INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH THIRUVANANTHAPURAM

An autonomous institution under the
Ministry of Human Resource Development, Government of India

CURRICULUM AND SYLLABUS FOR

THE BS-MS DUAL DEGREE PROGRAMME IN

i^2 SCIENCES

2020 – 2021
www.iisertvm.ac.in

Course Codes

The FOUNDATION and CORE courses are numbered in the format,

XYZ LSC (LTPC)

The ELECTIVE courses are numbered in the format,

XYZ LSCD (LTPC)

The numbering may be understood as

XYZ	:	Subject/Programme Code
L	:	Level of the course (1, 2, 3, 4 or 5)
S	:	Semester (1 = Varsha, 2 = Vasanth)
C (CD)	:	Course number in that Semester
L	:	Lecture hours per week
T	:	Tutorial hours per week
P	:	Practical hours per week
C	:	Credits

Subject codes:

BIO : Biological Sciences
MAT : Mathematical Sciences
IDC : Interdisciplinary Studies
DSC : Data Sciences
I2C : i^2 Chemical Sciences
I2M : i^2 Mathematical Sciences
CHY : Chemical Sciences
PHY : Physical Sciences
HUM : Humanities
I2B : i^2 Biological Sciences
I2D : i^2 Data Sciences
I2P : i^2 Physical Sciences

Structure and Syllabus

Foundation Courses (Semesters 1 – 4)

Semester 1	Semester 2	Semester 3	Semester 4
BIO 111 Ecology and Evolution (3103)	BIO 121 Biomolecules (3103)	BIO 211 Genetics and Molecular Biology (3103)	BIO 221 Cell Biology and Microbiology (3103)
CHY 111 Atomic Structure & Chemical Bonding (3103)	CHY 121 Basic Concepts in Organic & Inorganic Chemistry I (3103)	CHY 211 Basic Concepts in Organic & Inorganic Chemistry II (3103)	CHY 221 Physical Chemistry I (3103)
MAT 111 Single Variable Calculus (3103)	MAT 121 Introduction to Linear Algebra (3103)	MAT 211 Multivariable Calculus (3103)	MAT 221 Introduction to Probability (3103)
PHY 111 Mechanics (3103)	PHY 121 Electromagnetism (3103)	PHY 211 Optics (3103)	PHY 221 Thermal and Statistical Physics (3103)
BIO 112 Biology Lab I (0031)	BIO 122 Biology Lab II (0031)	BIO 212 Biology Lab III (0031)	
CHY 112 Chemistry Lab I (0031)		CHY 212 Chemistry Lab II (0031)	CHY 222 Chemistry Lab III (0031)
PHY 112 Physics Lab I (0031)	PHY 122 Physics Lab II (0031)		PHY 222 Physics Lab III (0031)
IDC 111 Mathematical Tools I (2102)	IDC 121 Mathematical Tools II (3103)	IDC 211 Physical Principles in Biology (3103)	IDC 221 Principles of Spectroscopy (3103)
IDC 112 Fundamentals of Programming (0031)	IDC 122 Numeric Computing (0031)	IDC 212 Data Handling and Visualisation (0031)	IDC 222 Scientific Computing (0031)
Communication Skills I (1001)	Communication Skills II (1001)	Economics (1001)	Languages (1001)
[19]	[19]	[19]	[19]

i^2 Biological Sciences - Course Structure (Semesters 5 – 10)

Thematic Areas: Systems & Synthetic Biology and Precision Medicine & Imaging

<table>
<tr><th colspan="2">Semester 5</th><th>Semester 6</th><th>Semester 7</th><th>Semester 8</th><th>Semester 9</th><th>Semester 10</th></tr>
<tr><td colspan="2">BIO 311
Microbiology
(3003)</td><td>BIO 321
Structural Biology
(3003)</td><td>BIO 411
Developmental Biology
(3003)</td><td>BIO XXX
Stem Cells & Regenerative Medicine
(3003)</td><td>Elective III
(3003)</td><td rowspan="7">Project
I2B 522</td></tr>
<tr><td colspan="2">BIO 312
Advanced Genetics & Genome Biology
(3003)</td><td>BIO 322
Immunology
(3003)</td><td>I2B 411
Systems Biology Theory
(3003)</td><td>I2B 421
Systems Biology Applications
(2002)</td><td>Elective IV
(3003)</td></tr>
<tr><td colspan="2">BIO 313
Physiology
(3003)</td><td>BIO 323
Cell Biology
(3003)</td><td>I2B 412
Microbiome & Vaccinology
(2002)</td><td>I2B 422
Bio-Imaging & Processing
(2002)</td><td rowspan="5">Project
I2B 511</td></tr>
<tr><td colspan="2">BIO 314
Biochemistry
(3003)</td><td>BIO 324
Molecular Biology
(3003)</td><td>I2B 413
Synthetic Biology
(3003)</td><td>I2C 422
Biomaterials
(3003)</td></tr>
<tr><td colspan="2">BIO 315
Advanced Biology Lab - I
(0093)</td><td>BIO 325
Advanced Biology Lab - II
(0093)</td><td>I2B 414
Biological Spectroscopy & Microscopy
(3003)</td><td>I2B 521
Systems Biology & Imaging Lab
(0062)</td></tr>
<tr><td colspan="2">BIO 316
Bioinformatics
(3003)</td><td>BIO 326
Biostatistics
(3003)</td><td>I2B 415
Human Genetics, Gene Therapy & Personal Genomics
(3003)</td><td>I2C 511
Pharmacology & Pharmacokinetics
(3003)</td></tr>
<tr><td colspan="3"></td><td>Elective I
(3003)</td><td>Elective II
(3003)</td></tr>
<tr><td>Credits</td><td>18</td><td>18</td><td>20</td><td>18</td><td>18</td><td>18</td></tr>
</table>

*i*² Biological Sciences – Elective Courses

Semester 7 - Elective I	Semester 8 - Elective II	Semester 9 - Elective III & IV
Host-Pathogen Interactions BIO 4101	Chronobiology BIO 4201	Chemical Genomics I2C 523
Cancer Biology BIO 4102	Computational Chemistry I2C 521	Digital Image Processing I2P 4XX
Neurobiology BIO XXX	Big Data Analytics DSC 421	Nanoscale Physics PHY 5121
Cryo-Electron Microscopy & 3D Image Processing for Life Sciences BIO XXX	Principles of Digital Imaging PHY 5220	Sensor Technology I2P 5XXX

i^2 Biological Sciences - Credit Structure

Sems.	Course	Credits	Total
1	Foundation	19	76
2	Foundation	19	
3	Foundation	19	
4	Foundation	19	
5	Biological Sciences Core Courses	18	18
	Thematic Courses	-	
	Electives	-	
6	Biological Sciences Core Courses	18	18
	Thematic Courses	-	
	Electives	-	
7	Biological Sciences Core Courses	3	20
	Thematic Courses	14	
	Electives	3	
8	Thematic Courses	15	18
	Electives	3	
9	Electives	6	18
	Project	12	
10	Project	18	18
5 - 10	General Courses (IP/Ethics/Languages/Music/Psychology)	4	4
	Total	**190**	**190**

*i*² Chemical Sciences - Course Structure (Semesters 5 to 10)

Thematic Areas: Chemical Biology and Biomaterials

<table>
<tr><th>Semester 5</th><th>Semester 6</th><th>Semester 7</th><th>Semester 8</th><th>Semester 9</th><th>Semester 10</th></tr>
<tr><td>CHY 311
Coordination Chemistry
(3003)</td><td>CHY 321
Organometallic Chemistry
(3003)</td><td>CHY 411
Main Group Chemistry
(3003)</td><td>CHY 421
Instrumental methods for Structure Determination
(3003)</td><td>I2C 523
Chemical Genomics
(3003)</td><td rowspan="6">Project</td></tr>
<tr><td>CHY 312
Organic Chemistry - Reactions and mechanisms
(3003)</td><td>CHY 323
Organic Chemistry-Synthetic methods
(3003)</td><td>CHY 412
Advanced Organic Chemistry
(3003)</td><td>I2C 521
Pharmacology and Pharmacokinetics
(3003)</td><td>Elective II
(3003)</td></tr>
<tr><td>CHY 313
Quantum Chemistry
(3003)</td><td>BIO 323
Molecular Biology
(3003)</td><td>CHY 414
Chemical Kinetics and Dynamics
(3003)</td><td>I2C 421
Soft Matter and Polymers
(3003)</td><td rowspan="4">Project</td></tr>
<tr><td>CHY314
Physical Chemistry II
(3003)</td><td>BIO 324
Cell Biology
(3003)</td><td>I2C 411
Medicinal Chemistry
(3003)</td><td>I2C 422
Biomaterials
(3003)</td></tr>
<tr><td>CHY315
Organic Chemistry Laboratory
(0093)</td><td>CHY 325
Inorganic Chemistry Laboratory
(0093)</td><td>I2C 412
Enzymology and Biocatalysts
(3003)</td><td>I2C 522
Computational Chemical Biology
(3003)</td></tr>
<tr><td>I2C 311
Biochemistry & Bioconjugation
(3003)</td><td>Elective I
(3003)</td><td>I2C 413
Biophysical Chemistry
(3003)</td><td>I2C 423
Chemical Biology Lab
(0093)</td></tr>
</table>

i^2 Chemical Sciences – Elective Courses

Semester 6 - Elective I	Semester 9 - Elective II
Bioinformatics I2B 421	Developmental Biology (3003) BIO 411
Immunology BIO 322	Microbiome and Vaccinology (3003) BIO 413
Solid-State Chemistry CHY 42XX	Modern Organic Synthesis: Advances in Methods and Reagents (3003) CHY 51XX
Drug Discovery Design and Development CHY 42XX	Supramolecular chemistry (3003) CHY 51XX
I2P Principles of Digital imaging (3003)	I2P Digital Image Processing (3003)
I2P Sensor Technology (3003)	I2P 411 Material Characterization (3003)

i^2 Chemical Sciences - Credit Structure

Sems.	Courses	Credits	Total
1	Foundation Courses	19	76
2	Foundation Courses	19	
3	Foundation Courses	19	
4	Foundation Courses	19	
5	Chemistry Core Courses	15	18
	Thematic	3	
	Electives	0	
6	Chemistry Core Courses	9	18
	Thematic Courses	6	
	Electives	3	
7	Chemistry Core Courses	9	18
	Thematic Courses	9	
	Electives	0	
8	Chemistry Core Course	3	18
	Thematic Courses	15	
	Electives	0	
9	Electives	6	18
	Project	12	
10	Project	18	18
5 - 10	General Courses (IP/Ethics/Languages/Music/Psychology)	6	6
	Total	**190**	**190**

*i*² Data Sciences **Course Structure (Semesters 5 to 10)**

<table>
<tr><th>Semester 5</th><th>Semester 6</th><th>Semester 7</th><th>Semester 8</th><th>Semester 9</th><th>Semester 10</th></tr>
<tr><td>DSC 311
Mathematical Statistics
(3014)</td><td>DSC 321
Design and Analysis of Algorithms
(3003)</td><td>DSC 411
Statistical Modelling (3003)</td><td>DSC 421
Big Data Analytics
(2033)</td><td>Elective
I2D 52XX</td><td rowspan="7">Project</td></tr>
<tr><td>DSC 312
Optimization Techniques
(2002)</td><td>DSC 322
Scientific Computing
(3034)</td><td>DSC 412
Parallel & Distributed Computing
(3003)</td><td>DSC 422
Humans and Data
(1001)</td><td>Elective
I2D 52XX</td></tr>
<tr><td>DSC 313
Discrete Mathematics
(2002)</td><td>DSC 323
Database Management System
(3003)</td><td>DSC 413
Data Warehousing & Business Intelligence
(3003)</td><td>DSC 423
Stochastic Process
(3003)</td><td rowspan="5">Project</td></tr>
<tr><td>DSC 314
Advanced Data Structures
(3034)</td><td>DSC 324
Machine Learning-II
(3003)</td><td>DSC 414
Artificial Intelligence
(3003)</td><td>Elective I
I2D 42XX/I2D 52XX</td></tr>
<tr><td>DSC 315
Computer Organisation & Operating System
(3003)</td><td>DSC 325
Data Science Lab-II
(1032)</td><td>DSC 415
Data Analysis & Visualization
(2033)</td><td>Elective II
I2D 42XX/I2D 52XX</td></tr>
<tr><td>DSC 316
Machine Learning-I
(3003)</td><td>Open Elective-I
I2D 32XX/</td><td>Open Elective-II
I2D 41XX/I2D 51XX</td><td>Elective III
I2D 42XX/I2D 52XX</td></tr>
<tr><td>DSC 317
Data Science Lab-I
(0031)</td><td colspan="2"></td><td>Elective IV
I2D 42XX/I2D 52XX</td></tr>
<tr><td>19</td><td>18</td><td>18</td><td>19</td><td>18</td><td>18</td></tr>
</table>

i^2 Data Sciences – Elective Courses

Electives	
I2D 4xxx/5xxx Mathematical Modelling	I2D 4xxx/5xxx Internet of Things and Cloud Computing
I2D 4xxx/5xxx Probabilistic Machine Learning	I2D 4xxx/5xxx Big Data in Ecology and Environmental Sciences
I2D 4xxx/5xxx Statistical Simulation and Computation	I2D 4xxx/5xxx Text Mining and Natural Language Processing
I2D 4xxx/5xxx Data Science for Finance	I2D 4xxx/5xxx Clinical Data Analysis
I2D 4xxx/5xxx Machine Learning for Material Science	I2D 4xxx/5xxx Quantum information theory
I2D 4xxx/5xxx Particle Physics data processing	I2D 4xxx/5xxx Drug discovery and data science
I2D 4xxx/5xxx Data science in Chemistry	I2D 4xxx/5xxx Systems biology
I2D 4xxx/5xxx Computer Vision	I2D 4xxx/5xxx Cryptography and data security

Open Electives
I2D 3xxx/4xxx Advanced Genetics and Genomics
I2D 3xxx/4xxx Bioinformatics
I2D 3xxx/4xxx/5xxx Computational Fluid Dynamics
I2D 3xxx/4xxx/5xxx Computational Chemical Biology
I2D 3xxx/4xxx/5xxx Modelling Materials

i^2 Data Sciences – Credit Structure

Sems.	Course	Credits	Total
1	Foundation Courses	19	76
2	Foundation Courses	19	
3	Foundation Courses	19	
4	Foundation Courses	19	
5	Core Courses	19	19
	Thematic	0	
	Electives	0	
6	Core Courses	15	18
	Thematic	0	
	Electives	3	
7	Core Courses	15	18
	Thematic	0	
	Electives	3	
8	Core Courses	7	19
	Electives	12	
9	Electives	6	18
	Project	12	
10	Project	18	18
5-10	General Courses (IP/Ethics/Languages/Music/Psychology)	5	5
	Total	191	191

i^2 Mathematical Sciences Course Structure (Semesters 5 to 10)

Thematic Areas: Mathematical Modelling and Scientific Computing

Semester 5	Semester 6	Semester 7	Semester 8	Semester 9	Semester 10
MAT 311 Real Analysis [3 0 0 3]	MAT 321 Complex Analysis [3 0 0 3]	MAT 411 Measure Theory [3 0 0 3]	MAT 421 Functional Analysis [3 0 0 3]	Elective IV	Project
MAT 312 Theory of Groups and Rings [3 0 0 3]	MAT 323 General Topology [3 0 0 3]	MAT 414 Partial Differential Equations [3 0 0 3]	I2M 521 Variational Methods and Control Theory [3 0 0 3]	Elective V	
MAT 313 Linear Algebra [3 0 0 3]	MAT 324 Theory of Ordinary Differential Equations [3 0 0 3]	MAT 415 Programming and Data Structures [3 0 3 4]	I2M 522 High Performance Computing [3 0 0 3]	Project	
MAT 314 Numerical Analysis [3 0 0 3]	MAT 325 Probability Theory and Stochastic Processes [3 0 0 3]	I2M 411 Applied Stochastic Analysis [3 0 0 3]	I2M 523 Finite Element Methods [3 0 0 3]		
MAT 315 Mathematical Statistics [3 0 3 4]	I2M 321 Scientific Computing [3 0 3 4]	I2M 412 Numerical Solutions of Differential Equations [3 0 0 3]	Elective II		
I2D 315 Machine Learning I [3 0 0 3]	I2M 322 Mathematical Modelling [3 0 0 3]	Elective I	Elective III		
I2D 316 Data Science Lab I [0 0 3 1]					

i^2 Mathematical Sciences – Elective Courses

Biological Sciences

- I2M 4XXX Mathematical Biology [3 0 0 3]
- I2B 4XXX Bioinformatics [3 0 0 3]
- I2M 5XXX Stochastic Modelling of Biological Processes [3 0 0 3]
- I2B 4XXX Systems Biology [3 0 0 3]

Atmospheric Sciences

- I2P 4XXX Fluid Dynamics [3 0 0 3]
- I2M 5XXX Modelling Environment Systems [3 0 0 3]
- I2M 5XXX Computational Fluid Dynamics [3 0 0 3]
- I2M 5XXX Atmosphere & Big Data [3 0 0 3]

Market & Finance

- I2M 4XXX Mathematical Finance & Option Pricing [3 0 0 3]
- I2D 5XXX Big Data Analytics [3 0 0 3]
- I2M 4XXX Statistical Methods in Finance [3 0 0 3]
- I2M 5XXX Financial Data Analysis [3 0 0 3]

i^2 Sciences Electives

- I2D 32XX Machine Learning II [3 0 0 3]
- I2D 32XX Data Science Lab II [1 0 3 2]
- I2D 41XX Artificial Intelligence [3 0 0 3]
- I2D 41XX Statistical Modelling [3 0 0 3]
- I2D 4XXX Probabilistic Machine Learning [3 0 0 3]
- I2D 4XXX Modelling Materials [3 0 0 3]
- I2M 5XXX Computational Stochastic Modelling [3 0 0 3]
- I2M 4XXX Methods of Applied Mathematics [3 0 0 3]
- I2M 5XXX Sobolev Spaces and Elliptic Boundary Value Problems [3 0 0 3]

i^2 Mathematical Sciences - Credit Structure

Sems.	Course	Credits	Total
1	Foundation Courses	19	76
2	Foundation Courses	19	
3	Foundation Courses	19	
4	Foundation Courses	19	
5	Mathematics Core Courses	16	20
	Thematic Courses	4	
6	Mathematics Core Courses	12	19
	Thematic Courses	7	
7	Mathematics Core Courses	10	19
	Thematic Courses	6	
	Electives	3	
8	Mathematics Core Courses	3	18
	Thematic Courses	9	
	Electives	6	
9	Electives	6	18
	Project	12	
10	Project	18	18
5 - 10	General Courses (IP/Ethics/Languages/Music/Psychology)	4	4
	Total	192	192

i^2 Physical Sciences Curriculum (Semesters 5 - 10)

Thematic Areas: Advanced Materials, Devices and Sensors, Chem. Physics & Energy, Modelling

Semester 5	Semester 6	Semester 7	Semester 8	Semester 9	Semester 10
PHY 311 Mathematical Methods in Physics (3003)	PHY 321 Statistical Mechanics (3003)	PHY 412 Condensed Matter Physics II (3003)	I2P 421 Optoelectronic Devices (3003)	Electives/ Modules	I2P 522 Project
PHY 312 Classical Mechanics (3003)	PHY 322 Condensed Matter Physics I (3003)	I2P 411 Experimental Methods (3003)	I2P 422 Device Technology (0093)	Electives/ Modules	
PHY 313 Electronics (3003)	I2P 321 Electrochemical Energy Systems (3003)	I2P 412 Semiconductor Physics & Technology (3003)	I2P 423 Thermal Transport and Thermoelectrics (3003)	I2P 511 Project	
PHY 314 Quantum Mechanics I (3003)	I2C 421 Soft Matter & Polymers (3003)	I2P 413 Fluid Mechanics & Transport Phenomena	I2P 424 Finite Element Modelling (1063)		
I2M 315 Applied Statistics (3034)	I2P 422 Numerical Methods (3003)	I2P 414 Modelling Materials (2033)	I2P 521Machine Learning for Physical Sciences (2033)		
Electives/Modules	Electives/Modules	Electives/Modules	Electives/Modules		

Physics Core Courses Thematic/Elective Courses

Electives/Modules

Semesters 5, 7 and 9	Semesters 6 and 8
Physics Electives 1.PHY5101 Lasers and Fibre Optic Communications (3003) 2.PHY5102 Physics at Low Temperatures (3003) 3.PHY5103 Nanoscale Physics (3003) i^2 Sciences Electives 1.I2P 5101 Digital Image Processing (3003) 2.I2P 5102 Data Science for Physical Sciences (3003) 3.I2M 5101 Applied Mathematical Methods (3003) 4.I2D 3101 Machine Learning I (3003) 5.I2D 3102 Data Science Lab I (0031) 6.I2D 4101 Statistical Modelling (3003) 7.I2D 4102 Artificial Intelligence (3003) 8.I2B 5101 Cryo-Electron microscopy and 3D image processing for Life sciences (3003)	Physics Electives 1. PHY 323 Electrodynamics and STR 2. PHY4201 Quantum Information Theory (3003) 3. PHY4202 Nonlinear Dynamics (3003) 4. PHY4203 Nonlinear Optics and Photonics (3003) 5. PHY4206 Astrophysics (3003) 6. PHY5201 Probes in Condensed Matter Physics (3003) 7. PHY5202 Quantum Transport (3003) 8. PHY5205 Numerical Simulation Techniques in Physics (3003) 9. PHY5206 Introduction to Cosmology (3003) 10.PHY5211 Theory of Open Quantum Systems (3003) i^2 Sciences Electives 1. I2P 4201 Computer Interfacing (1032) 2. I2P 4202 Energy Materials Laboratory (0031) 3. I2P 4203 Battery & Fuel Cell Laboratory (0031) 4. I2P 4204 Organic Photovoltaic Devices Laboratory (0031) 5. I2P 4205 Renewable Energy Systems (2002) 6. I2P 5201 Principles of Digital imaging (3003) 7. I2P 5202 Organic Semiconductors: Fundamentals and Applications (3003) 8. I2P 5203 Sensor Technology (3003) 9. I2D 3201 Machine Learning II (3003) 10.I2D 3202 Data Science Lab II (1032) 11.I2D 4201 Humans and Data (1001) 12.I2C 3201 Chemical Kinetics and Dynamics (3003)

Maximum/minimum number of allowed credits in each subset Physics/i^2Sc to be specified. Prerequisites must be satisfied or exemption obtained.

i^2 Physical Sciences - Credit Structure

Sems.	Courses	Credits	Total
1	Foundation Courses	19	76
2	Foundation Courses	19	
3	Foundation Courses	19	
4	Foundation Courses	19	
5	Physics Core Courses	12	18
	Thematic	3	
	Electives	3	
6	Physics Core Courses	6	18
	Thematic Courses	9	
	Electives	3	
7	Physics Core Courses	3	18
	Thematic Courses	12	
	Electives	3	
8	Thematic Courses	15	18
	Electives	3	
9	Electives	6	18
	Project	12	
10	Project	18	18
5 - 10	General Courses (IP/Ethics/Languages/Music/Psychology)	6	6
	Total	190	190

i^2 Sciences - Foundation Courses

School of Biology

BIO 111	Ecology and Evolution (3103)
Learning Outcomes	The course will introduce students to the basics of what life is, scales of biological organization and how interactions between an organism and its environment shape all aspects of the organism's biology. A student of the course will understand the fundamentals of biological evolution, how evolution has shaped phenotypic diversity & behavior, and why evolution is a unifying theme in biology.
Syllabus	1. Overview of Biology: What is life? Characteristics of living organisms; Importance of studying biology; Scales in biology (molecules (including DNA), organelles, cells, tissues, organs, organisms, populations, communities and ecosystems); Disciplines of biology in relation to these scales; Origins of life. [3] 2. Principles of Evolutionary Biology: History of evolutionary thinking - ideas that formed the basis of modern understanding of evolution; Genes and alleles; Fundamental concepts (variation, selection, units of selection, fitness, adaptation); Prerequisites for evolution by natural selection; Evidence for natural selection and evolution; Types of selection (directional, stabilizing, disruptive); Evolution without selection (genetic drift, gene flow); Species concepts and speciation; Phylogenetics (basic terminology, tree of life, phylogenetic reconstruction, molecular dating); Macroevolutionary patterns (mass extinction, adaptive radiation, convergent evolution, divergent evolution). [10-12] 3. Principles of Ecology: Biomes; Ecosystems (trophic levels, trophic structure, energy transformation, gross and net production, primary productivity, secondary productivity); Ecosystem types (tropical, temperate, subtropical); Population ecology (population characteristics, growth, life history strategies, population regulation, metapopulations); Community ecology (ecological succession, microhabitats, niche, structure of communities); Species interactions (predation, parasitism and mutualism).[6] 4. Behavioural ecology: Adaptive value of behaviour; Sexual selection; Mating systems; Kinship; Cooperation; Sociality (altruism, cooperation, kin selection, reciprocal altruism, etc.); Optimal foraging theory; Parental care; Social symbiosis. [10] 5. Biodiversity and conservation biology: Taxonomy and phylogenetic systematics; Diversification of life - a phylogenetic perspective; Diversification of life - a timeline; Measuring extant diversity; Threats to extant biodiversity (habitat loss and degradation, Invasive species, Pollution, Over-exploitation, Global climate change); *In-situ* and *ex-situ* conservation; Biodiversity of India; Island biogeography. [4-5]
Text and Reference Books	1. Manuel C Molles, Ecology: Concepts and Applications Mc Graw Hill 7th Edition 2014 2. Douglas J Futuyma, Evolution Oxford University Press 3rd Edition 2013 3. Barton et al., Evolution Cold Spring Harbor Laboratory Press 1st Edition 2007 4. Stephen C. Stearns and Rolf F. Hoekstra, Evolution: An Introduction Oxford University Press 1st Edition 2000 5. Nicholas J. Gotelli, A primer of Ecology Oxford University Press, 4th Edition 2008 6. Begon et al., Ecology: From Individuals to Ecosystem Wiley-Blackwell, 4th Edition 2005

<table>
<tr><th>BIO 121</th><th>Biomolecules (3103)</th></tr>
<tr><td>Learning Outcomes</td><td>To understand the importance of biomolecules (carbohydrates, lipids, proteins and nucleic acids) and its chemical diversity in shaping the biological structure and function. Students can appreciate how complex living systems are built from a handful of simple atoms and how their molecular interactions in the aqueous environment of the cells interior bring about unique functions to life matter which is essential to sustain diverse life forms in our planet.</td></tr>
<tr><td>Syllabus</td><td>
1. Chemical Characteristics of living matter: Biological macromolecules and importance of carbon in life's chemistry, role of inorganic/monoatomic ions in living organisms.[2]
2. Water and life: Unique physical and chemical properties of water that support life: high specific heat, high surface tension, high latent heat of vaporization, high heat of fusion, high tensile strength, transparency to light, universal solvent, density. Hydrogen bonding in water and its importance in maintaining the shape, stability and properties of biological macromolecules. [3]
3. Stabilizing interactions in biological macromolecules: Importance of hydrogen bonds, ionic interactions, salt bridge, hydrophobic interactions, van der Waals forces, concept of dipole, instant and induced dipole. Importance of these noncovalent interactions in macromolecular interaction using an example of antigen-antibody interaction and higher order protein structure.[2]
4. Principles of biophysical chemistry: Bioenergetics and laws of thermodyanamics, reaction kinetics: differences between ΔG, ΔG^o, $\Delta G^{o\prime}$. Acid dissociation constants, pH, pka and relationship between. Importance of Henderson-Haselbach equation and calculation of problems associated with this equation. [4]
5. Biological macromolecules:
(a) Carbohydrates: Structure and function of important mono, oligo and polysaccharides present in the kingdom of life: Cellulose, starch, glycogen, Raffinose family of Oligosaccharides, dextrins, dextrans, agar and agarose. Stereochemical relationship between aldo and keto monosaccharides, anomers, epimers. Cyclization of monosaccharides, acetal, hemiacetal, ketal and hemiketal linkages. Derivatives of carbohydrates and their importance in biological structure and function: sugar acids, sugar alcohols, deoxy sugars, sugar esters, amino sugars, glycosides. Carbohydrates in blood group determination, biochemistry of Bombay blood group to demonstrate the structural diversity of carbohydrates. Glycemic Index and Glycemic Load and its importance in metabolism. Importance of proteoglycans and glycoproteins in cell structure and function. [5]
(b) Proteins: Structure and importance of proteinogenic amino acids: Physical and chemical properties of amino acids : Nonionic and zwitter ion forms of amino acids: pH,pKa and titration curve characteristic of amino acids, concept of dihedral angles phi and psi, importance of these dihedral angles in protein structure and function, Ramachandran plot and its importance in protein structure determination: Hierarchy of protein structures: Primary, secondary, tertiary and quaternary structure of proteins. Important secondary structures alpha helix, beta sheets, turns and loops, protein domain and motifs, supersecondary structures and its importance in determining protein function. [8]
(c) Lipids: Classification of Lipids: Introduction to fatty acids and its nomenclature. Simple and complex lipids: Types, structure and importance of phospholipids, glycolipids, sphingolipids, glycerophospholipids with examples in biological structure and function. Introduction to sterols and sterol-based derivatives in life matter. [3]
(d) Nucleic acids: Introduction to nucleic acid bases and nucleotides. Structure and function of DNA and RNA, physicochemical properties of these informational macromolecules. Ambiguous codes of nucleotide bases and amino acids. Central dogma of life: introduction of transcription, translation and protein synthesis. Concept of gene and its regulatory elements in bringing out gene function. Conceptual understanding of Polymerase Chain reaction learning about primer design, concept of sense, antisense, template and non-template strands. [7]
6. Biological catalysis: Functioning of enzymes, classification of enzymes, Michael Menten reaction kinetics to understand the enzyme function, Line-Weaver burke plot, competitive and non-competitive inhibition of enzyme kinetics [3]
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	7. **Introduction to metabolic pathways:** Principles of energy release from fuels, importance of ATP and NADH in energy transduction during glycolysis, Krebs cycle and oxidative phosphorylation. [2]
Text and Reference Books	1. Rodney F Boyer, Concepts in Biochemistry. John Wiley & Sons; 3rd Ed (2 December 2005). 2. Thomas Miilar, Biochemistry Explained: A Practical Guide to Learning Biochemistry CRC Press; 1 edition (30 May 2002) 3. Lubert Stryer et al., Biochemistry.W. H. Freeman; 6th Edition edition (14 July 2006) 4. David L Nelson, and Michael M Cox et al., Lehninger principles of biochemistry WH Freeman; 7th ed. 2017 edition (1 January 2017)

BIO 211	Genetics and Molecular Biology (3103)
Learning Outcomes	This course will introduce basic concepts of genetic inheritance and genetic interactions. It also introduces the primary concepts of gene, gene expression, genome organization and replication and use of model organisms.
Syllabus	1. Introduction to genetics [1] 2. Mendelian genetics: Mendel's law and examples, Monohybrid and di- hybrid cross,recessive and dominant mutation, concept of allele [3] 3. Non-Mendelian genetics: incomplete dominance, semi-dominance, and introduction to epigenetics, Cytoplasmic inheritance, infection heredity [6] 4. Genetic interactions: approach towards generating a network (epista- sis, redundancy,synthetic lethality, lethal interactions) [4] 5. Model organisms and studies on molecular and genetic interactions [4] 6. Basics of Expression genetics, transcription, translation [6] 7. Genome composition and organization, Cot analysis [3] 8. Chromosome structure and function [3] 9. Mitosis and Meiosis [3] 10. DNA replication, Mutations [3]
Text and Reference Books	1. Anthony JF Griffiths et al., An Introduction to Genetic Analysis W.H. Freeman and Co 7th Edition 2000 2. Watson et. al., Molecular Biology of the Gene, Pearson, 7th Edition 2013 3. Jocelyn E. Krebs et al., Lewin's Gene Jones & Bartlett Learning; 11 edition (December 31, 2012) 4. Richard Kowles, Solving Problems in Genetics Springer; 2001 edition (June 21, 2001)

BIO221	Introduction to Cell Biology and Microbiology (3103)
Learning Outcomes	Students will understand the structures and functions of prokaryotic and eukaryotic cells as whole entities and in terms of their subcellular process and communications. Students will understand the biology of bacteria, viruses and other pathogens related with infectious diseases in humans.
Syllabus	1.Structure of prokaryotic and eukaryotic cells Introduction of cell biology, classification of living organisms, Prokaryotic cells, eukaryotic cells. [3] 2.Membrane structure and function. Structure and Composition of the Cell Membrane, Membrane Proteins, Transport across the Cell Membrane [4]. 3.Structural organization and function of intracellular organelles Structure and function of cytoplasm, Cytoskeletal elements and architecture, Structure and Function of mitochondria, Ribosomes, Endoplasmic reticulum, Rough endoplasmic reticulum and protein secretion, Lysosomes, The Golgi Complex, Peroxisomes, Vacuoles, , plant cell organelles, Cell locomotion [6]. 4.Cell division and cell cycle Cell division and its significance, Mitosis, Meiosis, Cell cycle regulation [4]. 5.Principles of signal transduction and role of secondary messengers [basic level] Characterization of signaling components: signaling molecules, receptors, second messengers, effectors, signaling complexes [3].

BIO221	Introduction to Cell Biology and Microbiology (3103)
	6. Basic classification and characterization of membrane receptors. G protein-coupled Receptors, Receptor Tyrosine Kinases [3] 7. Hormones and their receptors Human Endocrine system, types of hormone receptors, insulin, thyroid hormone, steroid hormones [3] 8. History of Microbiology - discovery of microbes and important milestones, microbial diversity - evolution & taxonomy, microbial nutrition - growth requirements, culture media and growth kinetics - cell cycle, growth curve [3]. 9. Viruses and prions: Introduction - development of virology, general characteristics - virus structure, reproduction, cultivation, taxonomy, viruses of bacteria and archaea [4]. 10. Microbial physiology: structure of microbes - prokaryotic cell structure & function, autotrophic and heterotrophic metabolisms - , growth and its control factors - culturing and measurement of microbial growth, physical & chemical methods of microbe control [3]
Text and Reference Books	1. Gerald Karp, Cell Biology, WILEY (Feb. 4th, 2013) 2. Wayne M. Becker et al., World of the Cell; Benjamin Cummings; 7th edition (February 19, 2008) 3. Bruce Alberts et al., Essential Cell Biology; Richard Goldsby and Thomas J, &F/Garland, 4th Edition, (2014) 4. Alberts, Bruce.; Molecular Biology of the Cell, Garland Science; 5th edition (2 January 2008) 5. Kindt, Kuby, Immunology, W. H. Freeman; 6th edition (9 October 2006) 6. Willey, Joanne M; Sherwood, Linda; Woolverton, Christopher J; Prescott Harley Klein's Microbiology, McGraw-Hill, 7th Edition, 2008

Laboratory Courses

BIO112	Biology Laboratory I
Learning Outcomes	To provide a basic hands-on learning of Biological experimental methods.
Syllabus	1. Hypothesis testing and sampling – [12] -How to formulating a hypothesis? -Understanding Type I and Type II errors -What is a sample? Why is sampling required? How to sample? -Classroom exercises in hypotheses testing and sampling 2. Life under a microscope – [12] -Plant and animal cells under a microscope -Structure and function of plant tissues 3. Analysis of light reaction of photosynthesis by DCPIP method – [3] 4. Analysis of microbial world – [9] -Isolation of microorganisms -Gram staining -Plaque assay

BIO122	Biology Laboratory II
Learning Outcomes	To provide a basic hands-on learning of Biological experimental methods.
Syllabus	1. Biological solutions preparation and quantification of biomolecules (proteins, lipids, carbohydrates, DNA) – [12] 2. Genomic DNA isolation- [6] 3. PCR – [9] 4. Enzyme assays – [9]

BIO 212	Biology Laboratory III
Learning Outcomes	To provide a basic hands-on learning of Biological experimental methods.
Syllabus	1. Mutation frequencies, fluctuation tests – [6] 2. Analyze data from crosses: theoretical problem solving – [9] 3. Plasmid DNA isolation – [9] 4. SDS-PAGE – [6] 5. Mitosis –[3] 6. Meiosis –[3]

School of Chemistry

CHY 111	Atomic Structure and Chemical Bonding (3103)
Learning Outcomes	• To introduce quantum theory with the aim of understanding the structure of atoms • To describe various aspects of molecular symmetry and theories of bonding
Syllabus	Atomic Structure: • Thomson's and Rutherford's models of atoms, spectral emissions from atoms, Bohr's model of atom, quantization of angular momentum, discrete energy level structure, concept of quantum numbers, and Franck-Hertz experiment [4] • Photo-electric effect, dual nature of light and matter, de-Broglie's relation, blackbody radiation, electron diffraction by crystals, double slit experiments with light and matter, Stern-Gerlach experiment, and concepts of spin and orbital angular momenta [4] • Classical wave equation, Schrödinger equation, operators, postulates of quantum mechanics, solutions of Schrödinger equation for a free particle, particle-in-a-box, applications of particle-in-a-box solutions for describing electronic levels and spectra in conjugated molecules [8] • Schrödinger equation for the hydrogen atom, qualitative description of solutions, concepts of orbitals and quantum numbers, qualitative description of many-electron systems, effective nuclear charge, and orbital approximation [4] Chemical Bonding: • Molecular symmetry, symmetry elements, symmetry operations, point groups and character tables [6] • Valence bond and molecular orbital descriptions of bonding, linear combination of atomic orbitals (LCAO) approach, hybridization, bonding in $(H_2)^+$ and H_2 [4] • Bonding in homonuclear diatomic molecules of second period, bond orders, bond lengths and bond strengths, bonding in heteronuclear diatomic molecules, concepts of g and u symmetries of molecular orbitals, polarity and electronegativity, and photoelectron spectroscopy [6]
Text & Reference Books	1. D. A. McQuarrie, Quantum Chemistry, Viva Student Edition, Viva (2011). 2. P. Atkins, J. de Paula and J. Keeler, Atkins' Physical Chemistry, 11th Ed.,OUP (2018). 3. J. Barrett, Structure and Bonding, Wiley-Royal Society of Chemistry (2002). 4. T. Engel and P. Reid, Physical Chemistry, 3rd Ed., Pearson (2013). 5. R. J. Silbey, R. A. Alberty and M. G. Bawendi, Physical Chemistry, 4th Ed., Wiley Student Edition (2006).

CHY 121	Basic Concepts in Organic and Inorganic Chemistry I (3103)
Learning Outcomes	• This course introduces basic concepts in organic and inorganic chemistry with the aim to provide a structured understanding of chemistry.
Syllabus	1. Elements and periodicity: Classification of elements; concepts of atomic, ionic, and covalent radii; oxidation state, ionization energy, electronegativity, electron affinity, polarizability, inert pair effect, and lanthanoid contraction. [3] 2. Structure and bonding: Crystal lattices and unit cell; crystal packing and defects; structures of NaCl, CsCl, and Wurtzite; lattice enthalpy, Born-Haber cycle; structures of elemental B, C, Si, P, and S; Bonding in boron halides, PF5, SF6, interhalogens, and xenon flourides; Bent's rule, Berry pseudorotation; molecular orbital diagrams of selected triatomic molecules: HF2-, BeH2, and CO2. [9] 3. Oxidation and reduction: Reduction potential; electrochemical series; redox reactions; balancing of redox equations; factors affecting redox stability; Frost diagrams for redox reactions; Ellingham diagram and extraction of elements. [4] 4. Acids and bases: Arrhenius concept, solvent systems (in H2O, NH3, SO2, and HF), Brønsted concept, Lux-Flood concept, and Lewis concept; HSAB principle, superacids, relative strengths of acids; acid-base neutralisation curves and indicators. [4] 5. Aromaticity: Aromaticity, antiaromaticity, and homoaromaticity; aromatic ring currents; examples of nonbenzenoid aromatic and antiaromatic compounds. [3] 6. Acidity, basicity, pKa, steric inhibition of resonance, ortho effect, nucleophilicity, and electrophilicity dealing with organic molecules. [3] 7. Stereochemistry: Baeyer's strain theory, Pitzer strain (torsional strain) and conformational analysis (up to decalin), geometrical isomerism (E/Z), optical isomerism, projections, CIP rules (R/S nomenclature of acyclic and cyclic molecules); nomenclature – threo and erythro, syn and anti, endo and exo, and meso and d/l; Chirality – axial and planar chirality and helicity; topicity - homotopic, enantiotopic and diastereotopic atoms, groups and faces (including Pro-R, Pro-S, and Re/Si stereodescriptors); chirotopicity and stereogenicity. [9] 8. Reactive Intermediates: Structure, stability and reactivity of carbocations, carbanions, free radicals, carbenes, and nitrenes. [5]
Text & Reference Books	1. P. Atkins, T. Overton, J. Rourke, F. Armstrong, and M. Hagerman, Shriver and Atkins' Inorganic Chemistry, 5ed, W. H. Freeman and Company New York, 2009. 2. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3ed, Pearson, 2008. 3. J. E. House, Inorganic Chemistry, 3ed, Academic Press, 2019. 4. J. E. Huheey, E. A. Keiter, and R. L. Keiter, Inorganic Chemistry – Principles of Structure and Reactivity, 4 ed, Pearson Education, 2006. 5. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, 2ed., Oxford University Press, 2012. 6. J. McMurry, Organic Chemistry, 9ed., Cengage Learning, 2015. 7. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 7ed., Addison-Wesley, 2003. 8. D. Nasipuri, Stereochemistry of Organic Compounds-Principle and Applications, 4 Revised ed., New Academic Science, 2012.

CHY 211	Basic Concepts in Organic and Inorganic Chemistry II (3103)
Learning Outcomes	This course is a continuation of CHY 121 and deals with the basic concepts in organic and inorganic chemistry with the aim to provide a structured understanding of chemistry.
Syllabus	1. Nucleophilic Substitution at Saturated Carbons: S_N1, S_N2, S_Ni and S_N2' with emphasis on stereochemical considerations, substrate structure, leaving group, nucleophiles and role of solvents. [3] 2. Elimination Reactions: Types (E1, E2 and E1cB), stereochemical considerations, and role of solvents; Saytzeff/Hofmann elimination, Bredt's rule; elimination vs substitution. [3] 3. Electrophilic Aromatic Substitution: Mechanism, orientation, and reactivity of benzene and substituted benzene derivatives (substituent effects); mechanistic aspects of special cases such as nitration of aniline, alkylation of benzene, sulfonation. [3] 4. Nucleophilic Aromatic Substitution. [1] 5. Reduction and Oxidation: Mechanism and selectivity in reduction of carbonyl compounds using $NaBH_4$, $LiAlH_4$ (including esters, amides and nitriles), and oxidation of alcohols using Jones, Collins, PCC, and PDC reagents. [4] 6. Synthesis of Drug Molecules: Naproxen, Ibuprofen, Aspirin and L-DOPA; examples love drugs and molecules of death. [3] 7. Synthesis and Applications of Organic Materials: Polymers (biodegradable polymers, conducting polymers, etc.); smart materials, OLEDs, intelligent gels, dyes, etc. [3] 8. Coordination Compounds: Geometries and isomerism of coordination compounds; crystal field theory, spectrochemical series, weak field and strong field ligands, spinel and inverse spinel structures; Jahn-Teller effect; thermodynamic stability and kinetic lability of coordination complexes; chelate and macrocyclic effect; optical activity of coordination complexes. [9] 9. Metals in Biology: Introduction to types of metalloenzymes with various metals (Mg, Mo, Mn, Fe, Co, Ni, Cu, and Zn); O_2-transporting and storage proteins (hemocyanin, myoglobin, hemoglobin, and hemerythrin); bio-medical application of cis-platin. [5] 10. Catalysis: Concepts and applications of catalysis in homogeneous and heterogenous processes such as Haber-Bosch process, Fischer-Tropsch process, Wilkinson hydrogenation, Wacker oxidation, Monsanto process, hydroformylation, and Ziegler-Natta polymerization. [3] 11. Lanthanoids and Actinoids: Properties and reactivity trends; nuclear reactions of thorium and uranium; synthesis of trans-uranium elements; applications of radioisotopes. [3]
Text & Reference Books	1. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, 2ed., Oxford University Press, 2012. 2. J. McMurry, Organic Chemistry, 9ed., Cengage Learning, 2015. 3. O. Snow, Love Drugs, Thoth Press, 2005. 4. R. H. Waring, G. B. Steventon and S. C. Mitchell Molecules of Death, Imperial College Press, 2007. 5. D. E. Newton, Chemistry of New Materials, Facts on File, 2007. 6. P. Atkins, T. Overton, J. Rourke, F. Armstrong, and M. Hagerman, Shriver and Atkins' Inorganic Chemistry, 5ed, W. H. Freeman and Company New York, 2009. 7. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3ed, Pearson, 2008. 8. J. E. House, Inorganic Chemistry, 3ed, Academic Press, 2019. 9. J. E. Huheey, E. A. Keiter, and R. L. Keiter, Inorganic Chemistry – Principles of Structure and Reactivity, 4ed, Pearson Education, 2006. 10. W. Kaim and B. Schwederski, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, 2ed, Wiley, 2013.

CHY 221	Physical Chemistry I (3103)
Learning Outcomes	To introduce the formalisms for the microscopic description of states of matter, leading to an understanding of the fundamental intermolecular interactions governing them To provide an appreciation for the application of the ideas from thermodynamics for the description of solution state properties
Syllabus	1. Gaseous State: Revision of gas laws, ideal gas equation of state, kinetic theory of gases, interpretation of gas pressure, Maxwell-Boltzmann distribution for velocities, speeds and energies of gas particles, average, most probable and root-mean-squared speeds, collision rate, collision flux, effusion, collision number, mean free path, transport properties, diffusion, Fick's laws, Einstein relation, thermal conductivity, viscosity, real gases, deviations from ideality, compressibility factor, van der Waals and virial equations of state, Boyle temperature, liquefaction of gases, critical constants, and law of corresponding states [10] 2. Intermolecular Interactions: Hard sphere potential, Lennard-Jones potential, ion-ion, ion-dipole, ion-induced dipole, dipole-dipole, dipole-induced dipole and induced dipole-induced dipole interactions, orientational averaging effects, Keesom interactions, Debye interactions, London interactions, hydrogen bonding, aromatic interactions, manifestation of intermolecular interactions in governing boiling points, states of matter, and heats of vaporization [8] 3. Review of Concepts in Thermodynamics: Concepts of temperature, enthalpy, entropy, Gibbs and Helmholtz energies, laws of thermodynamics, state and path functions, standard states, thermochemistry and Maxwell relations [1] 4. Physical Transformations of Pure Substances: Molar Gibbs energy, temperature and pressure dependence, Clausius-Clapeyron equation, phase equilibria of pure substances, application of Clausius-Clapeyron equation to solid-liquid, liquid-vapor and solid-vapor equilibria, phase rule, phase diagrams of one-component and two-component systems [4] 5. Thermodynamics of Mixtures: Partial molar quantities, partial molar Gibbs energy and chemical potential, thermodynamics of mixing, chemical potential of liquids, ideal dilute solutions, Henry's and Raoult's laws and their applications, fugacity and activity, liquid mixtures, excess functions and regular solutions [4] 6. Colligative Properties: Elevation of boiling point, depression of freezing point, lowering of vapour pressure, osmosis, and solubility [1] 7. Phase Equilibria of Binary Systems: Vapor pressure diagrams, temperature-composition diagrams, liquid-liquid phase diagrams, liquid-solid phase diagrams, azeotropic mixtures, fractional distillation and steam distillation [2] 8. Chemical Equilibria: Responses to temperature and pressure, Le Chatelier's principle, and van't Hoff equation [1] 9. Electrochemistry: Properties of ions in solutions, ionic mobility and conductivity, Debye-Hückel theory, standard electrode potential, Nernst equation, electrochemical cells, redox reactions, electromotive force and free energy [2] 10. Chemical Kinetics: Chemical reactions of various orders, integration of rate equations, elementary reactions, opposing reactions, consecutive reactions, parallel reactions, steady state approximation, enzyme catalysis, and Arrhenius equation [3]
Text & Reference Books	1. P. Atkins, J. de Paula and J. Keeler, Atkins' Physical Chemistry, 11th Ed., Oxford University Press (2018). 2. T. Engel and P. Reid, Physical Chemistry, 3rd Ed., Pearson (2013). 3. R. J. Silbey, R. A. Alberty and M. G. Bawendi, Physical Chemistry, 4th Ed., Wiley Student Edition (2006). 4. D. A. McQuarrie and J. D. Simon, Physical Chemistry: A Molecular Approach, Viva Student Edition, Viva (2019).

Laboratory Courses

CHY 112	Chemistry Laboratory I (0031)
Learning Outcomes	This laboratory course provides opportunities for hands-on laboratory experiences related to qualitative and quantitative analyses.
Syllabus	1. Experiment 1 – Gravimetric Analysis: (a) Estimation of chloride anion in a water sample; (b) Estimation of nickel in a given sample as $Ni(DMGH)_2$. 2. Experiment 2 – Colors of transition metal complexes: (a) Preparation and UV-vis analysis of coordination complexes of Co(II), Co(III), Ni(II), and Cu(II) with a series of ligands such as H_2O, NH_3, ethylenediamine, tartrate, SCN^-, Cl^-. 3. Experiment 3 – Preparation and analysis of $[Zn(NH_3)_4][BF_4]$: (a) Synthesis of $[NH_4][BF_4]$; (b) Synthesis of $[Zn(NH_3)_4][BF_4]$; (c) Analysis of the NH_3 content in $[Zn(NH_3)_4][BF_4]$. 4. Experiment 4 – Titrimetric Estimations Based on Acidimetry and Alkalimetry: (a) Standardisation of NaOH solution using N/20 oxalic acid solution; (b) Estimation of acetic acid concentration in commercial vinegar using standard NaOH solution as titrant; (c) Standardisation of HCl solution using N/20 oxalic acid solution, (d) Estimation of alkali content in commercial antacid tablet. 5. Experiment 5 – Redox-Titrimetric Estimations Based on Permanganometry: (a) Standardisation of potassium permanganate using sodium oxalate; (b) Preparation of $K_3[Fe(C_2O_4)_3]\cdot 3H_2O$; (c) Estimation of the oxalate content of Potassium trisoxalatoferrate(III) trihydrate, (d) Photochemical reactions of Potassium tris-oxalatoferrate(III) trihydrate. 6. Experiment 6 – Redox-Titrimetric Estimations Based on Dichromatometry: (a) Preparation of N/20 potassium dichromate solution; (b) Estimation of iron and chromium in a mixture using a standard N/20 potassium dichromate solution as titrant. 7. Experiment 7 – Estimations Based on Iodimetry and Iodometry: (a) Preparation and standardisation of sodium thiosulfate solution; (b) Preparation of $Cu(NH_3)_4SO_4$ and estimation of copper(II) using standard thiosulfate solution as titrant; (c) Solubility product of $Ca(IO_3)_2$. 8. Experiment 8 – Complexometric Estimations Based on EDTA: Quantitative estimation of calcium and magnesium in milk by EDTA complexometry - (a) Standardisation of EDTA solution using a standard zinc acetate solution; (b) Estimation of % amount of calcium and magnesium in a milk sample.
Text & Reference Books	1. G. H. Jeffery, J. Bassett, R. C. Denny, Vogel's Quantitative Chemical Analysis, 5ed, ELBS and Longmans Green & Co Ltd, 1971. 2. A. J. Elias, General Chemistry Experiments, 3ed, Universities Press (India) Pvt Ltd, 2002. 3. J. Derek Woollins, Inorganic Experiments, 3ed, Wiley, 2010.

CHY 212	Chemistry Laboratory II (0031)
Objectives	To learn the principles and applications of separation, isolation, and analytical techniques in organic chemistry.
Syllabus	Basic Lab Techniques [6] a) Thin layer chromatography (TLC) and calculation of Rf values. b) Column Chromatography: separation of organic mixture. c) Purification of organic compounds by crystallization. d) Filtration techniques. e) Determination of melting and boiling points. Experiment No 1: Separation and quantification [6] a) Separation of napthol, aspirin, and napthalene b) Determination of purity by melting points and TLC. Experiment No 2: Isolation of Natural Products [6] a) Extraction of eugenol from cloves by steam distillation b) Extraction of caffeine from tea leafs. Experiment No 3: Organic preparations [6] a) Preparation of paracetamol b) Preparation of aspirin Experiment No 4: conversion of nitrobenzene to aniline and its estimation [6] a) Qualitative test for nitrobenzene b) Reduction of nitro compound c) Qualitative test for aniline d) Estimation of aniline Experiment No 5: Phenol and its derivatives [6] a) Qualitative test for phenol b) Nitration of phenol c) synthesis of 7-hydroxy-4-methylcoumarin Experiment No 6: Cannizarro Reaction [6] a) Qualitative tests for benzaldehyde b) Preparation of benzyl alcohol and benzoic acid from benzaldehyde c) Qualitative tests for benzyl alcohol d) Qualitative tests for benzoic acid Experiment No 7: Claisen- Schmidt Reaction [3] a) Preparation of dibenzalacetone (1,5-diphenylpenta-1,4-diene-3-one) b) Qualitative test for bibenzalacetone Experiment No 8: Beckmann Rearrangement [6] a) Preparation of benzophenone oxime b) Conversion of benzophenone oxime to benzanilide c) Qualitative analysis of benzanilide Experiment No 9: Preparation of ester and its estimation [6] a) Preparation methyl benzoate b) Qualitative test for ethyl benzoate c) Estimation of ester
Text & Reference Books	1. Vogel's Text book of Practical Organic Chemistry - Revised by Brian S. Furniss, Antony J. Hannaford, Peter W. G. Smith, and Austin R. Tatchell, - 5 ed., John Wiley & Sons, 1991.

CHY 222	Chemistry Laboratory III (0031)
Objectives	Chemistry Laboratory III offers opportunities to familiarize the principles of physical chemistry through hands-on approaches. This laboratory is designed to have experiments related to the physical chemistry concepts taught in the theory course CHY221.
Syllabus	1. Viscosity: a. Determination of Viscosity of Pure Liquids b. Effect of Salt on Viscosity of Liquids 2. Surface Tension: a. Determination of the Surface Tension of a Liquid by Drop Number Method b. Determination of Parachor Values **3.** Chemical Kinetics a. Determination of the Rate Constant of the Hydrolysis of Ester by Sodium Hydroxide at Different Temperature b. Activation Energy 4. Refractometry: a. Determination of Molar Refractions of Pure Liquids b. Determination of Molar Refraction of Solids c. Solvent-Solvent Interaction in Binary Solvent System 5. Conductivity Measurements: a. Determination of the Degree of Ionization of Weak Electrolytes. b. Titration of a Strong Acid and Weak Acid Against a Strong Base. c. Titration of a Mixture of Acids Against a Strong Base. d. Titration of a Mixture of Weak Acids Against a Strong Base. 6. Potentiometry: a. Determination of Single Electrode Potentials (Cu and Zn). b. Verification of Nernst Equation c. Oxidation-Reduction Titration. 7. Distribution Law a. Distribution Coefficient of Iodine Between an Organic Solvent and Water. b. Determination of the Equilibrium Constant of the Reaction $KI + I_2$ KI_3 8. Phase Diagrams-1: Phenol Water System: a. Determine the Mutual Solubility Curve of Phenol and Water and Hence the Consolute Point. b. Determine the Critical Solution Temperature of Phenol and Water in Presence of (i) Sodium Chloride (ii) Naphthalene and (iii) Succinic acid. 9. Phase Diagrams-2: Three Component System: a. Construction of the Triangular Phase Diagram of Acetic Acid, Chloroform and Water b. Construction of the Tie Line c. Determination of the Composition of the Given Mixture 10.Solid Liquid Equilibrium: a. Determination of Molal Depression Constant of Naphthalene d. Determination of Molecular Weight of Solute
Reference	1. M. Halpern and G. C. McBane, Experimental Physical Chemistry: A Laboratory Text Book, 3rd Edition, W. H. Freeman, 2006 2. D. P. Shoemaker, G. W. Garland and J. W. Nibler, Experiments in Physical Chemistry, 5th Edition, McGraw Hill, London.

School of Mathematics

MAT 111	Single Variable Calculus (3103)
Learning outcomes	Under the BS-MS program, a few students join without mathematics background in their 10+2 standard. This course, in one hand, provides the necessary back ground in basic calculus to such students, on the other, it also exposes all the students to an abstract approach to calculus, which is necessary for more advanced courses on analysis.
Syllabus	Properties of real numbers, the least upper bound and greatest lower bound properties (4 hours) Limits of Sequences: Convergence and limit laws, limsup and liminf of sequences, some standard limits, Subsequences. (7 hours) Series: absolute and conditional convergence of an infinite series, tests of convergence, examples. (5 hours) Continuous functions on the real line: Formal definition, continuity and discontinuity of a function at a point; left and right continuity, examples of continuous and discontinuous functions, intermediate value theorem, extreme value theorem, monotonic functions, uniform continuity, limits at infinity.(8 hrs) Differentiation of functions: Definition and basic properties, local maxima, local minima, and derivatives, monotone functions and derivatives, inverse functions and derivatives, Rolle's theorem, mean value theorem, Taylor's theorem. (8 hrs) Riemann Integration: Partitions, upper and lower Riemann integrals, basic properties of the Riemann integral, Riemann integrability of continuous functions, monotone functions, and discontinuous functions, non-Riemann integrable functions, the fundamental theorems of calculus (8 hrs)
Texts and References	1. T. M. Apostol, Calculus, vol 1, 2nd ed., Wiley, 2007. 2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 4th ed., Wiley, 2011. 3. S. Lang, A first course in Calculus, 5th ed., Springer India, 2006. 4. M. Spivak, Calculus, Publish or Perish, 2008. 5. W. Rudin, Principles of Mathematical Analysis, 3rd ed., McGraw Hill India, 1953.

MAT 121	Introduction to Linear Algebra (3103)
Learning outcomes	The basic linear algebra is foundation for every future mathematics course. The objective is to introduce the Linear algebra in a mathematically abstract form and relate it to the matrix algebra.
Syllabus	• Matrices: Systems of linear equations, Row echelon form, Elementary matrices, The determinant of a matrix, Properties of determinants. (6 hours) • Vector spaces: Definition and examples, Subspaces, Linear independence, Basis and dimension, Change of basis, Row space and column space (9 hours) • Linear maps: Definition and examples, Matrix representations of linear maps, Similarity, Rank-nullity Theorem. (7.5 hours) • Inner product spaces: The scalar product in R^n, Inner product spaces, Orthonormal sets, The Gram-Schmidt orthogonalisation process. (7.5 hours) • Eigenvalues and eigenvectors, Diagonalisable matrices, Cayley- Hamilton Theorem. (6 hours) • Hermitian Matrices. (4 hours)
Texts and References	1. S. Axler, Linear Algebra Done right, Springer; 3rd ed. 2015 edition. 2. S. H. Friedberg, A. J. Insel, L.E. Spence, Linear Algebra, Pearson Education India; 4 edition. 3. L. N. Childs, A Concrete Introduction to Higher Algebra, Springer, 2009

	4. S. Kumaresan, Linear Algebra : A Geometric Approach, Phi Learning, 2009. 5. Hoffman and R. Kunze, Linear Algebra, 2nd edition, Pearson Education, New Delhi, 2006 6. P. Halmos, Finite Dimensional Vector Spaces, Van Nostrand, Princeton, N.J, 1958

MAT 211	Multivariable Calculus (3103)
Learning outcomes	This course is an extension to MAT 111. Limit, continuity, differentiation and integration in R^n are explained in a more problem solving manner, although abstract mathematical concepts are slowly introduced. The course also introduces some very basic topological properties of R^n.
Syllabus	• Differential calculus: Limits and continuity of functions of several variables; Differentiability, Partial derivatives, total derivative, composite functions, chain rule, partial derivatives of higher order, change of variables; inverse and implicit function theorems (without proof), unconstrained maxima and minima, Lagrange multipliers; Leibniz's formula, Taylor's formula, mean value theorems. (20 hours) • Integral Calculus: Double integrals on rectangular regions, conditions of integrability, properties of integrable functions, repeated or iterated integrals, double integrals over finite regions, changing the order of integration; Fubini-Tonelli Theorem (without proof); triple integrals over any bounded domain, evaluation of multiple integral by change of variables; surface area, volume of a region, theorems of Green, Gauss, and Stokes (without proof). (20 hours)
Texts and References	1. T. M. Apostol, Calculus, vol. 2, 2nd ed., Wiley (India), 2007. 2. S. Lang, Calculus of several variables, 3rd ed., Springer 1987. 3. V. Zorich, Mathematical Analysis I, Springer 2004. 4. V. Zorich, Mathematical Analysis II, Springer 2004. 5. Moskowitz, F Paliogiannis, Funtions of several Real Variables, World Scientific Publishing 2011.

MAT 221	Introduction to Probability (3103)
Learning outcomes	The aim of this problem oriented course is to give the students a broader perspective how the combinatorial probability and statistical methods can be used in all areas of sciences.
Syllabus	• Basic probability: Set operations, counting, finite sample spaces, axioms of mathematical probability, conditional probability, independence of events, Bayes' Rule, Bernoulli trials, Poisson trials, multinomial law, infinite sequence of Bernoulli trials.(10 hours) • Random variables and probability distributions: Binomial distribution, geometric distribution, Poisson distribution, normal distribution, exponential distribution, Gamma distribution, Beta distribution; Cumulative and marginal distribution functions; Transformation of random variables in one and two dimensions.(15 hours) • Mathematical expectations: Expectations for univariate and bivariate distributions, moments, variance, standard deviation, higher order moments, covariance, correlation, moment generating functions, characteristic functions. Central limit theorem, law of large numbers.(15 hours)
Texts and References	1. R. V. Hogg, J. McKean and A. T. Craig, Introduction to Mathematical Statistics, Pearson, 7th ed., 2012 2. S. Ross, Introduction to Probability and Statistics for Engineers and Scientists, 3rd ed., Elsevier, 2004. 3. C. M. Grinstead and J. L. Snell, Introduction to Probability, 2nd ed., American Mathematical Society, 1997. 4. S. Ross, A first course in Probability ,8th edition, Prentice Hall, 2009. 5. K. L. Chung, Elementary Probability Theory, 4th edition, Springer, 2003. 6. P. G. Hoel, S.C. Port and C.J. Stone, Introduction to Probability Theory, 1st edition, Houghton Mifflin, 1972.

School of Physics

PHY 111	Mechanics (3103)
Learning Outcomes	1. Understand and express the fundamental principles of mechanics 2. Undertake mathematical formulation of physical problems 3. Solve equations of motion (EOM) with suitable initial and boundary conditions 4. Comprehend relativistic concepts of space and time, reference frames.
Syllabus	• Newton's Laws [4]: Critical analysis of the Newton's laws, Concept of homogeneity and isotropy of space-time, symmetry, Concept of inertial, non-inertial reference frames, fictitious forces, Introduction to Galilean Relativity. • Motion in one dimension [8]: Analytical solutions of EOMs, Conservation of momentum, Work energy theorem, Use of potential energy graphs to understand motion. Motion under gravity (rocket motion, block-pulley systems); Simple harmonic oscillator and damped oscillator. • Motion in higher dimensions [3]: Position vector and its derivatives. EOM in Cartesian and Polar Coordinates; • Force as the gradient of potential energy; Conservation of angular momentum for a point particle; Projectile motion, Motion under central force, The Kepler problem [7] • Rigid bodies [4]:Centre of mass; Rotational inertia, Momentum and Energy, • Conservation laws, Moment of inertia-Examples with simple symmetric bodies. [5] • Torque and work energy theorem. [3] • Non-inertial frames [6]:Rotating reference frames and pseudo-forces • Special Theory of Relativity: Measuring space-time in Galilean relativity; Michelson-Morley experiment, Postulates of special relativity, Lorentz transformation-Relativity of Simultaneity, Length contraction, Time dilation; Minkowski space-time diagram, Examples: Twin paradox, Doppler Effect. [8 hrs]
Text & Reference Books	1. D. Kleppner and R. Kolenkow, An introduction to Mechanics, McGraw-Hill Science/ Engineering/ Math, 1973. REFERENCES 1. Serway and Jewett, Physics for Scientists and Engineers, Brooks/Cole Publishers 2004. 2. C. Knight, W. D. Ruderman, M. A. Helmholz, C. A. Moyer and B. J. Kittel, Berkeley Physics Course: Vol. I – Mechanics, McGraw-Hill, 1965. 3. R. Shankar, Fundamentals of Physics, Yale Press.

PHY 121	Electromagnetism (3103)
Learning Outcomes	1. Understand and express the fundamental laws and principles of Electricity and Magnetism. 2. Describe concepts and phenomena of electromagnetic fields, and their mathematical formulation in free space and matter. 3. Calculate physical quantities associated with electromagnetism.
Syllabus	• Electrostatics : *Electric field:* Coulomb's law, Divergence and Curl of electrostatic fields, Gauss's law in differential and integral form and simple application [3] *Electric Potential:* Electrostatic potential, Poisson's equation and Laplace equation, Potential due to a localized charge distribution, Electrostatic Boundary conditions [3] *Work and energy in electrostatics:* Work done to move a charge, Electrostatic energy for point charge as well as continuous charge distribution, Simple examples [2] *Conductors:* Basic Properties, Surface charges induced on a conductor, Force on a conductor. *Capacitors:* Definition of capacitance, Calculation of capacitance for parallel plates, concentric spherical shells, coaxial cylindrical tubes.[2] • Special Techniques to solve the potential due to a given charge configurations: Solution by the method of separation of variables in Cartesian, spherical polar and cylindrical coordinates; Examples involving solution of boundary value problems such as a conducting sphere in uniform electric field; Potential due to an arbitrary charge distribution; Solving the potential for point charge configuration in a system of grounded conducting planes using method of images. [8]

PHY 121	Electromagnetism (3103)
	• Multipole Expansion; Electrical field and potential due to a point dipole; Dipole in an electric field [2] • Electric field in matter [4]: Dielectrics, Polarization, Field of a polarized object, Electric displacement vector (D); Gauss's theorem in dielectric media; Boundary value problem with linear dielectrics; • Electrostatic field energy; Computation of capacitance in simple cases (parallel plates); spherical and cylindrical capacitors containing dielectrics – uniform and non-uniform. [4] • Magnetostatics: Biot - Savart and Ampere's laws; Ampere's law in differential form; Magnetic vector potential, Magnetostatic boundary conditions [4] Multipole expansion of the vector potential; Determination of magnetic fields for simple cases. Energy in a magnetic field[4] • Magnetic field in matter [6]: Field of a Magnetized object; Auxiliary Field H, Ampere's law in Magnetized materials; Magnetic Susceptibility and Permeability. • Electrodynamics [6]: Current electricity: Electromotive force. Ohm's law; Motional emf; Electromagnetic induction; Faraday's law; Self-inductance and mutual inductance; Impedance; LCR circuit; Maxwell's equations; Equation of continuity; Poynting's theorem;
Text & Reference Books	TEXTBOOKS 1. D. J. Griffths, Introduction to Electrodynamics, Prentice-Hall India, 2007. Additional References 2. E. M. Purcell, Berkeley Physics course: Vol 2. Electricity and Magnetism, McGraw Hill. 3. Serway and Jewett, Physics for Scientists and Engineers, Brooks/Cole Publishers, 2004.

PHY 211	Optics (3103)
Learning Outcomes	1. Analyse optical systems using lens equations and matrix formalism 2. Evaluate the effect of different aberrations on image formation 3. Write expression for a travelling wave using wave properties such as wavelength, polarization and phase velocity 4. Distinguish between polarization states and polarization conversion 5. Analyse interference patterns and interferometers using the concept and conditions for interference. 6. Analyse effect of aperture on wave propagation, diffraction and applications
Syllabus	• Geometrical Optics [3] Fermat's Principle, Laws of reflection and refraction from Fermat's principle, • Refraction at a Single Spherical Surface, The thin lens, Thin lens equation,[3] • Matrix method in paraxial optics, Thin lens combinations, Aberrations, Prisms, Optical Systems.[3] • Wave Optics [4]: Wave Motion, One dimensional waves, Harmonic Waves, Phase Velocity, Group Velocity of a wave packet, • Three-dimensional wave equation, Spherical waves, and cylindrical waves.[3] • Polarisation: The nature of polarized light, Polarizers, Malus law, Dichroism, Birefringence, Scattering and Polarization, Polarization by reflection, Brewster angle, Retarders; full-wave plate, half-wave plate, quarter-wave plate, Circular Polarizers, Polarization of Polychromatic light [6] • Maxwell's equation, wave equation, Poynting Vector, Fresnel reflection coefficient, Total internal reflection, Optical fibre, single mode fibre, multimode fibre, evanescent wave. [5] • Interference [3]: The superposition principle, phasors and the addition of waves, Condition for interference, Coherence, • Two beam interference by division of wave-front; Fresnel' Biprism, [2] • Interference by division of amplitude; interference by a plane parallel film, Newton's rings, Michelson interferometer, multiple beam interferometry; Fabry-Perot interferometer. [5] • Diffraction: Fresnel diffraction: Fresnel Half-period zones, The zone-plate, Diffraction by a straight edge, The Fresnel propagation [6]

PHY 211	Optics (3103)
	• Fraunhofer approximation, Fraunhofer diffraction and Fourier optics: Single slit diffraction, Diffraction by a circular aperture, Two-slit Fraunhofer diffraction, N-slit Fraunhofer diffraction, The diffraction grating, Oblique incidence, X-ray diffraction.[5]
Text & Reference Books	1. Ajoy Ghatak, Optics, Tata Mcgraw-Hill, 2009. REFERENCES 1. Eugune Hecht and A. R. Ganesan, Optics, AddisonWesley Longman, 2002. 2. Francis A. Jenkins and Harvey E. White, Fundamentals of Optics, McGraw- Hill Higher Education, 4th Ed. 3. Frank S. Crawford,Waves: Berkeley Physics Course Vol. 3, Tata Mgraw Hill, 2008.

PHY 221	Thermal & Statistical Physics (3103)
Learning Outcomes	1. Apply concepts and laws of thermodynamics to describe physical processes and systems. 2. Analyze the energy changes of physical/chemical systems using first law of thermodynamics. 3. Apply concepts in probability and distribution functions to different physical systems and connect single particle quantum behaviour that of macroscopic thermodynamic systems. 4. Evaluate intensive and extensive variables using statistical formulations for an ideal gas.
Syllabus	• Macroscopic and microscopic description of state; Thermal equilibrium and the Zeroth law; Concept of temperature; Temperature scales. [3] • Thermodynamic equilibrium; Thermodynamic variables; Equation of state; Relevant theorems in partial differential calculus; [3] • Thermodynamics of simple systems (hydrostatic system, stretched wire, surfaces, electrochemical cell, dielectric slab, paramagnetic rod); Intensive and extensive variables. [5] • Work, Heat and Internal energy; Thermodynamic Processes (reversible, irreversible, quasi-static, adiabatic, isothermal, etc); Work done in various processes; [4] • First law of thermodynamics, Specific heat capacity; Heat conduction and conductivity; Blackbody radiation; Kirchhoff's law; Stefan-Boltzmann law. [4] • The Second Law of thermodynamics; Gasoline Engine; Carnot cycle and Kelvin temperature scale, [4] • Clausius' theorem, Entropy change for simple processes; Physical interpretation of Entropy; Applications of Entropy principle. [4] • Thermodynamic functions (Enthalpy, Helmholtz free energy, Gibbs free energy, etc.);[4] • Conditions of equilibrium; Maxwell's relations, Chemical potential. [3] • Equilibrium between two phases; General equilibrium conditions; The Clausius-Clapeyron equation and phase diagrams;[3] • Stability conditions: Le-Chatelier's principle; Third law of thermodynamics. [3] • Concept of ensembles and Statistical postulates; Examples of probability distributions; Maxwell's distribution (Mean and variance); Canonical partition function of an ideal mono-atomic gas; [4] • Evaluate pressure, internal energy, and entropy of ideal gas; Equipartition of energy; Distribution of speeds (average speed, average square of speed) [4]
Text & Reference Books	1. M. W. Zemanski and R. H. Dittman, Heat and Thermodynamics, McGraw- Hill, 1997. REFERENCES 1 F. Reif, Statistical Physics: Berkeley Physics Course Vol. 5, Tata McGraw-Hill, 2011. 2. Daniel V. Schroeder, An introduction to thermal Physics, Addison- Wesley, 2000. 3. S. J. Blundell and K. M. Blundell, Concepts in Thermal Physics, Oxford, 2006.

Laboratory Courses:

PHY112	Experiments in Mechanics [0031]
Learning Outcomes	1. Apply laws of mechanics to describe real life systems 2. Handle apparatus and Assemble simple experimental setup 3. Record measurements and Perform data analysis 4. Calculate physical parameters from experimental results and their deviation from theoretical predictions and Error Analysis
Syllabus	1. Simple pendulum & variable g pendulum 2. Conservation of energy 3. Conservation of momentum & ballistic pendulum 4. Centripetal force 5. Symmetric compound bar pendulum 6. Projectile motion 7. Melde's string 8. Newton's laws of Motion 9. Moment bar 10. Sonometer
Text & Reference Books	Laboratory Notes and Reference Material

PHY122	Experiments in Optics, Electricity and Magnetism [0031]
Learning Outcomes	1. Experimentally verify theoretical concepts in electromagnetism and optics 2. Handle apparatus and Assemble simple experimental setup 3. Record measurements and Perform data analysis 4. Calculate physical parameters from experimental results and their deviation from theoretical predictions and Error Analysis 5. Appreciate safety protocols and measures taken
Syllabus	1. Magnetic field along the axis of a circular coil 2. Deflection magnetometer 3. Spot galvanometer- high resistance by leakage 4. Spectrometer: refractive index of prism and i-d curve 5. Spectrometer-Grating 6. Newton's rings 7. Diffraction at slits-single and double 8. Liquid lens 9. Reflection grating 10. Malu's law
Text & Reference Books	Laboratory Notes and Reference Material

PHY222	Experiments in Heat and Thermodynamics [0031]
Learning Outcomes	1. Experimentally verify laws of Thermodynamics and Determine thermal properties of matter. 2. Handle apparatus and Assemble simple experimental setup 3. Record measurements and Perform data analysis 4. Calculate physical parameters from experimental results and their deviation from theoretical predictions and Error Analysis
Syllabus	1. Specific latent of steam 2. Thermal conductivity of rubber 3. Specific heat capacity of solid-method of mixtures 4. Joule's calorimeter-specific heat capacity of liquid 5. Thermal conductivity - Lee's disc method 6. Potentiometer and thermo emf 7. Latent heat of fusion of ice 8. P V Diagram 9. Stefan's Law 10. Newton's law of cooling
Text & Reference Books	Laboratory Notes and Reference Material

Interdisciplinary Courses:

IDC 111	Mathematical Tools I (2102)
Learning Outcomes	● Perform analysis of functions of several variables ● Use concepts of vector calculus in physical problems ● Perform operations with complex numbers
Syllabus	● Functions of several variables - partial differentiation. Cartesian, Spherical and Cylindrical coordinate systems: introduction and equivalence. Parametric representation of an equation. Introduction to Taylor's series with examples. [6] ● Vector Calculus: Review of vector algebra: addition, subtraction and product of two vectors - polar and axial vectors with examples; triple and quadruple product. Concept of Scalar and Vector fields. Differentiation of a vector w.r.t. a scalar unit tangent vector and unit normal vector. Directional derivatives - gradient, divergence, curl and Laplacian operations and their meaning. Concept of line, surface and volume integrals. Statement of Gauss' and Stokes' theorems with physical examples. Gradient, divergence and curl in spherical polar and cylindrical coordinate systems. [15] ● Complex numbers and functions: Arithmetic operation, conjugates, modulus, polar form, powers and roots; Derivatives. [4]
Text & Reference Books	1. E. Kreyszig, Advanced Engineering Mathematics, 8th Edition Wiley India Pvt Ltd, 2006. 2. Murray R. Spiegel, Schaum's Outlines Vector Analysis, Tata Mcgraw Hill 2009. 3. Murray R. Spiegel, Seymour Lipschutz, John Schiller, Dennis Spellman, Schaum's Outlines Complex Variables. Tata McGraw Hill Education; 2 edition, 2017

IDC 121	Mathematical Tools II (3103)
Learning outcomes	The aim of the second part of the interdisciplinary maths methods course is to making the students aware of various mathematical tools which are applied to other branches of sciences and engineering. This is a complete problem oriented course with lots of applications drawn from various fields.
Syllabus	● Solving techniques for first and second order linear ODEs: constant and variable coefficients [10] ● Power series method, Legendre, Hermite, Bessel, Lauguerre, Chebyshev polynomials. [10] ● Laplace transforms and application to ODEs.(6 hours) ● BVPs and Green's functions.(7 hours) ● Linear 2x2 systems of ODEs.(4 hours) ● Application to other fields.(3 hours)
Texts and References	1. E. Kreyszig, Advanced Engineering Mathematics, 8th Edition Wiley India Pvt Ltd, 2006. 2. C. Edwards and D. Penny, Elementary Differential Equations with Boundary Value Problems, 5th Edition Prentice Hall 2007. 3. R. Bronson and G. Costa, Schaum's Outlines Differential Equations, 3rd Edition Mcgraw-hill 2009. 4. William E. Boyce, and Richard C. DiPrima, Elementary Differential Equations 9th Edition, Wiley, 2008.

IDC 211	Physical Principles in Biology (3103)
Learning Outcomes	Biological living organisms reach organizational complexity that far more exceeds the complexity of any inanimate objects or matter from which they are made of. The objective of the course is to introduce the students to the spatial (size) and temporal (time) scales that span the living organisms in order to understand the physical principles behind their complexity. The course will introduce students to the physical principles of biomolecules, their interactions/recognition, their census in time and scale, the techniques used to probe the physical properties that govern the functions of biomolecules and the linearity, non-linearity and stochasticity in biological systems.
Syllabus	1. Physical biochemistry of the cell: Chemical forces translation and rotation, diffusion, directed movements, biomolecules as machines, work, power and energy, thermal, chemical and mechanical switching of biomolecules, Responses to light and environmental cues [8-9] 2. Physical principles of molecular structure: organization of biomolecules, molecular census in size and time, macromolecular assemblies, sizing up HIV, channels, transporters and motors [19] 3. Molecular recognition: principles of specificity in biological recognition, hormone-receptor interaction, antigen-antibody interaction, transient interactions, importance of transient interaction in biology.[5-6] 4. Linearity and non-linearity in biological systems : Definitions and example of linear and non-linear systems. Representing linear and nonlinear functions and applications. Stochasticity in Biological systems. [3-4]
Text & Reference Books	1. John Kuriyan, The Molecules of Life: Physical and Chemical Principles. 2. Rob Phillips et al., Physical Biology of the Cell. Garland Science. 3. Peter Atkins and Julio de Paula, Physical Chemistry for the Life Sciences. 4. Watson J.D. and Crick F.H.C. A Structure for Deoxyribose Nucleic Acid (1953), Nature, 171, 737-738. 5. Michael J. Rust. Orderly wheels of the cyanobacterial clock (2012), PNAS, 09, 16760–16761 (Review). 6. Erwin Schrödinger. The Physical Aspect of the Living Cell (1944). Science book written for the lay reader by a physicist. 7. Kaern M, Elston TC, Blake WJ, Collins JJ (2005), Stochasticity in gene expression: from theories to phenotypes, Nat Rev Genet., 6:451-464. (Review).

IDC 221	Principles of Spectroscopy (3103)
Learning Outcomes	To describe the fundamental principles governing various spectroscopic techniques and the relevant applications
Syllabus	• Fundamental Aspects of Spectroscopy: Electromagnetic radiation, absorption, emission, scattering, Einstein A and B coefficients, signal to noise ratio, resolving power, lasers, spectral lineshapes, Fourier transform spectroscopies, and pump-probe techniques [6] • Atomic Spectroscopy: Spectra of hydrogenic systems, coupling of orbital and spin angular momenta in many-electron systems, term symbols, fine and hyperfine structure, Zeeman and Stark effects [8] • Rotational Spectroscopy: Rigid rotor model for diatomics, rotational angular momentum, rotational energy levels, rotational constant, selection rules, microwave spectra of representative diatomics, structure determination, and isotope effects [5] • Infrared Spectroscopy: Harmonic oscillator model for diatomics, energy levels, selection rules, anharmonic effects, dissociation energies, and Morse oscillator [5] • Raman Spectroscopy: Light scattering, Raman effect, classical model of scattering, polarizability, Stokes and anti-Stokes lines, selection rules, mutual exclusion principle, structure determination using IR and Raman spectroscopies [2]

IDC 221	Principles of Spectroscopy (3103)
	• Electronic Spectroscopy of Molecules: Jablonski diagram, absorption, emission, Frank-Condon principle, Stokes shift, 0-0 band, fluorescence, phosphorescence, and quantum yields [4] • Photoelectron Spectroscopies: X-ray photoelectron spectroscopy, ultraviolet photoelectron spectroscopy, and Auger processes [2] • Spin Resonance Spectroscopies: Nuclear and electron spins, effect of applied external fields, nuclear magnetic resonance spectroscopy, electron spin resonance spectroscopy, illustrative examples and applications [3] • Mössbauer Spectroscopy: Principle and illustrative examples [1]
Text & Reference Books	1. T. Engel, Quantum Chemistry and Spectroscopy, 3rd Ed., Pearson (2006). 2. J. M. Hollas, Modern Spectroscopy, 4th Ed., Wiley (2004). 3. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., Tata McGraw-Hill (2017). 4. P. Atkins, J. de Paula and J. Keeler, Atkins' Physical Chemistry, 11th Ed., Oxford University Press (2018). 5. T. Engel and P. Reid, Physical Chemistry, 3rd Ed., Pearson (2013). 6. I. N. Levine, Physical Chemistry, 6th Ed., Tata McGraw-Hill (2011).

IDC 112	Fundamentals of Programming (0031)
Learning Outcomes	1. Write structured programs for accomplishing specific tasks in programming languages like C, C++ and Python. 2. Develop object-oriented programs and design computational methods for scientific and data applications. 3. Choose appropriate algorithms, libraries and Datatypes. 4. Understand the role of computation in solving problems. 5. Test and debug programs
Syllabus	• Introduction to computer architectures and components • Programming Languages, Editors and Compilers. • Variables and types, operators and comparisons, compound types: strings and lists, control flow, loops, functions • Simple Programs - Sorting - Searching
Text & Reference Books	1. Byron S Gottfried, Programming with C, Schaums Outlines, 2nd Ed, Tata McGraw-Hill, 2006. 2. John R. Hubbard, Programming with C++, Schaums Outlines, 2nd Ed, Tata McGraw-Hill, 2002. 3. R.G. Dromey, How to Solve it by Computer, Pearson Education, Fourth Reprint, 2007 4. Bjarne Stroustrup, The C++ Programming Language, Fourth Edition, Addison-Wesley 2013. 5. Guttag, John. Introduction to Computation and Programming Using Python: With Application to Understanding Data Second Edition. MIT Press, 2016. ISBN: 9780262529624. 6. H. P. Langtangen, A Primer on Scientific Programming with Python, Springer, 2016

IDC 122	Numeric Computing (0031)
Learning Outcomes	1. Write structured programs for accomplishing specific tasks in programming languages like C, C++ and Python. 2. Develop object-oriented programs and design computational methods for scientific and data applications. 3. Choose appropriate algorithms, libraries and Datatypes. 4. Understand the role of computation in solving problems. 5. Test and debug programs
Syllabus	• Arrays: Arrays and Matrices, Multidimensional arrays, array and matrix operations, indexing, slicing, reshaping and resizing. • Pointers - Arrays - Functions • Computing eigenvalues and eigenvectors, norm and determinant, solving linear system of equations, computing gradient.
Text & Reference Books	1. Byron S Gottfried, Programming with C, Schaums Outlines, 2nd Ed, Tata McGraw-Hill, 2006. 2. John R. Hubbard, Programming with C++, Schaums Outlines, 2nd Ed, Tata McGraw-Hill, 2002. 3. R.G. Dromey, How to Solve it by Computer, Pearson Education, Fourth Reprint, 2007 4. Bjarne Stroustrup, The C++ Programming Language, Fourth Edition, Addison-Wesley 2013. 5. Guttag, John. Introduction to Computation and Programming Using Python: With Application to Understanding Data Second Edition. MIT Press, 2016. ISBN: 9780262529624. 6. H. P. Langtangen, A Primer on Scientific Programming with Python, Springer, 2016

IDC 212	Data Analysis and Visualisation (0031)
Learning Outcomes	1. Write structured programs for accomplishing specific tasks in programming languages like C, C++ and Python. 2. Develop object-oriented programs and design computational methods for scientific and data applications. 3. Choose appropriate algorithms, libraries and Datatypes. 4. Understand the role of computation in solving problems. 5. Test and debug programs
Syllabus	• Introduction to data structures, classes, templates • Object oriented Programming • Understanding Program Efficiency • File input/output, Loading and storing data, data files. • Plotting and visualisation of scientific data,
Text & Reference Books	1. Byron S Gottfried, Programming with C, Schaums Outlines, 2nd Ed, Tata McGraw-Hill, 2006. 2. John R. Hubbard, Programming with C++, Schaums Outlines, 2nd Ed, Tata McGraw-Hill, 2002. 3. R.G. Dromey, How to Solve it by Computer, Pearson Education, Fourth Reprint, 2007 4. Bjarne Stroustrup, The C++ Programming Language, Fourth Edition, Addison-Wesley 2013. 5. Guttag, John. Introduction to Computation and Programming Using Python: With Application to Understanding Data Second Edition. MIT Press, 2016. ISBN: 9780262529624. 6. H. P. Langtangen, A Primer on Scientific Programming with Python, Springer, 2016

IDC 212	Scientific Computing (0031)
Learning Outcomes	1. Write structured programs for accomplishing specific tasks in programming languages like C, C++ and Python. 2. Develop object-oriented programs and design computational methods for scientific and data applications. 3. Choose appropriate algorithms, libraries and Datatypes. 4. Understand the role of computation in solving problems. 5. Test and debug programs
Syllabus	• Special Functions, interpolation, optimisation and fit, random numbers, numerical integration, fast Fourier transforms, signal processing and image manipulations. • Numerical solution of differential equations • Applications to problems in natural sciences
Text & Reference Books	1. Byron S Gottfried, Programming with C, Schaums Outlines, 2nd Ed, Tata McGraw-Hill, 2006. 2. John R. Hubbard, Programming with C++, Schaums Outlines, 2nd Ed, Tata McGraw-Hill, 2002. 3. R.G. Dromey, How to Solve it by Computer, Pearson Education, Fourth Reprint, 2007 4. Bjarne Stroustrup, The C++ Programming Language, Fourth Edition, Addison-Wesley 2013. 5. Guttag, John. Introduction to Computation and Programming Using Python: With Application to Understanding Data Second Edition. MIT Press, 2016. ISBN: 9780262529624. 6. H. P. Langtangen, A Primer on Scientific Programming with Python, Springer, 2016

*i*² Biological Sciences - Core Courses

BIO 311 Microbiology [3003]	
Prerequisite	NA
Learning Outcomes	The course introduces various aspects of microbiology including prokaryotic cellular structure, different types of metabolism utilized by the microbes. Microbial development, microbial organelles are discussed. Basic concepts of microbial communication, chemosensing and pathogenesis are introduced in this course.
Syllabus	**Microbial physiology:** structure of microbes - prokaryotic cell structure & function, autotrophic and heterotrophic metabolisms - , growth and its control factors - culturing and measurement of microbial growth, physical & chemical methods of microbe control. [6] **Microbial development:** division - bacterial cell division, sporulation - endospores, organelle, biofilms. Overview of microbial development with examples from model systems such as Bacillus, cyanobacteria, yeast, filamentous fungi and protozoa. [8] **Microbial communication** - quorum sensing and chemosensory response - bacterial chemotaxis, regulatory network of chemotaxis. [3] **Microbial pathogenesis:** types, mode of infection with examples of human and plant pathogens. Antimicrobial agents and their mode of action. [6] **Applied microbiology:** biodegradation, bioremediation, fermentation, recombinant protein production [6] **Bacterial Genetics:** transposition, mapping of mutations, plasmids, bacterial two-hybrid systems, genetics of bacteriophages, conjugation, transformation, transduction as a tool in bacterial genetics. [6]
Text and Reference Books	1. Willey, Joanne M; Sherwood, Linda; Woolverton, Christopher J; Prescott Harley Klein's Microbiology, McGraw-Hill, 7th Edition, 2008. 2. Cardona (2016) The Progress of Therapeutic Vaccination with Regard to 3. Tuberculosis, Frontiers in Microbiology 7 4. Wai-Leung Ng and Bonnie L. Bassler (2009) Bacterial Quorum-Sensing 5. Network Architectures Annu Rev Genet, 2009; 43: 197?222. doi:10.1146/annurevgenet-102108-134304. 6. chemotaxis: http://chemotaxis.biology.utah.edu/ParkinsonLab/projects/ecolichemotaxis /ecolichemotaxis.html 7. Endotoxin: http://textbookofbacteriology.net/endotoxin.html

BIO 312 Advanced Genetics and Genome Biology [3003]	
Prerequisite	NA
Learning Outcomes	This course provides an overview of genome organization, genome variation and methods used to analyze genomes. Recent advances in genome sequencing, genome wide association studies and advanced genetic analysis are also covered. The course will also introduce students to the emerging field of personal genomics and its relevance to human health.
Syllabus	1. Model genomes, Genome organization and features. [1] 2. Genome variation: SNPs, RFLPs, structural variation, ploidy changes, extent of genome variation between individuals. [1] 3. Genomics and medicine: Sanger sequencing, next generation sequencing technologies, Human genome sequencing, Personalized medicine. [3-4] 4. Methods to study genomes: Vectors (Lambda vector, Bacterial Artificial Chromosome, Yeast Artificial Chromosome), PCR, microarrays, comparative genomic hybridization, pulse field gel analysis. [5] 5. Genetic mapping: genetic markers (auxotrophic markers, RFLPs, SSLPs, SNPs), Recombination mechanisms, linkage analysis using markers, tetrad mapping, sperm typing, DNA fingerprinting, linkage disequilibrium analysis, haplotype analysis, meiotic hotspots. [7-8]

	6. Physical mapping: Restriction maps, Sequence Tag sites, Radiation hybrid maps, FISH, mapping contigs, shotgun sequencing. [2] 7. Co-relating genotype with phenotype: Mendelian traits, Quantitative traits, Genome wide association studies. [2] 8. Genome evolution: plasticity of genomes, genetic incompatibilities, gene duplication. [1]
Text and Reference Books	1. TA Brown, *Genomes* 4, Garland Science, 4th edition, Published May 24, 2017. 2. Tom Strachan, Andrew Read, *Human Molecular Genetics*, Garland Science, 5th edition, 20-Dec-2018. 3. Greg Gibson and Spencer V. Muse, *A Primer of Genome Science*, Sinauer Associates, Third Edition, February 15, 2010.

BIO 313 Physiology [3003]	
Prerequisite	NA
Learning Outcomes	The objective of the course is to familiarize the students with the functional basis of animal life. Main focus of the course is on mammalian system but examples from lower order animals are used to, 1) appreciate the conservation of some of the fundamental functions of life and 2) to understand the physiological relevance of evolution. Wherever required, the students are exposed to the structural, chemical and physical basis of life. As a whole, emphasis is given to understand the integration between what seems to be very isolated components of mammalian physiology. The course is also extended to pathological basis of some of the most-common/rare pathologies.
Syllabus	1. Nervous system and Sensory processing: The course further treats the systematic and topographic organisation of the nervous system and the structure and function of the neuron. Central and peripheral nervous system; sympathetic and parasympathetic nervous system; molecular basis of sensory systems: vision, hearing, taste, smell and touch. [7] 2. Endocrine system and Reproduction: endocrine glands and functions, hormonal function and regulation of different physiological systems by endocrine system, basics of molecular regulation of function by hormones, neuroendocrine systems; reproductive physiology. Principles behind circadian rhythm, their physiological relevance and the underlying neural and molecular basis. [7] 3. Feeding and Digestive system: nutrition, feeding and digestion; structural basis of digestive system function. Emphasis will be given to anatomical and histological details of the tissues involved. Digestion of macromolecules, absorption and assimilation, energy metabolism. [5] 4. Muscular system and movement: control of movement; neuromuscular junction and regulation of muscle contraction. Muscle types and functions, biochemical basis of muscle contraction, exercise, training and fatigue. [7] 5. Respiratory system: Overall anatomy of the respiratory system and structural basis of gaseous exchange, the physiology of breathing; transport of oxygen and carbon dioxide, oxygen and evolution of animals. [4] 6. Circulatory system: circulatory systems in vertebrates. Structure of heart and relevance in the homeostatic processes. Regulation of heart function and blood pressure. Vascular system and regulation of blood flow. [6] 7. Excretory system: managing water, salt and body fluids in animals. Structure of kidney, regulation of kidney function. [4]
Text and Reference Books	1. Animal Physiology by Richard W Hill, Gordon A Wyse and Margaret Anderson: Sinauer Associates. 4th Edition. 2. Eckert's Animal Physiology: Mechanisms and Adaptations. David Randall, Warren Burggen and Kathleen French: 5th edition.

BIO 314 Biochemistry [3003]	
Prerequisite	NA
Learning Outcomes	Life matter (unicellular or multicellular) is built using simple precursor molecules present in the biosphere. This course aims to understand the chemistry of life, how all biomolecules that comprise life matter is synthesized starting from simpler molecules by anabolic pathways, how these biomolecules are interconverted to each other by crossover metabolic pathways and ultimately the complex biomolecules are degraded back to simpler molecules by various catabolic pathways, generating bioenergy for the life to tick. At the completion of the course, the students can appreciate that "Life is a redox reaction".
Syllabus	1. **Design principles of metabolism:** Fundamental chemical reaction mechanisms, importance of resonance stabilization, addition-elimination (to both phosphates and carbonyls), reactivity of bond beta to carbonyl emphasizing the repetitive nature of these chemical logic by studying reactions involved glycolysis and krebs cycle pathways [2] 2. Principles of energy release from biological macromolecules: biological oxidation and hydrogen transfer systems: Role of ATP,CoA,NAD(P), NAD(P)H,F AD and FMN in fuel metabolism [1] 3. **Principles of bioenergetics:** Equilibrium constants, free energy changes, coupled reactions: Concepts and misconcepts. Role of ATP in bioenergetics, ATP as energy transducing agent and nature's dehydrating agent in metabolism.[2] 4. **Carbohydrate metabolism:** Glycolysis, energy release from glucose, principles of aerobic, anaerobic respiration and fermentation, Shuttle systems for transport of electrons between cell compartments: Importance of Malate Asparate shuttle and Glycerol -3 phosphate shuttle. Gluconeogenesis, glycogen synthesis and breakdown, enzymatic mechanisms, reciprocal regulations and hormonal regulations. [4] 5. Alternative oxidation of glucose by Pentose Phosphate pathway (PPP). Oxidative and non-oxidative branches of PPP. Importance of PPP in the interconversion of monosaccharides, nucleotide biosynthesis and biosynthesis of aminoacids. Game of pentose phosphate pathway to appreciate the evolution of PPP. Importance of glutathione and NADPH. Inborn errors of metabolism in PPP- Favism. [3] 6. **Krebs /TCA /CAC cycle:** (PDH complex, cofactors, TPP), amphibolic nature of citric acid cycle (CAC), mechanisms of CAC reactions, regulation of CAC, anapleurotic reactions, differential role of CAC in different tissues.[3] 7. Strategies in citrate cycle: Segmental coupling, unidirectional driving and stoichiometric incorporation of reducing equivalent. Evolution of CAC. Importance of glyoxylate bypass in the conversion of fats to carbohydrates. [3] 8. **Oxidative phosphorylation**: principles of electron transport chain, hierarchy of electron carriers, redox potentials of electron carriers, chemiosmotic theory of oxidative phosphorylation, generation of ATP coupled to electron transport, Q cycle. Structure of ATP synthase – F0 and F1 complex, mechanism of proton flow in Fo subunit. Chemical inhibitors of electron transport chain.[4] 9. **Fatty acid metabolism:** fatty acid oxidation, Importance of carnitine shuttle, alpha, beta and omega oxidation of fatty acids, working out the energetics of fatty acid oxidation with carbohydrate oxidation. Fatty acid synthesis: mechanism of fatty acid biosynthesis by FAS complex enzyme. HMG COA pathway, biosynthesis of cholesterol. Formation of ketone bodies and its importance in metabolism.[5] 10. **Amino acid metabolism:** Nitrate and ammonium assimilation; amino acid biosynthesis, degradation, urea cycle and its relationship with gluconeogenesis, shikimate pathway for the biosynthesis of aromatic amino acids, heme synthesis. [3] 11. **Nucleic acid metabolism:** purine and pyrimidine biosynthesis and catabolism of purines and pyrimidines. [3] 12. **One carbon metabolism:** Importance of folate, SAM and Metcobalamine in folic acid pool of one carbon metabolism [1] 13. **Secondary metabolism:** Isoprenoid metabolism, biosynthesis of IPP and DMAP by Mevalonate and non-mevalonate pathway for biosynthesis of terpenoid precursors, shikimic acid pathway for production of phenolics, alkaloids [2] 14. Interconvertibility of fuels: Relationship between glucose, fat and amino acid oxidation for energy generation. [1]

	15. Molecular chaperones in protein folding, experimental strategies to study protein mis-folding and disease, regulation of metabolism through metabolic networks, metabolic messengers, generation of NO and oxygen radicals.[2]
Text and Reference Books	1. Rodney F Boyer, Concepts in Biochemistry. John Wiley & Sons; 3rd Edition edition (2 December 2005) 2. Thomas Millar, Biochemistry Explained: A Practical Guide to Learning Biochemistry. CRC Press; 1 edition (30 May 2002) 3. Lubert Stryer et al., Biochemistry. W. H. Freeman; 6th Edition edition (14 July 2006) 4. John E. McMurry and Tadgh Begley. The Organic Chemistry of Biological Pathways. WH Freeman; 2nd edition (11 December 2015) 5. Laurence A Moran, Principles of Biochemistry. Pearson; 5 edition (30 July 2013) 6. David L. Nelson and Michael M. Cox, Lehninger Principles of Biochemistry WH Freeman; 7th ed. 2017 edition (1 January 2017)

BIO 316 Bioinformatics [3013]	
Prerequisite	NA
Learning Outcomes	This is a must-have course for a student of biology, who would benefit from learning the computational tools and methods in biological data analysis to take advantage of massively developing biological data. Topics will cover basics of bioinformatics to advanced algorithms in next-generation sequence analysis.
Syllabus	1. Biological data & sources - origin and types of biological data, public databases, storing biological data and data security. [1] 2. Data mining - concept of data mining, methods of data mining: text-based, mining tasks, applications. [2] 3. DNA sequence analysis - dot plot, basic concepts of sequence similarity, identity and homology, homologs, orthologs, paralogs, concepts behind scoring matrices, dynamic programming pairwise alignment - Smith-Waterman and Needleman-Wunsch algorithm, FASTA. [5] 4. BLAST & Remote homology search - the BLAST algorithm, parsing BLAST results, advanced BLAST algorithms. [3] 5. Multiple Sequence Alignment - methods of MSA: progressive alignments, consistency-based and structure-based alignment, programs for MSA. [3] 6. Motif finding algorithms - sequence motif concepts, algorithms to detect DNA sequence motifs, Gibbs sampler, MEME. [2] 7. Protein bioinformatics - Protein secondary structure calculation – DSSP, membrane topology prediction, ligand-receptor interactions, composition of active sites in functional proteins, conformational change and activity, allostery, effects of point mutations on proteins structure and function. [5] 8. RNA structure analysis - RNA structure, RNA sequence databases, RNA structure prediction: Nussinov algorithm, EM algorithm. [3] 9. Next generation sequencing and principles of NGS data analysis - introductory concepts, types of NGS data, various platforms of NGS, alignment algorithm - BWA, RNA-Seq, ChIP-Seq, single-cell genomics. [4] 10. R for bioinformatics - introduction, basic elements of R, plotting high-dimensional data, statistical analysis, programming. [3]
Text & Reference Books	1. Bioinformatics, David Mount, CSHL, 2003 2. Bioinformatics & Functional Genomics, Jonathan Pevsner, Wiley 2015 3. M. Michael Gromiha, Protein Bioinformatics: From Sequence to Function, Elsevier, 2010

BIO 321 Structural Biology [3003]	
Prerequisite	NA
Learning Outcomes	To introduce Biology major students the importance of Structural Biology in everyday research and to impart in them the knowledge to understand the principles of protein structures and protein structure determination using protein crystallography, single particle cryoEM etc., and their applications in structure-based drug design. The course also aims to introduce the students to other biophysical methods like CD, ITC, SPR, DLS, MALS etc. used to characterize biomolecules and their interaction with ligands.
Syllabus	1. Principles of proteins and nucleic acid structures, conformation and analysis. Structural Bioinformatics. Molecular phylogenetic analysis.**[9]** 2. Tools for analysing protein structures to understand the molecular basis of their functions.Structure Based Drug Design.**[6]** 3. X-ray crystallography, electron microscopy and NMR in structural biology. Graphics and structural validation. Structural databases. Other biophysical and spectroscopic techniques to understand conformations of biomolecules.**[19-20]**
Text and Reference Books	1. Schulz GE and Schirmer RH, Principles of protein structure, Springer-Verlag, 1979. 2. Branden C and Tooze J, Introduction to protein structure, Garland Science, 2nd Edition. 1999. 3. Stout GH and Jensen LH, X-ray structure determination, John;Wiley and Sons Inc., New York, 1989. 4. Jan Drenth, Principles of protein crystallography, Springer Science & Business Media, 2007. 5. Liljas A, Liljas L, Piskur J, st Lindblom G, Nissen P and Kjeldgaard M. (2009). Textbook of Structural Biology, 1st edition, World Scientific Publishing, 2009. 6. Joachim Frank, Three-Dimensional Electron Microscopy of Macromolecular Assemblies, Academic Press, 1996. 7. A. K. Downing, Protein NMR techniques, Methods in Molecular Biology, Volume 278, 2004.

BIO 322 Immunology [3003]	
Prerequisite	NA
Learning Outcomes	To introduce students the basic and advanced concepts in Immunology, and emphasize the importance of immunology in health and disease. The course will provide in-depth knowledge on functioning of immune systems, with specific emphasis to humans. Further, the clinical and therapeutic aspects of immunology will be covered.
Syllabus	1. Introduction, Organization of the immune system (lymphoid tissues and organs). [3] 2. Immune cell development (hematopoiesis, T and B cell development). [6] 3. Innate and adaptive immunity (including cellular and humoral responses). [4] 4. Antigens and Antibodies (antibody classes, Ag/Ab structure and function). [4] 5. Immune signaling (T cell receptor, TLRs, inflammatory and cytokine re-sponses)ancer. [5] 6. The MHC and Ag presentation and T cell development. [6] 7. Immunity mechanisms in disease (allergies, autoimmunity, immuno-deficiency). [6] 8. Immunotherapy (clinical use of monoclonal antibodies).[2] 9. Tumor Immunology [2]
Text and Reference Books	1. Judith A. Owen, Jenni Punt, Sharon A. Stranford, Patricia P. Jones., Kuby Immunology, W.H. Freeman and Company, 2013. 2. Kenneth Murphy , Paul Travers , Mark Walport, Janeway's Immunobiology, Garland Science, Taylor & Francis Group, 2008.

BIO 323 Cell Biology [3003]	
Prerequisite	NA
Learning Outcomes	The course will provide in-depth understanding of the fundamental cellular processes that regulate and coordinate growth, division and death of eukaryotic cells and their underlying molecular pathways. Functional links of the processes with human diseases will be touched upon. The course also will introduce advanced methodologies including various microscopy tools employed in modern cell biology research.
Syllabus	1. Methods used in cell biology: microscopy, cell sorting, fractionation of cellular components, radioisotopes and antibodies as tools to study cellular functions. All light microscopy platforms (while light and fluorescence) covering basic principles and applications. Fluorescence activated cell sorting and radio-isotope/antibody based cellular biochemistry will include isotope based cellular and molecular fractionation and different immunoblot platforms. [4-5] 2. Cell membrane: organization and composition of the cell membrane, structural property of the membrane micro-domains. Details of compositions of the membranes of intracellular organelles and plasma membrane and their properties; and the structural properties of the micro-domains (lipid rafts etc.) of membranes. Understanding of the functional link of the compositional diversity of the cell membrane (plasma membrane and intracellular membrane) to cellular processes pertaining to the organelles and plasma membranes. [2-3] 3. Membrane transport- endocytosis and exocytosis Vesicular transport system and intracellular trafficking, protein targeting. In depth understanding of the molecular pathways pertaining to intra-cellular trafficking/transport and their mechanistic insights in model organisms from unicellular yeast to animal cells, cellular methods/tools/approaches to study these processes. [4-5] 4. Organelle biogenesis: Understanding the biogenesis of subcellular structures such as mitochondria, centrosome, kinetochore in cells across eukaryotic kingdom, similarity/diversities in their composition, structural organization and functions. [2-3] 5. Components of the cytoskeleton and their regulations: organization and function of actin, intermediate filaments, microtubules and motor proteins, integrins, cadherins. Compositions and cellular/molecular properties of different types of cytoskeletal elements, studies on the involvement of actin and microtubule cytoskeleton in intra-cellular trafficking, chromosome organization and cell motility. Functions of actin and microtubule-based motor proteins in regulating these processes, and the activation/inactivation of signaling molecules associated with the processes. [4-5] 6. Cell-cell signaling: overview of extracellular signaling, cell surface receptors, cell signaling during growth and differentiation. overview of different cell surface receptor-based signaling with emphasis on receptor tyrosine kinase-mediated RAS signaling and its link to cell growth and division. [4-5] 7. Cell cycle and its control: mechanisms of growth and division of eukaryotic cells, cell cycle checkpoints. Understanding the molecular processes/components that control cells' progression to growth/DNA replication/genome segregation phases in eukaryotic cells, mechanisms underlying activation/inactivation cell cycle check-points and their roles in controlling growth and division of cells. [6-7] 8. Cell death: Apoptosis and autophagy pathways Canonical and non-canonical apoptosis pathways, molecular pathways and cellular processes linked to autophagy. [2-3]
Text and Reference Books	1. Cell Biology, Gerald Karp, (c2010). 2. Cell Cycle, Tim Hunt, Andrew Murray, (c1993). 3. Molecular Biology of the Cell, Bruce Alberts and co-authors, 6th Edition, 2015.

BIO 324 Molecular Biology [3003]	
Prerequisite	NA
Learning Outcomes	This course is designed to introduce the concepts of gene expression and regulation starting from basic concepts of transcription, translation, replication and DNA repair. Basics of post-transcriptional, post-translational regulation and epigenetics are also discussed. The course also covers basic molecular biology techniques.
Syllabus	1. Nucleic acid: building blocks, nucleotide analogs as drugs [1] 2. DNA STRUCTURE- base pairing and stabilizing forces, different forms of DNA. minor and major groves, supercoiling, organization into chromosomes, nucleosomes, heterochromatin, euchromatin, genes and organization, unique genes, operons, gene families, repetitive DNA, genome organization, transposons. [2] 3. Replication: basic processes in bacteria and eukaryotes, telomeres and telomerase [3] 4. DNA damage and repair: ionic radiation induced damage, chemical mutagens, different repair mechanisms, recombination, mechanisms of bacterial DNA repair, SOS response, measuring mutations, mutator strains. [3] 5. Basic steps in gene expression and regulation, transcriptional and post-transcriptional regulation of gene expression [3] 6. Bacterial translation: introduction to codon, tRNA mediated decoding, aminoacylation of tRNA and classes of aminoacyl-tRNA synthetase, basic subunits of ribosome, steps and factors involve in bacterial translation. [3] 7. Eukaryotic translation: Basic steps of translation and factors involved in translation. GTPases in translation [3] 8. Molecular aspects of RNA processing, transcription- Basic steps in transcription, splicing, transport across the nuclear membrane, recognition by translational apparatus, IRES [5] 9. Epigenetics: DNA methylation in prokaryotes and eukaryotes, epigenetic gene regulation by DNA methylation in plants and mammals. Methods to detect epigenetic modifications [3] 10. Protein-nucleic acid interactions - nucleic acid recognition by proteins binding motifs - techniques to study protein-nucleic acid interactions. [3] 11. Non-coding RNA: Biogenesis and its function. Function and use of Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR). [3] 12. Recombinant DNA technology and molecular cloning, purification of recombinant protein. [4]
Text and Reference Books	1. Molecular Biology of the cell by Bruce Alberts et al. 6th edition 2. DNA Repair and Mutagenesis (2nd Edition) Friedberg and others. 3. Mehta, A. and Haber J. E. (2014) sources of DNA double strand breaks and Models of Recombination DNA repair Cold Spring Harb Perspect Biol 6: a016428. 4. Anand, R.P, Lovett, S.T. and Haber J.E. (2013) Break Induced DNA Replication. Cold Spring Harb Perspect Biol 5: a010397.

BIO 326 Biostatistics [3003]	
Prerequisite	NA
Learning Outcomes	This is an essential and important course for a student of biology, as statistics is critical to conclude any biological results. The course will cover basic of statistics, standard and advanced statistical tests that are routinely used in interpreting biological data and in health sciences. Students will also be trained to use R statistical package.
Syllabus	1. Introduction to statistics for biologists: importance of statistics, hypothesis testing, overview of statistical tests, variables. [2] 2. Summarizing and visualizing data: types of data, summarizing data, displaying data, descriptive statistics, tools for graphical display. [2] 3. Probability & distributions: basic probability, laws of probability, types of distributions, statistics of distributions, probability distributions. [3] 4. Methods of sampling: populations and samples, sampling & non-sampling errors, various methods of sampling, experimental design. [2] 5. Hypothesis testing: need for statistical testing, acceptable errors, P-values. [2]

	6. Parametric & non-parametric tests: concept of parametric & non-parametric statistics, tests for differences. [7] 7. ANOVA: one-way ANOVA, Two-way ANOVA, Three-way ANOVA, Multiway ANOVA, Nested ANOVA, ANCOVA. [4] 8. Correlation & regression: scatter plot, correlation coefficient, partial correlation coefficient, linear regression, non-linearity, non-linearity. [4] 9. Survival analysis: censoring, survival times, summarizing and presentation. [2] 10. R for biostatistics: introduction, performing common statistical tests in R, visualizing data in R, exporting data and analysis. [6]
Text and References	1. Michael C. Whitlock and Dolph Schluter, The Analysis of Biological Data, Roberts And Company Publishers, 2015. 2. Steve McKillup, Statistics Explained: An Introductory Guide for Life Scientists, Cambridge University Press, 2006. 3. Calvin Dytham, Choosing and Using Statistics: A Biologist's Guide, Wiley-Blackwell, c2011.

BIO 411 Developmental Biology [3003]	
Prerequisite	NA
Learning Outcomes	In this course students will be introduced to the main principles of development. There will be a strong emphasis on classic developmental model organisms to illustrate fundamental processes in development. Early events in development, developmental processes behind generation of body plan and formation of tissues and organs will be the main focus of the course. Regulation of gene expression, cell signaling pathways and cytoskeletal rearrangements in development will be discussed. Also, sexual maturation, regeneration in adult organisms and developmental diseases will be covered. Finally, evolution of development will be covered to help the students to understand the significance of evolutionary pressures that has converged on development.
Syllabus	1. Basic Concepts and history of developmental biology. [1] 2. Introduction to Developmental model organisms: Seaurchin, Drosophila, Xenopus, Chick .[3] 3. Early embryonic development: Cleavage, gastrulation and development of germinal layers, Maternal inheritance, Maternal to zygotic transition of gene expression, Early control of cell cycle, Cell-cell communication during early development. [3] 4. Morphogenesis and development of body plan: Formation of body axes (A/P and D/V axis), Maternal effect genes, gap genes, pair-rule genes, segment polarity genes and Hox genes, Morphogen gradients and morphogen signaling. [3] 5. Cellular differentiation and Organogenesis: Development of nervous system in vertebrates, Mechanisms of neural tube development, Neural crest development, migration and fates. Limb development in vertebrates: organizers of the limb (AER and ZPA), FGF and proximal – distal axis, Sonic hedgehog signaling and digit specification. [4] 6. Cytoskeleton and Mechanical forces in development: Cytoskeletal regulation of growth and cell fate changes Cell proliferation and morphogenesis under mechanical control of cytoskeleton Cell adhesion and cell migration in organogenesis. [4] 7. Growth and post-embryonic development: Hormonal control of metamorphosis in Drosophila and amphibians, Germ cells and gonad development. Dosage compensation and sex determination, Regeneration and tissue repair, Ageing, Developmental basis of behavior: courtship behavior, neural circuitry of behavior. [3] 8. Evolution and development. [2] 9. Defects in development and diseases: Neural tube defects, limb formation defects, growth defects. [1]
Text and Reference Books	1. Scott F Gilbert, Developmental Biology, Sinauer, 10th Ed, 2014 2. Lewis Wolpert and Cheryll Tickle, Principles of Development, OUP, 4th Ed, 2011 3. Other references would be provided during the lectures

i^2 Biological Sciences - Laboratory Courses

BIO 315 Advanced Biology Lab I [0093]	
Prerequisite	NA
Learning Outcomes	To provide a hands-on training of advanced Biological experimental methods.
Syllabus	1. Microbiology: Microbial growth kinetics, bacterial motility assay; antibiotics susceptibility testing, Construction of bacterial gene deletions by homologous recombination, [24] 2. Genetics: Tetrad analysis in yeast, analysis of genomic data. [24] 3. Biochemistry: Identification of proteins by Western blotting, purification of proteins by chromatography techniques, analysis of protein-protein interaction by biochemical techniques, Determination of binding parameters of protein-ligand interaction. [48]

BIO 325 Advanced Biology Lab II [0093]	
Prerequisite	NA
Learning Outcomes	To provide a hands-on training of advanced Biological experimental methods.
Syllabus	1. Structural Biology: Basic UNIX commands, shell scripts and C programming; PDB and graphics visualization using Pymol/Chimera, Sequence analysis at Expasy and PDB, Protein Crystallization, Visualizing reciprocal lattice and diffraction using X-Ray View, X-ray diffraction and data collection, Molecular Replacement, Refinement, model building and refinement, Validation of the protein structures, Analyzing protein structures. [32] 2. Immunology & Cell Biology: Purification and analysis of Immunoglobulins, – Immunoprecipitation, – Enzyme-linked immunosorbent assay (ELISA), Fluorescence-activated cell sorting (FACS) and analysis of cells, Immunostaining and imaging, Mammalian Cell Counting, Phagocytosis Cell Biology, Separation of cellular organelles by density gradient, Immunofluorescence imaging of cellular organelles, Analyses of cell cycle. [32] 3. Molecular Biology: Molecular cloning, Site-directed Mutagenesis, qRT-PCR, In vitro transcription and translation [32]

i² Biological Sciences - Thematic Courses

I2B 411 Systems Biology - Theory [3003]	
Prerequisite	MAT 111, 211
Objectives	Fast evolving multidisciplinary field that combines the power of mathematical & statistical models to decipher the functioning of biological systems. This is a multidisciplinary course, designed for applicants with a biological, biomedical, physical, computational or mathematical background. It equips students with the necessary skills to produce effective research in systems biology. After completing this course, students will have acquired an understanding of research topics is several areas of theoretical systems biology, which has wide-range of application in big-data analysis.
Syllabus	1. Introduction to Systems Biology: introduction to biological physics, basic principles of biological systems, overview of experimental techniques. 2. Mathematics of Biological System: differential equations, deterministic ODE and PDE models, graph & network theory, linear, Boolean and Bayesian networks. 3. Networks structure & dynamics - mathematical graphs, random graphs, scale-free networks, clustering, network motifs, dynamic models, modularity. 4. Data formats & Simulations - types of biological data and their formats, Systems Biology Markup Language (SBML), SBML models, BioPAX, models and parameters for simulation of biological processes, stochastic simulation, Monte Carlo simulation. 5. Discrete, stochastic & spatial models - modelling of biological systems, classification of models, modelling process, formulation, and validation. 6. Variability, Robustness & Information - genetic & non-genetic variability, quantification of noise in biological systems, robustness mechanisms and scaling laws, adaptation and exploration strategies.
References	1. Systems Biology, Edda Klipp, Christoph Wierling, Wolfram Liebermeister, Axel Kowald, Ralf Herwig, Hans Lehrach, 2nd Edition, Wiley 2009 2. Mathematical Modeling in Systems Biology, Brian Ingalls, MIT Press 2013

I2B 412 Microbiome & Vaccinology [2002]	
Prerequisite	NA
Learning Outcomes	It is fascinating that human body harbors more microbial cells than the actual human cells. Microbiome of human is vast and diverse, and is strongly linked to human health and several diseases. The course aims to combine the microbiome of human, with emphasis on Indian population. Additionally, the course will provide on a very important overview on vaccinology, the theory and clinical applications of vaccines.
Layout	1. Introduction to microbiome - overview, animal microbiome, microbiome & immune system. [1] 2. Human microbiome analysis - microbiota, gut microbiota, host diet, probiotics, ecosystem, evolutionary perspective, phylogeny & function. [4] 3. Methods to study microbiomes - culture-based methods, molecular methods: non-sequencing & sequencing-based, metabolic methods, metagenomics, metatranscriptomics, human microbiome project. [2] 4. Clinical relevance of microbiomes - microbiota in health and diseases, case studies. [2] 5. Introduction to Vaccinology - overview, historical perspective, disease prevention, therapeutic vaccines. [2] 6. Immunology of vaccines - chemical nature of antigens, antigen-presenting cells, cytokines, pathogen recognition, immune memory, mucosal immunity, pediatric & elderly immunology. [4] 7. Vaccine development - vaccine design: development pathway, antigens & epitopes, adjuvants, micro- and nanotechnology, recombinant vaccines, delivery technologies, formulation & manufacturing. [3] 8. Clinical trials - regulatory pathways, clinical evaluation, vaccine safety, vaccine recommendations. [2]

	9. Health economics - overview, demand for health care services, health insurance, pharmaceutical manufacturers, public & private funding, cost-benefit analysis. [2] 10. Bio-manufacturing - overview, biopharmaceuticals, biotechnology-based therapeutics, production process, applications. [2]
Text & Reference Books	1. Haller, Dirk, The Gut Microbiome in Health and Disease, Springer, 2018 2. The Human Microbiome, Diet, and Health: Workshop Summary, National Academies Press 2013 3. Angela E. Douglas, Fundamentals of Microbiome Science: How Microbes Shape Animal Biology, Princeton University Press, 2018 4. Gregg N. Milligan, Alan D. T. Barrett, Vaccinology: An Essential Guide, Wiley-Blackwell, 2016 5. Giese, Matthias, Introduction to Molecular Vaccinology, Springer, 2016

I2B 413 Synthetic Biology [3003]	
Prerequisite	I2B 323, I2B 324
Learning Outcomes	This is yet another fast-evolving multidisciplinary field that combines the principles of biological systems with the power of engineering tools to develop practicable solutions for wide-range of applications, particularly in health sciences.
Layout	1. Introduction to Synthetic biology – origin and concepts, quick overview of molecular biology, applications. [2] 2. Kinetics and dynamics of biological systems – biochemical networks, gene regulatory networks, signal transduction pathways. [6] 3. Biomechanics – introduction, cellular biomechanics, circulatory system, respiratory systems, ocular biomechanics, muscle & movement, skeletal biomechanics, locomotion. [7] 4. Genetic circuits & Feedback systems – development of synthetic modules, design & methods, expansion of genetic code. [3] 5. Bioengineering designs – prokaryotic & eukaryotic platforms – genes, genomes and proteins, engineering therapeutic pathways. [3] 6. Biosensors – enzyme-based electrochemical biosensors, optical technologies, transducer technologies, living biosensors. [7] 7. Tissue engineering – introduction, stem cells, extra-cellular matrix, mechanical surfaces, surface immobilization, biomaterials, examples of tissue engineering: skin, nerve, cardiac tissue regeneration. 8. Bionanotechnology – nanomaterials, biomolecules-nanoparticles interactions, applications in diagnostics & medicine [3] 9. Biomedical engineering – introduction, biomedical sensors, bio-signal processing, diagnostic devices, wearable sensors. [4]
Text & Reference Books	1. Daniel G. Gibson, J. Craig Venter; Clyde A. Hutchison III, J. Craig Venter Joseph D. Bronzino, Donald R. Peterson, The Biomedical Engineering Handbook, CRC Press, 2015 2. Biological and pharmaceutical nanomaterials; Nanotechnologies for the Life Sciences, Vol 2, Challa Kumar, Wiley-VCH, 2006. 3. Ajit Sadana, Engineering biosensors, kinetics and design applications , San Diego,Academic Press, 2002 4. Fredrick H. Silver: Biomaterials, Medical Devices & Tissue Engineering: An integrated approach. 5. C. Ross Ethier and Craig A. Simmons: Introductory Biomechanics: From Cells to Organisms. 2nd Edn., Cambridge University Press. 2009

I2B 414 Biological Spectroscopy & Microscopy [3003]	
Prerequisite	NA
Learning Outcomes	Essence of biology is in understanding how macromolecular machines function in a cell. Hence, sophisticated tools are required to investigate the structure and function. Spectroscopy and Microscopy are indispensable tools for research towards gaining insights into human health and disease. The course will cover theoretical basis of spectroscopy and microscopy for analyzing biological samples, various applications in biological research and clinic.
Layout	1. Fundamentals of spectroscopy & microscopy - introduction, quantum mechanics, properties of particles and waves. [2]

	2. Circular dichroism and optical rotary dispersion - concepts, analysis of nucleic acids and proteins, small molecule binding to DNA, protein folding, fluorescence polarization. [2] 3. Macromolecular vibration spectroscopy - fundamentals, infrared & near-infrared, Raman and Resonance Raman spectroscopy of biomolecules, structure determination, examples: enzyme-substrate complexes. [3] 4. Magnetic resonance - NMR, chemical shifts, spin-spin splitting, relaxation times, multidimensional NMR, MRI, electron spin resonance, applications in biology. [3] 5. X-ray crystallography - X-ray scattering, structure determination, neutron diffraction, nucleic acid & protein structure, enzyme catalysis, software tools. [2] 6. Light microscopy - light & color, lenses & geometrical optics, diffraction & interference, spatial resolution. [2] 7. Fluorescence spectroscopy & Microscopy - physical basis fluorescence, properties of fluorescent dyes, autofluorescence, fluorescent proteins, quenching, blinking & photobleaching. [2] 8. Mass spectrometry - introduction, mass analysis, problems in mass spectrometry, tandem mass spectrometry, ion detectors, ionization of samples, sample preparation & analysis, application in biology. [3] 9. Advanced microscopic methods for biology - overview, confocal microscopy, multiphoton microscopy, super-resolution imaging methods applied in biology. [3] 10. Optical traps - introduction to optical tweezers, applications in biology. [1] 11. Electron & cryo-electron microscopy - overview, TEM, SEM, image analysis, cryo-EM overview and development, Fourier transformations, sample preparation, data collection, image processing, single particle cryo-EM, 2D-crystallography. [3]
Text & Reference Books	1. Gordon G. Hammes, Spectroscopy for the Biological Sciences, Wiley 2005 2. James M. Thompson, Mass Spectrometry, CRC Press 2017 3. Douglas B Murphy, Fundamentals of Light Microscopy and Electronic Imaging, Wiley, 2001 4. Michael J. Dykstra, Biological Electron Microscopy: Theory, Techniques, And Troubleshooting, Springer 2003 5. David L. Spector, Robert D. Goldman, Basic Methods in Microscopy Protocols and Concepts from Cells: A Laboratory Manual, CSHL 2006

I2B 415 Human Genetics, Gene Therapy & Personalized Medicine [3003]	
Prerequisite	BIO 312
Objectives	Genetics & genomics has revolutionized the field of medicine both in terms of diagnosis and treatment. The economical next-gen sequencing has made it possible to treat patients with more personalized treatment for various disorders including cancer through gene therapy. The course will cover brief introduction into genetics, human genome sequencing, various gene therapy approaches and personalized medicine.
Syllabus	1. Human genome & variations - overview, organization & features of human genome, gene expression, mutation rates, nature of variation, evolution & population genetics. [3] 2. Human genetic disorders - Mendelian inheritance, chromosomal abnormalities, single-gene disorders, complex diseases, other genetic diseases, genetic testing. [3] 3. Genome-wide association studies - linkage analysis, common variants, haplotype map, linkage disequilibrium, genotyping technologies, study design, multi-locus analysis, meta-analysis, cancer genome. [6] 4. Gene therapy - concept & development, methods of gene therapy, genetic pharmacology. [6] 5. Types of gene therapy - somatic & germline gene therapy, in vivo gene therapy, DNA vaccines; [4] 6. Clinical applications of gene therapy - general considerations, clinical trials, therapeutic case studies, cancer gene therapy. [4] 7. Personalized medicine - concept of individualized therapy, genomic medicine, molecular diagnostics basis of personalized medicine, role of biomarkers, clinical genomics - childhood & adulthood treatments. [7] 8. Genome editing - targeted genome editing methodologies, genome editing in disease biology, case studies, bioethics. [4] 9. Statistics for GWAS - summary statistics, multiple testing, graphical models, Bayesian methods. [6]

	10. Big data genomics - 1000 genomes project, cancer genome atlas, human microbiome project. [3]
References	1. Jeanette McCarthy & Bryce Mendelsohn, Precision Medicine: A Guide to Genomics Clinical Practice, McGraw-Hil, 2016 2. Krishnarao Appasani, Genome Editing and Engineering: From TALENs, ZFNs and CRISPRs to Molecular Surgery, Cambridge University Press, 2018 3. Ricki Lewis, Human Genetics: Concepts and Applications, McGraw-Hill Co., c2012. 4. Tom Strachan and Andrew Read, Human Molecular Genetics, Garland Science, c2011 5. Mauro Giacca, Gene Therapy, Springer, 2010 Roland W Herzog and Sergei Zolotukhin, A Guide to Human Gene Therapy, World Scientific Publishing Company, 2010

BIO XXX Stem Cells and Regenerative Medicine [3003]	
Prerequisite	NA
Learning Outcomes	The objective of the course is to expose the students to the principles of stem cells and tissue regeneration and introduce them to the potential of the field to revolutionize modern medicine. Starting with the founding principles and history of stem cells, the course will take the steps to introduce the students to their functional regulation and links with regeneration. The course will explore application part of various stem cell types.
Syllabus	1. Introduction to Stem cells: Basics of stem cells and principles of stemness, Early mammalian development, Evolution of stem cells. [1.5] 2. Biology of stem cells: Cell cycle regulation in stem cells, Mechanisms of differentiation, Signal transduction (More elaborative for mechanisms involved in development), Metabolism of stem cells. [3] 3. Pluripotent stem cells: Types of pluripotent stem cells; Isolation, characterization of embryonic stem cells; Generation of iPS cells and disease modeling; Biology of ES and iPS cells; Genome editing technologies; Alternative medicine. [6] 4. Adult stem cells: Properties, identification and separation of various stem cells, Biological principles of HSCs; hematopoietic development, regulation of proliferation and differentiation, Sources of HSCs and their clinical use. [6] 5. Cancer stem cells: Concepts, identification, biology and potential applications of cancer stem cells. [3] 6. Stem Cell niches: Extrinsic factors in the regulation of stem cell function. Biological, physico-mechanical properties of stem cell micro-environment (for HSCs, epidermal, germ and intestinal stem cells). [3] 7. Transplantation biology: Immunology of transplantation and graft rejection, mechanisms of homing of transplanted stem cells. [3] 8. Tissue engineering: Ex vivo expansion of stem cells, Ex vivo construction of tissues, scaffolds, bioreactors. [4.5] 9. Stem cells in clinic: Avenues for stem cell use (metabolic, genetic diseases, cancers and trauma), Potential application of stem cells in clinic and present clinical use. Hurdles and future directions. [4.5] 10. Methods in stem cells: In vitro and in vivo methods to assay stem cells. [6]
Text and Reference Books	1. Essentials of Stem Cell Biology by Robert Lanza Anthony Atala (Eds.): Academic Press. 3rd Edition 2013. 2. *Stem Cells: An Insider's Guide* by Dr. Paul Knoepfler: World Scietific publishing Co. Pvt. Ltd. 1st Edition 2013. 3. The science of stem cells by JMW Slack: Wiley Blackwell publishers. 1st Edition 2017. 4. Stem Cells, Tissue Engineering and Regenerative Medicine by David Warburton (Ed.) World Scietific publishing Co. Pvt. Ltd. 1st Edition 2014. 5. Stem Cells Handbook by Stewart Sell (Ed.). Springer 1st edition 2013. 6. Stem Cells: A Short Course Rob Burgess. Wiley Blackwell publishers. 1st Edition 2016. 7. Principles of Tissue Engineering Robert Lanza Robert Langer Joseph Vacanti (Eds.). Academic Press 4th edition 2013. 8. The Biomedical Engineering Handbook by Joseph D. Bronzino, Donald R. Peterson. CRC Press Taylor & Francis. 1st edition. 2015.

I2B 421 Systems Biology - Applications [2002]	
Prerequisite	I2B 412 Systems Biology - Theory
Objectives	Application of theoretical knowledge & models to high-throughput data in Biology to predict the behavior of biological processes. This is both theoretical & practical course, designed for applicants with a biological, biomedical, physical, computational or mathematical background. It equips students apply the theoretical knowledge on actual research problem for empirical analyses and applications beyond bench.
Syllabus	1. Transcriptional Networks - elements of transcriptional networks, dynamics and response, models of gene expression (basic, stochastic, and thermodynamic models), gene expression noise, network component analysis, dissecting transcriptional control networks. [6] 2. Biochemical Networks - structural modeling & reconstruction, reaction kinetics & thermodynamics, constraint-based flux optimization, metabolic control analysis. [6] 3. Feedback, Bistability & Memory - feedforward loops, feedback loops, network motifs, protein-protein interaction networks. [4] 4. Biological Oscillator - oscillations in biological systems: biochemical, gene expression, signal transduction, non-linear dynamics. [2] 5. Optimality in Biology - optimal gene-circuit design, optimal metabolic adaption, fitness landscape, pareto optimality, modularity, evolution and self-organization. [2] 6. Systems Medicine - introduction, modeling of diseases pathology, tumor biology, infection & immunity, metabolic diseases, stem cells, aging. [2]
References	1. An Introduction to Systems Biology: Design Principles of Biological Circuits, Uri Alon, Chapman and Hall 2019 2. Systems Biology, Edda Klipp, Christoph Wierling, Wolfram Liebermeister, Axel Kowald, Ralf Herwig, Hans Lehrach, 2nd Edition, Wiley 2009

I2B 422 Bioimaging & Processing [2002]	
Prerequisite	I2B 415 Biological Spectroscopy & Microscopy
Learning Outcomes	Imaging is essential to understand the functioning of organelles, macromolecules, etc., in a cell in health and diseases states. Thus, biological imaging has enabled faster and precise diagnosis in medicine. This theory combined with practical course enables students to learn various techniques used in imaging biological samples and their application in clinic. Further, students also gain knowledge about digital image processing.
Syllabus	1. Foundations of bioimaging - overview of bioimaging technologies, need for bioimaging, cost & ease of bioimaging. [3] 2. Research-oriented imaging - applications of imaging in biological/clinical research, live cell imaging, data acquisition & processing. [6] 3. Biomedical imaging - overview, X-ray imaging, nuclear medicine, ultrasonic imaging, MRI. [6] 4. Biomarkers design for imaging - overview, developing biomarkers for disease diagnosis, genetics & proteomics-based markers, applications in cancer diagnosis. [3] 5. Functional imaging - brain imaging, fMRI, PET, data acquistion & analysis. [2] 6. Image processing algorithms and software - workflows & components of bioimaging, quantification of image data, segmentation in bioimaging, Matlab for bioimaging, image data storage and publishing. [6]
Text & Reference Books	1. Guy Cox, Optical Imaging Techniques in Cell Biology, 2nd edition, CRC Press, 2012 2. Rajagopal Vadivambal and Digvir S. Jayas , Bio-Imaging: Principles, Techniques, and Applications, CRC Press, 2018 3. Wheeler, Ann and Henriques, Ricardo, Standard and Super-Resolution Bioimaging Data Analysis A Primer, Wiley & Sons, 2017 4. Kota Miura, Bioimage Data Analysis, Wiley & Sons, 2016

I2C 423 Biomaterials [3003]	
Prerequisite	NA
Objectives	The course focuses on the study of biocompatible, biomimetic and nature-based materials as well as their diverse areas of application. The course provides an understanding of the characteristics of common biomaterials, its structure, properties and morphology. Students also learn the different interaction between biomaterials, proteins and cells.
Syllabus	1. Concepts in material science: bulk properties of materials, surface properties and surface characterisation of materials, interpretation of phase diagram [10] 2. Classes of materials used in medicine: Polymers, silicone biomaterials, hydrogels, smart polymers, metals (basic structure and types of alloys, stress-strain behaviour, hardness, impact energy, fractured toughness, fatigue) [8] 3. Ceramics and glasses: characterising crystalline and non-crystalline materials, mechanical properties and processing methods: brittle fracture, static fatigue, thermal shock and viscous deformation, composites, surface immobilised biomolecules [6] 4. Biological response to biomaterials: biocompatibility and heme compatible, mechanism of foreign body response to implanted biomaterials. biodegradation of biomaterials. surface modification to control biological response [8] 5. Biomaterial application: biomaterial for joint versus blood vessel, biomaterial for soft and hard tissue replacement, cardiovascular, drug delivery system, biosensors, synthetic bioresorbable polymer scaffolds [8]
References	1. Biomaterial Science by Buddy Ratner, Allan Hoffman, Frederick Schoen, Jack Lemons, Academic press, 2012 2. Biomaterials: The Intersection of Biology and Materials Science by J.S. Temenoff and A.G. Mikos, Pearson Prentice Hall, 2008. 3. Fundamentals of Biomaterials by Vasif Hasirci & Nesrin Hasirci, Springer, 2018

I2C 521 Pharmacology & Pharmacokinetics [3003]	
Prerequisite	NA
Objectives	The course explores drug actions on living systems, their metabolism, and their toxic effects. The course focuses on the main principles of pharmacology: pharmacokinetics; drug metabolism and its transport and drug therapy.
Syllabus	1. General pharmacology and pharmacodynamics. a general understanding of how drugs work and how their actions may be modified. [10] 2. Pharmacokinetics: variability in drug response, pharmaceutical aspects and drug development, how drugs are developed, formulated and the importance of additives in drugs. [6] 3. Pharmacology of drugs used in anesthesia, intensive care and pain medicine, inhalational anesthetic agents, intravenous anesthetic agents, local anesthetic drugs-pain, non-steroidal anti-inflammatory drugs, neuromuscular blocking agents. [8] 4. Anticholinesterase drugs, anticholinergic drug, pharmacology of the autonomic nervous system, adrenoceptor blocking agents, anti-hypertensive drugs, anti-arrhythmic drugs, therapy of cardiac arrest, ischemia and failure, neuropharmacology, anti-emetic drugs, respiratory pharmacology and therapeutic gases, histamine and serotonin, diuretics, drugs and coagulation, obstetric pharmacology, endocrine pharmacology, gastrointestinal pharmacology, intravenous fluids, pharmacological basis of poisoning, chemotherapeutic drugs. [16]
References	1. A Pharmacology Primer: Theory, Application and Methods. Terry P. Kenakin, 3rd Edition, Academic Press, 2009. 2. Golan, D., et. al., eds. Principles of Pharmacology: The Pathophysiologic Basis of Drug Therapy. 3. Hardman, J. G., et. al., eds. Goodman and Gilman's The Pharmacological Basis of Therapeutics. 4. Molecular Biology in Medicinal Chemistry 1st Edn, Theodor Dingermann, Dieter Steinhilber, Gerd Folkers, Wiley-VCH, 2004. 5. Pharmacokinetics Made Easy, Donald Birkett, McGraw-Hill, 2002. 6. Drug-like Properties: Concepts, Structure Design and Methods: from ADME to Toxicity Optimization, Li Di, Edward H Kerns, 1st Edition, Academic Press, 2008.

I2B 521 Systems Biology & Imaging Lab [0062]	
Prerequisite	I2B 423 Systems Biology Applications, I2B 424 Bioimaging & Processing
Learning Outcomes	The practical course will introduce students to systems biology problems and analyzing large-scale ‘omics datasets. In addition, hands-on-training will be provided on advanced microscopy and spectroscopy, data collection and analysis.
Layout	1. Stochastic simulations. [4] 2. Modelling biological networks. [6] 3. Matlab and R packages. [6] 4. NMR spectroscopy. [8] 5. AFM imaging. [8] 6. Cryo-electron microscopy. [8]
Text & Reference Books	Methods’ articles will be shared during the course.

BIO 4101 Host-Pathogen Interactions [3003]	
Prerequisite	NA
Learning Outcomes	Host-pathogen interactions provide information that can help students understand disease pathogenesis and transmission of disease, the biology of a pathogen, as well as the host.
Syllabus	1. Introduction to Host-pathogen interaction [2]. 2. Viral, Bacterial and parasite pathogens [3]. 3. Pathogen external interactions, Viral pathogen attachment and entry into the host cell [3]. 4. Virus replication cycle [3]. 5. Animal models [3]. 6. Experimental approaches to study Microbial pathogenesis: Identification of virulence factors Genome-wide approaches to study host-pathogen interactions [4]. 8. Monitoring host response and immunity to pathogens [3] 9. Pathobiology of Infection: Survival strategies of viral, bacterial and parasite pathogens. Immune response to infectious diseases Mechanisms of pathogenesis, pathogens immune evasion mechanism [6] 10. Manipulation and reprogramming of the intracellular environment [3] 11. Infection of the human host: Gastrointestinal Infections, Respiratory infections, CNS infections, and organ infections [4].
Text and Reference Books	1. Gerald Karp, Cell Biology, WILEY (Feb. 4th, 2013) 2. Wayne M. Becker et al., World of the Cell; Benjamin Cummings; 7th edition (February 19, 2008) 3. Bruce Alberts et al., Essential Cell Biology; Richard Goldsby and Thomas J, &F/Garland, 4th Edition, (2014) 4. Kindt, Kuby, Immunology, W. H. Freeman; 6th edition (9 October 2006)

BIO 4102 Cancer Biology [3003]	
Prerequisite	I2B 323 Cell Biology, I2B 324 Molecular Biology
Learning Outcomes	The objective of this course is to introduce students to topics on fundamental cancer biology from basic research to therapy. This course aims to provide an overview of the biology and pathology of cancer. The course will educate students on various genetic and molecular changes normal cells undergo during transformation into malignant cancer cells. These modifications include unregulated cell proliferation, evasion of cell death and metastasis. The course describes factors that contribute to cancer development and discuss cancer prevention and treatment options.

Syllabus	1. Types of cancers (Hematopoetic malignacies leukemia and lymphomas, carcinomas, Sarcomas, melanomas and neuro ectodermal malignancies) and hallmarks of cancers (Self-sufficiency in growth signals, insensitivity to anti-growth signals, evading apoptosis, limitless replicative potential, sustained angiogenesis, tissue invasion and metastasis) [7] 2. The common cellular and molecular mechanisms that are deregulated in cancerous cells, and how does their deregulation contribute to the development of cancer? (General out lay of different pathways, aberrant genes and gene expression, aberrant cell structures and cell behavior, role of the cytoskeleton in cell adhesion, cell division, cell migration, invasion, and metastasis) [8] 3. Oncogenes and their role in tumor development (ex: c-src, Ras, erbB2/neu, myc etc.) [6] 4. Tumor suppressor genes and their role in neoplasia (ex: p53, pRb, VHL, and APC etc.) [6] 5. Gene translocations and types of gene mutations that contribute to tumor formation (ex: Burkitt's lymphomas, chronic myelogenous leukemia (CML), deregulated firing of growth factor receptors etc.) [3] 6. Chronic inflammation and infectious agents and their role in cancer development (Colonic, liver and skin inflammation and tumor promotion) [3] 7. Cancer detection/screening and therapy (Mamography, pop smear, radiation, surgery, and chemotherapy etc.) [3]
Text and Reference Books	1. The Biology of Cancer by Robert A. Weinberg 2. Cancer: Principles & Practice of Oncology: Primer of the Molecular Biology of Cancer by DeVita Jr., Vincent T., Theodore S. Lawrence, Steven A. Rosenberg 3. Molecular Biology Of Cancer by Pecorino

BIO XXX Neurobiology [3003]	
Prerequisite	NA
Learning Outcomes	This course is designed to introduce students to major fields of neurobiology. This course will provide an understanding on the electrical activity of the neuron and how they communicate in the nervous system. They will be introduced to sensory physiology and its function. Students will gain an understanding on ongoing research approaches in neurobiology and techniques in order to develop critical thinking skills and formulate novel research questions.
Syllabus	1. Organization of the nervous system [1] 2. Neuroanatomy [1] 3. Historical overview of neuroscience from Empedocles to Bernstein [1] 4. Electrical properties of the neuron: Equilibrium potential, The Nernst potential and Cable equations; Voltage gated ion channels; Resting and action Potentials [2]; 5. Goldman-Hodgkin-Katz equation, Hodgkin and Huxley model. Electrophysiological recording techniques: Patch-clamp and Voltage-clamp techniques [2]. 6. Energetics of the Nervous System [1]. 7. Synaptic transmission: Ligand gated ion channels; Electrical and chemical synapses. Synaptic plasticity, Short term potentiation, Long term potentiation [4]. 8. Learning and memory [1]. 9. Sensory Physiology: Vision: Photoreceptors, Rods, Cones and Retinal ganglion cells. Electrical response to light. Light signal transduction, Concept of receptive fields. Colour vision Visual pathway, lateral geniculate nucleus and visual cortex [4-5]. Olfaction: Structure of olfactory epithelium and odorant receptors. Role of nasal olfactory neuron in odour detection. Odor coding and perception, Olfactory signal transduction. Spatial encoding of odorant information in the olfactory bulb. Processing of olfactory information in the cerebral cortex [3]. Somatosensory system: Touch, pain, cold and warmth receptors on skin and the signal transduction. Somatosensory map, homunculus, spinal cord and cerebral cortex in somatosensation [3-4]. Hearing: Sound perception and localization. Functional anatomy of ear and cochlea. Mechano-transduction, Converting mechanical stimulus to electrical signals. Cochlear inner and outer hair cells and perception of mechanical stimulus frequency and intensity. Adaptation to stimulus. Central auditory pathways [3].

	10. Motor systems: Upper and lower motor system. Reflex and contractions, rhythmic movements, central pattern generators, Role of basal ganglia and cerebellum on cortical and brain motor mechanisms [3-4]. 11. Experimental methods to study neurobiology [1-3]. 12. Diseases of the nervous system [1-2].
Text and Reference Books	1. John G. Nicholls, A. Robert Martin, David A. Brown, Mathew E. Diamond, David A. Weisblat, and Paul A. Fuchs, From neuron to brain, Sinauer Associates, Inc. Fifth edition, November 2011. 2. Mark F. Bear, Barry W. Connors, Michael A. Paradiso, Neuroscience: Exploring the Brain, Lippincott Williams & Wilkins, Third Edition, April 1995. 3. Eric R. Kandel, James H. Schwartz, and Thomas M. Jessell. Principles of Neural Science. Fifth Edition, October 2012. 4. Arthur C. Guyton and John E. Hall. Textbook of Medical Physiology, Twelfth Edition.

BIO XXX Cryo-Electron microscopy and 3D image processing for Life sciences [3003]	
Prerequisite	Preferred: I2B 321 course: Structural Biology (not mandatory).
Learning Outcomes	To introduce Biology major students the importance of the new resolution revolution in electron cryo microscopy (that led to the 2017 Nobel Prize in Chemistry) and the kindred subjects. The objective of the course is to provide biology students with information to understand the history of cryoEM, the basic physics behind negative stain and cryo-EM of bio-molecules, its potential and limitations and an introduction to cellular tomography and future challenges of cryo-EM. It will also introduce single particle cryoEM and their applications in structure based drug design.
Syllabus	1. Cryoelectron microscopy and three-dimensional image processing of biological molecules is among the hottest growth areas in biophysics and structural biology at present. This course will introduce the theory of image processing and 3-D reconstruction techniques used in cryo-EM field to solve the structure of macromolecules. Topics covered will include basic principles of light and electron microscopes, types of electron microscopes and their applications. A basic introduction to electron microscopes' physics and optics. Principles of image formation, Basic Concepts of Fourier Transform in TEM image analysis (a biologist's approach), Contrast transfer function, Point Spread function and its effect on image acquisition and concepts of convolution etc.**[10]** 2. Single-Particle methods in electron microscopy Past, present and future. EM sample, specimen preparation methods, imaging, data collection techniques, Movie processing, Image selection and Initial Model generation of bio-molecules by negative staining and cryo-electron microscopy. 3D image processing hands-on will be arranged with a standard data set over the duration of the course.**[10]** 3. Potential and limitations of protein crystallography and cryo-EM. Hybrid Methods in structure determination of bio-molecules. Theoretical, computational and practical aspects 3D image processing techniques.**[10]** 4. Cryo-EM map interpretation and data analysis, validation, molecular docking and Flexible Fitting in EM maps.**[5-6]**
Text and Reference Books	1. John J. Bozzola and Lonnie D. Russell. Electron Microscopy, Second Edition, Jones and Bartlett Publishers, Inc., Sudbury, MA, 1999, 2. Joachim Frank (2006). Three-Dimensional Electron Microscopy of Macromolecular Assemblies: Visualization of Biological Molecules in Their Native State. 2nd Ed. (New York, Oxford U. Press). 3. Single-particle Cryo-electron Microscopy: The Path Toward Atomic Resolution/ Selected Papers Of Joachim Frank With Commentaries (Series in Structural Biology) 4. Michael F Moody (2011). Structural Biology using Electrons and X-rays, An Introduction for Biologists. Elsevier Ltd. 5. Natesh R* (2014). Crystallography beyond Crystals: PX and SPCryoEM. Resonance, 19(2), 1177-1196. 6. Natesh R* (2019). "Single Particle Cryo-EM as a pipeline for obtaining atomic structures of drug targets in pharma-industry"

BIO 4201 Chronobiology [3003]	
Prerequisite	NA
Learning Outcomes	The objective of this course is to provide students a fully textured academic experience in circadian rhythm research. The course will give an overview in terms of the circadian clock and its role in rhythmic behavior, physiology, metabolism and cognitive function. Research articles are discussed throughout the semester to facilitate the learning process by identifying the hypothesis, understand the experiment and statistical methods to critically assess the conclusion and to develop future research question(s).
Syllabus	1. Historical overview of chronobiology. Fundamental properties of circadian clock: Entrainment, masking and zeitgebers, parametric and non-parametric entrainment, phase shift, phase response curves (PRC), temperature compensation of circadian clock [4]. 2. Molecular biology of the circadian clock: The central oscillator, , molecular components of circadian pacemakers, genetics of circadian rhythms, the circadian feedback loops, post-transcriptional regulation of circadian rhythms, circadian clocks in various model organisms [5]. 3. Circadian clock neuronal network: circadian pacemaker neuronal circuit, morning and evening oscillators, neurotransmitters-the chemical signals of the circuit, electrophysiological properties of the clock neurons [4]. 4. Circadian photoreception: Input signals into the circadian clock, molecular pathway of circadian photoreception, light entrainment of circadian clock, extra-ocular photoreception [3]. 5. Neural circuitry of sleep: Circadian and homeostatic drive for sleep, Genetics of sleep, organization of sleep arousal circuit, wake promoting and sleep promoting neurotransmitters-Adenosine, GABA, Acetyl choline, dopamine [5]. 6. Sleep for memory consolidation, sleep and synaptic plasticity, Sleep disorders. Evolution of sleep [4] 7. Circadian clock and metabolism: Central and peripheral circadian clocks, circadian disruptions and metabolic disorders, neuro-degenerative diseases, ageing and circadian clock [4]. 8. Evolution of the circadian timing system: Evolution of circadian clocks, fitness, adaptive significance of circadian clocks [3].
Text and Reference Books	1. Jay C. Dunlap, Jennifer J. Loros, Patricia J. DeCoursey, Chronobiology: Biological time keeping, Sinauer Associates, Inc. Publishers, First Edition, December 2009. 2. D.S. Saunders, Insect clocks, Elsevier science & Technology, Third Edition, November 2002

i^2 Chemical Sciences - Core Courses

CHY 311	Coordination Chemistry (3003)
Prerequisites	NA
Learning Outcomes	This course covers theories in bonding for coordination complexes with the application of group. The course also includes electronic spectra, magnetism, reaction mechanisms in coordination chemistry, and a brief discussion on bioinorganic chemistry.
Syllabus	• Application of Group Theory: Reducible and irreducible representations; construction of character tables for point groups; applications of group theory in molecular vibrations and molecular orbital diagram construction of H_2O, NH_3, and BF_3 [15] • Bonding and Electronic Spectra: MO theory of transition metal complexes in various geometries; σ-type, π-type, δ- type interactions in transition metal complexes, electronic spectra of d- and f-block compounds, spectroscopic term symbols, selection rules, Tanabe-Sugano diagram, and charge transfer bands [10] • Magnetism of Coordination Complexes: Magnetic susceptibility and magnetic moment; spin-orbit coupling; ferromagnetism and antiferromagnetism; anomalous magnetic moment; thermal effects; single molecular magnets [3] • Reactions of Coordination Complexes: Mechanism and stereochemistry of ligand substitution reactions in square-planar and octahedral complexes; electron transfer reactions (outer–sphere and inner–sphere reactions), photochemical reactions, and ligand centered reactions [6] • Bioinorganic Chemistry: Oxygen-activating proteins (cytochrome P450 and cytochrome c oxidase), electron transport proteins (blue copper proteins, Fe–S clusters, and cytochromes), photosystems, and hydrolase enzymes (carbonic anhydrase and peptidase) [6]
Text & Reference Books	1. F. A. Cotton, Chemical Applications of Group Theory, 3ed; Wiley, 2010. 2. Y. Jean, Molecular Orbitals of Transition Metal Complexes, Oxford press, 2005. 3. S. F. A. Kettle, Physical Inorganic Chemistry – A Coordination Chemistry Approach, Springer, 1996. 4. K. F. Purcell and J. C. Kotz, Inorganic Chemistry, Cengage, 2017. 5. P. Atkins, T. Overton, J. Rourke, F. Armstrong, and M. Hagerman, Shriver and Atkins' Inorganic Chemistry, 5ed, W. H. Freeman and Company New York, 2009. 6. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3ed, Pearson, 2008. 7. J. E. House, Inorganic Chemistry, 3ed, Academic Press, 2019. 8. B. Douglas, D. McDaniel, and J. Alexander, Concepts and Models of Inorganic Chemistry, 3ed, Wiley, 2001. 9. J. E. Huheey, E. A. Keiter, and R. L. Keiter, Inorganic Chemistry – Principles of Structure and Reactivity, 4ed, Pearson Education, 2006. 10. R. L. Dutta and A. Syamal; Elements of Magnetochemistry, 2ed, Affiliated East-West Press, 2004. 11. W. Kaim and B. Schwederski, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, 2ed, Wiley, 2013. 12. R. R. Crichton, Biological Inorganic Chemistry - An Introduction, Elsevier, 2008.

CHY 312	Organic Chemistry — Reactions and Mechanisms (3003)
Prerequisites	CHY 121 and CHY 211
Learning Outcomes	The course covers various aspects of organic reaction mechanisms with emphasis on the stereochemistry of the reactions. Stereochemical problems related to chemical reactions are dealt with in detail. The topics covered will include asymmetric synthesis, reactive intermediates and molecular rearrangements.
Syllabus	• Reactive Intermediates: Carbocations (non-classical carbocation, sigma and π-participation), neighboring group participation; carbanions (homoenolate anion, etc.); free radicals (electrophilic and nucleophilic radicals, radical cations, radical anions, etc.); carbenes and carbenoids; benzyne [10] • Molecular Rearrangements: Rearrangements involving reactive intermediates (anionotropic, cationotropic, free radical, inter- and intramolecular processes) – Wagner-Meerwein, pinacol-pinacolone, Demjanov, Beckmann, Hofman-Loffler-Freytag, Hoffman, Curtius, Schmidt, Lossen, Wolff, benzilic acid, Claisen (including Johnson-Claisen, Ireland-Claisen), Cope and oxy-Cope, Favorskii, Fries, Baeyer-Villiger, Dakin, and Wittig rearrangements (both 1,2 and 2,3); rearrangements involving migration from nitrogen to ring carbon such as Hoffman-Martius, Fischer-Hepp, Bamberger, Orton, benzidine, etc. [12] • Chemistry of Carbonyl Compounds: Enolization catalysed by acids and bases, generation of thermodynamic vs kinetically controlled enolates; α-alkylation of carbonyl compounds including dianions, alkylation using acyl anion equivalent such as dithiane; C-alkylation vs O-alkylation; generation and reactions of enamines, silyl enol ethers, and boron enolates; diastereoselective-, Mukaiyama-, and intramolecular aldol reactions [11] • Conjugate additions to α,β-unsaturated systems; direct addition versus conjugate addition [2] • Mannich reaction, Henry reaction, Robinson annulation, Dieckmann condensation, Darzens reaction, acyloin condensation, Wittig and Horner-Emmons reactions, Baylis-Hillman reaction [5]
Text & Reference Books	1. 1. a) F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, 5ed., Springer, 2008., b) F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part B: Reaction and Synthesis, 5ed., Springer, 2008. 2. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, 2ed., Oxford University Press, 2012. 3. R. Bruckner, Advanced Organic Chemistry, Reaction Mechanisms, 3ed., Springer, 2010. 4. W.S. Carruthers and I. Coldham, Modern Methods of Organic Synthesis, 4ed., Cambridge University Press, 2004.

CHY 313	Quantum Chemistry (3003)
Prerequisites	NA
Learning Outcomes	• To provide an understanding of the basic formalisms of quantum theory involving the operator approach • To equip the students with the techniques of obtaining solutions to the Schrödinger equation for exactly-solvable model systems • To appreciate the need to adopt approximation methods for the description of many-electron systems and beyond

CHY 313	Quantum Chemistry (3003)
Syllabus	• Formal Development of Quantum Mechanics: Operators in quantum mechanics, postulates of quantum mechanics, Born interpretation, properties of Hermitian operators, Gram-Schmidt orthogonalization, expectation values of operators, variance in observable properties, stationary state solutions, time-independent Schrödinger equation, superposition of states, forms of the linear and angular momenta operators, commutators, properties of commuting operators, hypervirial theorem, Ehrenfest theorem, generalized uncertainty principle, orbital angular momenta operators in spherical polar coordinates, ladder operators for orbital and spin angular momenta, and parity operator [12] • Exactly-solvable Model Systems: Free particle, particle in 1D, 2D and 3D boxes, quantum numbers and degeneracies, particle-in-a-box with finite walls, tunneling, scattering state solutions, harmonic oscillator, building up of the solutions from the recursion relations of Hermite polynomials, particle on a ring, particle on a sphere, rigid rotor, hydrogen atom, building up of the solutions from the recursion relations of Laguerre polynomials, and radial distribution function [14] • Approximate Approaches for Many-electron Systems: Introduction to many-electron systems, orbital approximation, anti-symmetry principle, Slater determinants, formal development of non-degenerate perturbation theory up to second order, perturbation treatment of the ground state of He atom, Rayleigh-Ritz variational method, application to the electronic structure of He atom, excited states of He, Coulomb and exchange integrals, Hückel molecular orbital theory, linear combination of atomic orbitals-molecular orbitals (LCAO-MO) approach, valence bond and molecular orbital theory treatments of $(H_2)^+$ and H_2 [10]
Text & Reference Books	1. P. Atkins and R. Friedman, Molecular Quantum Mechanics, 5th Ed., Oxford University Press, 2011. 2. I. N. Levine, Quantum Chemistry, 7th Ed., Pearson, 2016. 3. T. Engel, Quantum Chemistry and Spectroscopy, 3rd Ed., Pearson, 2006. 4. J. P. Lowe and K. A. Peterson, Quantum Chemistry, 3rd Ed., Elsevier Academic Press, 2006. 5. D. A. McQuarrie, Quantum Chemistry, Viva Student Edition, Viva, 2011. 6. F. L. Pilar, Elementary Quantum Chemistry, 2nd Ed., Dover Publications, 2001.

CHY 314	Physical Chemistry II (3003)
Prerequisites	Physical Chemistry I (desirable)
Learning Outcomes	• To provide advanced physical chemistry concepts involving electrochemistry, surfaces, colloids and polymers • To underscore the importance of various physical chemistry principles in understanding molecular processes
Syllabus	• Fundamentals of Electrochemistry: Electrochemistry as interdisciplinary science, electrochemistry and battery technology, and electrochemical approaches to environmental problems [2] • Electrodics: Electrochemical cells and reactions, nature of electrode-solution interface, Faradaic reactions, mass transfer-controlled reactions, coupled chemical reactions, overpotentials, exchange current density, Butler-Volmer equation, Tafel plot, multistep electrode reactions, mass transfer by diffusion, charge transfer at electrode-solution interfaces, quantization of charge transfer, tunneling, and structure of double layer at semiconductor solution interface [8]

CHY 314	Physical Chemistry II (3003)
	• Ionics: True and potential electrolytes, ion-solvent interactions, solvation of salts, size and structure of solvation shell, solvation number, IR, NMR, X-ray and neutron diffraction methods to study hydration of salts, review of Nernst equation, electrochemical cells, electrolytic conductance, Kohlrausch's law, ionic equilibria, conductometric and potentiometric titrations, Debye-Hückel theory, activity coefficients, theoretical estimation of activity coefficients, triumphs and limitations of Debye-Hückel law, extended Debye-Hückel law based on finite-size ion model, Bjerrum ion-pair formation, ion pairs to triplet ions to cluster of ions, and Onsager limiting law [10] • Electrochemical Methods: Controlled potential and current techniques, hydrodynamic techniques, electrochemical instrumentations, scanning probe techniques, linear sweep voltammetry, cyclic voltammetry, square wave voltammetry, chronoamperometry, chronopotentiometry, rotating disk electrode, rotating ring-disk electrode, AC impedance, and spectro electrochemistry [6] • Surfaces: Physisorption and chemisorption, Brunauer-Emmett-Teller (BET) equation, estimation of surface area, surface films of liquids, Freundlich adsorption isotherm, and Langmuir adsorption isotherm [3] • Colloids and Interfaces: Colloids, surfactants, micelles, stability and properties, thermodynamics of micellization, surface tension, Gibbs adsorption isotherm, capillary action, viscosity, pressure across curved surface, vapor pressure of droplet, microemulsions, interfacial phenomena, micellar catalysis, and host-guest chemistry [3] • Polymers: Molecular weight determination of polymers, thermodynamics and kinetics of polymerization, thermodynamics of polymer and biopolymer solutions, phase separation of polymer solutions, properties of polymer solutions, and stereochemistry of polymers [4]
Text & Reference Books	1. A. J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, 2nd Ed., Wiley Student Edition, 2004. 2. S. Glasstone, An Introduction to Electrochemistry, Franklin Classics Trade Press, 2018. 3. P. Atkins, J. de Paula and J. Keeler, Atkins 'Physical Chemistry, 11th Ed., Oxford University Press, 2018. 4. G. W. Castellan, Physical Chemistry, 3rd Ed., Narosa Publishing House (2004).F. L. Pilar, Elementary Quantum Chemistry, 2nd Ed., Dover Publications, 2001.

CHY 321	Organometallic Chemistry (3003)
Prerequisites	CHY 311 (Coordination Chemistry)
Learning Outcomes	The course deals with the fundamentals of organometallic chemistry including bonding and reactivity trends of organometallic complexes. Moreover, applications of fundamental organometallic chemistry in catalysis and their underlying mechanisms are included in this course.
Syllabus	• General Concepts: Types of ligands and their binding modes, metal–ligand frontier orbital interactions, valence electron counting, usefulness and limitations of $18e^-$ rule [5] • Metal Complexes of Carbonyl, Phosphine, N-heterocyclic Carbene (NHC) Ligands: Synthesis, structure, bonding, and reactivity of metal-carbonyl complexes; steric and electronic properties of phosphine ligands; structure and bonding of metal-NHC complexes [5]

CHY 321	Organometallic Chemistry (3003)
	• Pi-complexes: Synthesis, structure, bonding, and reactivity of metal complexes bound to alkene/ alkyne/ diene/ allyl; chemistry of metallocenes, fluxionality in complexes with cyclopentadienyl ligand [5] • Complexes with Metal–H/C Sigma Bonds: Synthesis, bonding, and reactivity patterns of metal–dihydrogen, metal–alkane, metal–hydride, metal–C(sp^3), metal–C(sp^2), and metal–C(sp) complexes [5] • Organometallic Reactions and Mechanisms: Substitution reactions, oxidative addition, reductive elimination, transmetallation, migratory-insertion, elimination, addition, abstraction, electrophilic and nucleophilic attacks on the coordinated ligands [5] • Metal–ligand Multiple Bonds: Fischer and Schrock type carbene complexes, carbyne complexes, and metal–heteroatom (O/N) multiple bonds [5] • Catalysis: Mechanism driven catalyst/ process developments for various catalytic transformations such as carbonylation, alkene hydrofunctionalization, deuteration reaction, coupling reactions, alkene/ alkyne metathesis, alkene polymerization, and C–H functionalization [10]
Text & Reference Books	1. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, 6ed, Wiley, 2013. 2. J. Hartwig, Organo-transition Metal Chemistry: From Bonding to Catalysis, University Science Books, 2010. 3. B. D. Gupta and A. J. Elias, Basic Organometallic Chemistry: Concepts, Syntheses and Applications, 2ed, Universities Press, 2013. 4. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3ed, Pearson, 2008. 5. B. Douglas, D. McDaniel, and J. Alexander, Concepts and Models of Inorganic Chemistry, 3ed, Wiley, 2010.

CHY 323	Organic Chemistry — Synthetic Methods (3003)
Prerequisites	CHY312
Learning Outcomes	Emphasis in this course will be on general methods of chemical transformations and general methods and strategies for the synthesis of complex organic molecules. Oxidations and reductions with various reagents will be discussed in detail. Also covered are transformations of carbonyl compounds, focusing on strategies to control the stereochemistry of these reactions.
Syllabus	• Oxidation: Oxidations involving sulfur (such as Kornblum, Swern, Parikh-Doering, etc.); Cr, Mn, and Ru based reagents; Dess-Martin, and IBX oxidations; Ag_2CO_3/Celite; CAN, DDQ, and selenium in oxidation reactions; chemoselective oxidations of allylic and benzylic alcohols; Babler-Dauben-Michno oxidative rearrangement, and oxidation of aldehydes; oxidation of alkenes with OsO_4, periodic acid, and $Pb(OAc)_4$, Prevost reaction and Woodward modification; Fleming-Tamao oxidation; epoxidation of alkenes (electrophilic and nucleophilic epoxidation). Discussions with emphasis on chemo-, regio-, and stereoselectivities [10] • Reduction: Catalytic hydrogenation; hydrazine based reductions; reductions using hydrides (Al and B based reagents including DIBAL, Luche reduction, L-selectride, K-selectride, Red-Al etc.), tin and silicon based reducing agents including Barton-McCombie deoxygenation; dissolving metal reductions, low valent Ti species mediated reduction reaction (McMurry coupling). Discussions with emphasis on chemo-, regio-, and stereoselectivities [9] • Synthetic aspects of Diels-Alder reaction, inverse Diels-Alder reaction, hetero Diels-Alder reaction and ene-reaction [5] • Dynamic stereochemistry: Effect of conformation on reactivity of acyclic and cyclic molecules dealing with S_N1, S_N2, S_N2' reactions and neighbouring group participation; E2 and syn-

CHY 323	Organic Chemistry – Synthetic Methods (3003)
	eliminations; oxidation of alcohols; enols and enolates; electrophilic addition to alkenes; nucleophilic addition to enones; nucleophilic addition to carbonyl group: Bürgi-Dunitz angle, addition of organometallic reagents (RM; M= Mg, Li, Zn), hydride reductions; Cram and Felkin-Anh models, chelation controlled stereoselectivity; examples of stereospecific reactions; stereoselectivity versus stereospecificity [10] • Asymmetric Synthesis – Fundamental Aspects: Specific rotation, optical purity (enantiomeric excess), racemization (through cationic, anionic and radical intermediates); methods of asymmetric induction – auxiliary control, substrate control, reagent control, and solvent control; chemical and enzymatic resolution, kinetic resolution and dynamic kinetic resolution; desymmetrization – chemical and enzymatic [6]
Text & Reference Books	1. W.S. Carruthers and I. Coldham, Modern Methods of Organic Synthesis, 4ed., Cambridge University Press, 2004. 2. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, 2ed., Oxford University Press, 2012. 3. H.O. House, Modern Synthetic Reactions, 2 Revised ed., Benjamin-Cummings Publishing, 1972. 4. R. Bruckner, Advanced Organic Chemistry, Reaction Mechanisms, 3ed., Springer, 2010. 5. a) F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, 5th Ed., Springer, 2008., b) F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part B: Reaction and Synthesis, 5ed., Springer, 2008. 6. D. Nasipuri, Stereochemistry of Organic Compounds-Principle and Applications, 4 Revised Ed., New Academic Science, 2012. 7. E. L. Eliel, S. H. Wilen and L. N. Mander, Stereochemistry of Carbon Compounds, 1ed., Wiley, 2010.

CHY 411	Main Group Chemistry (3003)
Prerequisites	Foundation courses
Learning Outcomes	The course offers an enhanced appreciation of how periodic trends affect the structures, reaction chemistry and applications of the s- and p-block elements. The course also develops a knowledge of a wide range of structures adopted by main group compounds and also an awareness of how structures and reactivity influence their use and application in both synthesis and industry.
Syllabus	• Hydrogen: Preparation, properties and applications of dihydrogen; molecular, saline and metallic hydrides; hydrogen bonding [4] • s-block elements: Alkali metal solutions in liquid ammonia, oxides, hydroxides, nitrides, halides, and oxoacids; Zintl compounds; crown ether and cryptand complexes; organometallic compounds of Li, Na, Be, Mg and Ca; Na^+, K^+ ion transports, ion channels, and ion pumps in biological systems [4] • Boron group: Structure and bonding of diborane, higher boranes, and borohydrides; Wade's rules, carboranes and metalloboranes, borazine and boron nitrides, hydrides of Al and Ga; organometallic compounds and low oxidation state compounds of Group 13. [6] • Carbon group: Allotropes of carbon, fullerenes and nanotubes, carbides and silicides, silicates, hydrogen and oxygen compounds of Group 14, organometallic compounds of silicon, germanium, tin, and lead [6] • Pnictogens: N_2 and P_4 activation; oxides of nitrogen and phosphorus; pnictogen halides; phosphazenes, rings and clusters; nitrogen fixation, phosphate uptake, metabolism, and feedback [6]

CHY 411	Main Group Chemistry (3003)
	• Chalcogens: Hydrides and halides of chalcogens; polyanions of sulphur, selenium, and tellurium; bonding situations in sulphur-nitrogen & phosphorus-based compounds; sulphur and selenium in biology [5] • Halogens: Pseudohalogens; polyhalides; structure and bonding of interhalogen compounds; oxoacids and oxoanions of halogens; chlorofluorocarbons, fluorocarbons and hydrofluorocarbons, effect of halogenated compounds on ozone layer [5] • Noble Gases: Occurrence and chemical properties, Bartlett discovery of reactivity of noble gases; synthesis, structure, and reactivity of fluorides and oxides of xenon [4]
Text & Reference Books	1. P. Atkins, T. Overton, J. Rourke, F. Armstrong, and M. Hagerman, Shriver and Atkins' Inorganic Chemistry, 5ed, W. H. Freeman and Company New York, 2009. 2. N. N. Greenwood, A. Earnshaw; Chemistry of the Elements, 2ed, Elsevier, 1997. 3. F. A. Cotton, G. Wilkinson, C. A. Murillo, and M. Bochmann, Advanced Inorganic Chemistry, 6ed, Wiley, Wiley. 4. A. J. Elias; The Chemistry of p-Block Elements: Synthesis, Reactions, and Applications, 2ed, Universities Press, 2019. 5. J. E. House; Inorganic Chemistry, 3ed, Academic Press, 2019.

CHY 412	Advanced Organic Chemistry (3003)
Prerequisites	CHY 312, CHY 323
Learning Outcomes	Advanced synthetic methods in organic chemistry is covered in this course. Topics include enantioselective synthesis, reagents based on sulfur and silicon, chemical synthesis of biomolecules and bioactive molecules and natural product synthesis.
Syllabus	• Organosilicon chemistry (Brook rearrangement, Peterson olefination, chemistry of allyl and vinyl silane, Saegusa oxidation, etc.); organosulfur chemistry (Corey-Chaykovsky reaction, Julia olefination, Mislow-Evans rearrangement, etc.); cross-coupling reactions such as Heck, Stille, Suzuki, Sonogashira, Negishi, and Buchwald-Hartwig; ring-closing, ring-opening and cross metathesis reactions (11) • Asymmetric Synthesis: Sharpless epoxidation and dihydroxylation; Jacobsen-Katsuki and Shi epoxidation; CBS reduction, Midland-alpine borane reduction, Noyori asymmetric reduction [9] • Enantioselective Alkylation and Aldol Reactions: Diastereoselective reactions of enantiomerically pure starting materials (chiral pool manipulation); auxiliary controlled stereoselection - Evans oxazolidinones, Oppolzer sultam, Meyers amides, Enders RAMP/SAMP; enantioselective allylation and crotylation reactions; asymmetric Diels-Alder reaction [6] • Natural Products: Structure, properties and reactions of mono- and di-saccharides, steroids, terpene and terpenoids, carotenoids, and alkaloids [8] • Heterocyclic Compounds: Structure, preparation, properties and reactions of common heterocyclic compounds containing one or two heteroatoms O, N, and S like furan, pyrrole, thiophene, pyridine, indole, quinoline, isoquinoline [6]
Text & Reference Books	1. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, 2ed., Oxford University Press, 2012. 2. R. Bruckner, Advanced Organic Chemistry, Reaction Mechanisms, 3ed., Springer, 2010. 3. E. L. Eliel, S. H. Wilen and L. N. Mander, Stereochemistry of Carbon Compounds, 1ed., Wiley,, 2010.

CHY 412	Advanced Organic Chemistry (3003)
	4. D. Nasipuri, Stereochemistry of Organic Compounds-Principle and Applications, 4 Revised ed., New Academic Science, 2012. 5. W.S. Carruthers and I. Coldham, Modern Methods of Organic Synthesis, 4ed., Cambridge University Press, 2004. 6. L. Kurti and B. Czako, Strategic Applications of Named Reactions in Organic Synthesis, 1ed., Elsevier, 2005. 7. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, 5th Ed., Springer, 2008., b) F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part B: Reaction and Synthesis, 5ed., Springer, 2008. 8. John A. Joule and Keith Mills, Heterocyclic Chemistry, 5ed., Wiley-Blackwell, 2013. 9. I. L. Finar, Organic Chemistry, Volume 2: Stereochemistry and the Chemistry Natural Products, 5ed., Pearson, 2002.

CHY 414	Chemical Kinetics and Dynamics (3003)
Prerequisites	Physical Chemistry I & II, Quantum Chemistry (desirable)
Learning Outcomes	• To offer an advanced treatment of chemical kinetics in terms of microscopic theories such as the transition state theory • To provide an understanding of the complex phenomena at surfaces and in presence of electromagnetic radiation
Syllabus	• Fundamental Aspects of Kinetics: Introductory chemical kinetics, collision theory of reaction rates, Arrhenius equation, activated complex theory, macroscopic reaction rates from microscopic properties, and collision cross-section [7] • Molecular Kinetics: Potential energy surfaces for reactive and non-reactive scattering processes, classical trajectories, transition state theory, Eyring equation, quantum and statistical mechanical estimation of rate constants, elementary gas phase reactions, Lindemann-Hinshelwood mechanism, Rice-Ramsperger-Kassel-Marcus (RRKM) theory for unimolecular reactions, study of fast reactions by flow method, relaxation method, flash photolysis, pulsed radiolysis, dynamics of unimolecular reactions, laser and molecular beam methods, energy transfer in gases and liquids, collision dynamics, scattering theory, reaction rate theory, collisional and radiationless energy transfer [19] • Kinetics at Surfaces: Physical and chemical adsorption, adsorption isotherms, surface catalysis, Langmuir-Hinshelwood mechanism, Eley-Rideal mechanism, heats of adsorption, and kinetics of solid-state reactions [5] • Photochemistry: Kinetics in the excited electronic states, Jablonski diagram, photophysical and photochemical processes, photoisomerization, excimers, exciplexes, sensitization, quantum yields, static and dynamic quenching, Stern-Volmer equation, resonance energy transfer, light-induced electron transfer, and Marcus theory [9]
Text & Reference Books	1. K. J. Laidler, Chemical Kinetics, 3rd Ed., Pearson, 2003. 2. M. R. Wright, An Introduction to Chemical Kinetics, John Wiley, 2004. 3. P. Atkins, J. de Paula and J. Keeler, Atkins 'Physical Chemistry, 11th Ed., Oxford University Press, 2018. 4. N. J. Turrro, V. Ramamurthy and J. C. Scaiano, Modern Molecular Photochemistry of Organic Molecules, Viva Student Edition, Viva, 2017. 5. J. I. Steinfeld, J.S. Francisco and W. L. Hase, Chemical Kinetics and Dynamics, 2nd Ed., Prentice Hall, 1999.

CHY 421	Instrumental Methods for Structure Determination (3003)
Prerequisites	NA
Learning Outcomes	The course deals with the applications and interpretations of major types of spectroscopy: absorption, infrared, nuclear magnetic resonance spectroscopy, and mass spectrometry. Moreover, this course targets to focus heavily on interpretation of various physical methods to identify structures and reactivity patterns of organic, organometallic, and inorganic materials.
Syllabus	• Infrared and UV Spectroscopy: Functional group characterization using IR technique; classification of UV absorption bands, examples of UV chromophores, Woodward rule [3] • NMR Spectroscopy: ^{1}H-NMR – chemical shift, inductive and anisotropic effects, chemical and magnetic equivalence, spin-spin coupling and coupling constants; Karplus relationship of J on dihedral angle, first order J splitting patterns and structure correlation, strong coupling effects; second order effects, examples of AB, AX and ABX systems, simplification of second order spectrum, selective decoupling; use of chemical shift reagents for stereochemical assignments [5] • ^{13}C-NMR: natural abundance, sensitivity, ^{13}C chemical shifts and structure correlations, ^{13}C satellites, and DEPT [2] • 2D NMR: COSY, one-bond (HSQC) and multiple-bond (HMBC) ^{1}H–^{13}C correlations; defining molecular stereochemistry using the Nuclear Overhauser Effect (NOE); dynamic processes by NMR - restricted rotation (DMF, DMA, biphenyls, annulenes), ring inversion etc [4] • Mass Spectrometry: Basic principles; hard (EI, FAB, etc.) and soft (MALDI, ESI, etc.) ionisation methods, interpretation of EI mass spectra, molecular ion, mass analyzers; fragmentation patterns (McLafferty rearrangement) [3] • Structure elucidation of organic compounds using above techniques [5] • Multinuclear NMR in Inorganic Structure Analysis: Analysis of spectral patterns of diamagnetic transition metal complexes and main group compounds with multiple NMR-active nuclei in various geometries, fluxionality, elucidation of reaction mechanism, NMR of paramagnetic complexes [2] • Electron Paramagnetic Resonance Spectroscopy: Introduction and analysis of isotropic and anisotropic EPR spectrum with the examples of organic radicals and transition metal ions; introduction to ENDOR spectroscopy [5] • Mössbauer Spectroscopy: Introduction and analysis of spectral patterns of zero-field spectrum to determine oxidation state, spin state, and coordination geometry with examples [3] • X-ray Photoelectron Spectroscopy: Basic concepts and application to determine atomic charges, oxidation state, and catalyst surface structures; analysis of spectrum with examples [3] • X-ray Absorption Spectroscopy: Basic concepts and application to determine oxidation state, spin state, and coordination geometry; analysis of spectrum with examples [3] • Structure elucidation of inorganic compounds using above techniques [2]
Text & Reference Books	1. R. M. Silverstein, F. X. Webster, D. J. Kiemle, and D. L. Bryce, Spectrometric Identification of Organic Compounds, 8ed., Wiley, 2014. 2. W. Kemp, Organic spectroscopy, 2ed., Macmillan, 2019. 3. L. D. Field, S. Sternhelland, J.R. Kalmann, Organic Structures from Spectra, 5ed., Wiley, 2012. 4. M. H. Levitt, Spin Dynamics, 2ed., Wiley, 2008. 5. S. Braun, H. O. Kalinowski and S. Berger, 150 and More Basic NMR Experiments, 2 Revised ed., Wiley-VCH, 1998.

CHY 421	Instrumental Methods for Structure Determination (3003)
	6. D. Neuhaus and M. Williamson, The Nuclear Overhauser Effect in Structural and Conformational Analysis, 2ed., Wiley-Blackwell, 2008. 7. D. L. Pavia, G. M. Lampman, G. S. Kriz, J. A. Vyvyan, Introduction to Spectroscopy 5ed., Cengage, 2014. 8. R. S. Drago; Physical Methods in Inorganic Chemistry, Affiliated East-West Press, 2015. 9. L. Que, Jr.; Physical Methods in Bioinorganic Chemistry, University Science Books, 2000. 10. Encyclopedia of Inorganic and Bioinorganic Chemistry, Wiley, 2011.

Laboratory courses

CHY 315	Organic Chemistry Laboratory (0093)
Prerequisites	CHY 212
Learning Outcomes	Hands on laboratory experience on the preparation of organic compounds and their characterization using IR, NMR, and mass spectrometric techniques.
Syllabus	Experiment No 1: Protection of Alcohol and Amine Groups [9] a) Boc_2O protection of amine. b) Alcohol protection with tosyl chloride. Experiment No 2: Michael Addition [9] a) Hydrolysis of 2-amino-6-methylbenzothiazole b) Aza-Michael addition reaction Experiment No 3: Wittig Reaction [9] a) Preparation of ylide c) Synthesis of ethyl cinnamate Experiment No 4: Reductive Amination [9] a) Synthesis of imine. b) Reduction of imine. Experiment No 5: Oxidation of Aromatic Amine [9] a) Synthesis of 2,2'-(diazene-1,2-diyl)diphenol. Experiment No 6: Bromination of Binaphthol [9] Synthesis of (R)-6,6''-dibromo-2,2''-dihydroxy-1,1''-binaphthyl. Experiment No 7: Acetylation of Glucose [9] a) Acetylation of glucose Experiment No 8: Ketalization of Mannitol [9] a) Ketalization of mannitol Experiment No 9: Pyrylium Tetrafluoroborate [9] a) Coupling of aldehyde and acetophenone. Experiment No 10: $KMNO_4$ Oxidation of Dimethyl Pyridine [9] a) Synthesis of dipicolinic acid Experiment No 11: Synthesis of Diazene [18] a) Coupling of dicarbonate and hydrazine. b) Bromine mediated oxidation of hydrazine to diazene. Experiment No 12: Epoxidation of geraniol acetate [18] a) Preparation of geranyl acetate b) Epoxidation of geraniol acetate
Text & Reference Books	1. Vogel's Text book of Practical Organic Chemistry - Revised by Brian S. Furniss, Antony J. Hannaford, 2. Peter W. G. Smith, and Austin R. Tatchell, - 5ed., John Wiley & Sons, 1991 3. Relevant literature

CHY 325	Inorganic Chemistry Laboratory (0093)
Prerequisites	
Learning Outcomes	This laboratory course provides the opportunities for hands on laboratory experiences related to the preparation and characterization of transition metal complexes. In addition to the preparation of historically important coordination complexes, preparation of complexes related to bioinorganic and organometallic chemistry are also included.
Syllabus	Experiment 1 – Linkage isomers of nitro-pentammine-cobalt (III): (a) Synthesis of $[Co(NH_3)_5Cl]Cl_2$, $[Co(NH_3)_5ONO]Cl_2$ and $[Co(NH_3)_5NO_2]Cl_2$; (b) Characterisation by UV-vis and IR spectroscopic methods. Experiment 2 – Cis-trans isomerism and kinetics in coordination chemistry: (a) Preparation of trans-dichlorobis(ethylenediamine)cobalt(III) chloride; (b) Preparation of cis-dichlorobis(ethylenediamine)cobalt(III) chloride; (c) The kinetics and thermodynamics of cis to trans isomerization. Experiment 3 – Synthesis, optical, and electrochemical studies of metal-acetylacetonato complexes: $M(acac)_3$ ($M = Mn^{3+}$ and Fe^{3+}) Experiment 4 – Effect of symmetry on the infrared spectra of metal-sulfate complexes: Preparation and IR spectroscopic characterisation of (a) Hexamminecobalt(III) sulphate pentahydrate, (b) Sulphato-pentamminecobalt(III) bromide, (c) Sulphato-bis(ethylenediamine)cobalt(III) bromide. Experiment 5 – Electronic spectra of nickel(II) complexes: Preparation and UV-vis spectroscopic characterisation of (a) $[Ni(bipy)_3]SO_4$, (b) $[Ni(en)_3]Cl_2.2H_2O$, (c) $[Ni(NH_3)_6]Cl_2$, (d) $[Ni(DMSO)_6]Cl_2$. Experiment 6 – Synthesis and study of an oxygen-binding cobalt complex: (a) Preparation of $salenH_2$ ligand, (b) Preparation of Co(salen) and its reactivity towards oxygen. Experiment 7 – Synthesis of zinc-porphyrin complex: (a) Preparation of 5,10,15,20-meso-tetra(p-tolyl)porphyrin (H_2TTP) ligand, (b) Preparation of Zn(II)-tetra(p-tolyl)porphyrin (ZnTTP). Experiment 8 – Preparation of ferrocene derivatives: Synthesis and characterisation of 1,1'-diacetylferrocene and 1,1'-ferrocenecarboxaldehyde.
Text & Reference Books	1. J. Derek Woollins, Inorganic Experiments, 3ed, Wiley, 2010.

I2C 515	Experimental Chemical Biology (0093)
Prerequisite	
Learning Outcomes	To provide hands on training on the techniques involved in chemical biology and to equip the students for careers in pharmaceutical industry/chemical biology research.
Syllabus	1. DNA Synthesis and DNA hybridization. [9] 2. Doubly labelled Peptide-nucleic acids as probes for the detection of DNA point mutation. [9] 3. Synthesis and Characterization of a covalent oligonucleotide-streptavidin conjugate and its applications in DNA directed immobilization. [9] 4. Solid Phase Synthesis of peptides: Bradykinin Analogs and the evaluation of calcium mobilization in PC-12 cells [9] 5. In silico Protein Ligand Design [9] 6. Lipidation of proteins and peptides: Farnesylation of the Ras proteins [18]

I2C 515	Experimental Chemical Biology (0093)
	7. Insertion of lapidated peptides into model membranes [9] 8. Isolation of potato phosphorylase and enzymatic Synthesis of amylose [9] 9. Proteome analysis: identification of proteins isolated from yeast [9] 10. Lectins: determination of the sugar specificity of jacalin by a sugar-lectin binding assay [9] 11. Combinatorial synthesis and genetic algorithm [9] 12. Solid-phase synthesis of an antibiotic [9]
Text & Reference Books	1. Chemical Biology, A practical course. Herbert Waldmann, Petra Janning. Wiley-VCH, 2004.

Thematic Courses

I2C 311	Biochemistry & Bioconjugation
Prerequisite	NA
Learning Outcomes	To impart knowledge about the biochemical processes and bioconjugation techniques to unravel biological functions and dynamics of biomolecules (proteins, nucleic acids, polysaccharides, lipids etc.) and to equip the students for careers in pharmaceutical industry/Chemical biology research. The course consist of Biochemistry module from BIO 314 & Bioconjugation module given by chemistry department
Syllabus	• Introduction to bioconjugation: Protein chemistry, reactive groups, different functional groups targeting reactions, blocking of specific functional groups, buffer systems • Bioconjugate reagents: different cross linkers (zero, homo and hetero-biofunctional cross linkers etc.), cleavable cross linkers, fluorescent tags, biotinylation reagents, radio-labeling reagents, light activated reagents • Practical applications and techniques: PEGylation of proteins, microspheres, liposomes, dendrimers, immobilization of proteins, antibody-enzyme conjugate (ELISA), label transfer reagents, DNA probes and hybridization, bioorthogonal reagents (click chemistry), Solid-phase peptide synthesis, labelling of sugars, bioconjuagation by exploiting Cell's translational machinery (Auxotrophs)-Bioconjugation using posttranslational machinery (Formyl glycine generating enzymes) • Application of bioconjugates with examples
Text & Reference Books	1. Bioconjuagte Techniques, Greg T. Hermanson, 3rd Edn, Academic Press, 2013. 2. Bioconjugation: Methods and Protocols, Sam Massa & Nick Devoogdt, Humana Press, 2019. 3. Kuriyan, Konforti & Wemmer, The molecules of life: Physical and chemical principles, 2012. 4. Walsh, Enzymatic reaction mechanisms, 1978

I2C 411	Medicinal Chemistry (3003)
Prerequisite	Organic Chemistry — Reactions and Mechanisms, Organic Chemistry — Synthetic Methods (desirable)
Learning Outcomes	Describe the overall process of drug discovery, and the role played by medicinal chemistry in this process. Demonstrate an understanding of concepts such as drug metabolism, bioavailability and pharmacokinetics and the role of medicinal chemistry in improving these parameters.
Syllabus	• Structure, energy and interactions in drug molecules [2] • Receptorology, Enzyme Inhibition, drug action and metabolism, chirality in drug design, The Lipinski's Rule in drug discovery [4] • Routes of administration, drug leads and pharmacokinetics (PK), ADME [3]

I2C 411	Medicinal Chemistry (3003)
	• Structure-Activity Relationships (SAR): Structural modifications in drug design Oral bioavailability-Quantitative SAR-Receptor interactions, Receptor interaction theories [4] • Enzyme inhibitors: Stereochemistry, Enzymes-Enzyme mechanisms, Enzyme inhibition, Reversible enzyme inhibitors, Transition-State inhibitors, Irreversible enzyme inhibitors/inactivators, antibiotics-Enzyme inhibitors [6] • Case Studies, discovery of antibiotic [2] • Drug Metabolism-Discovery; Anticancer Types of drug metabolism-anticancer MMP inhibitors Prodrugs [3] • Physico-chemical properties: drug-likeness, design (diversity, scaffold-hopping), halogenes in biologically active organic substances [3] • Proteins: structures, protein-ligand interactions, sequence/structure homology, structure-based design, docking [6] • Synthesis of substances: Retrosynthetic analysis, diversity-oriented synthesis, scaffold-based synthesis using example benzodiazepines, piperidinones, indoles, purines, and benzofurans [5] • Biological evaluation of substances: Cell-free assays, whole cell assays , animal assays [4]
Text & Reference Books	1. Medicinal Chemistry: Principles and Practice, F. D. King, 2nd Edn, RSC, 2002. 2. The Organic Chemistry of Drug Design and Drug action. Richard B. Silverman, 2nd Edn, Academic Press, 2004. 3. Real World Drug Discovery: A Chemist's Guide to Biotech and Pharmaceutical Research. Robert M. Rydzewski, Elsevier, 2008. 4. The Practice of Medicinal Chemistry, Camille-Georges Wermuth, 3rd Edn, Academic Press, 2008. 5. Graham L. Patrick. An Introduction to Medicinal Chemistry, Oxford 6th edition, 2013. 6. John Saunders. Top Drugs, Top Synthetic Routes, Oxford University Press, 1st edition, 2012.

I2C 412	Enzymology and Biocatalysis (3003)
Prerequisite	Physical Chemistry I
Learning Outcomes	The course provides understanding of the potential of biocatalysts for the molecular transformation of simple molecules. Advantages of biocatalysts and chemo-catalysts, as well as the complementation of these sub-disciplines of catalysis are given. The course should be able to equip the student to responsibly select the right biocatalyst, process conditions and reactions for required transformations.
Syllabus	• Introduction, general characteristics of enzymes, purification and structure of enzymes [3] • Mechanism of enzyme action: Activation energy, coupled reactions, active site and its importance, thermodynamics and equilibrium, enzyme activity, specific activity and units, enzyme turnover [4] • Case studies : Enzymes in organized system and enzymes in cells, EgsIsozyme, Ribozymes, Zymogens, Abzymes, Classification and nomenclature of enzymes [3] • Regulation and control of enzyme activity: reversible covalent modification, irreversible covalent modification, half-site reactivity, bifunctional enzymes, compartmentalization [4] • Enzyme Inhibition: Models and types of inhibition, kinetics and diagnostic plots multi-substrate enzymes, multisite and allosteric enzymes, models and examples [4] • Applications of enzymology: Clinical aspect of enzymology, enzyme technology, enzyme assay (types, continuous and discontinuous assays, optimization of enzyme assays, factors influencing catalytic efficiency and the mechanisms employed) [7] • Introduction to biocatalytic reactions: hydrolyses, oxidoreductase, Diels Alderase, epoxidase, cyclo-oxygenase, isomerases, lysasase, phosphorylase, glycosyl transferase [6] • Biocatalysis in biofuels: hydrolyse of cellulose, biocatalysis in the synthesis of pharmaceutical intermediates [9]

I2C 412	Enzymology and Biocatalysis (3003)
Text & Reference Books	1. Enzyme Biocatalysis: Principles and Applications, Andrés Illanes, Springer Netherlands, 2008. 2. Fundamentals of Enzymology: Cell and Molecular Biology of Catalytic Proteins, Nicholas C. Price & Stevens Lewis, OUP, 1999. 3. Modern Biocatalysis: Stereoselective and Environmentally Friendly Reactions, Wolf-Dieter Fessner & Thorleif Anthonsen, Wiley VCH, 2009. 4. Enzymology, T. Devasena OUP, 2010. 5. Applied Biocatalysis, 2nd edition, Edited by Adrie J. J. Straathof and Patrick Adlecreutz., CRC press, 2000. 6. Biocatalysis, Fundamentals and Applications, A. S. Bommarius, Bettina R. Riebel Bommarius, Wiley-VCH, 2004. 7. Introduction to Biocatalysis using Enzymes and Microorganisms, Stanley M. Roberts, Nicholas J. Turner, Andrew J. Willets, Michael K. Turner, Cambridge University Press, 1995.

I2C 413	Biophysical Chemistry (3103)
Prerequisite	Physical Chemistry 1 & II (desirable)
Learning Outcomes	The course emphasises the connections between molecular structure, interactions, and biological function. The course also introduces students to the methods used to visualize and analyze macromolecular structures and assemblies.
Syllabus	• **Basics of thermodynamics and Kinetics of biological process**: Chemical equilibria, thermodynamics of transport process (diffusion), redox reaction is biology (respiratory chain, light reaction in biology), electrochemical potential and membrane potential [4] • Electrophysiology: patch clamp method [2] • Enzyme kinetics: Cooperativity and Hill equation, inhibition of enzyme activity [2] • Protein folding: driving force, Levinthal paradox, energy landscape for protein folding, folding pathways [2] • Protein-protein interactions: Energetics of macromolecular interactions, role of water [2] • Nucleic acids: structure of DNA and RNA; folding of RNA, DNA-protein interaction, small molecule binding to DNA [2] **Methods:** • Optical spectroscopy, linear and circular dichroism and IR [2] • Fluorescence: fluorescence anisotropy, time resolved fluorescence, Foerster resonance energy transfer [4] • Light scattering, solution scattering, SAXs and small angle neutron scattering [4] • Imaging and Microscopy: Fluorescence(Wide-field, confocal scanning, Fluorescence lifetime imaging) microscopy techniques, fluorescence correlation spectroscopy, single molecule fluorescence microscopy, super resolution microscopy. [7] • Electron microscopy: Principle of electron microscopy, 3D electron microscopy, cryo-electron tomography and single particle cryo-EM [5] • Scanning probe microscopy: Scanning tunnelling, scanning force microscopy [2] • Atomic force Microscopy: Force spectroscopy with AFM optical and magnetic tweezers [2]
Text & Reference Books	1. Biophysical Chemistry by Dagmar Klostermeier & Markus G. Rudolph, CRC Press, 2020. 2. Charles Cantor, Paul Schimmel. Biophysical Chemistry Part 1, W. H. Freeman; 1980. 3. Charles Cantor, Paul Schimmel. Biophysical Chemistry Part 2 , W. H. Freeman; 1980. 4. Charles Cantor, Paul Schimmel. Biophysical Chemistry Part 3, W. H. Freeman; 1980. 5. Alan Fersht. Enzyme Structure and Mechanism (1985), W H Freeman & Co (Sd), 1985. 6. David Eisenberg and Donald Crothers. Physical Chemistry with Applications to Life Sciences, The Benjamin / Cummings Publishing Company, 1979. 7. Modern Biophysical Chemistry by Peter Jomo Wall, Second edition, Wiley-VCH, 2014.

I2C 511	Pharmacology and Pharmacokinetics (3003)
Prerequisite	NA
Learning Outcomes	The course explores drug actions on living systems, their metabolism, and their toxic effects. The course focuses on the main principles of pharmacology: pharmacokinetics; drug metabolism and its transport and drug therapy
Syllabus	• General pharmacology and pharmacodynamics. a general understanding of how drugs work and how their actions may be modified [10] • Pharmacokinetics: variability in drug response, pharmaceutical aspects and drug development, how drugs are developed, formulated and the importance of additives in drugs [6] • Pharmacology of drugs used in anesthesia, intensive care and pain medicine, inhalational anaesthetic agents, intravenous anesthetic agents, local anesthetic drugs-pain, non-steroidal anti-inflammatory drugs, neuromuscular blocking agents [8] • Anticholinesterase drugs, anticholinergic drug, pharmacology of the autonomic nervous system, adrenoceptor blocking agents, anti-hypertensive drugs, anti-arrhythmic drugs, therapy of cardiac arrest, ischemia and failure, neuropharmacology, anti-emetic drugs, respiratory pharmacology and therapeutic gases, histamine and serotonin, diuretics, drugs and coagulation, obstetric pharmacology, endocrine pharmacology, gastrointestinal pharmacology, intravenous fluids, pharmacological basis of poisoning, chemotherapeutic drugs [16]
Text & Reference Books	1. A Pharmacology Primer: Theory, Application and Methods. Terry P. Kenakin, 3rd Edition, Academic Press, 2009. 2. Golan, D., et. al., eds. Principles of Pharmacology: The Pathophysiologic Basis of Drug Therapy, Lippincott Williams & Wilkins, 2012. 3. Hardman, J. G., et. al., eds. Goodman and Gilman's The Pharmacological Basis of Therapeutics. McGraw Hill, 2011. 4. Molecular Biology in Medicinal Chemistry 1st Edn, Theodor Dingermann, Dieter Steinhilber, Gerd Folkers, Wiley-VCH, 2004. 5. Pharmacokinetics Made Easy, Donald Birkett, McGraw-Hill, 2002. 6. Drug-like Properties: Concepts, Structure Design and Methods: from ADME to Toxicity Optimization, Li Di, Edward H Kesrns, 1st Edition, Academic Press, 2008.

I2C 512	Soft Matter and Polymers (3003)
Prerequisite	**Physical Chemistry-1**
Learning Outcomes	The course covers topics on the physical chemistry of soft matter, liquid crystals, surfactants, colloidal particles and polymers. The course will deepen the understanding of the structure, dynamics and properties of these materials in a concerted manner and introduce you to some of their technical applications.
Syllabus	• Introduction: Intermolecular interactions, structural organization, dynamics, Phase transition, order parameters, scaling laws, polydispersity, experimental techniques for investigating soft matter, thermodynamic and mechanical properties of soft matter, aggregation and assembly [8] • Liquid crystals: Introduction, anisotropy in liquid crystals, thermotropic and Lyotropic liquid crystals, birefringence in liquid crystals, thermotropic liquid crystal phases, various experimental technique to characterise the liquid crystal [6] • Applications of liquid crystals: LC displays, the twisted Nematic displays, spatial light modulators, LC temperature sensors [2]

I2C 512	Soft Matter and Polymers (3003)
	• Surfactants: Surface tension and surfactants, self-assembly and phase behaviour; membrane elasticity and curvature; Applications of surfactants (Detergent, detergent foams, Emulsifiers & emulsions, paints and inks, surfactants and gel electrophoresis, lung surfactants [6] **Polymers** • Polymer Introduction: polymer structure, LC polymers, Polymer solutions ; Natural Polymers, organic chemistry and polymers, polymer synthesis, condensation & free radical polymerizations, polycarbonates and polyanhydrides, degradation, glassy and polymer melt phases, the mechanical properties of polymer [6] • Functional polymers, Responsive Polymers & Scaffolds; controlled drug delivery, nanostructured polymers, polymers at interfaces, polymer mechanics and rheology, self-assembly, polymers in energy [6] • Colloidal materials: Characteristics of colloidal systems, colloids in suspension, forces in collided dispersions, interparticle interactions, colloidal aggregations, colloidal crystals, granular materials, foams [6]
Text & Reference Books	1. Fundamentals of Soft matter Science by Linda S. Hirst (CRC press), 2019. 2. Polymer Chemistry by Malcolm P. Stevens, Oxford University Press, Inc, 1990. 3. Text book of polymer Science, Billmeyer, John Wiley and Sons 1984. 4. Principles of Polymer Systems, Rodriguez, Hemisphere Publishing Corpn, 1982. 5. Introduction to Polymer Science and Technology, H. S. Kaufman and J. J. Falcetta, Wiley, 1977. 6. Polymer chemistry, Seymour and Carraher, Marcel Dekker, CBS Publishers, 2003. 7. Odian, George. Principles of Polymerization. 4th ed. Hoboken, NJ, 2004.

I2C 513	Biomaterials (3003)
Prerequisite	Fundamental Chemistry courses and polymer & soft matter (desirable)
Learning Outcomes	The course focuses on the study of biocompatible, biomimetic and nature-based materials as well as their diverse areas of application. The course provides an understanding of the characteristics of common biomaterials, its structure, properties and morphology. Students also learn the different interaction between biomaterials, proteins and cells.
Syllabus	• Concepts in material science: bulk properties of materials, surface properties and surface characterisation of materials, interpretation of phase diagram [10] • Classes of materials used in medicine: Polymers, silicone biomaterials, hydrogels, smart polymers, metals (basic structure and types of alloys, stress-strain behaviour, hardness, impact energy, fractured toughness, fatigue) [8] • Ceramics and glasses: characterising crystalline and non-crystalline materials, mechanical properties and processing methods: brittle fracture, static fatigue, thermal shock and viscous deformation, composites, surface immobilised biomolecules [6] • Biological response to biomaterials: biocompatibility and heme compatible, mechanism of foreign body response to implanted biomaterials. biodegradation of biomaterials. surface modification to control biological response [8] • Biomaterial application: biomaterial for joint versus blood vessel, biomaterial for soft and hard tissue replacement, cardiovascular, drug delivery system, biosensors, synthetic bioresorbable polymer scaffolds [8]

I2C 513	Biomaterials (3003)
Text & Reference Books	1. Biomaterial Science by Buddy Ratner, Allan Hoffman, Frederick Schoen, Jack Lemons, Academic press, 2012. 2. Biomaterials: The Intersection of Biology and Materials Science by J.S. Temenoff and A.G. Mikos, Pearson Prentice Hall, 2008. 3. Fundamentals of Biomaterials by Vasif Hasirci & Nesrin Hasirci, Springer, 2018.

I2C 514	Computational methods in Chemical Biology (3003)
Prerequisite	Quantum Chemistry
Learning Outcomes	The course applies computational methods to understand chemical and biochemical properties and processes. The course also emphasises on the required theory and application of atomistic simulations needed to model and understand systems of biological relevance (proteins, DNA, small molecule therapeutic drug properties)
Syllabus	• Molecular structure and Stability: Proteins, peptide bond, post translational modifications, protein structure, protein-protein interactions, membrane protein and their lipid environment [5] • Folding and stability: energy landscape for protein folding, protein folding disease [3] • Nucleic acids: Structure of DNA and conformations, higher order DNA structures, DNA interactions with proteins [3] • RNA structure: secondary structure, tertiary structure, RNA folding [2] • Protein sequence composition and properties, secondary structure prediction [2] • Molecular modelling: Force fields, Energy minimisation, molecular mechanics and dynamics, Boundary conditions and solvation, integration of Newtonian equations, trajectory analysis, extraction of information from MD, enhanced configurational sampling, simulating rare events [10] • Applications: Fold recognition, homology modelling, simulated annealing, coarse-grained modelling [4] • Design of substances: Conformational analysis and basic cheminformatics; force-field, energy minimisation, 3Ds, pharmacophore identification, sub-structure search, similarity search, databases [5] • Computational Chemistry: structure, energies, conformational analysis of small molecules; studies of biomolecules and interactions between drug molecules and receptors, rational design, structure-based design, docking [6]
Text & Reference Books	1. Biophysical Chemistry by Dagmar Klostermeier & Markus G. Rudolph, CRC press, 2020. 2. Real World Drug Discovery: A Chemist's Guide to Biotech and Pharmaceutical Research. Robert M. Rydzewski, Elsevier, 2008. 3. Molecular dynamic simulation by J.M. Haile, Wiley, 1997. 4. Computational Tools for Chemical Biology, by Sonsoles Martín-Santamaría. RSC publishing, 2017.

I2C 516	Chemical Genomics and Proteomics (3003)
Prerequisite	Biochemistry
Learning Outcomes	A comprehensive introduction to the origins and emerging frontiers of chemical biology. This course develops the fundamental chemistry of molecules in nature, a quantitative description of their interaction with themselves and each other and subsequent effects on biological function.
Syllabus	• Protein design • Molecular evolution • Chemical genetics • Metabolic engineering • Methods in genomics and proteomics research. • Biomolecules: lipids, carbohydrates, peptides and nucleic acids- • Chemical methods to synthesize proteins and peptides- • Chemical methods to synthesize DNA and RNA • DNA recognition • Protein-Protein interactions • Ligands for protein surfaces • Small molecule arrays
Text & Reference Books	1. Chemical Biology: From Small Molecules to Systems Biology and Drug Design, vol 1–3, Stuart L. Schreiber, Tarun M. Kapoor & Günther Wess, Wiley VCH, 2007. 2. Chemical Genomics and Proteomics, Ferenc Darvas, Andras Guttman, Gyorgy Dorman, 2nd Edition, CRC press, 2016. 3. Essentials of Chemical Biology, Andrew Miller & Julian Tanner, Wiley, 2008. 4. Chemical genomics, Ferenc Darvas, Andras Guttman, Gyorgy Dorman, Marcel Dekker, 2004.

i^2 Data Sciences - Core Courses

DSC 311	Mathematical Statistics [3-0-3-4]
Prerequisite	Nil
Learning Outcomes	This course provides students with decision theory, estimation, confidence intervals, and hypothesis testing. Students will get hand-on experience in the lab component of the course which will be implemented either in Matlab or R.
Syllabus	Sampling Distributions [9]: Populations and samples; distribution of samples; graphical repre-sentation of data; basic distributions, properties, fitting, and their uses; distribution theory for transformations of random vectors; sampling distributions based on normal populations; t, χ^2 and F distributions. Estimation of Parameters [9]: Method of maximum likelihood; applications to different popu-lations; point and interval estimation; method for finding confidence intervals; applications to normal populations; approximate confidence intervals. Bivariate Samples [7]: Sample from a bivariate population; least square curve fitting; maxi-mum likelihood estimation; multivariate samples. Testing of Hypotheses [15]: Statistical hypotheses - simple and composite; best critical region; application to normal population; likelihood ratio testing; normal and bivariate normal populations and comparison; binomial populations and comparison; Poisson population; multinomial population; χ^2- test of goodness of fit. Practicals: Objects and functions, Arithmetical and Boolean operators, Importing and Exporting Data sets, Packages, Loops and Conditional statements, Measure of central tendency, basic plots. Density, distribution function, quantile function and random generation for standard discrete and continuous distributions. Q-Q plots and P-P plots. Fitting distributions. Maximum Like-lihood estimation. Generating bivariate random sample. Test for mean, variance, proportion and independency.
Text & Reference Books	1. D. Freedman, R. Pisani and R. Purves, *Statistics, Â* W. W. Norton & Company; 4th edition (2007). 2. R. V. Hogg, J. McKean and A. T. Craig, *Introduction to Mathematical Statistics,* Pearson Education India; 7 edition (2013). 3. A. Mood, F. Graybill and D. Boes, *Introduction to the Theory of Statistics,* McGraw Hill Education; 3 edition (2017). 4. P. J. Bickel and K. A. Doksum, *Mathematical Statistics: Basic Ideas and Selected Topics,* Volume 1. 2nd edition. Chapman and Hall / CRC (2015). 5. Grolemund, Garrett. *Hands-on programming with R: write your own functions and simulations.* O'Reilly Media, Inc., 2014. 6. Schumacker, Randall, and Sara Tomek. *Understanding statistics using R.* Springer Science & Business Media, 2013. 7. Zuur, Alain, Elena N. Ieno, and Erik Meesters. *A Beginner's Guide to R.* Springer Science & Business Media, 2009.

DSC 312	Optimization Techniques [2-0-0-2]
Prerequisite	Nil
Learning Outcomes	• To apply optimization techniques. • Understanding of linear and nonlinear techniques
Syllabus	Classification and general theory of optimization[1]; Linear programming (LP): Formulation and geometric ideas, simplex and revised simplex methods[5]- Duality and sensitivity, interior-point methods for LP problems[5]- Transportation- assignment-and integer programming problems[5] Nonlinear optimization: Method of Lagrange multipliers[2]- Karush-Kuhn-Tucker theory[2]- Numerical methods for nonlinear optimization[2]- Convex optimization, quadratic optimization[2]- Dynamic programming[2].
Text & Reference Books	1. D. G. Luenberger and Y. Ye, Linear and Nonlinear Programming, Third Edition, Springer India, 2008. 2. N. S. Kambo, Mathematical Programming Techniques, East-West Press, 1997. 3. E. K. P. Chong and S. H. Zak, An Introduction to Optimization, Second Edition, Wiley India, 2001. 4. M. S. Bazarra, H. D. Sherali and C. M. Shetty, Nonlinear Programming Theory and Algorithms, Third Edition, Wiley India, 2006. 5. K. G. Murty, Linear Programming, Wiley, 1983.

DSC 313	Discrete Mathematics[2-0-0-2]
Prerequisite	Nil
Learning Outcomes	• Have knowledge of the concepts needed to test the logic of a program. • Have an understanding in identifying structures on many levels. • Be aware of a class of functions which transform a finite set into another finite set which relates to input and output functions in computer science. • Be able to apply basic counting techniques to solve combinatorial problems • Acquire ability to describe computer programs in a formal mathematical manner.
Syllabus	Logic: Propositions, negation, disjunction and conjunction, implication and equivalence,truth tables, predicates, quantifiers, rules of inference, methods of proof.[3] Set theory: definition and simple proofs in set theory, Inductive definition of sets andproof by induction, inclusion and exclusion principle, relations, representation of relations by graphs, properties of relations, equivalence relations and partitions, partial orderings, linear and well-ordered sets.[7] Functions: mappings, injection and surjections, composition of function, inverse functions, special functions, recursive function theory.[3] Elementary combinatorics: Counting techniques, pigeonhole principle, recurrence relation, generating functions.[3]

	Graph theory: Elements of graph theory, Euler graph, Hamiltonian path, trees, tree traversals, spanning trees.[5] Algebra: groups, Lagrange's theorem, homomorphism theorem, rings and fields, structure of the ring Zn and the unit group Zn*, lattice.[5]
Text & Reference Books	1. Kenneth H. Rosen, Discrete Mathematics and Its Applications, Seventh Edition, Mcgraw-Hill, 2017. 2. Norman L. Biggs, Discrete Mathematics, Oxford University Press, Second Edition, 2003. 3. P. B. Bhattacharya, S. K. Jain, S, R. Nagpaul, Basic Abstract Algebra, Second Edition, Cambridge University Press,2003

DSC 314	Advanced Data Structures [3-0-3-4]
Prerequisite	Nil
Learning Outcomes	• Learn to define operations on data structures like arrays, linked lists, trees and graphs • Learn to design algorithms involving these data structures • Learn to analyze simple algorithms and solve recurrences, asymptotic analysis
Syllabus	Introduction- Algorithm Analysis, Finding Complexity. Fundamental data structures - List- Sorted Lists, Double Linked Lists, Stack & Queue application.[10] Binary Trees – Insertion and Deletion of nodes, Tree Traversals, Polish Notations, Red Black Trees, B-Trees, Heaps,Priority Queues.[10] Sorting – Bubble, Selection, Insertion, Merge Sort, Quick Sort, Radix Sort, Heap sort. Searching.[10] Graphs- Shortest path algorithms, Minimum Spanning Trees, BFS, DFS.[10]
Text & Reference Books	1. Clifford A Shaffer, Data Structures and Algorithm Analysis, Edition 3.2 (Java Version), 2011. 2. Michael T. Goodrich, Roberto Tamassia, Michael H. Goldwasser. Data Structures And Algorithms In Java™ Sixth Edition, Wiley Publishers, 2014. 3. Mark Allen Weiss Data Structures And Algorithm Analysis In Java, Third Edition, 2012. 4. Robert L. Kruse, Data Structures And Program Design In C++, Pearson Education, Second Edition, 2006. 5. Ellis Horowitz, Fundamentals of Data Structures in C++, University Press, 2015. 6. Ajay Agarwal, Data Structure through C, A Complete Reference Guide, Cyber Tech Publications, 2005. 7. Thomas H Cormen, Charles E Leiserson, Ronald L Rivest, Clifford Stein - Introduction to Algorithms, MIT Press, Third Edition, 2010.

DSC 315	Computer Organisation & Operating System [3-0-0-3]
Prerequisite	Nil
Learning Outcomes	• Understanding the fundamental concepts underlying modern computer organization and operating system. • Understanding the memory organization and execution of programs • Designing of an OS.
Syllabus	***Part-I : Computer Organization*** Computer abstraction and technology: Basic principles, hardware components, Measuring

	performance: evaluating, comparing and summarizing performance. Instructions: operations and operands of the computer hardware, representing instructions, making decision, supporting procedures, character manipulation, styles of addressing, starting a program. [5] Computer Arithmetic: signed and unsigned numbers, addition and subtraction, logical operations, constructing an ALU, multiplication and division, floating point representation and arithmetic, Parallelism and computer arithmetic. [4] The processor: building a data path, simple and multi-cycle implementations, microprogramming, exceptions, Pipelining, pipeline Data path and Control, Hazards in pipelined processors [4] Memory hierarchy: caches, cache performance, virtual memory, common framework for memory hierarchies Input/output: I/O performance measures, types and characteristics of I/O devices, buses, interfaces in I/O devices, design of an I/O system, parallelism and I/O. Introduction to multicores and multiprocessors.[5] ***Part-II : Operating System*** Operating system overview: Computer System Organization, Operating System structure, operations of OS, process management, memory management, storage management, protection and security, distributed systems. [2] Processes: Process concept, Process scheduling, Operations on processes, Cooperating processes, inter-process communication [3] Threads: Overview, Multi-threading models, threading issues, P threads, Windows XP threads[3] CPU Scheduling: Basic concepts, scheduling criteria, scheduling algorithms, multiple-processor scheduling [3] Process synchronization: The critical section problem, Peterson's solution, synchronization hardware, Semaphores, Monitors. Synchronization examples [2] Deadlocks: Methods for handling deadlocks, Deadlock prevention, deadlock avoidance, Deadlock recovery[1] Memory management: Swapping, Paging, Segmentation, Virtual memory, Demand paging, Page replacement [4] I/O Systems: I/O hardware, Application I/O interface, Kernel I/O subsystem, transforming I/O requests to hardware operations[4]
Text & Reference Books	1. D. A. Pattersen and J. L. Hennesy, Computer Organisation and Design: The Hardware/ Software Interface, Fourth Edition, Morgan Kaufman, 2009. 2. V. P. Heuring and H. F. Jordan, Computer System Design and Architecture, Prentice Hall, 2003. 3. J.L. Hennessy & D.A Pattersen , Computer Architecture: A Quantitative Approach, Fifth Edition, Morgan Kaufman, 2011. 4. Carl Hamazher, ZvonkoVranesic and SafwatZaky, Computer Organization, Fifth Edition, McGraw Hill, 2002. 5. William Stallings,Operating systems: Internals & design principles, Pearson, Seventh edition, 2014. 6. Andrew S. Tanenbaum, Modern Operating Systems, Pearson Fourth Edition, 2016. 7. Charles Crowley, Operating Systems - Design Oriented Approach, Mc. Graw Hill Education, First edition, 2017.

DSC 316	Machine Learning-I [3-0-0-3]
Prerequisite	Nil
Learning Outcomes	• Understanding the theoretical foundations of important learning algorithms. • Applications of learning algorithms. • Evaluation of learning algorithms and model selection procedures.
Syllabus	Review of linear algebra, optimization and probability: Matrices, Eigen values and vectors, gradient, hessian, least squares, optimization; random variables and distributions[6] Definitions, goals and history of Machine Learning; Introduction, linear classification; Classification errors; Regression Techniques[9] Supervised learning (generative/discriminative learning, parametric/non-parametric learning, neural networks, support vector machines);[10] Unsupervised learning (clustering, dimensionality reduction, kernel methods); learning theory (bias/variance trade-offs; VC theory; large margins);[10] Reinforcement learning and adaptive control. Applications of machine learning[5].
Text & Reference Books	1. Mitchell, Tom, Machine Learning. New York, NY: McGraw-Hill, 1997. 2. Bishop C. ,M., Pattern Recognition and Machine Learning, Springer, 2006 3. P. Langley, Elements of Machine Learning, Morgan Kaufmann, 1995. 4. Hastie, T., R. Tibshirani, and J. H. Friedman. The Elements of Statistical Learning: Data Mining, Inference and Prediction, Second Edition, Springer, 2009 5. MacKay, David. Information Theory, Inference, and Learning Algorithms. Cambridge, UK: Cambridge University Press, 2003.

DSC 317	Data Science Lab-I [0-0-3-1]
Learning Outcomes	• Extraction of information from data. • Evaluation of algorithms and model selection procedures • Hands-on experience in handling real world data.
Syllabus	Introduction: What is Data Science?- Big Data and Data Science hype, Introduction to statistical packages (R /Python/ S-Plus / MATLAB / SAS). Exploratory Data Analysis(EDA) and Statistical Inference: Populations and samples,- Statistical modelling, probability distributions, fitting a model, Exploratory data analysis tools (plots, graphs and summary statistics) of EDA, kernel density estimation; Basic estimation and testing; Random number generator and Monte Carlo samples, Least square Estimation, Inference, Model Checking, Multivariate data analysis - multivariate normal and inference.
Text & Reference Books	1. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk From The Frontline, O'Reilly, 2014. 2. Joel Grus, Data Science from Scratch: First Principles with Python, O'Reilly Media, 2015. 3. Trevor Hastie, Robert Tibshirani and Jerome Friedman. Elements of Statistical Learning: Data Mining, Inference and Prediction, Second Edition, Springer, 2009. 4. Mohammed J. Zaki and Wagner Miera Jr. Data Mining and Analysis: Fundamental Concepts and Algorithms. Cambridge University Press. 2014. 5. Jiawei Han, MichelineKamber and Jian Pei. Data Mining: Concepts and Techniques, Third Edition. Elsevier, 2012. 6. T.W. Anderson, An Introduction to Multuvariate Statistical Analysis, 3rd Edn, Wiley India, 2009.

DSC 321	Design and Analysis of Algorithms[3-0-0-3]
Prerequisite	Nil
Learning Outcomes	• Understanding the basics of algorithms • Complexity analysis of algorithms • Approximation algorithms
Syllabus	Prim's Algorithm – Locally Modifying Solutions to Build Better Solutions – Exchange Arguments [5] Dijkstra's Algorithm – Kruskal's Algorithm – Knapsack – Huffman Coding[6] Dynamic Programming: Reusing work across sub computations – Definition of DynamicProgramming – Optimal Rod Cut Problem - Optimal Matrix Chain Multiplication - Bellman-Ford Algorithm, Floyd-Warshall Algorithm – Longest Common Subsequence – Machine Scheduling Problem.[12] Amortized Complexity Analysis – Aggregate Method, Accounting Method, Potential Method,Dynamic Tables – Balanced Trees.[8] Intractable Problems: Polynomial Time – class P – Polynomial Time Verifiable Algorithms –class NP – NP completeness and reducibility – NP Hard Problems – NP completeness proofs – Approximation Algorithms.[9]
Text & Reference Books	1. Thomas H Cormen, Charles E Leiserson, Ronald L Rivest, Clifford Stein - Introduction to Algorithms, MIT Press, Third Edition, 2010. 2. Jon Kleinberg, Eva Tardos, Algorithm Design ,Pearson Addison, Wesley, 2013.

MAT 322	Scientific Computing [3-0-3-4]
Prerequisite	Nil
Learning Outcomes	• Apply standard techniques to analyse key properties of numerical algorithms, such as stability and convergence. • Understand and analyse common pitfalls in numerical computing such as ill- conditioning and instability. • Perform data analysis efficiently. • Derive and analyse numerical methods for constrained and unconstrained optimization problems. • Introduce the basics of Monte Carlo methods
Syllabus	Brief review of the sources of error and local analysis: Relative error, absolute error, and cancellation; Computer arithmetic; Truncation error; Error propagation and amplification; Condition number and ill-conditioned problems. [3] Numerical linear algebra: [18] ○ Direct solution methods for linear systems, Gaussian elimination and its variants; LU, QR,Singular value decomposition, ○ Iterative methods for a linear system, Stationary iterative methods- Jacobi, Gauss-Seidel, and successive overrelaxation methods. Non-stationary iterative methods-conjugate gradient (CG), convergence analysis; preconditioning.

	○ Estimation and computation of eigenvalues- Gershgorin disc, power methods, the QR algorithm, ○ Chebyshev polynomials and Chebyshev semi-iterative methods; Nonlinear equations and optimization: [14] ○ Unconstrained Optimization: Optimality conditions, steepest descent method, Newton and quasi-Newton methods, General line search methods, Trust region methods, Least squares problems and methods. ○ Constrained Optimization: Optimality/KKT conditions, penalty and augmented Lagrangian for equality-constrained optimization, interior-point/barrier methods for inequality constrained optimization. SQP methods. Monte Carlo methods: Basic review of probability; Random number generators, Sampling, Error bars, Variance reduction. [5]
Text & Reference Books	1. L. N. Trefethen and D. Bau III, Numerical Linear Algebra, SIAM, 1997. 2. J. W. Demmel, Applied Numerical Linear Algebra, SIAM, 1997. 3. A. Greenbaum, Iterative Methods for Solving Linear Systems, SIAM, 1997. 4. G. H. Golub and C. F. van Loan, Matrix Computations, John Hopkins University Press, 1996. 5. H. C. Elman, D. J. Silvester and A. J. Wathen, Finite Elements and Fast Iterative Solvers, Oxford University Press, 1995. 6. J. Nocedal and S. J. Wright, Numerical Optimization, Springer, 2006. 7. D. P. O'Leary, Scientific Computing with Case Studies, SIAM, 2009.

DSC 323	Database Management System[3-0-0-3]
Prerequisite	Nil
Learning Outcomes	• Understanding basic concepts of DBMS • Understanding the E R model and relational model • Applying normalization techniques • Understanding query processing and query optimization.
Syllabus	Database Modeling: Database System concepts and architecture, Data modeling using Entity Relationship (ER) model and Enhanced ER model, Specialization, Generalization.[4] Database Indexing: Data Storage and indexing- Single level and multi-level indexing, Dynamic Multi level indexing using B Trees and B+ Trees[6] Relational Databases: The Relational Model, Relational database design using ER to relational mapping Relational algebra, Relational calculus, Tuple Relational Calculus, Domain Relational Calculus, SQL[10] Database Design: Database design theory and methodology, Functional dependencies and normalization of relations, Normal Forms, Properties of relational decomposition, Algorithms for relational database schema design[10] Database Transactions: Transaction processing concepts, Schedules and serializability, Concurrency control, Two Phase Locking Techniques, Optimistic Concurrency Control, Database recovery concepts and techniques[8] Database Security: Introduction to database security[2]
Text & Reference Books	1. RamezElmasri and Shamkant B. Navathe, Fundamentals of Database Systems, Fifth Edition, Pearson Education, 2008. 2. Raghu Ramakrishnan and Johannes Gehrke, Database Management Systems, Third Edition, McGraw Hill,2014. 3. Peter Rob and Carlos Coronel, Database System- Design, Implementation and Management, Seventh Edition, Cengage Learning, 2007.

DSC 324	Machine Learning-II [3-0-0-3]
Prerequisite	DSC 316
Learning Outcomes	• Understanding Neural Network structures and learning. • Understanding the deep learning algorithms for domains. • Implementing deep learning algorithms to solve real-world problems
Syllabus	Introduction: Biological Neuron, Idea of computational units, McCulloch–Pitts unit and Thresholding logic, Linear Perceptron, Perceptron Learning Algorithm, Linear separability. Convergence theorem for Perceptron Learning Algorithm.[2] Feedforward Networks: Multilayer Perceptron, Gradient Descent, Backpropagation, Empirical Risk Minimization, regularization.[2] Deep Neural Networks: Difficulty of training deep neural networks, Greedy layerwisetraining[3]. Better Training of Neural Networks: Newer optimization methods for neural networks (Adagrad, adadelta, rmsprop, adam, NAG), second order methods for training, Saddle point problem in neural networks, Regularization methods (dropout, drop connect, batch normalization). [5] Convolutional Neural Networks: Architectures, convolution / pooling layers , LeNet, AlexNet.[3] Recurrent Neural Networks: Back propagation through time, Long Short Term Memory, Gated Recurrent Units, Bidirectional LSTMs, Bidirectional RNNs.[4] Generative models: Restrictive Boltzmann Machines (RBMs), Introduction to MCMC and Gibbs Sampling, gradient computations in RBMs, Deep Boltzmann Machines.[5] Deep Unsupervised Learning and Recent Trends: Autoencoders (standard, sparse, denoising, contractive, etc), VariationalAutoencoders, Adversarial Generative Adversarial Networks, Autoencoder and DBM , Multi- task Deep Learning, Multi-view Deep Learning. [6] Applications of Deep Learning to Computer Vision: Image segmentation, object detection, automatic image captioning, Image generation with Generative adversarial networks, video to text with LSTM models. Attention models for computer vision tasks. [5] Applications of Deep Learning to NLP: Introduction to NLP and Vector Space Model of Semantics Word Vector Representations: Continuous Skip-Gram Model, Continuous Bag-of-Words model (CBOW), Glove, Evaluations and Applications in word similarity, analogy reasoning[5]
Text & Reference Books	1. Ian Goodfellow and YoshuaBengio and Aaron Courville, Deep Learning, MIT Press, 2016. 2. Bishop, C. ,M., Pattern Recognition and Machine Learning, Springer, 2006. 3. Raúl Rojas, Neural Networks : A Systematic Introduction, Springer, 1996.

DSC 326	Data Science Lab-II[1-0-3-2]
Prerequisite	DSC 317
Learning Outcomes	• Understand the data science and data science process • How various tools can be applied in data science process. • Develop an appreciation for what is involved in learning from data. • Understand how to extract the basic information from the data. • Understand how to perform evaluation of algorithms and model selection.
Syllabus	Data Science Process & Basic Machine Learning Algorithms: - Data Science Process, Linear Regression, k-Nearest Neighbours (k-NN), k-means, Naïve based algorithms. Feature Generation and Feature Selection (Extracting Meaning From Data): Feature Generation (brainstorming, role of domain expertise, and place for imagination) and Feature Selection algorithms. Recommendation Systems: Building a User-Facing Data Product: Algorithmic ingredients of a Recommendation Engine, Dimensionality Reduction,- Singular Value Decomposition, Principal Component Analysis Data Visualization: Basic principles, ideas and tools for data visualization. Issues: Discussions on privacy, security, ethics, A look back at Data Science, Next-generation data scientists.
Text & Reference Books	1. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk From The Frontline, O'Reilly, 2014. 2. Data Science from Scratch: First Principles with Python, Joel Grus ,O'Reilly Media , 2015 . 3. Trevor Hastie, Robert Tibshirani and Jerome Friedman. Elements of Statistical Learning: Data Mining, Inference and Prediction, Second Edition, Springer, 2009. 4. Mohammed J. ZakiandWagnerMiera Jr. Data Mining and Analysis: Fundamental Concepts and Algorithms. Cambridge University Press. 2014. 5. Jiawei Han, MichelineKamber and Jian Pei. Data Mining: Concepts and Techniques, Third Edition. Elsevier, 2012. 6. T.W. Anderson, An Introduction to Multuvariate Statistical Analysis, 3rd Edn, Wiley India, 2009.

DSC 411	Statistical Modeling [3-0-0-3]
Prerequisite	Nil
Learning Outcomes	• Understanding the theoretical foundations of various statistical models • Fitting of linear and nonlinear regression and time series models.
Syllabus	Introduction to Economic Questions and Data, Review of Probability, Review of Statistics[6] Linear regression with one regressor, Regression with multiple regressors,[8] Non-linear regression functions[6], Assessing studies based on linear regression (internal and external validity), Regression with a binary dependent variable, Panel Data Regression[10] Introduction to Time-series regression and forecasting, Estimation of Dynamic Causal Effects,VAR, ARCH and GARCH models.[10]

Text & Reference Books	1. Douglas C Montgomery, Elizabeth A. Peck and G. Geoffrey Vining, Introduction to Linear Regression Analysis, Wiley Fifth Edition 2013 2. Norman R. Draper, Harry Smith, Applied Regression Analysis, Wiley, Third Edition, 2011. 3. Peter J Brockwell, Richard A Davis, Introduction to Time Series and Forecasting, Springer, Second Edition, 2010.

DSC 412	Parallel & Distributed Computing [3-0-0-3]
Prerequisite	DSC 315
Learning Outcomes	• Understanding various programming languages for HPC applications. • Gaining sufficient practical knowledge to utilize the performance analysis tools.
Syllabus	Architectures – Multi-core and Many-core architectures, Accelerators (SIMD untis -Vectorization, GPUs), Goals of parallel systems. [4] Applications – Scientific applications, Characteristics, requirements, regular grid applications, irregular applications, data dependence, parallelization process. [8] Parallel Programming on Shared Memory – OpenMP, Execution Model, Shared and private data, Directives, Barriers, Sections, Run-Time library functions, scheduling strategies, Scalability study, OpenMP for accelerator programming. [10] Parallel Programming on Distributed Memory – MPI, Collective operations, Non-Blocking, Collectives, Process topologies, Parallel I/O, Single sided communications. [8] Performance Tools – Concepts, Event-Model execution, profiling, tracing, types of profiling, profiling tools – Scalasca, Score-P, MPI-P, EnergyAnalyzer, Tracing tools, Autotuning – Periscope Tuning Framework. [10]
Text & Reference Books	1. Ian Foster, Designing and Building Parallel Programs – Concepts and tools for Parallel Software Engineering, Pearson Publisher, 1st Edition, 2019. 2. Eric Stotzer and Christian Terboven, Using OpenMP—The Next Step: Affinity, Accelerators, Tasking, and SIMD (Scientific and Engineering Computation, Ruud van der Pas, 2017. 3. P Michael J. Quinn, Parallel computing theory and Practice, McGraw Hill, Second Edition, 2017.

DSC 413	Data ware Housing & Business Intelligence [3-0-0-3]
Prerequisite	Nil
Learning Outcomes	• Creating data warehouse and process raw data to make it suitable for various data mining algorithms. • Discovering and measuring interesting patterns from different kinds of databases. • Applying the techniques of clustering, classification, association finding, feature selection and visualization to real world data.

Syllabus	Overview of Knowledge extraction, Data Warehousing concepts and Architecture, Online Analytical Processing (OLAP) – OLAP and Multidimensional Data Representation, Data cube technologies, Business Intelligence. [6] Data Mining: - Data Mining Functionalities – Data Pre-processing – Data Cleaning – Data[4] Integration and Transformation – Data Reduction – Data Discretization and Concept Hierarchy Generation. Association Rule Mining.[6] Classification and Prediction:-Issues Regarding Classification and Prediction – Classification [4] by Decision Tree. Introduction – Bayesian Classification – Rule Based Classification – Classification by Back propagation – Support Vector Machines – Associative Classification –Lazy Learners – Other Classification Methods.[10] Cluster Analysis:- Types of Data in Cluster Analysis, Model-Based Clustering Methods, Hierarchical and Partitioning methods. Outlier Analysis. Applications and trends in Data Mining: Mining Text and Web data. [10]
Text & Reference Books	1. Alex Berson,Stephen J. Smith, "Data Warehousing, Data Mining, & OLAP", Tata Mcgraw- Hill, 2004. 2. Jiawei Han. Data Mining: Concepts and Techniques. Morgan Kaufmann Publishers 3. Anahory and Murray .,Data warehousing in the real world ,Pearson Education/Addison Wesley. 4. Berry Micheal and Gordon Linoff,.Mastering Data Mining. John Wiley & Sons Inc. 5. Margaret H. Dunham Data Mining: Introductory and Advanced Topics. Prentice Hall

DSC 414	Artificial Intelligence [3-0-0-3]
Prerequisite	DSC 324
Learning Outcomes	• Acquiring a thorough knowledge of fundamental concepts and techniques in artificial Intelligence. • Learning simulation tools. • Developing intelligent and expert systems.
Syllabus	Introduction to Artificial Intelligence: Artificial Intelligence (AI),Major Branches of AI, Applications-Characteristics and Fundamental issues for AI problems, Steps to build Artificial intelligence (AI) systems,Intelligent systems,Characteristics of intelligent systems[3] Search Techniques: Why Search, Applications of search, Tree and Graph, Search strategies,Complexity of Search[6] Knowledge Representation: Knowledge, Characteristics of knowledge representation, Types of knowledge representation,Propositional Logic,Tautology and Contradiction,Predicate Logic, Production Systems, Semantic network, Frame systems, Scripts.[10] Neural Networks:Introduction to Neural network,Structure of Neural network, Neural Network Architecture, Network Layers, Neural Network Learning, Back-Propagation Algorithm[10] Intelligent agents:Introduction to Agents, Functions,Examples of Agents, Intelligent Agent classification, Features of intelligent agents, Structure of Agents, Intelligent Agents Models[2] Fuzzy logic:Crisp logic, Fuzzy logic, Member ship function,Member ship function,Fuzzy logic Applications.[4] Expert Systems:What is Expert system, Conventional systems vs. Expert systems,Basic Concepts, Human Expert Behaviors, Knowledge Types, Inferencing, Rules,Structure of Expert Systems, ES Components, Knowledge Engineer, Expert Systems Working, Problem Areas Addressed by Expert Systems, benefits-limitations- Applications of expert systems.[5]

Text & Reference Books	1. Stuart J Russell, Peter Norvig, Artificial Intelligence: A Modern approach, Third Edition, 2015. 2. Elaine Rich and Kevin Knigh, Introduction to Artificial Intelligence, McGraw Hill, Third Edition, 2017. 3. Michael Negnevitsley, Artificial Intelligence: A guide to Intelligent Systems, Addison Wesley, Third Edition, 2017. 4. G.F. Luger, and W.A. Stubblefield, Artificial Intelligence: Structures and Strategies for Complex Problem Solving, Addison-Wesley Publishing Company, 2011. 5. C.S. Krishnamoorthy and S. Rajeev, Artificial Intelligence and Expert Systems for Engineers by CRC Press, 1996.

DSC 415	Data Analysis & Visualization [2-0-3-3]
Prerequisite	DSC 325
Learning Outcomes	• Familiarizing with data visualization tools such as Tableau, python • Making reports and dash boards.
Syllabus	Creating static graphs, animated visualizations - loops, GIFs, and Videos.[6] Introduction to Visualization Toolkit (VTK) for 3D computer graphics, image processing, and visualization, visualization pipeline, isosurfaces, volume rendering, vector field visualization, applications to biological and medical data.[10] - Visualization for deep learning.[2] Data Visualization BI Tool : Tableau 9.x-Introduction to Data Visualization with Tableau, Exploring Data Visualization with Tableau. What is Data Visualization?, Exporting Data and Working With Tableau. [4] Building Data Visualization BI Project With Tableau 9.x, BI Reporting Understanding, Report and Dashboard Template Document, Tableau Design and Development Database Source Connection[4]
Text & Reference Books	1. Ossama Embark, Data Analysis and Visualization Using Python: Analyze Data to Create Visualizations for BI Systems, Apress, 2018. 2. Kieran Healy, Data visualization: A practical introduction, Princeton university press, 2019. 3. Tristan Guillevin, Getting Started with Tableau, Packet publishing, 2019. 4. Hansen, C.D., and Johnson, C.R., Visualization Handbook, Academic Press, 2004.

DSC 421	Big Data Analytics [2-0-3-3]
Prerequisite	DSC 413, 324
Learning Outcomes	• Working with big data processing tools and its analysis techniques • Designing efficient algorithms for mining the data from large data set • Designing an efficient recommendation system and tools for visualization. • Learning Hadoop/ NoSQL databases and management.

Syllabus	Evolution of Big data - Best Practices for Big data Analytics - Big data characteristics - Big Data Use Cases- Characteristics of Big Data Applications- Big Data Modelling- Hadoop Eco system.[5] An Overview of Clustering - K-means clustering - Use Cases - Determining the Number of Clusters - Classification- Decision Trees - Decision Tree Algorithms - Evaluating a Decision Tree - Decision Trees in R - Bayes Theorem - Naive Bayes Classifier.[8] Association Rules - Overview - Apriori Algorithm - Evaluation of Candidate Rules - Applications of Association Rules - Finding Association & similarity [4] Recommendation System: Collaborative Recommendation- Content Based Recommendation - Knowledge Based Recommendation- Hybrid Recommendation Approaches[5] Introduction to Streams Concepts – Stream Data Model and Architecture - Sampling Data in a Stream – Filtering Streams – Counting Distinct Elements in a Stream –Real time Analytics Platform(RTAP) applications - Case Studies - Real Time Sentiment Analysis- Stock Market Predictions.[9] NoSQL Databases - Schema less Models- Increasing Flexibility for Data Manipulation-Key Value Stores- Document Stores - Tabular Stores - Object Data Stores - Graph Databases– Big data for twitter - Big data for E-Commerce blogs [9]
Text & Reference Books	1. Jure Leskovec, AnandRajaraman and Jeffrey David Ullman, "Mining of Massive Datasets", Cambridge University Press, 2012. 2. Tom White , Hadoop: The Definitive Guide, 4th edition O'Reily Publications, 2015 3. David Loshin, "Big Data Analytics: From Strategic Planning to Enterprise Integration with Tools, Techniques, NoSQL, and Graph", 2013. 4. EMC Education Services, "Data Science and Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data", Wiley publishers, 2015. 5. Bart Baesens, "Analytics in a Big Data World: The Essential Guide to Data Science and its Applications", Wiley Publishers, 2015. 6. DietmarJannach, Markus Zanker, Alexander Felfernig and Gerhard Friedrich "Recommender Systems: An Introduction", Cambridge University Press, 2010. 7. Kim H. Pries and Robert Dunnigan, "Big Data Analytics: A Practical Guide for Managers " CRC Press, 2015. 8. Jimmy Lin, Chris Dyer and Graeme Hirst, "Data-Intensive Text Processing with MapReduce", Synthesis Lectures on Human Language Technologies, Vol. 3, No. 1, Pages 1-177, Morgan Claypool publishers, 2010.

DSC 422	Humans & Data [1-0-0-1]
Prerequisite	Nil
Learning Outcomes	• Demonstrate a clear understanding of debates on central ethical and legal issues in Big Data and be able to contribute to these debates • Explain how various positions taken on these topics relate to deeper principles and problems in ethics. • Be able to apply a framework of dealing with issues related to Big Data. Perform their own evaluation and critique of the validity and soundness of arguments with care and clarity, both orally and in writing

Syllabus	• The course will be based on topical and immediately relevant case studies available in the public domain
	• Introduction to the ethics of big data
	  • Case Study 1 – Who owns Data [1]
	  • Case Study 2 – Transaction transparency [1]
	  • Case Study 3 – Consent and Privacy [1]
	  • Case Study 4 – Value/currency of big data transactions [1]
	• Issues with mass surveillance and privacy
	  • Case Study 1 – Mass surveillance systems around the world [1]
	  • Case Study 2 – Mass surveillance in India [1]
	  • Case Study 3 – Use and misuse of mass surveillance data [1]
	• Corporate accountability
	  • Case Study 1 –Individual data available with corporations [1]
	  • Case Study 2 – Consents signed when using services [1]
	• Big data and the question of identity
	  • Case Study 1 – Big data used to profile individuals [1]
	  • Case Study 2 – Targeted advertising: pros and cons [1]
	  • Case Study 3 – Big data in elections and mass movements [1]
	• Correlation and causation and its connection to data and knowledge
	  • Case Study 1 – Difference between correlation and causation and big data [1]
	  • Responsible use of AI [1]

Text & Reference Books	1. Online material on various case studies like NSA and Edward Snowden, Uber and self driving cars. Data collected by amazon through alexa and its uses. Cambridge analytica and its influence on elections. Privacy concerns and facebookdatat etc.

DSC 423	Stochastic Process [3-0-0-3]
Prerequisite	Nil
Learning Outcomes	• Understanding the basic concepts and types of stochastic processes • Understanding finite and large sample properties of important stochastic processes.
Syllabus	Generating functions; Bivariate distributions and Conditional expectations.Introduction to stochastic processes - time and state space, classification of stochastic processes,stationary processes, processes with independent increments, Gaussian process, Martingales,Markov process, random walk and Wiener process (examples only). [14] Markov chain, transition probabilities and stationary transition probabilities, transition probabilitymatrix, Chapman - Kolmogorov equation: classification of states, first passage time distribution,stationary distribution, irreducible Markov chain, aperiodic chain, ergodic theorem and Gamblersruin problem. [14] Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, birth and death process, pure death process. [12]

Text & Reference Books	1. Sheldon M. Ross, Stochastic Processes, Second edition, Wiley India, 2009. 2. S. Karlin and H. Taylor, A first course in Stochastic Process, Second edition, Academic Press, 1975. 3. Bhat, U.N. and Miller, G.K. Elements of Applied Stochastic Processes, Third Edition, John Wiley, New York. 2002 4. Basu, A.K., Introduction to Stochastic Processes, NarosaPublishing , 2005. 5. Cinlar E. , Introduction to Stochastic Processes, Prentice Hall, 2013. 6. Medhi J., Stochastic Processes, New Age International Publishers, New Delhi 2009. Ross, S.M, Introduction to Probability Models, Elsevier, 2014.

DSC XXX	Bioinformatics[3-0-0-3]
Prerequisite	NA
Learning Outcomes	This is a must-have course for a student of biology, who would benefit from learning the computational tools and methods in biological data analysis to take advantage of massively developing biological data. Topics will cover basics of bioinformatics to advanced algorithms in next-generation sequence analysis.
Syllabus	Biological data & sources - origin and types of biological data, public databases, storing biological data and data security. Data mining - concept of data mining, methods of data mining: text-based, mining tasks, applications. [2] DNA sequence analysis - dot plot, basic concepts of sequence similarity, identity and homology, homologs, orthologs, paralogs, concepts behind scoring matrices, dynamic programming pairwise alignment - Smith-Waterman and Needleman-Wunsch algorithm, FASTA. [5] BLAST& Remote homology search - the BLAST algorithm, parsing BLAST results, advanced BLAST algorithms. [3] Multiple Sequence Alignment - methods of MSA: progressive alignments, consistency-based and structure-based alignment, programs for MSA. [3] Motif finding algorithms - sequence motif concepts, algorithms to detect DNA sequence motifs, Gibbs sampler, MEME. [2] Protein bioinformatics - Protein secondary structure calculation – DSSP, membrane topology prediction, ligand-receptor interactions, composition of active sites in functional proteins, conformational change and activity, allostery, effects of point mutations on proteins structure and function. [5] RNA structure analysis - RNA structure, RNA sequence databases, RNA structure prediction: Nussinov algorithm, EM algorithm. [3] Next generation sequencing and principles of NGS data analysis - introductory concepts, types of NGS data, various platforms of NGS, alignment algorithm - BWA, RNA-Seq, ChIP-Seq, single-cell genomics. [4] R for bioinformatics - introduction, basic elements of R, plotting high-dimensional data, statistical

	analysis, programming. [3]
Text & Reference Books	1. Bioinformatics, David Mount, CSHL, 2003 2. Bioinformatics & Functional Genomics, Jonathan Pevsner, Wiley 2015 3. M. Michael Gromiha, Protein Bioinformatics: From Sequence to Function, Elsevier, 2010

DSC XXX	Systems Biology[3-0-0-3]
Prerequisite	MAT 111, 211
Learning Outcomes	Fast evolving multidisciplinary field that combines the power of mathematical & statistical models to decipher the functioning of biological systems. This is a multidisciplinary course, designed for applicants with a biological, biomedical, physical, computational or mathematical background. It equips students with the necessary skills to produce effective research in systems biology. After completing this course, students will have acquired an understanding of research topics is several areas of theoretical systems biology, which has wide-range of application in big-data analysis.
Syllabus	Introduction to Systems Biology: introduction to biological physics, basic principles of biological systems, overview of experimental techniques.[2] Mathematics of Biological System: differential equations, deterministic ODE and PDE models, graph & network theory, linear, Boolean and Bayesian networks. [7] Networks structure& dynamics - mathematical graphs, random graphs, scale-free networks, clustering, network motifs, dynamic models, modularity. [7] Data formats & Simulations - types of biological data and their formats, Systems Biology Markup Language (SBML), SBML models, BioPAX, models and parameters for simulation of biological processes, stochastic simulation, Monte Carlo simulation. [6] Discrete, stochastic & spatial models - modelling of biological systems, classification of models, modelling process, formulation, and validation. [4] Variability, Robustness & Information - genetic & non-genetic variability, quantification of noise in biological systems, robustness mechanisms and scaling laws, adaptation and exploration strategies. [4]
Text & Reference Books	1. Systems Biology, Edda Klipp, Christoph Wierling, Wolfram Liebermeister, Axel Kowald, Ralf Herwig, Hans Lehrach, 2nd Edition, Wiley 2009 2. Mathematical Modeling in Systems Biology, Brian Ingalls, MIT Press 2013

DSC XXX	Data Science in Chemistry
Prerequisite	Courses on Quantum chemistry and Computational chemistry
Learning Outcomes	To appreciate the applicability of techniques in data science to chemistry research
Syllabus	**Essentials of numerics:** Finding the roots, bracketing, bisection, secant, Newton-Raphson methods, interpolation, splines, polynomial fits, Chebyshev approximation, numerical evaluation of integrals, elementary analytical methods, trapezoidal and Simpson's rules, Gaussian quadrature, orthogonal polynomials, multidimensional integrals, summation of series, Euler-Maclaurin summation formula, numerical differentiation and estimation of errors [4] **Essentials of data analysis:** Statistical description of data, data-fitting methods, nonlinear and linear regression analysis, analysis of variance, goodness of fit, multivariate methods, probability and random processes, discrete and continuous distributions, central limit theorem, measure of randomness, Monte Carlo methods, stochastic processes, Markov chains, and applications of preliminary data analysis approaches such as principal component analysis, linear and nonlinear regressions, multivariate methods etc. in chemistry research [6] **Optimization:** Basics of optimization, extremization of functions, simple search, unconstrained numerical optimization techniques such as modified Newton, quasi-Newton, steepest descent, nonlinear conjugate gradientand constrained numerical optimization techniques such as simplex, barrier, penalty, sequential gradient, and sequential linear constrained method, derivative-free methods such as simulated annealing and Bayesian optimization, optimization of molecular geometries, and drug design [4] **Machine learning:**Applications of machine learning for drug discovery, design of high-strength polymers, analysis of spectroscopic data on complex systems, heterogeneous catalysis, predicting organic reaction outcomes and developing organic dyes; neural networks for molecular excitation spectra, deep learning techniques for energy prediction and geometry optimization [8] **Artificial Intelligence:** Applications of swarm intelligence techniques such as ant colony algorithm and particle swarm optimization in chemistry research,optimization of atomic clusters, molecular clusters, nanoclusters, adsorption and confinement, adsorption isotherms, crystal structure prediction, protein docking, and reaction pathways [8] **Cheminformatics:**Exploration of current chemoinformatics resources for synthetic polymers, pigments, pesticides, herbicides, diagnostic markers, biodegradable materials, biomimetics etc. [4] **Combinatorial chemistry:** Combinatorial library design, synthesis and deconvolution [2]
Text & Reference Books	1. Machine Learning in Chemistry: The Impact of Artificial Intelligence, Edited by H. M. Cartwright, Royal Society of Chemistry (2020). 2. R. Fletcher, Practical Methods of Optimization, 2nd Edition, Wiley (1999). 3. J. Nocedal and S. J. Wright, Numerical Optimization, 2nd Edition, Springer Series in Operations Research (2006). 4. Chemoinformatics: A Textbook, Edited by J. Gasteiger and T. Engel, Wiley-VCH (2003). 5. H. Iba, AI and Swarm Evolutionary Approach to Emergent Intelligence, CRC Press, Taylor & Francis Group (2020).

PHY 4207	Quantum Information Theory [3-1-0-3]
Prerequisite	PHY 314: Quantum Mechanics 1
Learning Outcomes	• Understanding and appreciating the essential differences between classical and quantum information theory • Get closely acquainted with the qubit which is the basic unit of quantum information processing • Learning about the circuit model of quantum computing and other such approaches to quantum information processing • Studying a few basic quantum algorithms that can be run on quantum information processors to solve certain classes of problems exponentially faster than any known classical algorithm
Syllabus	• Introduction to probabilities: Events, Boolean lattice of events, The axioms of probability, Laws of large numbers [2] • Review of Classical Information Theory: Quantifying information, sequences, Shannon entropy, typical sequences theorem, Shannon's noiseless coding theorem, properties of Shannon entropy, relative entropy, conditional entropy, mutual information, sub-additivity [4] • Review of quantum mechanics: Axioms of quantum mechanics, state space, linear operators, density matrices [2] • Qubits and multiple quantum systems: The single qubit state space, the Bloch ball, representations of one qubit states, Unitary transformations on single qubit states, bipartite quantum systems, tensor product Hilbert spaces and operators on them, quantum entanglement, partial trace operation, two qubit systems [5] • Bell's inequalities and quantum teleportation: Bell states, Pauli representation of Bell states, CHSH-Bell inequality, Tsirilson bound, superdense coding and quantum teleportation. [2] • Quantum measurements with introduction to open quantum dynamics: Measurement models, the Stern-Gerlach case, VonNeumman measurements, Positive Operator Valued Measures (POVM), implementing POVMs, Connecting quantum measurements to open quantum dynamics, Kraus representation theorem, Qubit operations [3] • Quantum circuit model: Simple circuits, universal quantum gates, measurements and operators in circuits, circuit identities [4] • Quantum algorithms: Deutsch Josza algorithm, the quantum Fourier transform, the quantum period finding algorithm and Shor's algorithm [5] • Physical Implementations: Trapped ion and trapped atom implementation, superconducting qubits, semiconducting quantum dot based qubits, NMR quantum information processing, measurement based quantum computing [2] Formal aspects of quantum information theory: VonNeumman entropy, the quantum relative entropy, conditional entropy and mutual information. The strong sub-additivity of VonNeumman entropy [2]
Text & Reference Books	1. M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information , Cambridge University Press, 2010.

MAT 311	Real Analysis [3-0-0-3]
Learning outcomes	Objective is to discuss some of the topological properties of a metric space and study the properties of real valued sequences and functions, such as convergence, limits, continuity, compactness, connectedness, smoothness, integrability.
Syllabus	• Preliminaries: Zorn's lemma, Axiom of choice. (1 hour) • Metric spaces: Properties and examples, open sets, limit points, Bolzano-Weierstrass theorem, derived sets, closed sets, adherent points, closure of a set, nested intervals, Cantor intersection theorem, cover, open cover, subcover, Heine-Borel theorem, converse of Heine-Borel theorem, compact sets, connected sets, completeness, continuous functions, continuity and compactness, continuity and connectedness. (20 hours) • The Riemann-Stieltjes integral: Functions of bounded variation, total variation, bounded variation functions as difference of monotone functions, continuous functions of bounded variations, partitions, definition of Riemann- Stieltjes integral, refinement, existence of the integral, properties of the integral, fundamental theorems of integral calculus, mean value theorems, integration by parts. (12 hours) • Sequences and series of functions: Pointwise and uniform convergence, uniform convergence and continuity, uniform convergence and integration, uniform convergence and differentiation, sufficient condition for uniform convergence of a series, power series and convergence, equicontinuity, Ascoli's theorem, Stone-Weierstrass theorem (7 hours)
Texts and References	1. T. M. Apostol, Mathematical Analysis, 2nd edition, Addison Wesley, 1974. 2. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 4th Edition, Wiley, 2011. 3. R. M. Dudley, Real Analysis and Probability, Cambridge University Press, 2002. 4. S. R. Ghorpade and B. V. Limaye, A Course in Calculus and Real Analysis, Springer, 2006. 5. R. R. Goldberg, Methods of Real Analysis, 2nd edition, Wiley, 1976. 6. S. Lang, Undergraduate Analysis, 2nd edition, Springer, 1996. 7. W. Rudin, Principles of Mathematical Analysis, 3rd edition, McGraw-Hill, 1976. 8. T. Tao, Analysis I, Hindustan Book Agency, 2006. 9. H. L. Royden, Real Analysis, 3rd edition, PHI Learning, 2009.

MAT 312	Theory of Groups and Rings [3-0-0-3]
Learning outcomes	This first course in algebra introduces the group theory, rings and modules. Main focus is abstract group theory. Serves as the prerequisite for several advanced mathematics courses.
Syllabus	• Definition of group, examples of symmetric groups, cyclic groups, multiplicative group Z_n*, Dihedral groups, subgroups and normal subgroups, homomorphisms.(4.5 hours) • Quotient groups, Noether Isomorphism Theorems, Theorems of Lagrange and Cauchy.(4.5 hours) • Group actions, examples of group actions, Cayley's Theorems, Orbit Stabilizer theorem, Class Equation, Burnside's Counting lemma, Sylows theorems.(9 hours) • Direct Products and Semi-Direct Products, Solvable groups, Nilpotent Groups (6 hours) • Rings, Ideals, Ring homomorphisms, subrings, examples of rings, Prime ideals, maximal ideals, Integral domains.(4.5 hours) • Noether Isomorphism theorems, Euclidean domains, PID's, UFD's, Gauss theorem, Eisenstein Criterion for Irreducibility, power series rings.(7.5 hours) • Modules, definitions and examples, Fundamental theorem of finitely generated modules over a PID. (6hours)
Texts and References	1. M. Artin, Algebra, Phi Learning Pvt. Ltd., New Delhi, 2011 2. D. S. Dummit and R.M. Foote, Abstract Algebra, 3rd Edition, Wiley India, 2011 3. Serge Lang, Algeba, 3rd Revised Edition, Springer International Edition.

MAT 313	Linear Algebra [3-0-0-3]
Learning outcomes	This is a more advanced course on linear algebra. The approach is also more abstract and formal as compared to the first year introductory linear algebra course. The course is the prerequisite for almost all the advanced mathematics courses, as well as for several interdisciplinary courses.
Syllabus	• Vector spaces, subspaces, quotient spaces, basis, change of basis, linear functional dual space, projection, eigenvalues and eigenvectors. (5 hours) • Cayley Hamilton Theorem ,invariant subspaces, simultaneous diagonalization, direct sum decomposition, invariant direct sum, the primary decomposition theorem. (9 hours) • Nilpotent Operators, Jordan Canonical form (6 hours) • Inner product spaces, orthonormal basis, Gram-Schmidt process; adjoint operators, least squares problem, normal and unitary operators, self adjoint operators, spectral theorem for self adjoint and normal operators (12 hours) • LU decomposition, QR factorization, Singular Value Decomposition, Orthogonal matrices. (8 hours)
Texts and References	1. S. Axler, Linear Algebra Done Right, Springer, 1997 2. W. H. Greub, Linear Algebra, 4th ed., Springer, 1981. 3. K. Hoffman and R. Kunze, Linear Algebra, 2nd edition, Pearson Education, New Delhi, 2006.

MAT 314	Numerical Analysis [3-0-0-3]
Learning outcomes	This introductory numerics course aims to make the students aware of various classical approximation schemes in order to solve algebraic equations and differential equations. The lab component of this course will enable the students to have hand on experience in implementing numerical schemes.
Syllabus	• Round off errors and Computer Arithmetic (2 hours) • Interpolation: Lagrange interpolation, divided differences, Hermite interpolation, splines. (5 hours) • Numerical differentiation, Richardson extrapolation. (3 hours) • Numerical integration: Trapezoidal, Simpson, Newton- Cotes, Gauss quadrature, Romberg integration. (6 hours) • Solutions of linear algebraic equations: Direct methods, Gauss elimination, pivoting, matrix factorisations; Iterative methods: Matrix norms, Jacobi and Gauss-Siedel methods, relaxation methods.(8 hours) • Computation of eigenvalues and eigenvectors: Power method, Householder's method, QR algorithm. (4 hours) • Numerical solutions of nonlinear algebraic equations: Bisection, Secant and Newton's method, fixed-point iteration. (4 hours) • Initial Value Problems: Euler method, Higher order methods of Runge-Kutta type. Multi-step method, Adams-Bashforth, Adams-Moulton methods. Boundary Value Problems: Shooting methods, Finite differences. (8 hours)
Texts and References	1. K. E. Atkinson, An Introduction to Numerical Analysis, 2nd Edn., JohnWiley, 1989. 2. E. K. Blum, Numerical Analysis and Computation, Theory and Practice, Addison Wesley Publishing Company, 1972. 3. R. L. Burden and J. D. Faires, Numerical Analysis, 7th edition, Brookes/ Cole, 2011. 4. S. D. Conte and C. deBoor, Elementary Numerical Analysis-an algorithmic approach, 3rd edition, McGraw Hill, 1980. 5. J. W. Dummel, Applied Numerical Linear Algebra, SIAM, 1997. 6. C. F. Gerald and P. O. Wheately, Applied Numerical Analysis, 5th edition, Addison Wesley, 1994. 7. G. H. Golub and C. F. vanLoan, Matrix Computations, John Hopkins University Press, 1996. 8. F. B. Hildebrand, Introduction to Numerical Analysis, McGraw Hill, New York, 1974. 9. E. Sueli and F. D. Mayers, An Introduction to Numerical Analysis, Cambridge University Press, 2003. 10. L. N. Trefethen and D. Bau, Numerical Algebra, SIAM, 1997. 11. D. S. Watkins, Fundamentals of Matrix Computations, Wiley, 1991

MAT 315 — Mathematical Statistics [3-0-3-4]

Learning Outcomes

This is the first theory course on statistics. This course provides students with decision theory, estimation, confidence intervals, and hypothesis testing. Students will get hand-on experience in the lab component of the course which will be implemented either in Matlab or R.

Syllabus

- Sampling Distributions: Populations and samples; distribution of samples; graphical representation of data; basic distributions, properties, fitting, and their uses; distribution theory for transformations of random vectors; sampling distributions based on normal populations; t, χ^2 and F distributions. (9 hours)
- Estimation of Parameters: Method of maximum likelihood; applications to different populations; point and interval estimation; method for finding confidence intervals; applications to normal populations; approximate confidence intervals. (9 hours)
- Bivariate Samples: Sample from a bivariate population; least square curve fitting; maximum likelihood estimation; multivariate samples. (7 hours)
- Testing of Hypotheses: Statistical hypotheses - simple and composite; best critical region; application to normal population; likelihood ratio testing; normal and bivariate normal populations and comparison; binomial populations and comparison; Poisson population; multinomial population; χ^2- test of goodness of fit. (15 hours)

Practicals:

- Objects and functions, Arithmetical and Boolean operators, Importing and Exporting Data sets, Packages, Loops and Conditional statements, Measure of central tendency, basic plots.
- Density, distribution function, quantile function and random generation for standard discrete and continuous distributions. Q-Q plots and P-P plots. Fitting distributions. Maximum Likelihood estimation. Generating bivariate random sample. Test for mean, variance, proportion and independency.

Text and References

1. D. Freedman, R. Pisani and R. Purves, *Statistics,* W. W. Norton & Company; 4th edition (2007).
2. R. V. Hogg, J. McKean and A. T. Craig, *Introduction to Mathematical Statistics,* Pearson Education India; 7 edition (2013).
3. A. Mood, F. Graybill and D. Boes, *Introduction to the Theory of Statistics,* McGraw Hill Education; 3 edition (2017).
4. P. J. Bickel and K. A. Doksum, *Mathematical Statistics: Basic Ideas and Selected Topics,* Volume 1. 2nd edition. Chapman and Hall / CRC (2015).
5. Grolemund, Garrett. *Hands-on programming with R: write your own functions and simulations.* O'Reilly Media, Inc., 2014.
6. Schumacker, Randall, and Sara Tomek. *Understanding statistics using R.* Springer Science & Business Media, 2013.
7. Zuur, Alain, Elena N. Ieno, and Erik Meesters. *A Beginner's Guide to R.* Springer Science & Business Media, 2009.

I2D 316 — Machine Learning I [3-0-0-3]

Learning outcomes

- Understanding the theoretical foundations of important learning algorithms.
- Applications of learning algorithms.
- Evaluation of learning algorithms and model selection procedures.

Syllabus

- Review of linear algebra, optimization and probability: Matrices, Eigen values and vectors, gradient, hessian, least squares, optimization; random variables and distributions. (9 hours)
- Definitions, goals and history of Machine Learning; Introduction, linear classification; Classification errors; Regression Techniques. (6 hours)
- Supervised learning (generative/discriminative learning, parametric/non-parametric learning, neural networks, support vector machines); (10 hours)
- Unsupervised learning (clustering, dimensionality reduction, kernel methods); learning theory (bias/variance trade-offs; VC theory; large margins); (10 hours)
- Reinforcement learning and adaptive control. Applications of machine learning (5 hours).

Texts and References

1. Mitchell, Tom. Machine Learning. New York, NY: McGraw-Hill, 1997.
2. Bishop, C. ,M., Pattern Recognition and Machine Learning, Springer, 2006
3. P. Langley, Elements of Machine Learning, Morgan Kaufmann, 1995.
4. Hastie, T., R. Tibshirani, and J. H. Friedman. The Elements of Statistical Learning: Data Mining, Inference and Prediction, Second Edition, Springer, 2009
5. MacKay, David. Information Theory, Inference, and Learning Algorithms. Cambridge, UK: Cambridge University Press, 2003.

I2D 317 — Data Science Lab I [0-0-3-1]

Learning outcomes

- Extraction of information from data.
- Evaluation of algorithms and model selection procedures
- Hands-on experience in handling real world data.

Syllabus

Introduction: What is Data Science?- Big Data and Data Science hype, Introduction to statistical packages (R /Python/ S-Plus / MATLAB / SAS).

Exploratory Data Analysis(EDA) and Statistical Inference: Populations and samples,- Statistical modelling, probability distributions, fitting a model, Exploratory data analysis tools (plots, graphs and summary statistics) of EDA, kernel density estimation; Basic estimation and testing; Random number generator and Monte Carlo samples, Least square Estimation, Inference, Model Checking, Multivariate data analysis - multivariate normal and inference .

Texts and References

1. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk From The Frontline, O'Reilly, 2014.
2. Joel Grus, Data Science from Scratch: First Principles with Python, O'Reilly Media, 2015.
3. Trevor Hastie, Robert Tibshirani and Jerome Friedman. Elements of Statistical Learning: Data Mining, Inference and Prediction, Second Edition, Springer, 2009.
4. Mohammed J. Zaki andWagner Miera Jr. Data Mining and Analysis: Fundamental Concepts and Algorithms. Cambridge University Press. 2014.
5. Jiawei Han, Micheline Kamber and Jian Pei. Data Mining: Concepts and Techniques, Third Edition. Elsevier, 2012.
6. T.W. Anderson, An Introduction to Multuvariate Statistical Analysis, 3rd Edn, Wiley India, 2009.

MAT 321	Complex Analysis [3-0-0-3]
Prerequisite	MAT 311 Real Analysis
Learning outcomes	Objective is to study the complex valued functions and their analytical properties. Complex analysis has several important theorems/constructions, which are very much relevant for more advanced mathematical topics, such as algebraic topology and differential geometry. Also it has a wide applications in various areas of physics and engineering. This course caters for both purposes.
Syllabus	• Geometric representations of Geometric representation of complex numbers, Analytic functions: limits, derivatives, Cauchy-Riemann equations, sufficient conditions, CauchyRiemann equations in polar form, harmonic conjugate. (6 hours) • Mapping by elementary functions: Linear functions, the function 1/z, linear fractional transformations, the logarithmic function and its branches, special fractional transformations. (6 hours) • Cauchy's theorem and Cauchy's integral formula for convex regions, Morera's Theorem, power series representation of analytic functions, zeros of analytic functions, open mapping theorem, maximum modulus principle, Schwarz lemma, Weierstrass' theorem on limits of analytic functions. (12 hours) • Laurent's theorem, classification of singularities, residue theorem, the principal part of a function, poles, quotient of analytic functions, evaluation of improper real integrals, improper integrals involving trigonometric functions, argument principle, Rouche's theorem. (9 hours) • Riemann Mapping Theorem. (7 hours)
Texts and References	1. V. Ahlfors, Complex Analysis, Mcgraw-Hill, 1980. 2. T. W. Gamelin, Complex Analysis, Springer-Verlag, 2001. 3. R. Greene and S. G. Krantz,Function Theory of One Complex Variable, 3rdEdition, GSM, Vol. 40, AMS, 2006. 4. E. M. Stein and R. Shakarchi, Complex Analysis, Princeton University Press, 2003.

MAT 323	General Topology [3-0-0-3]
Prerequisite	MAT 311 Real Analysis
Learning outcomes	This is a first formal course in topology. The main purpose is to cover the point set topology in full details and then to introduce some basics of algebraic topology.
Syllabus	• Topological spaces and continuous functions: Topological spaces, Basis for a topology, The order topology, The product topology, The subspace topology, Closed sets and limit points, Continuous functions, The metric topology, The quotient topology.(12 hours) • Connectedness and Compactness: Connected spaces, connected sets in the real line, Components and path components, Local Connectedness, Compact spaces, Limit point compactness, Local compactness. Tychonoff's theorem for finite products. (12 hours) • Countability and Separation Axioms: The countability axioms, The separation axioms, The Urysohn lemma, The Tychonoff theorem, Completely regular spaces, one-point compactification. (6 hours) • Homotopy, Fundamental Groups, examples and computations, Van Kampen Theorem, covering spaces. (10 hours)
Texts and References	1. J. R. Munkres, Topology, 2nd Edition, Prentice Hall, 2000. 2. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963. 3. J. Dugundji, Topology, Prentice Hall, 1965.

MAT 324	Theory of Ordinary Differential Equations [3-0-0-3]
Prerequisite	MAT 311 Real analysis, MAT 313 Linear algebra
Learning outcomes	This course aims at developing the theory of existence, uniqueness and continuous dependence on data for initial value problems. It also focuses on qualitative properties of solutions of linear and nonlinear systems. Sturm-Liouville theory for boundary value problems are also discussed.
Syllabus	• General theory of initial value problems: Cauchy - Peano existence theorem, sufficient condition for uniqueness, Picard - Lindeloef theorem, existence via fixed point theory, dependence on initial conditions and parameters, continuation and maximal interval of existence. (10 hours) • Linear systems and qualitative analysis: existence and uniqueness of solutions of systems, general properties of linear systems, fundamental matrix solution, stability theory and phase plane analysis, periodic systems. (14 hours) • Nonlinear systems and qualitative analysis: two-dimensional autonomous systems, limit cycles and periodic solutions, Lyapunov's method for autonomous systems, Poincare- Bendixson theory in 2-dimensions. (10 hours) • Boundary value problems: Linear BVP, Green's function, Sturm-Liouville theory, comparison principle, eigenfunction expansion. (6 hours)
Texts and References	1. A. K. Nandakumaran, P. S. Datti and R. K. George, Ordinary Differential Equations - Principles and Applications, Cambridge-IISC Series, Cambridge University Press, 2017. 2. Philip Hartman, Ordinary Differential Equations, 2nd edition, SIAM, 2002. 3. E. A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, McGraw-Hill, 1984. 4. L. Perko, Differential Equations and Dynamical Systems, 3rd edition, Springer, 2006. 5. G. F. Simmons, Differential Equations with Applications and Historical Notes, 2nd edition, McGraw-Hill, 1991. 6. M. W. Hirsch and S. O. Smale, Differential Equations, Dynamical Systems and Linear Algebra, Academic Press, 1974. 7. I. Stakgold, Green's Functions and Boundary Value Problems, Wiley, New York, 1979. 8. G. Birkhoff and G.-C. Rota, Ordinary Differential Equations, 4th edition, Wiley, 2004

MAT 325	Probability and Stochastic Processes [3-0-0-3]
Learning outcomes	This course will introduce the theory in discrete and continuous time stochastic processes with the aim towards applications in queuing theory, random network and financial market.
Syllabus	• Review of Probability: Events and probability; random variables; conditional probability; independence. (2 hours) • Conditional Expectation: Conditioning on an event; conditioning on a discrete random variable; conditioning on an arbitrary random variable; some applications (e.g. Polya's urn model, a random graph). (6 hours) • Markov Chains: Chapman-Kolmogorov equations; classification of states; limiting probabilities; the Gambler's Ruin problem; birth and death chains; branching and queuing chains.(10 hours) • Markov Pure Jump Processes: Poisson process - exponential distribution and lack of memory, construction of the Poisson process, properties; birth and death processes; properties of a Markov pure jump process; applications. B r o w n i a n Motion: General notions;(10 hours) • Brownian motion - Definition and basic properties, increment of Brownian motion, sample paths; hitting times; variations on Brownian motion - Brownian motion with drift, geometric Brownian motion; the Gaussian and Wiener processes; applications. (12 hours)
Texts and References	1. S. M. Ross, Introduction to Probability Models, 11th edition (2014), Elsevier. 2. P. G. Hoel, S. C. Port and C. J. Stone, Introduction to Stochastic Processes, Waveland Pr Inc (1986). 3. G. R. Grimmett and D. R. Stirzaker, Probability and Random Processes, 3rd edition (2001), Oxford University Press. 4. G. R. Grimmett and D. R. Stirzaker, One Thousand Exercises in Probability, Oxford University Press (2001). 5. J. R. Norris, Markov chains, Cambridge University Press (1997).

I2M 321	Scientific Computing [3-0-3-4]
Learning outcomes	• Apply standard techniques to analyse key properties of numerical algorithms, such as stability and convergence. • Understand and analyse common pitfalls in numerical computing such as ill-conditioning and instability. • Perform data analysis efficiently. • Derive and analyse numerical methods for constrained and unconstrained optimisation problems. • Introduce the basics of Monte Carlo methods

Syllabus	• Brief review of the sources of error and local analysis: Relative error, absolute error, and cancellation; Computer arithmetic; Truncation error; Error propagation and amplification; Condition number and ill-conditioned problems. (3 hours)
	• Numerical linear algebra: Direct solution methods for linear systems, Gaussian elimination and its variants; LU, QR,Singular value decomposition, Iterative methods for a linear system, Stationary iterative methods- Jacobi, Gauss-Seidel, and successive over-relaxation methods. Non-stationary iterative methods-conjugate gradient (CG), convergence analysis; preconditioning.Estimation and computation ofÂ eigenvalues- Gershgorin disc, power methods, the QR algorithm, Chebyshev polynomials and Chebyshev semi-iterative methods. (18 hours)
	• Nonlinear equations and optimisation:
	  • Unconstrained Optimisation: Optimality conditions, steepest descent method, Newton and quasi-Newton methods, General line search methods, Trust region methods, Least squares problems and methods. (6 hours)
	  • Constrained Optimisation: Optimality/KKT conditions, penalty and augmented Lagrangian for equality-constrained optimisation, interior-point/barrier methods for inequality constrained optimisation. SQP methods. (8 hours)
	• Monte Carlo methods: Basic review of probability; Random number generators, Sampling, Error bars, Variance reduction. (5 hours)

Texts and References	1. L. N. Trefethen and D. Bau III, Numerical Linear Algebra, SIAM, 1997. 2. J. W. Demmel, Applied Numerical Linear Algebra, SIAM, 1997. 3. A. Greenbaum, Iterative Methods for Solving Linear Systems, SIAM, 1997. 4. G. H. Golub and C. F. van Loan, Matrix Computations, John Hopkins University Press, 1996. 5. H. C. Elman, D. J. Silvester and A. J. Wathen, Finite Elements and Fast Iterative Solvers, Oxford University Press, 1995. 6. J. Nocedal and S. J. Wright, Numerical Optimisation, Springer, 2006. 7. D. P. O'Leary, Scientific Computing with Case Studies, SIAM, 2009.

I2M 322	Mathematical Modelling [3-0-0-3]
Prerequisite	MAT 313 Linear Algebra
Learning outcomes	• This course will introduce student to mathematical models of real world problems • Emphasis is on the use of elementary functions to investigate and analyze applied problems and questions. • Linear, exponential, logarithmic, and polynomial function models will be discussed with examples taken from physics, biology, chemistry, and other fields.
Syllabus	• Introduction- Modelling philosophy: Why model? What's a good model? Model validation. Simple and complex models, simulation vs. modelling, stochastic vs. deterministic. Example problems: Growth of a Yeast Culture, Spread of a Contagious Disease, Decay of Digoxin in the Bloodstream, Heating of a Cooled Object. (4 hours) • Probabilistic models :Monte Carlo (Buffon's needle, profit vs. risk, Bernoulli trials, Poisson distributions), Markov Chain Applications to the inventory problem, the queuing problem, genetics, gambling, and the Internet and Google's Page Rank algorithm. (12 hours) • The Modelling Process, Proportionality, and Geometric Similarity: Example from Model Fitting, Experimental Modelling, Simulation Modelling, Discrete Probabilistic Modelling, Optimization of Discrete Models. (8 hours) • Modelling with a Differential Equation: Population Growth. Prescribing Drug Dosage, A Predator-Prey Model, A Competitive Hunter Model, Two competing species: deadly survival struggle between sheep and Rabbits. Introduction to phase plane, fixed points, stability, classification of linear systems, nonlinear limit cycles. Predator-prey oscillations, Lotka-Volterra equations. Application to epidemiology, Numerical Approximation Methods. (16 hours)
Texts and References	1. Giordano, F. R., Fox W. P., and Horton S. B. (2014), A first course in mathematical modeling, Brooks/Cole. 2. Li, Michael Y. (2018), An Introduction to Mathematical Modeling of Infectious Diseases, Springer 3. Heinz, Stefan(2011), Mathematical modeling, Springer.

MAT 411 Measure Theory [3-0-0-3]

Prerequisite

MAT 311 Real analysis

Learning outcomes

The Riemann integral, dealt with in calculus courses and also in Real Analysis course, is well suited for computations but less suited for dealing with limit processes. In this course, we will introduce the so called “Lebesgue integral”, which keeps the advantages of the Riemann integral and eliminates its drawbacks. At the same time we will develop a general theory which serves as the basis of contemporary analysis and probability.

Syllabus

- Outer measure, σ-algebra of measurable sets and its properties, Lebesgue measure and its properties, a non- measurable set, measurable functions. (9 hours)
- Lebesgue integral of Simple functions, Lebesgue integral of a bounded function, bounded convergence theorem, Lebesgue integral of nonnegative measurable functions, Fatou’s Lemma, monotone convergence theorem, the general Lebesgue integral, Lebesgue dominated convergence theorem. (12 hours)
- Differentiation and integration: Differentiation of monotone functions, functions of bounded variation, differentiation of an integral, absolute continuity. (9 hours)
- L^p-spaces: Definition and properties, Minkowski’s inequality and Holder’s inequality, convergence and completeness of L^p, approximation in L^p, bounded linear functionals on L^p spaces. (10 hours)

Texts and References

1. K. B. Athreya and S. N. Lahiri, Measure Theory, Hindustan Book Agency, 2006.
2. G. Debarra, Measure Theory and Integration, New Age International,1981.
3. G. B. Folland, Real Analysis: Modern Techniques and Their Applications, 2nd edition, John Wiley and Sons, 1999.
4. P. R. Halmos, Measure Theory, Springer, 2009.
5. H. L. Royden, Real Analysis, 3rd edition, PHI Learning, 2009.
6. W. Rudin, Real and Complex Analysis, 3rd edition, McGraw-Hill Education (India) Ltd, 2007.
7. E. M. Stein and R. Shakarchi, Real Analysis: Measure Theory, Integration, and Hilbert Spaces, Princeton University Press, 2005.
8. T. Tao, An Introduction to Measure Theory, GSM, Vol.126, AMS, 2011.
9. M. Taylor, Measure Theory and Integration, American Mathematical Society, 2006.

MAT 414 Partial Differential Equations [3-0-0-3]

Prerequisite

MAT 324 Theory of Ordinary Differential Equations

Learning outcomes

This course aims at developing theory of first order partial differential equations as well as three second order linear partial differential equations.

Syllabus

- First order partial differential equations: first order nonlinear equations, Charpit’s equations, Cauchy problem, the complete integral; Hamilton- Jacobi equations, calculus of variations, Hopf-Lax Formula. (10 hours)
- Second order linear partial differential equations: Laplace’s equation, fundamental solution, mean value formulas, Green’s function, maximum principle, energy methods; Heat equation, fundamental solution, mean value formulas, energy methods; Wave equation, solution by spherical means, non-homogeneous problem, energy methods. (30 hours)

Texts and References

1. Lawrence C. Evans, Partial Differential Equations, 2nd Edition, American Mathematical Society, 2010.

MAT 414	Partial Differential Equations [3-0-0-3]
	2. R. McOwen, Partial Differential Equations: Methods and Applications, 2nd Edition, Pearson, 2002. 3. Gerald B. Folland, Introduction to Partial Differential Equations, 2nd Edition, Princeton University Press, 1995. 4. Fritz John, Partial Differential Equations, 4th Edition, Springer, 1981.

MAT 415	Programming and Data Structures [3-0-3-4]
Learning outcomes	• Learn to define operations on data structures like arrays, linked lists, trees and graphs • Learn to design algorithms involving these data structures • Learn to analyze simple algorithms and solve recurrences, asymptotic analysis.
Syllabus	• Introduction- Algorithm Analysis, Finding Complexity. Fundamental data structures - List- Sorted Lists, Double Linked Lists, Stack & Queue application. (10 hours) • Binary Trees – Insertion and Deletion of nodes, Tree Traversals, Polish Notations, Red Black Trees, B-Trees, Heaps, Priority Queues. (10 hours) • Sorting – Bubble, Selection, Insertion, Merge Sort, Quick Sort, Radix Sort, Heap sort. Searching. (10 hours) • Graphs- Shortest path algorithms, Minimum Spanning Trees, BFS, DFS. (10 hours)
Texts and References	1. Clifford A Shaffer, Data Structures and Algorithm Analysis, Edition 3.2 (Java Version), 2011. 2. Robert L. Kruse, Data Structures And Program Design In C++, Pearson Education, Second Edition, 2006 3. Michael T. Goodrich, Roberto Tamassia, Michael H. Goldwasser. Data Structures And Algorithms In JavaTM Sixth Edition, Wiley Publishers, 2014. 4. Mark Allen Weiss Data Structures And Algorithm Analysis In Java, Third Edition, 2012.

I2M 411	Applied Stochastic Analysis [3-0-0-3]
Prerequisite	MAT 311 Real Analysis, MAT 325 Probability and Stochastic Processes
Learning outcomes	This course will introduce the major topics in stochastic analysis from an applied mathematics perspective, and will be a continuation of the course on *Probability & Stochastic Processes*. The course will pay particular attention to the connection between stochastic processes and ODEs and PDEs, as well as to physical principles and applications.
Syllabus	• Review of Markov Chains (Discrete and Continuous time), Gaussian Processes and Stationary Processes; (3 hours) • Brownian Motion; (7 hours) • Stochastic Integration; (10 hours) • Stochastic Differential Equations; (10 hours) • Applications from finance and biology; (7 hours) • Numerically solving SDEs (basic concepts). (3 hours)
Texts and References	1. Stochastic Processes and Applications, G. A. Pavliotis, Springer Verlag (2014). 2. Stochastic Methods: A Handbook for the Natural and Social Sciences, C. Gardiner, 4th Edition, Springer (2009). 3. Stochastic Differential Equations, B. Oksendal, 6th Edition, Springer (2014).

I2M 412	Numerical Solutions of Differential Equations [3-0-0-3]
Prerequisite	MAT 313 Linear Algebra, MAT 314 Numerical Analysis
Learning outcomes	• Understand the key-ideas, concepts and definitions of the computational algorithms, sources of errors, convergence theorems. • Implement a given algorithm in a programming language and test and validate codes to solve a given differential equation numerically. • Choose the best numerical method to apply to solve a given differential equation and quantify the error in the numerical (approximate) solution. • Analyse an algorithm's accuracy, efficiency and convergence properties.
Syllabus	• Numerical methods for initial value problems (IVPs): Euler forward and backward methods, stability analysis, error estimates. Higher order methods, Runge-Kutta methods, convergence, Multistep methods, Predictor corrector methods. Stiff ODEs: Implicit-explicit (IMEX) method. (10 hours) • Numerical methods for boundary value problems (BVPs): Shooting method, Finite difference schemes, consistency, truncation error, stability and convergence, Galerkin collocation method. (6 hours) • Numerical methods for partial differential equation: Review of Poisson equation in one dimension, finite difference method for Poisson equation, stability and convergence, finite difference method for heat equation, Crank-Nicolson method, theta method, alternate direction implicit methods (ADI methods), CFL condition, stability and convergence, finite difference method for linear advection equation, method of lines, upwind scheme, CFL condition, stability and convergence. (14 hours) • Practicals: Implementation of the above algorithms, demonstration of stability, truncation error and order of accuracy. (10 hours) Optional topics: • Numerical methods for differential algebraic equations (DAEs), Keller-box method, numerical methods in polar coordinates.
Texts and References	1. Numerical Analysis, R. L. Burden and J. D. Faires. 2. An introduction to numerical analysis, Endre Suli and David F. Mayers 3. Numerical solution of ordinary differential equations, K. Atkinson, W. Han and D. Stewart 4. K. W. Morton and D. F. Mayers, Numerical Solution of partial differential equations

MAT 421	Functional Analysis [3-0-0-3]
Prerequisite	MAT 411 Measure Theory
Learning outcomes	Based on core analysis courses and linear algebra, this course builds further on the study of Banach and Hilbert spaces. The theory and techniques studied in this course support, in a variety of ways, many advanced courses, in particular in analysis and partial differential equations, as well as having applications in mathematical physics and other areas.
Syllabus	• Normed linear spaces, Riesz lemma, characterization of finite dimensional spaces, Banach spaces. Operator norm, continuity and boundedness of linear maps on a normed linear space. (6 hours) • Fundamental theorems: Hahn-Banach theorems, uniform boundedness principle, divergence of Fourier series, closed graph theorem, open mapping theorem and some applications. (8 hours) • Dual spaces and adjoint of an operator: Duals of classical spaces, weak and weak* convergence, adjoint of an operator. (5 hours) • Hilbert spaces: Inner product spaces, orthonormal set, Gram-Schmidt ortho-normalization, Bessel's inequality, orthonormal basis, separable Hilbert spaces. Projection and Riesz representation theorems: Orthonormal complements, orthogonal projections, projection theorem, Riesz representation theorem. (10 hours) • Bounded operators on Hilbert spaces: Adjoint, normal, unitary, self-adjoint operators, compact operators. (5 hours) • Spectral theorem: Spectral theorem for compact self adjoint operators, statement of spectral theorem for bounded self adjoint operators. (6 hours)
Texts and References	1. R. Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, 2009 2. S. Kesavan, Functional Analysis, Hindustan Book Agency, 2014. 3. B. V. Limaye, Functional Analysis, New Age International, 2014. 4. V. S. Sundar, Functional Analysis: Spectral Theory, Birkhauser, 1998. 5. J. B. Conway, A Course in Functional Analysis, Springer, 1997. 6. M. Schechter, Principles of Functional Analysis, AMS (Indian Edition Uni. Press), 2009. 7. P. D. Lax, Functional Analysis, Wiley-Inter Science, 2002. 8. M. Reed and B. Simon, Functional Analysis (Methods of Modern Mathematical Physics - Volume 1), Academic Press, 1981. 9. Y. Eidelman, V. Milman and A. Tsolomitis, Functional Analysis: An Introduction, GSM, Vol. 66, AMS, 2004. 10. B. Bollabas, Linear Analysis, Cambridge University Press (Indian edition), 1999.

I2M 521	Variational Methods and Control Theory [3-0-0-3]
Prerequisite	MAT 324 Theory of Ordinary Differential Equations
Learning outcomes	The larger aim of this course is to train students in an area of application-oriented mathematics that deals with the basic principles underlying the analysis and design of control systems.
Syllabus	• Calculus of variations; (6 hours) • Introduction to classical control theory; (6 hours) • Controllability, rank condition, Kalman decomposition, observability; (8 hours) • Stability and Lyapunov theory, stabilisation; (6 hours) • Optimal control problems, Pontryagin's maximum principle, Ekeland's principle; (8 hours) • Dynamic programming principle. (6 hours)
Texts and References	1. Mathematical Control theory, An Introduction, J Zabczyk, Birkhauser (2007). 2. Deterministic and Stochastic Optimal Control, W H Flemming and R W Rishel, Springer (1982). 3. Optimal Control and Calculus of Variations, E R Pinch, Oxford University Press (1993).

I2M 522	High Performance Computing [3-0-0-3]
Prerequisite	I2M 321 Scientific Computing
Learning outcomes	• Explain how large-scale parallel systems are architectured and how massive parallelism are implemented in accelerator architectures. • Write parallel programs for large-scale parallel systems, shared address space platforms, and heterogeneous platforms. • Design efficient parallel algorithms and applications. • Be conversant with performance analyse and modelling of parallel programs. • Perform optimisation using well-established algorithms. • Implement a range of numerical algorithms efficiently in a modern scientific computing programming language.
Syllabus	There will be four major aspects of the course: • Part I will start with current trends in high-end computing systems and environments, and continue with a practical short description on parallel programming with MPI, OpenMP, and Pthreads. (12 hours) • Part II will illustrate the modelling of problems from physics and engineering in terms of partial differential equations (PDEs), and their numerical discretization using finite difference, finite element, and spectral approximation. (12 hours) • Part III will be on solvers: both iterative for the solution of sparse problems of part II, and direct for dense matrix problems. Algorithmic and practical implementation aspects will be covered. (9 hours) • Finally in Part IV, various software tools will be surveyed and used. This will include PETSc, Sca/LAPACK, MATLAB, and some tools and techniques for scientific debugging and performance analysis. (7 hours)
Texts and References	The Sourcebook of Parallel Computing, Edited by Jack Dongarra, Ian Foster, Geoffrey Fox, William Gropp, Ken Kennedy, Linda Torczon, Andy White, Morgan Kaufmann Publishers (2002).

I2M 523	Finite Element Methods [3-0-0-3]
Prerequisite	MAT 414 Partial Differential Equations
Learning outcomes	• This course provides a mathematical introduction to finite elements and how to apply it to basic partial differential equations (PDEs). At the end of the course the students would have gained familiarity with algorithms for numerically solve PDEs on complex domains, software tools implementing the FEM, and scope for learning how to solve multiphysics application problems.The course builds on elementary calculus, analysis and linear algebra and, of course, requires some acquaintance with partial differential equations. Numerical analysis would be helpful but is certainly not essential. Function Space material will be introduced in the course as needed.
Syllabus	• Examples of PDEs, introduction to Sobolev spaces, Weak (variational) formulation of elliptic boundary-value problems of second order, natural and essential boundary conditions, Ritz-Galerkin method, some standard finite elements. (8 hours) • General finite element theory. V-ellipticity, Lax-Milgram, Cea's lemma, error estimates in the energy norm, examples of finite elements including standard continuous Lagrange elements and non-conforming finite elements. Finite element methods for time-dependent problems.(12 hours). • Data Structures and Implementation : The mesh data structure, programming the finite element method: Linear Lagrange triangles, Lagrange triangles of arbitrary degree, numerical integration, assembling global matrices, and solution of the algebraic systems.(8 hours). • Multi-physics applications - heat and mass transfer and fluid dynamics and chemical reactions, theory of elasticity, multiphase systems, static electric and magnetic fields and interaction with matter, electrodynamics, wave optics. Solving the Schrödinger equation in different potentials, Electrical transport in microsystems, sensors and allied devices.(12 hours)
Texts and References	1. Claes Johnson, Numerical Solution of Partial Differential Equations by the Finite Element Method,Cambridge University Press, 19872 2. S. C. Brenner and L. R. Scott, The Mathematical Theory of Finite Element Methods, Springer-Verlag,New York, 1994. 3. S. M. Muhsa, "Computational Finite Element Methods in Nanotechnology", CRC Press 2013. 4. R. Pryor, "Multiphysics Modeling Using COMSOL 4", Mercury Learning, 2012. 5. S. Ganesan, L. Tobiska, Finite Elements: Theory and Algorithms, Cambridge IISc Series, Cambridge Univesity press, 2016.

Elective Courses

Focus Area: Biological Sciences

I2M/I2B 4XXX	Mathematical Biology [3-0-0-3]
Learning outcomes	This course is an exploration in applications of mathematics to various biological, ecological, physiological, and medical problems. By the end of this course, students will be able to derive, interpret, solve, simulate, understand, discuss and critique discrete and differential equation models of biological systems. Lab component of the course will be Python based.
Syllabus	• Introduction to discrete models • Discrete models of breathing, tumour initiation • Nonlinear discrete equations - steady states, stability, bifurcations • Nonlinear Systems: The Nicholson-Bailey Model • Continuous Models; The Spruce Budworm Outbreak Model, The Chemostat/Phase Portraits; Models in Immunology, Tumour-Immune Interactions • Multiple Species Models; The SIR and STD models
Texts and References	1. Leah Edelstein-Keshet, Mathematical Models in Biology, Magraw-Hill, 1988

I2M/I2B	4XXX Biostatistics [3-0-0-3]
Learning outcomes	This is an essential and important course for a student of biology, as statistics is critical to conclude any biological results. The course will cover basic of statistics, standard and advanced statistical that are routinely used in interpreting biological data and in health sciences. Students will also be trained to use R statistical package.
Syllabus	• Introduction to statistics for biologists • Summarizing and visualizing data • Probability & distributions • Methods of sampling • Hypothesis testing • Parametric & non-parametric tests • ANOVA • Correlation & regression • Survival analysis • Non-linear curve fitting • R for biostatistics
Texts and References	1. Michael C. Whitlock and Dolph Schluter, The Analysis of Biological Data, Roberts And Company Publishers, 2015 2. Steve McKillup, Statistics Explained : An Introductory Guide for Life Scientists, Cambridge University Press, 2006 3. Calvin Dytham, Choosing and Using Statistics : A Biologist's Guide, Wiley-Blackwell, 2011

I2M/I2B 4XXX	Systems Biology [3-0-0-3]
Learning outcomes	Fast evolving multidisciplinary field that combines the power of mathematical & statistical models to decipher the functioning of biological systems. This is a multidisciplinary course, designed for applicants with a biological, biomedical, physical, computational or mathematical background. It equips students with the necessary skills to produce effective research in systems biology. After completing this course, students will have acquired an understanding of research topics is several areas of theoretical systems biology, which has wide-range of application in big-data analysis.
Syllabus	• Introduction to Systems Biology • Mathematics of Biological Systems • Networks structure, dynamics & modeling • Data formats & Simulations • Discrete, stochastic & spatial models • Variability, Robustness & Information
Texts and References	1. Systems Biology, Edda Klipp, Christoph Wierling, Wolfram Liebermeister, Axel Kowald, Ralf Herwig, Hans Lehrach, 2nd Edition, Wiley 2009 2. Mathematical Modeling in Systems Biology, Brian Ingalls, MIT Press 2013

I2M/I2B	4XXX Bioinformatics [3-0-0-3]
Learning outcomes	This is an application oriented course meant for not only for the students of biology but also of mathematics, who would benefit from learning the computational tools and methods in biological data analysis to take advantage of massively developing biological data. Topics will cover basics of bioinformatics to advanced algorithms in next-generation sequence analysis.
Syllabus	• Biological data & sources • Methods for data exploration • Concept of data mining • DNA sequence analysis • BLAST • Remote homology searched • Motif finding algorithms • Protein bioinformatics • RNA structure analysis • Next generation sequencing and principles of NGS data analysis • R for bioinformatics
Texts and References	1. Bioinformatics, David Mount, CSHL, 2003 2. Bioinformatics & Functional Genomics, Jonathan Pevsner, Wiley 2015 3. M. Michael Gromiha, Protein Bioinformatics : From Sequence to Function, Elsevier, 2010

I2M/I2B 5XXX	Stochastic Modelling of Biological Processes [3-0-0-3]
Learning outcomes	This course provides an introduction to stochastic methods for modelling biological systems, covering a number of applications, ranging in size from molecular dynamics simulations of small biomolecules to stochastic modelling of groups of animals.
Syllabus	• Stochastic simulation of chemical reactions in well-stirred systems: Gillespie algorithm, chemical master equation, analysis of simple systems, deterministic vs. stochastic modelling. • Review of stochastic differential equations; numerical methods, Fokker-Planck equation, first exit time, backward Kolmogorov equation, chemical Fokker-Planck equation. • Stochastic reaction-diffusion modelling: compartment-based (lattice-based) models, reaction-diffusion master equation, Brownian dynamics, diffusion-limited reactions. • Molecular dynamics: molecular mechanics, generalised Langevin equation. • Stochastic models of dispersal in biological systems: velocity-jump processes, bacterial chemotaxis, collective animal behaviour.
Texts and References	1. R. Erban, S. J. Chapman and P. K. Maini, A practical guide to stochastic simulation of reaction-diffusion processes (2007) Available at http://arxiv.org/abs/0704.1908 2. H. Berg, Random Walks in Biology (Princeton University Press, 1993). 3. D. T. Gillespie, Markov Processes, an Introduction for Physical Scientists (Gulf Professional Publishing, 1992). 4. P. Attard, Non-Equilibrium Thermodynamics and Statistical Mechanics, (Oxford University Press, 2012). 5. A. Nitzan, Chemical Dynamics in Condensed Phases, (Oxford University Press, 2006). 6. P. Krapivsky, S. Redner and E. Ben-Naim, A Kinetic View of Statistical Physics, (Cambridge University Press, 2010). 7. D. Anderson, T. Kurtz, Stochastic Analysis of Biochemical Systems, (Springer, 2015). 8. B. Leimkuhler, C. Matthews, Molecular Dynamics: with Deterministic and Stochastic Numerical Methods, (Springer, 2015).

Other Elective Courses

I2M 5XXX	Computational Stochastic Modelling [3-0-0-3]
Prerequisite	I2M 421 Applied Stochastic Analysis, I2M 422 Numerical Solutions of Differential Equations
Learning outcomes	Most physical and biological phenomena are modelled by stochastic differential equations (SDEs). This course aims to provide a strong numerical background on solving techniques of SDEs.
Syllabus	• Basics of Monte Carlo simulation: Central Limit Theorem, confidence interval, mean square error decomposition for a biased estimator • Brownian motion / Wiener process: definition and basic properties. SDEs: Ito and Stratonovich forms, as limits of discrete approximations, informal derivation of Ito calculus • Numerical methods for SDEs: Euler, Milstein, predictor-corrector and implicit Euler • Definitions of weak and strong convergence. Numerical determination of order of convergence • Multi-dimensional SDEs and Levy areas. Clark-Cameron result on the strong order of convergence for multidimensional SDEs • Markov, Holder, Jensen and Doob's martingale inequalities. Gronwall and Burkholder-Davis-Gundy inequalities • Analysis of strong convergence of Euler-Maruyama discretisation • Multilevel Monte Carlo (by Milstein discretisation) • Mean-square strong stability: definition and analysis Optional topic: • Parabolic SPDE driven by Brownian motion. Numerical analysis of accuracy and stability
Texts and References	1. Numerical Solution of Stochastic Differential Equations, Peter E. Kloeden and Eckhard Platen, Springer-Verlag (1992)

I2M 4XXX	Methods of Applied Mathematics [3-0-0-3]
Prerequisite	MAT 311 Real analysis, MAT 313 Linear algebra
Learning outcomes	Introduction to the various solving techniques useful in applied sciences
Syllabus	• Perturbation Methods and Asymptotic Expansions • Integral equations, Green's functions, Fredholm theory, Hilbert-Schmidt theorem
Texts and References	1. Methods of Applied Mathematics, F B Hildebrand, 2nd Edition, Dover Publications. 2. Applied Mathematics, J David Logan, 3rd Edition, Wiley Interscience.

PHY 311	Mathematical Methods in Physics (3003)
Learning Outcomes	1. Illustrate the properties of a Sturm Liouville eigenvalue problem. 2. Solve homogeneous linear Ordinary Differential Equation (ODE) using the series method and Wronskians. 3. Solve homogeneous linear Partial Differential Equation (PDE) using separation of variables. 4. Apply special functions to several physical problems. 5. Solve non-homogeneous ODE/PDE using Green's function. 6. Classify a complex function and its singularities. 7. Perform Taylor/Laurent expansion of complex functions. 8. Perform non trivial real integrals using the method of contour integrals and residue theorem.
Layout	• Ordinary differential equations [12]: Linear equations: Solution space, linear independence, Wronskians. Eigenvalue problems: Boundary conditions, self-adjointness, completeness of Eigen functions, Fourier series, continuous spectrum and Fourier integrals. Series solution; Green Functions for ordinary differential operators. • Partial Differential equations [10]: Preliminaries, important partial differential equations (e.g. heat and wave equations, Poisson and Laplace equations, Helmholtz equation), Solution by separation of variables in Cartesian and spherical polar coordinate systems; Green's function for partial differential operators. • Special functions and Applications [4]. • Complex Analysis [12]: Functions of complex variable, limits and continuity, derivatives, analyticity, Cauchy-Riemann conditions, Types of singularities with examples, Contour integrals, Cauchy's theorem, Cauchy's integral formula, Morera's theorem, Taylor series, Laurent series, Calculus of residues: Residue theorem, definite real integrals using residue theorem, Cauchy's principal value.
Text & Reference Books	1. G. B. Arfken and H. J. Weber, Mathematical methods for physicists, Elsevier; 7Ed, (2012) 2. M Spiegel, S Lipschutz, J Schiller and D Spellman, Schaum's Outline of Complex Variables, 2Ed (Schaum's Outline Series). McGraw Hill Education; (2017)

PHY 312	Classical Mechanics (3003)
Learning Outcomes	1. Apply techniques like least action principles and calculus of variations on intuitively understandable models of classical objects in motion. 2. Compute motion of objects within a classical framework e.g. motion under a central force, motion of rigid bodies, oscillators etc. using the mathematical techniques developed over the 17th, 18th and 19th centuries.
Layout	• Variational Principle and Lagrange's equation: [9 hours] Review of Newtonian mechanics, Hamilton's Principle, Calculus of Variations, Constraints and generalised coordinates, Derivation of Lagrange's equation using Hamilton's principle, Extension of Hamilton's principle for non-holonomic systems, The Lagrangian for a free particle and for a system of particles, Symmetries, Conservation laws and Noether's theorem, Conservation of energy, momentum and angular momentum. • Central Force Motion: [6 hours] Reduction of the two body central force problem to the equivalent one body problem. Integrating the equations of motion: Equivalent problem in one dimension and classification of orbits. Conditions for closed orbits (Bertrand's theorem). Kepler's problem, Laplace-Runge-Lenz vector. Scattering in a central force field and Rutherford's formula. • Rigid Body Motion: [6 hours] coordinates of a rigid body, orthogonal transformation and its properties, Euler angles, Euler's theorem on motion of rigid bodies, Finite Rotations and Infinitesimal Rotation, Motion in a non-inertial frame. Motion of a rigid body, Angular velocity and Kinetic energy, Inertia Tensor, Moment of inertia, Principal axis transformation. Euler's equations, Example of a heavy symmetrical top with one point fixed. • Small oscillations: [6 hours] Eigenvalue equation and principal axis transformation, frequency of free vibration and normal coordinates, Example of a linear triatomic molecule. Forced, damped and anharmonic oscillations. • Hamiltonian Formulation: [9 hours] Legendre transformations, The Hamilton equations of motion, Cyclic coordinates, Routhian; Principle of least action, Invariance properties of the Lagrangian and Hamiltonian descriptions, Canonical Transformations, Poisson and Lagrange brackets; Hamilton-Jacobi theory and action-angle variables with examples (Harmonic oscillator, Kepler problem).
Text & Reference Books	1. Goldstein, C. Poole and J. Safko, Classical Mechanics, 3rd Ed. Addison Wesley, 2005. 2. L. D. Landau and E. M. Lifshitz, Mechanics, Vol. 1 of course of Theoretical Physics, Pergamon Press, 2000. 3. S G Rajeev, Advanced Mechanics, Oxford University Press, 2013

PHY 313	Electronics (3003)
Learning Outcomes	1. Comprehend working principles of common electronic components & circuits 2. Apply circuit analysis to analyse and evaluate electronic circuits 3. Comprehend electrical properties of semiconductors and their control 4. Apply pn junction physics and its characteristics for designing devices 5. Analysis and applications of transistors and operational amplifiers 6. Differentiate between analog and digital devices. 7. Appreciate the basics of digital electronics and their operation
Layout	• Introduction to conductors, semiconductors and insulators. Band structure, Fermi level, mechanism of conduction in metals and semiconductors, mobility and conductivity, intrinsic and extrinsic semiconductors, doping, donor and acceptor levels, carrier lifetime (8 hours). • PN junction formation. Basic semiconductor devices: PN junctions, band structure in open circuit PN junction, depletion region, PN Diode: IV characteristics and its temperature dependence, space charge capacitance, diode resistance, half-wave and full-wave, ripple factor, filters: L, C, RC, LC and LCR filters. (6 hrs) • Bipolar transistors and operation: PNP and NPN transistors, transistor currents, active, saturation and cut-off regions. Common emitter amplifier. AC and DC analysis of transistor circuits amplifiers and differential amplifiers. Operating principles of FET, MOSFET. (8 hours) • Operational amplifiers: Ideal op-amp characteristics, common-mode rejection ratio, inverting and non-inverting configurations. FET amplifier, Op-Amp based circuits e.g. summing amplifier, logarithmic amplifier, pulse generator, differentiator, and integrator. (10 hours) • Digital Electronics: Boolean algebra, De Morgan's theorem, Karnaugh Map, Logic gates, adder circuits. Digital analog and Analog Digital Converters. Flip-flops, Counters and Shift registers. (4 hrs)
Text & Reference Books	1. A. Malvino and D. J. Bates, Electronic principles, Mcgraw-hill, 2006. 2. J. Millman, C. C. Halkias and S. Jit, Electronic devices and circuits, Tata Mcgraw Hill, 2007. 3. J. Millman, and C. C. Halkias, Integrated electronics, Tata Mcgraw Hill, 2008. 4. S. M. Sze, Semiconductor Devices, Physics and Technology (2nd Ed.), Wiley India, 2008. 5. T. L. Floyd and R. P. Jain, Digital Fundamentals (8th Ed.), Pearson Education, 2005.

PHY 314	Quantum Mechanics (3003)
Learning Outcomes	1. Solving time independent and time dependent Schrodinger equations for wave functions for simple 1D potentials. Calculate probability, probability current density, reflection and transmission coefficients. 2. Learn linear algebra, linear vector space and operator methods and apply principles of quantum mechanics to determine wave functions and calculate observables. 3. Solve Schrodinger equation for simple three-dimensional/spherically symmetrically potentials and determine the wave function and various quantum numbers
Layout	• Quantum Origins: (3): Particle aspect of radiation, Wave aspect of particles, Quantum measurements • Mathematical tools of Quantum Mechanics:The state vector, Dirac Bra and Ket notation, Hilbert space and some general properties of linear vector spaces, Rays and vectors in Hilbert space, Normalisation, Basis vectors.(4) • Non-commutating operators and observables, Operators, eigenvalues, eigenvectors, observables and expectation values Quantum amplitudes, probabilities and the Born rule. (4) • A basis labelled by a continuous parameter and the wave function, The position and momentum bases, Fourier transforms, Delta function normalisation, Function spaces, The uncertainty principle revisited, The probability current and the continuity equation. (4) • Postulates of Quantum mechanics: (3) Quantum Kinematics, Quantum measurements, Quantum Dynamics (Hamiltonian and Schrödinger equation) • General properties of the Schrödinger equation: (4) Properties of wave functions; Probability density, Current density, and Continuity equation; The time-independent Schrödinger equation, Energy eigenstates; Time-dependent Schrödinger equation; Stationary states; Decomposition of initial state in terms of stationary states; Evolution of the state in terms of the stationary states and their eigenvalues; Finite time evolution and unitary transformations, properties of unitary transformations; Time evolution of expectation values; • Applications: One dimensional motion, free particle, Particle in a box, Potential Barrier and Well, Infinite and finite square well potential (5) • Harmonic oscillator, Spin of an electron, (5) • The Schrödinger equation in three dimensions: The Schrödinger equation in spherical coordinates, Separation of variables, The radial equation and energy quantisation, the angular equation, spherical harmonics and introduction to quantised angular momentum. Spin, the Hydrogen atom; Charged Particle in a Magnetic Field: Oscillator algebra; Energy spectrum and Eigenstates; Landau levels, Wave functions. (4)
Text & Reference Books	1. Zettili, Quantum Mechanics: Concepts And Applications, 2nd Edn, Wiley India, 2016, 2. D. J. Griffiths, Introduction to quantum mechanics, 2004 3. J. J. Sakurai, Modern quantum mechanics, Addison-Wesley, 1994., 4. R. Shankar, Principles of quantum mechanics, Plenum Publishers, 1994.

PHY 321	Statistical Mechanics (3003)
Learning Outcomes	1. To calculate the most probable macrostate of a given Thermodynamical system in equilibrium 2. Distinguish the nature of distributions in microcanonical, canonical and grand canonical ensembles. To relate the resulting statistics with thermodynamics parameters with applications to physical systems 3. Evaluate the distribution of particles in Maxwell Boltzmann's, Fermi-Dirac and Bose-Einstein distributions along with their applications. 4. To estimate the phase transitions and order parameters.
Layout	• Review of thermodynamics and Probability theory: The Laws of Thermodynamics. Interactions The Conditions for Equilibrium, Thermal Interaction Temperature, and Volume change Pressure, Particle interchange chemical potential. Random variable, Distribution function, Central limit theorem; (4) • Statistical Picture of Mechanics: Statistical description of a classical particle, Dynamics in Phase space, Ergodicity, Stationary states and Liouville theorem, Micro canonical and Canonical states. (4) • Methodology of Statistical Mechanics: Definition of counting and partition function Density of states, Classical Partition function, Examples Two level system, Harmonic oscillator, Particle in a 1D and 3D box. Equipartition theorem, Virial theorem; (4) • Thermodynamic Averages: The Partition Function, Generalised Expression for Entropy Gibbs entropy, Free Energy and Thermodynamic Variables, The Grand Partition Function, Grand Potential and Thermodynamic variables, Examples of non-interacting systems Einstein and Debye model, Ideal Paramagnet (negative temperature). (6) • Quantum Distributions: Bosons and Fermions, Grand Potential for Identical Particles, The Fermi and Bose Distribution, The Classical Limit, the Maxwell Distribution, Examples: Black-body radiation, Bose Einstein Condensation and Fermi gas at low temperatures. (6) • Weakly interacting Systems: Cluster Expansion, Van der Waals gases; Phase transitions - Phenomenology: Phase diagrams, Symmetry, Order of phase transitions and Order parameter, Conserved and non-conserved order parameters, Critical exponents, Scaling theory and scaling of free energy. (6) • Strongly interacting systems – Phase transitions: Introduction to the Ising model. Magnetic case, lattice gas and phase separation in alloys and Bragg-Williams approximation. Transfer matrix method in 1D. Landau theory, Symmetry breaking, Distinction between second order and first order transitions, Discussion of ferroelectrics. Broken symmetry, Goldstone bosons, fluctuations, scattering, Ornstein Zernike, soft modes. (6)
Text & Reference Books	1. F. Reif, Statistical Physics: Berkeley Physics Course Vol. 5, Tata Mcgrawhill, 2011. 2. F. Mandl, Statistical Physics (2nd Ed.), John Wiley & Sons, 1991. 3. H.B.Callen,ThermodynamicsandanIntroductionToThermostatistics,Wiley, 2006. 4. R. K. Pathria, Statistical Mechanics (2nd Ed.), Elsevier, 2002.

PHY 322	Condensed Matter Physics I (3003)
Learning Outcomes	Understand classical and quantum models of electrons and lattice vibrations in solids, emphasising physical models for elastic properties, electronic transport and heat capacity. Applications to determine electrical and structural properties of solids
Layout	• Crystal structure: Bravais lattice, two and three dimensional lattices, primitive cells, symmetry, space group and point groups, classification of lattices by symmetry; [4] • Experimental determination of crystal structure: Scattering from crystals, Laue method, rotating crystal method, powder method, interaction of X-rays with matter, deciphering the structure; [4] • Electronic structure: The single electron model, free electron model, specific heat of non-interacting electrons; The Schrodinger equation and symmetry: Bloch's theorem, Fermi surface, density of levels, van Hove singularities, Kronig-Penney model, band structure, rotational symmetry and group representations. [8] • Models: Nearly free electrons, Brillouin zones, tightly bound electrons, Wannier functions, tight binding model, electron-electron interactions, Hartree Fock equations, density functional theory; [8] • Mechanical properties: elasticity, liquid crystals, phonons, Einstein and Debye models, inelastic scattering from phonons; [6] • Electron transport: Drude theory, semi classical electron dynamics, non-interacting electrons in an electric field, Zener tunnelling.[6]
Text & Reference Books	1. Michael P. Marder, Condensed Matter Physics, John Wiley, 2000. 2. N. W. Ashcroft, N. David Mermin, Solid state physics, Harcourt, 1976. 3. C. Kittel, Introduction to Solid State Physics, 7th edition, John Wiley, 2004. 4. A. J. Dekker, Solid State Physics, Macmillan India , 2005.

PHY 412	Condensed Matter Physics II (3003)
Prerequisites	PHY 322: Condensed Matter Physics I
Learning Outcomes	• Solve problems related to electronic properties of intrinsic and extrinsic semiconductors, p-n junctions. • Estimate concentration of simple defects like point defects in a solid in thermal equilibrium. • Calculate the magnetic susceptibilities of a solid for simple cases like insulating solid, free electron metal etc. • Solve the ferromagnetic/antiferromagnetic Heisenberg Hamiltonian using mean field theory. • Application of Landau's phenomenological theory to calculate the observable properties of a homogeneous superconductor. • Solve the BCS Hamiltonian for superconductors using mean field theory.
Layout	• Semiconductors: intrinsic and extrinsic semiconductors, hole, effective mass, laws of mass action, electron and hole mobilities, impurity band conduction , p-n junction , Shottky barrier , quantum Hall effect [4]; Crystal defects: Schottky vacancies, Frenkel defects, F-center etc.[2]; Optical Processes: Optical reflectance, Kramers-Kronig relations, Electronic interband transitions, Frenkel excitons, Mott-Wannier excitons, Raman effect in crystals etc.[6] • Magnetism: dia-, para- magnetism, Curie-Weiss law, Van-Vleck and Pauli paramagnetism, ferro-, anti- and ferrimagnetism.[2] Classical and quantum theories, Hunds rule, Exchange interaction, Heisenberg model, mean field theory, spin wave.[6] • Superconductivity: Experimental survey, Thermodynamics of superconductors, Meissner effect, Londons equation,[2] BCS theory, Ginzburg-Landau theory, flux quantization, coherence length, Type-I and Type-II superconductors,[4] Superconducting tunneling, DC and AC Josephson effects SQUIDs, High-T superconductivity: structure and transport properties.[3] • Dielectric and Ferroelectrics: General concept, dielectric constant and polarizability, Structural phase transitions, Ferroelectric crystals, Displacive transitions:[3] Soft phonon modes, Landau theory of the phase transition, first and second order phase transitions, Ferroelectric domains, Piezoelectricity, and Ferroelasticity; Magnetic resonance.[6]
Text & Reference Books	1. Michael P. Marder, Condensed matter physics, John Wiley, 2000. 2. N. W. Ashcroft, N. David Mermin, Solid state physics, Harcourt, 1976. 3. C. Kittel, Introduction to solid state physics, 7th edition, John Wiley, 2004.

I2M 315	Applied Statistics (2033)
Prerequisites	None
Learning Outcomes	1. Understand the basic of statistical distributions their classification and methods of analysis. 2. Apply decision theory, estimation, confidence intervals, and hypothesis testing.
Layout	• Sampling Distributions: Populations and samples; distribution of samples; graphical representation of data; basic distributions, properties, fitting, and their uses; distribution theory for transformations of random vectors; sampling distributions based on normal populations; t, χ^2 and F distributions. (9 hours) • Estimation of Parameters: Method of maximum likelihood; applications to different populations; point and interval estimation; method for finding confidence intervals; applications to normal populations; approximate confidence intervals. (9 hours) • Bivariate Samples: Sample from a bivariate population; least square curve fitting; maximum likelihood estimation; multivariate samples. (7 hours) • Testing of Hypotheses: Statistical hypotheses - simple and composite; best critical region; application to normal population; likelihood ratio testing; normal and bivariate normal populations and comparison; binomial populations and comparison; Poisson population; multinomial population; χ^2- test of goodness of fit. (15 hours) Practicals: • Objects and functions, Arithmetical and Boolean operators, Importing and Exporting Data sets, Packages, Loops and Conditional statements, Measure of central tendency, basic plots. • Density, distribution function, quantile function and random generation for standard discrete and continuous distributions. Q-Q plots and P-P plots. Fitting distributions. Maximum Likelihood estimation. Generating bivariate random sample. Test for mean, variance, proportion and independency.
Text & Reference Books	1. D. Freedman, R. Pisani and R. Purves, Statistics, W. W. Norton & Company; 4th edition (2007). 2. R. V. Hogg, J. McKean and A. T. Craig, Introduction to Mathematical Statistics, Pearson Education India; 7 edition (2013). 3. A. Mood, F. Graybill and D. Boes, Introduction to the Theory of Statistics, McGraw Hill Education; 3 edition (2017). 4. P. J. Bickel and K. A. Doksum, Mathematical Statistics: Basic Ideas and Selected Topics, Volume 1. 2nd edition. Chapman and Hall / CRC (2015). 5. Grolemund, Garrett. Hands-on programming with R: write your own functions and simulations. O'Reilly Media, Inc., 2014. 6. Schumacker, Randall, and Sara Tomek. Understanding statistics using R. Springer Science & Business Media, 2013. 7. Zuur, Alain, Elena N. Ieno, and Erik Meesters. A Beginner's Guide to R. Springer Science & Business Media, 2009.

I2P 321	Electrochemical Energy Systems (3003)
Prerequisites	Thermal and Statistical Physics
Learning Outcomes	1. Understand thermodynamics and electrochemistry of electrochemical energy systems. 2. Apply electrochemical equations to model storage and transducer systems. 3. Comprehend the relevance of various component of batteries, super capacitors and fuel cells. 4. Appreciate existing problems in storage and converter systems and devise solutions, especially involving nanotechnology and smart materials. 5. Comprehend basic electrochemical measurement methods and parameters in design and performance quantification.
Layout	• Various forms of electrochemical energy systems - batteries, super capacitors and fuel cells [3] • Basics of Chemical Kinetics and Rate Equations [2] • Electrochemical principles: voltage series, half-cell, Galvanic cell, Nernst equation, over voltage etc. [3] • Electrochemical double layer: Helmholtz, Gouy-Chapman model.[3] • Measurement methods (staionary, quasi-stationary) [3] • Potentiostatic and galvanostatic methods, RDE, cyclic voltammetry etc. [5] • Memory and converter systems: temporal development from historical to modern systems, [4] • Emphasis on metal ion batteries, but also different types including lead acid, nickel metal hydride, metal air, sodium sulfur and redox flow. [6] • Advanced battery materials, device structure and components (electrolytes, separators, additives and electrode-electrolyte interfaces). [4] • Application to Batteries, Accumulators, fuel cells. [3]
Text & Reference Books	1. D. Linden and T. B. Reddy, Handbook of Batteries, 3rd edition, Mc Graw Hill, New York(2002) 2. A. J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications,2nd edition, Wiley, New York (2000) 3. Hamann CH, Hamnett A, Vielstich W. Electrochemistry 2nd Edition, Wiley. VCH: New York. 1998. 4. P. Kurzweil: Fuel Cell Technology, 1st Edition, Springer-Verlag London, 2006.

I2C 421	Soft Matter and Polymers (3003)
Learning Outcomes	1. Understand the physics and chemistry of soft matters such as polymers, gels, colloids etc. 2. Quantify/mathematical formulation of mechanical (viscoelastic) properties and shear moduli 3. Apply knowledge of soft matter into various electronic, mechanical, optical devices/ processes.
Layout	• What is soft condensed matter. Forces, energies, and time scales in soft condensed matter. Intra- and intermolecular interactions, structural organisation, phase transitions, order parameters, scaling laws. • Experimental techniques to investigate soft matter. • Polymers: Chemistry and architecture, Synthesis and characterisation Copolymers and polymer blends, Poly-dispersity, Phase separation and segregation, Polymer solution, Liquid Crystalline polymers. Functional polymers. • Gelation: Classes of gels: physical gels, chemical gels, Theory of Gelation.Hydrogels: Types of hydrogels, Application of hydrogels, formation of hydrogels, Processing of hydrogels • Colloids: Types of colloids and their formation, Forces between colloidal particles. Assembly and phase behaviour, Charges and stabilisation, Kinetics,Defects in assembly, Approaches to control long range order. • Soft matter in nature, nucleic acids, proteins, membranes. • Applications of colloids in photonics and optoelectronics. Applications of soft materials in micro and nano technology.
Text & Reference Books	1. Richard. A. L. Jones, Soft Condensed Matter, Oxford University Press, 2002 2. Malcolm P. Stevens, Polymer Chemistry, Oxford University Press, Inc, 1990. 3. Fundamentals of Soft matter Science by Linda S. Hirst (CRC press) 4. Text book of polymer Science, Billmeyer, John Wiley ans Sons 1984. 7. 5. Principles of Polymer Systems, Rodriguez, Hemisphere Publishing Corpn, 1982. 8. 6. Introduction to Polymer Science and Technology, H. S. Kaufman and J. J. Falcetta, 7. Polymer chemistry, Seymour and Carraher, Marcel Dekker, 2003. 8. Odian, George. Principles of Polymerization. 4th ed. Hoboken, NJ:

I2P 422	Numerical Methods (3003)
Learning Outcomes	1. Perform numerical computation using a programming language. 2. Find root of an equation, numerical differentiation and integration. 3. Solve sSolve differential equations, linear algebra problems numerically. 4. Obtain numerical solutions to problems in classical and quantum physics and classical statistical mechanics problems using Monte Carlo simulation.
Layout	• Binary numbers, floating point representation of real numbers, machine precision, rounding errors. [1.5] • Root finding: Bisection method, Newton method, Secant method, Brent method etc. Application to physics problems [4.5] • Interpolation: Lagrange interpolation, Newton's divided differences, Chebyshev Interpolation, Cubic splines [4.5] • Least squares: Fitting models to data, models with linear parameters, non-linear parameters. [3] • Differentiation and Integration: Finite difference formulae and rounding errors, Trapezoid rule, Simpson rule, Composite Newton-Cotes formulae for integration, Gaussian Quadrature [3] • Systems of Equations: Gaussian elimination, LU factorization, Pivoting, Non-linear system of equations. Use of linear algebra packages like LAPACK, Numpy, SciPy etc. [4.5] • ODE: Initial value problems, Euler method, Runge Kutta methods, Higher order equations, Boundary value problems by finite difference menthods, applications. PDE: Forward difference, Backward difference methods, Wave equation, Heat equation, Poisson equation. [6] • Monte Carlo technique: Pseudo-random numbers, random number sequences with uniform, normal distribution etc. Monte Carlo integration, random walks, Brownian motion, Monte Carlo simulation in statistical physics, Markov chain, importance sampling, Metropolis algorithm, application of Ising model. [10]
Text & Reference Books	1. Timothy Sauer, Numerical Analysis, Pearson 2. R. W. Hamming, Numerical methods for Scientists and Engineers, Dover 3. K . E. Atkinson, An Introduction to Numerical Analysis, 2nd Edn., JohnWiley, 1989 4. Paul Devries and Javier Hasbun, A First Course on Computational Physics, John Willey & Sons 5. Nicholas Giordano and Hisao Nakanishi Computational Physics (2nd Ed.), Prentice-Hall 6. Hans Petter Langtangen, A primer on scientific programming with Python, Springer 7. K. Binder and D.W. Heermann, Monte Carlo simulation in statistical physics, Springer

I2P 411	Experimental Methods (3003)
Learning Outcomes	1. Describe methods of examining the micro/nanostructure of materials (structure, morphology and physical properties) 2. Comprehend the physical principles of various experimental techniques in characterising the microscopic and nanoscopic properties of materials and devices. 3. Layout a protocol for characterising materials and systems for specific applications (e.g. solar cells, batteries, biosensors and electronic devices)
Layout	• Electrical characterisation techniques: Resistance measurement, various configurations (2/4 probe and van der Pauw). AC/DC techniques and their range of application. Voltage and current sourcing techniques, source meter and sample impedance matching; Low current measurement, leakage current; AC measurement techniques, lock-in-amplifiers - operating principle (phase locking); [6] • Fitting bare data by linearisation techniques, obtaining best fit; Introduce calibration curve of a sensor and its predictive value. Error Analysis [3] • Imaging and microanalysis: Concepts in microscopy: Brightness, contrast, resolution. Principle and limitations of optical microscopy, Scanning Electron microscopy: Construction, electron gun, EM lenses, detectors. Energy dispersive spectroscopy: X-ray sources, detection principle, analysis and instrumentation. Transmission electron microscopy: Imaging [7] • Diffraction: Crystal systems, X-ray diffraction, single crystal, powder XRD. Unit cell determination. electron diffraction, pattern analysis. [6] • Scanning probe techniques: Atomic force microscopy and Scanning tunnelling microscopy [6] • Spectroscopy: Infra red, Raman, x-ray and UV photoelectron spectroscopy. • Optical Spectroscopy : Review of Properties of Light, wavelength and energy scale, Interaction of electromagnetic waves with matter, Beer Lambert's Law, Transmission, absorption, reflection, elastic and inelastic scattering, Rayleigh scattering, Raman scattering, Vibrational spectroscopy, [3] • Magnetic Characterisation: Types of magnetic interactions and their experimental signatures. Principle of Vibrating Sample Magnetometer (VSM) and SQUID magnetometer; Magnetic circular dichroism. Principle of NMR and ESR. [7]
Text & Reference Books	1. R. A. Dunlap, Experimental Physics - Modern Methods, Oxford University Press, 1988. 2. JH. Moore, C C. Davis, M A Coplan, S C. Greer, Building Scientific Apparatus, Cambridge University Press, (4th Ed) 2009. 3. Low Level Measurements Handbook (6/7th Ed) Keithley Instruments Publication 4. G. L. Weissler, R W Carlson, Methods of Experimental Physics Volume 14 : Vacuum Physics and Technology , Academic Press, 1990. 5. G K. White, P. Meeson, Experimental Techniques in Low Temperature Physics (3rd/4th Ed) , Oxford University Press, 1979. 6. C. J. Chen, Introduction to Scanning Tunnelling Microscopy (2nd Ed), Oxford University Press, 2008. 7. Shailaja Mahamuni, Deepti Sidhaye, Sulabha Kulkarni, Foundation of experimental Physics, CRC Press London, 1st edition, June 2020.

PHY 41X	Semiconductor Devices (3003)
Learning Outcomes	1. Describe the origin of electrical, optical and optoelectronic properties of semiconductors. 2. Comprehend semiclassical equations of motion, role of impurity states and band structure of selected semiconductors, Apply Boltzmann transport to semiconductor device modelling. 3. Band theory based description of optical response and processes in semiconductors 4. Scope of reduced dimensional systems and heterostructures in devices.
Layout	**Review of Bulk semiconductor physics:** crystals, compound semiconductors, band-structure, density of states, doping and carrier concentration, Fermi statistics. [4] **Electrical Transport in Bulk Semiconductors:** Drude model, Boltzmann transport; equations in electric and magnetic field; moments of transport equation, continuity equation, diffusion, drift, thermal gradient etc.[6] **Semiconductor Junctions:** Schottky and heterojunctions, role of interfaces, band bending concept, self-consistent band bending equations (Poisson - Schrodinger etc). Band bending near surfaces and interfaces. Forward and reverse biased diodes. Special diodes: pin, tunnel diodes etc. [7] **Optical Properties of metals and semiconductors:** Optical interactions in metals and semiconductors, reflection, refraction, optical absorption, free carrier absorption, refraction, Kramers Kronig relation; classical and quantum mechanical description of optical absorption, excitons; spontaneous and stimulated emission, Einstein coefficients; Photoluminescence and Electroluminescence. [7] **Quantum Heterostructures & Reduced dimensional systems:** 3D, 2D, 1D electron gas and quantum dot systems; engineering heterostructures and superlattices; optical properties of reduced dimensional systems; Quantum confined Stark effect. [6] **Screening in 3D and 2D electron systems:** Lattice polarisation; screened Coulomb potential, remote doping and mobility. [3] **Photovoltaic Devices:** photoconductors, photodiodes, Light Emitting Diodes, Laser Diodes; Quantum cascade lasers etc. [3]
Text & Reference Books	1. Semiconductor Devices: Physics and Technology, S M Sze and M Lee, Wiley India, 3rd Ed, 2007 2. Seeger, K., Semiconductor Physics, Springer-Verlag, 1990. 3. Optical Properties of Solids, Oxford University Press, M Fox 4. Physics of Low-Dimesnional Semiconductors, J. H. Davies, Cambridge, 1997 5. Solid State Physics, N. W. Ashcroft and D. Mermin, Brooks/Cole, 1976 6. Semiconductor Device Fundamentals, R F PIERRET, Pearson India, 2006

I2P 413	Fluid Mechanics and Transport Phenomena (3003)
Learning Outcomes	1. Apply the laws of discrete mechanics to continuous systems Model or analyse static fluid systems - conditions for hydrostatic equilibrium. 2. Apply advanced tools for analysing and modelling momentum, energy and mass transport in fluid or solid media 3. Identify relevance of macroscopic and microscopic balances and their applications 4. Differentiate Newtonian vs non-Newtonian fluids - properties and models 5. Model Mass, Momentum and Energy transport and their applications.
Layout	• Ideal Fluids (Continuity Equation, Euler's Equation) [6] • Hydrostatics and Potential Flow [5] • Viscous Fluids (Equations of Motion, Energy Dissipation) [8] • Thermal Conduction in Fluids (Equation of Heat Transfer) [7] • Thermal Conduction in an Incompressible Fluid [4] • Free Convection and Convective Instability of a Fluid at Rest [6]
Text & Reference Books	1. G. Falkovich, Fluid Mechanics, Cambridge University Press, 2011 2. Merle Potter and David Wiggert, Fluid Mechanics, Schaum Outline, Mc Graw Hill, 2008 3. G. Hauke, An Introduction to Fluid Mechanics and Transport Phenomena, Springer 2008 4. B. Lautrup, Physics of Continuous Matter, Institute of Physics Publishing Ltd, 2005 5. J.O. Wilkes, Fluid Mechanics for Chemical Engineers, 3rd Ed. Mc Graw Hill, 2017 6. R.B. Bird, W.E. Stewart and E.N. Lightfoot, Transport Phenomena, 2nd Ed., Wiley, India, 2005. 7. Duderstadt, J. J., and W. R. Martin. Transport Theory. Wiley, 1979. 8. F.P. Incropera and D.P. DeWitt, Fundamentals of Heat and Mass Transfer, 5 Ed., Wiley India, 2006. 9. W.M. Deen, "Analysis of Transport Phenomena", Oxford University Press, 2nd Ed. 2012

I2P 414	Modelling Materials (2033)
Prerequisites	Quantum Mechanics, Condensed Matter Physics I
Learning Outcomes	1. Apply computational methods to model, comprehend and predict material properties and material design. 2. Apply first-principles approaches, molecular dynamics simulations, stochastic methods for optimization and sampling. 3. Hands-on training using open-source software packages provide experience with simulations of classical force fields, electronic-structure approaches, molecular dynamics, and Monte Carlo.
Layout	• Energy models from classical potentials to first-principles approaches [4L] • Density Functional Theory and the total-energy pseudopotential method [6 L] • Errors and accuracy of quantitative predictions [2L] • Monte Carlo sampling and molecular dynamics simulations [4L + 12P] • Free energy and phase transitions; fluctuations and transport properties; and coarse-graining approaches and mesoscale models. [8L] • Predictive Simulations of Novel Functional Materials [24P]

I2P 414	Modelling Materials (2033)
Text & Reference Books	1. Allen, M. P., and D. J. Tildesley. Computer Simulation of Liquids. New York, NY: Oxford University Press, 1989. ISBN: 9780198556459. 2. Frenkel, D., and B. Smit. Understanding Molecular Simulation. 2nd ed. San Diego, CA: Academic Press, 2001. ISBN: 9780122673511. 3. Jensen, F. Introduction to Computational Chemistry. New York, NY: John Wiley & Sons, 1998. ISBN: 9780471984252. 4. Kaxiras, E. Atomic and Electronic Structure of Solids. Cambridge, UK: Cambridge University Press, 2003. ISBN: 9780521523394. 5. Martin, R. Electronic Structure: Basic Theory and Practical Methods. Cambridge, UK: Cambridge University Press, 2004. ISBN: 9780521782852. 6. Phillips, R. Crystals Defects and Microstructures. Cambridge, UK: Cambridge University Press, 2001. ISBN: 9780521793575. 7. Thijssen, J. M. Computational Physics. Cambridge, UK: Cambridge University Press, 1999. ISBN: 9780521575881.

I2P 421	Optoelectronic Devices (3003)
Prerequisites	Semiconductor Physics, Condensed Matter, Quantum Mechanics
Learning Outcomes	1. Design PV architectures including, Inorganic, perovskite, hybrid materials. 2. Understand light-matter interaction at device application level along with designing techniques to control and enhance it. 3. Apply characterisation techniques and device parameters for optoelectronic devices. 4. Design and fabrication of field-effect transistors, photodetectors and light-emitting diodes. Estimate device parameters like quantum efficiency, fill factor, ON/OFF ratio etc.
Layout	• Overview of optoelectronic properties and electronic structure of crystalline and amorphous semiconductors. Basics of Organic Semiconductors. [3] • Light–Semiconductor Materials Interaction, Electrons and Optics of Quantum Structures, Devices Based on Intraband Phototransitions in Quantum Structures and Silicon Optoelectronics. [6] • Photovoltaic Devices: Basic principle, Junctions, Generation and Recombination, nanocrystalline and thin film solar cells, 1st/2nd/3rd generation Solar Cells. Strategies for high efficiency. [6] • Optical transmitter circuits - LED and laser drive circuits- LED – power and efficiency - double hetero LED - LED structure - LED characteristics - Junction laser operating principles - Condition for laser action - Threshold current – Homojunction – Heterojunction - Double heterojunction lasers - Quantum well laser - Distributed feedback laser - laser modes, strip geometry- gain guided lasers- index guided lasers. [9] • Photo detectors - thermal detectors – photoconductors – detectors - photon devices – PMT photodiodes - photo transistors - noise characteristics - PIN diode - APD characteristics - APD design of detector arrays – CCD - Solar cells. [8] • Modulation of light – birefringence - electro optic effect - EO materials - Kerr modulators. [4]
Text & Reference Books	1. J. Wilson, Hawkes, Optoelectronics, an introduction, Prentice Hall; 3rd edition, January 1998 2. Vladimir V. Mitin, Michael A. Stroscio, Mitra Dutta, Viatcheslav A. Kochelap, Introduction to Optical and Optoelectronic Properties of Nanostructures, Cambridge University Press. March 2019. 3. E. Fred Schubert ,Light-Emitting Diodes, Cambridge University Press, 2nd edition, 2006. 4. Jenny Nelson, The Physics of Solar Cells, Imperial College, UK, May 2003. 5. Jasprit Singh, Electronic and Optoelectronic Properties of Semiconductor Structures, Cambridge University Press, 2003. 6. Mark Johnson, Photodetection and Measurement: Maximizing Performance in Optical Systems, McGraw-Hill Education; 1st edition, August 2003.

I2P 422	Device Technology (0093)
Prerequisites	Material Characterisation, Condensed Matter I
Learning Outcomes	1. Understand manufacturing processes, testing and prototype development 2. Appreciate multidisciplinary approach towards fabrication and the end-use of devices. 3. Physical understanding of fabrication and characterisation technologies. 4. Design and describe components and processes for a target component and its applications, and develop improvement processes. 5. Fabricate a electrical/electronic/photonic device using standard device fabrication methods.
Layout	PART A: (8 weeks) • Micro-fabrication techniques (photolithography, soft lithography) • Deposition, growth and engineering of materials (physical and chemical routes) • Thermal and e-beam evaporation, DC-RF magnetron sputtering, sol-gel method, spin and dip coating. Etching: Wet (chemical), dry (Ar ion plasma) • Advanced nano-fabrication and characterisation techniques (electron-beam lithography, focused ion-beam etching and scanning probe microscopy) • Electrical and Optical characterisation: DC/AC I-V, C-V methods, RF electronics. Reflection, transmission and emission spectroscopy. Fabrication and Characterisation of; • Sensors: chemical and bio-sensors using electrical, optical, acoustic, magnetic etc. • Mechanical Energy harvester: piezoelectric or magnetic material based micro-cantilever fabrication by PCB or 3D printing. Demonstration of electricity generation from vibration of cantilever. • Photovoltaic Energy conversion: Fabrication of thin film solar cell using Physical vapour deposition and spin coating (organic) techniques. Determination of device efficiency, fill factor. • Thin film transistor (FET) using organic materials and inorganic 2D materials. Deposition of gate dielectric layer. Top / bottom / ionic liquid gating and evaluating the device performance. • Si photonic structures and wave guide using lithography and etching. • Design and fabrication of a bio-mechanical devices using 3D printing or microfluidic channels for biosensor platform. FET based or SAW based biosensor device to monitor glucose/biomarkers. • Fluorescent materials based sensor arrays and principle component analysis. PART B: (4 weeks) One Mini Project — Building prototypes integrating devices. Examples: • Project 1: Robotics – Build an automated robot (e.g. driverless car using Raspberry Pi and sensor, GPS/GSM based animal tracker) • Project 2: Photovoltaic Device —Build a solar light by using the solar cell film and other electronics. • Project 3: Analysis of climatic changes or health of student community and analysis by using Python/MATLAB.
Text & Reference Books	1. Marc J. Madou, Fundamentals of Microfabrication and Nanotechnology, CRC Press 3 rd edition, December 2011. 2. Stephen D. Senturia, Microsystem Design, Springer US,1 st edition, 2001. 3. Sami Franssila, Introduction to Microfabrication, Second Edition, John Wiley and Sons Ltd 2010. 4. Ampere A. Tseng,Nanofabrication: Fundamentals and Applications World Scientific, 2008. 5. Bharat Bhushan (editor), Springer Handbook of Nanotechnogy, Springer-Verlag Berlin Heidelberg 2010.

I2P 423	Thermal Transport and Thermoelectrics (3003)
Prerequisites	Condensed Matter, Fluid Mechanics and Transport Phenomena
Learning Outcomes	1. Develop quantitative understanding of fundamental physical processes that govern heat transfer. 2. Formulate heat, mass and momentum transfer processes based on basic transport equations. 3. Principles and technologies for converting heat into electricity. 4. Thermoelectric energy conversion and thermoelectric materials, therm-ionic energy conversion. 5. Appreciate applied solar thermal technologies, solar heat collection systems, solar thermo-photovoltaics and solar thermo-electrics.
Layout	• Introduction, review of heat transfers and laws of radiative heat transfer. Conduction, Radiation, Development and Use of Heat Transfer Correlations Thermoelectric Generators, Thermoelectric Coolers, Optimal Design. [5] • Thomson Effect, Exact Solution, and Compatibility Factor, Thermal and Electrical Contact Resistances for Micro and Macro Devices, Modeling of Thermoelectric Generators and Coolers with Heat Sinks, Applications [6] • Review of electronic band structure and phonon spectrum, Physics of Electrons, Density of States and Fermi Energy, Thermoelectric Transport Properties, Phonons, Low-Dimensional Nanostructures, Generic Model of Bulk Silicon and Nanostructures, Theoretical Model of Thermoelectric Transport Properties. [8] • Thermoelectric effects and current research in thermoelectric materials, Graded materials, TE leg geometry impact, Ballistic thermionic coolers and non-linear Peltier. [8] • Thermionics vs. Thermoelectrics, Thermionic power conversion, Thermionic engines: vacuum, solid-state, Schottky barrier and diode. [5] • Solar concentration and solar thermal technology and Applications of Solar thermal technologies, Selective surfaces, Methods for concentration: trough, tower, dish, EM wave calculation of surface properties. [6]
Text & Reference Books	1. R.B. Bird, W.E. Stewart and E.W. Lightfoot, Transport Phenomena, John Wiley, II Edition 2006 2. G.S. Nolas J. Sharp H.J. Goldsmid, Thermoelectrics Basic Principles and New Materials Developments, Springer-Verlag Berlin Heidelberg New York 2001 3. Goldsmid, H. J. Thermoelectric Refrigeration. New York, NY: Plenum Press, 1964. 4. Petros J. Axaopoulos (ed.)Solar Thermal Conversion. Active Solar Systems, Symmetria., 2011 ISBN: 9602663286 5. L.S.Sissom, and D.R.Pitts, “Elements of Transport Phenomena”, McGrawHill, New York, 1972. 6. R.W.Fahien, Elementary Transport Phenomena, McGraw-Hill, New York, 1983. 7. D.M. Rowe (Ed.), CRC Handbook of THERMOELECTRICS , CRC Press LLC 1998.

I2P 424	Finite Element Modelling (1063)
Prerequisites	Numerical Solutions of ODE/PDE
Learning Outcomes	1. Apply finite element modelling methods to solve partial differential equations and develop an understanding of the various solvers. 2. Apply the numerical techniques to simulate physical systems. 3. Finite element formulation of Boundary Value Problems. 4. Understand the scope for applications and limitations in the fields of electronics, photonics, thermoelectrics, microfluidics etc. especially incorporating multi physics applications.
Layout	• Introduction to Finite Element Methods (FEM) to solve partial differential equations (PDE) Numerical methods (solvers) for solving stationary, transient and eigenvalue problems and other systems of linear equations. [3 L] • Introduction to Sobolev spaces, Weak (variational) formulation of elliptic boundary-value problems of second order, natural and essential boundary conditions, Ritz-Galerkin method, some standard finite elements. [4 L] • Simulating Electrical conduction, Optical reflection, transmission, absorption, meta-materials, thermal and fluid transport [1 L + 12 P] • Multi-physics applications - heat and mass transfer and fluid dynamics and chemical reactions, theory of elasticity, multiphase systems, static electric and magnetic fields and interaction with matter, electrodynamics, wave optics [2 L + 24 P] • Micro and Nano Technology: Solving the Schrödinger equation in different potentials, Electrical transport in microsystems, sensors and allied devices. Photonics: Optical Components, Fiber and Fiber Bragg grating. Kinetics and Transport: Modelling Chemical Reactions, Microfluidic Systems. [2L+36P]
Text & Reference Books	1. S. M. Muhsa, "Computational Finite Element Methods in Nanotechnology", CRC Press 2013. 2. Claes Johnson, Numerical Solution of Partial Differential Equations by the Finite Element Method, Cambridge University Press, 1987 3. S. C. Brenner and L. R. Scott, The Mathematical Theory of Finite Element Methods, Springer-Verlag, New York, 1994. 4. R. Pryor, "Multiphysics Modeling Using COMSOL 4", Mercury Learning, 2012. 5. M. Tabatabaian, "COMSOL for Engineers", Mercury Learning 2014. 6. J. Berthier, P. Silberzan, "Microfluidics for Biotechnology", 2nd Edition, ARTECH HOUSE, 2010. 7. S. Ganesan, L. Tobiska, Finite Elements: Theory and Algorithms, Cambridge IISc Series, Cambridge University Press, 2016.

I2P 521	Machine Learning for Physicists (2033)
Prerequisites	Introduction to Programming, Numerical Methods and Applied Statistics. Machine Learning I (advisable)
Learning Outcomes	1. Understand the fundamental concepts/tools used in Machine Learning 2. Discriminate pros and cons of various ML models/algorithms 3. Apply ML toolkits on data analysis problems relevant to Physics e.g. image/pattern recognition, string/language analysis. 4. Prepare data and train ML models. 5. Assess the quality of machine learning systems.
Layout	• Introduction to the core concepts, theory and tools of machine learning as required by physicists addressing practical data analysis tasks. • Supervised learning: linear models for regression and classification • Nonlinear models; Neural networks, Structure, Training and Analysing Neural Networks. Convolutional Neural Networks, Auto-encoders, Principal Component Analysis • Unsupervised learning: dimensionality reduction for clustering. • Recurrent networks, time series and sentence analysis. • Implementation of ML in real applications, relevant to problems in physics. • Free software, libraries and publicly available data-sets will be used.
Text & Reference Books	1. Understanding Machine Learning: From Theory to Algorithms, Shai Ben-David and Shai Shalev-Shwartz, Cambridge University Press, NY 2014 2. Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer-Verlag Berlin, Heidelberg, 2006 3. Deep Learning, Ian Goodfellow, Yoshua Bengio, Aaron Courville, The MIT Press, 2016

I2P 4201	Computer Interfacing (1032)
Prerequisites	None
Learning Outcomes	1. Understand the basics of AD/DA conversion and data transfer. 2. Interface instruments and devices using AD/DA data acquisition and control systems.
Layout	• Basics of Analog to Digital conversion and vice versa. Analog and Digital data acquisition and generation. Counters and Timers, real-time data acquisition and instrument control and acquisition speed. [4] • Real-time data acquisition and instrument control and acquisition speed. Practical aspects of interfacing external hardware with a computer. Serial and Parallel Interfacing. Virtual instrumentation using IEEE GPIB, RS232, USB interfaces.[4] • Interfacing external hardware platforms like Arduino and Raspberry Pi [4] • Practicals [30] • Softwares: Labview, Python, Arduino IDE, C++ etc (5 hrs)
Text & Reference Books	1. C E Strangio, Digital Electronics: Fundamental Concepts and Applications, Prentice Hall, NJ, 1980 2. S. Gupta and J. John, Virtual Instrumentation using LabVIEW, Tata McGraw-Hill Publishing Company Limited, 2010. 3. Jovitha Jerome, Virtual Instrumentation Using Labview, Prentice Hall of India, 2010 4. Bruce Mihura, LabVIEW for Data Acquisition, Prentice Hall of India, 2013 5. R Bitter, T Mohiuddin, M Nawrocki, LabVIEW: Advanced Programming Techniques, CRC Press, 2007

I2P 4202	Energy Materials Laboratory (0031)
Prerequisites	Electrochemical Energy Systems and Thermal Transport and Thermoelectrics (be registered for)
Learning Outcomes	1. Characterise thermal and thermoelectric parameters of materials 2. Synthesise materials and coatings for applications 3. Understand practical methods of hydrogen generation and storage
Layout	• Measurement of various thermal transport (conduction/radiation) • Measurement of Specific Heat of Metals & Semiconductors • Synthesis of thermoelectric materials (Bi_2Te_3) by Solution methods, Powder metallurgy, • Characterising the Thermal Efficiency of Thermoelectric Modules • Design, modelling and simulation of solar concentrators • Synthesis and characterisation of electrode materials for Li ion battery applications • Experimental investigation of hydrogen storage properties of porous carbon materials • Investigation on the electrocatalytic properties of noble metal catalysts towards hydrogen generation • Photocatalytic hydrogen generation and quantification of hydrogen evolution • Synthesis and characterisation of porous carbon materials • Electrochemical synthesis and characterisation of metal nanowires
Text & Reference Books	1. R.B. Bird, W.E. Stewart and E.W. Lightfoot, “Transport Phenomena”, John Wiley, II Edition 2006 2. G.S. Nolas J. Sharp H.J. Goldsmid, “Thermoelectrics Basic Principles and New Materials Developments” Springer-Verlag Berlin Heidelberg New York 2001

I2P 4203	Battery and Fuel Cell Laboratory (0031)
Prerequisites	Electrochemical Energy Systems (be registered for)
Learning Outcomes	1. Apply potentiostatic and galvanostatic methods, RDE, Cyclic Voltammetry, Electrochemical Impedance Spectroscopy techniques to characterise electrochemical cells 2. Fabricate and benchmark electrochemical storage devices.
Layout	• Fabrication of coin cell devices and charge/discharge characterization of Lithium ion battery electrodes • Electrochemical Impedance spectroscopy studies of Lithium ion battery electrodes • Fabrication and electrochemical characterization of carbon-based supercapacitor devices • Electrochemical characterization of Hydrogen fuel cell device • Fabrication electrochemical characterization of microbattery devices
Text & Reference Books	Allen J Bard and Larry Faulkner, Electrochemical Methods: Fundamentals and Applications, 2nd Edition, Wiley, Jan 2001.

I2P 4204	Organic Photovoltaic Devices Laboratory (0031)
Prerequisites	Optoelectronic Devices (be registered for)
Learning Outcomes	1. Fabricate and characterise organic semiconductor based photoactive and light emitting devices 2. Comprehend the physics of organic molecule as semiconductors 3. Analyse photophysics of organic semiconductors and optoelectronic devices.
Layout	• Fabrication and characterisation of Photodetectors • Fabrication and characterisation of solar cells • Fabrication and characterisation of light emitting diodes • Fabrication and characterisation of field effect transistors • Fabrication and characterisation of electrochromic devices • Fabrication and characterisation of electrochemical transistors
Text & Reference Books	1. Von A. Gilbert und J. Baggott, Essentials of Molecular Photochemistry. Blackwell Scientific Publications, Oxford 1991 2. K. K. Rohatgi-Mukherjee, Fundamentals of Photochemistry, New Age International, 3rd edition, 1978. 3. Pope & Swenberg, Electronic Processes of Organic Crystals and Polymers, Oxford University press, 2nd edition, 1999. 4. H. Meier, Organic Semiconductors. Verlag Chemie GmbH, 1974. 5. Wolfgang Brutting, Physics Of Organic Semiconductors", John Wiley & Sons Canada; 1st edition, 2005. 6. “Organic Electronics: Materials, Manufacturing, and Applications*1, Hagen Klauk, John wiley & Sons; 1st edition, 2006. 7. Von K. C. Kao und W. Hwang, Electrical transport in solids with particular Text & Reference Books to organic semiconductors Pergamon Press New york, 1984

I2P 5101	Digital Image Processing (3003)
Learning Outcomes	1. Represent, process, and interpret physical properties via digital images. 2. Represent images by matrix (1D, 2D, 3D, and higher dimension) & vice-versa 3. Design and develop digital image processing system and algorithms 4. Apply fundamental techniques used for reconstruction of distribution of physical quantities from a set of boundary measurements. 5. Appreciate scope and importance of digital images and their processing, in real life applications.
Layout	• Introduction to Image Processing – overview and applications; • Mathematical preliminaries; image transform – orthogonal and unitary, cosine, sine, Karhunen Loeve (KL), Hadamard, Haar, slant, wavelet; image enhancement – point and spatial operation, histogram modelling, transform operation; • Image filtering and restoration – image model and inverse filtering, Wiener filtering, filtering in frequency domain, single value decomposition (SVD) and recursive filtering; image analysis – feature extraction, registration, segmentation (point, line, and edge detection; thresholding; region growing and region splitting), classification, SVD and principle component analysis (PCA); morphological image processing – • Erosion and dilation, opening and closing, Hit-or-Miss transform, morphological reconstruction; image reconstruction; • Applications on scientific data from optical and electron microscopy and biomedical image processing
Text & Reference Books	1. A K Jain, Fundamentals of Digital Image Processing, Prentice Hall, 2009. 2. Rafael C Gonzalez and Richard E Woods, Digital Image Processing, Prentice-Hall India, 2002. 3. Avinash C. Kak and Malcolm Slaney, Principles of Computerized Tomographic Imaging, IEEE Press (1999). 4. Alan V Oppenheim, Ronal W Schafer, and John R Buck, Discrete-time Signal Processing, Prentice Hall, 1999. 5. Rudra Pratap, Getting Started with MATLAB, Oxford University Press, 2010.

I2P 5201	Principles of Digital Imaging (3003)
Prerequisites	Familiarity with programming and Numerical Methods
Learning Outcomes	1. To differentiate among analog, discrete, and digital signals 2. To learn representation of image by matrix (1D, 2D, 3D, and higher dimension) and its vice-versa 3. To learn fundamental theories of discretisation and digitisation of signals or images, and its processing 4. To learn various techniques for reconstruction of distribution of physical quantities from a set of boundary measurements 5. To build-up or develop imaging system with a given theory and to establish the theory of a given imaging system.

I2P 5201	Principles of Digital Imaging (3003)
Layout	• Introduction and overview of imaging - photography, microscopy and tomography; aspects and prospects in industry, and laboratory research; theories of matrix and its application in imaging (using MATLAB software); basics of signal processing and image processing; image artefacts; temporal, spatial and contrast resolution, numerical methods (12 lectures) • Forward model and inverse problems; Tomographic imaging with non-diffracting sources • Radon transform. Fourier slice theorem, filtered back projection convolution back projection, reconstruction from parallel and fan projections; Computed tomography (CT) - transmission* reflection, emission; tomographic imaging with diffracting sources - Born and Rytov approximations, Fourier diffraction theorem; filtering and interpolation; Algebraic reconstruction algorithms - algebraic reconstruction technique (ART), simultaneous iterative reconstructive technique (SIRT); simultaneous algebraic reconstructive technique (SART) (14 lectures) • Wave propagation in diffusive medium • ultrasound and optical wave propagation in homogeneous and inhomogeneous media, and soft tissues; Radiation transport equation (RTE); Recovery of physical parameters; Multispectral technique (6 lectures) • Tomography in selective imaging modalities - X-ray, ultrasound, magnetic resonance imaging (MRI), positron emission tomography (PET), photoacoustic tomography (PAT), diffuse optical tomography (DOT) (4 lectures)
Text & Reference Books	1. Avinash C. Kak and Malcolm Slaney, Principles of Computerized Tomographic Imaging, IEEE Press (1999). 2. Fundamentals of digital image processing, A K Jain, Prentice Hall. 3. Discrete time signal processing, Oppenheim Schafer, Pearson.

I2P 5202	Organic Semiconductors Fundamentals and Applications (3003)
Learning Outcomes	1. Describe physical models and applications of unconventional semiconductors and organic molecules. 2. Analyse the of photophysics of organic semiconductors and identify their difference with inorganic counterparts 3. Comprehend applications of organic semiconductors in optoelectronics 4. Device physics of the optoelectronic devices based on organic semiconductors
Layout	PART I: • Organic Molecules: Electronic structure of atoms, Atomic and Molecular Orbitals, LCAO, Bonding and antibonding orbitals, Covalent Bond, Sigma and Pi Bonds, Energy Levels, Spectroscopic properties [4] • Photophysics of Molecules and Aggregates: Excited states: Absorption and emission, Singlet and triplet states, Radiative and non-radiative transitions, Aggregates, Van der Waals Bonding, Hydrogen Bonding, Dimer, and Excimers. [2] • Excitons: Wannier Exciton, Charge-transfer Exciton Frenkel Exciton, Exciton Diffusion, Excitonic Energy Transfer. [2] • ConductionMn Organic Solids: Conductivity: carrier concentration versus mobility, Carrier generation, Hopping transport, Mobility measurements, Traps. [2] • Photovoltaics and Photodetectors: Photovoltaic Devices: Organic Heterojunction Photovoltaic Cells, Organic/Nanorod hybrid Photovoltaics, Gratzel Cells (Dye sensitized solar 1 cells),Photodetector Devices [5] • Organic Light Emitting Devices: Basic OLED Properties, Charged Carrier Transport, Organic LEDs, Quantum Dot LEDs. [8] • Lasing Action in Organic Semiconductors: Lasing Process, Optically Pumped Organic Lasers, Electrical Pumping of Organic Lasers. [2] • Organic Thin Film Transistors: OFETs: Materials, Contacts, Applications, And Nanotube Transistors. [2] • Device Fabrication Technology: Growth Techniques: Evaporation, Langmuir-Blodgett, Chemical Vapor Phase Deposition, Ink-Jet Printing, Self-Assembly. [3] PART II. • Project: Literature review on a certain relevant topic. [10]
Text & Reference Books	1. Essentials of Molecular Photochemistry, Gilbert &Baggott, CRC Press, 1991. 2. Fundamentals of Photochemistry, K. K. Rohatgi-Mukherjee, NewAge International, 1978. 3. Electronic Processes of Organic Crystals and Polymers, Pope & Swenberg, Oxford University press, 2nd edition (1999). 4. Organic Semiconductors, H. Meier, Verlag Chemie GmbH, 1974 - 5. Physics Of Organic Semiconductors" Wolfgang Brutting, John Wiley & Sons Canada; 1 edition (2005) 6. Organic Electronics: Materials, Manufacturing, and Applications, Hagen Klauk, John Wiley & Sons; 1st edition (2006), 7. Electrical transport in solids: with particular reference to organic semiconductors, Kao, Pergamon Press; 1st edition (1981).

I2P 5203	Sensor Technology (2002)
Learning Outcomes	1. Understand the working principles and designs of sensors used to monitor gases, humidity, pressure. 2. Appreciate the design strategy of nanoscale and microscale sensors 3. Develop and apply sensor devices in technologically relevant areas.
Layout	• Overview, definition and classifications of sensors. (2 hrs) • Physical-chemical and technological principles of ceramic sensors: basic concepts, technological principles, operating principles of porous ceramic sensors. Ceramic humidity sensor: classification, basic parameters and characteristics, control of the sensitivity of ceramic humidity sensors. (5) • Ceramic gas sensor: classification, parameters and characteristics of resistive gas sensor, selectivity and sensitivity of gas sensor, operating principles, reducing gas sensor, alcohol sensor, odor and product quality sensor, oxygen sensor, ceramic sensor for other gases, Composite material based sensors, ChemFETs and eNose, manufacturing of gas sensor. (6) • Surface Acoustic Wave based sensors, introduction and principles. Microcantilever technology. Thermal sensors, Optical and radiation sensor, Pressure sensors, smart sensors and other methods of transduction in sensors. (6) • Application of sensors: MEMS based sensor, Nanotechnology in Sensor applications, recent developments in this area. (5)
Text & Reference Books	1. Fraden, Jacob, Handbook of Modern Sensors: Physics, design and applications, 3rd Edition, Springer-Verlag, Inc. 2004. 2. Jon S. Wilson (editor), Sensor Technology Handbook , Elsevier, 2004. 3. Wang W, editor. Advances in chemical sensors. inTech; Jan 2012. 4. Peter Gründler, Chemical Sensors: An Introduction for Scientists and Engineers, Springer Berlin Heidelberg New York 2007.