

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

EE5230 **POWER SYSTEM DYNAMICS & CONTROL**

Credits:
Semester:
Segment:

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

EE5240 **ELECTRICAL MACHINES AND ANALYSIS CONTROL**

Credits:
Semester:
Segment:

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.

EE5300 **DIGITAL SIGNALS PROCESSING**

Credits:
Semester:
Segment:
Pre-Req:

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.

EE5310 **PROBABILITY AND RANDOM PROCESSES**

Credits:
Semester:
Segment:

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.

EE5320	**DIGITAL COMMUNICATIONS**
Credits: Semester: Segment:	Basebad Digital Transmission:PAM, PWM, PPM,PCM,DM. Digital Transmission: BPSK, QPSK, QAM, BER Analysis, Performance in Rayleigh, Rician and Nakagami Fading

EE5330	**INFORMATION THEORY & CODING**
Credits: Semester: Segment:	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	**DETECTION AND ESTIMATION**
Credits: 3 Semester: Segment:	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.

EE5350	**ERROR CORRECTING CODES**
Credits: Semester: Segment:	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.

EE5350	**PRACTICAL CHALLENGES IN IMAGE ANALYSIS**
Credits: 3 Semester: Segment:	Various scientific disciplines requiring image analysis: medical fields including ophthalmology and radiology, surveillance and navigation, biological sciences, and so on; unique image analysis challenges; basic image analysis tools such as histogram, contrast enhancement, edge and other feature detection, basic morphological processing, elementary segmentation, wavelet analysis; various strategies towards tackling practical challenges: case studies.

EE5360	**PRACTICAL CHALLENGES IN IMAGE ANALYSIS**
Credits: Semester: Segment:	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.

EE5370	**INTRODUCTION TO MACHINE LEARNING**
Credits: 1 Semester: Segment:	Unsupervised learning - clustering, latent variable models, supervised learning - classification, regression, multilayer perceptrons

EE5410	**NONLINEAR CONTROL THEORY**
Credits: 3 *Semester:* *Segment:*	Why Nonlinear Control?; Phase plane analysis; Fundamentals of Lyapunov Theory; Advanced stability theory; Describing Function analysis; Feedback Linearization; Sliding Control; Adaptive control
EE5440	**CLASSICAL CONTROL TECHNIQUES FOR MIMO SYSTEMS**
Credits: *Semester:* *Segment:*	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
EE5450	**STATE FEEDBACK CONTROL**
Credits: *Semester:* *Segment:*	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.
EE5460	**ANALYSIS OF NONLINEAR SYSTEMS**
Credits: *Semester:* *Segment:*	Why Nonlinear Control?; Phase plane analysis; Fundamentals of Lyapunov Theory; Advanced stability theory; Describing Function analysis; Input-output stability; Notion of passivity;
EE5470	**NONLINEAR CONTROL TECHNIQUES**
Credits: *Semester:* *Segment:*	Feedback Linearization;
EE5480	**OPTIMAL CONTROL**
Credits: *Semester:* *Segment:*	Pontryagin's Principle; Linear Quadratic Regulator; Time Optimal Control; Fuel Optimal Control
EE5490	**ROBUST CONTROL TECHNIQUES**
Credits: *Semester:* *Segment:*	Why robust control? What is robust control: Problem definition; Youla parameterization; H-infinity control.
EE6010	**APPLIED ALGEBRA**
Credits: 2 *Semester:* *Segment:*	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	**NANOELECTRONICS: PRINCIPLES AND DEVICES**
Credits: *Semester:* *Segment:*	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 **INTRODUCTION TO BIOSENSOR TECHNOLOGY**

Credits:
Semester:
Segment:

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).

EE6180 **BIOMEDICAL IC DESIGN**

Credits:
Semester:
Segment:

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.

EE6210 **SWITCHED MODE POWER CONVERSION**

Credits: 1
Semester:
Segment:

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).

EE6220 HVDC & FACTS APPLICATIONS

Credits:
Semester:
Segment:

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 & CONTROL

Credits:
Semester:
Segment:

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

Credits: 3
Semester: Jan
Segment: 16

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)

EE6300 SPEECH SIGNAL PROCESSING

Credits:
Semester:
Segment:

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.

EE6310 IMAGE & VIDEO PROCESSING

Credits:
Semester:
Segment:

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 WIRELESS SENSOR NETWORK

Credits:
Semester:
Segment:

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

EE6330 ADVANCED CELLULAR COMMUNICATIONS

Credits:
Semester:
Segment:

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.

EE6340 COOPERATIVE COMMUNICATIONS

Credits:
Semester:
Segment:

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

EE6350 MULTIPLE ANTENNA SYSTEMS

Credits:
Semester:
Segment:

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.

EE6360 MULTIMEDIA COMMUNICATION SYSTEMS

Credits:
Semester:
Segment:

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.

EE6360/EE6600 **LTE-4G**

Credits: 3
Semester:
Segment:

Modulation, coding and protocols used in the standard. Software implementation of the LTE standard (transmitter). Receiver algorithm design and implementation. Testing on the IITH LTE base station.

EE6380 **DEEP LEARNING**

Credits: 3
Semester:
Segment:

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 **WAVELETS AND SUBBAND CODING**

Credits: 3
Semester:
Segment:

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 **BIOMEDICAL IC DESIGN**

Credits: 3
Semester:
Segment:

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 **QUEUING THEORY**

Credits: 2
Semester:
Segment:
Pre-Req: 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/∞,M/M/m/∞, 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 **MORE THAN MOORE ELECTRONICS**

Credits:
Semester:
Segment:

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

EE7120 **CMOS SENSORS**

Credits: 2
Semester:
Segment:

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 **SMART GRIDS**

Credits: 3
Semester:
Segment:

Part - I Smart Grid (SG) Core Concepts: SG Conceptual Model, SG Architectures, SG 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 **MICROGRID OPERATION AND CONTROL**

Credits: 3
Semester:
Segment:

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.

EE7310 **COGNITIVE RADIO**

Credits:
Semester:
Segment:

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 **IMMERSIVE MULTIMEDIA**

Credits:
Semester:
Segment:

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	**NETWORK INFORMATION THEORY**
Credits: *Semester:* *Segment:*	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	**SPECIAL FUNCTIONS IN COMMUNICATIONS.**
Credits: 2 *Semester:* *Segment:*	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	**ADAPTIVE SIGNAL PROCESSING**
Credits: *Semester:* *Segment:*	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.
EE7360/EE7370	**MARKOV CHAINS - MAC MODELLING**
Credits: 2 *Semester:* *Segment:*	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
EE7370	**MARKOV CHAINS - MAC MODELLING**
Credits: 2 *Semester:* *Segment:*	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	**PATTERN RECOGNITION AND MACHINE LEARNING**
Credits: 3 *Semester:* *Segment:*	Introduction to PRML; General Notions: Parameter estimation, overfitting, model selection, curse of dimensionality, bias-variance tradeoff; Supervised Learning (Regression & Classification): Density estimation, Bayes decision theory, generative vs. discriminative models, Linear Methods: linear & 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 & Density Estimations): K-means clustering, vector quantization, Gaussian mixture models, autoencoders, dimensionality reduction (linear & nonlinear) Handling Sequential Data: Hidden Markov models, and Linear Dynamical systems.

EE7710	**PROBABILISTIC MODELS OF THE BRAIN**
Credits: 3 *Semester:* *Segment:*	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.
	DIGITAL DESIGN THROUGH ARDUINO
Credits: 1 *Semester:* *Segment:*	• Objective: To teach Karnaugh Maps (combinational logic) and State Machine (sequential logic) design using an arduino. • Methodology: This is done by designing a decade counter through state machines and implementing it completely on an arduino. The output is verified at every stage using a seven segment display (SSD). • Details: Driving SSD segements using arduino, displaying decimal digits on the SSD through the decoder IC and arduino, decimal to binary conversion using arduino, simulating the SSD decoder in arduino using Karnaugh maps and boolean logic functions, state machine design for the decade counter, implementing the decade counter using flip flop ICs and arduino for combinational logic and testing it through the SSD, simulating flip flops using arduino, simulating the decade counter completely in arduino and testing through the SSD.
	INTRODUCTION TO SOLAR CELLS
Credits: 2 *Semester:* *Segment:*	• Working principle and equivalent circuit of p-n junction. • Renewable energy and photovoltaic effect. • Characteristics and parameters of solar cells. • Fabrication and characterization. • Crystalline and amorphous silicon solar cells. • Organic solar cells: Working principle, materials, geometry. • Stability and degradation of solar cells. • Applications of solar cells at small and large scales.
	INTERNET OF THINGS
Credits: 1.5 *Semester:* *Segment:*	• Introduction: Concept, Importance, Interdisciplinary, Challenges, Various applications/smart objects, Major Players/Industry, Standards • IoT Architecture: • Node structure: Sensing, Processing, Communication, Powering • Networking: Topologies, Layer/Stack architecture • Communication Technologies: : Introduction to ZigBee, BLE, WiFi, LTE, IEEE802.11ah, Discuss data rate, range, power, computations/bandwidth, QoS • Smartness - Signal Processing/Analytics: Impact on Power/Energy savings, dynamic networks, simple case studies • IoT Fabricator: Introduction to Embedded electronics, fabricating electronics, Communication Network requirements, Data processing challenges - recreation, IP/security, Challenges…. • Hands-on in IoT (Starts in the first week and goes on until end of course): Projects based on some Hardware (Raspberry pi, Arduino, Intel, IITH Mote, Smartphones), Software (Contiki, TinyOS, Android), IoT Fabricator

LIBERAL ARTS

LA 1020 **PSYCHOLOGY OF WELL-BEING**

Credits: 1
Semester: Jul
Segment: 34

Well being is one of the most popular topics in positive psychology. This is a relatively new approach that focuses on positive aspects as opposed to the psychopathological perspective of traditional psychology. This course will trace research in the area of well being. Relevant concepts such as positive emotions, character strengths and resilience will be introduced and their relation to well being will be examined. Positive psychology interventions that enhance subjective well being and meaningfulness in life will be explored.

LA 1030 **INTRODUCTORY ECONOMICS**

Credits: 1
Segment:12

- Ten Principles of Economics
- Thinking like an Economist
- Interdependence and gain from trade
- The Market Forces of Supply and Demand
- Elasticity and Its Application
- Supply, Demand, and Government Policies
- Consumers, Producers, and Efficiency of Markets
- The Costs of Production

LA1040 **POST-COLONIAL STUDIES: A CRITICAL INTRODUCTION**

Credits: 1
Semester: Jan
Segment: 23

This course introduces fundamental concepts in the Postcolonial Studies. It also focus on the broad political contexts for the emergence of this discourse, the major departures that it makes from the western discourses and its relevance to Indian theory production. The course involves in analyzing some texts which are considered seminal in the discipline both in the western and Indian contexts.

LA1050 **INTRODUCTION TO WESTERN ART**

Credits: 1
Semester: Jan
Segment: 12

In this course, we will explore Western Art—especially painting and architecture—from its beginnings in pre-history to the present. 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 context, art's dialogue with society will also be of special interest. And, of course, we will study in detail magnificent paintings, buildings and sculptures!

LA1067 **ORIGIN OF ETHICS IN POLITICAL THEORY**

Credits: 1
Semester: Jul
Segment: 23

First philosophical contemplations about abstract ethical notions like virtue, truth, valor, wisdom, love etc took place in ancient Greece in 6th century BC. These philosophers have incorporated debates and analyses on these abstract notions in most of their discourses on metaphysics, politics, ontology, rhetoric and aesthetics etc. This course explains the students the importance of looking at how and why they originated and more importantly what were they like in their nucleus form. Greece philosophy matured into its fullness in a span of less than a century with the emergence Socratic field in 5th century. This ancient Greece philosophy has created an epistemological base for all the later political theories despite their ideological moorings. In brief, this course introduces the students to a political universe which for the first time (or at least according to recorded data) tried to grasp several notions related to what the current generation calls 'ethics', its importance to human kind and more importantly how we can apply 'ethics' to solve problems that arise in a society from time to time.

Presocratic Period: Views of Milesians (Thales, Anaximander and Anaximenes) on the origin; Pythagoras theory of harmony, soul's transmigration and reincarnation; Herclitus theory of "all is flux"; Eleatics (especially Zeno of Elea) counter to Herclitus: Empedocles and Anaxagoras on pluralism; Greek Atomism with special reference to Epicurus; Sophists' relativism and extreme skepticism (with specific reference to Protagoras); Socratic Period (Athenian Period): Socrates passion for dialogue and critical reasoning; his debate on what is (and why something becomes) right and/or wrong/ truth and how to arrive it, virtue etc; his disagreement with Sophists; why the then Athens daunted of him/reasons for his capital punishment;

Plato's admiration for Socrates (in the sense how Plato tried to carry philosophical legacy of Socrates); Immorality and the Forms; Philosopher King (virtues in human soul; education and value of justice; Allegory of Cave;
Aristotle: Ethics and Virtues; nature of virtue. 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.

LA1077 **PSYCHOLOGY OF INTERPERSONAL RELATIONSHIPS**

Credits: 1

We are social creatures and are in constant need to relate and orient ourselves towards animate beings. This course is designed as an overview to the field of interpersonal relationships, focusing on the psychological processes of human relationships. We will utilize major theories of interpersonal relationships, such as evolutionary, attachment, interdependence, and social exchange theory. We will also cover topics such as how relationships develop, family and communication, attraction, how relationships break down and so on. The course is

- Introduction
- Evolutionary theory
- Attachment theory
- Social exchange theory
- Relationship development and maintenance
- Family
- Attraction, love, jealousy
- Relationship breakdown and dissolution

LA1080 **THE SOCIOLOGY OF DIGITAL MEDIA: A GLOBAL PERSPECTIVE**

Credits: 1
Semester: Jul

This course focuses on the sociology of new media technologies, with a specific aim to anchor them within select theoretical debates and in specific geographic contexts. The course is intended to contribute to an understanding of impacts on individual and society through the use of new digital media tools [example the internet, Social media, mobile phone technologies and devices]. Many of the case studies, supporting theory, will center on people in cross-cultural, resource-poor and emerging market settings [for example, developing countries, the urban slum etc…].
The course will selectively but succinctly and comprehensively understand digital media:
As everyday social practice in multiple contexts: where is it found [social geographies], who uses it [ownership], its social learning [sharing and skill building].
As means to achieving social goals: From downloading latest Bollywood movies, chatting on social network sites and virtual gaming.
Theories that frame and analyze digital media behaviors Example, Facebook, Twitter, Gaming, Multi-media, Search etc.
Case-studies from the global North and South highlighting contemporary trends and their interaction with traditional media
As emerging economies globalize and urbanize rapidly, and users in the global south become 'prosumers' or more critical consumers and creative contributors of digital content, we require a shift in approaching new media users with a more open-ended and explorative perspective. Thereby, the motivating question for our course is what are the implications and impacts of new media as leisure (entertainment/pleasure/ play) artifacts and as professional tools for social mobility especially in the contexts of developing economies and emerging markets. This course will cover interesting social transformations happening in the domain of communication and information channels and, consequentially, the shift registering through social media behaviors and practices.
This class has no pre-requisite requirements and open to students from any background.
Students will be continuously evaluated with periodic quizzes/short tests and a course end test that will gauge student ability in engaging with and comprehending the course readings and class room discussions.

LA 1100 **INFORMATION TECHNOLOGY AND DEVELOPMENT: CONTEMPORARY DEBATES AND PRAXIS**

Credits: 1 or 2
Semester: Jul

A sociological understanding of development in specific social contexts and the role of specific technologies in aiding it. The question we ask is how technology seeks to address the needs and

aspirations of people who are increasingly consuming technologies and services despite inadequate infrastructures and resources.
Highlight with case-studies from India, Africa, Latin America, Sri Lanka and Bangladesh. These will provide a ground-view of processes aiding deployment and adoption of ICTs
Offer a critical lens to evaluate the processes and impacts ICT for D field deployments. This would provide a well-rounded and practical perspective on issues of assessment and successes of development projects

LA1110 **FINANCIAL MARKETS**

Credits: 1
Semester: Jan
Segment: 12

- Role of financial markets
- Interest rates and their role in valuation
- Money Market
- Bond Market
- Equity market
- Foreign Exchange Market

LA1120 **INTRODUCTION TO SOCIAL PSYCHOLOGY**

Credits: 1
Semester: Jan

This course is an introduction to the field of social psychology, one of the important sub-fields of psychology. While psychology is generally concerned with understanding and explaining individual human behaviour, social psychology can be described as the scientific field concerned with the understanding of individual behaviour in social situations. It explores how human thought and behaviour is influenced by the actual or imagined presence of others. How and why do people behave differently in different contexts? Why are some people more helpful while others more aggressive? What distinguishes good leaders from non-leaders? Why do we believe claims made by advertising companies which are obviously unreasonable? What are some of the techniques used to persuade people to change their minds? Why do people have extreme prejudices and stereotypes and how can these be overcome? These are some of the important questions that concern the field of social psychology.

LA1130 **INDIAN GODS IN JAPAN: HISTORY, IDENTITY AND SUPREMACY IN SOCIETY**

Credits: 1
Semester: Jul

This course is about Indian gods worshipped in Japan. The course projects insights into the socio-cultural scenario within which the worship of Indian gods in Japan is contextually located.

LA1140 **INTRODUCTION TO THE SHORT STORY**

Credits: 1
Semester: Jul
Segment: 56

Designed for the beginning student of literature, this course provides an overview of the traditional and modern approaches of narration used largely by the short story genre. By reading a selection of short literary narratives that represent various cultures across the world, this course examines how plot and authorial intent function in short stories to give rise to a variety of forms presently associated with this genre. The student is expected to read and critically interpret these narratives and submit their responses in the form of both oral and written presentations.

LA1150 **CULTURES OF THE WORLD**

Credits: 1
Semester: Jan

This course will introduce students to the field of social and cultural anthropology and sociology. They will be exposed to different cultures of the world, and how social and cultural attitudes and behaviours are so different and yet so similar, across cultures. The course will enable them to understand cultures in the Americas (north and south America), Asia, Europe and Africa. Students will also learn to understand and appreciate ethnography as a method and an approach to study world cultures. It will give them an international exposure to some major issues of interest in the 21st century- about environment, globalisation, media and health. Students will read chapters from the assigned textbook, as well as articles, and will watch documentaries in class. Assessment will be based on response papers written regularly about the readings, and a research paper. based on a topic chosen by the student.

LA1200 **INTRODUCTION TO PSYCHOTHERAPY**

Credits: 1
Semester: Jan

This course will present an introduction to the field of psychotherapy, including a theoretical understanding of different therapies such as psychodynamic and psychoanalytic theories and approach, humanistic-experiential theories and approach, group therapy. The aim of this course is

to give students an idea about the various approaches of counseling in different settings. The course especially aims to sensitize students the holistic nature of this field and its subsequent benefits. This course is practical and interactive in its style of instruction, with student participation being particularly recommended. The mode of evaluation for this course is through assignments and presentations.

Topics:

- Transactional analysis
- Psychodynamic & psychoanalytic theories & approach
- Humanistic-experiential theories & approach
- Cognitive-behavioural theories & approach
- Group therapy
- Family and couples counseling

LA1220 **UNDERSTANDING HYDERABAD AND ITS HERITAGE**

Credits: 1

This course takes an in-depth look at the history and heritage of the city of Hyderabad. With more than four hundred years of history, including sites suggested for inclusion in the world heritage list, and simultaneously traversing the 'global' tag, Hyderabad has lots of stories to tell. Through assigned readings and lectures, field trips to selected heritage sites, and interviews with residents, students will get to understand various facets to the city of Hyderabad. Assessment will be based on individual written essays and group projects. This course involves significant amount of reading and writing, and discussions in class.

LA1230 **INTRODUCTION TO MEDICAL HUMANITIES**

Credits: 1
Semester: Jan
Segment: 12

The course will focus on the interpretation of medicine from the world of arts, literature, history, anthropology and psychology. By looking at paintings, biographies, novels, ethnographies, and films, the course will engage in detailed discussions on some key topics such as narrative medicine, history of medicine, cross-cultural communication, disability studies and lived experience. Field trips to practitioners of different systems of medicine will be undertaken. Readings will be followed by interactive class discussions. Students will also choose a topic to work on for a research paper. Assessment will be based on written essays and class presentations.

LA1240 **LITERATURE AND SCIENCE**

Credits: 1
Semester: Jul
Segment: 34

This course explores the dialogue between literature and scientific disciplines over a period of about 200 years. The split between the arts and sciences is relatively recent in the history of human knowledge and creativity: many of the great artists of the Renaissance or the 17th century, for example, would also qualify as great scientists in the way we understand the word 'science' today. And both artists and scientists have, despite appearances to the contrary, a continuing history of speaking to and about each other—even if sometimes what they have to say might not be very flattering to the other party. It is this history that we will explore and try to learn from. We will look at classic science fiction like Mary Shelley's Frankenstein and Philip K. Dick's Do Androids Dream of Electric Sheep?; we will read the work of highly articulate scientists like Richard Feynman and James Watson; we will look at what poets make of quantum physics, biochemistry and—of course—fractals. We will occasionally look at visual material including films and paintings.

The course has an optional creative component: assignments and projects can be works of creative writing. This course involves close reading of literary texts, so those who take this course should be comfortable with reading English literature.

Plagiarism warning: Copy-pasting from the internet or other sources in your assignments will lead to a failing grade.

LA1250 **MODERN TELUGU AND ENGLISH POETRY: A COMPARATIVE STUDY OF CULTURAL POLITICS**

Credits: 1
Semester: Jan
Segment: 23

Poetry has been written from ancient times in order to fulfill several purposes like personal satisfaction, royal or divine aggrandizement, fascination, political articulation etc. However, it keeps on changing its form and content with the changing times and history and Telugu poetry is no exception from it. It is a perfect prototype of modern poetry written from colonial and postcolonial background and it strongly reflects the trends of the cultural politics, which are due for any other postcolonial nation. Therefore, this course requires at least two types of attention:

One is thematic and the other is theoretical. In other words, some of the major cultural studies theory will be applied in order to understand the thematic universal of postcolonial poetry.
Unfortunately, the only question that has been contemplated in the vernacular about art is: 'is art for the sake of art or not.' Though this question carries its own ideological impinges it also greatly delimited theory on poetry from growing. On the other hand western world especially ancient Greece has given serious thought into the subject of poetry. For instance, Aristotle had given a rigorous thought to poetry and argued that it is basically a mimesis (imitation) and interestingly Plato hated poetry for the same reason. After several thousands of years, now in postcolonial times, some of the nations from Caribbean perceive its poetry as essentially hybrid (close to mimesis). Thus this course deals with several questions pertinent to comparative analysis. These questions are broadly: Does India, a postcolonial nation produce hybrid poetry like Caribbean? If not, why? In other words, why Indian vernacular fail to produce poetry on certain cultural experiences like its other postcolonial sister like Caribbean? Why vernacular poetry fails to be enough imaginative? Etc.

LA1260 **FUNDAMENTALS OF ORGANIZATIONAL STRUCTURE**

Credits: 1
Semester: Jul

Course Objective: To help students understand the elements of the structure of an organization and the role of organizational structure in organizational effectiveness. This course will be very useful for engineering graduates to understand the design behind social structures like organizations.
Brief Course Outline:

- Defining organizations
- Fundamental concepts in organizational design
- Elements of organizational structure
- Factors influencing organizational structure
- Role of organizational structure in organizational effectiveness

LA1270 **AN INTRODUCTION TO HUMAN-COMPUTER INTERACTION AND ITS INTERFACE WITH THE SOCIAL SCIENCES**

Credits: 1
Semester:

Quote: "A sushi restaurant puts sensors on its plates to assess, in real time, what's being eaten so it can adjust its food offerings" [Goodman, The Atomic Age of Data, 2015]" End Quote.
This course is an introduction to the field of Human-Computer interaction research with a focus on 'human' and how the HCI domain interfaces with the social sciences. The course begins with a selection of seminal work that establish the HCI domain: interactive systems/techniques, design and user interfaces. We will then move on to topics including social and context aware computing, design research and evaluation methods.
Radically different ways of interacting with computationally based systems are possible, ranging from the visual [surfaces, input devices] to the invisible [sensor technologies, back end processors] and importantly social [which means non-technological] affectations triggering diverse ways of interfacing with technology.
This course will center on the processes and challenges of ideating, designing and evaluating technologies as products, their usability and immersion into the social contexts of users. We will study contextual design as a field that emerged in response to the challenges of designing for context and usability. Another important strand in this course will dwell on the sociological aspects of HCI and explore the 'mediation' of technology use by a range of contextual situations: socio-cultural obligations, habits, values, infrastructure, material objects and not in the least family, kinship and human bonds. Some examples of the above are:
Understanding social interactions with a webcam as an important new development in communication interfaces and its widespread adoption in the real world supporting family relationships, business work flows and social networking. Another example will be looking at technologies driven by data science, like mobile marketing analytics, and their consequences for society.
This course has no pre-requisites and is open to students from any background. Students are expected to do all of the readings. Students will be evaluated with a quiz or a test and a presentation that will gauge student ability in engaging with and comprehending the course readings and class room discussions. The class test and the presentation will be based on the class lectures and readings assigned for the course

LA1280	GLOBALIZATION AND SOCIETY
Credits: 1 *Semester: Jan* *Segment: 34*	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, migration, media images, and gender ideologies. Through looking at empirical evidence from different parts of the world, the course aims to educate students on the effect of globalization processes in people's lives.

LA1290	INTRODUCTION TO THE NOVEL
Credits: 1 *Semester: Even* *Segment: 56*	Designed to introduce the student to the novel as a literary genre this course provides a broad historical overview of the development and rise of the novel. Focusing on narrative strategies, plot development, and characterization among others, used in their various forms and guises by the novel, this course seeks to help the student understand, evaluate and interpret how this genre functions as a medium of dialogue between literature and society. The student is expected to articulate her/his responses both as class discussions as well as written presentations.

LA1300	GENERAL FICTION I: THRILLERS
Credits: 1 *Semester: Odd* *Segment: 56*	This course examines two representative works of genre fiction, namely, psychological thriller and detective fiction. By focusing on the connections between literary artefacts and the social context, the course aims to familiarize the student with genre fiction as a discursive practice whose socio-cultural roots are embedded deeply in history. It also provides a crucial link between literature and other aesthetic media of communication such as films and television by reading literary works in tandem with their audio-visual adaptations. The student is expected to read and interpret texts and contexts and present an analysis of the same through class discussions and written assignments.

LA1310	GENERAL FICTION II: HORROR AND SCIENCE FICTION
Credits: 1 *Semester: Jan* *Segment: 56*	This course analyzes classic works of horror and science fiction to explore the relationship between literature and socio-cultural realities, specifically with regard to development of global politics and history over the last two centuries in Europe and America. In addition, the literary texts chosen for this course demonstrate how the fantastical realms of horror and science fiction are not only elemental to human imagination but also progenitors of ideologies around which social reality is constructed.

LA 2010	INTRODUCTION TO WORLD LITERATURE
Credits: 3 *Semester: Odd* *Pre-Req: Only UG*	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.

LA 2020	PRINCIPLES OF ECONOMICS
Credits: 3 *Semester: Jul*	• 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 **EVOLUTION OF GENDER QUESTION IN INDIA**

Credits: 3
Semester: Jan

LA2080 **INTRODUCTION TO WESTERN ART: FROM CAVE ART TO MIDDLE AGE**

Credits: 3
Semester:
Segment:

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 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 **LANGUAGE, COGNITION, AND COMPUTATION**

Credits: 3
Semester: Jan
Segment: 16
Pre-Req: none

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 **FINANCIAL INSTITUTIONS AND MARKETS**

Credits: 3
Semester: Jan
Segment: 16

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 **ETHICS AND MODERN POLITICAL THEORY**

Credits: 3
Semester: Jul
Segment: 16

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 ETHICS IN POLITICAL THEORY

Credits: 3
Semester: Jul
Segment: 16

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 POSTMODERN THEORIES AND ETHICS

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: None

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 POPULAR FICTION

Credits: 3
Semester: Jan
Segment: 16
Pre-Req: see syllabus

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 & basic proficiency in English with primary background in literature.

LA4050 PERSONALITY PSYCHOLOGY

Credits: 3
Semester: Jan
Segment: 16

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 **INDIAN ECONOMIC DEVELOPMENT**

Credits: 3
Semester: Jan
Segment: 16

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 ORGANIZATIONAL BEHAVIOR AND OWRK PSYCHOLOGY

Credits: 3
Semester: Jan
Segment: 16

- 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 **NATURAL LANGUAGE AND NATURAL MEANING**

Credits: 3
Semester: Jul
Segment: 16

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 **GENDER AND SOCIETY**

Credits: 3
Semester: Jan
Segment: 16

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 **MACROECONOMICS**

Credits: 3
Semester: Jul
Segment: 16

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 INDUSTRIAL ORGANIZATION

Credits: 3
Semester: Jan
Segment: 16

- 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
- R&D 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 BASIC ECONOMETRICS AND FORECASTING

Credits: 3
Semester: Jul
Segment: 16

- 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 QUALITATIVE RESEARCH METHODS

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: Only for PG students

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 ADVANCED HEALTH PSYCHOLOGY

Credits: 3
Semester: Jul
Segment: 16

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 THEORIES ON CULTURE

Credits: 3
Semester: Jan
Segment: 16

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 MEDICAL ANTHROPOLOGY

Credits: 3
Semester: Jan
Segment: 16

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 LITERARY AND CRITICAL THEORY

Credits: 3
Segment: 16
Pre-Req: Only for 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 POSITIVE PSYCHOLOGY

Credits: 3
Semester: Jan
Pre-Req: students from psychology background

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 CONTEMPORARY INDIA

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: 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.

LA6100 MODERNISM

Credits: 1+2
Semester: Jul
Segment: 16

This course provides an overview of Modernism—provisionally defined as art produced between 1900 and 1945—through canonical British and American literary texts. Since developments in the visual arts were particularly influential in the evolution of literary Modernism, we will also periodically examine Modernist art—principally painting and sculpture—in order to understand wider aesthetic tendencies. Through close readings of important prose, verse, and visual texts of

the period, we will ask ourselves: What is Modernism? How is Modernism in the arts and literature related to dominant historical, philosophical, political, and cultural trends in the first half of the twentieth century? In what ways do Modernist texts reimagine the act of reading? How is Modernism related to preceding movements like Romanticism and to Postmodern literature and art?

LA6110 **CRITICAL PSYCHOLOGY**

Credits: 3
Semester: Jan
Segment: 16
Pre-Req: Only PG

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 **ADVANCED THEORY IN SOCIOLOGY AND SOCIAL ANTHROPOLOGY**

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: 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 **ISSUES IN INTERNATIONAL FINANCE**

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: Only PG

This course introduces major topics in international finance 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 **QUANTITATIVE RESEARCH METHODS FOR BEHAVIORAL SCIENCES**

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: 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 **AMERICAN TRANSCENDENTALISM**

Credits: 3
Semester: Even/Odd

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,

Segment: 16
Pre-Req: Only PG

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 AMERICAN FICTION AFTER 1945

Credits: 3
Segment: 16
Pre-Req: 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 CONTINENTAL AESTHETICS: FROM THE EIGHTEENTH CENTURY TO THE PRESENT

Credits: 3
Segment: 16
Pre-Req: 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 ADVANCED ECONOMETRICS

Credits: 3
Semester: Jan
Segment: 16
Pre-Req: 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 SPECIAL TOPICS IN ECONOMIC RESEARCH

Credits: 3
Segment: 16
Pre-Req: 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 R&D
- Productivity shocks, budget deficits and the current account

LA6220 **CULTURE AND MENTAL HEALTH**

Credits: 3
Semester: Jan
Segment: 16
Pre-Req: 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 **SOCIOLOGY OF GLOBALIZATION**

Credits: 3
Semester: Jan
Segment: 16
Pre-Req: 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 **LOGICAL FOUNDATIONS OF LANGUAGE AND COGNITION**

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: 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 **CHRONIC DISEASE MANAGEMENT**

Credits: 3
Segment: 16
Pre-Req: 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 **PSYCHOLOGICAL RESILIENCE**

Credits: 3
Semester: Jul

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

Segment: 16
Pre-Req: Students from the psychology background

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 **ANTHRPOLOGY AND POPULAR CULTURE**

Credits: 3
Segment: 16
Pre-Req: Only PG

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 **FILMS**

Credits: 3
Semester: Jan
Segment: 16
Pre-Req: 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.

FC5704 **ENGINEERING AND DEMOCRACY**

Credits: 1
Semester: Jan

Facets of Engineering: The View from Engineering

- Locating Engineering in STEM
- Engineering for Profit and Progress
- Power of Corporate: Engineering as Captive Discourse
- Engineering, Ethics and the Humanities
- Democracy and Engineering: for Progress and Social Minimum
- Information Age: Opportunity for India.

Facets of Engineering: The View from The Humanities

- ENS and its Place in the Overall Scheme of Disciplinary Studies
- ENS in the context of Education and Democracy
- Engineering, Humanities and Ethics
- Scientific and Technological Progress
- Philosophy of Technology

MATERIALS SCIENCE AND METALLURGICAL ENGINEERING

MS1010	**SCIENCE AND ENGINEERING OF MATERIALS**
Credits: 1 *Semester:* *Segment:*	Introduction to general concepts of metallurgy and materials science and general considerations in application orientated material design - through three example case studies on bone, sensors, and defence materials, Types of materials (metals, ceramics, polymers, hybrids), general material properties (structural and functional), trade off in material properties and brief introduction to optimisation, followed by classroom discussion sessions. Overall, the course offers a wide vision on how materials have led to technological advancement in all aspects and is designed to help appreciate the courses in following semesters.
MS1020	**METALLIC MATERIALS**
Credits: 1 *Semester:* *Segment:*	Structure of metals, Determination of structure and chemical composition, concepts of alloys, phase and phase diagrams
MS1030	**MATERIALS CHARACTERIZATION I**
Credits: 1 *Semester:* *Segment:*	Spectroscopic techniques - Vibrational spectroscopy (IR and Raman); visible and ultraviolet spectroscopy; nuclear magnetic resonance (NMR) spectroscopy; electron spin resonance (ESR) spectroscopy; X-ray spectroscopies (energy dispersive spectroscopy (EDS), wavelength dispersive spectroscopy (WDS), absorption edge fine structure (AEFS), extended X-ray absorption fine structure (EXAFS)); Electron spectroscopies (electron spectroscopy for chemical analysis (ESCA), X-ray photoelectron spectroscopy (XPS), ultraviolet photoelectron spectroscopy (UPS), Auger electron spectroscopy (AES), electron energy loss spectroscopy (EELS)); Mössbauer spectroscopy. Microscopic techniques- Optical microscopy, atomic force microscopy. Thermal analysis- Thermogravimetric analysis (TGA), differential thermal analysis (DTA), differential scanning calorimetry (DSC), Electrical and magnetic measurements
MS1040	**MATERIALS SYNTHESIS**
Credits: 1 *Semester:* *Segment:*	Introduction to chemical synthesis of ceramic materials by solution based approaches- co-precipitation, sol-gel, hydrothermal, sonochemical. Vapour phase synthesis -PVD, CVD, molecular beam epitaxy etc. Solid State route- solid state reaction basics, combustion synthesis
MS1050	**PHYSICS OF SOLIDS**
Credits: 1 *Semester:* *Segment:*	Atomic structure - Chemical bonding - Types of bonds - Metals - Fermi level - Fermi surface - Crystal structure - Bravais lattice - Atomic stacking - Reciprocal lattice - Kroenig Penning model - Band formation - Material classification
MS1060	**POLYMERS**
Credits: 1 *Semester:* *Segment:*	Introduction to polymers- synthetic and natural, structure (states and configuration) of polymers, synthesis, effect of temperature (glass transition and melting), branching, cross-linking on properties, structure - properties relationship and application, processing techniques and product development
MS1070	**SEMICONDUCTOR MATERIALS**
Credits: 1 *Semester:* *Segment:*	Semiconductor crystals - Band formation in semiconductors - Direct & Indirect Band gap semiconductors - Concept of holes - Hall Effect - Effective mass - heavy and light mass carriers - Doping in semiconductors - Band bending - Heavily doped semiconductors - Excitons
MS1080	**COMPUTATIONAL METHODS IN MATERIALS SCIENCE I**
Credits: 1 *Semester:* *Segment:*	Length scales in materials - macro to electronic structure; overview of modeling techniques at different length and time scales; concepts of linear algebra and matrix computation; Introduction to Mathematica® - symbolic and numeric calculations, basic plotting and visualization, roots of equations.

MS1090	**MICROMECHANICS OF SOLIDS**
Credits: 1 *Semester:* *Segment:*	Concepts of scalar, vectors, matrix and tensor; Cartesian tensors; Vector and tensor algebra; Deformation - displacement and strain; Stress and mechanical equilibrium; Concepts of linear elastic solids.
MS2010	**SOFT MATTER SCIENCE**
Credits: 1 *Semester:* *Segment:*	Colloids, foams, gels, surfactants soft biological materials such as DNA, liquid crystals - structure, property, characterisation and applications, theoretical concepts
MS2020	**PHYSICAL METALLURGY**
Credits: 2 *Semester:* *Segment:*	Imperfections in crystals-point defects, dislocations and voids, theory of dislocations, strengthening mechanisms, diffusion in solids, heat treatments and phase transformations, mechanical response and microstructure-property relationship
MS2030	**MATERIALS CHARACTERIZATION II**
Credits: 2 *Semester:* *Segment:*	X-ray diffraction and imaging, Properties of X-ray; Diffraction: Directions and intensities; Experimental methods: Laue diffraction, Powder diffraction, Diffractometer measurements; Applications: Crystal structure and size (grain & particle); Orientation; Phase diagram; Order-disorder transformations; Chemical analysis; Stress measurement, X-ray tomography. Electron diffraction and imaging: Reciprocal space; Electron diffraction pattern; Kikuchi diffraction; Convergent beam electron diffraction (CBED) pattern; Imaging: Amplitude contrast, phase-contrast, thickness-bend contrast; Secondary electron imaging; Back scatter electron imaging
MS2040	**ADVANCED MATERIALS SYNTHESIS**
Credits: 2 *Semester:* *Segment:*	Basics of nucleation and growth processes in solution based synthesis. Solid liquid interface interactions Influence of reaction conditions on morphological properties of materials. Approaches for synthesis of nanomaterial. Basics of sintering process- chemical reaction and phase transformation kinetics in solids. Solid substrate- vapour interactions in CVD, PVD. Effect of vapour deposition conditions on growth and morphology of ceramic films
MS2050	**MECHANICAL BEHAVIOUR OF MATERIALS**
Credits: 2 *Semester:* *Segment:*	Hardness testing, Tensile and compression testing, Torsion testing, Fatigue testing, Fracture, High temperature deformation- Creep and superplasticity, Impact testing and failure
MS2060	**FUNCTIONAL AND STRUCTURAL POLYMERS**
Credits: 2 *Semester:* *Segment:*	Structural polymers, crystallisation in polymers (types and mechanism), mechanical behaviour - viscoelasticity -spring dash pod models - relaxation behaviour (time and temperature effect), functional polymers (conducting polymers, liquid crystalline polymers, polymeric photonic crystals), characterisation- scattering by polymers, flow in polymers- rheology, polymer blends and composites, blending (solubility and compatibility),
MS2070	**CERAMICS AND REFRACTORIES**
Credits: 1 *Semester:* *Segment:*	Introduction, Ceramic Materials: structure, microstructure and polymorphism, synthesis of ceramics, ceramic forming processes, structural ceramics, Properties and applications. Refractory materials, Properties of Refractories, Fracture of refractories, Corrosion of Refractories, Different Refractory lines, Testing of Refractory Materials.
MS2080	**PROCESS METALLURGY**
Credits: 1 *Semester:* *Segment:*	Introduction to stoichiometry, thermochemistry, basics of materials and energy balance, applications in minerals processing
MS2090	**ELECTRONIC MATERIALS**
Credits: 1	Dielectrics - Polarizability, Temperature and frequency effects - Dielectric breakdown - high-k dielectrics - DRAM devices - Ferroelectrics - structural phase transitions - Domains - Domain walls

Semester:
Segment:

- Domain Switching - Piezo-pyro and anti-ferroelectrics - Multiferroics - Relaxor materials - NVRAM applications - low dimensional insulators - Introduction to interaction of light with electrons in solids; absorption, colour, refraction, polarization, optical process

MS2100 **RATE PHENOMENA IN PROCESS METALLURGY**

Credits: 1
Semester:
Segment:

Mass and energy balance in metallurgical processes; Applications of heat and mass transfer in steel making; concepts of physical and mathematical modeling of metallurgical processes (iron making, steel making, etc.)

MS3010 **MAGNETIC MATERIALS**

Credits: 1
Semester:
Segment:

Origin of magnetism - Types of magnetic materials: dia-para-ferro-ferri and antiferro-magnetism - Soft and Hard magnetic materials - Domains and Domain walls - Experimental observation of Domains - CMR - magneto caloric materials - spin glasses - magneto optic materials - MOKE

MS3020 **CASTING AND SOLIDIFICATION**

Credits: 2
Semester:
Segment:

Pattern making, moulding processes and materials, core and core materials, pouring and feeding castings, solidification microstructures, ferrous and non-ferrous castings

MS3030 **NON-FERROUS EXTRACTIVE METALLURGY**

Credits: 1
Semester:
Segment:

Basics of extractive metallurgy (thermodynamic, kinetic and electrochemical aspects). Types of extractive metallurgy processes ((Pyro-metallurgy, Hydrometallurgy and electrometallurgy), extraction from oxides, halides and sulphide ores. Refining and purification. Waste management, energy and environmental issues in nonferrous metals extraction

MS3040 **THIN FILMS**

Credits: 2
Semester:
Segment:

Introduction to thin films: Definition of thin films - Formation of thin films, Environment for thin film deposition; Deposition parameters and their effects on film growth, Substrates - overview of various substrates utilized. Vacuum technology, Physical vapor deposition (PVD) techniques, Chemical vapor deposition techniques, Metallorganic (MO) CVD, Epitaxy Thickness Determination techniques, Characterization of Thin film.

MS3050 **IRON MAKING**

Credits: 1
Semester:
Segment:

Raw Materials for Iron Making, Burden Preparation from raw materials, Blast Furnace design and operations, Physical-Thermal-Chemical Processes in a Blast Furnace, Alternative Routes of Iron Production

MS3060 **STEEL MAKING**

Credits: 1
Semester:
Segment:

Acidic and basic steelmaking processes, principles of C, Si, Mn, S and P removal, selected steel making processes, ingot casting, continuous casting of steels

MS3070 **POWDER METALLURGY**

Credits: 2
Semester:
Segment:

Historical perspective, scope of powder metallurgy industries, techniques of near net shape manufacturing, techniques of powder manufacturing, characterization of powders, powder compaction methods, introduction to sintering, post-sintering operations.

MS3080 **COMPUTATIONAL METHODS IN MATERIALS SCIENCE II**

Credits: 2
Semester:
Segment:

Conservation and continuity equations; Constitutive equations describing behaviour of materials; Numerical solution of ordinary and partial differential equations - finite difference and finite volume methods, spectral methods; numerical implementation of random walk model; overview of mesoscale modelling - phase-field models, cellular automata, dislocation dynamics; overview of atomistic simulations - molecular dynamics, Monte Carlo methods; application of quantum mechanics - electronic structure calculations.

MS3090 **PHASE EQUILIBRIA**

Credits: 1

Concepts of classical thermodynamics - first, second and third laws - extensive and intensive properties; Heat capacity, enthalpy, entropy and Gibbs free energy; Partial molar quantities -

Semester: chemical potential; Phase equilibrium in single component systems; Ideal and nonideal solutions;
Segment: Gibbs free energy composition diagrams; Phase diagrams

MS3100 KINETICS OF MATERIALS

Credits: 2 Principles of diffusion in continuum - continuity equation; Concepts of fields, fluxes and gradients;
Semester: Fick's laws of diffusion - steady state and nonsteady state; Solutions to the diffusion equation;
Segment: Atomic mechanisms of diffusion - random walk; Interstitial and substitutional diffusion; Solutions to diffusion equations; Interdiffusion - Kirkendall effect, Darken relations.

MS3110 TRANSPORT PHENOMENA

Credits: 2 Concepts of fluid flow, heat and mass transfer; Viscosity; Flow through porous media; Heat transfer
Semester: - conduction, convection and radiation; Diffusion and advection; Analogy between heat and mass
Segment: transfer; Unit operations in process metallurgy.

MS3120 PHASE TRANSFORMATIONS

Credits: 2 Overview of phase transformations - thermodynamic driving force; Theory of nucleation -
Semester: homogeneous and heterogeneous nucleation; Diffusional growth and interface controlled growth;
Segment: Precipitation; Phase separation - spinodal microstructures; Particle coarsening; Eutectoid, massive, disorder-to-order, martensitic transformations; Elastic stress effects on microstructural evolution;

MS3130 NON DESTRUCTIVE TESTING

Credits: 1 Types of discontinuities in different product forms, principles of NDT Methods and techniques,
Semester: applications, ultrasonic testing, radiographic testing and other techniques, limitations.
Segment:

MS3140 TECHNICAL COMMUNICATION

Credits: 1 Drafting of communication- written content - organization of content elements, writing style,
Semester: formatting and grammar. Data and image representation. Reference management. Ethical issues
Segment: in technical communication.

MS3150 CORROSION

Credits: 1 Thermal and electrochemical basis for corrosion in metallic materials. Types of corrosion (general,
Semester: Galvanic, Intergranular, Crevice, Pitting, Erosion etc.) detection and analysis of corrosion.
Segment: Preventive measures and economical consideration

MS3160 AEROSPACE MATERIALS

Credits: 1 Aerospace materials - Past, present and future; Materials and materials requirements for aerospace
Semester: structure and engine; Production, casting, processing and machining of aerospace materials;
Segment: Mechanical and durability testing of aerospace materials; Degradation and protection for aerospace materials Science and engineering of aerospace materials - Aluminium alloys, Titanium alloys, Magnesium alloys, Steels, Superalloys, Polymers, Composites

MS3170 ADDITIVE MANUFACTURING TECHNOLOGY

Credits: 1 Overview, Direct digital manufacturing, types of additive manufacturing processes, additive
Semester: manufacturing of different materials, selective laser sintering, Direct Metal Deposition (DMD) and
Segment: Laser Engineered Net Shaping (LENS), structure and properties.

MS3190 LOW DIMENSIONAL MATERIALS

Credits: 1 Classification of low dimensional materials (Zero-, one-, two-, and three dimensional
Semester: nanostructures-quantum dots, quantum wells, quantum rods, quantum wires.)- Synthetic
Segment: approaches for nanomaterial fabrication. Effect of confinement on materials properties (optical, electronic, magnetic, mechanical etc.). Applications of nanomaterial.

MS3210 CARBON MATERIALS

Credits: 1 Classification physicochemical properties and applications of conventional carbon based materials
Semester: (activated carbon, graphite, diamond). Nanocarbons (carbon nanofibers, nanotubes, fullerenes,
Segment: graphene) effect of size and shape on their physical and functional properties.

MS3220	**AMORPHOUS MATERIALS**
Credits: 1 *Semester:* *Segment:*	Amorphous semiconductors - Band tailing - Fermi pinning - phase change materials - switching behavior - optical and mobility gap - magnetic metallic glasses, Glasses, Bulk Metallic Glasses, Amorphous alloys,
MS3240	**METAL JOINING**
Credits: 2 *Semester:* *Segment:*	Welding processes - Gas welding, arc welding, electro slag welding, Electron beam and Laser beam welding, resistance welding, thermit welding, solid state welding, Welding metallurgy of metals and alloys; Heat flow, residual stresses, welding defects and testing; Adhesive and diffusion bonding of materials; Soldering and brazing
MS3250	**SURFACE ENGINEERING**
Credits: 2 *Semester:* *Segment:*	Surface dependent engineering properties, common surface initiated engineering failures, mechanism of surface degradation, classification and scope of surface engineering in metals, ceramics, polymers and composites, Surface protection and surface modification techniques.
MS3260	**BIOMATERIALS**
Credits: 2 *Semester:* *Segment:*	Application of materials in medicine: introduction to structure and biological properties of hard and soft tissues and requirement of implant materials. Classification of implant materials (metallic, ceramic, polymeric), physical, mechanical and biological attributes necessary for specific implant function. Practical aspects of Implant materials- host tissue response, implant failure.
MS4010	**DEFECTS IN FUNCTIONAL MATERIALS**
Credits: 1 *Semester:* *Segment:*	Types of Defects - Colour centres - optical emission - solid state lasers - Luminescence - types of luminescence - Band gap tuning - ionic conductivity - Varistors - Gas sensors - Characterization techniques of Defects - Demerits of defects - Defect induced functional failures
MS4020	**RESEARCH METHODOLOGY**
Credits: 1 *Semester:* *Segment:*	Defining research problem, laboratory safety measures, do's and don'ts of data collection and processing (graphical, statistical, image processing etc.). Ethical issues with laboratory protocol and data reporting.
MS4030	**MATERIALS SELECTION & DESIGN**
Credits: 1 *Semester:* *Segment:*	The design process - Function, material, shape and process relationship with data. The selection process - Material and shape co-selection from charts, process selection with diagrams. Various case studies.
MS4040	**RECYCLING OF MATERIALS**
Credits: 1 *Semester:* *Segment:*	Introduction, Environmental issues, Waste characterization, Size reduction and classification, techniques of materials separations, methods of recycling of papers, glass, plastics and metals, Recycling of precious materials.
MS4050	**FATIGUE AND FRACTURE**
Credits: 2 *Semester:* *Segment:*	Mechanisms of fatigue in metals - stages of fatigue, constitutive relations; Design for fatigue - microstructural aspects; Fracture mechanisms in brittle and ductile solids; Thermodynamics of fracture - Griffith theory; Measurement of toughness.
MS4060	**THERMO-MECHANICAL PROCESSING**
Credits: 2 *Semester:* *Segment:*	Work-hardening mechanisms, static and dynamic softening processes, processing techniques, thermo-mechanical processing of steel, aluminium, magnesium, titanium and advanced alloy systems
MS4080	**CRYSTALLOGRAPHIC TEXTURE**
Credits: 1 *Semester:* *Segment:*	Description of orientation, representation of texture, measurement of texture, Texture of FCC, BCC and HCP materials

MS4090	**WEAR AND TRIBOLOGY**
Credits: 1 *Semester:* *Segment:*	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, wears resistance materials.
MS4100	**SUPRAMOLECULAR MATERIALS**
Credits: 1 *Semester:* *Segment:*	Study of natural materials existing in different environmental conditions such as wood, bone and glass sponge - understanding of their structure, property and synthesis, Supramolecular organisation in natural fibres (cellulose, silk, collagen) and biological macromolecules (DNA)-molecular interactions (driving force for supramolecular assembly), structural properties. Implementation in material synthesis for applications
MS4110	**ANTIFOULING AND HEALTH CARE MATERIALS**
Credits: 1 *Semester:* *Segment:*	Introduction to the interactions between cells and the surfaces of biomaterials. Surface chemistry and physics of selected metals, polymers, and ceramics; surface characterization methodology; modification of biomaterials surfaces; Introduction to materials in biosensors and microarrays, implants, drug delivery, and tissue engineering.
MS4120	**PHONONS IN SOLIDS**
Credits: 1 *Semester:* *Segment:*	Phonons - specific heat capacity - Free electron model, Einstein and Debye theory - Phonon dispersion in solids - Thermal conductivity - Thermal expansion - Thermoelectric solids - electron phonon scattering - soft and hard phonons - solid state spectroscopic techniques
MS4130	**LIQUID CRYSTALS**
Credits: 1 *Semester:* *Segment:*	What are Liquid crystals, types of liquid crystals, theories of formation, properties of liquid crystals, phase transitions - temp driven and concentration driven, characterisation of liquid crystals - DSC, POM, SAXS, common applications and processing
MS4150	**COMPOSITES**
Credits: 2 *Semester:* *Segment:*	Introduction, classification of composites, strengthening mechanism in composite, types of reinforcements, production methods for reinforcements, metal matrix composites, carbon-carbon composites, ceramic matrix composites, polymer matrix composites, interfaces and interphases, properties.
MS4160	**ENERGY MATERIALS**
Credits: 2 *Semester:* *Segment:*	Green energy resources: Introduction to non- conventional energy resources- Overview of solar cells, battery and fuel cell technology. Materials properties, challenges and current developments in each category
MS4180	**SEMICONDUCTORS AND DEVICES**
Credits: 2 *Semester:* *Segment:*	Junction formation - Electronic transport in junctions - Excitons - pn diode - Band structure under biased conditions - solar cells - diode lasers - LED - Photodiodes - Quantum heterostructures - Quantum tunnelling - Tunnel diodes - Resonant Tunnel Diodes - Coloumb blockade conduction - Quantum cascade lasers - MOS capacitors - Silicon and its applications - Conversion of indirect to direct band gap semiconductors - Quantum dots - opto-electronic devices
MS4097	**WEAR AND TRIBOLOGY**
Credits: 1 *Semester:* *Segment:*	Introduction to tribological 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, wears resistance materials.
MS5210	**HIERARCHICAL NANOSTRUCTURED MATERIALS**
Credits: 1 *Semester:* *Segment:*	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**
Credits: 2 *Semester:* *Segment:* *Pre-Req: MS5210*	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
MS5200	**PHASE TRANSFORMATIONS**
Credits: 3 *Semester:* *Segment:*	Phase stability and free energy of mixing; free energy-composition diagrams and phase diagrams; defects and diffusion; nucleation and growth; liquid-solid, precipitation, disorder-order, spinodal and martensitic phase transformations.
MS5170	**THERMODYNAMICS AND KINETICS OF MATERIALS**
Credits: *Semester:* *Segment:*	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.
MS5190	**SOFT MATERIALS**
Credits: 3 *Semester:* *Segment:*	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
MS 5140	**INTRODUCTION TO COMPUTATIONAL METHODS IN MATERIALS SCIENCE**
Credits: 3 *Semester:* *Segment:*	Basic concepts of modeling and simulation in materials science and engineering - why do we need to model across length scales; concepts of transport phenomena - conservation and continuity equations; constitutive equations describing behavior of materials; introduction to ordinary and partial differential equations - initial and boundary conditions; numerical methods - finite difference method, finite element method, spectral method for periodic boundary conditions; description of materials properties and phenomena using vector and tensor representations; introduction to mesoscale methods - phase-field model, continuum crystal plasticity; introduction to atomistic simulations - molecular dynamics, Monte Carlo methods; application of quantum physics - electronic structure calculations. The course uses open source computational tools and MATLAB programs to demonstrate the fundamentals and applications of the computational methods to key technological problems.
MS 5160	**POLYMER SCIENCE AND ENGINEERING**
Credits: 3 *Semester:* *Segment:*	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
	NATURE INSPIRED MATERIALS ENGINEERING FOR MECHANICAL APPLICATION
Credits: 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

Semester: *Segment:* *Pre-Req: MS5120*	materials and their synthesis for actuation properties like muscle, selection and design of materials for regenerative medicine

	NATURE INSPIRED MATERIALS ENGINEERING FOR WETTABILITY, OPTICAL TUNABILITY
Credits: 1 *Semester:* *Segment:* *Pre-Req: MS5120*	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)

MATHEMATICS

MA1110	**ELEMENTS OF BASIC CALCULUS-I**
Credits: 1 *Semester: Jul* *Segment: 12*	Sequences and Series: Limit of a sequence, monotone and Cauchy sequences and properties of convergent sequences, examples. Infinite series, positive series, tests for convergence and divergence, integral test, alternating series, Leibnitz test. Differential Calculus: Continuity and differentiability of a function of single variable, statement of Rolle's Theorem, Lagrange's mean value theorem and applications.

MA1140	**LINEAR ALGEBRA**
Credits: 1 *Semester: Jan* *Segment: 34*	Vector spaces, Subspaces, basis and dimension, linear transformations, representation of transformations by Matrices, linear functionals, transpose of linear transformations, canonical forms. Linear functionals and adjoints, Bilinear forms, symmetric bilinear forms, skew symmetric bilinear forms.

MA1150	**DIFFERENTIAL EQUATIONS**
Credits: 1 *Semester: Jan* *Segment: 56* *Pre-Req: MA1110, MA1140*	Ordinary Differential Equations: First order linear equations, Bernoulli's equations, Exact equations and integrating factor, Higher order linear, differential equations with constant coefficients. Partial Differential Equations: First order linear PDE, quasi linear PDE, method of characteristics, Cauchy problem, first order nonlinear PDE's of special type.

MA1220	**ELEMENTS OF BASIC CALCULUS-II**
Credits: 2 *Semester: Odd* *Segment: 36* *Pre-Req: MA1110*	Integral Calculus: Definite Integrals as a limit of sums, Applications of integration to area, volume, surface area, Improper integrals. Functions of several variables: Continuity and differentiability, mixed partial derivatives, local maxima and minima for function of two variables, Lagrange multipliers. Functional Series: Pointwise and uniform convergence, basic aspects of Power series, Fourier series.

MA2110	**INTRODUCTION TO PROBABILITY**
Credits: 1 *Semester: Jul* *Segment: 12* *Pre-Req: MA1110*	Sample space and events, definitions of probability, properties of probability, conditional probability. Random variables: distribution functions, discrete and continuous random variables, moments of random variables, conditional expecta*tion*, Chebyshev inequality, functions of random variables. Special Distributions: Bernoulli, Binomial, Geometric, Pascal, Poisson, Exponential, Uniform, Normal distributions, Limit Theorems: Law of large numbers.

MA2120	**TRANSFORM TECHNIQUES**
Credits: 1 *Semester: Jul* *Segment: 34* *Pre-Req: MA1110*	Laplace and Inverse Laplace transform, linearity, Laplace transforms of Derivatives and Integrals, partial fractions, unit step function, shifting on the t-axis, periodic functions, applications of Laplace transform for solving differential equations. Fourier integral, Fourier Sine and Cosine transform, convolution, applications of Fourier transform for solving differential equations.

MA2140	**INTRODUCTION TO STATISTICS**
Credits: 1 *Semester: Jan* *Segment: 34* *Pre-Req: MA2110*	Random sampling, Estimation of parameters, Confidence Intervals, Testing of Hypothesis, Goodness of fit, Nonparametric tests, Correlation Analysis.

MA1130	**VECTOR CALCULUS**
Credits: 1 *Semester: Jan* *Segment: 12* *Pre-Req: MA1110*	Double and Triple Integrals: Calculations, Areas, Volumes, change of variables, Applications. Integrals of Vector Functions: Line integrals, Green's formula, path independence, Surface integral: definition, evaluation, Stoke's formula, Gauss-Ostrogradsky divergence theorem.

MA2130 **COMPLEX VARIABLES**

Credits: 1
Semester: Jan
Segment: 12
Pre-Req: MA1110

Complex Functions limits, Continuity, Differentiability, analytic functions, Cauchy -Riemann equations, Laplace equations, Harmonic functions, conformal mapping, Cauchy integral theorem, Cauchy integral formula, derivations of an analytic function,Power series, Taylor series, Laurent series, zeros, singularities, residues, evaluation of real integrals.

MA4010 **ANALYSIS OF FUNCTIONS OF A SINGLE VARIABLE**

Credits: 3
Semester: Jul
Pre-Req: MA1110

- Real number system: Field properties, ordered properties, completeness axiom, Archimedean property, subsets of 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 & compactness, Continuity and connectedness, Monotonic functions, Limit at infinity.
- Differentiation, Properties of derivatives, Chain rule, Rolle's theorem, Mean-value theorems, L'Hospital's rule, Derivatives of higher order, Taylor's theorem.
- Definition and existence of Riemann integral, properties, Differentiation and integration.
- Revision of Series, Sequences and Series of functions, Pointwise and uniform convergence, Uniform convergence of continuous functions, Uniform convergence and differentiability, Equicontinuity, Pointwise and uniform boundedness, Ascoli's theorem, Weierstrass approximation theorem, Fourier series.

MA4020 **LINEAR ALGEBRA**

Credits: 3
Semester: Jul

- System of Linear Equations, Elementary Operations, Row-Reduced Echelon Matrices, Gaussian Elimination.
- Vector Spaces, Subspaces, Direct Sums, Bases and Dimension, Linear Maps, Rank-Nullity Theorem, The Matrix of a Linear Map, Invertibility.
- Eigenvalues and Eigenvectors, Invariant Subspaces, Upper-Triangular Matrices, Diagonal Matrices.
- Inner Products, Norms, Orthonormal Bases, Gram-Schmidt process, Schur's theorem, Orthogonal Projections and Minimization Problems, Linear Functionals and Adjoints.
- Self-Adjoint and Normal Operators, The Spectral Theorem for finite dimensional operators.
- Generalized Eigenvectors, The Characteristic Polynomial, Cayley-Hamilton Theorem, The Minimal Polynomial, Jordan Form.

MA4030 **ORDINARY DIFFERENTIAL EQUATIONS**

Credits: 3
Semester: Jul
Pre-Req:

- Mathematical Models, Review of methods, First Order Equations, Existence, Uniqueness and continuity theorems, separation and comparison theorems. Higher order equations, Solutions in Power Series, Legendre equation, Bessel equation, generating functions, orthogonal properties,
- System of differential equations, existence theorems, Homogeneous linear systems, Nonhomogeneous linear systems, linear systems with constant coefficients.
- Two point boundary value problem, Green's functions, construction of Green's functions, Sturm-Liouville problems, Eigen values and Eigen functions.
- Autonomous systems, Stability of linear systems with constant coefficients, Linear plane autonomous systems.

MA4040 **PROBABILITY THEORY**

Credits: 3
Semester: Jul
Pre-Req:

- 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 **BASICS OF PROGRAMMING**

Credits: 3
Semester: Jul

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

MA4060 **COMPLEX ANALYSIS**

Credits: 3
Semester: Jan

- 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 **ELEMENTS OF GROUPS AND RINGS**

Credits: 3
Semester: Jan

- 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 **PARTIAL DIFFERENTIAL EQUATIONS**

Credits: 3
Semester: Jan
Pre-Req: *MA4030, MA5010*

First order partial differential equations: Surfaces and Curves, Classification of 1st order p.d.e. Classification of solutions-Pfaffian differential equations - Quasi-linear equations, Lagrange's method-compatible systems-Charpit's method- Jacobi's method-Integral surfaces passing through a given curve- method of characteristics for quasi-linear and non-linear p.d.e., Monge cone, characteristic strip.

Second order partial differential equations: Origin of second order p.d.e's - classification of second order p.d.e's. Wave equation - D'Alemberts' solution - vibrations of a finite string - existence and uniqueness of solution - Riemann method. Laplace equation - boundary value problems, Uniqueness and continuity theorems - Dirichlet problem for a circle - Dirichlet problem for a circular annulus - Neumann problem for a circle - Theory of Green's function for Laplace equation. Heat equation - Heat conduction problem for an infinite rod - Heat conduction in a finite rod - existence and uniqueness of the solution.

MA4090 **ANALYSIS OF FUNCTIONS OF SEVERAL VARIABLES**

Credits: 3
Semester: Jan
Pre-Req: ***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.

MA5010 **COMBINATORICS AND GRAPH THEORY**

Credits: 3
Semester: Jul

- Basic counting: Bijections, Counting objects with repetitions, de Bruijn-Erdos theorem, Listing combinatorial objects.
- 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 **FUNCTIONAL ANALYSIS**

Credits: 3
Semester: Jul
Pre-Req: *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 **MEASURE AND INTEGRATION**

Credits: 3
Semester: Jul
Pre-Req: 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.
- Lp spaces, duals of Lp spaces. Riesz Representation Theorem for C([a,b]).

MA5040 **TOPOLOGY**

Credits: 3
Semester: Jan

- 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 **MATHEMATICAL METHODS**

Credits: 3
Semester:

- 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.

MA5060 **NUMERICAL ANALYSIS**

Credits: 1
Semester: Jul
Segment: 12

- 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 **MODULES AND FIELDS**

Credits: 3
Semester:

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 **ADVANCED PROGRAMMING**

Credits: 3
Semester:

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 **SETS, LOGICS AND BOOLEAN ALGEBRA**

Credits: 3
Semester:

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 **INTRODUCTION TO ALGEBRAIC TOPOLOGY**

Credits: 3
Semester:
Pre-Req: 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	FOURIER ANALYSIS AND APPLICATIONS
Credits: 3 *Semester:* *Pre-Req: 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	NUMERICAL LINEAR ALGEBRA
Credits: 3 *Semester:* *Pre-Req: 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	THEORY OF COMPUTATION
Credits: 3 *Semester:*	• 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	MATHEMATICAL INTRODUCTION TO ELLIPTIC CURVES
Credits: 3 *Semester:* *Pre-Req: 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.

MA5150	ALGEBRAIC NUMBER THEORY
Credits: 3 *Semester:* *Pre-Req: 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	AN INTRODUCTION TO MODULAR FORMS
Credits: 3 *Semester:* *Pre-Req: 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	BASIC INTRODUCTION TO ALGEBRAIC GEOMETRY
Credits: 3 *Semester:* *Pre-Req: 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 **ADVANCED MEASURE THEORY**

Credits: 3
Semester:
Pre-Req: *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 C0(X), the space of all complex valued continuous functions vanishing at infinity on a locally compact Hausdorff X.
- A revision on the spaces Lp(\mu) for a \sigma finite measure \mu. Dual of Lp(\mu). Dense subclasses of Lp(\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 **ADVANCED PARTIAL DIFFERENTIAL EQUATIONS**

Credits: 3
Semester:
Pre-Req: *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.

MA6040 **FUZZY LOGIC CONNECTIVES AND THEIR APPLICATIONS**

Credits: 3
Semester:

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 **WAVELETS AND APPLICATIONS**

Credits: 3
Semester:

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

MA6060 **REDUNDANT AND SPARSE REPRESENTATION THEORY**

Credits: 3
Semester:

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 **APPROXIMATION THEORY**

Credits: 3
Semester:

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 **MEASURE THEORETIC PROBABILITY**

Credits: 3
Semester:

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 **OPERATOR THEORY**

Credits:
Semester:

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 **MATHEMATICS *B*EHIND MACHINE LEARNING**

Credits: 3
Semester:

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 **CONVEX FUNCTIONS AND THEIR APPLICATIONS**

Credits: 3
Semester:

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.

MA6120 **AN INTRODUCTION TO OPERATOR ALGEBRAS**

Credits: 3
Semester:

Banach Algebras: Banach Algebras & invertible group; spectrum; multiplicative linear functionals; Gelfand transform & 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 L_α functional Calculus; equivalence projections; Type decompositions

MA6130 **BANACH SPACE THEORY**

Credits: 3
Semester:

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

MA6140 **COMPRESSIVE SENSING**

Credits:
Semester:

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 **DISCRETE DYNAMICAL SYSTEMS**

Credits: 3
Semester:
Pre-Req: 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	BANACH ALGEBRAS
Credits: 3 *Semester:* *Pre-Req: MA4010, MA4020, MA4060, MA5020, MA5040*	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.

MA6190	TRANSCENDENTAL NUMBER THEORY
Credits: 3 *Semester:* *Pre-Req: 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 ζ(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.

MA6010	TOPICS IN ANALYSIS
Credits: 3 *Semester:*	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	TOPICS IN ALGEBRA
Credits: 3 *Semester:*	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.

MA6170	TOPICS IN DIFFERENTIAL EQUATIONS
Credits: 3 *Semester:*	• 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	TOPICS IN COMPUTATIONAL MATHEMATICS
Credits: 3 *Semester:*	• 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.

Mechanical & Aerospace Engineering

AE3010	INTRODUCTION TO AEROSPACE VEHICLES
Credits: 1.5	• History of Aviation • Pre Wright brothers, up to World War II, post World War II, space age • Key people in the history of aerospace engineering and their contribution • Classification of aerospace vehicles and their characteristics • Civilian aircrafts, military aircrafts, fighters, bombers, reconnaissance • AWACS, helicopters, gliders, launch vehicles, satellites, UAVs • Missiles: SAM, AAM, anti-tank, cruise missiles, strategic missiles • Key aerospace companies in the current scenario • Future of Aerospace vehicles

AE3020	AERODYNAMICS
Credits: 3 *Pre-Req: ID1100, ID1140, AE3010*	• Inviscid aerodynamics • Subsonic, transonic, and supersonic airfoil theory • Wing theory • Introduction to compressible flow • Normal and oblique shock waves • Prandtl-Meyer expansions • Linearized compressible flow • Hypersonic aerodynamics • Computational aerodynamics methods

AE3030	FLIGHT MECHANICS
Credits: 1.5	• Introduction to flight instruments and earth's atmosphere • Characteristics of aerospace vehicles • Case study of some of the popular aerospace vehicles • Basic aerodynamics, generation of lift/drag. Airfoils & finite wings. Elements of aircraft performance & atmospheric flight mechanics. Introduction to aircraft design, stability & control.

AE3040	AEROSPACE STRUCTURES
Credits: 3 *Pre-Req: ID1160, ID2020, AE3010*	• Basic equations of linear elasticity: Concept of stress and strain, Constitutive behavior of materials, Two-dimensional problems in elasticity. • Aircraft structures and materials: Basic structural elements in aircraft structure, Loads on the aircraft, Aircraft materials • Beams and thin walled structures: Three-dimensional beam theory, Torsion of bars with arbitrary cross-section, Bending of thin walled beams, Shear center, Torsion of thin walled beams, Warping of thin walled beams. • Plates: Kirchhoff plate theory, Bending and buckling of plates • Introduction to Aeroelasticity: Wing divergence and flutter calculations.

AE3050	AIRCRAFT PROPULSION
Credits: 1.5 *Pre-Req: ID1140, AE3010*	• Basic one-dimensional flows: isentropic area change, heat addition • Overall performance characteristics of propellers, ramjets, turbojets, turbofans, rockets • Performance analysis of inlets, exhaust nozzles, compressors, burners, and turbines

AE3070	ROCKET PROPULSION
Credits: 1.5 *Pre-Req: ID1140, AE3010*	• Rocket flight performance, • Single-/multi-stage chemical rockets, • Solid propellants • Liquid propellants • Cryogenic engines

- Advanced propulsion concepts

ME1010	**MANUFACTURING TECHNOLOGY**
Credits: 1 *Semester: Jul* *Segment: 56*	Introduction to Product Design, Introduction to manufacturing, Evolution of manufacturing. Engineering Materials and their selection, Classification of Manufacturing Processes: Formative Processes (Molding Processes, Deformation Processes), Additive Processes (Joining and Rapid Prototyping Processes), Removal Processes (machining, non-conventional), Introduction to Measurements, Machine Tools and Data Communication, Importance of Integrated Design and Manufacturing.

ME1030	**DYNAMICS**
Credits: 2 *Semester: Jan* *Segment: 46* *Pre-Req: ID1130*	Kinematics of particles - Rectilinear motion of particles, curvilinear motion of particles, Kinematics of rigid bodies, Kinetics of particles, system of particles, plan motion of rigid bodies, energy and momentum methods, kinetics of rigid bodies in three dimensions, and introduction to mechanical vibrations.

ME2030	**MANUFACTURING SCIENCE -I**
Credits: 2 *Semester: Jan* *Segment: 36* *Pre-Req: ME1010*	Introduction to Manufacturing and its evolution, Net and near-net shape manufacturing; Metal Casting: Solidification of Alloys and its mechanism, Gating System Design and Estimation of Solidification time, Riser Design and Riser Placement, Process Variations, Defects and Product Design; Metal Forming: Mechanism of plastic deformation, fundamentals of plasticity, Introduction to Force equilibrium method, State of Stress and boundary conditions in Upsetting/forging, Rolling, Wire and tube drawing, Extrusion and Deep Drawing, Defects, Load estimation for one plane strain and one axi-symmetric bulk deformation processes, Analysis of Deep Drawing and Bending, Introduction to High velocity forming processes; Powder Processing (Metals and Ceramics), Polymer Part Manufacturing, Introduction and properties of polymer melts and Visco-elasticity, Processing of Thermoplastics (Extrusion, Injection Molding, Blow Molding, Rotational Molding) and Thermosets (compression and transfer molding), Tool and product design principles; Rapid Manufacturing: Need for RP/RT/RM, Introduction to Processes for Prototyping, Tooling and Manufacturing; Joining and Welding: Introduction, Solid State and Fusion Joining, Brazing and Soldering, Mechanical and Adhesive Joining, Metal and nonmetal joining; Metrology: Tolerancing (Dimensional and Geometric) principles and their measurements (Geometrical tolerances using point data), Interferometry - principles, flatness testing using optical flat, optical interferometers, Moire fringe system measurements.

ME2040	**INSTRUMENTATION**
Credits: 1.5 *Semester: Jan* *Segment: 46*	Introduction to measurements, various principles of measurements, errors in measurement, basic statistics, calibration procedures, displacement measurement, measurement of temperature, measurement of pressure, measurement of fluid flow, obstruction meters, measurement of fluid velocities, thermal anemometry, strain gauges, measurement of force, torque and power, load cells, torque cells, dynamometers, vibration measurement, velocity and acceleration measurement.

ME2080	**INTRODUCTION TO MATHEMATICAL MODELLING**
Credits: 1 *Semester: Jan* *Segment: 12* *Pre-Req: MA1110, MA1220, MA1130, MA1140, MA1150*	Introduction to mathematical modelling, introduction to symbolic and numerical computation, degrees of freedom, modelling in dependent and independent coordinates, lagrange equations, and numerical solution of mathematical models.

ME2090	**KINEMATICS OF MECHANISMS**
Credits: 2 *Semester: Jan* *Segment: 13* *Pre-Req: ID1130, ME1030*	

ME2100	DYNAMICS OF MECHANISMS
Credits: 2 *Semester: Jan* *Segment: 46* *Pre-Req: ID1130, ME1030*	Dynamics of rigid body in a plane; static and dynamic force analysis of machines; balancing of rotating masses; balancing of reciprocating masses - single and multi-cylinder engines; turning moment diagram, flywheel analysis; free and forced vibration of single degree of freedom systems - resonance, vibration isolation

ME2421	SOLID MECHANICS LAB
Credits: 1 *Semester: Jan* *Segment: 13* *Pre-Req: ID2020*	Solid Mechanics: Torsion testing, UTM-tensile testing, thin cylinder behavior, buckling of struts, deflection of beams, spring stiffness, impact testing and hardness testing.

ME2431	FLUID MECHANICS LAB
Credits: 1 *Semester: Jan* *Segment: 46* *Pre-Req: ID1100*	Fluid Mechanics: Measurement of fluid properties: density, specific gravity and viscosity, surface tension; Measurement of pressure: Manometers, Bourdon pressure gauge; Measurement of discharge coefficient: Venturi meter, Orifice meter, Rota meter and V/Rectangular notches; Friction loss coefficients in pipe flows: Impact of water jet and stability of floating bodies; channel flow.

ME3010	MANUFACTURING SCIENCE - II
Credits: 2 *Semester: Jul* *Segment: 14* *Pre-Req: ME1010*	Conventional Removal and Finishing Processes: Importance of Material Removal and allied processes, classification; Chip Formation; Types of Chips; Tool Specification: Coordinate and Orthogonal Systems; Mechanics of Metal Cutting: Merchant's Circle Diagram, Stress, Strain and Strain Rate, determination of Shear Plane Angle; Tool Wear and Tool Life; Variables affecting Tool Life; Practical Machining Operations: Turning, drilling, milling; Finishing Operations: Grinding (MRR estimation, Wheel Specifications, Wheel Wear) and other processes; Economics of machining: Minimum Production Cost Criterion, Maximum Production Rate and Maximum Profit Rate Criteria; Unconventional Removal and Finishing Processes: Abrasive Jet Machining, Ultrasonic Machining; Electro Discharge Machining; Abrasive Jet Machining; Electron Beam Machining; Laser Beam Machining, Finishing processes (AFM and other variants); Micro-Manufacturing and Scaling Laws: Miniaturization and its importance, Micro-Manufacturing Processes (Additive, formative and Removal), Scaling laws with emphasis on micro-Manufacturing.

ME3050	COMPUTER INTEGRATED MANUFACTURING
Credits: 1.5 *Semester: Jul* *Segment: 46*	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 & reverse engineering, manufacturing process simulation, virtual & distributed manufacturing, computer integrated manufacturing.

ME3060	EXPERIMENTAL TESTING TECHNIQUES
Credits: 1 *Semester: Jan* *Segment: 56* *Pre-Req: ID1100, ID1160*	Basics of statistics. Determining the sample size, hypothesis testing and confidence intervals. Design of experiments, curve fitting and regression analysis, error analysis, practical aspects to documenting, interpreting and reporting experimental data. Data Acquisition and Processing. Data interpretation using graphical tools. Case studies.

ME3070	POWER AND REFRIGERATION SYSTEM
Credits: 1.5 *Semester: Jul* *Segment: 13*	*Power and Refrigeration Systems -Gaseous Working Fluids:* The Brayton Cycle, The Simple Gas-Turbine Cycle with a Regenerator, Gas-Turbine Power Cycle Configurations, The Air-Standard Refrigeration Cycle, Reciprocating Engine Power Cycles, Combined-Cycle Power and Refrigeration Systems *Gas Mixtures:* A Simplified Model of a Mixture Involving Gases and a Vapor, the Energy Equation Applied to Gas-Vapor Mixtures, the Adiabatic Saturation Process, Wet-Bulb and Dry-Bulb Temperatures and the Psychrometric Chart

Thermodynamic Relations: The Clapeyron Equation, Mathematical Relations for a Homogeneous Phase, The Maxwell Relations, Thermodynamic Relations Involving Enthalpy, Internal Energy, and Entropy, Volume Expansivity and Isothermal and Adiabatic Compressibility, Real-Gas Behavior and Equations of State, The Generalized Chart for Changes of Enthalpy at Constant Temperature, The Generalized Chart for Changes of Entropy at Constant Temperature, The Property Relation for Mixtures, Pseudo-pure Substance Models for Real Gas Mixtures, Engineering Applications—Thermodynamic Tables

Chemical Reactions: Fuels, The Combustion Process, Enthalpy of Formation, Energy Analysis of Reacting Systems, Enthalpy and Internal Energy of Combustion; Heat of Reaction, Adiabatic Flame Temperature, The Third Law of Thermodynamics and Absolute Entropy, Second-Law Analysis of Reacting Systems, Fuel Cells, Engineering Applications

Introduction to Phase and Chemical Equilibrium: Requirements for Equilibrium, Equilibrium Between Two Phases of a Pure Substance, Metastable Equilibrium, Chemical Equilibrium, Simultaneous Reactions, Coal Gasification, Ionization, Engineering Applications

ME3080 **DESIGN OF MACHINE ELEMENTS**

Credits: 2
Semester: Jul
Segment: 13
Pre-Req: ID2020

Design consideration - limits, fits, tolerances, and standardization, a brief introduction to strength of materials, modes of failure, failure theories, design of springs - helical, compression, tension, torsional and leaf springs, design of joints - threaded fasteners, preloaded bolt joints, welded and glued joints.

ME3090 **DESIGN OF TRANSMISSION ELEMENTS**

Credits: 2
Semester: Jul
Segment: 46
Pre-Req: ID2020

Design of shafts under static and fatigue loading, shaft components. Design and analysis of sliding and rolling contact bearings, analysis and applications of power screws and couplings, analysis of clutches and brakes, design of belt and chain drives, design of spur and helical gears.

ME3100 **MODELING & SIMULATION**

Credits: 2
Semester: Jan
Segment: 14
Pre-Req: ME2080

Introduction to modelling and simulation, introduction to symbolic and numerical computations, degrees of freedom, modelling in dependent and independent coordinates, Lagrange equations, state space formulation, Newton-Raphson method, explicit integrator, implicit integrator, dynamics of constrained mechanical systems as differential algebraic equations, Baumgaurte stabilization, Gauss principle, and inverse problems.

ME3110 **HEAT & MASS TRANSFER**

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: ID1110, ID1150

Introduction - Steady State heat conduction in one-dimensional systems. One dimensional unsteady state conduction; extended surface heat transfer (Fins). Convection: Basic equations, Dimensional analysis, Boundary layers; Forced convection: External and internal flows, correlations, Natural convection and Mixed convection. Design of heat exchangers: LMTD and NTU methods. Radiation heat transfer: Basic laws, Properties of surfaces, view factors, network method and enclosure analysis for gray-diffuse enclosures containing transparent media. Concepts of Mass transfer. Current trends of research in the field of heat transfer.

ME3140 **IC ENGINES**

Credits: 3
Semester: Jan
Segment: 16

Classification, Basic Working Principles, Components and Engine Operating Events of an IC Engine; Engine Operating Parameters: Geometry, Torque, Power and Work; Fuel Consumption and Efficiencies; Thermochemistry for IC Engines: Fuels and Testing; Combustion Reactions; Combustion Efficiencies; Chemical Kinetics and Exhaust Gas Analysis; Engine Cycle Models: Basic Thermodynamic Analysis; Air Standard Cycles; Fuel-Air Standard Cycles; Comparisons to Real Engines Cycles; Intake Flow Considerations: Gas Flow Processes; Valve Design; Fuel Induction Processes for SI and CI Engines; Combustion Chamber Considerations: In-cylinder Aerodynamics; Burning Process for SI and CI Engines; Abnormal combustion in SI Engines (Knock); Pollutant Formation and Control: Emission Measurement; NOx, CO, Unburned Hydrocarbon, Particulates, formation and their control.

ME3150	**APPLIED ELASTICITY**
Credits: 2 *Semester: Jul* *Segment: 14* *Pre-Req: ID2020*	Introductory tensor analysis, various strain measures and stress tensors, Balance laws, constitutive relations (commonly used energy density functions), special cases through simplification (incompressibility, plane stress and strain, hydrostatic loading, isotropy, linear elasticity), problems in Cartesian and other curvilinear coordinates. Introduction to FEM.
ME3413	**MACHINE DRAWING & SOLID MODELLING**
Credits: 2 *Semester: Jan* *Segment: 16* *Pre-Req: ID1041, ID1054*	Principle of drawing. Introduction to machine drawing, production drawing, assembly drawing. Different sectional views. Fits, limits, tolerances and surface finish. Solid modelling of different machine elements. Example, threads, bolts, and nuts, welded and riveted joints, shafts, keys, cotter, and pin joints; couplings and clutches, springs, belts, and pulleys; bearings, gears. Assembly of different components of IC engine.
ME3425	**MINI-PROJECT**
Credits: 3 *Semester: Jan* *Segment: 16*	Objective: To direct students toward the process of designing and development through visualization, planning and manufacturing of a product leading to 'Invention and Innovation'. Deliverables: Visualize, Draw, Build, Improve, Modify, Identify, Suggest. Constituents: Concept, Design (Mechanical, thermal, chemical), Drawing (2D/3D manufacturing details), Manufacturing, Testing, Simulation.
ME3445	**FINITE ELEMENT METHODS LAB**
Credits: 1 *Semester: Jul* *Segment: 13* *Pre-Req: ID2020*	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).
ME3455	**COMPUTATIONAL FLUID DYNAMICS LAB**
Credits: 1 *Semester: Jul* *Segment: 46*	CFD mesh generation techniques, CFD experiments using commercial code - boundary layer flow, convective heat transfer, turbulent mixing and heat transfer, at least one analysis on an advanced topic like multiphase flow, combustion, turbo-machines.
ME3465	**MANUFACTURING LAB**
Credits: 1 *Semester: Jan* *Segment: 13*	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.
ME3475	**IC ENGINES LAB**
Credits: 1 *Semester: Jan* *Segment: 46*	Objective: Experimental exposure to testing performance of IC engines at varying operating conditions. Experiment list: Components of an IC engine - CI and SI types; Testing & performance of IC engines by varying speed, load, compression ratio and other parameters. Study of Valve Timing Diagram.
ME4010	**CONTROL SYSTEMS**
Credits: 1.5 *Semester: Jul* *Segment: 13* *Pre-Req: MA2130*	Concept of control, modeling physical systems, Laplace transforms and transfer function, block diagrams, Routh's stability criterion, transient and steady state response specification, root locus analysis, lead, lag, and lead-lag compensator design through root locus - P, PI, PD, and PID controllers.
ME4020	**TURBO MACHINES**
Credits: 3 *Semester: Jul* *Segment: 16*	Axial and radial flow turbomachines; Basic Principles; Dimensional Analysis; Two-dimensional cascades; Axial flow turbines; Axial flow compressors and ducted fans; Centrifugal pumps, Fans, compressors; Radial flow gas turbines; Hydraulic turbines.

Pre-Req: ID1110, ID1150

ME4030	**OPERATIONS RESEARCH**
Credits: 1 *Semester: Jan* *Segment: 12*	Basics of probability and statistics, Linear Programming and applications, Queuing theory and its applications, forecasting approaches, Monte Carlo simulation procedure (OR). Inventory models discussion (deterministic and probabilistic Models), Newsvendor model, Inventory Planning & Control, Decision support system tools, Economic Order Quantity (EOQ).

ME4040	**INDUSTRIAL ENGINEERING**
Credits: 1 *Semester: Jan* *Segment: 34*	Product Design: Design for Manufacture and Assembly (DFM), Concurrent engineering Work systems design: Work study and classifications, Method study - work measurement, work sampling, Cost Estimation, Calculation of Machining Times, Cost Depreciation, Productivity, Productivity Measurement, Time study, Recording Techniques for Work Study, Information Collection Techniques, Job Evaluation, Ranking system, Incentive Schemes, Individual-Group-Company-wide Bonus Schemes, Behavioural aspects of Incentives Plant layout, Ergonomics, CRAFT, Cellular Manufacturing, Scheduling, Assembly Line Balancing, Future directions in Production.

ME4050	**PRODUCTION PLANNING & CONTROL**
Credits: 1 *Semester: Jan* *Segment: 56*	Quality management and control: Quality Improvement, Cost of Quality, Statistical Process Control, Central Tendency & Dispersion, Control Charts, Acceptance Sampling, New Quality Concepts, Taguchi Methods, Design of Experiments (DoE), Robust Design, Ishikawa Diagram, ISO certification, Kaizen, Zero Defects Program, Total Quality Management (TQM), Six Sigma; Maintenance Management: Preventive and breakdown maintenance approaches, reliability, Work study for Maintenance, Total Productive Maintenance (TPM), Spare Parts Management, Characteristics and classification of Spare parts; Supply Chain design, scheduling, layout design: Materials Requirement Planning (MRP), MRP-II, Enterprise Resource Planning (ERP), Logistic, Distribution and Supply chain Management, Applications of Newsvendor model in supply chains.

ME4435	**DYNAMICS LAB**
Credits: 1 *Semester: Jul* *Segment: 13* *Pre-Req: ME2090, ME2100*	Gear Efficiency Measurement, Planar Mechanism Demonstration, Rotary Balancing, Reciprocating Balancing, Static and Dynamic Analysis of Cam, Whirling of Shaft, Governors, Moment of Inertia Measurement.

ME4445	**HEAT TRANSFER LAB**
Credits: 1 *Semester: Jul* *Segment: 46* *Pre-Req: ME3110*	Heat Transfer: Temperature measurement and calibration; Measurement of thermal conductivity: solids and liquids; Heat exchangers: Concentric tube, shell and tube; Measurement of convective heat transfer coefficient: Free and Forced convection; Measurement of emissivity; Pool boiling and Condensation.

ME5010	**MATHEMATICAL METHODS FOR ENGINEERS**
Credits: 3 *Semester: Jul* *Segment: 16* *Pre-Req: 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 **ELASTICITY & PLASTICITY**

Credits: 1.5
Semester: Jul3
Segment: 1

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 **FLUID MECHANICS & HEAT TRANSFER**

Credits: 1.5
Semester: Jul3
Segment: 1

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 **COMPUTATIONAL FLUID DYNAMICS TOOLS**

Credits: 1.5
Semester: Jan6
Segment: 1

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 **MATERIAL SCIENCE & MATERIAL SELECTION**

Credits: 1.5
Semester:
Segment:

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.

ME5070 **DESIGN FOR MANUFACTURABILITY & ASSEMBLY**

Credits: 1
Semester:
Segment: 46

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.

ME5080 **SCALING LAWS & MULTI-SCALE MANUFACTURING**

Credits: 1.5
Semester: Jul
Segment: 46

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 **MATHEMATICAL ELEMENTS FOR GEOMETRICAL MODELING**

Credits: 1.5
Semester: Jul
Segment: 13

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	**COMPUTER INTEGRATED MANUFACTURING**
Credits: 1.5 *Semester: Jul* *Segment: 46*	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 & reverse engineering, manufacturing process simulation, virtual & distributed manufacturing, computer integrated manufacturing.
ME5110	**ADVANCED MECHANICS OF SOLIDS**
Credits: 3 *Semester:* *Segment:*	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, disk under compression, axisymmetric problems, rotating disk, torsion, Prandtl stress function, membrane analogy, special problems , wedge with boundary tractions, concentrated force on half plane and thermoelasticity.
ME5120	**DYNAMICS AND VIBRATION**
Credits: 3 *Semester: Jul* *Segment: 16*	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	**FINITE ELEMENT METHOD**
Credits: 3 *Semester: Jul* *Segment: 16*	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	**PROCESS MODELING & OPTIMIZATION**
Credits: 1.5 *Semester: Jul* *Segment: 46*	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	**COMPUTATIONAL INTELLIGENCE**
Credits: 1.5 *Semester: Jan* *Segment: 13*	Function approximation and Pattern recognition: Statistical modelling, Neural Network, Fuzzy system and Classification, Principal Component Analysis; Evolutionary computation: Genetic algorithms; Meta-heuristic methods: Simulated annealing, Ant colony optimization, Tabu search; Monte-Carlo simulation, Design and analysis of experiments.
ME5160	**MATERIAL REMOVAL PROCESSES**
Credits: 3 *Semester:* *Segment:*	Conventional and non-conventional machining operation; Machine tools; Cutting Tool: Tool material, Tool geometry, Tool wear; Metal working fluids; Machinability. Mechanics of Machining Operation, Dynamometry in machining operations. Surface Integrity; Precision machining; Machining Economics; Environmentally friendly machining, Machining of difficult to cut materials.
ME5170	**WELDING AND JOINING**
Credits: 3 *Semester:* *Segment:*	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, Arc physics. Parameters in welding and their control, Pre and post weld heat treatment. Welding of Steels, Aluminum alloys, Ceramics, Plastics, Composites, Welding of dissimilar materials; Weldment design for static and fatigue loading, Failure of welds, NDT of welds, Inspection codes, Welding symbols; Welding of pressure vessels, offshore structures and submarine pipelines, heavy structures.

ME5180	METAL FORMING PROCESSES
Credits: 3 *Semester:* *Segment:*	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.

ME5190	MANUFACTURING PROCESSES
Credits: 2 *Semester: Jan* *Segment: 13*	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	ADDITIVE MANUFACTURING
Credits: 1.5 *Semester:* *Segment:*	Overview of Rapid Product Development: Product Development Cycle, virtual prototyping, physical prototyping, Solid Modelling: Data formats, conversion, checking, repairing and transmission. Synergic integration technologies, Part slicing and Build Orientation, Area-filling strategies, applications and limitations of RPM. Classification of RPM processes: Sheet Lamination, Material Extrusion, Photo-polymerization, Powder Bed Fusion, Binder Jetting, Direct Energy Deposition. Popular RPM processes. Selection of rapid prototyping, tooling and manufacturing systems based on product requirements.

ME5210	CAD/CAM
Credits: 3 *Semester:* *Segment:*	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. 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 & reverse engineering, manufacturing process simulation, virtual & distributed manufacturing, computer integrated manufacturing.

ME5220	MATERIAL REMOVAL PROCESSES
Credits: 3 *Semester:* *Segment:*	Conventional and non-conventional machining operation; Machine tools; Cutting Tool: Tool material, Tool geometry, Tool wear; Metal working fluids; Machinability. Mechanics of Machining Operation, Dynamometry in machining operations. Surface Integrity; Precision machining; Machining Economics; Environmentally friendly machining, Machining of difficult to cut materials.

ME5230	DESIGN AND ANALYSIS OF WELDED JOINTS
Credits: 1.5 *Semester: Jan* *Segment: 46*	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	METAL FORMING
Credits: 1.5 *Semester: Jan* *Segment: 13*	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 **DESIGN FOR MANUFACTURABILITY & ASSEMBLY**

Credits: 1.5
Semester: Jan
Segment: 46

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 **CONTINUUM MECHANICS**

Credits: 3
Semester: Jan
Segment: 16

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 $\sigma=g(n)$. Hyperelasticity and energy-density function. Material symmetry and various symmetry groups. Invariance on change of observer. Special consequences of isotropy.

ME5270 **INTERFACIAL PHENOMENON**

Credits: 3
Semester: Jan
Segment: 16

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 **HYPERSONIC AND HIGH TEMPERATURE AERODYNAMICS**

Credits: 3
Semester:
Segment:

ME5290 **STABILITY OF TIME DELAYED SYSTEMS**

Credits: 1
Semester:
Segment:
Pre-Req:

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 **VARIATIONAL METHODS IN MECHANICS**

Credits: 2
Semester:
Segment:
Pre-Req:

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 **INCOMPRESSIBLE FLUID FLOW**

Credits: 3
Semester: Jul

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 & Parabolic equations; boundary

Segment: 16

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 ADVANCED HEAT TRANSFER

Credits: 3
Semester: Jul
Segment: 16
Pre-Req: 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 COMPUTATIONAL FLUID DYNAMICS

Credits: 3
Semester: Jul
Segment: 16

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; 1^{st} 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, 2^{nd} 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 IC ENGINE COMBUSTION AND POLLUTION

Credits: 3
Semester: Jul
Segment: 16

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 INTRODUCTION TO HYDRODYNAMIC STABILITY

Credits: 1.5
Semester:
Segment:

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 PLANAR MULTIBODY DYNAMICS

Credits: 1.5
Semester: Jan
Segment:
Pre-Req:

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	**IMPACT MECHANICS**
Credits: 2 *Semester:* *Segment:* *Pre-Req: ME3150 or ME5110 or ME5020*	Propagation of 1D stress pulse, coaxial collision of bars, reflection and superposition, review of continuum mechanics, dilatational and shear waves, Rayleigh and Lamb waves, longitudinal, torsional and flexural vibrations of rods, Pochhammer equations for cylindrical bars, design of a split hopkinson bar for high strain rate characterization, propagation of 1D stress pulse in elasto-plastic material, Taylor impact test, one dimensional impact on metal foams, plastic deformation of beams subjected to impact.
ME5411	**DESIGN ENGINEERING CORE LAB I**
Credits: 2 *Semester:* *Segment:*	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). 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.
ME5421	**FEM LAB**
Credits: 1 *Semester: Jul* *Segment: 46*	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	**INTEGRATED DESIGN & MANUFACTURING LAB**
Credits: 2 *Semester: Jan* *Segment:*	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	**CFD LAB**
Credits: 1 *Semester:* *Segment:*	Mesh generation techniques, experiment using commercial CFD solver - turbulent mixing and heat transfer, external flow, combustion, two-phase flow, turbo-machines.
ME5451	**COMPUTATIONAL MATHEMATICS LAB**
Credits: 1 *Semester: Jul* *Segment: 13*	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.
ME5471	**THERMO-FLUID ENGINEERING CORE LAB I**
Credits: 2 *Semester: Jan* *Segment:*	Mesh generation techniques, experiment using commercial CFD solver - turbulent mixing and heat transfer, external flow, combustion, two-phase flow, turbo-machines
ME5610	**FRACTURE MECHANICS**
Credits: 3 *Semester: Jan* *Segment: 16*	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	**MECHATRONIC SYSTEMS**
Credits: 3 *Semester:* *Segment:*	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	**NONLINEAR OSCILLATION**
Credits: 3 *Semester:* *Segment:*	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	**MULTIBODY DYNAMICS**
Credits: 3 *Semester:* *Segment:*	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	**ENGINEERING NOISE CONTROL**
Credits: 3 *Semester:* *Segment:*	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	**APPLIED MICRO AND NANOMECHANICS IN ENGINEERING**
Credits: 3 *Semester:* *Segment:*	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	**VEHICLE DYNAMICS AND MODELING**
Credits: 3 *Semester:* *Segment:*	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	**FATIGUE AND DAMAGE TOLERANCE EVALUATION**
Credits: 0.5 *Semester:*	Introduction - Structural materials - metallic alloys - polymer composites - mechanical properties. Fatigue - Fracture mechanics-Damage tolerance-Stress intensity factor- Strain energy release rate. Failure mechanisms - Metallic alloys: defects- dislocations- ductile and brittle failures, elastic and

Segment: plastic deformation: Composites: damage modes - matrix cracks - disband - fiber fracture - delamination. Mechanical testing and evaluation - Metallic materials: Tension, Fracture toughness, LCF, HCF, FCGR - ASTM standards - data acquisition and analysis: Composites: Tension, compression, ILSS, Flexure, Fatigue, delamination fracture, spectrum fatigue, ASTM standards, design allowables.
Fatigue of materials - Metallic alloys: Basquin's law, Coffin -Manson relation, fatigue crack growth rate, crack closure: Composites: Total fatigue life, delamination onset and growth behavior, stiffness and strength. Fatigue Life prediction and DTE - Life prediction methods under constant amplitude, Block and spectrum loads Metallic alloys:, Crack closure approach, SIF approach: Composites:, Concept of Constant life diagram, Damage tolerance evaluation: aircraft industry requirements.

ME5690 ADVANCED FEM

Credits: 3
Semester:
Segment:
Pre-Req: 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 ANALYSIS AND DESIGN OF COMPOSITE STRUCTURES

Credits: 3
Semester:
Segment:

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.

ME5710 CNC & PART PROGRAMMING

Credits: 3
Semester:
Segment:

Introduction: NC/CNC, CNC machines, Industrial applications of CNC, economic benefits of CNC. CNC Machine Tools: Classification of machine tools, CNC machines tool design, control systems. Position control velocity control and machine tool control, Interpolation and electronics. Data Input: Punched tape, manual data input, tape punch, reader error checking. CNC tooling: Qualified and pre-set tooling, tooling systems, tool setting, automatic tool changers, work holding and setting. Programming: Part programming language, programming procedures, proving part programmes, computer aided part programming. Advances: Advances in CNC programming, integration with CAD, material handling in CNC machines, manufacturing systems.

ME5720 ADVANCED MATERIAL JOINING PROCESSES

Credits: 3
Semester:
Segment:

Modern welding process: GMAW (Robotic, CMT, and STT), Micro plasma welding, EBW, LBW, Diffusion bonding, Ultrasonic welding, Pulsed current welding, Friction stir welding, Magnetic Pulse welding. Analysis of heat sources for material joining, 2D, 3D heat flow in welds, residual stress analysis, Arc physics. Parameters in welding and their control, Pre and post weld heat treatment. Welding of Steels, Aluminum alloys, Ceramics, Plastics, Composites, Welding of dissimilar materials.

ME5730 RAPID PROTOTYPING & MANUFACTURING

Credits: 3
Semester:
Segment:

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

ME5740 PLASTICITY AND METAL FORMING

Credits: 3
Semester:
Segment:

Plasticity - Plastic Behaviour of Metals: Introduction, Flow curve and Mechanism of Plastic Deformation, Introduction to Metal Forming; Stress: Introduction, Invariants, Deviatoric stress and equilibrium equations; Strain: Introduction, Compatibility, Strain Invariants and Deviatoric Tensor; Stress and Strain Relations; Yield and Flow: Yield Condition, Isotropic Yield Criterion (von-Mises, Tresca and Hill), Experimental Verification of Yield Criteria, Anisotropy and Anisotropic Yield

Criteria; Plastic Instability; Brief outline of Slip-line Field Theory; Limit Analysis: Lower and Upper Bound Techniques 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 and Micro-Forming; Analysis of Forming Processes including defects using Finite Element Analysis.

ME5810 **ADVANCED COMPUTATIONAL FLUID DYNAMICS**

Credits: 3
Semester: Jan
Segment: 16

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 **TURBULENCE**

Credits: 3
Semester: Jan
Segment: 16

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 **COMPRESSIBLE FLOW AND ITS COMPUTATION**

Credits: 3
Semester: Jan
Segment: 16

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 **INTRODUCTION TO OPEN CFD**

Credits: 1
Semester:
Segment:

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 **INTRODUCTION TO MOLECULAR SOLVERS**

Credits: 1
Semester:
Segment:

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 **INTRODUCTION TO COMBUSTION & REACTOR MODELS**

Credits: 1
Semester: Jan

Combustion background; 1st and 2nd law of thermodynamics applied to chemical reaction, Gibbs free Energy, equilibrium temperature & composition; Arrhenius law, reaction rate for single step

Segment: 12 and multistep reactions; PSR, PFR, const. pressure & const. volume reactor models and their applications to simulate practical combustion systems.

ME5870 CHEMICAL KINETICS & MODELING IN REACTING FLOWS

Credits: 2
Semester: Jan
Segment: 36

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

ME5880 COMBUSTION AND FLOW DIAGNOSTICS

Credits: 3
Semester:
Segment:

Detailed review of optical diagnostic techniques - PIV, PLIF, CARS, Raman & Rayleigh scattering, interferometry, schlieren & shadowgraph; experimental applications to flow field diagnostics; liquid fuel spray atomization characterization, combustion & pollutant formation; optical measurements in direct injected diesel & 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 DESIGN ENGINEERING CORE LAB II

Credits: 2
Semester: Jan
Segment: 16

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 THERMO-FLUID ENGINEERING CORE LAB II

Credits: 2
Semester: Jul
Segment: 16

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 MECHANICS OF COMPOSITE MATERIALS

Credits: 2
Semester:
Segment:
Pre-Req: 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 THEORY OF DISLOCATIONS

Credits: 2
Semester:
Segment:

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	SEMINAR
Credits: 2 *Semester: Jul* *Segment: 16*	Thesis writing, research paper writing, delivering technical seminars, group discussion, technical interview, text processing using LaTeX.

ME7100	ADVANCED TOPICS IN MATHEMATICAL TOOLS
Credits: 3 *Semester: Jan* *Segment: 16* *Pre-Req: 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	INTRODUCTION TO IMPACT MECHANICS
Credits: 1 *Semester:* *Segment:*	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.

PHYSICS

PH1017	**CLASSICAL PHYSICS**
Credits: 1 *Semester:* *Segment:*	Brief introduction to Newtonian mechanics, Constraints, Generalized coordinates, Degree of freedom, Virtual work, D'Alembert's Principle of virtual work, Lagrangian formalism, Hamilton's equation, Central force problem (equation of orbits, motion of planets and satellites), Rigid body dynamics
PH1027	**MAXWELL'S EQUATIONS AND ELECTROMAGNETIC WAVES**
Credits: 1 *Semester:* *Segment:*	Maxwell's equations, Maxwell's equations in matter, Boundary conditions, Continuity equation, Poynting's theorem, Newton's third law in Electrodynamics, Maxwell's stress tensor, Conservation of Momentum, angular momentum, Electromagnetic waves in vacuum, Electromagnetic waves in matter, absorption and dispersion, Guided waves
PH1567	**MATHEMATICAL METHODS FOR PHYSICISTS -I**
Credits: 1 *Semester:* *Segment:*	Vector Algebra, Matrices and determinants, Vector calculus (gradient, divergence, curl and related theorems), Line, surface and volume integrals, Curvilinear coordinates (spherical and cylindrical polar, Jacobian, grad, divergence, curl, Laplacian)
PH1577	**MATHEMATICAL METHODS FOR PHYSICISTS -II**
Credits: 2 *Semester:* *Segment:*	Infinite sequences and series - convergence and divergence, conditional and absolute convergence, ratio test for convergence, Special functions (Euler beta and gamma, Heaviside Step function, Dirac Delta function, Kronecker delta), Probability and Statistics (Various distributions e.g. Gaussian, Poisson, Binomial, Error analysis), Fourier Series and transforms, Laplace series and transforms, Ordinary differential equations, Partial differential equations: First order, second order, separation of variables, Laplace and Poisson equations, Wave equations.
PH1587	**TENSORS AND DIFFERENTIAL FORMS**
Credits: 1 *Semester:* *Segment:*	Tensor Analysis, Pseudo and Dual tensors, Tensors in general coordinates, Jacobians, Differential forms: Differentiating and integrating forms
PH2017	**RELATIVITY**
Credits: 1 *Semester:* *Segment:*	Galilean transformations, postulates of special theory of relativity, Lorentz transformations, length contraction, time dilation, relativistic mass, relativistic energy and momentum, notion of space, time and space-time, space-time diagram, Lorentz group, equivalence principle and general theory of relativity.
PH2027	**QUANTUM PHYSICS**
Credits: 1 *Semester:* *Segment:*	Classical to quantum cross-over, basic principles of quantum mechanics, wave function and uncertainty principle, probability wave amplitude, probability density, wave equation and Schrodinger formalism, time-independent and time-dependent Schrodinger equations, Dirac formulation of quantum mechanics, linear vector spaces, bra and ket vectors, completeness and orthonormalization of basis vectors, basis sets, change of basis, eigenstate and eigenvalues, expectation values.
PH2127	**ASTROPARTICLE PHYSICS**
Credits: 1 *Semester:* *Segment:*	Natural system of units, elementary particles of nature, Fundamental forces of nature, Concepts of metric, Robertson-Walker metric, Particle kinematics in FRW Universe, Particle dynamics of FRW universe, redshift, thermodynamics in the early universe, time, temperature and entropy, Boltzmann distribution and decoupling temperature of massive particles, neutrino decoupling, matter-radiation equality, photon-decoupling and recombination, baryon number of the Universe, horizons.
PH2177	**LINEAR VECTOR SPACES**
Credits: 1 *Semester:*	Linear vector space, Metric space, Function space, Hilbert space, Linear operators, N-dim. vector space, Tensors, Transformation of basis, Invariant subspaces, Hermitian and Unitary matrices.

PH2187	FOURIER SERIES AND INTEGRAL TRANSFORMS
Credits: 1 *Semester:* *Segment:*	Fourier series, Fourier transforms, Convolution theorem, Laplace transforms, Applications of Fourier and laplace transforms

PH2197	COMPLEX ANALYSIS
Credits: 1 *Semester:* *Segment:*	Analytic functions, Cauchy theorem, Cauchy's integral representations, Taylor and Laurent series, Calculus of residues, Analytic continuation, conformal mapping.

PH2217	CLASSICAL ELECTROMAGNETISM
Credits: 1 *Semester:* *Segment:*	Coulomb's law, Electric field, Divergence and curl of electrostatic fields, electric potential, work and energy in electrostatics, conductors, Special techniques to solve Laplace's equations, Method of images, separation of variables and Multiple expansion, Polarization, Field of a polarized object, Electric displacement and linear dielectrics. Lorentz force law, Biot-Savart Law, Divergence and curl of B, magnetic vector potential, magnetization, field of a magnetized object, linear and nonlinear media

PH2218	ELECTRODYNAMICS
Credits: 2 *Semester:* *Segment:*	Electromotive force, Electromagnetic induction, Maxwell's equations, conservation laws, Poynting theorem, Maxwell's stress tensor, conservation of momentum, angular momentum, and electromagnetic waves, Electromagnetic waves in vacuum, Electromagnetic waves in matter, Absorption and Dispersion, Wave Guides, Potentials and fields, Gauge transformations, Coulomb Gauge and Lorentz Gauge, Dipole radiation, Power radiated by point charge.

PH2287	SPECIAL FUNCTIONS AND DIFFERENTIAL EQUATIONS
Credits: 1 *Semester:* *Segment:*	Series solution, separation of variables, Sturm-Liouville theory, Bessel equation and function, Legendre equation and function, Spherical harmonics, Green function and Nonhomogeneous differential equations, Special functions such as hermite, Laguerre, Chebyshev etc.

PH2297	GROUP THEORY
Credits: 1 *Semester:* *Segment:*	Class, Cosets, Factor group, Character table, Reducible and Irreducible representations, Lie groups, Applications of group theory in Physics

PH2817	MODERN PHYSICS
Credits: 1 *Semester:* *Segment:* *Pre-Req: see syllabus*	Photo Electric Effect, Compton Effect, Atomic Spectra and Lasers, Bohr and deBroglie models, Stern-Gerlach and Entanglement experiments, Matter waves and Schrodinger Equation, Tunnelling, decay, STMs, Hydrogen Atom and Molecular Bonding, Conductivity, Semiconductors, BEC. Pre-Req: Courses on Relativity and Quantum Physics

PH2827	THERMODYNAMICS
Credits: 1 *Semester:* *Segment:* *Pre-Req: see syllabus*	Kinetic theory of Gases, Maxwell-Boltzmann Distribution, molecular distribution, mean free path and collisions, transport and thermal diffusion, viscosity, thermal conductivity. Thermodynamic systems, First law of Thermodynamics, Second law of Thermodynamics, Clausius theorem, thermodynamics and statistical definition of Entropy, Gibbs paradox, Entropy and probability, internal energy and heat capacity equations and their applications. Pre-req: Courses on Classical Physics and Electromagnetism & Maxwells Eqn.

PH2897	ACCELERATOR PHYSICS -I
Credits: 1 *Semester:* *Segment:*	Particle Accelerators, E&M in Particle Accelerators, Linear Beam Optics in straight systems, Linear Beam Optics in Circular Accelerators. RF systems for Particle Accelerators

PH3100/PH5100 ADVANCED SPECIAL RELATIVITY

Credits:
Semester:
Segment:
Pre-Req: PH2017

- Lorentz transformations, Relativistic four-vector notation
- Lorentz Group and Poincare Group: Lorentz tensors
- Infinitesimal transformations: Generators and Lie-derivatives
- Conservation laws for Lorentz symmetry: Noether charges,
- Lorentz Covariant laws of physics: Point Particle, Fluid mechanics, Electrodynamics and Lorentz force law, Relativistic Thermodynamics and Optics (Optional).

PH3117 WAVE FORMALISM OF QUANTUM MECHANICS

Credits: 1
Semester:
Segment:

Schrodinger Equation in one dimension, probability current density, equation of continuity, Free particle solution of Schrodinger equation, box and delta function normalisation of free particle solution, potential step, potential barrier, particle in a infinite potential box, square well potential and tunnelling, linear harmonic oscillator.

PH3127/PH5127 HYDROGENIC ATOM

Credits: 1
Semester:
Segment:

Orbital and spin angular momentum operators, angular momentum algebra, eigenstates and eigenvalues of angular momentum, addition of angular momenta, Clebsch-Gordon coefficients, spin-orbit interaction and applications, central potential, solutions of schrodinger equation in a central potential, Hydrogen-like atom, 3 dimensional harmonic oscillator.

PH3227 NONLINEAR DYNAMICS

Credits: 1
Semester:
Segment:

Nonliner methods and chaos, stability, logistic map, Nonlinear differential equations

PH3237 APPROXIMATION METHODS IN QUANTUM MECHANICS

Credits: 1
Semester:
Segment:

Time independent perturbation theory for non-degenerate and degenerate energy levels, variational method, WKB approximation and applications, time dependent perturbation theory, Fermi-golden rule, adiabatic approximation, sudden approximation.

PH3257 SCATTERING THEORY

Credits: 1
Semester:
Segment:

scattering experiments and cross-sections, general features of scattering in presence of a potential, partial wave analysis, scattering by square well, scattering by hard sphere potential, Born approximation, applications.

PH3267 SYMMETRIES IN QUANTUM MECHANICS

Credits: 1
Semester:
Segment:

Schrodinger and Heisenberg pictures, interaction picture, unitary transformations, symmetry principle and conservation laws, translation along spatial and temporal directions, spatial rotation and conservation of angular momentum, space reflection and parity conservation, time reversal invariance.

PH3277 RELATIVISTIC QUANTUM MECHANICS

Credits: 1
Semester:
Segment:

Elements of relativistic quantum mechanics, the Klein-Gordon equation, the Dirac equation, Dirac matrices, spinors, positive and negative energy solutions, physical interpretations, non-relativistic limit of Klein-Gordon and Dirac equations, equation of continuity and probability current density.

PH3287 ATOMIC-MOLECULAR PHYSICS

Credits: 1
Semester:
Segment:

The Schroedinger equation for One-electron Atoms, Special Hydrogenic systems, Interaction of one electron atoms with Electromagnetic Radiation, One-electron atoms: Fine Structure and Hyperfine Structure

PH3288 ANALYTICAL MECHANICS

Credits: 2
Semester:
Segment:

Hamilton's principle, Galilean invariance, Lagrangian and Lagrangian density, symmetry and conservation laws, scattering, small oscillations, rigid body dynamics, canonical equations, canonical transformations, action-angle variables, Hamilton-Jacobi.

PH3317	THERMAL PHYSICS
Credits: 1 *Semester:* *Segment:*	Laws of thermodynamics, entropy, Clausius theorem, approach to equilibrium, stability conditions; random variables, probability distributions, central limit theorem, information and uncertainty, entropy maximization under constraints.

PH3337	HIGH ENERGY PHYSICS
Credits: 1 *Semester:* *Segment:*	Basic constituents of matter, Forces in nature, Accelerators: Cosmic and Manmade, Detectors, Exotic Matter

PH3338	PHOTONICS & LASER
Credits: 2 *Semester:* *Segment:*	Polarization, Interference and Coherence of Light, Linear Interaction between Light and Matter, Non-linear Interaction between Light and Matter without absorption, Non-linear Interaction between Light and Matter with absorption, Lasers

PH3347	CRYSTAL STRUCTURE
Credits: 1 *Semester:* *Segment:*	Classification of solids- crystalline and non-crystalline solids - 2D and 3D lattice types - different crystal structures - Diffraction of waves by crystals: Bragg's law - Reciprocal lattice - Brillouin zones

PH3348	STATISTICAL PHYSICS
Credits: 2 *Semester:* *Segment:*	Liouville's theorem, ensembles: microcanonical, canonical and grand canonical; mixing entropy and Gibb's paradox, equilibrium distributions, partition functions, fluctuations and response, equivalence of ensembles; Quantum statistical mechanics: density matrix, quantum ensembles, quantum ideal gas, Fermions and Bosons, occupation number, equation of state, ideal Fermi gas, Pauli paramagnetism, ideal Bose gas, black body radiation, Bose-Einstein condensation.

PH3358	SPECTROSCOPY
Credits: 2 *Semester:* *Segment:*	Interaction of one-electron atoms with external electric and magnetic fields, Two electron atoms, Many electron atoms, Interaction of many-electron atoms with Electromagnetic Radiation and with static and magnetic fields, Molecular structure, Molecular Spectra, Electron-Atom Collisions and atomic photoionisation

PH3367/PH5167	EXPERIMENTAL TECHNIQUES
Credits: 2 *Semester:* *Segment:*	Vacuum Techniques, Spectroscopic Techniques, Charged Particle Optics, Data Analysis, Error Analysis

PH3478	PARTICLE PHYSICS
Credits: 2 *Semester:* *Segment:*	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.

PH3537/PH6327	NUCLEAR PHYSICS
Credits: 1 *Semester:* *Segment:*	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.

PH4110/PH6110	BLACK HOLES I: STATIC BLACK HOLES
Credits: 1 *Semester:* *Segment:*	• Gravitational Collapse: TLV equation, Neutron stars, Chandrasekhar limit • The Schwarzschild solution of vacuum Einstein Equations • Geodesics and trajectories, Horizons, Black holes and white holes

Pre-Req: see syllabus

- 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

PH4120/PH6120 INTRODUCTION TO ASTROPHYSICS

Credits: 2
Semester:
Segment:

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

PH4130/PH6130 STATISTICAL DATA ANALYSIS

Credits: 2
Semester:
Segment:
Pre-Req: Basic Probability and Statistics

Measurement, analysis, and interpretation in physics; basic mathematics of probability; Data simulation techniques; Parameter Estimation; Hypothesis testing; Error Analysis, Confidence Intervals; Discriminants.

PH4160/PH6160 TECHNIQUES IN PARTICLE PHYSICS

Credits:
Semester:
Segment:
Pre-Req: 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

PH4170/PH6170 INTRODUCTION TO ADS/CFT DUALITY

Credits: 1
Semester:
Segment:
Pre-Req: see syllabus

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.

PH4180/PH6180 BLACK HOLES II: STATIONARY BLACK HOLES

Credits: 1
Semester:
Segment:
Pre-Req: see syllabus

- 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

PH4268 SOLID STATE PHYSICS

Credits: 2
Semester:
Segment:

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 ELECTRONICS

Credits: 2
Semester:
Segment:

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	CLASSICAL MECHANICS
Credits: 1 *Semester:* *Segment:*	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.

PH5157/PH3257	NUMERICAL METHODS
Credits: 1 *Semester:* *Segment:*	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

PH5288	DIGITAL ELECTRONICS
Credits: 1 *Semester:* *Segment:*	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)

PH5317/PH3417	ELASTICITY
Credits: 1 *Semester:* *Segment:*	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.

PH5327/PH3527	FLUID MECHANICS
Credits: 1 *Semester:* *Segment:*	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/PH3398	COMPUTATIONAL PHYSICS
Credits: 2 *Semester:* *Segment:*	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/PH4118	LASER SPECTROSCOPY
Credits: 2 *Semester:* *Segment:*	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/PH3027	ACCELERATOR PHYSICS
Credits: 1 *Semester:* *Segment:*	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/PH3028	ACCELERATOR PHYSICS-II
Credits: 2 *Semester:* *Segment:* *Pre-Req: PH2218*	Accelerator magnets, Particle Dynamics, Steady state Electric and Magnetic fields, Modifications of E& 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/PH3238	LASER TECHNOLOGY
Credits: 2 *Semester:* *Segment:*	Atomic Radiation - line shape and broadening of spectral lines; Laser oscillations and amplification - gain saturation in homogenous and inhomogenous broadened transitions; General characteristics of Lasers; Methods of generating short and ultrashort pulses – Q switching and Mode locking;

Laser systems; Frequency multiplication of laser beam - introduction to nonlinear optical phenomena, second harmonic generation, optical parametric oscillation and implication.

PH6048/PH4148 ULTRAFAST OPTICS

Credits: 2
Semester:
Segment:

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/PH4158 FEYNMAN DIAGRAM TECHNIQUES IN CONDENSED MATTER PHYSICS

Credits: 2
Semester:
Segment:

Second quantization; Zero and Finite temperature Green functions; Feynman rules; Homogeneous electron gas; Strongly correlated systems, Linear response theory

PH6068/PH3268 COMPUTATIONAL SOLID STATE PHYSICS

Credits: 2
Semester:
Segment:

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/PH3278 PHYSICS OF SURFACES AND INTERFACES

Credits: 2
Semester:
Segment:

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/PH4188 THEORY OF PHASE TRANSITIONS

Credits: 2
Semester:
Segment:

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/PH4298 STATISTICAL PHYSICS OF FIELDS

Credits: 2
Semester:
Segment:

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/PH4108 FRACTAL CONCEPTS IN PHYSICS

Credits: 2
Semester:
Segment:

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

PH6118/PH3218 CLASSICAL THEORY OF FIELDS

Credits: 2
Semester:
Segment:

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

PH6128/PH3128 GROUP THEORY FOR PHYSICISTS

Credits: 2
Semester:
Segment:

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.

PH6138/PH3138 PLASMA PHYSICS AND APPLICATIONS

Credits: 2
Semester:
Segment:

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 QUANTUM YANG MILLS THEORY

Credits: 3
Semester:
Segment:
Pre-Req: 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/PH4248 ADVANCED SOLID STATE PHYSICS

Credits: 2
Semester:
Segment:

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/PH3150 MAGNETOHYDRODYNAMICS

Credits: 1
Semester:
Segment:
Pre-Req: 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/PH4058 SUPERCONDUCTIVITY

Credits: 2
Semester:
Segment:

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 & 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 & super-conducting technology.

PH6168/PH4068 SPINTRONICS

Credits: 2
Semester:
Segment:

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.

PH6178/PH4178 MICROMAGNETICS

Credits: 2
Semester:
Segment:

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

PH6188/PH3188 PHYSICS OF SOLAR CELL

Credits: 2
Semester:
Segment:

Basic principles of Photovoltaics; characteristics of the photovoltaic cell; Semiconductor physics: generation and recombination of electrons and holes, $p-n$ junctions; analysis of $p-n$ 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/PH3198	**ORGANIC ELECTRONICS**
Credits: 2 *Semester:* *Segment:*	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.
PH6317	**PHYSICS AND APPLICATIONS OF FUNCTIONAL MATERIALS**
Credits: 1 *Semester:* *Segment:*	Introduction to Functional Materials, Structure of typical materials, Ferroelectricity, Piezoelectricity, magnetoresistance (GMR, CMR etc) magnetocaloric materials.
PH6318/PH3518	**PHYSICAL BIOLOGY OF THE CELL**
Credits: 2 *Semester:* *Segment:*	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.
PH6328/PH3528	**NON-EQUILIBRIUM STATISTICAL MECHANICS**
Credits: 2 *Semester:* *Segment:*	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/PH4618	**ADVANCED FUNCTIONAL MATERIALS**
Credits: 2 *Semester:* *Segment:*	Introduction to Functional Materials, Processing methods (Bulk and Thin films) and Characterization techniques (XRD, SEM, etc.) in brief, Concept in dielectric , introduction to Impedance spectroscopy, magnetoresistive and magnetocaloric materials, Spintronics, thermoelectric materials, Nano-X (X = materials, wires, tubes, dots , magnetism, etc).
PH6348	**CRYSTALLOGRAPHY**
Credits: 2 *Semester:* *Segment:*	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/PH3758	**NONLINEAR DYNAMICS AND CHAOS**
Credits: 2 *Semester:* *Segment:*	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/PH4618	**QUANTUM FIELD THEORY**
Credits: 2 *Semester:* *Segment:*	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/PH4628	**QUANTUM OPTICS**
Credits: 2 *Semester:* *Segment:*	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/PH3638	**FUNDAMENTALS OF SEMICONDUCTORS PHYSICS AND DEVICES**
Credits: 2 *Semester:* *Segment:*	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/PH3648 MICROFABRICATION TECHNIQUES

Credits: 2
Semester:
Segment:

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/PH4258 GRAVITATION AND COSMOLOGY

Credits: 2
Semester:
Segment:

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/PH4268 ADVANCED PARTICLE PHYSICS

Credits: 2
Semester:
Segment:

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.

PH6478/PH4378 QUANTUM COMPUTATION AND QUANTUM INFORMATION

Credits: 2
Semester:
Segment:

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/PH4388 PARTICLE ASTROPHYSICS

Credits: 2
Semester:
Segment:

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/PH3588 COMPUTATIONAL PHYSICS - I

Credits: 1
Semester:
Segment:

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/PH3589 COMPUTATIONAL PHYSICS - II

Credits: 2
Semester:
Segment:

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/PH3592 PLASMA PHYSICS AND MAGNETOHYDRODYNAMICS (MHD)

Credits: 2
Semester:
Segment:

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/PH3593	OPTICAL ENGINEERING
Credits: 1 *Semester:* *Segment:*	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/PH3887	INTRODUCTION TO GENERAL RELATIVITY
Credits: 1 *Semester:* *Segment:* *Pre-Req: see syllabus*	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/PH4888	INTRODUCTION TO STRING THEORY
Credits: 2 *Semester:* *Segment:* *Pre-Req: see syllabus*	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

PH7013/PH4213	ADVANCED OPTICAL INSTRUMENTATION
Credits: 3 *Semester:* *Segment:*	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/PH4217	ADVANCES IN ATOMIC AND MOLECULAR IMAGING
Credits: 1 *Semester:* *Segment:*	Charged Particle Imaging in Chemical Dynamics; Velocity Map Imaging: Experimental Aspects; Reconstruction Methods (Abel and Hankel Inversion); 3-D Imaging

PH7190	LASER TECHNOLOGY
Credits: 3 *Semester:* *Segment:*	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.

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