COURSES OF STUDY

June 2023

(Applicable for students admitted till 2022-23-W semester)

Indian Institute of Technology Bhilai

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Terms Used

Undergraduate	A first-level degree program offered by the Institute.
Postgraduate	Degree programs offered by the Institute beyond the first-level.
Academic Program *aka* Program	The degree programs offered by the Institute, including undergraduate, postgraduate and research programs.
Academic Senate *aka* Senate	The Institute authority responsible for the promotion and maintenance of standards of research, instruction, education and examination. The senate carries out all decision making towards the academic and related activities.
Academic Year	An academic year starts in the month of July each calendar year and ends in the month of June of the next calendar year.
Semester	A division of an academic year (July-June), which comprises of three semesters – 2 regular semesters (Monsoon and Winter) and a Summer semester.
Monsoon Semester	A semester normally starting in the fourth week of July and continuing until the first week of December.
Winter Semester	A semester normally starting in the fourth week of December and continuing until the first week of May of the next calendar year.
Summer Semester	A semester normally starting in the second week of May and continuing until the second week of July.
DUGC	Discipline Undergraduate Committee.
DPGC	Discipline Postgraduate Committee.
Department	Department is an administrative unit having one or more disciplines
Discipline	Discipline is an academic unit offering two or more programs (undergraduate &/or postgraduate programs)
Grade	A letter system to indicate the performance of the students. Grades are awarded by the instructor in-charge of the course/thesis for the student. Each grade carries associated numeric points.

CGPA	Cumulative Grade Point Average. A weighted average of numeric points obtained in the courses cleared by a student.
SGPA	Semester Grade Point Average. A weighted average of numeric points obtained in the courses within a semester cleared by a student.
Credit	The numeric value associated with courses to indicate the load for a course. Typically a course spanning over *k* fractal segments carries a credit of *k*.
Institute Core courses (IC)	A program may specify a set of courses that every student of that program must register for and must clear.
Professional core courses (PC)	A department may specify discipline-wise a set of courses for each programs that every student of specific discipline in the program must register for and must clear.
Departmental elective courses (DE)	A bouquet of courses offered by the department out of which the students must choose to register in order to fulfil the requirements of the discipline in the program and must clear. Department may also declare some specific courses offered by other departments a-priori as departmental elective courses. Departments shall specify the total number of credits that should be cleared with departmental elective courses.
Open elective courses (OE)	A bouquet of courses offered by various departments of the institute which the students must choose to register from his/her own department or from any other department and clear. A department will allocate zero or more slots for open electives in each program discipline-wise. Open electives are meant to widen the knowledge beyond the parent discipline and broaden the horizon by exposing the problems/areas in other disciplines. Departments shall specify the credits that should be cleared with open elective courses.
Creative Arts and Liberal Arts courses (CALA)	The Institute believes in a well-rounded development of its students. To that extent, Institute specifies program-wise credits to be earned by students amongst a bouquet of courses in Creative Arts and Liberal Arts.

Scope

The provisions of this *course of study* are applicable to all programs and disciplines. The academic Senate may change any or all parts of this *course of study* at any time. The academic Senate may also authorize Dean of Academic Affairs to change any or all parts of this course of study.

Introduction

IIT Bhilai offers a semester-oriented undergraduate, postgraduate and research programs with an objective of imparting best quality science and engineering education. Admissions to the academic programs are synchronized with an academic year, though in some cases, it may be synchronized to the start of a semester. An academic year starts in the month of July each calendar year and ends in the month of June of the next calendar year. Each academic year is divided into three semesters – Monsoon, Winter and Summer semesters. The Monsoon and Winter semesters are two regular semesters. The Summer semester is a shorter semester and only applicable for BTech and MSc programs. IIT Bhilai is currently offering Bachelor of Technology (BTech), Master of Science (MSc), Master of Technology (MTech) and Doctor of Philosophy (PhD) programs in various disciplines. The medium of instruction in both theory and practical classes of the BTech, MSc, MTech and PhD programs is English. This document provides the curricula of all programs at IIT Bhilai along with the list of courses as on date.

Part A: Curriculum

Types of Courses

The course classification at IIT Bhilai is specific to the program and is categorized under five broad categories.

1. **Core courses (IC):** A set of courses that every student of a program at IIT Bhilai must register for and must clear.
2. **Professional core courses (PC):** For a program, the department may specify a set of courses discipline wise that every student of the specific discipline must register for and must clear.
3. **Departmental elective courses (DE):** A bouquet of courses declared by the department out of which students must register for and must clear program-wise specified minimum number of credits to fulfil the graduation requirements of the program.
4. **Open elective courses (OE):** A bouquet of courses offered by various departments of the institute, out of which the students must choose to register for and must clear a number of courses to meet the minimum specified OE credit requirements for a program. Open electives courses are meant to widen the knowledge beyond the parent discipline and broaden the horizon by exposing the problems/areas in other disciplines.
5. **Create Art and Liberal Art courses (CA/LA):** The Institute believes in a well-rounded development of its students. To that extent, Institute specifies a minimum number of program-wise credits to be earned by students amongst a bouquet of courses in Creative Arts and Liberal Arts.

Course pre-requisites

All the academic programs offered at IIT Bhilai follows a credit-based course structure, in which students shall register for courses of their interest, falling under various categories as defined above, based on their program credit requirement and suggested curriculum structure. While doing so, it is essential that the students meet all the pre-requisites of the course which the student intend to register for.

Pre-requisites of a course (i.e. dependent course) are those courses (i.e. precedent courses) which must be cleared (in some cases concurrent registration is also permitted) prior to registering for the course.

Each course, other than 100 level courses, may have specified pre-requisite(s) in terms of other course(s). A student who has obtained F grade in the pre-requisite(s) specified will not be eligible to register for the course.

Bachelor of Technology (BTech)

IIT Bhilai currently offers BTech program in five disciplines.

1. Computer Science and Engineering,
2. Data Science and Artificial Intelligence,
3. Electrical Engineering,
4. Mechanical Engineering, *and*

5. Mechatronics Engineering.

General structure of BTech program

BTech program at IIT Bhilai is a fully residential program with a nominal duration of 4 years.

Accordingly, the minimum credit requirements for students in various categories of courses to become eligible for the award of BTech Degree from IIT Bhilai is as follows.

S. No.	Category	Minimum Credits
1.	IC	60
2.	PC	60
3.	DE	60
4.	OE	30
5.	CA/LA	30
Total		**240**

The Discipline-wise curriculum of BTech program is mentioned in the following sections.

Discipline of Computer Science and Engineering

Semester I

Course Name	**Course Code**	**Credits**
Introduction to Programming	IC100	6
Digital Fabrication	IC101	6
Electromagnetism	IC102	2
Materials Chemistry I	IC103	2
Linear Algebra I	IC104	3
Probability and Statistics	IC105	4
Chemistry/Physics Lab	IC106/ IC107	3
Professional Communication Lab I – Sketching and Drawing	CA100	1
Creative and Liberal Arts courses	-	3
Essential Physical Activity	AA101	1
Total Credits (Excluding EPA)		**30**

In addition to the aforementioned courses, students have to spend sufficient number of hours in National Service Scheme (NSS) or National Sports Organization (NSO) activities as defined by the institute.

Semester II

Course Name	**Course Code**	**Credits**
Applied Digital Logic Design	IC150	6
Quantum Physics	IC151	2
Linear Algebra II	IC152	3
Calculus I	IC153	3
Physics/ Chemistry Lab	IC107/ IC106	3
Software Tools & Technologies Lab I	CS100	4
Discrete Structures I	CS101	4
Data Structures	CS102	4
Professional Communication Lab II - Presentation Skills	CA150	1
Total Credits		**30**

Semester III

Course Name	**Course Code**	**Credits**
Introduction to Astronomy and Astrophysics	IC200	4
Environmental Studies	IC201	2
Calculus II	IC202	3
Software Tools & Technologies Lab II	CS200	4
Discrete Structures II	CS201	2
Algorithms I	CS202	4
Theory of Computation I	CS203	4
Computer Organization & Architecture	CS204	4
Professional Communication Lab III – Technical Literature Structure	CA200	1
Creative and Liberal Arts courses	-	2
Total Credits		**30**

Semester IV

Course Name	**Course Code**	**Credits**
Materials Chemistry II	IC250	2
Basics of Bioinformatics	IC251	4
Operating Systems	CS250	4
Introduction to Language Processing	CS251	4
Algorithms II	CS252	4
Theory of Computation II	CS253	2
Database Management Systems	CS254	4
Professional Ethics	CA250	2
Creative and Liberal Arts courses	-	4
Total Credits		**30**

Semester V

Course Name	**Course Code**	**Credits**
Materials Chemistry III	IC300	2
Principles of Programming Languages	CS300	6
Computer Networks	CS301	6
Departmental Electives Courses	-	12
CALA Courses	-	4
Total Credits		**30**

Semester VI

Course Name	**Course Code**	**Credits**
Departmental Electives Courses	-	18
Open Electives Courses	-	6
CALA Courses	-	6
Total Credits		**30**

Semester VII

Course Name	**Course Code**	**Credits**
Departmental Electives Courses	-	12
Open Electives Courses	-	12
CALA Courses	-	6
Total Credits		**30**

Semester VIII

Course Name	**Course Code**	**Credits**
Departmental Electives Courses	-	18
Open Electives Courses	-	12
Total Credits		**30**

Discipline of Data Science and Artificial Intelligence

Semester I

Course Name	**Course Code**	**Credits**
Introduction to Programming	IC100	6
Digital Fabrication	IC101	6
Electromagnetism	IC102	2
Materials Chemistry I	IC103	2
Linear Algebra I	IC104	3
Probability and Statistics	IC105	4
Chemistry/Physics Lab	IC106/ IC107	3
Professional Communication Lab I – Sketching and Drawing	CA100	1
Creative and Liberal Arts courses	-	3
Essential Physical Activity	AA101	1
Total Credits (Excluding EPA)		**30**

In addition to the aforementioned courses, students have to spend sufficient number of hours in National Service Scheme (NSS) or National Sports Organization (NSO) activities as defined by the institute.

Semester II

Course Name	**Course Code**	**Credits**
Applied Digital Logic Design	IC150	6
Quantum Physics	IC151	2
Linear Algebra II	IC152	3
Calculus I	IC153	3
Physics/ Chemistry Lab	IC107/ IC106	3
Mathematical Foundations for Data Science	DS100	4
Discrete Structures I	CS101	4
Data Structures	CS102	4
Professional Communication Lab II - Presentation Skills	CA150	1
Total Credits		**30**

Semester III

Course Name	**Course Code**	**Credits**
Introduction to Astronomy and Astrophysics	IC200	4
Environmental Studies	IC201	2
Calculus II	IC202	3
Operations Research	MA605	4
Algorithms I	CS202	4
Data Analytics and Visualization	DS250	6
Data Analytics and Visualization Lab	DS210	2
Professional Communication Lab III – Technical Literature Structure	CA200	1
Creative and Liberal Arts courses	-	4
Total Credits		**30**

Semester IV

Course Name	**Course Code**	**Credits**
Materials Chemistry II	IC250	2
Basics of Bioinformatics	IC251	4
Architecture for Management of Large Datasets	DS200	6
Statistical Programming	DS201	4
Artificial Intelligence	DS251	6
Big Data Lab	DS252	2
Professional Ethics	CA250	2
Creative and Liberal Arts courses	-	4
Total Credits		**30**

Semester V

Course Name	**Course Code**	**Credits**
Materials Chemistry III	IC300	2
Information Security	DS2XX	6
Machine Learning	CS550	6
Artificial Intelligence and Machine Learning Lab	DS3XX	2
Departmental Electives Courses	-	12
CALA Courses	-	2
Total Credits		**30**

Semester VI

Course Name	**Course Code**	**Credits**
Departmental Electives Courses	-	18
Open Electives Courses	-	6
CALA Courses	-	6
Total Credits		**30**

Semester VII

Course Name	**Course Code**	**Credits**
Departmental Electives Courses	-	12
Open Electives Courses	-	12
CALA Courses	-	6
Total Credits		**30**

Semester VIII

Course Name	**Course Code**	**Credits**
Departmental Electives Courses	-	18
Open Electives Courses	-	12
Total Credits		**30**

Discipline of Electrical Engineering

Semester I

Course Name	Course Code	Credits
Introduction to Programming	IC100	6
Digital Fabrication	IC101	6
Electromagnetism	IC102	2
Materials Chemistry I	IC103	2
Linear Algebra I	IC104	3
Probability and Statistics	IC105	4
Chemistry/Physics Lab	IC106/ IC107	3
Professional Communication Lab I – Sketching and Drawing	CA100	1
Creative and Liberal Arts courses	-	3
Essential Physical Activity	AA101	1
Total Credits (Excluding EPA)		**30**

In addition to the aforementioned courses, students have to spend sufficient number of hours in National Service Scheme (NSS) or National Sports Organization (NSO) activities as defined by the institute.

Semester II

Course Name	**Course Code**	**Credits**
Applied Digital Logic Design	IC150	6
Quantum Physics	IC151	2
Linear Algebra II	IC152	3
Calculus I	IC153	3
Physics/ Chemistry Lab	IC107/ IC106	3
Digital Signal Processing	EE101	4
Circuits and Systems	EE103	6
EE Independent Project	EE171	2
Professional Communication Lab II - Presentation Skills	CA150	1
Total Credits		**30**

Semester III

Course Name	**Course Code**	**Credits**
Introduction to Astronomy and Astrophysics	IC200	4
Environmental Studies	IC201	2
Calculus II	IC202	3
Electronic Devices	EE201	4
Control Systems - I	EE202	6
Embedded Systems	EE203	4
Engineering Electromagnetics	EE207	4
Professional Communication Lab III – Technical Literature Structure	CA200	1
Creative and Liberal Arts courses	-	2
Total Credits		**30**

Semester IV

Course Name	**Course Code**	**Credits**
Materials Chemistry II	IC250	2
Basics of Bioinformatics	IC251	4
Analog Circuits	EE204	6
Power Engineering - I	EE205	6
Electrical Machines	EE208	4
Control systems Lab	EE251	2
Professional Ethics	CA250	2
Creative and Liberal Arts courses	-	4
Total Credits		**30**

Semester V

Course Name	**Course Code**	**Credits**
Materials Chemistry III	IC300	2
Communication Systems	EE301	4
Electrical Machines Lab	EE351	2
Departmental Elective Courses	-	18
CALA Courses	-	4
Total Credits		**30**

Semester VI

Course Name	**Course Code**	**Credits**
Communication Lab	EE352	2
Devices and Circuits lab	EE353	2
Departmental Elective Courses	-	12
Open Elective Courses	-	6
Independent Project	EE371	2
CALA Courses	-	6
Total Credits		**30**

Semester VII

Course Name	**Course Code**	**Credits**
Departmental Elective Courses	-	12
Open Elective Courses	-	12
CALA Courses	-	6
Total Credits		**30**

Semester VIII

Course Name	**Course Code**	**Credits**
Departmental Elective Courses	-	18
Open Elective Courses	-	12
Total Credits		**30**

Discipline of Mechanical Engineering

Semester I

Course Name	**Course Code**	**Credits**
Introduction to Programming	IC100	6
Digital Fabrication	IC101	6
Electromagnetism	IC102	2
Materials Chemistry I	IC103	2
Linear Algebra I	IC104	3
Probability and Statistics	IC105	4
Chemistry/Physics Lab	IC106/ IC107	3
Professional Communication Lab I – Sketching and Drawing	CA100	1
Creative and Liberal Arts courses	-	3
Essential Physical Activity	AA101	1
Total Credits (Excluding EPA)		**30**

In addition to the aforementioned courses, students have to spend sufficient number of hours in National Service Scheme (NSS) or National Sports Organization (NSO) activities as defined by the institute.

Semester II

Course Name	**Course Code**	**Credits**
Applied Digital Logic Design	IC150	6
Quantum Physics	IC151	2
Linear Algebra II	IC152	3
Calculus I	IC153	3
Physics/ Chemistry Lab	IC107/ IC106	3
Engineering and Machine Drawing	ME102	3
Thermodynamics	ME111	6
Fundamentals of Metallurgy	ME151	3
Professional Communication Lab II - Presentation Skills	CA150	1
Total Credits		**30**

Semester III

Course Name	**Course Code**	**Credits**
Introduction to Astronomy and Astrophysics	IC200	4
Environmental Studies	IC201	2
Calculus – II	IC202	3
Solid Mechanics – I	ME231	6
Manufacturing Science – I	ME251	6
Fluid Mechanics	ME212	6
Professional Communication Lab III – Technical Literature Structure	CA200	1
Creative and Liberal Arts courses	-	2
Total Credits		**30**

Semester IV

Course Name	**Course Code**	**Credits**
Materials Chemistry II	IC250	2
Basics of Bioinformatics	IC251	4
Heat and Mass Transfer	ME213	6
Dynamics	ME232	6
Manufacturing Science II	ME352	6
Professional Ethics	CA250	2
Creative and Liberal Arts courses	-	4
Total Credits		**30**

Semester V

Course Name	**Course Code**	**Credits**
Materials Chemistry III	IC300	2
Theory of Machines and Mechanisms	ME333	6
Mechanical Engineering Lab I	ME371	3
Departmental Electives Courses	-	15
Creative and Liberal Arts Courses	-	4
Total Credits		**30**

Semester VI

Course Name	Course Code	Credits
Design of Machine Elements	ME334	6
Mechanical Engineering Lab II	ME372	3
Departmental Electives Courses	-	9
Open Electives Courses	-	6
Creative and Liberal Arts Courses	-	6
Total Credits		**30**

Semester VII

Course Name	Course Code	Credits
Departmental Electives Courses	-	12
Open Electives Courses	-	12
Creative and Liberal Arts Courses	-	6
Total Credits		**30**

Semester VIII

Course Name	Course Code	Credits
Departmental Electives Courses	-	18
Open Electives Courses	-	12
Total Credits		**30**

Discipline of Mechatronics

Semester I

Course Name	Course Code	Credits
Introduction to Programming	IC100	6
Digital Fabrication	IC101	6
Electromagnetism	IC102	2
Materials Chemistry I	IC103	2
Linear Algebra I	IC104	3
Probability and Statistics	IC105	4
Chemistry/Physics Lab	IC106/IC107	3
Professional Communication Lab I – Sketching and Drawing	CA100	1
Creative and Liberal Arts courses	-	3
Essential Physical Activity	AA101	1
Total Credits (Excluding EPA)		**30**

In addition to the aforementioned courses, students have to spend sufficient number of hours in National Service Scheme (NSS) or National Sports Organization (NSO) activities as defined by the institute.

Semester II

Course Name	Course Code	Credits
Applied Digital Logic Design	IC150	6
Quantum Physics	IC151	2
Linear Algebra II	IC152	3
Calculus I	IC153	3
Physics/Chemistry Lab	IC107/IC106	3
Circuits and Systems	EE103	6
Dynamics	ME232	6
Professional Communication Lab II – Presentation Skills	CA150	1
Total Credits		**30**

Semester III

Course Name	Course Code	Credits
Introduction to Astronomy and Astrophysics	IC200	4
Environmental Studies	IC201	2
Calculus – II	IC202	3
Theory of Machines and Mechanisms	ME333	6
Control System – I	EE202	6
Sensors and Instrumentation	MT201	4
Mechatronics Lab – I	MT202	2
Professional Communication Lab III – Technical Literature Structure	CA200	1
Creative and Liberal Arts courses	-	2
Total Credits		**30**

Semester IV

Course Name	**Course Code**	**Credits**
Materials Chemistry II	IC250	2
Basics of Bioinformatics	IC251	4
Embedded System for Mechanical Controls	MT***	6
Fundamental of Robotics	MT***	6
Hydraulics and Pneumatics Systems	MT***	6
Professional Ethics	CA250	2
Creative and Liberal Arts courses	-	4
Total Credits		**30**

Semester V

Course Name	**Course Code**	**Credits**
Materials Chemistry III	IC300	2
Solid Mechanics-I	ME231	6
Digital Control	MT301	2
Mechatronics Lab – II	MT***	2
Mechatronics Lab – III	MT***	2
Departmental Electives Courses	-	12
Creative and Liberal Arts courses	-	4
Total Credits		**30**

Semester VI

Course Name	**Course Code**	**Credits**
Introduction to Microfabrication	MT***	3
Design Project	MT***	3
Departmental Electives Courses	-	12
Open Electives Courses	-	6
Creative and Liberal Arts courses	-	6
Total Credits		**30**

Semester VII

Course Name	**Course Code**	**Credits**
Departmental Electives Courses	-	12
Open Electives Courses	-	12
Creative and Liberal Arts courses	-	6
Total Credits		**30**

Semester VIII

Course Name	**Course Code**	**Credits**
Departmental Electives Courses	-	18
Open Electives Courses	-	12
Total Credits		**30**

Bachelor of Technology with Honours (BTech (Honours))

General structure of BTech (Honours) program

Students completing two years of BTech program in IIT Bhilai can opt for conversion to BTech (Honours) subject to the conditions and procedures prescribed by the Senate. IIT Bhilai offers BTech (Honours) program in two different modes.

1. Through additional courses in a discipline (called as specialization) other than the one, student has registered for his BTech program.
2. Through thesis in the discipline, the student has registered for his BTech program.

The structure of BTech (Honours) program upto 4th Semester remains same as that of BTech program. From 5th Semester onwards, in addition to the courses mentioned in the BTech program structure, BTech (Honours) students have to register for additional six credits per semester towards discipline-specific courses/thesis based on the mode of their BTech (Honours) program.

BTech (Honours) through thesis

i. Students admitted to thesis-based BTech (Honours) must earn a minimum of 18 credits through thesis. Thesis credits are earned by registering for thesis course.

ii. Students would register for additional courses from 5th semester of their BTech program with the nominal load of 36 credits to fulfill the credit requirements of BTech (Honours) program.

iii. Students shall register for thesis credits from their 6th semester onwards. Students should register for thesis credits for a minimum of 2 semesters.

iv. Students can make use of the summer semester between the 5th and 6th semester for executing the research work by registering for thesis not exceeding 12 credits during the summer semester.

v. Thesis credits will be evaluated and graded in units of 6 credits (i.e.) there will be a grade associated with every 6 thesis credits (or part thereof) registered for.

vi. Students should do the research work towards a minimum thesis credit requirement of 18. The remaining credit requirements for BTech (Honours) should be earned by registering for courses within/across the department(s).

vii. Upon recommendation of the supervisor, the DUGC convener may permit the students to register for more than 18 thesis credits.

BTech (Honours) through Courses

The curriculum for course-based BTech (Honours) in various disciplines/departments are as follows.

Discipline of Computer Science and Engineering

Students registered in course-based BTech (Honours) program with specialization in the discipline of Computer Science and Engineering will take the following courses as per the requirement of the program:

Course Name	Course Code	Credit	Compulsory/Optional
Discrete Structure I	CS101	4	Compulsory
Data Structure	CS102	4	Compulsory
Algorithms – I	CS202	4	Compulsory
Computer Organization and Architecture	CS204	4	Compulsory

Apart from the above mandatory courses, the students have to register for courses of their choice within the discipline of Computer Science and Engineering for 8 more credits.

Discipline of Data Science and Artificial Intelligence

Students registered in course-based BTech (Honours) program with specialization in the discipline of Data Science and Artificial Intelligence will take the following courses as per the requirement of the program:

Course Name	Course Code	Credit	Compulsory/Optional
Data Analytics and Visualization	DS250	6	Compulsory
Artificial Intelligence	DS251	6	Compulsory
Foundations of Data Science	DS100	4	Optional
Architecture for Management of Large Datasets	DS200	6	Optional
Statistical Programming	DS201	4	Optional
Big Data Lab	DS252	2	Optional
Machine Learning	CS550	6	Optional

The student must earn a minimum of 18 credits from the above-prescribed courses. Apart from this, students have to register for courses of their choice within the department (EECS) for 6 more credits.

Discipline of Electrical Engineering

Students registered in course-based BTech (Honours) program with specialization in the discipline of Electrical Engineering must earn a minimum of 18 credits by registering to any of the following courses of their choice:

Course Name	Course Code	Credit	Compulsory/Optional
Digital Signal Processing	EE101	4	Compulsory
Circuits and Systems	EE103	6	Compulsory
Control System-I	EE202	6	Optional
Power Engineering-I	EE205	6	Optional
Communication systems	EE301	4	Optional
Power Engineering-II	EE306	6	Optional

The student must earn a minimum of 18 credits from the above-prescribed courses. Apart from this, six more credits must be earned by registering further to any of the above stated courses or other courses within the department (EECS).

Discipline of Mechanical Engineering

Students registered in course-based BTech (Honours) program with specialization in the discipline of Mechanical Engineering must earn 18 credits by registering to the following courses:

Course Name	Course Code	Credit	Compulsory/Optional
Solid Mechanics – I	ME231	6	Compulsory
Manufacturing Processes – I	ME251	6	Compulsory
Thermodynamics	ME111	6	Optional
Fluid Mechanics	ME212	6	Optional

The student must earn a minimum of 18 credits from the above-prescribed courses. Apart from this, six more credits could be earned by registering to any other courses within the department (ME).

Discipline of Chemistry

Students registered in course-based BTech (Honours) program with specialization in the discipline of Chemistry will take the following courses as per the requirement of the program:

Course Name	Course Code	Credit	Compulsory/Optional
Quantum Chemistry	CY501	6	Compulsory
Bioinorganic Chemistry	CY509	6	Compulsory
Advance Organic Chemistry	CY605	6	Compulsory

Apart from this, six more credits should be earned by registering to any elective courses within the department (CY).

Discipline of Mathematics:

Students registered in course-based BTech (Honours) program with specialization in the discipline of Mathematics will take the following courses as per the requirement of the program:

Course Name	Course Code	Credit	Compulsory/Optional
Real Analysis	MA500	6	Compulsory
Numerical Techniques	MA507	6	Compulsory
Operations Research	MA605	4	Compulsory
Numerical Optimization Techniques	MA609	2	Compulsory

Apart from this, six more credits should be earned by registering to any of the elective courses within the department (MA).

Discipline of Physics

Students registered in course-based BTech (Honours) program with specialization in the discipline of Physics will take the following courses as per the requirement of the program:

Course Name	Course Code	Credit	Compulsory/Optional
Quantum Mechanics-I	PH502	6	Compulsory
Solid State Physics	PH512	6	Compulsory
Any two Course from following Courses			
Statistical Physics	PH506	6	Optional
Electrodynamics	PH508	6	Optional
Nuclear and Particle Physics	PH509	6	Optional
Mathematical Physics	PH503	6	Optional

Master of Science (MSc)

MSc program at IIT Bhilai is offered in three disciplines.

1. Chemistry,
2. Mathematics and Computing, *and*
3. Physics.

General Structure of MSc program

The MSc program offered at IIT Bhilai is a fully residential program with a nominal duration of 2 years. Accordingly, the minimum credit requirements for students in various categories of courses to become eligible for the award of MSc Degree from IIT Bhilai is as follows.

S. No.	**Category**	**Minimum Credits**
1.	PC	72
2.	DE/OE	12
3.	Thesis	24
Total (Minimal requirement)		**120**

The discipline-wise curriculum MSc of program is mentioned in the following sections.

Discipline of Chemistry

Semester I

Course Name	Course Code	Credits
Quantum Chemistry	CY518	4
Mathematics for Chemists / Basics of Molecular Biology	CY516 / CY517	4
Chemical Kinetics and Surface Science	CY502	4
Coordination Chemistry	CY503	6
Chemistry of Main Group Elements	CY504	6
Organic Reactions and Reagents	CY505	6
Total Credits		**30**

Semester II

Course Name	Course Code	Credits
Statistical Mechanics and Thermodynamics	CY507	4
Molecular Spectroscopy	CY508	4
Bioinorganic Chemistry	CY509	6
Stereochemistry and Reaction Mechanism	CY510	6
Physical Organic Chemistry	CY511	2
Organic Photochemistry	CY519	2
Computations in Chemistry	CY520	2
Physical Chemistry Practical	CY513	2
Organic Chemistry Practical	CY514	2
Total Credits		**30**

Semester III

Course Name	**Course Code**	**Credits**
Solid State Chemistry	CY604	4
Inorganic Chemistry Practical	CY506	2
Organometallic Chemistry: Principles and Applications	CY603	6
Interpretative Molecular Spectroscopy	CY607	6
Advanced Organic Chemistry	CY605	6
Thesis	CY699	6
Total Credits		**30**

Semester IV

Course Name	**Course Code**	**Credits**
Departmental Elective	-	6
Departmental Elective	-	6
Thesis	CY699	18
Total Credits		**30**

Discipline of Mathematics and Computing

Semester I

Course Name	**Course Code**	**Credits**
Real Analysis	MA500	6
Linear Algebra	MA501	6
Modern Algebra	MA502	4
Introduction to Probability Theory	MA503	4
Differential Equations	MA504	4
Introduction to Programming	IC100	6
Total Credits		**30**

Semester II

Course Name	**Course Code**	**Credits**
Complex Analysis	MA505	6
Multi-Variable Calculus	MA506	4
Numerical Techniques	MA507	6
Topology	MA508	6
Discrete Structures I	CS101	4
Data Structures	CS102	4
Total Credits		**30**

Semester III

Course Name	**Course Code**	**Credits**
Functional Analysis	MA604	6
Operations Research	MA605	4
Numerical Optimization Techniques	MA609	2
Departmental Elective	-	6
Open Elective	-	6
Thesis	MA699	6
Total Credits		**30**

Semester IV

Course Name	**Course Code**	**Credits**
Departmental Elective	-	6
Open Elective	-	6
Thesis	MA699	18
Total Credits		**30**

Discipline of Physics

Semester I

Course Name	Course Code	Credits
Classical Mechanics	PH501	6
Quantum Mechanics-I	PH502	6
Mathematical Physics	PH503	6
Computational Physics	PH504	6
Electronics Laboratory	PH505	6
Total Credits		**30**

Semester II

Course Name	Course Code	Credits
Statistical Mechanics	PH506	6
Quantum Mechanics-II	PH507	6
Electrodynamics	PH508	6
Nuclear and Particle Physics	PH509	6
Experimental Laboratory	PH510	6
Total Credits		**30**

Semester III

Course Name	**Course Code**	**Credits**
Atomic and Molecular Physics	PH511	6
Solid State Physics	PH512	6
Experimental and Measurement Techniques	PH513	6
Departmental Elective	-	6
Thesis	PH699	6
Total Credits		**30**

Semester IV

Course Name	**Course Code**	**Credits**
Departmental Elective	-	6
Departmental Elective	-	6
Thesis	PH699	18
Total Credits		**30**

Master of Technology (MTech)

MTech program in IIT Bhilai is currently being offered in the following six disciplines.

1. Computer Science and Engineering,
2. Data Science and Artificial Engineering,
3. Electric Vehicle Technology,
4. Electrical Engineering,
5. Mechanical Engineering, *and*
6. Mechatronics Engineering

General structure of MTech program

MTech program in IIT Bhilai had a nominal duration of 21 months with a minimum residential requirement of one regular semester.

The minimum credit requirements for students in various categories of courses for the award of MTech Degree from IIT Bhilai is provided in the following table.

S. No	**Category**	**Minimum Credits**
1.	IC	6
2.	DE	18
3.	Thesis	48
Total (Minimal requirement)		**108**

The curriculum for MTech program is common across the disciplines, which is defined hereunder.

Semester I

Course Name	**Course Code**	**Credits**
Research Methodology	IC601	6
Departmental Electives	-	18
Total Credits		**24**

Semester II onwards

Course Name	**Course Code**	**Credits**
Departmental Electives / Thesis	-	24
Total Credits		**24**

Summer Semester

Course Name	**Course Code**	**Credits**
Departmental Electives / Thesis	-	12
Total Credits		**12**

Doctor of Philosophy (PhD)

IIT Bhilai offers PhD degree program in the following disciplines.

- Chemistry,
- Computer Science and Engineering,
- Data Science and Artificial Intelligence,
- Electric Vehicle Technology,
- Electrical Engineering,
- Mathematics,
- Mechanical Engineering,
- Mechatronics Engineering,
- Physics, *and*
- Liberal Arts.

General structure of PhD program

Candidates are admitted to PhD program in IIT Bhilai either after completion of Under-Graduate (UG) or Post-Graduate program subject to fulfilling the other eligibility criteria defined by the Institute. Further, the PhD program is offered under two different modes with the nominal duration mentioned as below.

1. Full-time – Nominal program duration of 3 years for students admitted after PG and 3.5 years for students admitted after UG.
2. Part-time – Nominal program duration of 4.5 years for students admitted after PG and 5 years for students admitted after UG.

Accordingly, the minimum credit requirements for students in various categories of courses for the award of PhD Degree from IIT Bhilai is provided in the following table.

S.No	**Category**	**Minimum Credits**	
		After PG	**After UG**
1.	IC	6	6
2.	DE	18	42
3.	Thesis	108	108
Total (Minimal requirement)		**168**	**192**

The curriculum for PhD program is common across the disciplines which is defined hereunder.

Semester I

Course Name	**Course Code**	**Credits**
Research Methodology	IC601	6
Departmental Electives	-	24 (18*)
Total Credits		**30 (24*)**

* For part-time students

Semester II onwards

Course Name	**Course Code**	**Credits**
Thesis / Departmental Electives [#]	-	30 (24*)
Total Credits		**30 (24*)**

[#] Students admitted after UG in Engineering departments are required to opt for 30 credits of courses in the second semester.

* For part-time students

Part B: Course Contents

(*Last updated on 17 April 2022*)

Institute Core Courses

IC100 Introduction to Programming (6 Credits)

Basics of programming using an appropriate language; Basic UNIX commands; Arithmetic operations; Data Types; Input and output functions; Conditionals; Loops; Function constructions; Recursion; Arrays; Pointers; Strings; Classes; File handling; Object oriented programming.

IC101 Digital Fabrication (6 Credits)

Freehand sketch: Orthographic, isometric projections, surface development, Familiarization with 3D solid modeling (CAD) for the creation of engineering and freeform geometries, 3D Scanning using CMM and laser scanners, 3D Printing for conversion of CAD model into a real part (additive manufacturing process): slicing, effect of part orientation, Familiarization with conventional machining processes: Centering, drilling, and milling using tabletop reconfigurable CNC machines, Familiarization with Casting and molding, Demonstration of Laser cutting machine.

IC102 Electromagnetism (2 Credits)

Vector algebra, Coordinate systems, Vector analysis, 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.

IC103 Materials Chemistry I (2 Credits)

Introduction to functional polymer materials with respect to types of polymers and their nomenclature; polymer synthesis; molecular weight determination; physical properties of polymers; applications of polymeric materials in everyday life. Introduction to bio-materials: amino acids, peptides, proteins, enzymes, carbohydrates, nucleic acids and lipids. Peptide-polymer conjugates: synthesis properties and applications.

IC104 Linear Algebra I (3 Credits)

Systems of linear equations, elementary operations, row-reduced echelon matrices, Gauss elimination, LU factorization, linear independence, rank of a matrix, solutions of linear systems: existence and uniqueness, vector spaces, subspaces, spanning space, bases and dimensions, linear transformations, matrix representations of linear transformations, range space and rank, null space and nullity, the rank and nullity theorem, invertibility.

Computer lab by using appropriate software tools like Python, MATLAB etc.

IC105 Probability and Statistics (4 Credits)

Probability spaces, conditional probability, Bayes' theorem; random variables, probability distribution functions, joint distributions, independence, mathematical expectations, Chebyshev's inequality; special distributions: binomial, hypereometric, Poisson, exponential, uniform, normal distributions. Random sampling, sample mean, sample variance, weak law of large numbers and central limit theorems; estimation of parameters, the method of maximum likelihood estimation, confidence intervals, testing of hypotheses, goodness of fit, nonparametric tests, correlation analysis.

IC106 Chemistry Lab (3 Credits)

Synthesis of aspirin and paracetamol, estimation of phenol, qualitative analysis of an organic compound, synthesis of potash alum, determination of hardness of water, red-ox titration, acid strength of a citrus fruit, pH and conductometric titration.

IC107 Physics Lab (3 Credits)

Studying Hall effect and Measure Hall coefficient, carrier density, and carrier mobility in semiconductor.

Studying Gouy's method and measure magnetic susceptibility in Aluminium.

Studying interference principle and measure wavelength of light by observing Newton's rings.

Studying Diffraction principle and measure slit width of single wire, cross wire and grating.

Studying energy bandgap theory and measure energy bandgap of silicon and germanium Diode.

Studying Zener Diode and Stefan's Law.

Studying application of Cathode Ray Oscilloscope (CRO) and measure voltage, Frequency and observe superposition principle.

Studying characteristics of a npn transistor.

IC150 Applied Digital Logic Design (6 Credits)

Introduction to FPGA and Hardware Description Languages (HDLs), Combinational Circuits – Logic gates, Boolean Algebra, gate-level minimization, Circuit design and implementation, Adders, Comparators, Multiplexers, Decoders/encoders, Applications, Data storage elements – Latches, Flip-Flops, Register, Memory, Applications, Sequential Circuits – State tables and diagrams, State representation in HDLs, Timing in sequential circuits, Shift register, Counters.

IC151 Quantum Physics (2 Credits)

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 ortho-normalization of basis vectors, basis sets, change of basis, eigenstate and eigenvalues, expectation values.

IC152 Linear Algebra II (3 Credits)

Eigenvalues, eigenvectors and some applications of eigenvalue problems, Hermitian, skew-Hermitian, unitary matrices and their eigenvalues; eigenbases, diagonalization, annihilating

polynomial, the minimal polynomial and the characteristic polynomial, Cayley-Hamilton theorem; Inner product spaces, orthonormal bases, Gram-Schmidt process.

Computer lab by using appropriate software tools like Python, MATLAB etc.

Prerequisite: IC104

IC153 Calculus I (3 Credits)

Real number system, convergence of a sequence, Sandwich theorem, Cauchy sequences, subsequence, monotone sequences, monotone convergence theorem; convergence of infinite series, comparison test, Cauchy condensation test, ratio test, root test and Leibnitz test; limits and continuity of functions, intermediate value property, differentiability of a function, local maxima and minima, Rolle's theorem, mean value theorem and applications.

Definite integrals as a limit of sums, fundamental theorems of calculus, applications of definite integrals to area, volume, surface area, improper integrals.

IC200 Introduction to Astronomy and Astrophysics (4 Credits)

Overview - Scales and Dimensions, Night Sky, Constellations, Earth, Sun, and the Solar System, Retrograde Motion of Planets, Sidereal Time.

Observations- Electromagnetic Waves, Electromagnetic Spectrum, Telescopes, Refractor Telescope, Reflecting Telescope, Observations at Visible Frequencies, Theoretical Limit on Resolution, Mounting of Telescope, Equatorial Mount, Azimuthal Mount, Interferometer, Observations at Other Wavelengths. Astrometry - Coordinate Systems, Doppler Effect, Parallax, Aberration, Precession of Equinoxes, Equatorial Mounting of a Telescope Star Formation and Stellar Evolution - Stellar Nuclear Reactions, White Dwarfs, Neutron Star, Black Holes, Supernova

Cosmology - Big Bang Cosmology, Cosmological Red shift and Hubble’s Law, Matter and Radiation, Accelerating Universe and Dark Energy, The Early Universe, Primordial Nucleo synthesis, Cosmic Microwave Background Radiation (CMBR)

Particle Physics and High Energy Physics

The Standard model of particle physics, elementary particle classification, fermions and bosons, electromagnetic, weak and strong processes. Introduction Large Hadron Collider.

IC201 Environmental Studies (2 Credits)

Understanding our environment: atmosphere composition and behaviour, ecosystem, flow of energy and nutrient cycles, sustainability

Global warming: greenhouse gases, results of global warming, brief overviews of ozone depletion and atmospheric pollutants.

Organic and Inorganic chemicals in environment: toxicity, polychlorinated hydrocarbons like DDT, polymers, detergents. impact on environment

Project on environment related topic.

IC202 Calculus II (3 Credits)

Continuity, partial derivatives, directional derivatives, gradient, differentiability, chain rule; tangent planes and normals, maxima and minima for function of two variables, Lagrange multiplier method; double and triple integrals with applications to volume, surface area, moments of inertia, change of variables; vector fields, line integrals, Green's theorem and its applications, path independence; surface integrals, evaluation, Gauss's divergence theorem and its applications.

Prerequisite: IC153

IC250 Materials Chemistry II (2 Credits)

Organic/Inorganic Hybrid Materials: design, synthesis and characterization, properties, applications, Organometallic materials, Materials for energy storage systems and fuel cells, Materials for redox flow batteries, Cluster compounds.

IC251 Basics of Bioinformatics (4 Credits)

Introduction to biomolecules (amino acids, proteins, DNA, RNA, Genes) and different tools to visualize and represent biomolecules on computer (Visual molecular dynamics (VMD) software)

General introduction to bioinformatics; Definition, Scope and applications, brief history of sequence analysis - Protein, DNA and RNA sequences; introduction to different bioinformatics related databases (EMBL, DDBJ, GenBank, PIR, PDB etc.) and their uses.

Sequence analysis - Comparing two sequences, Similarity searches on sequence databases, building multiple sequence alignment, local and global alignment, BLAST, FASTA.

Working with 30 protein structures - introduction to protein data bank (PDB) file, predicting the secondary structure of a protein sequence, primary structure to 30 structure of protein, finding proteins with similar shapes, folding a protein in a computer, predicting interactions; working with RNA.

IC300 Materials Chemistry III (2 Credits)

Introduction to light harvesting materials (organic, inorganic and hybrid materials), semiconductor basics. Light-matter interaction (black body radiation, photoelectric effect, wave-particle duality, concept of wave function, particle in 1D box). Applications of semiconductor systems and solar-cells, conjugated polymers (coupling reactions), inorganic (quantum dot synthesis and properties) and hybrid semiconductors (advanced synthetic protocols).

IC601 Research Methodology (6 Credits)

Literature search, review and citation practices Problem identification, formulating research questions Quantitative and qualitative methods – strengths and weaknesses Instrumentation and data logging, Data sampling, collection, testing Data analysis, interpretation and limitations, Validity, reliability, sources of error, Data management and presentation.

Courses in Creative Arts and Liberal Arts

CA100 Professional Communication Lab I – Sketching and Drawing (1 Credits)

Drawing as a means of visual organization. Emphasis on drawing fundamentals of proportion, composition, and layout. Subject matter and medium vary.

CA106 Madhubani Painting (2 Credits)

Introduction of Madhubani Painting

Drawing: -Uses of traditional tools, Border making technique, Main Image drawing and background filling

Design making process

Colour making process (Natural & Acrylic colour)

Introduction of Madhubani painting on fabric.

CA107 Understanding Kathak (2 Credits)

Origin of Kathak – Its Journey, Emergence of Gharanas – Differences with Practical Demonstration. Various Socio cultural Influences on Kathak, Kathak and Natyashastra, Bhava and Rasa in Kathak.

Influence of Wajid Ali Shah, Contribution of Kathak to Hindusthani Classical Music, Sufi in Kathak, Secular Aspect of Kathak

Kathak and Dhrupad, Concept of Dance Theatre in Kathak,

Physiological and Psychological – Impact of Dance and Correlation

CA108 Folk Theatre of India (2 Credits)

General Introduction: Origin of Indian Drama- various sources- Sanskrit drama/Folk drama

Understanding concept of space in drama, acting, human body, films etc

Improvisation - theatre games, acting

Making stories- on two dimension spaces like painting etc; on three dimension

spaces - performance

Working in groups - creating as a group - presentation as a team

CA109 Sculpture Design (2 Credits)

Introduction to Sculpture: Definition of Sculpture, Method of Sculpture, Main mediums of Sculpture, Fundamentals of art (visual art)

Practical: Drawing: Study of human and Animal forms and imaginative drawings, Clay modelling, Clay modelling of any human and animal, Form- architectures and geometrical form.

CA110 Fundamentals of Hindustani Music (2 Credits)

Introduction of seven shuddha & five vikrit swaras.

Five Alankaras in shuddha swaras.

Swarmalika (Sargam Geet) in Raga Yaman, Bhairav, Kati and Bhairavi.

Chhota khayal in Raga Yaman, Bhairav, Kati and Bhairavi.

Light compositions in above ragas.

Knowledge of Dadras, Kaherwa and Trital with hand gesture.

CA111 Understanding Cinema (2 Credits)

Brief introduction to cinema of the last century.

Evolution & transformation of cinema across the globe and in India.

Differences between cinematic genres.

Cinema as the art form: understanding the text and the communication.

Cinema and society.

CA150 Professional Communication Lab II- Presentations Skills (1 Credits)

Need of presentation skills for Engineers; Modes of presentation - writing, speaking, demonstrating;

Writing - reports, papers, reviews; Document structuring - Sections, footnotes, captions, cross reference, etc.

Speaking - workshops, conferences, interviews; Discussion - Ideation, pitching the ideas, Ideation to formulation.

Demonstrating -slides, videos, models, prototypes; Visual appeal - Usage of proper fonts, styles, colours, etc.

Effective presentation strategies; dos and don'ts.

CA200 Professional Communication Lab III – Technical Literature Structure (1 Credits)

Usage of appropriate language in technical communication - Types of scientific writings - Abstract writing - Technical report writing - Review writing – Online communication.

CA250 Professional Ethics (2 Credits)

The values of professional ethics, Foundations and norms of professional ethics

The nature, scope and challenges of professions, Code of conduct for professionals, Obligation to clients, colleagues and third parties.

Breach of confidentiality and trust, Relation between professional and general ethics, Nature of engineering ethics, the value of ethnical practices in engineering.

Certain specific issues pertaining to medical ethics, legal ethics, environmental ethics, computer ethics and business ethics.

LA302 Indian Writing in English (4 Credits)

Nationalism: migration; regionalism; history; diaspora, Gender and sexuality: womanhood; masculinity; agency Caste: access; representation; triple jeopardy Urbanisation: inequality; the everyday; aspiration.

Prerequisites: Instructor's consent is required

LA303 Chinese Language Beginner I (1 Credits)

Introduction - Basic concepts about Sino-Tibetan languages (Mandarin)

Phonetics & Listening - Pronunciation - Tones

Speaking - Pronouns - Question Particles - Verbs to BE - Nationality

Writing - Name writing - Vocabulary writing

Reading - Character Identifying.

LA305 City in Literature (4 Credits)

Planning: informality – risk

Home: design – family

Small Towns: community – aspiration

Love: desire - agency

LA308 Positive Psychology (2 Credits)

Introduction and brief overview: Shift from the traditional deficit approach to the strengths approach

History of well-being research; Overlaps among well-being concepts; Theories - hedonism-eudaimonism, authentic happiness- pleasant, engaged, and meaningful life, PERMA, broaden-and-build, structure of psychological wellbeing; Contributors to well-being - Genetics, circumstances, actions; VIA Classification: Character strengths and virtues (any three/four strengths in detail)

The positive side of negative emotions- Resilience and defensive pessimism

Assessment of well-being: Tools, methodological constraints, accepted indicators

Applications of positive psychology techniques- positive psychology interventions exercises, and practice.

Criticism and future of positive psychology.

Prerequisites: Instructor's consent is required

LA310 History of Medicine and Surgery (1 Credits)

Nature of Medical Literature in Ancient India, The two major Samhitas, Doctors and Quacks

History of Plastic Surgery in Ancient India, Four Physicians of the Past

Prerequisites: Instructor's consent is required

LA311 Chinese Language Beginners 3 (2 Credits)

Advanced daily topics, family terms and titles, expressing individual preferences and abilities, basic grammatical structure such as more measure words, “duo” as an indefinite number and so forth, and writing Chinese characters.

Prerequisite: LA315

LA312 Chinese Language Beginners 4 (2 Credits)

Expressing places, locations, and movement, the relationship between time and the progress of actions, basic grammatical structure such as complex sentences, “shi…de” sentence and so forth, and writing Chinese characters.

Prerequisites: LA311

LA313 Chinese Language Beginners 5 (2 Credits)

Relationship between work, rest and time, expressing seasonal and climate situations, basic grammar such as aspect particle and so forth, and writing Chinese characters.

Prerequisites: LA312

LA314 Communication in Chinese (1 Credits)

All kinds of situations for daily topics, expressing students’ opinions, having basic concept to know between the words and the lines, and some buzzwords.

LA315 Chinese Language Beginners II (1 Credits)

Additional daily topics, family terms and titles, expressing individual preferences and abilities, basic grammatical structure such as more measure words, "you" sentence and so forth, and writing Chinese characters.

Prerequisites: LA303

LA316 Chinese Language Phonetics (1 Credits)

Phonetic and spelling of Chinese, greeting, small numbers (from 1 to 99), classroom phrases.

LA317 Psychology of Memory (2 Credits)

Cognition – Understanding memory – Theories of memory – Types of memory – Forgetting – Mnemonics – Applications of memory in Law, clinical psychology, education.

Prerequisites: Instructor’s consent is required

LA318 Chinese Basic 1 (1 Credits)

Explaining vacation plans, explaining a country's geographic locations and introducing simple distinguishing features of the terrain, basic grammar and writing Chinese characters.

LA319 Chinese Basic 2 (1 Credits)

Learning on: Ordering food, telephone conversations, basic grammar and writing Chinese characters.

Prerequisites: LA318

LA320 Chinese Basic 3 (1 Credits)

Comparative sentences, asking others for assistance, basic grammar and writing Chinese characters.

Prerequisites: LA319

LA321 Macroeconomics (2 Credits)

Macroeconomic data, GDP concepts.

Money demand and money supply, role of central bank, inflation.

Unemployment, The economy in the short run: Aggregate Demand-Aggregate supply

(AD-AS) model.

Aggregate Demand in a closed economy: Building and applying the IS-LM model.

Aggregate Demand in the open economy: the open economy IS-LM model and the exchange rate regime.

The open economy and exchange rate dynamics

Prerequisites: Instructor’s consent is required

LA322 Microeconomics (2 Credits)

Economic way of thinking, important core principles of economics, Basics of demand and supply, consumer behavior, price elasticities, government pricing policies of tax and subsidy.

Industrial production and costs, market structures such as perfect competition, monopoly, imperfect competition and oligopoly, Product pricing strategies of companies.

Prerequisites: Instructor’s consent is required

LA323 Introduction to Popular Culture (2 Credits)

Definition of 'culture' - comparing Arnold's and Williams' ideas

'high' vs. 'low' culture- 'popular culture' - definitions and debates

Different kinds of constituents of popular culture - mass media products, practices, objects, people, places etc.

Ways to 'read' texts critically - both text as itself and text with context.

Popular culture and the 'common sense' of society.

Prerequisites: Instructor’s consent is required

LA324 Leadership: An Organizational Behaviour Perspective (2 Credits)

Introduction to organizational behaviour, Understanding the nature of leadership.

Approaches to leadership- trait, behavioural and contingency approaches.

Leaders and followers- leader-member exchange model, dynamics of in-group versus outgroup

Decision Theory: Vroom and Yetton's Leader Participation Model

Leadership development, Global implications

Prerequisites: Instructor’s consent is required

LA325 Concepts of Personality Psychology (2 Credits)

Introduction: Personality Psychology, Schools of Personality Psychology

Selected Trait and type approaches, Psychoanalysis and Psychodynamic approaches

Behavioristic Approach, Humanistic Approach, Assessment of Personality

Prerequisites: Instructor’s consent is required

LA326 Adaptation: Literature and Beyond (2 Credits)

Define and differentiate between adaptation, appropriation and intertextuality

Adaptation as product and process

Adaptation across literary genres: Kolatkar's Sarpa Satra

Intermedial adaptation: Hamlet on film

Cultural adaptation: Nina Paley's Sita Sings the Blues

Discussion on various adaptations of writers including Shakespeare and Austen,

and the Indian epics.

Prerequisites: Instructor’s consent is required

LA327 Introduction to Partition Literature (2 Credits)

Mapping out partition literature, Historical perspective on the partition of Punjab and Bengal

Remembrance and trauma expressed in literature, Representations of the partition in some popular films

Prerequisites: Instructor’s consent is required

LA328 Economic Development in India (2 Credits)

India's economic growth and development experience since Independence, Current issues in economic growth, Poverty alleviation and income inequality, Indian labour (job) market: current issues and prospects

Education in India: progress and problems, Healthcare in India: progress and problems, Current issues and problems in the unorganized/informal sector, Developments and problems in the agriculture sector

Prerequisites: Instructor’s consent is required

LA329 Selected Topics on Indian Economy (2 Credits)

Introduction to the Indian economy, growth and development experience thus far, the 1991 Economic Liberalization

The Industry sector: issues and prospects

Developments in banking and financial markets

Fiscal policy, Government of India's Annual Budget

Progress and problems in the Agriculture sector

The Services sector: issues and prospects

Developments in international trade sector

Prerequisites: Instructor’s consent is required

LA332 Chinese Culture (1 Credits)

Philosophy, virtue, and etiquette system, Cuisine and tea art, Clothing, dance and music, Chinese New Year.

LA333 Chinese Calligraphy (1 Credits)

History of Chinese calligraphy, Tools for Chinese calligraphy, Strokes in Chinese calligraphy

Practice Chinese calligraphy with names, Practice writing short spring rolls (good phrases used in Chinese New Year)

LA334 Themes in Literature (2 Credits)

Introduction to various themes in literature: Self-reliance and individualism, The American Dream, Marginalized perspectives, Women and self-expression, Reinvention of mythology

Prerequisites: Instructor’s consent is required

LA335 Economic Growth: Theory and Applications (2 Credits)

Macroeconomic data, GDP concepts, History of economic growth in India and the world

Classical growth models, Solow's neoclassical growth model, theory and empirics, Romer's endogenous growth theory and empirics, Modem growth theories: Political institutions and economic growth (Acemoglu, Alesina, Besley etc.), corruption and growth

Political economy of India's growth experience

Prerequisites: Instructor’s consent is required

LA336 Pricing Strategy (4 Credits)

Introduction and overview of strategic pricing, Pricing under different market structures such as monopoly and oligopoly, Economic value to the customer (value creation, customer-based pricing), price sensitivity of demand and supply, demand analysis using regression, Role of costs and cost-based pricing, pricing for profit, competition-based pricing, Price discrimination, segmentation, product line pricing, geographic pricing,

Psychology of pricing, price perceptions, various types of strategic pricing schemes, Ethical issues of pricing, Basics of auctions as a price discovery mechanism, pricing of new products, Government ricin laws and regulations, pricing and firms' market power

LA337 Entrepreneurship and Startups (4 Credits)

Introduction and overview of the course. Ideation, innovation, and start-up issues: Generating and evaluating venture ideas, disruptive innovation, opportunity recognition and entry

strategies, Creation, and protection of intellectual property; and legal issues, initial organizational culture, Business model: developing an initial business plan, lean startups Entrepreneurial financing: early-stage valuations of startups; matching stage with various sources of venture financing, Entrepreneurial marketing and sales strategies, advertising, and communications strategy Competitive business and pricing strategies for the new product, product and company launch, Company registration and corporate processes for startups in India, Venture life cycle issues appearing at various stages: development, survival, rapid growth, and maturity. Sustaining and reinforcing the competitive advantage, negotiating with government regulation and policies, managing growth, scaling up the business, exit strategies

LA338 Childhood, Adolescence and Youth in Modern Short Fiction (2 Credits)

Comparing and contrasting socio-cultural context(s) through a story's setting. (Customs, mannerisms, speech, etc., geographic, historic, and social conditions)

Understanding the narrative voice and the child's point of view. (First-person and third-person narrative, the innocent eye or the nalve narrator, the limited and the omniscient narrator)

Analyzing the development of themes through the child/adult interaction. (Uncovering the moral(s) of the story and figures of speech, e.g. symbols, allusions, etc.)

Tracing character development and the assimilation of gender norms. (Physical and psychological representation of the characters, protagonist v/s antagonist, etc.)

Representations of the coming-of-age through plot development. (Main aspects of the plot and the various forms of conflict)

Prerequisites: Instructor’s consent is required

LA339 Financial Economics (2 Credits)

Basic concepts: cashflow; discounting; present and future values; internal rate of return; principal and interest; arbitrage; financial instruments and markets.

Fixed-income securities: bond prices and yields; interest rate sensitivity; duration; immunization; the term structure of interest rates; yield curves; spot rates and forward rates; other fixed-income securities.

Stock market: asset returns and risks; efficient market hypothesis; Markowitz model; capital asset pricing model (CAPM); investment analysis and asset pricing.

Derivatives: Hedging; forward contract, futures contracts, options, types of options.

Prerequisites: Instructor’s consent is required

LA340 Public Finance (2 Credits)

Introduction to public finance, India's fiscal policy and budgeting

Public goods, cost-benefit analysis

Externalities: issues and remedies

Elections, models of voting, democracy

Income redistribution, social security, public healthcare

Equity and efficiency implications of taxation

Personal income tax, effect of taxes on labour supply and savings

Indirect (commodity) taxes, corporate taxation.

Prerequisites: Instructor's consent is required

LA341 Labour Economics (2 Credits)

Historic background and current issues in Indian labour Gob) market; Labour supply; Labour demand; Labour market equilibrium, wage structure, returns to education; Compensating wage differentials, human capital; Labour mobility; Labour market discrimination; Unemployment; Labour unions. labour market regulation

Prerequisites: Instructor's consent is required

LA342 Economics of Information Technology (4 Credits)

Introduction, economics of information goods, services and platforms, economies of scale and scope, Hotelling differentiation; Network effects, switching costs, lock-in, strategic pricing of information products; Online price discrimination, bundling, versioning, freemium; Price conditioning, competition models; Game theoretic models of network traffic; Internet auctions; Complements and substitutes, platforms and two-sided markets, digital economy; Loci of competition, market power; Economics of information: regulation and network neutrality, free & open source software, value of information; Information asymmetries; Online privacy; Economics of information security, cybercrime, digital piracy, network cascades and social epidemics; Social network structure, network formation, peer production, memes, social bots; Cryptocurrencies, online labour market, cyberloafing; Internet governance and policy

Prerequisites: Instructor's consent is required

LA343 Internet and Society (2 Credits)

Introduction, social issues involving life on the Internet, digital culture; Social networks, online publics, relationship formation; Social media and wellbeing, meaning-making, peer production, trolling, memes, social bots; Social media and politics, fake news, cyber activism, E-governance; Internet governance and policy: regulation and network neutrality, digital inclusion, Internet freedom, free & open source software; Online privacy, data ownership, surveillance; Cybercrime, digital piracy, information and communication ethics.

Prerequisites: Instructor's consent is required

LA345 Introduction to Classical Theatre (2 Credits)

Introduction to Ancient Greek and Roman Classical Theatre from a comparative approach.

Familiarization of ancient myths (e.g. Oedipus, Jason and Medea, the Trojan War etc.); understanding the relationship between human beings and the gods, between the sexes, master and slave, and between genres (e.g. tragedy and comedy).

Themes including sexuality, violence, conceptions of justice, and madness.

Importance of literature and relevance of the classical literary canon in the modem age.

Prerequisites: Instructor's consent is required

LA346 Microeconomics 2 (2 Credits)

Overview on demand, supply and market equilibrium; Budget constraints: concept, properties, changes in budget constraints; Preferences: assumptions, utility, indifference curve, marginal rate of substitution, Cobb-Douglas function, optimal choice

Demand: Income offer curve and Engel curve, price offer curve and demand curve, inverse demand function, substitution effect, income effect.

Overview of imperfect markets and producer theory

Prerequisites: Instructor's consent is required

LA348 The Individual and Society (2 Credits)

Relation between individual and society: Aristotle; Hobbes; Rousseau; Williams; the individual as "single example of a group" vs. as "fundamental order of being"; reading clusters focusing on the relation of the individual to the following socio-cultural themes: technology and social media; identity community; choice

Prerequisites: Instructor's consent is required

LA349 Contemporary Indian Cinema: Beyond Bollywood (2 Credits)

Mapping the terrain of Indian cinema - a general introduction - mainstream vs. arthouse vs. regional; understanding Bollywood as "popular" Indian cinema - history, cultural significance, pan-Indian presence; the influence of globalisation and transregionalism on trends in Indian cinema with the 2010s as the period in focus, select movies exploring themes of:; Family; Love; The City; Community.

Prerequisites: Instructor's consent is required

LA350 Political Economics (2 Credits)

Introduction to the economic analysis of political factors and outcomes. Economic and electoral impact of political factors. Democracy, dictatorship, government, political competition. Elections, models of voting, electoral politics in a democracy. History, political institutions and economic development. Corruption in public programs, bureaucracy, state capacity. Political economy of judiciary and news media.

Prerequisites: Instructor's consent is required

LA351 Elements of World Literature (2 Credits)

The place of the literary text and the process of canonicity

The importance of translation in the context of world literature

Prize-winning authors and their impact on the literary field

Understanding world literature as a mode of reading and critical analysis

Tracing the various intercultural trajectories of the texts

Prerequisites: Instructor's consent is required

LA352 Classics and Science (4 Credits)

Form: epic – lyric
Craftsmanship: divine origins – armaments
Urbanization: planning – defences

LA353 Experiencing in the Indian University (2 Credits)

Campus cultures: universities - institutions
Competition: anxiety – friendship
Caste: meritocracy - reservations

LA354 Introduction to Postcolonial Literature (2 Credits)

Defining the key terms: colonialism, imperialism and postcolonialism

Understanding the many meanings and inflections of the term 'postcolonial'

Primary focus on literature that contends with the colonial legacy – including texts from South Asia, the Caribbean, Africa and Latin America.

Exploring the themes of freedom, nation, identity, migration and diaspora

Prerequisites: Instructor's consent is required

LA355 Chinese Basic 4 (1 Credits)

Auxiliary verb in negative forms, Grammar construction by utilizing certain verbs, Verbal suffix, Time elapsed sentences, Short articles writing practice

Prerequisites: LA320

LA356 Chinese Basic 5 (1 Credits)

Resultative Compounds, Directional endings used as resultative endings, Verbal Compounds, listening Practice, Short articles writing practice

Prerequisites: LA355

LA357 Chinese Basic 6 (1 Credits)

Review - Basic 1 to 5 - dictations

Vocabulary - Nouns - Measure words - form sentences

Grammar - Motion verbs - coverbs - form sentence with coverbs

Writing - small paragraphs - small articles in given topics.

Speaking - Two-way Immersion programme

Prerequisites: LA356

LA358 Game Theory (2 Credits)

Introduction, background, rules, and examples

Symmetric games: Best response function, dominant strategies, Nash equilibrium, Iteratively eliminating dominated strategies, Mixed strategy, Cournot model, Bertrand model of duopoly, Auctions.

Extensive games: Strategies and outcomes, Nash equilibrium, Backward induction, Subgame perfect equilibrium, Finite and infinite repeated games, Stackelberg model of duopoly.

Prerequisites: Instructor's consent is required

LA359 Introduction to Corporate Finance (2 Credits)

Valuation of stocks and bonds, risk-return trade-off, market efficiency and inefficiency, corporate financing- equity and debts, financial markets and institutions, Initial public offering, dividend distribution, capital structure, hedging, financial analysis, corporate mergers

Prerequisites: Instructor's consent is required

LA360 Self and Society in Modern India (2 Credits)

Life writing: autobiography – memoir – biography
Selfhood: self-fashioning – aspiration – privilege
Gender: womanhood – transgendering - sexuality

LA361 Introduction to Modern American Poetry (2 Credits)

Characteristics of modern poetry: representation of tradition and nature – intertextuality - feminism - masculinity- the poetic voice - modernism and the avant-garde - globalization.

Contextualizing modern poetry: historical and geopolitical contexts - migration - race - war - the Great Depression - McCarthyism - influence - reception – circulation

Close reading and critical analysis: scansion - simile, metaphor, personification -structure and rhyme scheme - speaker - repetition - allusion - ambiguity

Prerequisites: Instructor's consent is required

LA365 Applied Positive Psychology (2 Credits)

Meaning and purpose of applied positive psychology, Theories in applied positive psychology and character strengths- Learned optimism -

PER MAH theory- LIFE Model- versions of character strengths, Interventions and their effects - characteristics of the mind that lead us to move in negative spirals- counteracting these cognitive biases Internet based interventions and their effects - techniques and problems related to online interventions - how to make them feasible and effective

Gratitude and closure- introduction to open memories - reframing process - grateful reappraisal

Culture and subjective well-being- interdependent self-construal and interdependent self-construal - identifying the self in the culture- strategies to use these to improve subjective well-being

Buffering and building mental health - integrated findings on physical health, organizational health, and inter-personal processes - critique and future directions.

Prerequisites: LA308

LA701 Econometric Methods (6 Credits)

Review of basic statistics, simple and multivariate linear regression, hypothesis testing and confidence intervals, nonlinear regression functions, estimation problems (multicollinearity, heteroscedasticity, autocorrelation) and solutions, assessing studies based on multiple regression, introductory overview of regression with panel data and timeseries data, regression with limited dependent variables (legit, probit, tobit), causal inference methods (instrumental variables regression, experiments and quasi-experiments)

Prerequisites: Instructor's consent is required

LA702 Advanced Positive Psychology (6 Credits)

Introduction: Medical model and its differences with the strengths model. Shift from the traditional deficit approach to the strengths approach

Historical and philosophical foundations both Western and Eastern.

Determinants of well-being- research, implications and areas to explore

The study of Strengths: different strength classifications with focus on VIA (three/four strengths in detail)

The role of negative in positive psychology: charting the domain of uneasy but necessary emotions and experiences.

Issues in Assessment of well-being: Tools and their standardization, methodological constraints, accepted physiological and psychological indicators

Prospects, practices and prescriptions for attainment of well-being

Criticism and prospects of positive psychology and its practice in clinical, organizational, health, and teaching

Prerequisites: Instructor's consent is required

LA703 Positive Organizational Behaviour (6 Credits)

Introduction and brief overview, need and call for Positive Organizational Behaviour Understanding what is positive- traits, states, and processes. Understanding POB and Positive Organizational Scholarship (POS) and their differences.

Framework: Psychological Capital and its effects on the workplace

Framework: Work engagement and its effects on the workplace

Understanding the two major methodological challenges in POB

Positive Organizational Psychology in India: Current position of positive organizational psychology in India and identifying the areas which still need to be explored

Interventions in the workplace: effects on well-being and performance, current state of positive psychology interventions at the workplace in India, scope of cross cultural interventions for influencing workplace well-being and performance, designing a workplace intervention

Prerequisites: Instructor's consent is required

LA704 Literary Theory (6 Credits)

An overview of critical theory: from new criticism, to feminism, postcolonialism, psychoanalysis, structuralism, post-structuralism and reader-response criticism.

An introduction to major literary theorists from Aristotle to Bakhtin, Barthes, Benjamin, Kristeva, Said, Derrida, Showalter, Spivak, and Zizek.

Individual case studies of critical papers in literary theory.

Prerequisites: Instructor's consent is required

LA705 Cultural Studies: Theory and Practice (6 Credits)

Key concepts and debates: Debates on culture - Arnold, Leavis, Thompson, Williams; Mass culture; popular culture: Adorno, Hall, Fiske; Ideology; hegemony; power - selections from Williams, Althusser, Gramsci, Foucault; Representation – Hall

Modern contexts: Globalisation; Neoliberalism; Social movements shaping questions of identity: gender, class, caste, race, and sexuality

The texts: Media; spaces; subcultures; everyday practices

Prerequisites: Instructor's consent is required

LA706 Development Economics (6 Credit)

Introduction to and overview of development economics Labour: labour supply, labour demand, wage structure, agricultural labour market, labour mobility, labour market discrimination, unemployment, skills, labour unions, labour market

Health: health behaviours, health insurance, health financing, health inequality, physicians, health policy, industrial organization of health (pharmaceutical and hospitals), environment and health, health and public finance

Education: Quality of education, exams and outcomes, returns to education, schooling, teacher quality, public policies to address education production function problems, education financing higher education regulation

Prerequisites: Instructor's consent is required

LA707 Macroeconomic Theory (6 Credits)

Classical Economics: Employment and output determination, Say's Law, quantity theory of money.

Keynes and Macroeconomics: General Theory, main prupusitious, analysis uf lite labour market, on Say's Law and the quantity theory of money.

Orthodox Keynesian School: TS-1,M model for a closed economy, underemployment equilibrium in the Keynesian model, IS-LM model for an open economy, Phillips curve.

Monetarist school of thought: Quantity theory of money approach, expectationsaugmented Phillips curve, balance of payments theory and exchange rate determination.

New Classical Economics: Rational expectation hypothesis, continuous market clearing, aggregate supply hypothesis, equilibrium business cycle theory, policy implication and Lucas critique

Real Business Cycle school: The transition from monetary to real equilibrium business

cycle theory, Supply-side shocks, Real business cycle theory, Technology shocks

New Keynesian Economics: Core propositions and features of new Keynesian economics, Nominal rigidities, Real rigidities, New Keynesian business cycle theory

Prerequisites: Instructor's consent is required

LA710 Modern Indian Literature: Currents and Countercurrents (6 Credit)

Modernity: bhashas – indigeneity – forms
Nation: decolonisation – Partition
Caste: ritualism – Dalits – aesthetics
Cities: everyday – risk - empowerment

Prerequisites: Student must have completed the course credit requirement of the program registered for.

LA711 Culture and the Study of Human Strengths (6 Credit)

Introduction to human strengths and different strength classifications- Gallup, Clifton and Seligman and Peterson classifications; Eastern and Western perspectives on strengths- value systems, orientation to time and thought processes; Identification of strengths - methods and tools; Understanding the debate on culture free and culturally embedded research and practice of strengths - individual case studies

Prerequisites: Instructor consent is required.

LA795 Candidacy (0 Credit)

Evaluation of candidate's ability to carry out research, knowledge breadth of the student, research comprehension.

Prerequisites: Student must have completed the course credit requirement of the program registered for.

LA798 Independent Study (variable Credits)

Course content and credits are to be assigned by the course instructor.

LA799 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: LA795.

Courses in Chemistry

CY200 Smart Functional Materials (2 Credits)

Introduction to smart “stimuli-responsive” materials with respect to types of materials: single stimuli responsive, dual stimuli responsive and multiple-stimuli responsive materials. Application towards drug delivery, tissue engineering, biomedical sensors and actuators and multi-layer data writing.

Prerequisites: Instructor’s consent is required

CY201 Electrochemistry and Charge Transfer Dynamics (2 Credits)

Nernst equation, Normal and Formal potential, Redox potentials with sign conventions, Feasibility of a redox titration, redox potential at the equivalence point, redox indicators, high temperature redox reactions. Electrical Double layer formation at electrode surface: Theories of Double-Layer structure at electrode surface, diffuse-double-layer theory of Gouy and Chapman, the Stern Model, Influence of double layer on charge transfer processes. Current-potential relationship (Butler-Volmer and Tafel equations). Factors affecting electron transfer. Energetics at Solid/solid interface and solid/liquid interface, Determination of oxidation state and energetics of surfaces (XPS/UPs studies).

Prerequisites: Instructor’s consent is required

CY202 Applied Chemistry (2 Credits)

Introduction to Chemical kinetics, Basics in Electrochemistry: Electrochemical Principles and Reactions, Basic concepts of electrochemical cells and batteries, Basic concept of Industrial Chemistry, Laboratory vs Industrial synthesis, Homogeneous and Heterogeneous catalysis.

Prerequisites: Instructor’s consent is required

CY203 An Introduction to Food Science and Technology (2 Credits)

Introduction: Food in relation to health, Cooking methods; Cereals and Cereal Products; Pulses; Nuts and Oil Seeds; Milk and Milk Products; Eggs: structure and composition etc.; Flesh Foods; Vegetables and fruits: composition and nutritional value; Sugar and related products: structure, artificial sweeteners; Spices; Beverages and Appetites: Coffee, tea, milk and malted beverages etc.; Food Adulteration: types, international adulteration, metallic contamination, food laws; Food Preservation: different methods and chemicals employed for this process; Food Additives, Food Technology etc.

Prerequisites: Instructor’s consent is required

CY502 Chemical Kinetics and Surface Science (4 Credits)

Diffusion, Thermal conductivity, Viscosity, Effusion, Drift velocity, Nernst-Einstein equation, Stokes-Einstein equation Complex reactions, Chain reactions (free radical reaction, polymerization kinetics), Enzyme reaction, Inhibition kinetics, Temperature dependence of reaction rate: Linear and non-linear Arrhenius equation, Interpretation of Arrhenius parameters Various theories of unimolecular reactions, Potential energy surfaces for bimolecular reactions, Adiabatic and non-adiabatic curve crossing processes, Collision theory. Transition state theory, Activation/thermodynamic parameters, Erying equation Kinetics in the excited

state: Jablonski diagram, Kinetics of Unimolecular and bimolecular photophysical and photochemical processes, Quantum yield calculation, Excited state lifetime-quenching constant, Resonance energy transfer rates (RET), Rate and efficiency of RET, Dynamics of electron transfer, Solvent reorganization energy, Marcus theory of electron transfer. Importance of interfaces, adsorption isotherms, surface charge and zeta potentials, surface tension, characterization methods (SEM, TEM, XPS, UPS), surface catalytic reactions.

CY503 Coordination Chemistry (6 Credits)

Transition Metal Chemistry: Structure, bonding, and properties of transition metal ligand complexes - geometry, coordination number, isomerism, thermodynamic stability, chelate and macrocyclic effect, VBT, CFT and their limitations: d-orbital splitting, Term Symbols, microstates, R-S coupling, CFSE for d0 to d10 systems, pairing energy, low spin and high spin complexes and magnetic properties, J-T distortion, selection rules of electronic transition: Laporte Forbidden Rule, Spin Selection Rule Charge Transfer Spectra (CT), Ligand to Metal Charge Transfer (LMCT), Metal to Ligand Charge Transfer (MLCT), Ligand to Ligand Charge Transfer (LLCT), molecular orbital (MO) theory of small molecules.

Inorganic Reaction Mechanism: Substitution in Oh and Square Planner complexes, thermodynamics and kinetics, stability of complexes, lability, trans-effect, conjugate base mechanism, mechanism of redox reactions, racemization, electron transfer reaction: inner sphere and outer sphere mechanism, Marcus theory, photosubstitution and photo redox reactions of Cr, Co, and Ru compounds.

CY504 Chemistry of Main Group Elements (6 Credits)

Theories of bonding, acids and bases, thermodynamic acidity parameters; hydrogen and classical hydrogen bond, water, hydrates, hydrogen ions, metal hydrides, activation of hydrogen complexes; alkali metals in liquid ammonia; boron, boranes, carboranes, borazines and borates; allotropy of carbon; silane and polysilanes, silicone Polymers, silicates; compounds of nitrogen, activation of nitrogen, nitrogen fixation, hydrogen, halogen, oxygen and nitrogen compounds of phosphorous; oxygen and singlet oxygen, ozone, complexes of molecular oxygen; N-S compounds; sulphides, oxides and oxoacids of sulphur, chalcogenides and polychalcogenides; halogens, polyhalides, interhalogen compounds, charge-transfer complexes of Halogens; Compounds of Xenon and other noble gases; Zintl compounds and homometallic clusters.

CY505 Organic Reactions and Reagents (6 Credits)

A brief introduction to substitution, elimination, addition, oxidation, reduction, rearrangement and pericyclic reactions. Functional group transformations: alcohols to alkylating agents, Mitsunobu and related reactions, introduction of functional groups by nucleophilic substitution at saturated carbon, nucleophilic cleavage of C-O bonds in ethers and esters and inter-conversion of carboxylic acid derivatives. Oxidation: Metal based oxidizing reagents: A review and detailed discussion of chromium, manganese, ruthenium, silver and other metal based reagents. Non-metal based oxidizing reagents: DMSO, peroxide, peracid and oxygen based oxidation. Miscellaneous oxidizing reagents like IBX, DMP, CAN, DDQ, periodate etc. Reduction: Homogeneous and heterogeneous; Discussion on borane based racemic and chiral reagents, hydrogenations aluminium, tin, silicon based reducing agents. Dissolving metal reductions. Selectivity and protecting groups: Illustration of chemoselectivity, regioselectivity and stereoselectivity with examples; protecting groups for alcohols, amines,

acids, ketones and aldehydes.Cycloaddition reactions:Diels-Alder reaction; general features, dienes, dienophiles, selectivity, intramolecular and intermolecular reactions, hetero-Diels Alder reaction. 1,3-dipolar cycloaddition reactions; general features, dipoles, dipolarophiles. [2+2] cycloaddition reactions; general features, selected examples. Molecular rearrangements: Illustration of electron deficient and electron rich skeletal rearrangements with examples; Sigmatropic rearrangements-Claisen and related rearrangements, Cope and oxy-Cope rearrangements; 2,3-sigmatropic rearrangements and ene reaction.

CY506 Inorganic Chemistry Practical (2 Credits)

Synthesis inorganic and coordination compounds, Catalytic reaction and techniques, Purification and separation techniques, Characterization through analytical techniques, Qualitative determination of compounds, molecules and elements, Quantitative estimation of compounds, molecules and elements.

Prerequisites: CY503 and CY504. The course is meant only for MSc-CY students

CY507 Statistical Mechanics and Thermodynamics (4 Credits)

Concept of ensembles, partition functions and distributions, microcanonical, canonical and grand canonical ensembles, canonical and grand canonical partition functions, Boltzmann, Fermi-Dirac and Bose-Einstein distributions. Canonical partition function in terms of molecular partition function of non-interacting particles, Translational, rotational and vibrational partition functions.

Temperature dependence of the second virial coefficient. Thermodynamics of solids - Einstein and Debye models. T3 dependence of heat capacity of solids at low temperatures.

Fermi function, Fermi energy, free electron model and density of states, chemical potential of conduction electrons.

Prerequisites: For MSc-CY students without sufficient mathematics background, CY516 is an additional requirement.

CY508 Molecular Spectroscopy (4 Credits)

The rigid diatomic rotor, energy eigenvalues and eigenstates, selection rules, intensity of rotational transitions, the role of rotational level degeneracy, the role of nuclear spin in determining allowed rotational energy levels. Classification of polyatomic rotors and the non-rigid rotor. Vibrational spectroscopy, harmonic and anharmonic oscillators, Morse potential, mechanical and electrical anharmonicity, selection rules. The determination of anharmoncity constant and equilibrium vibrational frequency from fundamental and overtones. Normal modes of vibration, G and F matrices, internal and symmetry coordinates. Electronic transitions, Franck-Condon principle. Vertical transitions. Selection rules, parity, symmetry and spin selection rules. Polarization of transitions. Fluorescence and phosphorescence. Raman spectroscopy, polarizability and selection rules for rotation and vibrational Raman spectra.

Prerequisites: CY518 and CY502

CY509 Bioinorganic Chemistry (6 Credits)

Metal ions in biology: their occurrence and function, active-site structure and function of metalloproteins and metalloenzymes with various transition metal ions and ligand systems; oxygen binding properties of heme and non-heme proteins, their coordination geometry and

electronic structure, co-operativity effect, Hill coefficient and Bohr Effect; characterization of O bound species by Raman and infrared spectroscopic methods; representative synthetic models of heme and non-heme systems. Electron transfer proteins - active site structure and functions of ferredoxin, rubridoxin and cytochromes, and their comparisons. Vitamin B12 and cytochrome P450 and their mechanisms of action. Metals in medicine: therapeutic applications of cis-platin, radio-isotopes (e.g., Tc & I) and MRI agents. Toxicity of metals: Cd, Hg and Cr toxic effects with specific examples.

Prerequisites: CY 503. For MSc-CY students without sufficient biology background, CY517 is an additional requirement.

CY510 Stereochemistry and Reaction Mechanism (6 Credits)

Stereochemistry: Introduction to molecular symmetry and point groups. Topicity and prostereoisomerism, nomenclature of stereotopic ligands and faces, stereoheterotopic ligands and NMR spectroscopy. Centre of chirality, assignment of absolute stereochemistry, CIP rules, axial chirality, planar chirality and helicity, descriptors for absolute stereochemistry. Conformational analysis: acyclic systems, cyclic systems,cyclohexane and decalins, conformation and reactivity with examples from molecular rearrangements, neighbouring group participation, elimination reactions, formation and cleavage of epoxides, quantitative correlation between conformation and reactivity, Winstein-Eliel equation, Curtin-Hammett principle.

Stereoselectivity: Classification, terminology, principle of stereoselectivity, examples of diastereoselectivity and enantioselectivity including few examples from pericyclic reactions. Circular dichroism, ORD, cotton effect, application of ORD and CD in steriods, examples illustrating the usefulness of Cotton effect.

Reaction mechanisms: Definition of reaction mechanism, transition state theory, kinetics, qualitative picture. Substituent effects, linear free energy relationships, Hammett equation and related modifications. Basic mechanistic concepts like kinetic vs thermodynamic control, Hammond postulate, Curtin-Hammett principle, isotope effects, general and specific acid-base catalysis, and nucleophilic catalysis.

Nucleophilic substitution, various types, stability and reactivity of carbocations, nucleophilicity and basicity, neighbouring group participation and rearrangements, steric effects in substitution reactions, classical and non-classical carbocations.

Rearrangements: neighboring group participation, ring expansion, carbocation, pinacol, dienone-phenol, benzilic, Favorskii, Baeyer-Villiger and Beckmann rearrangements.

Prerequisites: CY505

CY511 Physical Organic Chemistry (2 Credits)

Symmetry-adapted orbitals. Mixing rules and buildup approach to molecules and molecular complexes. Energy surface for bond breaking and making. Kinetic vs thermodynamic control, Curtin-Hammett principle, Hammond Postulate Reactive intermediates: Carbocations, carbanions, carbenes, benzyne. Empirical scales for electronic, steric, and solvent effects. Mechanism according to free-energy correlation and correspondence with theory of orbital interaction. Illustrative examples. Linear free energy relationship, Hammett and Taft equations.

Prerequisites: CY 505. For MSc-CY students without sufficient mathematics background, CY516 is an additional requirement.

CY513 Physical Chemistry Lab (2 Credits)

Study of charge transfer complexes using colorimetric method, Study of fluorescence quenching, Phase behaviour studies, reaction kinetics study (spectroscopic and polarometric), Study of intermolecular hydrogen bonding, Denaturation Studies of biomolecules, Programming and electronic structure calculations.

Prerequisites: CY502. The course is meant only for MSc-CY students

CY514 Organic Chemistry Lab (2 Credits)

Separation of a binary mixture of organic compounds, synthesis and structural characterization of biologically relevant organic compounds, extraction and purifications of bio-sourced organic compounds, target oriented synthesis of macromolecules for emerging applications, templated synthesis and photo-physical characterization of nanomaterials for diverse applications.

Prerequisites: CY505. The course is meant only for MSc-CY students

CY516 Mathematics for Chemists (4 Credits)

Logarithm - Vectors - Probability and Statistics - Regression and Correlation - Matrix and determinant - Differentiation and integration

Prerequisites: Refresher course applicable only for MSc-CY students

CY517 Basics of Molecular Biology (4 Credits)

Cell theory and cell as the basic unit of life; Structure of prokaryotic and eukaryotic cell; Plant cell and animal cell.

Chemical constituents of living cells: Biomolecules-structure and function of proteins, carbohydrates, lipids, nucleic acids; Enzymes-types, properties, enzyme action.

Photosynthesis: Photochemical and biosynthetic phases of photosynthesis; Cyclic and non cyclic photophosphorylation; Chemiosmotic hypothesis; Photorespiration; C3 and C4 pathways;

Respiration: Exchange of gases; Cellular respiration - glycolysis, fermentation (anaerobic), TCA cycle and electron transport system (aerobic); Energy relationsNumber of ATP molecules generated; Amphibolic pathways.

Principles and process of Biotechnology: Genetic engineering (Recombinant DNA technology). Application of Biotechnology in health and agriculture:Genetically modified organisms.

Prerequisites: Refresher course applicable only for MSc-CY students

CY518 Quantum Chemistry (4 Credits)

Revisiting pre-quantum theory. Postulates of quantum mechanics (non-relativistic), Time-dependent and time-independent versions of Schrödinger equation, Eigenvalue problem for energy operator. Model problems (the particle-in-a-box, the harmonic oscillator, molecular vibration and normal modes). Hydrogen atom and atomic orbitals, probabilities and electron-density distribution. Born-Oppenheimer approximation, molecular orbitals from valence bond and molecular orbital theory and Linear Combination of Atomic Orbitals. Introduction to basis-set (Slater and Gaussian-type orbitals). Hartree-Fock Self-Consistent Field (SCF) theory,

electron correlation and variational principle; electron spin. Brief introduction to relativistic quantum chemistry.

Prerequisites: Instructor's consent is required

CY519 Organic Photochemistry (2 Credits)

Photochemistry: Basics principles of organic photochemistry - Reactivity of simple chromophores - photochemistry of carbon centered radicals.

Photochemistry of Alkenes: Excited States of alkenes - photochemistry of alkene - geometrical isomerisation - photosensitised geometrical isomerisation - photocycloaddition reactions of alkene - di-pi-methane rearrangement - electron transfer mediated reactions of alkene.

Photochemistry of carbonyl compounds: Norrish type I and type II reactions - photochemical cycloadditions - photochemistry of aromatic systems - electron transfer and nucleophile.

Prerequisites: CY502 and CY505.

CY520 Computations in Chemistry (2 Credits)

Computational Methods: Time-independent perturbation theory, degenerate states, Hellmann-Feynman theorem, Term symbols for atoms, Conjugated pi-systems and Huckel theory, frontier orbital theory, electronic structure calculations of simple systems.

Group theory: Concept of group, Symmetry operations and symmetry elements in molecules, Matrix representations of symmetry operations, Point groups, Irreducible representations and character tables, Great orthogonality theorem and its proof. Application of group theory to atomic orbitals in ligand fields, molecular orbitals, hybridization.

Prerequisites: CY 518. For MSc-CY students without sufficient mathematics background, CY516 is an additional requirement.

CY603 Organometallic Chemistry: Principles and Applications (6 Credits)

Definition, the first few organometallic complexes, thermodynamics and kinetics of organometallic compounds, the 18-electron rule. Different types organometallic bonding: Metal- alkyls, aryls, hydrides, organometallic bonding with multiple bonds, complexes of pi-bound ligands such as carbonyls, phosphine complexes, MO theory of organometallic complexes, isolobal analogy. Fundamental reaction process: oxidative addition and reductive elimination; insertion and elimination; ligand substitution processes, transmetallation, nucleophilic and electrophilic addition and abstraction. Preparative and characterization methods: general methods for the preparation of organometallic compounds and spectroscopic and analytical techniques for the elucidation of structure, properties and reactivates. Synthetic Applications: Coupling reactions, cyclization reactions, addition reactions, carbonylation, Pauson-Khand reaction, olefin oxidation, carbenes and activation reactions, hydrogenation, hydroformylation, isomerization, metathesis and polymerization reactions. CO_2 activation, C-H activation, C-C activation, click catalysis, oxidation reaction.

Prerequisites: CY503 and CY504.

CY604 Solid State Chemistry (4 Credits)

Crystal structure of solids; preparative methods; Braggs diffraction law and its limitations; crystal structure determination; phase diagram and phase transitions; optical; electrical and magnetic properties; conductivity; Nanostructured materials; organic solid state materials, conjugated polymers, fullerenes, carbon nanotubes and graphene.

Prerequisites: CY502 and CY503.

CY605 Advanced Organic Chemistry (6 Credits)

Retrosynthetic Analysis: Basic principles and terminology of retrosynthesis, Linear and convergent synthesis. Important strategies of retrosynthesis, functional group transposition, important functional group interconversions Protecting groups: Protection and deprotection of hydroxy, carboxyl, carbonyl, carboxy amino groups and carbon-carbon multiple bonds; chemo- and regioselective protection and deprotection; illustration of protection and deprotection in synthesis.

Selectivity in organic synthesis: chemo-, regio-, stereo- and enantioselectivity. Target-oriented synthesis: Designing organic synthesis, Asymmetric Synthesis: Use of chiral catalysts, organocatalysis, chiron approach and N-heterocyclic carbenes. Principles and use of enzymes in the syntheis of industrially important sugar/fatty acid esters, sugar nucleotide derivatives; enantiomeric pure compounds and biobased platform chemicals.

Methodolgies for the construction of 3-7 membered rings, medium and large rings. Application in natural product synthesis. Methodologies for the construction of 3-7 membered heterocyclic rings. Application In organic synthesis.

Prerequisites: CY505 and CY510.

CY607 Interpretative Molecular Spectroscopy (6 Credits)

Mass spectrometry, the production and analysis of positive ions, molecular ions, application of isotopic abundance measurements, fragmentation modes and rearrangement of ions. Mass spectra of certain chemical classes. Electronic spectroscopy (UV-visible,fluorescence and phosphorescence):Simple chromophoric groups, conjugated and aromatic systems. Characteristic absorption of organic and inorganic compounds. Infrared spectroscopy: Characteristic group frequencies of organic and inorganic molecules. Nuclear magnetic resonance spectroscopy of compounds containing 1H,13C,19F and 31P nuclei. Identification of organic and inorganic compounds using combination of spectral data.

Prerequisites: CY508.

CY608 Nanostructured Materials (2 Credits)

Concept of colloids, electrical properties of colloids, zeta potential, stabilization of nanomaterials, DLVO theory, Schultz-Hurdy Rule. Adsorption on nanoparticle surface, BET

adsorption isotherm (Principle). Surface functionalization of nanoparticles (Overview), grafting to and grafting from concept, Application in subsurface engineering, drug delivery systems, semiconductor work function modulation through controlled surface functionalization.

Prerequisites: Instructor’s consent is required

CY610 Molecular Physical Chemistry for Engineers (2 Credits)

Brief review of elementary thermodynamics and applications, laws of thermodynamics,

Gibbs free energy function, chemical application for Gibbs free energy.

Basic quantum chemistry, particle in the box, application of quantum theory, Schrodinqer equation, particle in a box, application of quantum theory to the energetics of electrons, atoms and molecules.

The kinetics of gases, Chemical kinetics, rates of chemical reactions in gases and surfaces.

Light-matter interactions and molecular spectroscopy, UV-Vis, IR, fluorescence and

Raman spectroscopy.

Prerequisites: Instructor's consent is required

CY612 Molecules in Electric Field (2 Credits)

Introduction to response of materials in presence of electric field, polarizability and hyperpolarizabilities, perturbation theory, linear response theory, calculations of polarizability and first and second hyperpolarizabilities of different molecules using Gaussian software.

Aim of this course is to provide the students an idea of how electronic systems behave under an externally applied electric field and how to calculate the response of the molecules in such fields.

Prerequisites: Instructor's consent is required

CY613 Materials for Emerging Applications (2 Credits)

Introduction to physical principles responsible for the properties of important functional materials, with emphasis on the design of material properties for current device technologies as well as emerging and potential engineering applications. Applications of these functional stimuli-responsive materials in 3D printing, actuation, self-cleaning glass, smart building and energy storage technology.

Prerequisites: Instructor's consent is required

CY614 Biomaterials Science and Engineering (2 Credits)

Introduction to Biomaterials, Background history, Properties (Mechanical and Physico-chemical), Resorbability, biodegradation, Biofilm, Material characterization - Analytical instruments, Biological responses, compatibility, cytotoxicity, Proteins, Tissue and blood Response Cell-biomaterial interaction, Animal trials (in vivo models), Metals types, classifications, applications, Polymers-types, classifications, applications, Biopolymers, Hydrogels, Drug delivery systems/encapsulation, Biomaterials for cardiovascular/ pulmonary/ ophthalmological applications, Biomaterials for cancer.

Prerequisites: Instructor's consent is required

CY615 Power of Computation in Chemistry (2 Credits)

Introduction to quantum chemical approximations used in theoretical chemistry, geometry optimization, study of energetics of chemical reaction, computation of various spectra.

Prerequisites: Instructor's consent is required

CY616 Molecular Geometry Predictions (2 Credits)

The meaning of geometry optimization, basis set, introduction to some useful QM methods (mainly HF and OFT) used for geometry optimization and implementation of geometry optimization techniques (GDIIS, Conjugate, Gradient, Quasi-Newton-Raphson) with those QM methods. Introduction to Gaussian and Gauss View software.

Prerequisites: Instructor's consent is required

CY617 Introduction to Solar Energy Materials (2 Credits)

Light harvesting materials, band-gap engineering in oxide/halide based semiconductors, metal-semiconductor junction. Conjugated polymer based systems and their synthesis and properties. DSSC and perovskite based systems and their light driven multifunctional application. Introduction to energy storage systems.

Prerequisites: Instructor's consent is required

CY618 Bionanotechnology (2 Credits)

Introduction to nanomaterials and bionanomaterials, nucleic acid nanotechnology and applications; synthesis and biofunctionalization of nanoparticles; RNA interference for gene knockdown; CRISPR-Cas9 for genomic engineering; protein nanotechnology, and design methods; amyloids, antibodies and their applications; biosensors; electrochemical biosensors; nanopore technology, artificial organelles, and cells.

Prerequisites: Instructor's consent is required

CY619 Industrial Inorganic Chemistry (2 Credits)

Importance of chemical industry, Industrial materials for environmental, renewable energy and energy storage applications.

Importance of primary inorganic materials, commodity chemicals, Mineral fertilizers, metals and their compounds.

Conversion methodologies of raw materials into industrial products, Metallic-lithium, sodium and its compounds.Inorganic pigments, TiO_2, lithopone, ZnS, ZnO and Fe_2O_3, luminescent pigments.

Prerequisites: Instructor's consent is required

CY620 Photocatalysis in Organic Chemistry (2 Credits)

Basic principles of photocatalysis; Visible-light photocatalysis, photoredox catalysis, Dual photocatalysis; organo-photocatalysis; photocatalysis in synthetic methods; applications of photocatalysis in total synthesis and pharmaceutical ingredients.

Prerequisites: Instructor's consent is required

CY622 Introduction to Molecular Modeling (2 Credits)

Basics of molecular modeling. Representation and visualization of molecules. Concept of target and lead identification and steps involved in drug discovery. Protein Data Bank {PDB). Modeling methods: Molecular docking, protein structure prediction methods, similarity search of ligands, quantitative structure-activity relationships (QSAR), pharmacophore modeling, physiochemical properties of compounds.

Working with modeling tools: Protein modeling using Modeller, SWISS-MODEL and Phyre 2, its validation using Ramachandran plot, and visualization using Maestro, PyMol and Swiss-PDB viewers. Protein and ligand preparation and molecular docking using Autodock.

Prerequisites: Instructor's consent is required

CY623 The Chemistry of Life (6 Credits)

Introduction to cells, chemistry of cells and bioenergetics, Proteins, DNA, chromosomes and genomes, DNA replication, repair and recombination, DNA replication, analyzing cells, molecules and systems, visualizing cells, membrane structure, transport of small molecules and electrical properties of membranes, intercellular compartment and protein sorting, Intracellular membrane traffic, energy conversion-mitochondria and chloroplasts, cell signalling, cytoskeletons, cell cycle, cell death, extracellular matrix, cancer, development of multicellular organism, stem cells and tissue renewal, pathogen and infection, the innate and adaptive immune systems.

Prerequisites: Instructor's consent is required

CY624 Chemistry of Heterocyclic Compounds and Natural Products (6 Credits)

Heterocyclic Compounds: Introduction to heterocyclic compounds, importance of heterocycles in medicine and materials, systematic nomenclature of heterocyclic compounds. Preparation, reactions and chemical properties of three membered heterocyclic compounds with one and two hetero atom, four membered heterocyclic compounds with one hetero atom. Structure, synthesis and reactivity of five and six membered heterocyclic compounds. Aromatic heterocyclic compounds: Pyrrole, furan, thiophene, pyridine, quinoline, isoquinoline, indole, etc. Named reactions of heterocyclic compound synthesis such as Fiest Benary furan synthesis, Knorr and Paal-Knorr pyrrole synthesis, Barton-Zard reaction, Robinson-Gabriel synthesis, Hofmann-Loffler-Freytag reaction, Hantzsch pyridine synthesis, Biginelli and Chichibabin reations. Natural Products: role of natural products in drug discovery, structure and chemical properties of alkaloids, terpinoids, and steroids. Physicocemical properties of amino acids, chemical synthesis of peptides, properties of mono- and di-saccharides.

Prerequisites: Instructor's consent is required

CY625 Cheminformatics and Rational Drug Design (6 Credits)

Introduction: Cheminformatics and rational drug designing.

Structure of macromolecules: Computational representation of chemical information, SMILES - Simplified Molecular Input Line Entry Specification, InChi - IUPAC International Chemical Identifier, 2D and 3D molecular structures, other representations.

Sequence and structure file formats: Plain sequence format, FASTA, GenBank flat file format, EMBL, NBRF/PIR, Swiss-Prot, PDB.

Chemical databases: Molecular descriptors and molecular similarity, data mining searching chemicals using online resources, molecular drawing and interactive visualization, applications.

Biological databases: Nucleotide and protein databases, pathway databases, literature databases, searching web-based biological databases, sequence analysis and comparison, data mining, patterns, motifs, profiles and domains.

Computer-aided drug design (CADD): Virtual Screening, drug-target interactions, combinatorial library design, ADME properties, drug-likeness and druggability, molecular dynamics simulation, hands on exercises.

Prerequisites: Instructor's consent is required

CY626 Advanced Molecular Simulation - Theory and Practice (6 Credit)

Introduction to programming: General introduction to algorithm, flowchart, and programming, introduction to syntax and hand-on exercises.

Density functional theory (OFT): Fermi and Coulomb holes - Different exchange-correlation.

Functionals - Kohn-Sham approach - Coding OFT - Hands-on exercise (Using Gaussian and

Gauss View software).

Classical Molecular dynamics (MD): Purpose of classical MD, Different interactions and force field, basic classical MD algorithm - Hands-on exercises.

Genetic Algorithm (GA): basic principle: Selection, Crossover, Mutation, Fitness; potential energy, function, application to atomic cluster.

Prerequisites: Instructor's consent is required

CY627 An Introduction to Catalyst Design: Function and Application (2 Credit)

Concepts in Catalyst: Design, Homogeneous Catalyst, Heterogeneous Catalyst, Metal Based Catalyst, Organo-Catalyst, Bio-Catalyst, Solid-Acid/Base Catalyst, Dual-Function Catalyst; Frustrated Lewis Pair (FLP), Engineering a Catalyst; Preparative Protocol, Characterization Techniques. Catalyst Function: Selected Examples of Industrially Important Catalytic Processes, Oxidation, Reduction, FLP Catalysis, Hydrocarbon Activation, Asymmetric Catalysis; Catalyst Poisoning, Transition State Model, Surface Phenomenon.

Prerequisites: Instructor's consent is required

CY628 Nano-engineered Molecular Materials (6 Credit)

Introduction to nano-engineered molecular materials; design, tailoring, and combination of chemical building blocks as carriers of desired physico - chemical properties to make such materials; structure-property relationships; application of such materials in automobile industry, aerospace and aeronautics, building/construction industry, consumer electronics, fuel cell, batteries, sensors, actuators, pharmaceutical industry and biomedical applications.

Prerequisites: Instructor's consent is required

CY629 Introduction to Health, Safety and Environmental Practices (2 Credit)

Concepts of HSE, Introduction to occupational safety and health (OHS), OHS regulations and law in India, technical standards, codes and guidelines on OHS, national and international standards of personal protective equipment and fire protection, health and safety at work place, hazards and risk assessments, waste management, fire protection and prevention, principles of chemical safety, radiation safety and bio safety, emergency preparedness, environment management and pollution control.

Prerequisites: Instructor's consent is required

CY630 Chemistry of Magnetic Resonance Imaging (MRI) and Contrast Agents (2 Credit)

Introduction: General principles of MRI - Theorical basis of NMR. Relaxation times: Saturation transfer - MRI pulse sequences - Basic of image contrast: Tl, T2 and T2 * weighted images Main contrast agents: Gd-complexes as T1 Agents - Iron oxide as T2 agents - CEST agents - Demerits of Gd complexes and alternatives.

Prerequisites: Instructor's consent is required

CY631 Semiempirical Quantum Methods (4 Credit)

Brief summary of self-consistent field method: Slater determinant, basis set, Hartree-Fock Roothan equations, basis set. The theoretical background of extended Huckel method with application on simple saturated molecules. The theoretical background of PPP method with application on simple molecules. The theoretical background of "neglect of differential overlap methods" (CNDO, INDO, NDDO, ZINDO) with application on simple molecules

Prerequisites: Instructor's consent is required

CY699 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: Only for MSc-CY students

CY795 Candidacy (0 Credit)

Evaluation of candidate's ability to carry out research, knowledge breadth of the student, research comprehension.

Prerequisites: Student must have completed the course credit requirement for the program registered for.

CY798 Independent Study (variable Credits)

Course content and credits are to be assigned by the course instructor.

Prerequisites: Instructor's consent is required

CY799 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: CY795.

Courses in Computer Science and Engineering

CS100 Software Tools & Technologies Lab I (4 Credits)

Scripting Languages (shell programming, python, Java Script), Web programming, GUI programming tools, Document Processing tools.

Prerequisites: IC100

CS101 Discrete Structures I (4 Credits)

Sets, relations, functions, Formal logic: Propositional logic: proof system, semantics, completeness, compactness. Notion of proof: proof by counter-example, the contrapositive, proof by contradiction, inductive proofs. Combinatorics: Basic counting techniques, pigeon-hole principle, recurrence relations Inclusion-exclusion principal Basics of graph theory.

Prerequisites: IC105

CS102 Data Structures (4 Credits)

Stacks, Queues, Lists; Sorting and Searching; Trees, Tree Traversals, Heaps; Binary Search, Binary Search Trees; Graphs: Representations, Depth First Search, Breadth First Search.

Prerequisites: IC100 and CS101. CS101 could be taken concurrently

CS200 Software Tools & Technologies Lab II (4 Credits)

Software Management tools, CVS, lab exercise for developing large system and application programs.

Prerequisites: CS100

CS201 Discrete Structures II (2 Credits)

Advanced counting techniques: generating functions, Polya's counting theorem. Introduction to number theory, and group theory; Introduction to probabilistic method in combinatorics.

Prerequisites: CS101

CS202 Algorithms I (4 Credits)

Algorithm analysis; worst and average case; Recurrences and asymptotes; Algorithms for sorting and selection; Randomized techniques; Search structures: heaps, balanced trees, skip lists, hash tables; Dynamic programming and greedy algorithms; Graph algorithms: breadth- and depth-first search, MSTs, shortest paths; NP-Complete problems.

Prerequisites: CS102, CS101 and CS201. CS201 could be taken concurrently

CS203 Theory of Computation I (4 Credits)

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.

Prerequisites: CS101, CS102 and CS202. CS202 could be taken concurrently

CS204 Computer Organization & Architecture (4 Credits)

Introduction, Overview of basic digital building blocks; truth tables; basic structure of a digital computer, Number representation, Assembly language programming for some processor, Basic building blocks for the ALU, Adder, Subtractor, Shifter, Multiplication and division circuits, Control path microprogramming (only the idea), hardwired, logic; External interface, Memory organization; Technology-ROM, RAM, EPROM, Flash etc. Cache; Cache coherence protocol for uniprocessor (simple), I/O Subblock, I/O techniques -interrupts, polling, DMA.

Prerequisites: IC150 and IC100

CS250 Operating Systems (4 Credits)

Introduction, System Calls; Processes and Threads Concepts; CPU Scheduling, Process Synchronization; Classical Problems (Producer Consumer, dining philosophers etc.); Deadlocks: Detection, Prevention and avoidance mechanisms. Memory Management, Segmentation& Paging Demand Paging; Files and Directories organization, Security and Protection Mechanisms; System Threats, Case studies: UNIX and NT.

Prerequisites: CS204 and CS102

CS251 Introduction to Language Processing (4 Credits)

Compiler structure: analysis-synthesis model of compilation, various phases of a compiler, tool based approach to compiler construction. Lexical analysis,Syntax analysis, Syntax directed translation, Type checking, Run time system, Intermediate code generation,Code generation.

Prerequisites: CS204 and CS203

CS252 Algorithms II (4 Credits)

Reviewing sorting and graph algorithms, Linear programming; Network flow algorithms; NP-completeness; Approximation algorithms; Randomized algorithms; Geometric Algorithms.

Prerequisites: CS202, CS203, CS253 and CS201. CS253 could be taken concurrently

CS253 Theory of Computation II (2 Credits)

Reviewing concepts of Turing Machines. Time and Space bounded computation. Reductions, theory of NP completeness, Introduction to time and space complexity.

Prerequisites: CS203

CS254 Database Management Systems (4 Credits)

Overview of file organisation techniques: sequential, direct, indexed, hashed, inverted, B-trees, Data models: relational, network, hierarchical, NoSql, Relational model: algebra, calculus, normal forms. Implementation of query languages, security and protection of data

recovery methods, Concurrent operations on data bases, introduction to distributed data base systems.

Prerequisites: CS250, CS102 and CS101. CS250 could be taken concurrently

CS300 Principles of Programming Languages (6 Credits)

Brief history of development of programming languages, Introduction - imperative programming, functional programming, logic programming and object oriented programming, Values and types, Notion of variables, Lifetime of variables: local, global and heap variables, Bindings and environments, bindables, scopeblock structure, static and dynamic scoping, Abstraction - procedural and function abstractions, Type systems - monomorphic type systems. Introduction to polymorphism, Types of polymorphism - overloading, parametric polymorphism, polymorphic types, Type checking and type inference – inference rules for monomorphic types, introduction to polymorphic type inference, Functional programming, Logic Programming, Object oriented programming.

Prerequisites: CS251

CS301 Computer Networks (6 Credits)

Layer approach, Packet switching techniques, Performance metrics; Applications: FTP, SSH, DNS, WWW; Transport Layer: TCP flow control, error control, congestion control, congestion control, UDP; Network Layer: Internetworking, Tunneling, Encapsulation, Fragmentation, IP, Routing and the related protocols, ICMP, ARP, RARP, DHCP, IPv6, RIP, OSPF; Advanced Internetworking, Multicast routing, Queuing disciplines and buffer management techniques; Data link layer: framing, medium access mechanism; Network security: Public key and private key cryptography, digital signature, firewalls; Advanced topics: SDN and Open flow Architectures.

Prerequisites: CS250

CS499 Thesis (Variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DUGC convener.

CS500 Science of Computation (TOC/DS/Algorithms) (3 Credits)

Reviewing concept of mathematical proof, sets, relations, bijection, Basic combinatorics and pigeon-hole principle, Elementary concepts in Graph Theory

Formal languages and various computational models: Finite Automaton, Push Down Automaton and Turing Machines. Halting Problem and Undecidability. P, NP, NP-Hard, NP-Complete classes

Methods for analysis of algorithms. Sorting and searching, Algorithm Paradigms: Greedy, Divide-Conquer, Dynamic Programming. Graph algorithms: breadth- and depth-first search, MSTs, shortest paths.

Prerequisites: Refresher course. Not applicable for BTech students

CS501 Computer Systems (OS, Architecture, Compilers, DBMS) (3 Credits)

Basic concepts of operating systems, architecture, compilers, and data base management systems.

Prerequisites: Refresher course. Not applicable for BTech students

CS502 Graph Theory and Applications (6 Credits)

Introduction to graphs, diagraphs, Paths, Cycles, connectivity, Euler tours, Hamiltonian paths and cycles, isomorphism, cut vertices, cut edges, contractions, minors, minimum spanning tree.

Graph Classes: trees, bipartite graphs, planar graphs, and other special classes of graphs.

Coloring of graphs: Vertex coloring, edge coloring and other coloring problems.

Matchings: Perfect matchings, Hall's theorem, Tutte's theorem, Konig's theorem.

Petersen's theorem.

Prerequisites: Instructor's consent is required

CS503 Lightweight Cryptography (6 Credits)

The Why and What of Lightweight Cryptography (LWC). Quantifying Lightweightness: Hardware/Software Perspectives. Lightweight block ciphers, hash functions, public key cryptography. Trends in lightweight design for non-linear/linear operations. The impact of MILP, SAT and SMT Solvers in LWC. Familiarization with tools: Sage, Gurobi, Z3. Design strategies for (lightweight) cryptographic hardware: ASIC/FPGA design flows. Familiarization with tools: LeonardoSpectrum, ModelSim. Understanding trade-offs in resource efficient cryptography. Advanced cryptanalytic strategies. Standardization efforts in LWC.

Prerequisites: Instructor's consent is required

CS505 Big Data Analytics (6 Credits)

Introduction: What is Big Data. Major tools used by data scientists, Data Analytics Fundamentals, Selected Topics of Distributed Systems, Hadoop Fundamentals I, Hadoop Fundamentals II (HDFS, Mapreduce), Spark Fundamentals I, Spark Fundamentals II (Spark ML}, SparkDL

Prerequisites: Instructor's consent is required

CS510 Approximation Algorithms (6 Credits)

Brief Introduction to NP-completeness and approximation algorithms, greedy algorithms and local search, rounding data and dynamic programming, linear programming and relaxations, randomized approximation algorithms, Semidefinite programing, primal dual method, Metric Rounding of LP Relaxations, Hardness of approximations.

Prerequisites: Instructor's consent is required

CS511 Introduction to Formal Verification and Its Applications (6 Credits)

Introduction to Formal methods of verification and model-checking; Modelling systems as finite-state systems; Introduction to first-order logic and temporal logics; Expressing properties

in logics; Binary Decision Diagrams; Algorithms for LTL and CTL; Introduction to SPIN and NuSMV model-checker.

Prerequisites: Instructor's consent is required

CS512 Parallel Algorithms (6 Credits)

Introduction: Different models of parallel computation, PRAM model and variations, interconnection networks, synchronous and asynchronous models, Performance Analysis.

Basic techniques: Matrix multiplications, Sorting, Searching and Selection, Balanced Trees, divide and conquer, partitioning, Pipelining, Tree contraction, Euler tour technique.

Graph Algorithms: Connected Components, Graph colouring, MST and shortest path algorithms.

Algorithms on Asynchronous model, Limit of Parallelizability, NC-reductions, P-completeness. Implementation: Introduction to Parallel Programming. Basic introduction to MPI and OpenCL.
Prerequisites: Instructor's consent is required

CS513 Electronic Payment Systems (6 Credits)

Evolution of currency; Traditional payment instruments: currency, cheques, demand drafts, debit systems etc; Credit systems: credit cards systems; Impact of communication networks, smart cards, introduction to various stakeholders and their roles in payment systems: Payment aggregators, payment gateways, payment processors etc.; Security aspects: Confidentiality, Integrity, Loss of control, loss of service. Dematerialized money and payment systems: Virtual money, digital money, electronic money etc. Purses, wallets; transactional properties: anonymity and traceability; payment settlement systems. Problems of identification, authentication,

authorization and settlements, cryptographic techniques for authentication using public key and symmetric key cryptosystems; password, tokens and biometric based authentications; case studies in India: EMV standards, metro ticketing, National mobility card, electronic toll collection, paytm and other wallet systems, NEFT, RTGS and IMPS systems, UPI, Aadhaar enabled payment systems (AEPS), frauds and dentification of frauds; safeguards etc; PKI concepts: certificates, non-repudiation, digital signatures, certification revocations; onefactor, two-factor and multifactor authentication.

Prerequisites: Instructor's consent is required

CS515 Randomized Algorithms (6 Credits)

Introduction and basic tools: random sequence. Generating uniform random numbers: the linear congruential method and others. Statistical tests for random numbers: Chisquare test, Kolmogorov-Smirnov test, empirical I theoretical I spectral tests. Non-uniform random sequences.

Tools and techniques of randomized algorithms: game theoretic techniques, moments and deviations, tail inequalities.

the probabilistic method: Lovasz Local Lemma, Markov chains and random walks, algebraic techniques.

Applications: Data structures, hashing, linear programming, computational geometry problems, graph problems, approximate algorithms, parallel and distributed algorithms, cryptography, online algorithms. Derandomization techniques.

Prerequisites: Instructor’s consent is required

CS516 Parallelization of Programs (6 Credits)

Introduction to parallelization; Performance; Amdahl's law; Techniques for extracting parallelism from sequential programs; Compile-time parallelization: Dependency analysis;

Dependency testing; Fine-grained parallelism -- loop interchange, reductions, node splitting, loop skewing, and loop peeling; Coarse-grained parallelism -- loop distribution and loop reversal; Control dependency; Runtime parallelization: Speculative execution, Inspector/Executor mechanisms, and Parallelizing irregular programs. Synchronization; Scheduling techniques; Parallelization for cache performance; Case studies.

Prerequisites: Instructor’s consent is required

CS517 Software Defined Networking (6 Credits)

Overview of traditional networks, SDN origin and evolution, programmable control and data planes, network abstraction, northbound/southbound interfaces, OpenFlow protocol, centralized and distributed SDN, Open vSwitch, network function virtualization, service function chaining, network slicing.

Hands-on using Mininet and RYU/ONOS controller: Introduction to network emulator tools like Mininet and OpenFlow protocol supported controllers like RYU and ONOS.

Prerequisites: Instructor’s consent is required

CS518 Simulation of Biology (2 Credits)

Cellular automata and Game of Life.
Coupled ordinary differential equations: SIR epidemiological model of disease spread.

Multi-Organism Interaction: Prisoner's dilemma, tit-for-tat, predator/prey models.

Prerequisites: Instructor’s consent is required

CS519 High Performance Computer Architecture (6 Credits)

Single-core processors: Introduction - performance - pipelining and memory review. Parallel processors: Introduction - types of parallel architectures: data-parallel architectures, shared memory architectures, and distributed architectures - programming models.
Data parallel architectures: GPU architecture - programming for GPUs – synchronization - architectural optimizations -- performance issues - case studies.
Shared memory architectures: Multicore processors - cache coherence protocols - synchronization - memory consistency models.

Distributed memory architectures: Scalability - interconnect - message passing - programming models - directo -based cache coherence - communication optimizations.

Prerequisites: Instructor’s consent is required

CS525 Distributed System (6 Credits)

Definition of distributed systems.
Goals of distributed system: Openness, Dimensions of scalability, Architectural models, Implementation problems,Hardware organization, Types of Distributed Systems.

Concept of Clock: Notion of solar time and wall clock time, External Clock-based mechanisms, Logical clock, Temporal ordering of events, Birman-Schipher-Stephenson protocol, Schipher-Eggli-Sandoz protocol, Multicast message ordering.

Global States: Cuts and Global States, Algorithm for recording global states, Liveness and Safety, Termination detection: Ring, tree and weight throwing scheme.

Leader Election: Impossibility results, Bully algorithm, Ring-based algorithms, Distributed spanning tree algorithms: Single initiator and Multiple initiators, Leader election in trees.

Mutual Exclusion: Coordinator-based solutions, Non-token-based solutions, Lemport's algorithm, Recart-Agrawal's algorithm, Maekawa's algorithm, Token-based solutions: Suzuki-Kassami's algorithm, Singhal's algorithm, Raymond's tree-based algorithm.

Agreement and Consensus: Equivalence of consensus problems Byzantine General Problem and its solutions, Lamport-Shostak-Pease algorithm.

Prerequisites: Instructor’s consent is required

CS550 Machine Learning (6 Credits)

Supervised Learning (Regression/Classification), Linear models: Linear Regression, Logistic Regression, Generalized Linear Models, Support Vector Machines, Nonlinearity and Kernel Methods, Multi-class/Structured Outputs, Ranking, Unsupervised Learning, Clustering: K-means/Kernel K-means, Dimensionality Reduction: PCA and kernel PCA, Matrix Factorization and Matrix Completion, Generative Models (mixture models and latent factor models), Assorted Topics, Evaluating Machine Learning algorithms and Model Selection, Ensemble Methods (Boosting, Bagging, Random Forests), Sparse Modeling and Estimation, Deep Learning and Feature Representation Learning.

Pre-requisites: MA605, DS250, DS251 (The course is a PC for BTech-DSAI)

CS551 Software Engineering (6 Credits)

Software Process Models, Requirement analysis and specification, Project planning & project monitoring, Design principles and structured design methodology, structured programming, verification concepts, Testing - testing purpose, levels of testing, black box testing, white box testing, different test case generation approaches.

Prerequisites: Instructor’s consent is required

CS552 Network Science (6 Credits)

Background, Graph theory related concepts, Network analysis metrics, Properties of many real networks, Network models and characteristics: Random Networks, Scale-free Networks, Small-world Networks, Community detection, Speeding Phenomena.

Prerequisites: Instructor's consent is required

CS553 Cryptography (6 Credits)

Introduction and brief history; mathematics background; symmetric cryptography: one-time pad, stream ciphers, block ciphers, hash functions, message authentication codes, authenticated encryption; information security vs. computational security: random function/permutation, pseudorandom function/permutation, integer factorization and discrete logarithm problems; asymmetric/public key cryptography: RSA and El Gamal based encryption and signature schemes; secret sharing; key distribution: Diffie-Hellman key agreement protocol, Kerberos; an advanced topic: Bitcoin-the first crypto-currency.

Prerequisites: Instructor's consent is required

CS554 Blockchain Technologies (6 Credits)

Introduction to cryptography, Cryptocurrency, Mining, Proof of work, Proof of Stake, Differences between Cryptocurrency and Blockchain, Security properties of Blockchain, Blockchain Networks and Anonymity, Ethereum, Zcash, Regulation

Prerequisites: Instructor's consent is required

CS555 Computer and System Security (6 Credits)

Basic Crypto: Public key and Private key Encryptions; Cryptographic protocols; Attack on Cryptographic protocols.

Operating System Security: Authentication and Authorization; Operating System and Program Security; Penetration Testing: Discovering and Exploiting Vulnerabilities; Malware Analysis; Security Policies and Models; Digital Rights Management and Trusted Computing.

Web Security: Pros and Cons of HTTPS; Cross site scripting; SQL Injection; Secure Session Management.

Network Security: Security aspects of TCP, DNS and Routing; Network defense tools: Firewall, Intrusion detection and filters; DDoS attack and defences.

Prerequisites: Instructor's consent is required

CS556 Hardware Security (6 Credits)

Fundamentals of hardware security and trust for integrated circuits. Cryptographic hardware, invasive and non-invasive attacks, side-channel attacks, physically unclonable functions (PUFs), true random number generation (TRNG), watermarking of Intellectual Property (IP) blocks, FPGA security, counterfeit ICs, hardware Trojans in IP cores and ICs.

Prerequisites: Instructor's consent is required

CS557 eCommerce (6 Credits)

Supporting technologies and tools, Architecture (e.g. Java commerce solution), Protocols and standards, Security, Business models, Payment mechanisms, and Case studies.

Prerequisites: Instructor's consent is required

CS558 CAD for VLSI (6 Credits)

Introduction: IC design flow, High level design, HDL design Synthesis - Full-custom, standard-cell, gate-array and FGPA, Backend, Verification and Test of ICS.

High-level synthesis: Partitioning, scheduling, allocation and binding

Logic Optimization: Review of Karnaugh map and Quine-McCluskey based optimization, Espresso, State assignment and optimization

Physical design automation algorithms: Floor-planning, Partitioning & Placement, Routing: Global routing, Detailed routing.

Introduction Verification Techniques: Introduction to Hardware Verification and methodologies, Binary Decision Diagrams(BDDs) and algorithms over BDDs, Combinational equivalence checking, Temporal Logics, Modeling sequential systems and model checking

VLSI Testing: Introduction, Fault models, Fault Simulation, Test generation for combinational circuits, Test generation algorithms for sequential circuits.

Prerequisites: Instructor's consent is required

CS559 Computer Systems Design (6 Credits)

Introduction to systems: Example Systems- Operating Svstems-Distributed File Systems Databases

Web Frameworks-Networks

Systems design intro: Setting goals for your system-Principles of good design

Modeling Fundamental: Quantitative Systems Design-Queuing Systems-Fundamental Laws and Applications-Asymptotic Bounds

Naming Schemes: Unix File System-Git-Network Naming

Caching: CPU Caching-CDN Caching

Resource Management: Scheduling-Load Balancing-TCP throughput Model

Other Topics: Virtualization-Security and Access Control-Reliability Models

Prerequisites: Instructor's consent is required

CS599 Thesis (Variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: For MTech-CS only

CS601 Cryptographic Protocols (6 Credits)

Security properties: privacy, correctness. fairness, robustness, independence of inputs: Semi-honest and malicious adversarial models; Universal composability; Commitment; Coin-flipping; Garbled circuit; Oblivious transfer: Yao's millionaires' problem; Secret sharing; GMW, BGW and BMR protocols; Fiat-Shamir Heuristic; Zero knowledge proofs: interactive and non-interactive; Pairing-based cryptography; Homomorphic encryption; Obfuscation; Witness encryption; Implementations: SPDZ and zkSNARK.

Prerequisites: Instructor's consent is required

CS607 Adversarial Machine Learning: Security and Privacy of ML (6 Credits)

Introduction of Machine Learning, Application and vulnerabilities.

Privacy and ML: Membership Inference Attack, Differential Privacy

Adversarial Attack and Defense: Decision Time Attack and Defense, Data Poinsoning Attack and Defense.

Attack and Defense of Deep Learning: 12, I., 111 norm attacks, Robust optimization, Retraining, Distillation,

Prerequisites: Instructor's consent is required

CS608 Advanced Graph Algorithms (6 Credits)

Review of Intractability. Introduction to several hard graph problems. Design of efficient algorithms for hard problems on various graph classes: Interval graphs, chordal graphs, comparability graphs, planar graphs etc.

fixed-parameter tractability and intractability; kernelization; Techniques For parameterized algorithms, Tree-width and tree decompositions, structural graph parameters, randomized methods, lower bounds based on ETH.

Prerequisites: Instructor's consent is required

CS610 Lower Bounds and Impossibility (6 Credits)

Introduction to lower bounds, different techniques: counting, reduction, decision tree, indistinguishability, adversaries, valency, covering, graph theory and linear algebra. Lower bounds results in data structures, computational complexity theory, communication complexity theory, distributed computing, parallel computing.

Prerequisites: Instructor's consent is required

CS611 Wireless Network & Mobile Data Management (6 Credits)

Introduction: Mobile and pervasive computing system, Characterizing mobile distributed system and mobile cloud system, Examples of mobile applications, Smart environments. Cellular wireless communication system: Frequency planning, Measurement of traffic intensity, Channel assignment, Handoff. GSM and GPRS system: GSM architecture, GSM Signaling protocols, GPRS architecture. WLAN: IEEE standards for WLAN, Topology, Spread spectrum, Wireless MAC. Routing protocols for mobile ad hoc networks: Classification of protocols, Proactive and reactive protocols, Distance vector-based protocols, DSDV, AODV. Mobile application protocols: Mobile IP, Mobile shell. Location management: Registration and

paging, Two-tier scheme, Hierarchic scheme, Caching, and replication. Data dissemination and broadcast disks: Data delivery mechanisms, Broadcast disk, Memory hierarchy, Client-side cache management. Indexing in Air: Temporal address matching and directory, Tuning and access latencies, Distributed indexing scheme, Exponential indexing scheme

Prerequisites: Instructor's consent is required

CS612 Introduction to Computational Complexity (6 Credits)

The Computational Model, Turing Machines, Decidability, Reducibility, Time Complexity, Space Complexity, Hierarchy Theorems, Boolean Circuits, Circuit Complexity, Limits of the diagonalization method, Randomized Computation, Probabilistic Turing machine, Interactive Proofs, Introduction to Quantum Computation and Algorithms

Prerequisites: Instructor's consent is required

CS613 Social and Complex Network Analysis (6 Credits)

Introduction to Structure of Graphs, Link Analysis: Page Rank, Random Graph Model, Network Construction and Inference, Motifs and Graphlets, Community Structure in Networks and Community Detection, Link Prediction, Graph Representation Learning, Network Effects and Cascading Behavior, Influence Maximization in Networks, Outbreak Detection in Networks, Network Robustness and Preferential Attachment, Network Centrality, Network Evolution, Knowledge Graphs and Metapaths, Network analysis tools: Networkx, Gephi, Cytoscape, Pajek etc.

Prerequisites: Instructor's consent is required

CS614 Quantum Symmetric-Key Cryptanalysis (6 Credits)

Overview of quantum information and quantum computing: Qubits, quantum states, quantum gates, Superdense coding, Quantum circuits and reversible computation, (Partial) measurements, Quantum Entanglement, Quantum Teleportation, Deutsch's Algorithm

Quantum search: A simple searching algorithm: the Deutsch-Jozsa algorithm, Simon's algorithm, Amplitude amplification and Grover's Algorithm, Brassard Hoyer Tapp (BHT) Algorithm

Shor's factoring algorithm and its impact on cryptography.

Quantum Cryptanalysis: Quantum Adversarial/Attack Models, Application of Simon's and Grover's search algorithm in symmetric key cryptanalysis (Grovermeets- Simon, Offline Simon's Algorithm), Quantum security analysis of AES, Quantum collision finding on hash functions

Quantum resource estimation: Synthesis and optimization of quantum circuits.

Quantum Programming with Qiskit and ProjectQ

Prerequisites: CS553

CS795 Candidacy (0 Credit)

Evaluation of candidate's ability to carry out research, knowledge breadth of the student, research comprehension.

Prerequisites: Student must have completed the course credit requirement of the program registered for.

CS798 Independent Study (variable Credits)

Course content and credits are to be assigned by the course instructor.

Prerequisites: Instructor's consent is required

CS799 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: CS795.

Courses in Data Science and Artificial Intelligence

DS100 Mathematical Foundations of Data Science (4 Credits)

Bayes Rule and its connection to inference, various sampling methods, Modern PAC analysis (probably approximately correct).

Geometry of high-dimensional space, distance metrics used for numerical and text data. Locality sensitive hashing (LSH).

Matrix approximation techniques: Principal Component Analysis, SVD and dimensionality reduction.

Application of transforms (Fourier, Laplace) to data analysis.

Linear regression problem, gradient descent.

Introduce some representative datasets using images, documents and tables. Use Matlab/Python/R to demonstrate and explore basic concepts.

Prerequisites: IC104, IC105 and IC152, IC152 could be taken concurrently.

DS200 Architecture for Management of Large Datasets (6 Credits)

Design of distributed program models and abstractions, such as MapReduce, Dataflow and Vertex-centric models, for processing volume, velocity, and linked datasets, and for storing and querying over NoSQL datasets.

Approaches and design patterns to translate existing data-intensive algorithms and analytics into these distributed programming abstractions.

Distributed software architectures, runtime and storage strategies used by Big Data platforms such as Apache Hadoop, Spark, Storm, Giraph, and Hive to execute applications developed using these models on commodity clusters and Clouds in a scalable manner. Design of distributed program models and abstractions, such as Map Reduce, Dataflow and Vertex-centric models, for processing volume, velocity, and linked datasets, and for storing and querying over NoSQL datasets.

Approaches and design patterns to translate existing data-intensive algorithms and analytics into these distributed programming abstractions.

Distributed software architectures, runtime and storage strategies used by Big Data platforms such as Apache Hadoop, Spark, Storm, Giraph and Hive to execute applications developed using these models on commodity clusters and Clouds in a scalable manner.

Prerequisites: DS250 and CS202

DS201 Statistical Programming (4 Credits)

Probability and statistics: Review, Statistical measures and tests, Statistical analyses using Rand Python, and MATLAB, Linear Regression, Hypothesis Testing, Resampling Techniques, and Bootstrapping, Introduction to contemporary statistical packages

Prerequisites: IC100 and DS100

DS210 Data Analytics and Visualization Lab (2 Credits)

Data analysis using SQL, Data Analysis and Visualization using Python scripts and libraries (e.g., Pandas, Numpy, Plotly, Dash), Data Analysis and Visualization using NoSQL DBs (e.g., MongoDB, Neo4j DB, Influx DB), NLP, Image processing and Speech processing with libraries (e.g., Scikit-image, OpenCV, Speech Recognition, NLTK).

Prerequisites: DS250 (Can be registered concurrently with this course)

DS220 Big Data Analytics Lab (2 Credits)

Map Reduce Basic Design patterns: Word Count, Summarization, Indexing, Filtering, Top-K, Partitioning, Binning Map Reduce Advanced Design patterns: Joins, Job Chaining, 1/0 Patterns Map Reduce Scheduling with YARN Hadoop Ecosystem: Pig, Hive, HBase.

Prerequisites: DS200 (Can be registered concurrently with this course)

DS250 Data Analytics and Visualization (6 Credits)

Data science workflow, Automated methods for data collection, Data and Visualization Models, Data wrangling and cleaning, Exploratory data analysis

Building Models for: Classification, Clustering, Regression, Time-series, Association Analysis, Recommendation Systems.

Model evaluation, statistical tests for significance of predictors. Model regularization: ridge, lasso, elastic-net.

Visualization Software and Tools, Visualization Design, Multidimensional Data, Graphical Perception, Interaction dynamics for Visual Analysis, Using Space Effectively, Stacked Graphs, Geometry & Aesthetics.

Networks, Graph Visualization and navigation in information Visualization, mapping & Cartography, Text Visualization

Prerequisites: DS100 and CS202. CS202 could be taken concurrently.

DS251 Artificial Intelligence (6 Credits)

Problem solving, search techniques, control strategies, game playing (mini-max), reasoning, knowledge representation through predicate logic, rule-based systems, semantic nets, frames, conceptual dependency formalism. Planning. Handling uncertainty: Bayesian Networks, Dempster-Shafer theory, certainty factors, Fuzzy logic, Learning through Neural nets - Backpropagation, radial basis functions, Neural computational models - Hopfield Nets, Bolzman machines, MATLAB programming, introduction to Machine Learning, Supervised and Unsupervised Learning, Introduction to Machine Learning libraries

Prerequisites: CS202

DS252 DSAI Lab (2 Credits)

Introduction, Data in Data Analytics, Descriptive Statistics, Programming with R, Probability Distributions, Sampling Distributions, Statistical Inference, Statistical Tables Relation

Analysis, Analysis of Variance (ANOVA), Bayesian Classifier, Information Based Classification.

Support Vector Machine Sensitivity Analysis Similarity Measures.

Prerequisites: DS250 and DS201. Both DS250 and DS201 could be taken concurrently.

DS320 AI and Machine Learning Lab (2 Credits)

Design and implementation of AI and machine learning models for image processing, speech processing, NLP and game playing. Deploy machine learning models on mobile, AI/ML development board/kits.

Prerequisites: DS251, CS550 (may be registered concurrent with this course)

DS500 Big Data Algorithms (6 Credits)

Introduction to big data and its peculiarities. Map Reduce as a datacenter-scale programming abstraction. Parallel algorithm design to process massive datasets. Algorithms to solve problems from a variety of domains: web search, e-commerce, social-networking, machine learning. Streaming Algorithms, sketching algorithms. Brief discussion of next generation systems like Spark and Flink.

Prerequisites: Instructor's consent is required

DS501 Information Retrieval (6 Credits)

Introduction, Document Indexing, Storage and Compression, Retrieval Models, Performance Evaluation, Text Categorization and Filtering, Text Clustering, Web Information Retrieval, learning to rank, Advanced Topics (Text Summarization, Question answering, Recommender Systems)

Prerequisites: Instructor's consent is required

DS502 Basic Maths for Data science and Artificial Intelligence (3 Credits)

Brief overview of Linear algebra: Orthogonality, Systems of Linear Equations Eigen decomposition and Diagonalization, Low rank Matrix Approximation.

Optimization: Optimization of Univariate and multivariate function, Fitting. model to Data, Linear programming, Gradient Descent, Stochastic Gradient Descent.

Probability and Statistic: Probability and Random Variables, Discrete and Continuous, Probabilities, Density function and estimation, Expected Value, Variance, Joint, Marginal, and Conditional Distributions, Bayes' Rule, Statistical Independence, Model Given Data.

Prerequisites: Instructor's consent is required

DS503 Advanced Data Analytics (6 Credits)

Analysis techniques for high dimensional datasets; Algorithms for massive data problems; Graph representation learning and Graph Neural Networks; Link Prediction, Graph and Node classification, Applications of Graph learning; Network algorithms including those for the World

Wide Web; Clustering algorithms for high dimensional datasets; Advanced techniques for Time Series analysis: Motifs, Anomaly detection, Matrix Profile Technique

Prerequisites: Instructor's consent is required

DS504 Natural Language Processing (6 Credits)

Basic Text Processing: Tokenization, Stemming; Language Modeling: N-grams, smoothing; Morphology, Parts of Speech Tagging; Syntax: PCFGs, Dependency Parsing; Topic Models; Distributional Semantics; Lexical Semantics, Word Sense Disambiguation; Information Extraction: Relation extraction; named entity recognition, coreference resolution, sentiment analysis, document summarization, discourse, machine translation; Deep Learning for NLP: Basic and Advanced Models (Seq-to-Seq, CNN, Word2Vec, BERT).

Prerequisites: Instructor's consent is required

DS505 Programming for Data Science and Artificial Intelligence Lab (3 Credits)

Low Code Data Analysis and Visualization software such as Alteryx, Tableau, KNIME; Data Structures: Lists-Graphs-Dictionary-Tuples-Multi-dimensional arrays/Tensors; Algorithms: Sorting-Histograms-Graph Algorithms-Matrix Operations-Gradient Descent; Data Analysis: SQL Queries-MongoDB-NetworkX-Sklearn-Graph Plotting {Cytoscape/Gephi).

Prerequisites: Instructor's consent is required

DS506 Computer Vision (6 Credits)

Introduction: Introduction and Goals of Computer Vision; Introduction to Image Formation, Radiometry, Capture and Representation; Geometric Camera Models; Stereo geometry; Geometric Transformation.

Visual Features and Representations: Texture Descriptors; Colour Features; Blobs and Corner Detection; Object Boundary and Shape Representations; Interest or Corner Point Detectors; Scale Space and Scale Selection; SIFT, SURF; HoG, LBP, Saliency, etc.

Visual Matching: Bag-of-words; RANSAC; Pyramid Matching; Optical Flow, Motion Estimation and Object Tracking.

Applications of Computer Vision: Machine Learning Algorithms and their Applications in some of the areas such as Medical Image Segmentation, Face and Facial, Expression Recognition, Image Fusion, Gesture Recognition.

Prerequisites: Instructor's consent is required

DS599 Thesis (Variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: For MTech-DSAI only

DS601 Digital Image Processing (6 Credits)

Fundamentals - Visual perception, image sampling and quantization; Intensity transformations - nonlinear transformations for enhancement, histogram equalization; Spatial filtering - convolution, linear and order statistic filters, unsharp masking. Image Transforms - discrete Fourier transform, discrete cosine transform; Transform domain processing - image smoothing, specialized filters (Gaussian, Laplacian, etc); Image restoration - using spatial filters, Wiener filter; Introduction to colour spaces and colour image processing; orphological image processing - erosion and dilation, opening and closing, hit-or-miss transform, thinning and shape decomposition; Binarization and Image segmentation - edge detection, thresholding, region-based segmentation; Image compression - fundamentals, lossless coding, predictive coding, transform coding.

Prerequisites: Instructor's consent is required

DS602 Digital Speech Processing (6 Credits)

Review of digital signal processing: Discrete-time signals and systems, transform representation of signals and systems, fundamentals of digital filters, sampling.

Fundamentals of human hearing and speech perception: Speech production, acoustic phonetics, Anatomy and functions of the ear, the perception of sound, auditory models, lossless tube models

Time-domain and Frequency-domain methods for speech processing: Short-time analysis (energy, magnitude, zero-crossing rate, autocorrelation), Discrete-time Fourier analysis, short-time Fourier analysis, spectrograms, Overlap-add method of synthesis, filter-bank summation method of synthesis

Cepstrum and homomorphic speech processing: Homomorphic analysis, computing the short-time cepstrum and the complex cepstrum, cepstrum analysis of all-pole models, cepstrum distance measures
Linear predictive analysis of speech: Basic ideas, gain computation, frequency-domain interpretation, solving LPC equations, the prediction error signal, representations of LP parameters

Algorithms for estimating speech parameters: Median smoothing, speech-background discrimination, pitch period estimation, formant estimation

Digital coding of speech signals: Sampling speech signals, statistical models for speech signals, quantization (instantaneous, adaptive), quantising speech model parameters, delta modulation, DPCM, ADPCM

Applications: Speech recognition, speech enhancement, speaker recognition, Hidden Markov models for speech recognition, statistical methods for speech enhancement, factor anal sis for speaker recognition.

Prerequisites: Instructor's consent is required

DS603 Advanced Machine Learning (6 Credits)

Biases and Fairness: Fair representation learning- fairness through input manipulation- Fair NLP Fairness in vision representations- Fair causal reasoning

Interpretability and transparency: feature interaction for interpretability- Example and visualization-based methods- interpreting deep neural networks

Robustness and adversarial attacks-adversarial defence

Privacy of data-differential privacy-federated learning

Prerequisites: DS250 or CS550

DS604 Big Data Processing with Spark (3 Credits)

Spark basics: Application Concepts, Transformations, Actions, Spark UI

Spark Structured APIs: Data Frames API, Dataset API

Stream Processing: Programming Model, Sources and Sinks, Transformations, Aggregations, Joins, Stateful Computations

Spark ML: Designing ML pipelines, Managing and Deploying

Prerequisites: Instructor's consent is required

DS795 Candidacy (0 Credit)

Evaluation of candidate's ability to carry out research, knowledge breadth of the student, research comprehension.

Prerequisites: Student must have completed the course credit requirement of the program registered for.

DS798 Independent Study (variable Credits)

Course content and credits are to be assigned by the course instructor.

Prerequisites: Instructor's consent is required

DS799 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: CS795.

Courses in Electrical Engineering

EE101 Digital Signals Processing (4 Credits)

Continuous-time and discrete-time signals and systems Random Processes, Linear systems, Fourier transform, Frequency response of LTI systems, Lowpass, highpass and bandpass filters, Z-transform, Sampling and reconstruction of bandlimited signals. Approximate reconstruction methods (ZOH, FOH), The Discrete Fourier transform and Fast Fourier transform (FFT) algorithm, Implementation of discrete-time systems using FFT.

Prerequisites: IC153 and EE103. Both IC153 and EE103 could be taken concurrently.

EE103 Circuits and Systems (6 Credits)

Introduction to Signals, Fourier Series and Fourier Transform, LTI System, Laplace Transform, Convolution, Circuit Elements, AC Power and Phasor, Network Theorems: (KVL, KCL, Max. Power Transfer, Thevennin, Norton, Milimann, Star-Delta, Telegen). Dot Convention and Dependent Sources, Application of Laplace Transform in Circuit Analysis, Transient Analysis, Final value theorem and steady state analysis, Transfer Function, Resonance, Bode Plot, Introduction to Filters.

Prerequisites: IC104

EE201 Electronic Devices (6 Credits)

Semiconductor Materials, concept of doping, majority and minority carriers, recombination and generation, temperature dependence of conductivity, Zener and avalanche breakdown, BJT, FET, JFET, MOSFET, Switching characteristics of devices: switching phenomenon in diodes, BJT, MOS & CMOS, switching times, switching speeds, Other elements: LED, Solar cells, Photo diodes, Thyristor, Resonant tunnel diode etc.

EE202 Control Systems –I (6 Credits)

Mathematical Modelling and Transfer Function, Signal Flow Graph, Feedback System, Time response analysis, Performance Indices, Frequency Response (Polar Plots), Stability Analysis (Routh-Hurwitz, Bode, Nyquist, Root Locus), Compensator Design (Lead, Lag, Lead-lag), PIO Controller. Introduction to MATLAB Control System Toolbox.

Introduction to State space and state variables, Eigen Vector, Canonical Forms, Observability and Controllability. MIMO systems.

Prerequisites: EE103

EE203 Embedded Systems (4 Credits)

Introduction to Embedded Systems Design, Software Design Basics, ARM Cortex-M Processor Core, C Code as Implemented in Assembly Language, Interrupts, General Purpose Digital Interfacing, Analog Interfacing, Timers, Serial Communication.

Prerequisites: IC150 and IC100

EE204 Analog Circuits (6 Credits)

Semiconductor Materials, concept of doping, majority and minority carriers, recombination

and generation, temperature dependence of conductivity, Zener and avalanche breakdown, BJT, FET, JFET, MOSFET, Switching characteristics of devices: switching phenomenon in diodes, BJT, MOS & CMOS, switching times, switching speeds.

Prerequisites: EE103 and EE201

EE205 Power Engineering–I (6 Credits)

Single phase AC systems: Introduction to real/reactive/apparent powers, power factor, introduction to phasors, phasor analysis and phasor diagram, poly phase AC systems.

Working principle, construction and applications of transformers, DC machine, AC, machines special machines and energy efficient motors.

Overview of the structure and components of power systems, major issues related to power systems.

Overview of power electronics devices and generic power electronic circuits.

Prerequisites: EE103 and IC104

EE207 Engineering Electromagnetics (4 Credits)

General field properties; Review of vector calculus and coordinate systems; static electric fields, static magnetic fields; Biot-Savart and Ampere's laws; Boundary value problems and method of images; Magnetic vector potential, Materials: dielectric and magnetic materials, their properties, capacitance and inductance, applications, Transformers and electrical machines, Time-varying fields and Maxwell's equations in differential, integral and phasor forms. Wave equation., Transmission lines fundamentals. Smith Charts, Impedance matching. Waveguides: modal analysis of rectangular metallic waveguides, Antennas.

Prerequisites: IC102 and IC153

EE208 Electrical Machines (4 Credits)

Single phase AC systems: Introduction to real/reactive/apparent powers, power factor, introduction to phasors, phasor analysis and phasor diagram, poly phase AC systems.

Working principle, construction and applications of transformers, DC machine, AC, machines special machines and energy efficient motors.

Overview of the structure and components of power systems, major issues related to power systems.

Overview of power electronics devices and generic power electronic circuits.

Prerequisites: EE103 and IC102

EE251 Control Systems Lab (2 Credits)

Design and Simulation of PID controller in Simulink and circuit implementation, Position control of AC servo motor using Analog and Digital PID controller, Position control of DC servo motor using Analog and Digital PID controller, Speed control of DC servo motor using Analog and Digital PID controller, Inverted pendulum on a cart - Linear model identification, PID control of cart position, Inverted pendulum on a cart - Inverted pendulum control, real time pendulum swing-up control, Magnetic levitation system - Non-linear model testing, model linearization, model identification, Magnetic levitation system - PD and PID control of ball position.

Prerequisites: EE202

EE301 Communication Systems-I (4 Credits)

Analog modulation techniques, Sampling, quantization and pulse modulation, Overview of multiplexing and multiple access techniques: TDM(A), CDMA, FDM and OFDM(A), Digital modulation techniques, Digital communication over bandlimited channels.

Prerequisites: EE103 and IC105

EE304 Computer Networks (6 Credits)

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. 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; Introduction to software defined networks.

Prerequisites: Instructor's consent is required

EE305 Semiconductor Device Modelling (6 Credits)

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.

Prerequisites: Instructor's consent is required

EE306 Power Engineering – II (6 Credits)

Converters: basics of dc-dc converters in continuous mode; buck, boost and buck-boost converters, flyback converter, voltage source inverters, power electronic converters with ideal switching, Speed control of induction machines, Synchronous machines, Power system: structure of power systems, transmission lines, speed and voltage control, Introduction to DC systems and renewable energy.

Prerequisites: Instructor's consent is required

EE307 Control Systems – II (6 Credits)

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.

Prerequisites: Instructor's consent is required

EE308 Information Theory and Coding (6 Credits)

Entropy, Relative Entropy, and Mutual Information, Typical Sequences and Asymptotic Equipartition Property, Source Coding and Data Compression, Channel Capacity, Differential Entropy and Gaussian Channel, Linear Binary Block Codes, Convolutional Codes.

Prerequisites: Instructor's consent is required

EE309 Power Electronics (6 Credits)

Characteristics of semiconductor power devices: Diode, Thyristor, Triac, GTO, MOSFET, IGBT; DC to DC conversion: Buck, Boost and Buck-Boost converters; Single and three phase configuration of uncontrolled rectifiers, Line commutated thyristor based converters, Bidirectional ac to de voltage source converters, Issues of line current harmonics, Power factor, Distortion factor of ac to de converters, Single phase and three phase inverters, Sinusoidal pulse width modulation.

Prerequisites: Instructor's consent is required

EE311 Advanced Digital Circuits (4 Credits)

Computer Arithmetic for data path design: Fast adders, multipliers, dividers. Design of basic computer components such as arithmetic logic units, Embedding a Soft-core microcontroller.

Prerequisites: Instructor's consent is required

EE351 Electrical Machine Lab (2 Credits)

This lab is intended to show the practical application of the Electric Machine principles which the students have learned in the theory course. The experiments performed are as follows:

Open circuit and short circuit tests of single-phase transformer, Polarity and Sumpner's test of a transformer, Speed control of a DC shunt motor, V and inverted V curves of synchronous motor, No load test and blocked rotor tests of a 3-phase induction motor, Determination of the open circuit characteristic of a 3-phase, Synchronous generator, Determination of the open circuit characteristics of a DC shunt generator.

Prerequisites: EE208

EE352 Communication Lab (2 Credits)

This lab is intended to provide students a working knowledge of modulation schemes used in commercially available communication systems by using a Software Defined Radio approach. The experiments performed are as follows:

Introduction to SDR &USRP: Full Adder, Signal Multiplier, etc, **Analog: AM, FM, PM** Modulator and Demodulator. Use a live audio source. Local FM radio station playout and also FM transmitter (an audio file will be sent via USRP and received on mobile). **Digital: ASK, FSK, PSK** Modulator and Demodulator. Use a live audio source. **Sampling Theorem, PCM:** Three cases of Nyquistic Criteria, PCM Modulation and Demodulation, **LoRa Application**

LoRaWAN Packet (chirp spread spectrum) transmitter and receiver. **WiFi Application**: WiFi Beacon Reception. **LTE Applications:** Synchronization and orthogonality. **LTE Applications:** System Information Reception and Cell Id. **Bluetooth Application**: Bluetooth Low Energy Service Discovery. **RFID/NFC:** Manchester Encoding.

Prerequisites: EE301

EE353 Electrical Engineering Lab-IV (2 Credits)

Selected experiments on following topics of Circuit Theory, Semiconductor Devices and Analog Circuits:

1. BJT and diode - single transistor amplifier and rectifier.

2. FET - Determination of equivalent Model by AC small signal analysis.

3. Op amp - Open and closed loop characterization, Bode plots, Realization of Inverting and non-inverting amplifiers.

4. Mathematical operation with Op amps - summing, differentiating, log and antilog amplifiers, integrator and differentiator.

5. RC and RLC circuits - C-V characterization, time and frequency response, resonance.

6. Twin-T network - Determine of two port parameters (Z, Y, ABCD and hybrid parameters) study on filtering action of Twin T.

7. Signal generators and Multivibrators-Sine, Square and Triangular wave generator.

8. Design of Active filters: Sallen-key and State variable filters.

9. Gyrator circuits: Op amp-based inductor realization and negative resistors.

Prerequisites: EE204

EE401 VLSI Technology (6 Credits)

Environment for VLSI Technology, Crystal defects, Wafer cleaning processes and wet chemical etching techniques; Impurity incorporation; Oxidation; 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.

Prerequisites: Instructor’s consent is required

EE402 Beyond Moore Electronics (6 Credits)

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

Prerequisites: Instructor’s consent is required

EE404 Power System Analysis (6 Credits)

Power Systems Evolution of Power Systems, Energy Sources Structure of Bulk Power Systems Basic three phase system concepts Power System Components: Generators, Loads, Transformers, Transmission Lines etc. Modelling, Performance and Constraints of these components Formulation/Solution of steady state equations for interconnected systems: Balanced and Unbalanced systems. Positive Sequence Network, Per Unit System, Y-bus formation Simple example of a load flow solution Introduction to generator swing equations and stability issues, Simple Example of Loss of synchronism Interconnected System Operation and Control: Operational Objectives, Frequency Control, Voltage Control and Power Flow Control: introduction to HVDC transmission and FACTS Economic Issues in Power Systems. Analysis of Faulted Power Systems and Protection: Unbalanced System Analysis using Sequence Components, Equipment Protection Schemes: Overcurrent, Differential and Distance Protection, Relay coordination Preventive Control and Emergency Control System Protection Schemes) Blackouts and Restoration

Prerequisites: Instructor's consent is required

EE499 Thesis (Variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

EE501 Nanoelectronics (6 Credits)

Introduction to the principles of quantum mechanics, Quantum-mechanical origin of the electrical and optical properties of materials and nanostructures, absorption, luminescence, transport including tunneling in low-dimensional semiconductors, transport in nano-MOSFET, Emerging nanomaterials and structures including graphene, graphene nanoribbons, carbon nanotubes; Nanostructured devices, Nano-electromechanical systems, Quantum-dot cellular automata.

Prerequisites: Instructor's consent is required EE502 Smart Grids (6 Credits)

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.

Prerequisites: Instructor's consent is required

EE503 HVDC Transmission (6 Credits)

Comparison of Ac and De Transmission Systems: Advantages and Disadvantages.

Fundamentals of the Rectification and Inversion Process, Mathematical Analysis of the HVDC Converter.

Operation of semiconductor device: Thyristor valve.

Control of HVDC Systems.

Fault Detection and Protection.

Reactive Power Requirement and Filter Designfor HVDC Systems.

Analysis of Maximum Power Transfer Capability and Steady-State Stability of HVDC Systems.

Emerging HVDC topologies (Voltage Sourced HVDC Converters, Multi-Modular Converter)

Ground Electrodes and De Transmission Lines

Use of Simulation Tools in analysis and Design of HVDC Systems

Prerequisites: Instructor's consent is required

EE504 Design of Analog and Mixed Signal Circuits (6 Credits)

OP AMP: Non ideal characteristics and analysis. Design of continuous time active filters: (i) Approximation functions: Butterworth, Chebyshev & Bessel approximations, (ii) Biquad Filters. Sallen Key and other filter configurations, cascade filter, GIC. Sample data filter: Switch capacitor filter; filter transfer function in z-domain. Mixed signal circuits: Introduction to switched current filter, current cell. Simple second order structure. Analog multiplexer, Sample and Hold Circuits, aliasing error and anti-aliasing filter, DAC& ADC. Over sampling method for A/D and D/A conversion. Delta-Sigma data converter. Noise and noise reductions. Interference signals and their reduction. Logarithmic and exponential amplifiers, analog multipliers and divider. Waveform generator and Oscillators, Voltage controlled

oscillator and Phase locked loop. Introduction to OPERATIONAL TRANSCONDUCTANCE AMPLIFIERS: characteristics and applications. PSpice simulations, PCB design and layout.

Prerequisites: Instructor's consent is required

EE505 Power System Operation Optimization (6 Credits)

Power flow analysis; Power system security; Sensitivity calculations; Economic Dispatch - Classic, Security-constrained and Multi areas' system; Unit commitment; Optimal power flow; Optimal load shedding; Optimal reconfiguration of electrical distribution network; Uncertainty analysis in power systems; Integration of renewable energy.

Prerequisites: Instructor's consent is required

EE506 Power Systems Planning (6 Credits)

Elements of economics, finance and regulation as applied to the power sector, in general, and power generation, in particular; Load-demand forecasting; Generation system reliability - concepts, measures and methodology of evaluation; Overview of generation system production simulation and analysis; Generation capacity planning; Bulk power transmission planning

Prerequisites: Instructor's consent is required

EE507 Sensors, Measurement, and Instrumentation (6 Credits)

Basics of measurement and Instrumentation: Characteristics, calibration and Error Analysis, Electrical Measurements: (i) bridge circuits for R, L, C measurements, (ii) wattmeter and energymeter (iii) dynamometers, potentiometers and instrument transformers. An introduction to sensors: (i) temperature sensors (ii) force and pressure sensors (iii) motion sensors and LVDT, (iv) flow sensors (v) Hall effect sensors. Signal conditioning circuit

design (bridge and filter circuits, instrument amplifier) and microcontroller based signal processing and display (using Arduino board).

Prerequisites: Instructor's consent is required

EE508 Fundamentals of Wireless Communication (6 Credits)

Wireless channels: Modeling of wireless channels; the wireless channel as a random linear time-varying (LTV) system; stochastic characterization of LTV systems; the wide-sense stationary uncorrelated scattering (WSSUS) assumption; characterizing key parameters of wireless channels; discretization and discrete-time representation.

Diversity: Non-coherent and coherent reception; error probability for uncoded transmission; realizing diversity; time diversity: interleaving, constellation rotation; frequency diversity: spread spectrum systems and the Rake receiver; code design for wireless channels: the product distance design criterion; diversity order estimates on the basis of the scattering function.

Information theory of wireless channels: Entropy and mutual information; capacity of the Gaussian channel and of parallel Gaussian channels; capacity of fading channels: ergodic capacity and outage capacity; high versus low SNR regime; water filling capacity.

Multiple-Input Multiple-Output (MIMO) wireless systems: Capacity of MIMO wireless systems; spatial multiplexing; space-time coding.

Cellular. systems: Multiuser communications; multiple access and interference management; CDMA and FDMA schemes; multi-user diversity.

Prerequisites: Instructor's consent is required

EE509 Power Electronics (6 Credits)

Characteristics of semiconductor power devices: Diode, Thyristor, Triac, GTO, MOSFET, IGBT; DC to DC conversion: Buck, Boost and Buck-Boost converters; Single and three phase configuration of uncontrolled rectifiers, Line commutated thyristor based converters, Bidirectional ac to de voltage source converters, Issues of line current harmonics, Power factor, Distortion factor of ac to de converters, Single phase and three phase inverters, Sinusoidal pulse width modulation. Advanced topic on modulation techniques, HVDC, and FACTS.

Prerequisites: Instructor's consent is required

EE510 Advanced Topics in Digital Signal Processing (6 Credits)

Review: sampling theory & basic DSP concepts, Multi-rate signal processing and filter

banks, Time-frequency analysis, STFT, wavelet transform, Linear prediction and optimum linear filters, Adaptive filtering, Compressed sensing & sparse recovery.

Prerequisites: Instructor's consent is required

EE512 Advanced and Digital Control System (6 Credits)

Revision to linear vector space, State space and state variables. Canonical Forms, Observability and Controllability, Ackerman's Formula, LQR/LQG problem, Solving of Riccati

equation using eigenvalue and eigenvector, Internal Stability, Lyapunov and asymptotic stability. Model based predictive controller, Simulation in MATLAB Simulink.

Fundamental of non-linear control, linearization, describing function, phase plane analysis, limit cycles, Lyapunov and BIBO stability, Aizermans and Kalmans conjecture.

Discretization of continuous system, Z-transform, basics of digital control, optimization problem, Kalman filter design, artificial neural network and fuzzy control.

Prerequisites: Instructor's consent is required

EE515 Wireless Communication Security with SDRS (3 Credits)

Introduction to SDRs; Security analysis of simple systems: Key-Fobs; Bluetooth Security analysis: Protocol Description followed by sniffer analysis; WiFi Security analysis: Protocol Description followed by sniffer analysis; L TE Security analysis: Protocol Description followed by sniffer analysis; Study of attack models for selective protocols.

Prerequisites: Instructor's consent is required

EE521 Analog IC design (6 Credits)

Fundamentles of Analog IC Design: Analog MOS transistor models - Fundamentals and analog IC specification parameters -Threshold voltage - MOSFET I-V and C-V characteristics - characterization of resistive - capacitive elements of MOS devices.

Second order effects: Body Effect -Subthreshold leagake- DIBL - GIDL - Velocity Saturation - Hot electron effect.

Basics of single stage amplifier: MOS small signal model - Small signal analysis of common source, common drain, common gate and cascade stage amplifier with various kind of loads.

Current mirrors: Various architectures, active current mirrors, Wiloson current source and modified version.

Frequency response of amplifiers.

CMOS Differential Amplifiers with balanced and unbalanced output - CMOS Operational

Amplifiers: telescopic - differential amp - folded cascade - multistage architecture – Common mode feedback (CMFB) circuits.

Feedback topologies in amplifiers: Voltage Shunt - Voltage Series - Current Shunt – Current Series type feedback.

Stability and frequency compensation.

Noise in amplifiers: Thermal noise - 1/f noise - Switching noise - Shot noise.

Non-linearity and mismatch analysis.

Switch capacitor circuits. Oscillators: LC oscillator and ring oscillators, VCO and PLL.

Analog layout Design: Common centroid - Uses of dummies -Antenna effect- Multiplier and finger structure, Latchup and prevention techniques - IO pad design - Supply, ground, and signal routing - Shielding techniques to remove crosstalk, deep n-well technique, Electrostatic Descharge: Iluman body model - Charged device model - Machine model – ESD Protection circuitry design.

Prerequisites: Instructor's consent is required

EE522 Machine Learning Applications for Wireless Communications (6 Credits)

Machine Learning Applications for Wireless Communications; Supervised, un-supervised, reinforcement learning; Review of Communication Systems.; ML in OSI layers of a communication system.; ML in Real time schedulers.; Filtering and machine learning; Weiner filtering and regression techniques in ML.; FIR, IIR and CNN, RNN.; Supervised Learning and its applications in wireless systems.; Modulation classification, adaptive modulation and coding for wireless channels; Un-supervised Learning and its applications in wireless systems.; Principal component analysis and massive MIMO system design; Auto encoders in wireless communication transceiver design,; Hidden Markov model, Viterbi algorithm and channel coding..

Prerequisites: Instructor's consent is required

EE523 Power System Analysis (6 Credits)

Power Systems Evolution of Power Systems, Energy Sources Structure of Bulk Power Systems Basic three phase system concepts Power System Components: Generators, Loads, Transformers, Transmission Lines etc. Modelling, Performance and Constraints of these components Formulation/Solution of steady state equations for interconnected systems: Balanced and Unbalanced systems. Positive Sequence Network, Per Unit System, Y-bus formation Simple example of a load flow solution Introduction to generator swing equations and stability issues, Simple Example of Loss of synchronism

Interconnected System Operation and Control: Operational Objectives, Frequency Control, Voltage Control and Power Flow Control: introduction to HVDC transmission and FACTS Economic Issues in Power Systems. Analysis of Faulted Power Systems and Protection: Unbalanced System Analysis using Sequence Components, Equipment Protection Schemes: Overcurrent, Differential and Distance Protection, Relay coordination Preventive Control and Emergency Control System Protection Schemes) Blackouts and Restoration, Discussion on some advanced topics of Power System Stability, Synchronous Machine, and Power System Operation and Control.

Prerequisites: Instructor's consent is required

EE525 Renewable Energy System (6 Credits)

Introduction to Renewable Energy, Worldwide scenario, Indian Scenario, Primary attributes of different renewable energy sources; Solar Thermal, Solar Photovoltaics, Wind energy, Bioenergy, Geothermal energy, other renewable sources, Integration of renewable energy to the grid.

Prerequisites: Instructor's consent is required

EE526 Digital IC Design (6 Credits)

Introduction, MOS Transistor Basics and Theory. Threshold voltage, MOSFET I-V and CV characteristics, characterization of resistive, capacitive elements of MOS devices. Logic implementation by CMOS. Static CMOS invertor and its Transfer characteristics.

Transistor sizing, Technology scaling, Gate delay and power models. Static and Dynamic characteristics, Noise margins, Interconnect basics and crosstalk. Logical effort, Electrical

effort, intrinsic/extrinsic delay. Circuit topologies and transistor sizing for optimal delay and power. Circuit Styles: Static CMOS circuits, Pass transistor logic, Transmission gate, Dynamic CMOS, Dual-rail-domino logic, Pseudo MOS logic and other families. Combination circuit design with various architectures. Sequential circuit design, Basic understanding, design, and timing analysis of sequential circuits like Flip- Flops and Latches. Time borrowing and pipelining. Circuit pitfalls, Clocking techniques, and Layout design basics. Memory design, EEPROM, DRAM, SRAM, and sense amplifiers. IOs, Low Power Techniques, Design methods and tools, CMOS testing, System Design Examples.

Prerequisites: Instructor's consent is required

EE529 Introduction to Wireless and Cellular Communications (6 Credits)

Overview of Cellular Systems and evolution 2G/3G/4G/5G, Cellular Concepts - Frequency reuse, Co-channel and Adjacent channel Interference, Handoff, Blocking, Erlang Capacity, Wireless propagation- Link budget, Free-space path loss, Noise figure of receiver, Wireless propagation - Multipath fading, Shadowing, Fading margin, Shadowing margin, Antenna Diversity, Wireless Channel Capacity, MIMO, CDMA, OFDM and LTE, Large Scale Propagation effects and Channel Models.

Prerequisites: Instructor's consent is required

EE533 Wireless MAC Modeling (6 Credits)

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, Variants of CSMA, Collision Resolution Protocols, IEEE 802.11 DCF and its fixed-point models, models for LoRaWAN throughput.

Prerequisites: Instructor's consent is required

EE543 Fundamentals of MLOps (2 Credits)

This hands-on course introduces participants to MLOps tools for deploying, automating, evaluating, monitoring, optimizing and operating production ML systems on practically available solutions including Google Cloud, Microsoft Azure, AWS Sagemaker, etc. Types of databases to be used for continuous functioning of the system. Data storage vs usage trade-offs. Repeatability in training. Analysis of pricing models of the possible solutions. KPIs offered by different solutions and their relevance to the nature of the ML problem.

Prerequisites: Instructor's consent is required

EE555 Mathematical Methods – I (6 Credits)

Linear Algebra: Linear Equations, Vector Spaces, Linear Transformations, Polynomials, Determinants, Elementary canonical Forms, Rational and Jordan Forms, Inner Product Spaces, Operators on Inner Product Spaces.

Probability and Random Processes: Introduction to Probability Theory, Random Variables, Conditional Probability and Conditional Expectation, Markov Chains, The Exponential Distribution and the Poisson Process, Renewal Theory and Its Applications, Queueing Theory, Simulation

Optimization Theory: Optimization in R^n, Existence of Solutions, Kuhn-Tucker Theorem

Markov Decision Processes and Finite Horizon Dynamic Programming.

Prerequisites: Instructor's consent is required

EE556 Mathematical Methods—II (6 Credits)

Mathematical Analysis: Real and complex numbers systems, Set theory, Point set topology, Limits and continuity, Derivatives, Functions of bounded variation and rectifiable curves, Riemann-stieltjes integral, Infinite series and Infinite Products, Sequence of Functions, Implicit Functions and Extremum Problems, Cauchy's theorem

Differential Equations: Separable Equations, First-order Equations, Second-order Linear Equations, Power Series Solutions and Special Functions, Partial Differential Equations and Boundary Value Problems, Systems of First-Order Equations, The Existence and Uniqueness of Solutions, Numerical Methods.

Prerequisites: Instructor's consent is required

EE566 Math of Turn-based Strategy Games (3 Credits)

Basics: Markov Chains - Markov Decision Processes (MOP} - Dynamic Programming. Game Classification: Turn-based Strategy (TBS} games - Real-time Strategy (RTS) games. Game Modelling: Application of MDPs to Modelling and Analysis of the TBS games Case studies: Compact Conflict or World Wars 2 - Variations of the selected game.

Prerequisites: Instructor's consent is required

EE567 Math of Machine Learning (3 Credits)

Basic Definitions: Convex functions and sets, Introduction to Theory of Learning: meaning of learning, overfitting etc, Gradient and Sub-gradient descent for non-smooth functions eg: SVM, Online Gradient Descent eg: SGD and its applications (NN), Duality and its examples, Bayesian Machine Learning, Estimating decisions using posterior distributions, Model selection: Variational Inference.

Prerequisites: Instructor's consent is required

EE577 Mobile Communications Systems (6 Credits)

General Introduction: ITU definitions, Standardization Bodies, Brief History of Mobile Communications Systems, IEEE and 3GPP Family of Technologies, Wireless Spectrum.

Radio Access Network: 4G.and SG Systems. Physical Layer/MAC: OFDMA and SC~FDMA, Uplink and Downlink Scheduling (proportionally fair, etc), HARQ, Transport Block Size, Modulation and Coding Index Determination, MIMO and Pre-coding, Multiple Access, Cell Search, PLMN Search, Random Access. SG NR Frame Structure. Radio Protocols: RLC, PDCP, SOAP, RRC. Mobility: Neighboring Cell Measurements, Lossless and Lossy Intra-system Handovers

Performance and System Design: Layer 1 peak bit rates, link budget, spectral efficiency, latency, Terminal Categories.

Prerequisites: Instructor's consent is required

EE599 Thesis (Variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

EE601 Solar Photovoltaic Devices and Systems (6 Credits)

Importance of photovoltaics in the present world scenario, Review of semiconductor fundamentals, Design of solar cells, Solar cell technologies, Emerging concepts, Solar PV modules, Balance of solar PV systems, PV system design and applications.

Prerequisites: Instructor's consent is required

EE602 Application of Stochastic Geometry in Wireless Networks (6 Credits)

Basics of spatial point processes and stochastic geometry, Outage and interference in random wireless networks, Applications to multi-antenna systems, power control, bandwidth partitioning, opportunistic relay selection, Multi-tier cellular networks, ARQ and local-connectivity delay, Non-Poisson networks (cluster, cognitive and CSMA), A final mini-research project to help students explore more advanced topics in this subject.

Prerequisites: Instructor's consent is required

EE603 Multi-Antenna Digital Communications (6 Credits)

Preliminaries: Review of Gaussian random variables and vectors, Complex Gaussian random vectors, Detection in Gaussian noise, Probability of error, union bound, some definitions and results from Information theory Capacity of the vector Gaussian or MIMO channel, Ergodic Capacity of multi-antenna Gaussian channels with Rayleigh fading, Outage capacity of multi-antenna Gaussian channels with fading Spatial multiplexing: V-BLAST Space-time codes: Design criteria, Alamouti code, Orthogonal designs, Quasi-orthogonal space-time codes, Diversity-multiplexing gain trade-off MIMO with feedback: Long-term and short-term power constraints, delay-limited capacity Multiuser MIMO: Multiple access, broadcast.

Prerequisites: Instructor's consent is required

EE604 Signal Processing Algorithms to DSP Architectures (6 Credits)

Architectures for VLSI implementation of signal processing systems - Multi-core, many-core, hardware accelerators - Metrics for analysis and comparison of architectures - DSP algorithms, properties relevant to hardware realizations - Modifications to algorithms to improve hardware realizability - Models such as dataflow graphs and their use in architecture exploration - Communication architectures, networks on chip - Specialized architectures for DSP functions.

Prerequisites: Instructor's consent is required

EE605 Advanced Computer Networks (6 Credits)

Basics of Computer Networking, TCP/IP protocol stack, Local Area Networks (Ethernet, Wi-Fi), Network Management, Network Security, Multimedia Transport, Next generation Internet architectures.

Prerequisites: Instructor's consent is required

EE606 5G NR Systems: Physical Layer Aspects (6 Credits)

Physical layer General description, Physical layer services provided by the physical layer, Physical channels and modulation, Multiplexing and channel coding, Physical layer procedures for control, Physical layer procedures for data, Physical layer measurements, Physical layer procedures for shared spectrum channel access.

Prerequisites: Instructor's consent is required

EE610 Application of power Electronics to power System (6 Credits)

Load Balancing, reactive power compensation and active filtering techniques. Flexible AC transmission systems (FACTS). Principles of series and shunt compensation. Description of static var compensators (SVC), Thyristor Controlled series compensators (TCSC), Static phase shifters (SPS), Static compensator (STATCOM), Static synchronous series compensator (SSSC) and Unified power flow controller (UPFC). Modelling and Analysis of FACTS controllers. Control strategies to improve system stability. High Voltage DC Transmission System (HVDC), and their control.

Prerequisites: Instructor's consent is required

EE611 Introduction to Information Theory and Coding (6 Credits)

Information, discrete memoryless source, entropy, mutual information, capacity, source and channel coding theorems, Shannon's capacity formula, rate-distortion theorem, differential entropy, Linear Binary Block Codes, Convolutional Codes, Turbo Codes, LDPC codes, Polar codes. Applications of coding theory in 4G and SG systems.

Prerequisites: Instructor's consent is required

EE702 Advanced Photovoltaics (6 Credit)

Shockley-Queisser limit, Multi-junction and Tandem solar cells, Perovskite, organic, dye-sensitized solar cells, Carrier-selective contacts, heterojunction solar cells, new designs in Si solar cells, Solar cell metrology, Modeling of solar cells, modules, solar irradiance, module temperature, shading, soiling, Performance degradation and reliability of PV modules and plants.

Prerequisites: Instructor's consent is required

EE795 Candidacy (0 Credit)

Evaluation of candidate's ability to carry out research, knowledge breadth of the student, research comprehension.

Prerequisites: Student must have completed the course credit requirement of the program registered for.

EE798 Independent Study (variable Credits)

Course content and credits are to be assigned by the course instructor.

Prerequisites: Instructor's consent is required

EE799 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: EE795.

Courses in Electric Vehicle Technology

EV501 Electric Vehicles- Policies and Regulations (3 Credits)

Guidelines and Standards - Battery Electric Vehicles, Charging Infrastructure, Battery Charging/Swapping Stations; Demand-side Incentives for EV; Supply-side Incentives for EV; Development of Manufacturing EV Manufacturing Ecosystem; Recycling ecosystem - Battery and EVs.

Prerequisites: Instructor's consent required

EV502 Introduction to Automobiles (3 Credits)

Introduction to Vehicle Design - Basic structures, Functional systems of automobiles; Transmission system - Hydraulic and Manual transmission systems, Manual transmission, Automatic transmission; Suspension system - Springs used in suspension, dampers, Modern suspension systems; Steering system - Types of Steering Ears, Power Steering; Braking - Disc and Drum Braking System, Tyres, modern braking systems.

Prerequisites: Instructor's consent required

EV503 Basics of Electrical Engineering (3 Credits)

Review of instantaneous and phasor quantities. Review on single and three phase networks. Star and Delta connection. Real and Reactive power in three phase circuits, and fault analysis. Basics of converters in power electronics such rectifiers, inverters, and DC-DC converters. Basic principle of Electromagnetism, various Electric Machines and Drives.

Prerequisites: Instructor's consent required

EV504 Energy Storage Materials and Technologies (3 Credits)

Introduction to various basic energy storage technologies.

Variety of batteries and its technology; non-rechargeable and rechargeable batteries

Lead-Acid batteries: working principle, advantages, and limitations

Metal batteries: Li metal battery and other metal batteries, working principle, advantages, and limitations

Metal-ion batteries: Li-ion batteries; Na-ion batteries; working principle, advantages, and limitations.

Comparison of various batteries: similarities and differences between various batteries.

Utility of specific batteries based on application

Supercapacitors and its working principle.

Prerequisites: Instructor's consent required

EV505 Hybrid and Electric Vehicles (3 Credits)

Introduction to Hybrid Electric Vehicles, Dynamics of Electric and Hybrid vehicles, Architecture of Hybrid and Electric Vehicles, DC-DC Converters, Electrical Machines for Hybrid and Electric Vehicles, Permanent Magnet Machines for Hybrid and Electric Vehicles, Design of Hybrid and

Electric Vehicles, Energy Storage, Control System for Electric and Hybrid Electric Vehicles, Regenerative braking, Design of Hybrid Electric vehicles.

Prerequisites: Instructor's consent required

EV506 Battery Chemistry, Components and Manufacturing (3 Credits)

Introduction: operation principle of battery.

Components: battery structure and cell assembling.

Manufacturing: aspects related to battery manufacturing, including design and safety.

Prerequisites: Instructor's consent required

EV601 Advanced Automobile Technology (3 Credits)

Construction and Working of Mechanical, Hydraulic and Air; Vehicle Handling and Stability; Structural Design- Terminology and Overview of Vehicle Structure Types; Vehicle Safety; Materials Design and Material Utilization, Materials for Consideration and Use in Automotive Body Structures; Aerodynamics- Body Design: Aerodynamics; Interior and Exterior Noise; Instrumentation; Transportation Vehicle - Combustion Vehicles Vs Electric Vehicles, Prospects of Electric Vehicles.

Prerequisites: EV502

EV602 Battery Management System (3 Credits)

Introduction to BMS, Explanations, Battery Monitoring Unit, Battery Control Unit, Isolation Monitoring, Battery Disconnect Unit, BMS Cell Balancing, Contactor Control, BMS Interface, BMS Protection, Passive Cell Balancing, Active Cell Balancing, Active Balancing Shared Active Bus, Battery Management Device.

Prerequisites: Instructor's consent required

EV605 EV Thermal Management System (6 Credits)

Introduction: Background of electrical vehicle (EV), introduction to EV and its components, importance of EV thermal management, new engineering challenges and opportunities for next generation EVs.

Heat Transfer: Principal of heat transfer and their modes along with examples, thermal conductivity, heat transfer coefficient and governing parameters, heating/cooling mechanism to battery, cabin, power electronics, and electric motor.

HVAC systems in Battery-driven EVs: Electrical heater, heat pump, air-conditioning, Choice of refrigerant, pressure-enthalpy diagram, heating/cooling cycle.

Thermal management and cooling methods: Air-based, liquid-based, direct refrigerant based, heat pipe-based, and phase change material (PCM)-based cooling methods, PCMs for effective/passive thermal management in EV, the basic properties/types of phase change materials, their advantages/drawbacks as well as methods to measure and improve their heat transfer capabilities thermal modelling of cooling system.

Battery Modelling: Introduction to CFD model and electrochemistry models, Battery thermal and abuse models (component level modelling- Multi-Scale Multi-Dimensional approach), Energy analysis of battery thermal management.

Case Studies: Economic and environmental comparison of conventional, hybrid, electric and hydrogen fuel cell vehicles; Thermal management solutions for electric vehicle lithium-ion batteries based on vehicle charge and discharge cycles; Heat transfer and thermal management of electric vehicle batteries with phase change materials; Battery Aging, Safety management and Future expectations.

Prerequisites: Instructor's consent required

EV606 EV Charging Technologies (3 Credits)

Basic Requirement of Charging System, Charger Architecture, Grid Voltage, Frequencies, and Wiring, Charger Functions, Charging Standards and Technologies {Type 1-4), Wireless Charging, Battery Swapping.

Prerequisites: Instructor's consent required

EV607 Integration of EV in Utility Grid (3 Credits)

Power system stability issues, small and large disturbance stability studies, Integration of Electric vehicles and its impact on the grid stability, Standards and Communication protocols between EV, EVSE, and Grid.

Prerequisites: Instructor's consent required

EV608 Application of Power Electronics in Electric Vehicle and Smart Grid (6 Credits)

Electro mobility and its climatic impacts, vehicle dynamics, Battery Sizing and Fuel Cells, Conventional and Hybrid powertrains. DC-DC converters, Isolated DC-DC Converters, CCM and DCM modes of operation, Battery Charging, Traction Drive and three phase inverters, Control of the Electric Drive, Microgrid operation and control.

Prerequisites: Instructor's consent required

Courses in Mathematics

MA200 Differential Equations (2 Credits)

First order linear ordinary differential equations, Bernoulli's equations, exact differential equations and integrating factor, solutions of second and higher order linear differential equations with constant coefficients.

First order linear partial differential equations, quasi-linear PDE, method of characteristics, Cauchy problem; classification of second order partial differential equation, separation of variable method for heat, Laplace and wave equations.

MA201 Complex Variables (2 Credits)

Complex numbers and elementary properties, complex functions - limits, continuity and differentiability. Cauchy-Riemann equations, Laplace equations, analytic functions and harmonic functions, path integrals, Cauchy-Goursat theorem, Cauchy integral formula, derivations of an analytic function, Taylor series, power series, Laurent series, zeros, singularities, Cauchy's residue theorem and applications.

MA202 Transform Techniques (2 Credits)

Laplace transform, inverse Laplace transform, properties, Laplace transforms of derivatives and integrals, partial fractions, unit step function, t-shifting, applications of Laplace transform to differential equations; Fourier integral and Fourier transform, inversion, convolution, applications of Fourier transform to differential equations.

Prerequisites: IC202

MA500 Real Analysis (6 Credits)

Real valued functions of real variables, continuity, intermediate value theorem, differentiability, mean value theorem and applications, Riemann integral and its properties, improper integrals.

Sequences and series of functions: uniform convergence, equicontinuity, Arzela-Ascoli's theorem.

Construction of Lebesgue measure, measurable functions, Lebesgue integration, abstract measure and abstract integration, monotone convergence theorem, dominated convergence theorem, Fatou's lemma, comparison of Riemann integration and Lebesgue integration.

MA501 Linear Algebra (6 Credits)

Systems of linear equations, matrices and elementary operations, row-reduced echelon matrices, solutions of linear systems: existence and uniqueness. vector spaces, subspaces, spanning space, bases and dimensions, ordered basis and coordinates, linear transformations, matrix representations of linear transformations, range space and rank, null space and nullity, the rank and nullity theorem, invertibility.

Eigenvalues and eigenvectors, the characteristic polynomial, the Cayley- Hamilton theorem, the minimal polynomial, algebraic and geometric multiplicities, diagonalization, the Jordan canonical form.

MA502 Modern Algebra (4 Credits)

Groups: Definition of group and its properties, subgroups, coset of a subgroup, Lagrange's theorem. Cyclic groups, normal subgroups, quotient groups. Homomorphism, isomorphism theorems. Group actions, Sylow's theorem. Direct products of groups actions.

Rings: Definition of ring with examples, homomorphism theorems, ideals and its properties, two• sided ideals, prime and maximal ideals. The Chinese Remainder Theorem; Maximal and prime ideals; Unique factorization domains, principal ideal domains, Euclidean domains, universal property of a polynomial ring; Criteria for irreducibility, Concept of field and related examples.

MA503 Introduction to Probability Theory (4 Credits)

Introduction to probability, probability spaces, conditional probability, Bayes' theorem and independence of events; Random variables -discrete and continuous, probability mass, probability density and cumulative distribution functions, joint distributions, independence, mathematical expectations, moments, covariance, correlation, Chebyshev's inequality; Special distributions: binomial, hypergeometric, Poisson, exponential, uniform, normal distributions.

Random sampling, sample mean, sample Variance, weak and strong law of large numbers, central limit theorems.

MA504 Differential Equations (4 Credits)

A review of first order equations, Picard's existence and uniqueness theorem, second order differential equations with constant coefficients - wronskian, method of variation of parameters; Series solution of second order linear equations: ordinary points, regular singular points, Legendre polynomials and properties, Bessel functions and properties. Systems of first order differential equations.

First order linear and quasi-linear partial differential equations (PDEs), Cauchy problem, classification of second order PDEs. Solutions methods for Poisson's, Laplace's and heat equations.

MA505 Complex Analysis (6 Credits)

Complex numbers, holomorphic functions, Cauchy Riemann equations, harmonic functions, Cauchy theorem and Cauchy's integral formula, Taylor and Laurent series, Liouville's theorem, open mapping theorem; The maximum -modulus theorem, isolated singularities, residue theorem, the argument principle, real integrals via contour integration. Mobius transformations, conformal mappings. The Schwarz lemma, automorphisms of the disc. The Riemann mapping theorem.

MA506 Multi-Variable Calculus (4 Credits)

Functions of several variables, continuity, directional derivatives, partial derivatives, total derivative, higher order derivatives and Taylor's theorem, maxima-minima problems, critical points, saddle points and the Hessian, constrained extrema and Lagrange's multipliers; The inverse and implicit function theorem; Integration on R", differential forms on R", closed

and exact forms; Green's theorem and its applications, Stokes' theorem and Gauss's divergence theorem.

Prerequisites: MA500

MA507 Numerical Techniques (6 Credits)

Linear systems of equations, direct and iterative schemes, ill conditioning and convergence analysis, sources of errors, solutions of nonlinear equations, Numerical Schemes for non-linear systems, bisection method, Newton's method and its variants, fixed point iterations,

convergence analysis; Finite differences, polynomial interpolation, Hermite interpolation, spline interpolation; Numerical integration - Trapezoidal and Simpson's rules, Gaussian quadrature, Richardson extrapolation; Initial value problems - Taylor series method, Euler and modified Euler methods, Runge-Kutta methods, single step, multistep methods, order, consistency,stability and convergence analysis; Numerical solution of differential equations; Boundary value problems: Shooting and finite difference methods.

MA508 Topology (6 Credits)

Definition of topological spaces and examples, bases, product topology, subspace topology, metric topology, quotient topology, second countability and separability; Continuous functions on topological spaces, homeomorphisms, connected set, examples, path connectedness and local connectedness.

Compact set and examples, local compactness, limit point compactness and sequential compactness; Tychonoff theorem, Stone-Weierstrass theorem.

Hausdorff, regular and normal spaces; Urysohn lemma, The Tietze extension theorem;

compactification; Urysohn's metrization theorem.

Prerequisites: MA500

MA509 Statistical Inference (6 Credits)

Order statistics: Distribution of rth order statistics, joint distribution of rth and sth order statistics, distribution of range, sample median and mid-range.

Estimator: Statistic, estimate, estimator, unbiasedness, consistency, strong consistency

efficiency, efficient estimator, sufficient statistics, minimal sufficient statistics, exponential family, completeness, ancillary statistic, Basu's theorem, Fisher information, Cramer-Rao lower bound (CRLB), Bhattacharyya bound, uniformly minimum variance unbiased estimator (UMVUE), Rao-Blackwell theorem, Lehman-Scheffe theorem.

Method of Estimation: Maximum likelihood estimator (MLE), properties of MLE's, limiting distribution of MLE, Method of moments.

Bayesian estimation (Basic): Loss functions, prior and conjugate prior, posterior distribution, Bayes' risk and Bayes' estimator.

Testing of hypothesis: Hypothesis, critical region, p-value, size of test, level of significance, types of errors, power of the test and power function, randomized and nonrandomized test, monotone likelihood ratio (MLR) property, Neyman-Pearson lemma-I and II, most powerful test (MP test), uniformly most powerful test (UMP test), uniformly most powerful unbiased test (UMPU test), Karlin-Rubin theorem, likelihood ratio test.

Interval Estimation: Interval estimator, method of finding interval estimators, pivotal quantity method.

Prerequisites: Instructor's consent is required

MA510 Elementary Number Theory (6 Credits)

Preliminaries: Well-Ordering Principle, Mathematical induction, Binomial theorem.

Divisibility theory: Division algorithm, The greatest common divisor and the least common multiple, Euclidean Algorithm, Prime numbers, Prime number theorem (statement only), Fundamental theorem of arithmetic, The linear Diophantine equation in two unknowns, The theory of congruences.

Fermat's theorem, Pseudoprimes, Wilson's Theorem, Euler's generalization of Fermat's theorem, Number Theoretic functions, Primitive roots, The quadratic reciprocity law. Brief introduction to public key cryptography.

Number of special forms: Perfect numbers, Mersenne primes, Fermat numbers, Fibonacci numbers.

Some nonlinear Diophantine equations: The Pythagorean equations, A special case of Fermat's last theorem.

Representation of integers as sums of squares, continued fractions, Pell's equation.

MA511 Topics in Nonlinear Analysis (6 Credits)

Distribution Theory: Test functions and distributions, Operations on distributions: differentiation, multiplication, convolution, Fourier transform, Schwartz spaces, tempered distributions

Sobolev Spaces: Review of Lebesgue spaces, approximation by smooth functions, extension, embedding and compactness theorems, dual spaces and trace theory

Weak Solutions of boundary value problems: Abstract variational problems, Stampacchia and Lax-Milgram theorems and its applications in elliptic boundary value problems

Prerequisites: Instructor's consent is required

MA512 Topics in Fixed Point Theory (6 Credits)

Metric Fixed Point Theory: Banach contraction principle and its various applications to integral equations, differential equations and numerical analysis; Some generalizations of Banach contraction principle; Fixed points results in partially ordered metric space and its applications to matrix quations; Multi-valued maps, examples, Hausdorff metric and Nadler's theorem.

Fixed Points in Topological Spaces: Brouwer's fixed point theorem and applications; Schauder's fixed point theorems and applications to Peano existence theorem, nonexpansive maps, examples, fixed point theorem for non-expansive maps, Kakutani fixed point theorem for mauti-valued maps and its applications, Key-Fan best approximation theorem.

Prerequisites: Instructor's consent is required

MA513 Introduction to Linear Regression and Experimental Design (6 Credits)

Descriptive Statistics, Sampling Distributions, Basic concept of estimation and hypotheses testing.

Simple and multiple linear regression models, estimation, tests and confidence regions for model parameters; model adequacy checking; diagnostics for leverage and influence; Multicollinearity, Polynomial Regression Model.

Analysis of Variance, Complete Randomized Designs, Randomized Block Designs, Factorial experiments.

Prerequisites: Instructor's consent is required

MA514 Analytic Number Theory (6 Credits)

Prime numbers, Fundamental theorem of arithmetic, Basic concepts of the theory of congruences.

Arithmetic functions: Basic concepts of arithmetic functions, Dirichlet multiplication, Asymptotic estimates for arithmetic functions.

Some elementary results on the distribution of prime numbers.

Characters of a finite abelian group, Dirichlet's theorem on the primes in an arithmetic progression.

Dirichlet series and Euler products, The Riemann zeta function.

Prime number theorem and its analytic proof.

Prerequisites: Instructor's consent is required

MA515 Matrix Analysis (6 Credits)

Review of some basic concepts, Matrices of special types and their properties (Projection and orthogonal projection matrices, Idempotent matrices, Nilpotent matrices, Orthogonal Matrices, etc). Generalized inverses, Moore-Penrose inverse, Quadratic forms, Positive Definite and Semidefinite Matrices, Similar and Equivalence Matrix, Matrix decomposition, Vector, and matrix differentiation, Kronecker Products and the Vee and Vech Operators, Matrix Norm and Sum of Matrices, Canonical forms, Eigenvalues and Eigenvectors, Location and Perturbation of Eigenvalues.

Prerequisites: Instructor's consent is required

MA516 Enumerative Combinatorics (6 Credits)

Basic counting: Sets and multisets, binomial and multinomial coefficients; counting permutations based on the number of cycles, inversions and descents; compositions. integer partitions and set partitions; Eulerian. Catalan and Stirling numbers; q-analogue of binomial and multinomial coefficients.

Sieve Methods: Principle of inclusion-exclusion, permutations with restricted positions, Ferrers board.

Partially ordered sets: Basic concepts, new posets from old, lattices, distributive lattices, chains in distributive lattices, the Mobius inversion formula, techniques for computing Mobius functions.

Hyperplane arrangement and pattern avoidance: The intersection poset and characteristic polynomial of hyperplane arrangements, counting regions in hyperplane arrangements, the finite field method; pattern avoidance in permutations and set partitions.

Prerequisites: For BTech students - CS101

MA517 Algebraic Topology (6 Credits)

The Fundamental Group: Paths and homotopy, contractible spaces and homotopy type, fundamental group and its applications, simply connected spaces, Siefert-Van Kampen theorem and its applications.

Covering Spaces: Lifting properties, applications of homotopy lifting theorem, lifting of an arbitrary map, covering homomorphisms, universal covering space and its applications.

Finite Simplicial Complexes: Simplicial complexes, polyhedra and triangulations, simplicial approximation, barycentric subdivision.

Simplicial Homology: Orientation of simplicial complexes, simplicial chain complex and homology, properties of integral homology groups, degree of a map and its applications, Lefschetz fixed point theorem and the Borsuk-Ulam theorem.

Prerequisites: MA508

MA604 Functional Analysis (6 Credits)

Review of metric spaces, normed linear spaces, Banach spaces, linear maps, boundedness, non-compactness of the unit ball in infinite dimensional normed linear spaces, quotient spaces; Banach-Steinhaus theorem, open mapping theorem and closed graph theorem, Hahn-Banach theorem.

Hilbert Spaces: Bessel's inequality, complete systems, Gram-Schmidt orthogonalization, Parseval's identity, projections, orthogonal decomposition.

Dual spaces, Riesz representation theorem, reflexivity, weak topologies, weak convergence, weak compactness, Banach-Alaoglu theorem.

Prerequisites: MA500

MA605 Operations Research (4 Credits)

Linear optimization: Formulation and geometrical ideas of linear programming problems, simplex Method, revised simplex method, duality, sensitivity analysis, transportation and assignment problems, introduction to interior-point methods.

Nonlinear optimization: Method of Lagrange multipliers, KKT conditions, convex optimization, quadratic optimization, numerical methods for constrained optimization, dynamic programming.

Prerequisites: For BTech students - IC152.

MA606 Partial Differential Equations (4 Credits)

First order PDEs: Cauchy problems-linear, quasilinear and nonlinear partial differential equations-method of characteristics-existence of local solutions-weak solution-introduction to conservation laws-weak solutions-Rankine-Hugoniot condition- shocks-Lax-Oleinik formula-entropy condition and uniqueness of entropy solution.

Second Order PDEs: Classification-Characteristics

Laplace and Poisson's Equation: Fundamental solutions-Mean value Property-Harmonic functions-Harnack inequality-Green's function-Maximum principle-Hopf Lemma-Perron's method-Duhamel's principle-energy methods-introduction to variational method;

Heat Equation: fundamental solution and initial-value problem-mean value formula-maximum principle-uniqueness and regularity-nonnegative solutions;

Wave equation: one dimensional wave equation-solutions in odd and even dimensions.

Prerequisites: Instructor's consent is required.

MA607 Fourier Analysis (6 Credits)

Convolution, elementary properties of convolutions; The Hardy-Littlewood maximal function, approximations of the identity, weak-type inequality, Marcinkiewicz interpolation theorem, Hardy-Littlewood maximal function and its properties, dyadic maximal function, Calderon• Zygmund theorem, Riesz-Thorin interpolation theorem.

Introduction to Fourier series, basis approximation theorem, Dini's conditions. Introduction to Fourier transform; Plancherel theorem, Wiener-Tauberian theorems, Interpolation of operators, maximal functions, Lebesgue differentiation theorem, Poisson representation of harmonic functions, introduction to singular integral operators.

Prerequisites: Instructor's consent is required

MA608 Martingale Theory (6 Credits)

Review of conditional expectation: Conditional expectation and conditional probability, regular conditional distributions, conditional independence. Martingales and Stopping times: Stopping times, random time change, sigma field, martingale property, optional sampling theorem, maximum and upcrossing inequalities, martingale convergence theorem.

Gaussian processes and Brownian motion: Symmetries of Gaussian distribution, existence and path properties of Brownian motion, law of iterated logarithm, Martingale central limit theorem.

Prerequisites: Instructor's consent is required

MA609 Numerical Optimization Techniques (2 Credits)

Numerical optimization techniques: line search methods, gradient methods, Newton's method, conjugate direction methods and quasi-Newton methods.

Prerequisites: MA605

MA610 Operator Theory (6 Credits)

Overview of Hahn-Banach theorem, Open mapping theorem, Closed graph theorem, Uniform boundedness principles.

Banach algebras, Gelfand theory, C*-algebras the GNS construction, spectral theorem for normal operators, Fredholm operators. The L-infinity functional calculus for normal operators.

Prerequisites: Instructor's consent is required

MA611 Stochastic Processes (6 Credits)

Review of random variables and distribution functions, Discrete-time Markov chains: Markov property, class division, hitting time and absorption probabilities, strong Markov property, recurrence and transience, invariant distributions, convergence to equilibrium. Continuous time Markov chains: Q-matrices, embedded Markov chain, Kolmogorov forward and backward equations, classification of states, limit theorems. Poisson Process: its different characterizations, inter-arrival and waiting time distributions, conditional distribution of arrival times. Random walk in 1,2,3-dimension, the Reflection Principle, hitting probabilities of a finite sets, coupling and total variation distance, mixing time.

Prerequisites: Instructor's consent is required

MA612 Set-Valued Analysis (6 Credits)

Definition of Set- Value Maps and Examples; Domain, range and graph of set-valued map; Upper semi-continuity, lower semi-continuity and closed graph of SVM; composition of two SVM and inverse image; some theorems that related continuity and closed graph of SVM; Hausdorff metric and its properties; Existence results for set-valued Variational inequalities and its applications to game theory in particular to Nash equilibrium problems.

Prerequisites: Instructor's consent is required

MA613 Operator Theory II (6 Credits)

Overview of Gelfand theory, C"*-algebras the GNS construction, Spectral theorem for normal operator. Compact Operator, Schatten-p-class operators, Basic van-Neumann algebras, Operator spaces, Contractive and complete contractive homomorphism, Function algebra, Dilation

Prerequisites: MA610. MA610 could be taken concurrently.

MA614 Introductory Additive Number Theory (6 Credits)

Basic number-theoretic concepts. Sumsets of finite sets of integers: Introduction to sumsets, Direct and inverse problems for sum sets, Freiman's inverse theorem (statement only), Applications to the number of sums and products, sumsets and powers of 2, Introduction to subset sums, Direct and inverse problems for subset sums.

Sumsets of sets of congruence classes: Set addition in groups, e-transform, Kemperman transform, Cauchy-Davenport theorem, Pollard's theorem, Erdos-Ginzburg-Zlv theorem, Chevalley-Warning theorem, Vosper's theorem, Freiman-Vosper theorem (statement only). Restricted sums of sets of congruence classes: Erdds-Heilbronn conjecture and Dias da Silva-Hamidoune theorem, Polynomial method in additive number theory: Proofs of Cauchy-Davenport theorem, Erdos-Heilbronn conjecture and its h-fold generalization.

Sumsets in groups: Periodic subset of a group, Kneser's addition theorem, Some applications of Kneser's theorem.

Prerequisites: Instructor's consent is required

MA615 Critical Point Theory (6 Credits)

A review of Sobolev spaces and differential calculus for real functionals on a Banach space, critical points via minimization, pseudo gradient field, deformation theorems, minimax theorems and applications: generalized mountain pass and saddle point theorems, constrained minimization problems, Ekeland variational principle, problems with lack of compactness.

Prerequisites: Instructor's consent is required

MA616 Algebraic Number Theory (6 Credits)

Historical Background, algebraic numbers, algebraic integers and their properties, Characteristic and minimal polynomial of an element- relative to a finite extension, Equivalent definitions of norm and trace.

Integral bases, discriminant, Stickelberger's theorem, Brille's theorem, description of integral basis of quadratic, pure cubic number fields and cyclotomic fields.

Ideals in the ring of algebraic integers and their norm, factorization of ideals into prime ideals, generalised Fermat's theorem, Euler's theorem.

Ramification index and Residual degree, Dedekind's theorem for decomposition of rational primes in algebraic number fields and its application, splitting of rational primes in quadratic and cyclotomic fields, Finiteness of ramified primes.

Factorisation into irreducible elements, Dirichlet's theorem on units, regulator of an algebraic number fields, explicit computation of fundamental units in real quadratic fields.

Prerequisites: Instructor's consent is required

MA617 Statistical Decision Theory (6 Credits)

Group of Transformations; Principle of invariance, Location, Scale and Affine Equivariant estimators. General Principle of equivariance; Minimum risk equivariant estimators under location scale and location-scale families; Pitman Estimator; Bayesian estimation; prior distributions; posterior distribution; Bayes estimators; limit of Bayes estimators; hierarchical Bayes estimators; Generalized Bayes estimators; Empirical Bayes Estimator, James-Stein estimator, Minimax estimators and their relationships with Bayes estimators; admissibility; Review of hypotheses testing problem. Invariance in hypothesis testing; Unbiased test and its Applications to Normal Distributions; Confidence Intervals; Equivariant Confidence Sets, Bayesian Confidence Sets.

Prerequisites: Instructor's consent is required

MA618 Introduction to Spectral Theory (6 Credits)

Introduction: Origin - spectrum and invertibility.
Banach Algebra: Ideals & quotients - spectrum of an element of a Banach algebra - spectral radius - Reisz functional calculus - dependence of the spectrum on the algebra.
Spectral Representation: Spectrum and resolvent - various sub-divisions of spectrum - spectral projection - spectral measure - spectral representation theorem of compact operators and self-adjoint operators.
Compact Perturbation & Fredholm theory: Calkin algebra - Fredholm operators Fredholm index - Riesz theory of compact operators - Fredholm alternative - essential spectrum - further analysis of spectrum.

Spectral properties of unbounded linear operators: unbounded linear operators and Hilbert adjoint - symmetric and self-adjoint linear operators - spectral properties of self-adjoint linear operators - multiplication operator - differentiotion operator - applications in quantum physics.

Prerequisites: Instructor's consent is required

MA619 Advanced Algebraic Number Theory (6 Credits)

Prime ideal decomposition in relative extensions: Relative Ramification Index and Residual Degree - Splitting of Prime Ideals in Galois Extensions - Norm of an Ideal in Relative Extensions - The Fundamental Equality in Relative Extensions.
Relative Discriminant and Dedekind's theorem on ramified primes: Notions of Relative Different and Relative Discriminant - Properties of Relative Different and Relative Discriminant - Dedekind's Theorem on Ramified Primes.
Class Group and Class Number: Finiteness of Class Number - Computation of Class Number - Hermite's Theorem on Discriminant.
Dirichlet's Class Number Formula and its Applications: Dirichlet's Class Number Formula and Ideal Theorem - Derivation of Dirichlet's Class Number Formula - Applications of Dirichlet's Class Number Formula.
Simplified Class Number Formula for Cyclotomic, Quadratic Fields: Numerical Characters and l-functions - Simplification of Class Number Formula for Cyclotomic Fields - Dirichlet's Theorem for Primes in Arithmetic Progressions - Simplified Class Number Formula for Quadratic Fields.

Prerequisites: MA616. MA616 could be taken concurrently.

MA699 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

MA795 Candidacy (0 Credit)

Evaluation of candidate's ability to carry out research, knowledge breadth of the student, research comprehension.

Prerequisites: Student must have completed the course credit requirement of the program registered for.

MA798 Independent Study (variable Credits)

Course content and credits are to be assigned by the course instructor.

Prerequisites: Instructor's consent is required

MA799 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: MA795.

Courses in Mechatronics

MT201 Sensors and Instrumentation (4 Credits)

Introduction: Fundamental blocks of instrumentation - static and dynamic characteristics of sensors. **Heat sensors:** RTD - thermistor- thermocouple - temperature IC. **Flow sensors:** Venturi meter- orifice plate - rotameter - electromagnetic - ultrasonic, **Servo Sensors:** proximity sensors - level sensors - position sensor - LVDT – tacho generator. **Force sensors:** strain gauge - load cell - accelerometer. **Signal conditioning circuit:** AC bridges - amplifiers - noise analysis - interference - filtering. **Data analysis:** LDA - PCA - SVD.

Prerequisites: EE103

MT202 Mechatronics Lab-I (2 Credits)

Temperature sensor: RTD -Thermistor-Temperature sensing IC. **Position and Speed Sensor:** LVDT - Level sensing using Capacitor - Magnetic pickup and Optical speed sensor. **Flow sensor:** Rotameter -venturi meter- electromagnetic flowmeter. **Force sensor:** Load cell - Strain gauge - Piezoelectric - Hall sensor. **Signal Conditioning:** Bridge circuit - output signal filtering - Signal amplification - IoT.

Prerequisites: EE103

MT301 Digital Control (2 Credits)

Discretization: Difference Equation Model for Sampled Data System – sampling theorem - Z Transform - Step Invariance, Rectilinear, Bilinear methods – Transfer function - stability. **State space model:** SS model in discrete domain - realization - state transition matrix - controllability, and observability **Design:** State feedback controller, state observer, MATLAB Simulation – Introduction to ANN

Prerequisites: IC150, EE202

MT501 Fundamentals of Sensing and Control (6 Credits)

Control System Fundamentals: Transients - Concept of Stability - Bode plots - PIO Controller - Computational control using MATLAB. Sensor Fundamentals: Basic blocks of instrumentation system - parameters of sensors - thermal, flow, pressure sensors - Hall sensors - Accelerometer Signal Conditioning Circuits: Bridge circuit -Amplifier - Basic filters with op amp. Modern Control Systems: State variables - Application of Control Action for DC Motor, Stepper Motor.

Prerequisites: Instructor’s consent is required

MT502 Fundamentals of Mechanical Engineering for Mechatronics (6 Credits)

Forces and Moments I transmitted by Slender Members: Axial force distribution - Shear force distribution - Bending moment distribution, Stress and Strain: Stress - Plane stress - Strain - Plane strain - Mohr's circle, Stress-Strain Relations: Tensile test - Elastic Stress-Strain relation - Stress concentration - Stress due to torsion - Stress due to bending, Column buckling, Basics of Mechanisms: Kinematic pairs, diagrams, and inversion, Analysis of Mechanisms: Displacement, velocity, and acceleration - Analysis of planar linkages - Dynamic force analysis

- Inertia forces, Basics of Dynamic components: Gears and gear trains - Cam - Flywheel - Gyroscope.

Prerequisites: Instructor's consent is required

MT503 Fabrication Techniques for MEMS (6 Credits)

Introduction to MEMS & Applications, clean-room standards and common practices; Common materials used in microfabrication: metals, semiconductors, insulators, polymers; Microfabrication Techniques: Photolithography (mask and mask-less), bulk and Surface Micromachining; Subtractive techniques: Wet and dry etching {Chemical etching, plasma based Reactive Ion Etching {RIE) and Deep Reactive Ion Etching {ORIE)), Precision machining: Micro milling, Laser, micromachining, diamond turning, ultra-precision grinding, Electron Beam Machining {EBM); Deposition techniques: Different types of Chemical Vapor Deposition {CVD) and Physical Vapour Deposition {PVD) processes; 30 High Aspect Ratio Techniques, LIGA, Electron and Ion-beam Lithography; Doping: Diffusion and Ion Plantation; Wafer Bonding: Anodic bonding and Silicon fusion bonding; Design and fabrication of few standard MEMS devices as a demonstrative/ hands-on session for students; Characterization Techniques: Topography Methods {Optical, Electrical and Mechanical Methods), Fluid, Thermal and Chemical Techniques.

Prerequisites: Instructor's consent is required

MT551 Design and analysis of Robotic Systems (6 Credits)

Introduction to robotics- History, growth; applications, Laws of Robotics, basic structure and classification of robots, workspace, and components of robots, Definition of mechanisms and manipulators; Classification of closed - and open loop kinematic systems. Kinematics and Dynamics- Frame transformation, D-H parameters, Forward and Inverse kinematics, Lagrange formulation, Velocity kinematics and Jacobian, Singularity analysis, Dynamic modelling, Euler-Lagrange, and Newton Euler equations of motion for robotic systems, Trajectory Planning- Traditional and non-traditional techniques, Robot Dynamics- Holonomic and Non-Holonomic Systems, Robot control- Control Schemes: Position, force &, hybrid controls, Sensors and actuators for robots, Robot vision, Mobile Robots: Modelling and Control, Odometry Analysis, Navigation problems with obstacle avoidance. Continuum and soft robotics.

Prerequisites: Instructor's consent is required

MT552 Industrial Data Communication and Processing (6 Credits)

Data Communications Basics: Basic data communications principles, Error detection, Dealing with noise, Serial Communications (RS-232, RS-485). **Overview of Networking basics and Protocols:** OSI model, Topologies, Medium access control, Repeaters, hubs, bridges, switches, routers, Protocol concepts, Bi-Sync, HDLC, File transfer protocols, **TCP/IP Internet Layer Protocols:** The TCP/IP protocol suite, IP addressing techniques and routing concepts, 1Pv4/1Pv6, ICMP, ARP. FTP, DHCP, HTIP, and other application-layer protocols, PING, ARP, TRACERT, and other TCP/IP utilities, **Industrial Communications:** CSMA/CD (half-duplex) Ethernet, Industrial Ethernet components and Techniques, Standardization bodies. Fieldbuses, HART, DeviceNet, ProfiBus, Modbus messaging protocol, **Wireless**

Industrial Networks: Wireless LAN, Wireless HART, 6LoWPAN, CoAP, **Robotic Operating System:** Publisher-Subscriber model, application development on ROS, Interfacing robots to exchange data, Uniform Robot Interfaces. Haptics application examples using Robotic hand and Haptic Glove, **Industrial IoT and Applications:** Connectivity architectures for Industrial Internet of Things (Example: ISAlOO standard), Multiaccess Edge Computing (ETSI Architecture), Digital Twins, Communication KPIs for applications, Data processing at the Edge by using ROS.

Prerequisites: Instructor's consent is required

MT553 Digital manufacturing (4 Credits)

Introduction to manufacturing techniques: casting, welding, forming, machining etc, Introduction to CAD/CAM: computer graphics, CNC, CNC coding etc, Introduction to DM-History, development; applications, components.

Theory System of Digital Manufacturing Science: operation reference mode and architecture of the digital manufacturing system, modelling theory and method of the digital manufacturing, the macro integrity theory of the digital manufacturing system and the meta theory constructing digital manufacturing, **Manufacturing Informatics in Digital Manufacturing Science:** the principle and properties of manufacturing information, the measurement and materialization of manufacturing information, self-assembling and the synthesis of manufacturing information and information security, **Digital twin for smart manufacturing:** back ground, concept etc. **Cyber-Physical Fusion in Digital Twin Shop-Foor:** Discussion on fusion of physical elements in physical shop-floor (PS), model fusion in virtual shop-floor (VS), data fusion in shop-floor digital twin data, (SDTD), and fusion of services in shop-floor service systems (SSS), **Digital Twin-Driven Prognostics and Health Management**: How DT is use to emulate physical equipment thoroughly with high fidelity and how it can help digital continuous monitoring, **Digital Twin and Virtual Reality and Augmented Reality/Mixed Reality:** How to integrate VR, AR and MR with the DT will be discussed to provide more immersive and interactive services to users.

Prerequisites: Instructor's consent is required

MT554 Optimal Control for Aerial System (6 Credits)

Dynamics of Flight: Static Stability and Control - Stability of Uncontrolled Motion - Response to Actuation of the Controls: Open Loop and Closed Loop - Sensors.

Optimal Control Design: Relocking the classical control theory - Parameter optimization: Servo Mechanism - State Space based Optimal Controller - State Regulator Problem - Infinite Time Regulator Problem - Output Regulator and Tracking Problem - Parameter Optimization: Regulator- MATLAB simulation.

Robust Controller Design: Concept of close loop robustness and sensitivity analysis, uncertainty models and Quantitative Feedback Theory (QFT) for robust design – State estimation in noisy environment, Recursive least-squares filters. Optimal & Robust State Feedback Control: the separation principle, Linear Quadratic Gaussian, H-alpha framework.

Autopilot: Stability augmentation systems - displacement autopilot - pitch attitude controller - altitude and glide path hold controllers - linear quadratic regulator based lateral control systems, pitch rate controller, yaw orientation controller incorporating servo dynamics,

Controllers for noisy & uncertain aircraft dynamics. Robust pitch rate controllers to handle wind gust and unmodelled dynamics. Special discussion: Underwater drone and surface robot

Prerequisites: Instructor’s consent is required

Courses in Mechanical Engineering

ME102 Engineering and Machine Drawing (3 Credits)

Introduction to sketching; Principal views; Principles of dimensioning; Introduction to computer aided graphics; Missing view, sectional view and assembly drawings; Pictorial representation, isometric drawing, Perspective drawing; Lines, planes, auxiliary view, Relationship between lines and planes; Intersections and development of lateral surfaces; Conceptual design, embodiment design, designing to standard, machine drawing, dimensioning as per standards, fits and tolerances, machine elements, assembly drawing, geometrical modelling, and use of CAD software for modelling and animation.

Prerequisites: CA100

ME111 Thermodynamics (6 Credits)

Introductory concepts and definitions; First law of thermodynamic; Quasi-static and reversible processes; Adiabatic changes; Carnot cycle; Second law of thermodynamics; heat engines and refrigerators, absolute temperature scale; Entropy and the Clausius inequality, second law in terms of entropy, the Gibbs equation, entropy for ideal gases, entropy change for reversible and irreversible processes, Availability; Thermodynamics property relations; Properties of pure substances; Thermodynamics cycles.

ME151 Fundamentals of Metallurgy (3 Credits)

Structure of metals: Interatomic bonding - Crystal system - Unit cells - Point coordinates - Crystallographic directions - Crystallographic planes - Millers indices - Bravais lattice - Allotropy.
Material properties: Theoretical strength - Defects in crystals - Slip and Twin -Anisotropy.
Phase Diagram: Formulation - Equilibrium structure - Fully soluble system - Partially soluble system - Gibbs phase-rule - Hardening and softening thermal treatments - m diagrams - CCC diagrams.

ME212 Fluid Mechanics (6 Credits)

Introduction and fundamental Concepts; Fluid statics; Kinematics of fluid; Governing equations and analysis of finite control volume; Applications of governing equations of motion and mechanical energy; Principles of physical similarity and dimensional analysis, flow of ideal fluids; Viscous incompressible flows; Laminar boundary layers; Turbulent flow; Applications of viscous flow through pipes; compressible flows.

ME213 Heat and Mass Transfer (6 Credits)

Introduction, rate equation and conservation of energy equations, modes of heat transfer; Conduction: 1D steady and unsteady state heat conduction, heat transfer of extended surfaces;

Convection: governing equations, dimensional analysis, boundary layers; Forced convection: external and internal flows; Natural and Mixed convection; Design of heat exchangers: LMTD

and NTU methods; Radiation: Processes and properties; Black and real body radiation; view factor and radiation exchanges between surfaces in an enclosure; concept of mass transfer.

Prerequisites: ME212

ME231 Solid Mechanics-I (6 Credits)

Fundamental principles of mechanics, Fundamental of Mechanics of Deformable solids - Introduction, analysis of axial and shear loaded components. Statically determinate and indeterminate problems. Castigliano's theorem. Beams - shear force and bending moment diagrams. Stress, strain, and their relationships. Thermal stress, fatigue and creep. Mohr circle. Stresses in beams. Torsion. Thick cylinders and rotating.

ME232 Dynamics (6 Credits)

Kinematics of particles, Rectilinear motion of particles, curvilinear motion of particles; Kinetics of particles; Kinetics of system of particles, Plane kinematics of rigid bodies; Plane kinetics of rigid bodies, energy and momentum methods, Kinetics and Kinematics of rigid bodies in three dimensions; Introduction to mechanical Vibrations.

ME251 Manufacturing Science I (6 Credits)

Introduction to manufacturing; Engineering Materials; Casting/Solidification; Welding; Deformation processes: Extrusion (direct and indirect), Rolling, Forging (open and closed die), Wire drawing, Sheet metal forming. Powder metallurgy: Introduction, Powder production, Compaction, and Sintering, Engineering stress-strain curve. Plastic injection molding: Flow forming of plastic components.

Prerequisites: IC101 and ME151. Both the courses could be taken concurrently.

ME314 Thermal and Fluid Engineering (6 Credits)

Overview of basic thermodynamics: Thermodynamic systems, processes, properties; Zeroth, First, Second, third law of thermodynamics, availability. Thermodynamic cycles: Pure substances, Rankine cycle, Otto, Diesel, Dual cycles, Brayton cycles, Refrigeration cycles.

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; Types of fluid flow: viscous vs inviscid flows, laminar vs turbulent flows, compressible vs incompressible flows; Non-dimensional analysis; Energy equations and its applications: Bernoulli equation, venturi, orifices, pitot tube etc; External and internal flows: flow over flat plate, cylinder, flow in a pipes and channels; Basics of hydraulic machines: rotary and reciprocating.

Overview of basic modes of heat transfer; Heat conduction: steady state heat conduction in plane and composite walls, critical thickness of insulation, lumped heat conduction, extended surfaces; Heat convection: Forced and free convection, internal and external flows; Heat exchangers: types, concept of LMTD, effectiveness; Radiation heat transfer: basic laws, radiation heat exchange between surfaces.

Prerequisites: Instructor’s consent is required

ME331 Solid Mechanics-II (6 Credits)

Introduction. Torsion of thin cylinders. Unsymmetrical Bending. Shear center. Deflection of beams - double integration, superposition, moment area and energy methods. Castigliano's theorem. Principle of virtual work. Statically inderminate problems. Continuous beams. Deflection in the presence of axial load. Buckling - Euler, Secant and Rankine - Gordon Formulae. Bending of Curved bars.

Prerequisites: ME231

ME333 Theory of Machines and Mechanism (6 Credits)

Kinematic pairs, diagrams and inversion; Mobility and range of movement; Displacement, velocity and acceleration; Analysis of planar linkages; Dimensional synthesis for motion, path and function generation; Gears and gear trains; Dynamic force analysis; Inertia forces and balancing for rotating and reciprocating machines; Cam mechanisms, Cam profile synthesis; Flywheels; Governors; Gyroscopes;

Prerequisites: ME232

ME334 Design of Machine Elements (6 Credits)

Introduction to design of systems and machine elements; Modes of failure, strength, stiffness and stability; Failure theories; Fatigue failure; Probabilistic approach to design; Design of joints; Design of spring; Design of Spur and Helical gear sets; Design of belt and chain drives; Analysis of clutches and brakes; Sliding and rolling contact bearings; Design of shafts; Analysis and application of coupling.

Prerequisites: ME102 and ME231. ME102 could be taken concurrently.

ME351 Metrology, Measurement and Instrumentation (4 Credits)

Fundamentals of measurement, Line and end standards, types of errors, Geometric dimensioning and tolerance (GD&T), types of fits, GO and NO GO gauges.

Static and dynamic characteristic of instrument, measurement of different geometric forms (flatness, circularity etc.), Coordinate measuring machine, Measurement of temperature, pressure, forces, torque, strain, calibration of instrument

Prerequisite: ME101

ME352 Manufacturing Science II (6 Credits)

Machining; Plastic Deformation, Mechanism of Plastic Deformation; Types of machining processes; Chip formation; Cutting; Tool Geometry; Multiple point cutting tools; Mechanics of Metal Cutting, Merchant's Circle Diagram; Friction in Metal Cutting; Mechanism of Oblique cutting; Rake angles in oblique cutting; velocity relationship and Force relationships in oblique cutting; General classification of unconventional machining, chemical machining, electric-discharge machining, Abrasive Jet and Ultrasonic Machining, electron beam machining, laser beam machining, ion beam machining, plasma arc machining; Comparative evaluation of different processes.

Prerequisites: IC101. The courses could be taken concurrently

ME353 Total Quality Management (3 Credits)

Introduction, Historical Review, TQM Principles, Continuous Process Improvement - Juran Trilogy, PDSA Cycle, Kaizen, Supplier Partnership - Partnering, TQM Tools: Benchmarking - Reasons to Benchmark, Benchmarking Process, Quality Function Deployment (QFD) House of Quality, QFD

Process, Benefits, Taguchi Quality Loss Function, Total Productive Maintenance (TPM) - Concept, Improvement Needs, FMEA - Stages of FMEA, The seven tools of quality, Process capability, Concept of six sigma, New seven management tools, Case studies. Quality Systems: Need for ISO 9000 and Other Quality Systems, ISO 9000:2000 Quality System - Elements, Implementation of Quality System, Documentation, Quality Auditing, QS 9000, ISO 14000 - Concept, Requirements and Benefits, Case Studies.

Prerequisites: Instructor's consent is required

ME371 Mechanical Engineering Lab-I (3 Credits)

Experiments to demonstrate/validate principles of solids mechanics, dynamics and fluid mechanics

Experiments related to measurement of stress, strain, deflection, velocity, acceleration, forces, pressure, flow, etc.

Prerequisites: ME231, ME232 and ME212. The pre-requisite courses could be taken concurrently

ME372 Mechanical Engineering Labs-II (3 Credits)

Experiments to demonstrate/validate principals of thermal engineering and manufacturing science

Experiments to demonstrate several machining process

Experiments related to measurement and characterization techniques in manufacturing science and thermal engineering

Prerequisites: ME102, ME251, ME352 and ME213. The pre-requisite courses could be taken concurrently

ME413 Refrigeration and Air-Conditioning (6 Credits)

Introduction and applications, Vapor compression systems: Ideal and real cycle analyses, Refrigerants and their properties, energy efficiency and environmental considerations. Advanced vapor compression cycles. Refrigeration system components: condensers, evaporators, compressors and expansion devices. Vapor absorption and gas cycle refrigeration.

Human Physiology and thermal comfort. Factors influencing thermal comfort. Introduction to air-conditioning, Properties of moist air, Psychrometric chart, Psychrometric Processes - heating, humidification, cooling and dehumidification etc. Cooling and heating load calculations. Room air distribution principles. Design of air duct systems. Indoor air quality. Ventilation. Various types of air conditioning systems. Cooling, dehumidification and

humidification equipment. Temperature, pressure and humidity controllers. Various types of controls and control strategies.

Prerequisites: ME111

ME415 Introduction to Turbomachines (6 Credits)

Definition and Classification of turbomachines - Specific Work - T-s and h-s Diagram - Incompressible and compressible flow - Losses - Total-to-Total efficiency - Total-to-Static efficiency - Effect of reheat and preheat factor. Degree of reaction. Energy transfer - Euler's equation, velocity triangles.

Dimensional analysis, Dimensionless parameters and their physical significance, specific speed, Hydraulic Pumps: Centrifugal Pumps - Some definitions - Pump output and Efficiencies - Effect of Vane angle - Cavitation - Pump Characteristics - Multistage pumps.

Hydraulic Turbines: Classification of hydraulic turbines - Velocity triangles. Efficiencies of draft

tubes - Hydraulic turbine characteristics. Francis and Kaplan turbines - Velocity triangles - Efficiencies of Draft tubes - Turbine characteristics.

Elementary cascade theory, cascade nomenclature, compressor cascade, turbine cascade, cascade efficiency. Dimensional analysis of compressible flow machines, stalling and surging.

Centrifugal Compressors: Constructional details - Stage Pressure rise - Stage Pressure Coefficient - Stage Efficiency - Degree of Reaction - Various Slip factors - Introduction to Fans

and Blowers, Working principle, Fan laws, Performance Characteristics.

Axial flow Compressors: general expression for degree of reaction; velocity triangles for different values of degree of reaction, Blade loading and flow coefficient, Static pressure rise,

Work done factor.

Steam and Gas Turbines: Axial turbine stages - Stage velocity triangles - Work - Single stage impulse turbine - Speed ratio - Maximum Utilization Factor - Compounding of Turbines and its

types, Degree of Reaction - Reaction Stages. Inward Flow radial turbine stages (IFR) - Working

principle and Performance Characteristics

Prerequisites: ME111 and ME212

ME416 Power Plant Engineering (6 Credits)

Economics of Power Generation: Introduction, Power plant economics, Types of power plants
Steam Power Plants: Introduction, Economics of Power Generation, Reheating and regeneration, Feedwater heaters, Supercritical pressure cycle, Deaerator, Binary vapour cycle, Combined cycle plants, Coal, Coal analysis, Combustion reactions, Energy balance of steam generator
Steam Generators, Steam Turbines, Condenser
Introduction, Basic types of steam generators, Fire tube and water tube boilers, Ash handling system, Feedwater treatment, Steam turbines, Condenser, Cooling towers
Diesel Engine and Gas Turbine Power Plants
Introduction, Combustion in a CI engine, Performance characteristics, Supercharging, Layout of a diesel engine power plant, Gas turbine power plant, Components of gas turbine plant, gas turbine fuels, Gas turbine Materials
Nuclear and Hydroelectric Power Plants

Nuclear fusion and fission, Chain reaction, Nuclear fuels, Components of nuclear reactor, Classification of reactors, Nuclear waste and its disposal, Advantages and disadvantages of Hydroelectric power plant, Classification of hydroelectric power plants, Pelton, Francis turbines and Kaplan turbines
Non-conventional and Renewable Power Generation
Introduction, Renewable energy sources potential, Solar power plants, Thermal energy, Wind energy, Wind power plant, Waste to power generation, Geothermal energy.

Prerequisites: ME111 and ME213

ME499 Thesis (Variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DUGC convener.

ME502 Advanced Engineering Mathematics (6 Credits)

Differential Equations: Review of first-order and second and higher order differential equations; System of differential equations; Series solutions, Special functions; Laplace transforms, Numerical methods for differential equations

Linear Algebra: Review of Matrix, Vectors, Determinants, Linear systems of equations, Eigen values, Eigen vectors, Vector differential and Integral calculus; Numerical methods in Linear algebra

Fourier Analysis and Partial Differential Equations: Fourier Series, Integrals and Fourier Transforms, Partial Differential equations

Prerequisites: Instructor's consent is required

ME512 Advanced Fluid Mechanics (6 Credits)

Revisiting some preliminary concepts of fluid mechanics: fluid kinematics, dynamics of inviscid flow, Reynolds transport theorem; Dynamics of viscous flows: Navier-Stokes equation; Exact solutions of Navier-Stokes equation; Boundary layer theory; Inviscid incompressible flow: potential flows and flow past immersed bodies; Turbulent flow; compressible flow.

Prerequisites: Instructor's consent is required

ME513 Convective Heat Transfer (6 Credits)

Overview of continuity and momentum equations; Derivation of energy equation; Similarity solutions for laminar external flows. Laminar internal flows; Transition flow - Heat transfer in transition flow; Turbulent flow - Reynolds averaged equations of motion, Averaged energy equations; Turbulent flow and heat transfer over a flat plate; Turbulent flow and heat transfer in pipes and channels; Laminar and turbulent natural convection - laminar and turbulent mixed convection; Pool boiling-nucleate boiling-film boiling; flow boiling-condensation; dropwise condensation; film condensation; Convective heat transfer with nanofluids; Combined convection and radiation; Double diffusive convection

Prerequisites: Instructor's consent is required

ME514 Internal Combustion Engines Fundamental (6 Credits)

Engine classifications; SI and CI engine principle and operation; Engine performance parameters; Rating of SI and CI engine fuels; Carburetion; Mechanical injection system; Electronic injection systems; Multi port fuel injection systems; Common rail diesel injection; Ignition; Mixture formation; Combustion in SI engines; Combustion in CI engines; Lubrication systems; Cooling system; Pollutants formation and their control; Nitrogen oxides, Carbon monoxide, Unburned hydrocarbons, Particulate formation; In-cylinder and after treatment techniques for emission reduction; NOx absorber; DOC and DPF; Engine performance calculations; Supercharging and turbo-charging.

Prerequisites: Instructor's consent is required

ME515 Engine Management Systems (6 Credits)

History and Introduction: Evolution of diesel and gasoline engines, Engine management system for internal combustion engines.
Engine Electronics: Piston displacement and speed sensing, Measurement of pressure, Temperature measurement, Intake air flow measurement
Gasoline engine management: Cylinder charge control systems, Manifold fuel injection, Gasoline direct injection, Operation of gasoline engine on natural gas, Ignition system, Inductive ignition systems, Different types of sensors such as temperature sensors, Engine speed sensors, Hot film air mass sensors, Piezoelectric knock sensor, High pressure sensor, Lambda sensor, Electronic control unit, Operating conditions.

Diesel engine management: Cylinder charge control systems, Principles of diesel fuel injection, Mixture distribution, Diesel fuel injection systems, Single plunger fuel injection pumps, Unit injector systems and Unit pump systems, Common rail systems, Injection nozzles, Minimizing emissions inside the engine, Electronic diesel control (EDC), Electronic control unit (ECU).

Prerequisites: Instructor's consent is required

ME516 Alternative fuels (4 Credits)

Combustion and Fuels: Flame propagation, Fuel spray pattern, Stratification, Combustion process in SI and CI engines. Liquid Alternative Fuels: Straight vegetable oils, Biodiesels, Emulsified Fuels, HVO, Methanol, Ethanol and higher versions of alcohols. Gaseous alternative fuels: Hydrogen, Liquefied petroleum gas, Di-methyl ether, Hythane. Modern developments in IC Engines such as EGR, MPFI, GDI, HCCI and Turbo-charging, Optical measurement techniques and tools, Pollution monitoring instruments and techniques, Non-Dispersive Infra-Red (NDIR) detectors, The flame ionisation detector (FID), chemiluminescence method for NOx measurement, Engine particle number emission, dilution and measurement. Principle and working of DOC, DPF, SCR and LNT.

Prerequisites: Instructor's consent is required

ME517 Building Environment and Energy Conservation (3 Credits)

Indoor environment - standards and recommendations; Heat loss and heat gains in buildings; Urban heat island effect; Energy Use and Thermal Comfort in Buildings; HVAC systems (performance and efficiency); Building heating and cooling (using conventional & renewable

energy); Energy efficiency in district cooling/heating system; Hybrid air-conditioning systems (performance and efficiency); Thermal storage systems integrated in the building envelope.

Indian climate map; Energy performance of Indian buildings; Integrated design process for energy efficient buildings; Passive building design Strategies: Building orientation, sun path, sun exposure, daylight and building natural ventilation, Indoor air quality, building envelope, building thermal insulation, single and double glazing windows, window location and solar protection; Building energy codes - Energy Conservation Building Code (ECBC); Energy Performance Index (EPI); Building rating; Green buildings.

Energy-efficient strategies to maintain thermal comfort; Personal cooling and heating systems; Local body cooling.

Prerequisites: Instructor's consent is required

ME518 Human Body Thermoregulation & Bio-heat Transfer (3 Credits)

Introduction to human body thermoregulation; Metabolism; Convection over body surface, sweating, respiration; Heat transfer to blood vessels; Body heat balance; Hypothalamus; Maintaining body temperatures; Cold thermoreceptors and heat receptors; Body temperature measurement (mean skin temperature, mean torso temperature and core temperature); Temperature induced dynamic change of blood flow (Vasodilation and Vasoconstriction); Body heat storage; thermal comfort; Cold-spell and heat wave conditions; Hypothermia and hyperthermia; fever; human-clothing interaction, Clothing thermal comfort; Fabric properties affecting thermal comfort; Thermal comfort evaluation - Thermal manikins and human trials. Thermo-regulation models; Bio-heat transfer models; Application of bioheat transfer - Detection of breast cancer, Tumor thermal treatment, Cryobiology, Determination of degree of skin burn.

Prerequisites: Instructor's consent is required

ME531 Advanced Mechanics of Solids (6 Credits)

Review of strength of Materials and its limitations. Mathematical Preliminaries; Deformation and Strains; Stress and equilibrium; Cauchy's principle; Constitutive law, Navier's equations, compatibility; Formulation of boundary value problems, Plane Problems; Different approach to solve plane problems with examples (for e.g. Stress function approach, Series solutions, Fourier transform methods); 3D problems by Potential methods, Energy methods and Problems.

Prerequisites: Instructor's consent is required

ME535 Theory of Elasticity (6 Credits)

Review of the Field Equations of Linear Elasticity: Kinematics and Kinetics of deformable solids, Constitutive models for linear elastic materials; Theorems of linear elasticity; Two dimensional formulation; Two dimensional boundary values problems; Complex variable methods. Three dimensional boundary value problems; Energy Theorems and Applications; Anisotropic elasticity.

Prerequisites: Instructor's consent is required

ME551 Advanced Manufacturing Process (6 Credits)

Modern Machining Processes: Electro Discharge Machining (EDM), Processes mechanism of material removal, parameters effects EDM & application, Electrical Discharge Grinding(EDG), Traveling Wire EDM, Electrochemical Machining (ECM), Processes, Mechanism of material removal, Tool design, Parameters affecting ECM , Applications, Electro-chemical Honing(ECH), Electrochemical Debarring (ECD), Electrochemical Grinding(ECG), Electrochemical Discharge Grinding, Chemical Machining, Ultrasonic Machining, Cutting Tool System Design, Mechanism of cutting, Parameters affects USM applications, Abrasive Jet Machining, Variables of AJM, Nozzle Design, Laser Beam Machining, Thermal and Non-thermal analysis, and applications, Electron – Beam Machining and its mechanism, Applications, Plasma arc machining, Equipment, Arc transfer mechanism, Metallurgical efforts, Safety precautions and applications, Plasma are surfacing and plasma Arc Springing, Iron Beam machining and water Jet Machining. High Energy rate forming processes, Advanced Welding Techniques, Additive Manufacturing.

Prerequisites: Instructor's consent is required

ME552 Knowledge Base Systems (3 Credits)

Introduction to knowledge base system/Expert system, Importance of expert system, Components of expert system.

Conventional optimisation tools, Genetic algorithm (Basic concepts; Population; Chromosomes; Operators), Fuzzy Set Theory, Fuzzy Logic Controllers (FLC), Neural Network (NN) Controllers - back propagation network. Combined techniques of soft computing - GA• FLC, GANN, NN-FLC, GA-FLC-NN.

Prerequisites: Instructor's consent is required

ME553 Advanced Materials and Processing (3 Credits)

Tools for characterization: Metallurgical sample preparation technique - Spectroscopies - Microscopies – Diffraction analysis.

Role of dislocation: Strengthening mechanisms - Softening mechanisms, structure-property correlationship.

Materials of importance: Special ferrous alloys - Important non-ferrous alloys - Special class of structural materials (non-alloy); Composites.

Processing: Need -Thermo-mechanical processing - Special Processing techniques: Coating, Surface treatment, Additive Manufacturing.

Prerequisites: ME559. ME559 could be taken concurrently.

ME555 The Science and Technology of Metal Forming (6 Credits)

Introduction: Metal forming processes, definition, advantages, disadvantages, forming equipment Plasticity theory: stress-strain relation, strain• displacement, incompressibility, strain compatibility, yield criteria, flow rule Fundamentals: slip lines field, upper bound and lower bound theorem, slab analysis. Bulk Forming Processes: forging; extrusion, wire and tube drawing, rolling; process description and application of theory. Sheet Forming Processes:

blanking, deep drawing, stretch forming, bending. Advanced techniques: numerical approaches in metal forming.

Prerequisites: Instructor's consent is required

ME556 Fluid Power Systems (6 Credits)

Introduction: Types of power systems - Physical properties of fluids - Types of fluids and fluid power systems - Application of fluid power systems. Hydraulic systems: Pumps -Actuators - valves - circuits design and analysis -Ancillary hydraulic devices. Pneumatic systems: Compressors-Air preparation units - circuit design. Advanced systems: Servo-hydraulics - Electro-pneumatics - Digital systems. Lab-practice: computer simulation of hydraulic and pneumatic circuits - design development and deployment of pneumatic systems.

Prerequisites: Instructor's consent is required

ME557 Laser Material Processing (6 Credits)

Introduction to laser, laser properties, advantages and disadvantages, application; Working principle of different industrial laser, C02 Laser, Nd-YAG laser, Diode laser, Excimer laser, Fiber laser etc. Laser material processing, cutting, drilling, welding, micro-machining, surface treatment, forming, cladding etc. Application of laser in 30 printing, selective laser sintering, laser melting, direct metal deposition, comparison of laser based additive manufacturing with other additive manufacturing process. Laser safety

Prerequisites: Instructor's consent is required

ME558 Surface Engineering (6 Credits)

Introduction to surface engineering - Concept and importance, Surface Degradation: Causes, types, and consequences of surface degradation. classification of surface modification techniques, advantages, and their limitations.

Materials for Surface Engineering: Selection of materials for engineering the surfaces for specific applications, structure and property relationship of coatings system.

Conventional surface engineering practices like pickling, grinding, buffing etc., Conventional heat treatment processes. surface modification of ferrous and non-ferrous materials like nitriding, cyaniding, aluminizing etc.

Vapour deposition processes: Chemical Vapour Deposition of different types of coatings. Vacuum Evaporation Deposition, Cathodic Arc Evaporation Deposition, Sputtering and its advancements)

Thermal Spraying methods: Classifications, Flame and plasma spraying, HVOF, cold spray techniques.

Electroplating, Electroless coating, Laser, Electron beam and Microwave assisted Surface Engineering, Friction Surfacing and Friction stir Processing.

Physical Characterization: Microstructure, Surface morphology, Phase analysis, Determination of Crystallite size.

Mechanical Characterization: Determination of thickness of coating, Coating hardness, Adhesion of surface coating, Surface roughness.

Performance evaluation of coatings: Friction and wear performance, Evaluation of corrosion resistance, Assessment of oxidation resistance, Applications of tribological coatings,

Performance of cutting tool coatings: Few case studies using hard and soft coatings, HFCVD Diamond coated tool.

Prerequisites: Instructor's consent is required

ME559 Mechanical Behaviour of Materials (3 Credits)

Introduction: Crystals - lattice - slip systems -Theoretical strength - defects - stress-strain curve. Deformation: Modes of deformation - deformation mechanisms -Anisotropy. Material testing: Common testing methods - Role of parameters: strain, strain-rate, temperature - cyclic loading - time-dependent deformation - Environmental Effects.

Prerequisites: Instructor's consent is required

ME560 Additive manufacturing Technology (6 Credits)

Introduction and additive manufacturing process chain: CAD model preparation, slicing, build file preparation
Additive manufacturing mechanism: sheet lamination, Material Extrusion, Direct energy deposition, powder bed fusion, Arc based additive manufacturing, Solid state additive manufacturing etc.
Post processing, Numerical modeling, Economic analysis, and application in various industries
Prerequisites: IC101, ME151

ME599 Thesis (Variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: For MTech-ME only

ME601 Applied Numerical Methods (6 Credits)

Introduction to Mathematical Modelling; Taylor and Fourier series expansion; Root finding; Interpolation, splines, extrapolation; Regression and curve fitting; Solution of simultaneous linear algebraic systems; nonlinear algebraic equations; Eigenvalues and eigenvectors; Solution of simultaneous nonlinear algebraic systems; Numerical integration, Simpson's rule, Gaussian quadrature; Solution of ODE: R. K. Methods; Predictor-Corrector methods; boundary value problems; Systems of ODEs; convergence and error studies; Linear PDEs by finite differences.

Prerequisites: Instructor's consent is required

ME613 Microfluidics (6 Credits)

Introduction: Significance in fundamental and applications; Governing equations: mass, momentum and energy and species conservation equations; Boundary conditions; Pressure

driven flows; Surface tension driven flows and it's modulation; Unsteady flows; Electrokinetic flows; Stokes drag on sphere; Introduction to lubrication theory; Gas flow through micro conduits; Biomicrofluidics; Microfluidics components; Introduction to microfabrication.

Prerequisites: Instructor's consent is required

ME614 Electronic Cooling Systems (6 Credits)

Introduction; heat transfer modes, thermal spreading and contact resistance, microscale heat transfer; Fin analysis, heat sink design optimization, Air and liquid jet impingement, immersion cooling, phase change energy storage, multi-mode heat transfer; Thermal systems analysis, cold plates and heat exchangers, flow network modeling, compact models, acoustic and mechanical design issues; Microscale measurement techniques; Emerging technologies.

Prerequisites: Instructor's consent is required

ME615 Computational Fluid Dynamics (6 Credits)

Conservation laws of fluid motion and boundary conditions: Governing equations, conservation vs non-conservation, Differential vs integral forms of general transport equations, classification of physical behaviours, classification method for simple PDEs; finite volume method for diffusion problems; finite volume method for convection-diffusion problems: differencing schemes; Solution of discretised equations: TDMA, Iterative methods; Solution algorithms for pressure-velocity coupling in steady flow: SIMPLE algorithm; The finite volume method for unsteady flows: Explicit scheme, Crank-Nicolson scheme, fully implicit scheme; Errors and uncertainty in CFD modelling. Application of CFD to analyze engineering problems.

Prerequisites: Instructor's consent is required

ME616 Interfacial Transport Phenomena (6 Credits)

Introduction: Basic concepts of interfaces and transport.

Capillarity: Deformable interfaces, emphasis on the effect of surface tension, liquid at interfaces, Surface curvature, Contact Angles and measurement.

Surface wettability: Hydrophilic, hydrophobic and superhydrophobic surfaces, and variable wettability gradient surfaces.

Hydrodynamics of wetting: Thin films, droplets, bubbles, puddles and waves.

Dynamics of Liquid-droplet in detail: Focus will be on droplet Impact (Fluid dynamics aspect) and evaporation (Fluid dynamics and Heat Transfer aspect) in detail. Droplet spreading, receding, bouncing, nonbouncing, partial bouncing, splashing. The partial differential equations and their solutions for these problem. Scaling approximations.

Surfactants: Applications, Soap films and bubbles.

Basics of manipulation of fluids and its applications in microchannels.

Colloidal Deposits and its interfaciat science: Coffee ring effect, blood-stain patterns, colloidal particle-sorting, etc.

Special Topics: Applications in Forensic science, biotechnology, energy and sustainable environment.

Prerequisites: Instructor's consent is required

ME617 Multiphase Flow and Heat Transfer (6 Credits)

Introduction of multiphase flow: Various definitions, examples and industrial applications; multiphase Flow regime types and their definitions; analysis of flow regimes and the simple analytical models; homogeneous flow model, Drift flux model, Separated flow model; two phase flows: Boiling heat transfer, boiling regimes, heat transfer in different regimes of boiling,

Instabilities of vapor layer; quenching/Rewetting and its analytical model; two-Phase Natural circulation loop and Heat Transfer; condensation and its types: Homogeneous, Heterogeneous, Dropwise, Filmwise condensation.; measurement Techniques for the multiphase flow parameters: Void fraction measurement, estimation of flow patterns.

Prerequisites: Instructor's consent is required

ME632 Fracture Mechanics (6 Credits)

Introduction; Background and history of fracture; Energy release rate; Crack-tip deformation and stress fields; Stress intensity factor; Westergaard's approach; Elasto-plastic fracture mechanics, CTOD; J-Integral; Test methods; Fatigue failure and environment assisted fracture; Numerical analysis of cracks; Mixed mode crack initiation and growth.

Prerequisites: Instructor's consent is required

ME633 Finite Element Method (6 Credits)

Introduction and historical background; Background on variational calculus: Galerkin methods, Collocation methods, Least-squares methods. Variational methods of approximation-Rayleigh-Ritz method, variational theorems; 1D FEM; Trusses; Beams and frames; 2D problems: Constant strain triangles, Axisymmetric problems; Isoparametric elements; 3D problems; Shell analysis; Solution of heat conduction, fluid flow, vibration, and stability.

Prerequisites: Instructor's consent is required

ME634 Composite Materials (6 Credits)

Introduction to the fiber reinforced composite materials: Basic terminologies, Advantages of composite, Applications, Manufacturing of FRC materials; Macromechanical and Micromechanical behaviour of a lamina; Macromechanical behaviour of a laminate; Analysis of laminated plates and beams; Fracture mechanics of FRP composites; Fatigue; Environmental effects; Experimental characterization of composites.

Prerequisites: Instructor's consent is required

ME652 Automation (6 Credits)

Introduction to manufacturing, Manufacturing system concept. Manufacturing automation, FMS, CIMS, Flow lines and assembly systems, Automated storage /retrieval systems, AGV. Introduction to CAD/CAM, NC, CNC, DNC, Adaptive control. Manual and computer assisted part programming. Introduction to robots and their application in manufacturing. Process planning and Computer Aided Process planning. Group Technology, Opitz System and GT benefits.

Prerequisites: Instructor's consent is required

ME653 Experimental Methods in Fluids and Thermal Science (6 Credits)

Analysis of Experimental Data: Causes and types of experimental error, uncertainty analysis, statistical analysis of data, probability distributions and curve fitting; Dynamic performance characteristics; Input types; Instrument types- zero order instrument, first-order instrument, second-order instrument;

Measurement of pressure: design of Pitot and Pitot static tubes, factors affecting the measurements of Pitot/Pitot Static Tubes: Alignment, wall effects, turbulence etc., the effect of flow compressibility on pressure measurements of PST, methods of measuring static and Pltot/stagnatlon pressure In the compressible flow. Flow measurements: 3 hole and 5 hole probes, directional sensitivity of 3 hole and five-hole probes, Hotwire anemometry (HWA): detail analysis of constant current anemometer (CCA) and constant temperature anemometer (CTA), comparison of CCA and CTA, measurements of fluctuating velocity in turbulent flow, Laser Doppler Velocimetry/Anemometry (LDV/LDA), Particle Image Velocimetry (PIV), micro-PIV, Flow visualization methods; Temperature Measurements: Details of Thermocouple measurements and its calibration; Liquid crystal thermography (LCT), lnfraRed Thermography (IRT), optical methods for temperature and density measurements: qualitative and quantitative analysis through Interferometer, Schlieren and Shadowgraph;

Prerequisites: Instructor's consent is required

ME654 Advanced Materials - Development and Characterization (6 Credits)

Advancement in engineering materials - Role of alloys, ceramics, intermetallics and other special class of materials in automobile and aerospace applications.

Development and characterization practice: Material identification - Development by conventional / unconventional material development route – microstructural characterization (Optical and Electron microscopies, XRD, etc) - mechanical performance (Room and high temperature properties, tribological characteristics, etc.). Documenting and reporting the results.

Prerequisites: ME553

ME673 Computational Fluid Dynamics Laboratory (1 Credits)

Modelling and analysis of various fluid flow and heat transfer problems involving:

Internal fluid flow: Flow through pipe and channels, sloshing and other similar problems.

External fluid flow: Flow over aerofoil/wing and automobiles; flow over stationary and rotating cylinder (magnus effect), and other similar problems.

Forced convection: Flow through pipe/channels; problems involving electronics cooling and jet impingement cooling.

Free convection: Natural convection cooling and heating; coupled natural convection-radiation problems.

Prerequisites: Instructor's consent is required

ME674 Finite Element Analysis Lab (1 Credit)

Preprocessing: Material model, boundary condition, mesh type, contact condition etc

Mesh sensitivity analysis

Simulation of various engineering problems from the domain of mechanical engineering such as structural analysis of components, deflection of beam, thermal analysis, metal cutting, welding etc.

Prerequisites: Instructor's consent is required

ME795 Candidacy (0 Credit)

Evaluation of candidate's ability to carry out research, knowledge breadth of the student, research comprehension.

Prerequisites: Student must have completed the course credit requirement for the program registered for.

ME798 Independent Study (variable Credits)

Course content and credits are to be assigned by the course instructor.

Prerequisites: Instructor's consent is required

ME799 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: ME795.

Courses in Physics

PH205 Relativity (2 Credits)

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.

Prerequisite: IC200

PH206 Light Absorption, Emission and evice (2 Credits)

Optical absorption and reflection (fundamentals, X- rays to microwaves), cyclotron resonances, excitons, polarons, plasmons, radiative and non-radiative carrier recombination, excitonic signatures in photoluminescence. Optical properties of OD, 10 and 20 semiconducting materials, quantum-dot-based light emitting diodes (lnGaN, GaP etc) and transistor (lnGaP, GaAs etc), semiconductor LASERS (GaAs, AlGaAs, etc), quantum-dot-based LASERS (eg lnGaAs) and optical properties of superlattices. Miscellaneous semiconductors (amorphous, organic, fullerenes, carbon nanotubes), molecular electronics, photoconductivity and dynamics, photovoltaics. Rayleigh, Raman and Brillouin scattering phenomena.

Prerequisite: IC102

PH207 Quantum Optics and Information Processing (2 Credits)

Classical optics, quantum properties of light, photon statistics, single photon source, polarizing beam splitter (analogy with Stern-Gerlach experiment), polarization state of a single photon, single photon polarization detector, Pockets cell, light amplifier, basic principles of quantum cryptography, quantum cryptographic systems and limitations, quantum key distribution-8884, -892 protocols, qubits, quantum logic gates, decoherence, error correction and applications of quantum computers.

Prerequisite: IC151

PH208 Self-Propelled Micro/Nanorobots (2 Credits)

Mechanism of propulsion at small scale (low Reynolds numbers), Scaling laws, Design strategies for self-propelled micro/nanorobots under different environmental conditions (e.g. aqueous and complex viscoelastic or biological media), Techniques of the localization and manipulation (external and self-guided motion). Observation and tracking methods.

Micro/nanorobots for the applications in targeted drug delivery, non-invasive surgery, environmental sensing, cargo delivery, and formation of dynamic and reconfigurable self assemblies.

Prerequisite: IC102

PH209 Unfurling Neutrino Stories (2 Credits)

History of Neutrinos: From Pauli to Fermi's theory to six Nobel Prizes in neutrino physics

Fundamental Constituents of our Universe (quarks, leptons, photon, W,Z bosons, Higgs) and forces: [electromagnetic, weak, Strong and gravitational interactions.

Status of Neutrinos in Weinberg, Salam and Glashow's SM of Particle Zoo.

Brief Idea about Solar, atmospheric, reactor/accelerator, supernovae neutrinos.

Neutrino oscillations and efforts by Indian Neutrino Observatory.

Neutrino Astronomy, Icecube Telescope: Neutrinos from Heaven.

Current Research Perspectives of Neutrino Physics in purview of Particle Physics, Astrophysics and Cosmology.

Prerequisites: IC151 and IC200

PH501 Classical Mechanics (6 Credits)

Review of Newtonian mechanics, Lagrangian mechanics, generalized coordinates, constraints, principle of virtual work, Lagrange's equation, calculus of variations, central forces, collisions, scattering small oscillations, anharmonic oscillators. perturbation theory, forced oscillators. Hamilton's equations, phase space & phase trajectories, canonical transformations, Poisson brackets, Hamilton- Jacobi theory, rigid body dynamics, nonlinear dynamics; Special Theory of Relativity: Relativistic Kinematics, Mass Energy equivalence, Continuous System.

PH502 Quantum Mechanics-I (6 Credits)

Origins of quantum theory, Schrödinger equation, wave mechanics, one and three-dimensional problems, Harmonic and other potentials; hydrogen atom, Hilbert space formalism for quantum mechanics, symmetries in quantum mechanics, general treatment of angular momentum; spin, identical particles; Pauli exclusion principle.

Prerequisites: For BTech students - IC151

PH503 Mathematical Physics (6 Credits)

Vector space, orthogonality, matrices, Cayley-Hamilton Theorem, eigenvalues, eigenvectors; Complex variable, Singularities, Taylor and Laurent series, residue theorem, contour integration; Fourier series, Fourier transformation, Laplace transformation; Special function: Gamma, Hermite, Bessel, Legendre, Laguerre and Green functions; Introduction of tensor and group theory, representation of O(N), SU(N).

Prerequisite: For BTech students - IC153

PH504 Computational Physics (6 Credits)

C Programming Language: Algorithms, flow charts, constants, expressions, conditional statements, loops, arrays, logical expressions, control statements, functions, structures, pointers, bit operation, files in C. Solving problems using C programming. Numerical Analysis: Interpolation by Lagrange method, Numerical solution of simple algebraic equation by Newton- Raphson method, Least Square fit using rational functions, Numerical integration: Trapezoidal method, Simpson's method, Romberg integration, Gauss quadrature method, Eigenvalues and eigenvectors of a matrix, Solution of linear homogeneous equations, Trace of a matrix, Matrix inversion, Solution of ordinary differential equation by Runge-Kutta Method, Introductory Monte Carlo techniques.

Prerequisite: PH503. The course could be taken concurrently

PH505 Electronics Laboratory (6 Credits)

Bipolar junction transistor (BJT) - characteristics, MOSFET characteristics, Cathode Ray Oscilloscope (CRO), Logic Circuit, Light Emitting Diode (LED) characteristics, Thin Film Deposition and its characterization, Characteristics of Solar cell, Photoluminescence, Raman effect experiment.

Prerequisite: The course is meant only for MSc-PH students.

PH506 Statistical Physics (6 Credits)

Classical Statistical Mechanics: Postulate of classical statistical mechanics, Liouville's theorem, micro canonical ensemble, Derivation of thermodynamics, equipartition theorem, classical ideal gas, Gibb's Paradox. Canonical ensemble and energy fluctuation, grand canonical ensemble and density fluctuation, Equivalence of canonical and grand canonical ensemble; Quantum Statistical Mechanics: The density matrix, ensembles in quantum statistical mechanics; Ideal gas in micro-canonical and grand canonical ensembles; Equation of state for ideal Fermi gas, Theory of white dwarf stars. Ideal Bose Gas, Photons and Planck's law, Phonons, Bose-Einstein condensation; Phase Transition: Thermodynamic description of phase transitions, phase transitions of second kind, Discontinuity of specific heat, change in symmetry in a phase transition of second kind. Ising model : Definition of Ising model, One Dimensional Ising model; Ideal Bose Gas, Photons and Planck's law Phonons, Bose- Einstein condensation; Thermodynamics description of phase transitions, phase transitions of second kind, Discontinuity of specific heat, change in symmetry in a phase transition of second kind.

Prerequisites: IC151 or PH502

PH507 Quantum Mechanics – II (6 Credits)

Time Independent Perturbation Theory, First and Second Order Correction, Perturbed Harmonic Oscillator, Anharmonic Oscillator, The Stark Effect. Degenerate Perturbation Theory, Removal of Degeneracy.

Variational Methods: Ground State, First Excited State and Second Excited State of One-Dimensional Harmonic Oscillator, Ground State of H-atom and He-atom, Rotational and Vibrational Degrees of Freedom, Hydrogen molecule ion, Hydrogen molecule.

WKB Approximation Method: General Formalism, Validity of WKB Approximation Method, Connection Formulas, Bohr Sommerfeld Quantization Rule, Application to Harmonic Oscillator, Tunneling Through a Potential Barrier, Cold Emission, Alpha Decay

Time Dependant Perturbation Theory: Transition Probability, Constant and Harmonic Perturbation, Fermi's Golden Rule, and Electric Dipole Radiation and Selection rules.

Scattering Theory: Scattering Amplitude and Cross Section. Born Approximation. Application to Coulomb and Screened Coulomb Potential,. Partial Wave Analysis for Elastic and Inelastic Scattering, Optical Theorem, Hard-Sphere Scattering, Resonance Scattering from a Square Well Potential.

Prerequisites: PH502, PH503 and PH506. PH506 could be taken concurrently

PH508 Electrodynamics (6 Credits)

Brief electromagnetism, Maxwell's equations, Poynting's theorem, Energy and momentum conservation; Electromagnetic waves: wave equation, propagation of electromagnetic waves in different media, reflection, refraction, and total internal reflection, complex refractive index; Multipole Radiation: Potential, Fields and radiation due to an oscillating electric dipole, angular distribution of power radiated, Rayleigh Scattering. Magnetic dipole and Electric Quadrupole radiation; Radiation by Point Charge: Lienard-Weichert potential, Field due to a point charge, Angular distribution of radiation and total power radiated by an accelerated charge, Thomson's scattering.

Prerequisites: For BTech students - IC102.

PH509 Nuclear and Particle Physics (6 Credits)

Ground state of Deuteron, Mesons and nuclear force field (Field theory of Nuclear forces); Liquid drop model and Weissacker's mass formula, Shell model of the nucleus, Fermi gas model Single particle shell model, Collective model of nucleus, rotational motion of the nucleus, vibration of spherical Nuclei; Description of nuclear Reactions, Q-value, derivation of elastic and reaction cross section, description by partial wave analysis, Resonances, Breit-winger one level formula; Accelerators and Detectors.

The Standard model of particle physics, particle classification, Spin and parity determination, Isospin, strangeness, hypercharge, and baryon number, lepton number, Gell-Mann-Nishijima Scheme, Quarks in hadrons: Meson and baryon octet, Elementary ideas of SU(3) symmetry, charmonium, charmed mesons and B mesons, Quark spin and colour.

Prerequisites: For BTech students - IC151.

PH510 Experimental Laboratory (6 Credits)

Typical set of experiments: Michelson Interferometer, X-Ray Diffraction, Planck's constant, Geiger-Muller counter, Hall effect, Faraday effect, Microwave Experiment, Electron Spin Resonance, 2D Grating, Kerr effect, Rydberg constant, Franck-Hertz experiment, Zeeman effect.

Prerequisite: The course is meant only for MSc-PH students.

PH511 Atomic and Molecular Physics (6 Credits)

Review of one and two-electron atoms; Many electron atoms: central field approximation, Thomas-Fermi model, Hartee-Fock and self-consistent field methods, Hund's rule, L-S and j-j coupling, Equivalent and nonequivalent electrons, Spectroscopic terms, Lande interval rule; Interaction with Electromagnetic fields: Zeeman, Paschen Back and Stark effects; Hyperfine structure and isotope shift, selection rules; Lamb shift; Molecular spectra: rotational, vibrational, electronic, Raman and Infra-red spectra of diatomic molecules; Hund's rule, Frank–Condon principle; Molecular structure: molecular potential, Born-Oppenheimer approximation, diatomic molecules, electronic angular momenta; Modern developments: optical cooling and trapping of atoms, Bose- Einstein condensation, Introduction of LASER physics.

Prerequisites: For BTech students – PH507

PH512 Solid State Physics (6 Credits)

Crystal structure: Miller indices and reciprocal lattice, Bragg and von Laue diffraction, structure factor; Lattice vibration and thermal properties: harmonic approximation, monatomic and diatomic lattices, Brillouin zone, density of states, acoustic and optical modes, phonons, crystal momentum, Debye model of specific heat, thermal expansion, thermal conductivity; Free electron theory: Fermi gas, specific heat, Ohm's law, magneto-resistance, thermal conductivity; Band theory: Bloch theorem, nearly free electron model, motion of electron in energy bands, effective mass; Semiconductor: Intrinsic and extrinsic semiconductors, mobility and electrical conductivity, Fermi level, Hall effect; Magnetism: Diamagnetism, Hund's rules, Lande g-factor, quantum theory of paramagnetism, Pauli paramagnetism, exchange interaction, ferromagnetism, hysteresis; Superconductivity: Meissner effect, London equations, type-I and type-II superconductors; Ginzburg-Landau theory, outlines of BCS theory.

Prerequisites: For BTech students - PH502

PH513 Experimental and Measurement Techniques (6 Credits)

The range of experimental methods covers X-ray diffraction technique-Neutron diffraction; Fundamentals of electron microscopy (SEM, TEM, Electron diffraction, STEM); Electron Probe Microanalysis (EPMA) (EDS, WDS); Scanning tunneling microscopy (STM) and atomic force microscopy (AFM); Electron emission spectroscopies (XPS, AES, UPS); Vibrational spectroscopy (IR, Raman); Resonance techniques (NMR, ESR); Lithography- optical, e-beam etc; chromatographic techniques (size exclusion chromatography, liquid chromatography, gas chromatography); mass spectroscopy (ESI-MS, MALDI-TOF); surface area analysis of porous materials, oxygen/moisture permeability analysis; mechanical testing; rheology. Whenever possible lab tours will be arranged showing the equipment in practical use.

Prerequisites: PH512. The course could be taken concurrently

PH514 Electronics (6 Credits)

Network theorems; application to simple circuits; p-n junction devices, diode, transistors; biasing schemes; small signal amplifiers; feed-back; theory; oscillators; power supply; wave shaping circuits; Bipolar junction transistor: configurations, small signal amplifier, oscillators; JFET and MOSFET: characteristics, small signal amplifier; OP-AMP: Differential amplifiers; Op-Amp (741) circuits (amplifiers; scalar; adder;subtractors; comparator; logarithmic amplifiers; etc.); Number systems and their inter-conversion; Boolean algebra; Logic gates; De-Morgan's theorem; Logic Families: TIL, MOS and CMOS; Combinational Circuits: Adders, subtractors, Encoder, etc.; Sequential Circuits: Flip-flops, Registers, Counters, Memories; A/D and D/A conversion Microprocessor and microcontroller basics

Prerequisites: The course is meant only for MSc and PhD students

PH515 Semiconductors and Applications (6 Credits)

Introduction to thin films and nanostructures; Growth modes and zone models; techniques for fabrication of semiconductor thin films and nanostructures using sputtering, e-beam evaporation, atomic layer deposition, electrospinning, dry and wet etching, chemical vapour deposition, sol-gel, spin-coating, and Langmuir-Blodgett technique etc. Characterization of optical, electrical, mechanical and structural properties using various techniques. Interaction of ultraviolet and visible photons with semiconductors; charge excitation, formation of excitons and polarons in general and molecular semiconductors; dynamics of photogenerated carriers;

some specific examples for the dynamics of charge carriers; photovoltaic effect: conduction, separation, and collection; working principles, photovoltaic characterization techniques, limitations or technological hurdles, and material aspects of different generation of solar cell technology.

Prerequisites: PH512

PH517 Astrophysics & Cosmology (6 Credits)

Astrophysics: basics, spectra, radiative transfer, stars, end-states of stars (white dwarfs, Chandrasekhar's mass limit, neutron stars, supernovae, black holes), quasars, gamma ray bursts, interstellar medium, galaxies, astrophysical fluids & plasmas, instabilities, magnetohydrodynamics, applications to stars/galaxies and the Universe.

Einstein's relativity: special relativity, equivalence principle, basics of general relativity. Cosmology: redshift, FRL W models of the Universe, expansion, Hubble's law, the early Universe, big-bang model, inflation, nucleosynthesis, matter and radiation dominated era, dark matter, dark energy, cosmic microwave background, baryon acoustic oscillations, formation of galaxies and stars, current forefront of research, supermassive black holes, first stars, epoch of reionization, 21 cm cosmology, N-body simulations

Prerequisites: (IC 100 and IC200) or (PH501 and PH504).

PH604 Advanced Quantum Mechanics (4 Credits)

Klein-Gordon equation and its drawbacks, Dirac equation, Properties of Dirac Matrices, Non-

relativistic reduction of Dirac equation.

Covariant form of Dirac equation, magnetic moment, Darwin’s term, Spin- orbit coupling, bilinear

covariant, Lorentz Covariance of Dirac equation, Free particle solution of Dirac equation, Projection operators for energy and spin.

Physical interpretation of free particle solution, Zitterbewegung, Hole theory, Charge conjugation, Space reflection and Time reversal symmetries of Dirac equation.

Continuous systems and fields, Transition of discrete to continuous systems, Lagrangian and Hamiltonian formulations, Noether’s theorem

Second quantization, Quantization of neutral scalar field, and charge scalar field, (Expansion of fields in terms of creation, annihilation operator and number operator, unequal space time commutators, anti commutators, propagator functions and their integral representations, Vacuum expectation value, Time ordered product, Feynman propagator).

Dirac field and electromagnetic field (Expansion of fields in terms of creation, annihilation operator and number operator, unequal space time commutators, anti commutators, propagator functions and their intergral representations, Vacuum expectation value, Time ordered product, Feynman propagator)

Prerequisites: PH502

PH605 Quantum Field Theory (6 Credits)

Relativistic quantum mechanics – Klein-Gordon equation, Dirac equation, free-particle solutions

Lagrangian formulation of Klein-Gordon, Dirac and Maxwell equations, Symmetries (Noethers theorem), Gauge field, Actions. Canonical quantization of scalar and Dirac fields. Interacting fields – Heisenberg picture, perturbation theory, Wicks theorem, Feynman diagram

Cross-section and S-matrix. Quantization of gauge field, gauge fixing. QED and QED processes. Radiative corrections – self-energy, vacuum polarization, vertex correction. LSZ and optical theorem. Introduction to renormalization.

Prerequisites: PH502.

PH606 Particle Physics (6 Credits)

The Standard model of particle physics, particle classification, fermions and bosons, lepton flavors, quark flavors, electromagnetic, weak and strong processes, Spin and parity determination, Isospin, strangeness, hypercharge, and baryon number, lepton number, Gell-Mann-Nishijima Scheme, Quarks in hadrons: Meson and baryon octet, Elementary ideas of SU(3) symmetry, charmonium, charmed mesons and B mesons, Quark spin and colour.

Dirac equation, Scattering processes of spin-1/2 particles (Feynmans rules as thumb rule), propagators

Current-current interactions, weak interaction, Fermi theory Gauge symmetries, spontaneous symmetry breaking, Higgs mechanism

Electroweak interaction, Glashow-Salam-Weinberg model Introduction to QCD, structure of hadrons (form factors, structure functions), parton model, Deep inelastic scattering.

Prerequisites: PH509

PH607 Relativistic Matter at finite magnetic field (6 Credits)

Two-body to N-body coupled oscillators to Continuous System, Relativistic ideal and dissipative Hydrodynamics, Magneto Hydrodynamics, Kinetic Theory in presence of magnetic field, quantum aspect of magnetic field, Landau quantization, quantum Hall effect, quantum field theory at finite temperature and magnetic field, Propagators at finite temperature, Propagators at finite magnetic field, Application towards High Energy Nuclear Physics and Astra Physics.

Prerequisites: PH501, PH502 and PH605

PH608 Physics of galaxies and interstellar medium (6 Credits)

Basics of gas dynamics, instabilities, shocks, supernovae, superbubbles, ionization fronts, basic magnetohydrodynamics, cosmic rays. Interstellar medium: phases of interstellar medium, molecular clouds and star formation, radiative processes in interstellar medium, Magnetic field in interstellar medium and galaxies. Galaxies: types of galaxies, components of galaxies, dynamics of gas and stars in galaxies, rotation curves of galaxies, cosmological perturbations and their growth, dark matter haloes, formation and evolution of galaxies, intergalactic medium, supermassive blackholes.

Prerequisites: Instructor’s consent required.

PH657 Feynman Diagram Calculation (2 Credits)

Motivation, Anatomy of S-matrix, structure of propagator and self-energy in vacuum as well as medium for spin 0, ½ and 1 particles, Application of Feynman diagram in particle and nuclear physics.

Prerequisites: PH507 and PH509

PH699 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

PH795 Candidacy (0 Credit)

Evaluation of candidate's ability to carry out research, knowledge breadth of the student, research comprehension.

Prerequisites: Student must have completed the course credit requirement for the program registered for.

PH798 Independent Study (variable Credits)

Course content and credits are to be assigned by the course instructor.

PH799 Thesis (variable Credits)

Course content is to be defined by the thesis supervisor. Course credit is to be assigned by the DPGC convener.

Prerequisites: PH795.