Guidebook of Curriculum

BS MS Dual Degree Program
IISER Tirupati

August 2015

Objectives

The IISER model of education is concept-based and inquiry-driven, as opposed to the more traditional content-based models. There is a strong emphasis on the interdisciplinary nature of today's science, and recognition of the importance of research experience in undergraduate education.

The courses offered in the undergraduate program at IISER Tirupati form part of a comprehensive program that will enable the students to understand the basic laws of nature and develop necessary skills to apply them to any desired area or discipline. The program is planned as a student centric collaborative learning. Students get trained for a career in basic sciences or any related applied science or technology.

General Pattern

The courses offered during the first two years (Semesters I to IV) are meant as basic and introductory courses in Biology, Chemistry, Mathematics and Physics. These are common and mandatory for all students. They include four theory courses and three lab courses from each stream. These courses are meant to give a flavor of the various approaches and analyses and to prepare the students for advanced courses in later years of study. In addition, there will be Interdisciplinary Courses for computational skills and mathematical methods as well as Trans-disciplinary Courses on Scientific Inquiry and Conceptual Inquiry. Students are also given training to develop skills in Communication, Creative & Technical Writing through courses in Humanities and Social Sciences.

In the third and fourth years (Semesters V-VIII), students have the freedom to choose advanced courses based on their interest and inclination. The courses offered in the first two years would help them to make an informed judgment to determine their real interest and their aptitude for a given subject. Students also have the freedom to choose advanced courses from more than one discipline to achieve interdisciplinary expertise.*

The fifth year will be devoted to a thesis by research, which completes the requirements of the program.

Credits and Coursework

Every student has to register for approximately 21 credits in a semester. During Semesters I-IV, she/he has to register for all the courses offered. Each credit earned requires 2.5 hours of study per week. This includes contact hours and self study as shown in the table below.

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Credits	Semesters	Nature of course	Contact hours per week	Self study* hrs/week
3	Semester I-IV	Introductory	2 lectures & 1 tutorial	4.5
3	Semester I-IV	Lab courses	1 Session of 3 hours	4.5
2	Semester I-IV	IDC /HSS	2	3.0

*The contact hours are to be supplemented by self study that includes assignments, seminars, projects, library work and group work.

Details of Courses

The list of courses offered from each discipline with brief contents and lists of reference books is given below. Other relevant details like objectives, prerequisites, topic in detail, pattern of assessment, additional books for study and reference etc. will be prepared by the course instructor and communicated to the students well in advance before start of each semester.

BIOLOGY

The overarching philosophy of the curriculum in Biology stems from one of the primary mandates of the IISERs - to expose undergraduate students to interdisciplinary research in the basic sciences, and provide them with the necessary skills, knowledge and training to pursue successful careers in science.

The first four semesters serve as an introduction to Biology. Keeping in mind the diversity amongst the incoming students in their school education, we introduce all students to the unity and diversity of biology and the hierarchy of organization of biological systems. We emphasize the distinctness of biological systems while demonstrating the continuum from the physical/chemical world to Biology.

The courses in these semesters introduce variation, evolution, diversity and the irreducible complexity of life and biological systems. The unity of life is presented through a thorough description of biology at sub-organismal (reductionist as well as systems view) and organismal levels. At the sub-organismal reductionist level, students are introduced to the building blocks of life (biochemistry and molecular biology), information perpetuation and transfer (genetics), cells as the basic functional unit of life (cell biology) and higher levels of organization (tissue systems and physiology). In terms of the systems view at the sub-organismal level, the students learn about design principles of biological systems (systems biology) and the development of the organism. In organismal biology, students focus on interactions of the organisms with the environment, dynamics of populations/ communities and evolution at various temporal and structural scales.

Courses in the third and fourth years cover in greater detail the content introduced in the first two years. Courses such as cell and molecular biology, biophysics and biochemistry, physiology, genetics, biostatistics and evolution and ecology comprise core courses that allow students to obtain a deeper understanding of biology. Advanced courses in areas such as immunology, neurobiology, disease biology, developmental biology, ecology, and epigenetics provide students an opportunity to gain a specialized and comprehensive understanding of those fields.

Building on the foundations in physical, mathematical, chemical and information sciences, the Biology curriculum integrates concepts, examples and techniques from other disciplines. Experts from other disciplines regularly contribute to courses in Biology, and the curriculum emphasizes quantitative and computational applications in biology through courses in mathematical biology, biostatistics, bioinformatics, biophysics, chemical biology and computational biology.

There is a strong emphasis on using current primary literature in the classroom. This ensures a continually updated content, and at the same time, trains students to read, understand, and critically evaluate the primary scientific literature. Participatory teaching techniques such as group learning, assignments and student presentations are actively used.

To encourage research-based learning techniques, our lab courses of the first three semesters are designed with small open-ended experimental modules. Third and fourth year students are encouraged to participate in lab/theory projects in Biology research groups in addition to the classroom-based courses. These provide an opportunity to independently design and carry out laboratory and/or theoretical projects and participate in reading projects, often leading to meta-analysis of published literature in a given field. The goal is to expose students to contemporary research practices and tools including literature reviews, advanced techniques, data collection and analysis, and also in scientific writing and presentation.

In the final (fifth) year, students undertake an independent, stand-alone research project. The project can be carried out in any laboratory within or outside Tirupati. The goal is to develop the technical, analytical and cognitive skills necessary to pursue a career in scientific research. This is the culmination of the training from the previous years and is an opportunity to directly participate in the process of knowledge production in Biology.

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List of Courses in Biology

Semester I

1. BIO 101 Introductory Biology I: Basic Principles [3 credits]
2. BIO 121 Biology Lab I: Basic Biology [3 credits]

Semester II

3. BIO 102 Introductory Biology II: Cellular and Molecular Biology [3 credits]
4. BIO 122 Biology Lab II: Biochemistry, Genetics & Molecular Biology [3 credits]

Semester III

5. BIO 201 Introductory Biology III: Evolution and Ecology [3 credits]
6. BIO 221 Biology Lab III: Ecology and Evolution [3 credits]

Semester IV

7. BIO 202 Introductory Biology IV: Biology of Systems [3 credits]

Details of Courses in Biology

BIO 101	Introductory Biology I: Basic Principles	3 credits

Introduction: Students attending this course need not have taken biology at the HSC level. The course is intended as an introduction to the main conceptual framework of biology as a science, outlining the diversity, organization and fundamental principles of living systems.

Content:
Module 1: Introduction: What is biology: Salient features of life; Importance of biology on the frontiers of science and technology; Brief history of biology; How plants, animals and microorganisms shaped human history.

Module 2: The logical structure of biology: concepts of complexity, emergent properties, adaptation, optimality, diversity, chance and necessity, structure-function relationship, theme and variations, individual variability and plasticity; Nature of experimentation in biology and statistical inference.

Module 3: Broad overview of life on earth, origin and progression of life on earth, Evolution, concept of adaptive versus neutral evolution; classification/taxonomy and phylogeny. Molecular relationships between life forms.

Module 4: Biological information: Nature of biological information. Mechanisms of transmission of information: genetic, epigenetic, cultural and other mechanisms of inheritance. Central dogma of molecular biology.

Module 5: Mechanism of perpetuation of life at molecular, cellular, organismal and population levels.

Recommended Reading:

1. Principles of Biology: Interactive textbook from Nature Education
2. Biology: N. Campbell and J. Reece (2005) 7th edition, Pearson, Benjamin, Cummings

BIO 102	Introductory Biology II: Cellular and Molecular Biology	3 credits

Introduction: This course aims to introduce you to several important facts and fundamental concepts in biology. It is aimed to give you an insight on how organisms work at the single and multicellular levels (cellular aspects) by initially providing a molecular framework to understand the basic inter-molecular interactions (biochemical aspects) that drive underlying cellular processes. This course, more than anything, hopes to spark your imagination and thinking about how biological systems function and are regulated.

Content: This course will cover a wide range of topics starting with the very basic molecules necessary for life (water) and go on to discover the structure, function and interrelationships between all important biomolecules (like proteins, carbohydrates, nucleic acids and lipids) that collectively carry out the essential functions of life. We will then move higher on the complexity scale to understand the principles underlying cellular organization and talk about the development of cell theory, cell types: prokaryotes vs. eukaryotes, single cell to multi-cellular organism. We will study cell structures, beginning with the cell envelope of bacteria, plant and animal cells, cell membranes and their properties and structure of the cell membrane. We will also discuss the cellular cytoskeletal components, actin, microtubules and microfilaments and motor proteins. Moving on, we will study the endomembrane system (endoplasmic reticulum, Golgi complex, endosomes, lysosomes), cell nucleus and chromatin structure. We will also look at how cells use many of the above components and processes to talk to each other and the environment. Finally, we will briefly discuss the central dogma of life, looking at DNA replication, mitosis and meiosis, RNA, transcription and translation.

Recommended Reading:

1. Biochemistry: D. Voet, and J.G. Voet (2010), 4th edition, Wiley
2. Harper's Illustrated Biochemistry: R. Murray,V. Rodwell, D. Bender, K.M. Botham, P.A. Weil and P.J. Kennelly (2009) 28th edition, McGraw Hill-Medical
3. Biology: N. Campbell and J. Reece (2005) 7thedition, Pearson, Benjamin, Cummings
4. Biology: P.H. Raven, G.B. Johnson, J.B. Losos and S.R. Singer (2005) 7thedition, McGraw Hill
5. Molecular Biology of the Cell: B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts and P. Walter (2007) 5th edition, Garland Science

BIO 121	Biology Lab I: Basic Biology	3 credits

Content: This practical course will cover basic concepts in biology, cell biology and cell culturing techniques with an emphasis on 3D's in biology – draw, describe and differentiate. Experiments include: Basics of microscopy; Field trip; Microscopy of samples; Micrometry of different cells; Staining of bacteria, fungi, Plant cells, Blood cells and Bone marrow; Osmosis; Mitosis; Crude cultures – Bacteria and Protozoa; Pure culture techniques; Sterilization and media preparation; Streaking of bacteria; Enumeration of bacteria.

BIO 122	Biology Lab II: Biochemistry, Genetics and Molecular Biology	3 credits

Content: This practical course will cover biochemical, genetic and molecular basis of life. Experiments include: Glucose estimation; Lipid estimation; Amino acid Paper chromatography; Protein estimation; Enzyme assay and Kinetics; Human genetic traits and blood grouping; DNA isolation; DNA estimation; Transformation; Plasmid isolation; Agarose gel electrophoresis; Restriction digestion and Ligation; PCR demonstration; ATC PTC demonstration; Animal handling, inoculation, dissection.

BIO 201	Introductory Biology III: Evolution and Ecology	3 credits

Introduction: This is an introductory course that would help the students in terms of A) understanding of: 1) the basic concepts in ecology and evolution, 2) how organisms interact with each other, and the environment, to form various patterns of distribution and behaviour, and 3) the modes of inquiry in the investigation of ecological and evolutionary questions; and B) ability to: 1) visualize how these concepts connect to real-life situations, and 2) investigate questions in classical genetics, ecology and evolution using the modes of inquiry in (A 3), as well as in biology/science/academic inquiry in general.

Content: Introduction: An overview of biological processes; Why study ecology and evolution?
Population ecology: Survivorship curves, Life-tables, Simple population dynamics models and their behavior, Spatial ecology.
Life history evolution: Basic concepts; Community ecology/ Species interaction: Competition; Predation; Ecosystem dynamics: Food webs; biodiversity; conservation biology; Classical Genetics: Mendel's laws, linkage; Population genetics: H-W equilibrium; mutation; selection; genetic drift; inbreeding
Macroevolution and diversity of life: Macroevolutionary concepts: reproductive isolation, speciation

Recommended Reading:

No single text book can be prescribed. The following books shall cover much of the proposed syllabus:

1. Ecology - From Individuals to Ecosystems:M. Begon,C.R. Townsend, and J.L. Harper (2005) Blackwell Publishing

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2. Ecology Concepts and Applications:M.C. Molles (2009) McGraw Hill
3. Evolutionary Analysis: S. Freeman, and J. Herron (2004) 4th edition, W. Prentice Hall

BIO 202	**Introductory Biology IV: Biology of Systems**	**3 credits**

Introduction: Biological systems are elaborate machines with parts that interact in surprising ways. This course can be envisaged as the antithesis of reductionism. Rather than take the biological machine apart, we will try to put it together and demonstrate the properties that emerge are often more than a sum of its parts. Using thematic examples from subcellular to organismal scales, we will try to derive organizational principles that mediate interactions between components. The course will introduce quantitative methods necessary to develop a systems perspective.

The goal of the course is to build from the previous introductory courses, introduce the concept of complex systems and demonstrate that by probing the design principles of complex biological systems on can begin to address the following:
What are the engineering constraints operating in biological systems?
How do biological systems achieve robustness?
How does complexity emerge from simple interactions?
How are biological systems optimized for efficiency?

Content: Introduction to complex systems; Emergent properties and evolution of biological complexity; Signal transduction; Gene regulation and gene regulatory networks; Network motifs; Fertilization and organismal development; Pattern formation; Reaction-diffusion; Evolution of body plans; Regeneration and stem cells; Physiology and models of the immune system; Physiology and models of the nervous system; Oscillation in biology.

Recommended Reading:

1. Molecular Biology of the Cell: B. Alberts, A. Johnson, J. Lewis, M. Raff, K. Roberts and P. Walter (2002) 4th edition, Garland Science
2. Principles of Development: L. Wolpert, J. Smith, T. Jessell, P. Lawrence, E. Robertson and E. Meyerowitz (2006) 3rd edition, Oxford University Press
3. An Introduction to Systems Biology: Design Principles of Biological Circuits: U. Alon (2006)1st edition, Chapman & Hall/CRC
4. Mathematical Biology: J.D. Murray (2007) Vol. I. 3rd edition, Springer

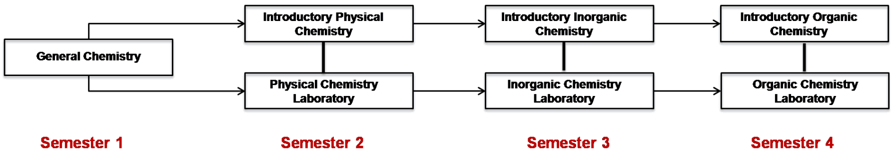
BIO 221	**Biology Lab III: Ecology and Evolution**	**3 credits**

Content: This practical course will cover basic concepts in ecology and evolution. Practicals include: Evolution of Ethnocentrism; Isolation of organisms; Global Population Dynamics Database; Plant Biodiversity field work; Growth curve (Factorial design 3 pH × 2 temperatures); Effect of nutritional selection on bacterial growth; Chemical ecology and its impact on diatom diversity; Behavioral Ecology.

CHEMISTRY

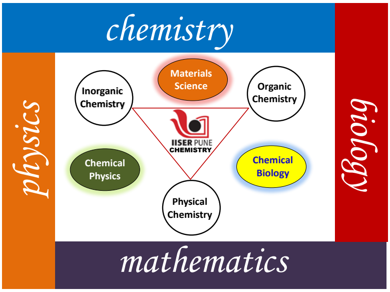
Core Courses in Chemistry during the First Two Years of the BS MS Program

The General Chemistry course covered during the first year will lay the foundation for advanced concepts in chemistry. Here the students would be exposed to a general overview of chemistry in everyday life. Some topics covered include units, measurement, periodicity, thermodynamics, kinetics, bonds, spectroscopy, solutions, chirality and biochemistry. This course serves as the common backbone for the ensuing three semesters of physical, inorganic and organic chemistry, all accompanied by laboratory courses. The laboratory course has been designed to complement classroom interactions. Together, these seven courses in the first four semesters should sufficiently prepare a student for advanced courses in chemistry and serve as the minimum for anyone who wishes to major in other disciplines of science such as physics or biology.



The Ideology behind the Chemistry Courses

The chemistry program has been broadly divided into three groups: physical chemistry, inorganic chemistry and organic chemistry. Each semester has at least one "core" course (4-credit) from these groups that a student may opt for. They are also arranged in sequence so that all topics in a particular group are covered by the end of the eighth semester. In addition to these core courses, students also have an option of choosing a potpourri of 3-credit courses. These 3-credit courses are not only important for students who wish to major in chemistry but also useful for students who wish to choose chemistry as a minor discipline of interest.



Suggestions to Students wanting to "Major in Chemistry"

Students who wish to study chemistry as the major subject of interest may opt for a majority of the core courses offered each semester and as many electives as possible in chemistry. Several sequences are available for students to choose from such as organic, inorganic and physical chemistry. If the student is interested in inter-disciplinary areas, one could choose from three available options, materials science, chemical physics and chemical biology. Of course, other combinations of courses yielding the right mix for chemistry and other disciplines might also be possible. In addition, students are allowed to register for two lab/theory projects during their third and fourth years as an elective course.

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List of Courses in Chemistry

Semester I

1. CHM 101 General Chemistry [3 credits]

Semester II

2. CHM 102 Chemistry I – Physical Chemistry [3 credits]
3. CHM 121 Chemistry Laboratory I – Physical Chemistry [3 credits]

Semester III

4. CHM 201 Chemistry II – Inorganic Chemistry [3 credits]
5. CHM 221 Chemistry Laboratory II – Inorganic Chemistry [3 credits]

Semester IV

6. CHM 202 Chemistry III – Organic Chemistry [3 credits]
7. CHM 222 Chemistry Laboratory III – Organic Chemistry [3 credits]

Details of Courses in Chemistry

CHM 101	General Chemistry	3 credits

Introduction: This course would be introductory to other major courses in Inorganic, Organic and Physical Chemistry. It would cover the fundamental concepts from the physical, inorganic and organic chemistry branches of chemistry and would be taught in a way to provide link between the 12th grade Science and the undergraduate General Chemistry.

Contents: Chemistry in the Modern World, Measure of Matter, Introduction to Thermodynamics, Chemical Equilibrium, Chemical Kinetics, Behaviour of Gases, Properties of Solutions, Solubility, Understanding Acid-Base Buffers, Solid State-Crystal versus Amorphous Solids, Symmetry and Organisation Principles for Crystalline Solids, Unit Cell, Periodic trends in properties of the Elements, Types of Bonds, Introduction to Organic Chemistry, Chirality, Functional groups and structural diversity, conformational analysis, Hetero atoms and Metals in Chemistry and Biology, Organic Materials, Asymmetric Synthesis, Chemistry of Life-Peptides, Nucleic acids, Carbohydrates, Lipids.

Recommended Reading:

1. Chemistry: Principles, Patterns and Applications: B.A. Averill and P. Eldredge (2007) 1st edition, Prentice Hall
2. Chemical Principles: S.S. Zumdahl (2009) 6th edition, Houghton-Mifflin Company
3. The Biological Chemistry of the Elements: J.J.R.F. da Silva, R.J.P. Williams (2001) 2nd edition, Oxford University Press

CHM 102	Chemistry I – Physical Chemistry	3 credits

Introduction: This course will deal with the basic principles of physical chemistry like thermodynamics, chemical kinetics, kinetic theory of gases and quantum mechanics. The physical chemistry concepts taught in this course will also serve as an important tool to understand reactions and mechanisms in organic, inorganic and biochemistry and principles of spectroscopy. At the end of this course, students should be able to apply these physical chemistry concepts to study various phenomena in physics, chemistry, materials science and biology.

Contents: *Chemical kinetics:* Basic laws of kinetics, Experimental determination of reaction order and rate, Study of fast reactions, Simultaneous reactions, Temperature dependence of reaction rate, Mechanism of chemical reactions *Kinetic Theory of Gases:* Maxwell's distribution of molecular velocities, collision in a gas, mean free-path, heat capacity of gases, Equi-partition of energy, viscosity, thermal conductivity Impact on environmental science and astrophysics; *Thermodynamics:* State and path functions, Internal Energy, Heat and Work, Laws of thermodynamics, Heat Capacity, Enthalpy, Entropy, Gibbs Free energy, Gibbs Helmholtz Equation, Chemical Potential, Colligative properties; *Chemical Bonding & Spectroscopy:* Historical development, Schrödinger equation and Postulates of Quantum Mechanics, Operators in Quantum

Mechanics, Particle in a 1 D Box to 3 Dimensional Box, Harmonic Oscillator, Hydrogen atom, Molecular Orbital Theory and Valence Bond Theory, Applications in Spectroscopy.

Recommended Reading:

1. Physical Chemistry: G.M. Barrow (2007) 5th edition, Tata McGraw Hill
2. Physical Chemistry: I.N. Levine (2002) 5th edition, Tata McGraw Hill
3. Physical Chemistry: P.W. Atkins (2006) 8th edition, Oxford University Press
4. Quantum Chemistry: D.A. McQuarrie (2003), Viva Books
5. Quantum Chemistry: I.N. Levine (2007) 5th edition, Pearson Education
6. Chemical Kinetics: K.J. Laidler (1987) 3rd edition, Pearson Education

CHM 121	Chemistry Laboratory I – Physical Chemistry	3 credits

Introduction: This course is designed to acquaint students with the practice of experimental physical chemistry. The goal of the labs is to provide modest introductions to the core area of scientific activity which would help students to apply the principles of thermodynamics, kinetics and spectroscopy presented in the physical chemistry lecture course in some illustrative experiments. Students are encouraged to understand the interconnection between the experimental foundation and the underlying theoretical principles and appreciate the limitations inherent in both theoretical treatments and experimental measurements. Students will gain familiarity with a variety of measurement techniques which will help them to understand the methods, to develop laboratory skills and to develop the ability to work independently. Orientation towards good attitudes and habits and toward learning the safe way of doing science will be provided.

Contents: Acid Base Titration using pH meter, Acid Base Titration using conductivity method, Potentiometric titrations, Heat of Neutralization, Kinetic Study of Ester hydrolysis, Activation Parameter calculations, Colligative properties of Solutions, Optical Activity by Polarimetry, UV-VIS Spectrophotometry

Recommended Reading:

1. Experiments in Physical Chemistry: C.W. Garland, J.W. Nibler and D.P. Shoemaker (2008) 8th edition, McGraw-Hill Science/Engineering/Math
2. Physical Chemistry: P. Atkins and J. de Paula (2006) 8th edition, W.H. Freeman

CHM 201	Chemistry II – Inorganic Chemistry	3 credits

Introduction: This course will introduce the students the most rudimentary principles behind the chemistry of inorganic compounds. In this course an overview introduction to the common elements of the periodic table from alkali metals to noble gases through transition-metal and main group elements will be given and their property such as periodicity, structure and bonding, acidity and basicity, redox reactivity etc. will be discussed. At the end of the course, the students should be able to derive the structure of various covalent compounds, apply the concept of acid-base chemistry to various reactions and as a whole understand the importance of the elements of the periodic table for living matter.

Contents: Atomic Structure, electronic configuration, periodicity, sizes of atoms and ions, ionization energy, electron affinity, relativistic effects, chemical bonding, Lewis theory, valance bond and molecular orbital theories, solid state structures and properties, concepts of acids and bases, Brønsted and Lewis theory, hard and soft acids and bases, oxidation and reduction, electrode potentials, Nernst equation, representation of electrochemical data, importance of water splitting, batteries and fuel cells, coordination complexes, theories of bonding in transition metal compounds, some introduction to main group compounds.

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1. Inorganic Chemistry: Shriver and Atkins (2006) International Student Edition, 4th edition, Oxford University Press
2. Concepts and Models of Inorganic Chemistry: B. Douglous, D. McDaniel and J. Alexander (2006) 3rd edition (student edition), Wiley- India
3. Inorganic Chemistry: J.E. Huheey, E.A. Keiter and R.L. Keiter (2007) 4th edition, Pearson Education
4. Concise Inorganic Chemistry: J.D. Lee (1999) 5th edition, Blackwell Science

CHM 202	Chemistry III – Organic Chemistry	3 credits

Introduction: This course includes structural chemistry of organic compounds with an emphasis on electronic structure, reactivity, conformation and stereochemistry. These concepts will prepare students for a mechanistic-based approach to learning organic reactivity. Emphasis will be given towards developing problem-solving skills unique to organic chemistry.

Contents: Carbon compounds and chemical bonding, Reactive Intermediates; Carbocations and Carbanions chemistry, Free radicals and Carbenes, Acidity, basicity, and pKa, Acidity, The definition of pKa, Basicity, Factors that influence the acidity and basicity, HSAB Principle, Stereochemistry: R and S descriptors, Axis of Chirality; E and Z system; erythro, threo; Helical descriptors- M and P. cis, trans, Conformational analysis of ethane and cyclohexane, Addition Reactions: Nucleophilic addition reaction: Nucleophilic addition reation to carbonyl group: Molecular orbitals explain the reactivity of the carbonyl Group, angle of nucleophilic attack on aldehydes and ketones, Electrophilic addition reactions: Alkenes react with bromine, water; bromohydrin formation etc. Conjugate addition: Conjugation changes the reactivity of carbonyl group, Alkenes conjugated with carbonyl groups, Substitution Reactions: Nucleophilic substitution at saturated carbon: Nucleophilic substitution**,** Structure and stability of carbocations, The SN1 and SN2 mechanisms for nucleophilic substitution. Neighbouring group participation (NGP), Aromatic electrophilic and nucleophilic substitutions, Elimination Reactions: Types of elimination reactions and factors that affecting the elimination reactions. Rearrangements: Various types: Electrophilic and nucleophilic rearrangement and Migratory aptitudes, Free radical rearrangements and Pericyclic rearrangements.

Recommended Reading:

1. Organic Chemistry: J. Clayden, N. Greeves, S. Warren and P. Wothers (2000) 1st edition, Oxford University Press
2. Organic Chemistry: T.W.G. Solomons, 2nd or 3rd edition, John Wiley & Sons
3. March's Advanced Organic Chemistry: M. Smith and J. March, 5th or 6th edition, Wiley-Interscience

CHM 221	Chemistry Laboratory II – Inorganic Chemistry	3 credits

Introduction: This laboratory course aims at demonstrating experimentally the concepts that are introduced in the introductory inorganic chemistry course that will run parallel to this lab course. Experiments based on some of the key topics that are introduced in the theory courses such as acids and bases, redox chemistry, chemistry of coordination and main group compounds will be carried out enhancing a further understanding to these topics. Through these experiments the students not only will have a complete knowledge of these topics but also will learnt the use of various techniques such as analytical and spectroscopic methods to study them.

Contents: Acid-base titrations relevant to the neutralizing power of antacids, conventional and photochemical synthesis of coordination compounds, complexametric and spectroscopic estimation of metal ion concentrations in coordination compounds, redox titration relevant to the iodine content in common salts, synthesis of disinfectants containing main group compounds such as Alum, soaps and micelles.

Recommended Reading:

A Collection of Interesting General Chemistry Experiments: A.J. Elias (2007) Revised edition Universities Press (India) Pvt. Ltd.

CHM 222	**Chemistry Laboratory III – Organic Chemistry**	**3 credits**

Introduction: This laboratory course will provide opportunity for the students to learn the nuances in organic synthesis. Students will be trained to setup reactions, monitor reactions by functional group analysis and by thin layer chromatography. In this course, students will learn basic separation and purification techniques (e.g., filtration, recrystallization and column chromatography) that are commonly used in organic synthesis. Students will be also trained in isolating natural products from natural sources. Furthermore, students will characterize the synthesized or isolated compounds by determining the melting point or by IR, UV and NMR spectroscopy. Together this organic chemistry lab course will set a platform for students who wish to pursue research in experimental chemistry.

Contents: Functional group analysis, classical name reactions and oxidation, reduction, cycloaddition, aromatic electrophilic substitution reactions, isolation of natural products and synthesis of fluorescent compounds, purification techniques such as recrystallization and column chromatography.

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MATHEMATICS

Core Courses in the First Two Years of the BS MS Program

Very basic mathematics, by which one means the bare minimum that any scientist should be familiar with, is treated in the following six core courses in the first four semesters: Single Variable Calculus, Multivariable Calculus, Linear Algebra, Probability & Statistics, Introduction to Proofs and Basic Structures of Mathematics.

> *Philosophy is written in that great book which ever lies before our eyes—I mean our universe—but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. The Book is written in the mathematical language... without which one wanders in vain through a dark labyrinth.* – Galileo Galilei

The Ideology behind the Mathematics Program

The mathematics program at IISER Tirupati is grouped into five streams: Algebra, Analysis, Geometry & Topology, Discrete Mathematics and Applicable Mathematics. These subjects seamlessly and indistinguishably blend into each other and such a coarse classification is purely for didactic purposes. The courses in the third and fourth year of the BS MS program as well as the courses for the PhD program are all based on this ideology.

List of Courses in Mathematics	
Semester I	
MTH 101 Single-Variable Calculus	[3 credits]
MTH 102 Introduction to Discrete Mathematics	[3 credits]
Semester II	
MTH 103 Multivariable Calculus	[3 credits]
Semester III	
MTH 201 Linear Algebra and Applications	[3 credits]
Semester IV	
MTH 202 Introduction to Probability and Statistics	[3 credits]
MTH 203 Basic Structures in Mathematics	[3 credits]

Details of Courses in Mathematics

MTH 101	**Single-Variable Calculus**	**3 credits**

Introduction: This course discusses some of the basic analytic properties of functions in one variable. We introduce the notions of continuity, differentiation and integration of functions.

Contents: Limits and continuity: Functions, limits, sequences, continuity, basic properties of limits and continuous functions, intermediate value theorem.
Differentiation: Derivative of a function, product and quotient rules, examples of derivatives, chain rule, implicit differentiation, related rates, critical points, maxima and minima, optimization problems, Rolle's theorem and mean value theorem, Newton's method of approximating zeros of a function.
Integration: Definite integrals, antiderivative, the fundamental theorem of calculus, Integration techniques - substitution, integration by parts and integration of rational functions using partial fractions, Applications - area between curves, volumes and arc length.
Infinite sums: series, some examples of convergent and divergent series, tests to decide convergence/divergence, Taylor expansions. Examples of ordinary differential equations.

Recommended Reading:

1. Calculus, vol. I by Tom Apostol
2. Introduction to Calculus and Analysis I by Courant and Fritz
3. Calculus by Spivak
4. Calculus by James Stewart

5. Calculus by George Thomas

MTH 102	**Introduction to Discrete Mathematics**	**3 credits**

Introduction: Discrete mathematics, unlike continuous mathematics, deals with objects that are separate from each other, like integers or train stations on a metro map.

Contents: Set theory: Sets and functions, relations, equivalence relations, cardinality, countable and uncountable sets, proof by induction.
Combinatorics: Counting, factorials, binomial coefficients, choosing, Pascal's triangle and binomial theorem, permutations, writing permutations as cycles, pigeonhole principle and inclusion-exclusion principle, Fibonacci numbers, recurrence relations.
Arithmetic: Integers, divisibility, greatest common divisor, Euclid's algorithm, primes, infinitude of primes, a digression on proofs by contradiction, sieve of Eratosthenes, congruences, Chinese remainder theorem, Fermat's little theorem, Wilson's theorem and its applications.
Lattices: Lattices in R^2 and R^3, counting lattice points, Minkowski's bound on lattice points, applications of Minkowski's bound on two square and four square theorems, sphere packing and Kepler's conjecture (now a theorem).
Graphs: Seven bridges of Königsberg, basic definitions and properties, Eulerian paths and graphs, Euler's formula, paths on a graph, traveling salesman problem, Hamiltonian paths and Hamiltonian cycle problem, trees, coloring graphs and the four color theorem.

Recommended Reading:
1. Introductory Combinatorics by Richard Brualdi
2. A course in Combinatorics by Lint and Wilson
3. An Introduction to the Theory of Numbers by Niven, Zuckerman and Montgomery
4. Introduction to Graph Theory by Douglas West

MTH 103	**Multivariable Calculus**	**3 credits**

Introduction: This course generalizes many of the ideas and concepts studied in the single-variable case to the case of functions in several variables. It results in a richer theory of limits, derivatives, integrals, etc.

Contents: Vectors, curves and surfaces: Vectors, coordinate systems (cartesian and polar), dot product and cross product, distance, equations of lines and planes, curves, arc length and curvature, level sets and quadrics, parametric surfaces.
Partial derivatives: Functions of several variables, limits and continuity, partial derivatives, tangent planes and linear approximations, normal vectors, chain rule, implicit differentiation, directional derivatives and the gradient vector, maximum and minimum values, Lagrange multipliers, examples of partial differential equations.
Multiple integrals: Double and triple integrals, applications to surface area and volumes, integration in spherical coordinates, change of variables.
Vector calculus: Vector fields, line integrals, fundamental theorem of line integrals, Green's theorem, curl and divergence, surface integrals, Stokes' theorem, divergence theorem.

Recommended Reading:
1. Calculus, vol. II by Tom Apostol
2. Introduction to Calculus and Analysis II by Courant and Fritz
3. Calculus and Analytic Geometry by George Thomas and Ross Finney
4. Multivariable Calculus by James Stewart

MTH 201	**Linear Algebra and Applications**	**3 credits**

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Introduction: Most people are familiar with the three-dimensional space and lines and planes within it. These are our prototypical "linear objects." They are called linear because they can be expressed using equations that have degree 1 (like a line). In this course we will study such objects and its generalizations in a systematic way.

Contents: Linear equations: Systems of linear equations, matrices, vectors, Gauss-Jordan elimination, matrix operations.
R^n and C^n: Vector spaces R^n and C^n, linear transformations and their inverses, relationship of between linear transformations and matrices, composition of linear transformation and product of matrices, examples of linear transformations in geometry, properties of the inverse matrix, image and kernel of a linear transformation, subspaces of R^n and C^n, linear combinations, linear independence, span, basis, dimensions of subspaces of R^n and C^n, coordinates with respect to a basis.
Abstract vector spaces: Definition of a vector spaces, generalization of linear transformations, linear combinations, linear independence, span, basis, dimension, etc. to any vector space. Examples.
Orthogonality: Orthogonal vectors, orthogonal projections and orthonormal bases, Gram-Schmidt process, orthogonal transformations and orthogonal matrices, least square solutions, applications to data fitting.
Determinants: Definition of determinants, basic properties of determinants, geometric interpretation of determinants.
Eigenvalues and Eigenvectors: Linear dynamical systems, understanding such systems using eigenvectors, characteristic polynomial, finding eigenvectors and eigenvalues, diagonalization, complex eigenvalues, symmetric matrices, spectral theorem for real symmetric matrices.

Recommended Reading:

1. Linear Algebra with Applications by Otto Bretscher
2. Linear Algebra by Kenneth Hoffman and Ray Kunz
3. Linear Algebra and its Applications by Gilbert Strang

MTH 202	Introduction to Probability and Statistics	3 credits

Introduction: This is an elementary introduction to the basic concepts in probability and statistics.

Contents:
Basics: Experiments, events, sets, probabilities, random variables, equally likely outcomes, counting techniques, conditional probability, independence, Bayes' theorem.
Discrete distributions: Expected values, mean, variance, binomial and geometric distributions,
Poisson distribution, moment generating functions.
Continuous distributions: Continuous random variables, uniform and exponential distributions, Gamma and chi-square distributions, distribution of functions of a random variable, the normal distribution, central limit theorem.
Multivariate distributions: Distributions of two random variables, correlations coefficient, conditional distributions, distributions of sums of random variables

<u>Statistics:</u>

Estimation: Maximum likelihood, optimal, unbiased estimators with examples, confidence intervals, confidence intervals for means with known variance in the normal case, large sample confidence intervals for means, confidence intervals for variances and ratios of variances and applied problems
Tests of statistical hypotheses: Tests about proportion, tests about one mean and one variance, tests of equality of two normal distributions, chi-square goodness of fit tests, contingency tables and one-factor analysis of variance.

Recommended Reading:

1. Probability and Statistical Inference by Hogg, Tanis and Rao
2. A First Course in Probability by Ross

3. Introduction to Probability and Statistics by Rohtagi and Saleh

MTH 203	Basic Structures in Mathematics	3 credits

Introduction: This course gives a basic introduction to some of the fundamental objects in mathematics. The objects that you encounter here will show up quite often in the higher level courses, you will get a preview here and an indication of their significance. The emphasis will be on examples and underlying mathematical ideas rather than proofs.

Contents: Groups: Finite groups, cyclic groups, subgroups, homomorphisms, permutation groups, rigid transformations, symmetry of geometric objects, abelian groups, structure of finite abelian groups, classical linear groups, special unitary group SU(2), special linear groups SL(2, R), one-parameter subgroups.

Rings: Introduction to rings, integral domains, ideals, homomorphisms, factorization, polynomial rings, division algorithm for polynomials, unique factorization of polynomials.

Metric spaces: Definition and basic properties, some examples, closed sets, open sets, continuity, sequences in a metric space, completeness.

Banach and Hilbert spaces: Norms, normed vector spaces, metric induced by a norm, Banach spaces, examples and basic properties, inner product spaces, norm induced by an inner product, Hilbert spaces, examples and basic properties, orthogonal complement, orthonormal sets, adjoint of an operator, self-adjoint operators, normal and unitary operators, projections.

Recommended Reading:

1. Algebra by Michael Artin
2. Topology and Modern Analysis by George Simmons
3. Analysis I & II by Terrence Tao

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PHYSICS

The courses offered in Physics at IISER Tirupati form part of a comprehensive program at the level of a Bachelor's and Master's degree (BS and MS). The Physics program aims to enable students to understand the basic laws of nature and develop the necessary skills and tools to apply this understanding to other areas and disciplines. Here students are prepared for careers in basic physics as well as in related applied sciences or technology.

The courses offered in Physics for the BS MS program are structured in two levels.

Courses in Semesters I-IV: Introduction to the World of Physics

The first level spans courses offered during the first four semesters of the BS MS Program. These courses are common and mandatory for all students. Based on their interests, the students specialize after completing the fourth semester. For this reason, the first level courses are designed to cover the basic concepts in physics in a very comprehensive manner, since they could be the only physics courses taken by students specializing in other disciplines. These courses are meant to give a flavor of the various approaches and analyses in Physics as well as to prepare them for advanced courses in later years of study.

The four World of Physics courses in the first four semesters offer all students an exposure to both the rigour and breadth of physics, concentrating mainly on mechanics, waves and matter, electricity and magnetism, and quantum physics. There are three Laboratory Courses that expose them to key experiments and teach them skills in handling basic equipment. In addition, there are two Interdisciplinary Courses offered during this period: Mathematical Methods that provides the basic mathematical tools needed for a program in science, and Thermodynamics and Optics that provides an introduction to the concepts needed for the further study of physics, biology and chemistry.

Courses in Semesters V-VIII

The courses at the second level of the program are designed for students who have chosen to specialize primarily in physics. These are in-depth courses with a strong emphasis on developing problem-solving skills.

The basic requirements for graduation during semesters V-VIII, consist of 12 courses of 4 credits each, as well as a number of courses of 3 credits each, to add up to a minimum total of 84 credits. The 4-credit courses are core courses meant for detailed and in-depth study covering all the basic areas of Physics. A student planning a career in Physics is expected to take all of them. These include Mathematical Methods, Classical Mechanics and Electrodynamics, two courses in Quantum Mechanics, Statistical Mechanics, Condensed Matter Physics, Nuclear and Particle physics, Atomic and Molecular Physics and Classical and Quantum Optics. In addition, advanced courses in Statistical Mechanics, Condensed Matter Physics, Quantum Information and Gravitation and Cosmology are offered as courses of 3 credits that are a sequel to some of the basic courses. Four Laboratory courses are offered, one in each semester, which will train students in advanced-level experiments and the use of modern equipment.

The courses at this level are designed to train students to enter into a career as experimental or theoretical physicists. For this purpose, students are encouraged to follow their own inclinations and can take any combination of basic theoretical courses including current research topics, as well as advanced laboratory courses, along with courses like electronics and experimental methods.

Semester IX-X

During the final two semesters of the program, students do an extended project for 36 credits that result in the MS thesis.

List of Courses in Physics

Semester I

1.	PHY 101	World of Physics I – Mechanics	[3 credits]
2.	PHY 121	Physics Lab I	[3 credits]

Semester II

3.	PHY 102	World of Physics II – Waves and Matter	[3 credits]

Semester III

4.	PHY 201	World of Physics III – Electricity & Magnetism	[3 credits]
5.	PHY 221	Physics Lab II	[3 credits]

Semester IV

6.	PHY 202	World of Physics IV – Quantum Physics	[3 credits]
7.	PHY 222	Physics Lab III	[3 credits]

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Details of Courses in Physics

PHY 101	World of Physics I – Mechanics	3 credits

Introduction: Overview of basics of mechanics and some important applications, introduced at a level which will help the students with succeeding courses.

Contents:
Section 1: Place of mechanics in physics, Range of validity of classical mechanics. Kinematics and mathematical tools, Newton's laws, Examples of one, two and three dimensional motion under forces.
Section 2: Central force motion and application to planetary motion, Rotational motion of a rigid body, Potential energy, multiparticle systems and conservation laws.
Section 3: Frames of reference, Galilean relativity, non-inertial frames, basic special relativity, Least action principle, Hamiltonian and phase space.

Recommended Reading:

1. Mechanics: C. Kittel, W.D. Knight, M.A. Ruderman, C.A. Helmholz and B.J. Moyer (2008) Berkeley Physics Vol 1, Tata McGraw-Hill Ltd
2. Classical Mechanics: R.D. Gregory (2008) Cambridge University Press
3. Introduction to Classical Mechanics: D. Borin (2009) Cambridge University Press
4. Classical Mechanics: J.R. Taylor (2005) University Science Books
5. Mechanics: L.D. Landau and E.M. Lifshitz (2007) 3rd edition, Butterworth-Heinemann

PHY 102	World of Physics II– Waves and Matter	3 credits

Introduction: To develop familiarity with classical phenomenology relating to deformable media and oscillatory phenomena which are ubiquitous in nature.

Contents:
Section 1 – Oscillations and waves: free oscillations of simple systems: linearity and the superposition principle, free oscillations of systems with many degrees of freedom, beats, transverse modes of a continuous string, general motion of a continuous string and Fourier analysis, forced oscillations, damped driven one-dimensional harmonic oscillator, resonances in a system with two degrees of freedom, forced oscillations of a closed system with many degrees of freedom.
Section 2 – Travelling waves: harmonic travelling waves in one dimension and phase velocity,index of refraction and dispersion, reflection and transmission, modulations, pulses and wave packets, group velocity, Fourier analysis of pulses and of traveling wave packets, waves in two and three dimensions, harmonic plane waves and the propagation vector
Section 3 – Properties of deformable media: stress and strain, Hooke's law, torsion of rods, bending of rods, small deflections of rods, stability of elastic systems, compressible and incompressible fluids, viscous fluids.
Section 4 – Elastic waves in fluids and solids, Isotropic and anisotropic media

Recommended Reading:

1. Waves: F.S. Crawford Jr (2008) Berkeley Physics volume 3, Tata McGraw-Hill Ltd
2. Physics of Waves: H. Georgi (2007) Benjamin Cummings
3. Classical Mechanics: N. Rana and P. Joag (2001) Tata McGraw-Hill Education
4. Classical Mechanics: J.R. Taylor (2005) University Science Books

PHY 121	Physics Lab I	3 credits

Introduction: To learn how to approach experiments in physics: design, observations, data analysis and interpretation, with a focus on mechanics, sound and optics.

Contents: Simple pendulum, Forced Oscillators and resonators, Damped Oscillations, Coefficient of friction, Viscosity and Stoke's law, Newton's rings, Resolving Power of a prism, Measurement of refractive index, Spectrum of Mercury and Sodium, Velocity of sound, Surface Tension

PHY 201	World of Physics III– Electricity and Magnetism	3 credits

Introduction: To introduce the basics concepts of electricity and magnetism and motivate students about the importance of understanding the behaviour of materials subjected to electric and magnetic fields.

Contents: Electrostatics, Coulomb's law, Gauss's law and its applications, method of images, magnetostatics, electric fields in matter, dielectrics, polarisation, magnetic fields in matter, magnetic materials, Biot-Savart law, Ampere's law, Faraday's law, Lorentz force law, displacement current, Maxwell equations.

Recommended Reading:

1. Electricity and Magnetism: E.M. Purcell (2008) Berkeley Physics Course, Vol 2, Tata McGraw-Hill Ltd
2. Feynman Lectures on Physics: R.P. Feynman, R.B. Leighton and M. Sands (2011) The Millenium edition, Vol 2, Basic Books
3. Introduction to Electrodynamics: D.J. Griffths (2012) Pearson Education

PHY 202	World of Physics IV – Quantum Physics	3 credits

Introduction: To introduce students to the fundamental laws of nature operating at the atomic scale and below.

Contents: Historical background, discrete spectra, wave-particle duality, wave packets, uncertainty principle, postulates of quantum mechanics, Schroedinger equation, expectation values, particle in a box, potential well and barrier in one dimension, Hydrogen atom

Recommended Reading:

1. Quantum Physics: S. Gasiorowicz (2003) 3rd edition, Wiley India Edition
2. Quantum Physics: E.H. Wichman (2008) Berkeley Physics Course, Vol 4, Tata McGraw-Hill Ltd
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles: R. Eisberg and R. Resnick, 2nd edition, John Wiley and Sons
4. Quantum Mechanics: C. Cohen-Tannoudji, B. Diu and F. Laloe (1977) Vol 1, Wiley-Interscience

PHY 221	Physics Lab II	3 credits

Introduction: Meant for students to gain exposure to experiments in basic Physics, as a continuation of experiments in Semester I.

Contents: Thermal expansion of solids, thermal conductivity by Lee's method, specific heat of solids, Stefan's law of radiation, temperature dependence of a thermistor, Malus's Law, Faraday's and Lenz's law of electromagnetic induction, Biot-Savart's law

PHY 222	Physics Lab III	3 credits

Introduction: This lab course is for introducing students to Modern Physics. The experiments include measurement of fundamental constants such as Plank's constant, e/m ratio. We aim to give basic introduction to optical spectroscopy and interferometry.

Contents: Photo-electric effect, Cornu's method to determine Young's modulus, e/m by Thomson's method

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Rydberg's Constant, Millikan's oil drop Methods, G-M Counter Characteristics, Constant Deviation spectrometer, Michelson interferometer

Recommended Reading:

1. Advanced Practical Physics: B.L. Worsnop and H.T. Flint, Asia Publishing House
2. Analytical Experimental Physics: Michael Ference Jr., Harvey B. Lemon, Reginald J. Stephenson (1970) University of Chicago Press
3. The Art of Experimental Physics: D.W. Preston and E.R. Dietz (1991) John Wiley

EARTH AND CLIMATE SCIENCE

The courses in Earth and Climate Science at IISER Tirupati aim to enable students understand the basic principles and controlling factors of various geological, oceanic and atmospheric processes. These inter-disciplinary courses present combined applications of various branches of science (i.e. geology, physics, chemistry and mathematics) in yielding useful information on the structure and evolution of our planet, magmatic and aqueous processes, and recent climatic changes through natural and man-made activities.
The courses offered in Earth and Climate Science are structured in two levels. The mandatory courses taught in the first two years introduce various geological reservoirs and feedback processes associated with them. The advanced courses deal with geophysical and geochemical approaches in understanding the internal dynamics of our planet and yielding quantitative information for processes responsible for reshaping the Earth and its resources.

List of Courses in Earth and Climate Science

Semester III

1. ECS 201 Earth System I [2 credits]

Semester IV

2. ECS 202 Earth System II [2 credits]

Details of Courses in Earth and Climate Science

ECS 201	Earth System-I	2 credits

Introduction: The Earth System operates through some fundamental cycles such as the Water, Energy, and the Carbon Cycles. This course deals with the concept of feedbacks within the Earth System, global energy balance and the Greenhouse Effect. A brief introduction to the atmospheric and oceanic circulation will lead to the water cycle connecting the land, ocean, and atmosphere to the Earth System. Introduction to the Global carbon, nitrogen, and sulfur cycles will be followed by the concept of long-term climate regulation and short-term climate variability.

Contents: Global change on short and long time-scales: Global warming and Greenhouse Effects, role of long-term variability of solar luminosity. Introduction to Systems and feedbacks: Systems, components, Daisy World. Global Energy balance, Greenhouse effect: Greehouse gases, clouds, radiation balance. Oceans and the Atmosphere: Wind-belts, ocean currents, Coriolis Effect, Solar forcing. Atmospheric and oceanic circulation, cells, seasons, deserts. Global Carbon Cycle: Recycling elements: Life on Earth, marine productivity, in/organic carbon, warm/cold waters, residence/response times, missing sink. Global Carbon Cycle: Ecosystems, biological pump, biomass, biodiversity, stability, and interactions with the environment. Other elemental cycles: Nitrogen, Phosphorus, Silica. Long-term Climate Regulation: Faint Young Sun Paradox.

Recommended Reading:

1. The Earth System by L. Kump, J. Kasting, and R. Crane, Prentice Hall, 3rd Edition, 2009.
2. Earth System Science by M. Jacobson, R. Charlson, H. Rodhe, and G. Orians, Academic Press, 1st Edition, 2000.

ECS 202	Earth System-II	2 credits

Introduction: Continuing with The Earth System-I, this course provides an integrated view of the Planet Earth dealing with the Earth's internal structure and processes (Earth materials, earthquakes, volcanism, plate movement), and surface processes.

Contents: Structure and composition of planets: a comparative study of the Earth and other planets; Understanding Earth Processes: Earth material, Rock formation processes and its deformation; Earthquakes and Earth Structure: Earthquakes due to brittle fracture; elastic wave propagation and detection;

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retrieving physical properties of the Earth's interior; Models of chemical constitution of the layered Earth; Earth's thermal state; convection in the outer core and the geomagnetic field; Plate Tectonics: A unique planetary mechanism for the outward flow of the Earth's internal heat (spreading center, transform fault, subduction).

Recommended Reading:

1. The Earth System by L. Kump, J. Kasting, and R. Crane, Prentice Hall, 3rd Edition, 2009.
2. Understanding Earth by J. Grotzinger and T J Jordan, W H Freeman and Co., 6th Edition, 2010.

INTERDISCIPLINARY COURSES

IDC 101	**Introduction to Computation**	**3 credits**

Introduction: The goal of this course is to teach the student to think like a computer scientist. This way of thinking combines some of the best features of mathematics, engineering, and natural science. Like mathematicians, computer scientists use formal languages to denote ideas (specifically computations). Like engineers, they design things, assembling components into systems and evaluating tradeoffs among alternatives. Like scientists, they observe the behavior of complex systems, form hypotheses, and test predictions. The single most important skill for a computer scientist is problem solving. Problem solving means the ability to formulate problems, think creatively about solutions, and express a solution clearly and accurately. As it turns out, the process of learning to program a computer is an excellent opportunity to practice problem-solving skills.

Contents: Variables, expressions and statements; Values and types; Variable names and keywords; Operators and operands; Expressions and statements; Order of operations; String operations; Functions; Function calls; Type conversion functions; Math functions; Composition; Adding new functions; Flow of execution; Parameters and arguments; Variables and parameters are local; Stack diagrams; Fruitful functions and void functions; Encapsulation; Generalization; Conditionals and recursion; Modulus operator; Boolean expressions; Logical operators; Conditional execution; Alternative execution; Chained conditionals; Nested conditionals; Recursion; Infinite recursion; Composition; Iteration; Multiple assignment; Updating variables; The while statement; break; Square roots; Algorithms; Strings; Lists; List operations; List slices; List methods; Map, filter and reduce; Dictionaries; Dictionary as a set of counters; Looping and dictionaries; Reverse lookup; Memos; Global variables; Long integers; Sequences of sequences; Random numbers; Files; Reading and writing; Filenames and paths; Classes and methods; Object-oriented features; Operator overloading; Polymorphism; Debugging; Inheritance; Card objects; Class attributes; Class diagrams; Analysis of Algorithms; Order of growth; Analysis of basic Python operations; Analysis of search algorithms.

Recommended Reading:

1. Think Python: How to Think Like a Computer Scientist: A. Downey (2012) O'Reilly
2. Python Programming: An Introduction to Computer Science: J. Zelle (2003) Franklin Beedle & Associates
3. Programming Pearls: J. Bentley (1999) 2nd edition, Pearson
4. How to Solve It by Computer: R.G. Dromey (2006) Pearson
5. Thinking in Java: B. Eckel (2000) Pearson
6. Structure and Interpretation of Computer Programs: H. Abelson, G.J. Sussman and J. Sussman (1996) MIT Press
7. Introduction to Computing: Explorations in Language, Logic, and Machines: D. Evans (1996) Createspace

IDC 104	**Mathematical Methods**	**3 credits**

Introduction: This course surveys the basic mathematical methods required by any undergraduate student of the natural sciences.

Contents: Basic calculus with emphasis on trigonometric, exponential and log functions; sketching functions of one variable; basics of complex numbers; vectors and matrices; partial differentiation; vector calculus; line integrals, surface integrals, volume integrals; ordinary differential equations; Fourier series and transforms.

Recommended Reading:

1. Mathematical Methods for Physics and Engineering, K.F. Riley, M.P. Hobson and S.J. Bence

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2. Mathematical Methods in the Physical Sciences, M. L. Boas

HUMANITIES AND SOCIAL SCIENCES

HSS 102	Critical Reading and Communication	2 credits

Introduction: This course has dual aims. The first is to develop skill sets applicable to a wide variety of settings for (1) critical reading and thinking; (2) effective writing in terms of appropriate language, organizational structure and sound content; and (3) oral presentations (including PowerPoint presentations). The second is to explore the natural sciences in the broader context of the philosophy and implications of Science, the impact of the sciences on society and vice-versa, and to study the relationships between Science, the Humanities, and the Social Sciences.

Contents: The course content includes assigned non-technical articles and videos on variety of topics related to science and society: the history of science & technology; biographies of scientists; the interactions between sciences and humanities; overlaps of and differences between the social sciences and natural sciences; the impact of social differences (e.g. gender/ class/ region etc.) and social institutions (e.g. nationalism/ politics/ religion) that affect scientific practice. Students are expected to analyze these topics through the study material provided, complete written assignments, and make presentations on a variety of topics.

Material: All study material and tasks will be provided by the instructors.