Elective Course

Course Code	Course Title	L-T-P-C
BB612	Animal Model in biomedical Research	3-0-0-6
BB614	Molecular and cellular Neuroscience	3-0-0-6
BB 420	Enzyme and Protein Engineering	3-0-0-3
BB 302	ALO-UG Research Laboratory Exposure	2-0-2-2
CL 405	Applications of Mass Transfer	3-0-0-6
CH 904	Advanced computational chemistry	3-0-0-6
CH 910	Seminar	2-0-0-4
CH 901	Coordination chemistry, Organometallics and Organometallic Reagents	3-0-0-6
CH 917	Organic Reactions and Mechanism	3-0-0-6
CE 601	Pavement Engineering	2-1-0-6
CE 602	Geosynthetic Engineering	2-1-0-6
CE 603	3D Concrete Printing Technology	2-0-2-6
CE 605	Advanced Soil Mechanics	2-1-0-6
CE 606	Vibrations and Structural Dynamics	2-1-0-6
CS 618	Advanced Software Development Laboratory	1-0-4-6
CS 619	Advanced Data Structures and Algorithms Lab	0-0-3-3
CS 633	Advanced data structures and algorithms	3-0-0-6
CS 634	Combinatorics and Probability	3-0-0-6
CS 639	Scalable Data Mining	3-0-0-6
CS 609	Software Defined Networking (SDN) and Network Function Virtualization (NFV)	3-0-0-6
CS 601	Software Development for Scientific Computing	3-0-0-6
CS 612	Statistical Pattern Recognition Laboratory	0-0-3-3
CS 616	Statistical Pattern Recognition	3-0-0-6
CS 428	Deep Learning	3-0-0-6
CS 403	Graph Theory and Combinatorics	3-0-0-6
CS 309	Research and Development Project	0-0-6-6
CS 405	B. Tech Project-CSE	
CS 320	Research and Development Project II	0-0-6-6
HS 409	Philosophy	3-0-0-6
HS 410	Modernism and the ‘Hero’	3-0-0-6
HS 435	Introduction to Industrial Organization	3-0-0-6
HS 427	Visual Narratives	3-0-0-6
HS 433	Introduction to Indian Knowledge System - I	3-0-0-6
HS 436	Introduction to Indian Knowledge System - II	3-0-0-6
HS 437	Sanskrit - I	3-0-0-6
HS 438	Introduction to Music - I	3-0-0-6
HS 601	Communication Skills	P/NP

Elective Course

HS 910	Seminar	0-0-4-4
HS 911	Seminar II	0-0-4-4
HS 902	Macroeconomics	3-0-0-6
HS 608	Principles of Microeconomics	3-0-0-6
HS 606	Meta-Ethics	4-0-0-8
HS 620	Normative Ethics	4-0-0-8
HS 801	Literary Theory and Criticism	4-0-0-8
HS 808	Interdisciplinary Approaches to Literary Research	4-0-0-8
HS 621	Postmodernism: Theory and Literarture	
HS 622	Modernism: Theory and Literarture	
HS 607	Research Methodology in Humanities and Social Sciences	4-0-0-8
HS 623	Literature and Philosophy	4-0-0-8
EE 334	Sensors and Instrumentation	3-0-0-6
EE 335	Hardware Descriptive Languages	2-0-2-6
EE 420	Digital Communication and Coding Theory	2-0-2-6
EE 699	Next Generation Wireless Networks	3-0-0-6
EE 601	Analog IC Design	3-0-0-6
EE 607	Power System Dynamics and Control	2-0-1-6
EE 610	VLSI Design	3-0-0-6
EE 615	Embedded systems Lab	0-0-3-3
EE 616	VLSI Simulations Lab	0-0-3-4
EE 622	Multivariable Control Systems	3-0-0-6
EE 625	Design of Power Converters	2-0-1-6
EE 629	Probability Models and Applications (PMA)	3-0-0-6
EE 634	Linear Algebra and its Applications	3-0-0-6
EE 688	Physics of Transistor	3-0-0-6
EE 690	Embedded systems Design	3-0-0-6
EE 695	Design of Magnetic Components for Power Electronics	3-0-0-6
EE 696	Power Quality Analysis (PQA)	3-0-0-6
EE 331	Research and Development Project	0-0-6-6
EE 333	Research and Development Project - II	0-0-6-6
EE 407	B.Tech. Project-EE	0-0-6-6
MA 603	Irrational and Transcendental Numbers	3-0-0-6
MA 604	Algebraic Number Theory	3-0-0-6
MA 602	Introduction to Lie Algebras	3-0-0-6
MA 920	Introduction to Representation Theory	3-0-0-6
MA 921	Differential Topology	3-0-0-6
MA 923	Introduction to Graduate Algebra	3-1-0-8
MA 910	Seminar	0-0-4-4
ME 426	Introduction to Computational Fluid Dynamics	3-0-0-6

Elective Course

ME 440	Rocket Propulsion	3-0-0-6
ME 605	Additive and Forming Manufacturing Processes	3-0-0-6
ME 607	Advanced Solid Mechanics	3-0-0-6
ME 608	Advanced Mechanisms and Dynamics of Mechanical Systems	3-0-0-6
ME 609	Advanced Fluid Mechanics and Heat Transfer	3-0-0-6
ME 621	Introduction to Programming and Modeling Laboratory	1-0-3-5
ME 629	Fundamentals of Acoustics	3-0-0-6
ME 643	Finite Element Analysis	3-0-0-3
ME 652	Fatigue and Fracture Mechanics	3-0-0-6
ME 668	Smart Materials and Structures	3-0-0-6
ME 903	Engineering Mathematics for Advanced Studies	3-0-0-6
ME 449	Bio energy conversion	-
ME 329	Research and Development Project	0-0-6-6
ME 330	Research and Development Project - II	0-0-6-6
ME 405	B.Tech. Project-ME	0-0-6-6
ME 634	Practicum	0-0-3-3
ME 666	M.Tech. Project - I	-
ME 910	Seminar	0-0-4-4
PH 402	Astrophysics	2-1-0-6
PH 404	Introduction to Quantum Information and Computation	2-1-0-6
PH 309	Research and Development Project	
PH 432	B.Tech Project-EP	

Elective Course

1	**Title of the course** (L-T-P-C)	**Molecular and Cellular neuroscience (3-0-0-6)**
2	**Pre-requisite courses(s)**	**None**
3	**Course content**	**1.** History of neuroscience Edwin Smith Papyrus, Aristotle's views on brain anatomy, Camillo Golgi, Santiago Ramón y Cajal. **2.** Organization of the nervous system Central nervous system, Brain, Cerebrum, Diencephalon, Brain Stem, **3.** Cerebellum, Ventricles and Cerebrospinal Fluid, spinal cord, peripheral nervous system, autonomic and somatic nervous system, cranial and spinal nerves, pain and itch Development of the nervous system **4.** Patterning the Vertebrate Body Plan, Axes and Germ Layers, The Mesoderm and Early Nervous System, Patterning of the Nervous System, **5.** Morphogenesis, Cell Differentiation and Stem Cells, Specification of Neural Fate, Axon guidance, Synapse Formation, Activity-Dependent Synaptic **6.** Competition, Plasticity and Language Development, Autism **7.** Cell types in the nervous system **8.** Neurons, establishment of polarity and compartmentalization, glia, astrocytes, oligodendrocytes, microglia, Schwann cells. Brain as a cellular ecosystem. **9.** Neuronal physiology and synaptic transmission, electrophysiology, synaptic plasticity, learning and memory, reinforcement learning, Spike-Timing Dependent Plasticity, Long term potentiation, long term depression, **10.** systems neuroscience, sensory systems, visual system, development of visual system, ocular dominance, higher order visual areas, auditory system, tonotopic mapping, somatosensory system, barrel cortex development and plasticity, sensory homunculus, Hallucinations and illusions, motor systems, motor homunculus, mesolimbic circuitry, Motivation and Addiction. **11.** Disorders of the brain, Alzheimer's disease, nigrostriatal pathway, Parkinson’s disease, multiple sclerosis, Schizophrenia, disease modeling.
4	**Texts/References**	1. Principles of Neural Science, Sixth Edition, Eric R. Kandel, John D. Koester, Sarah H. Mack, Steven A. Siegelbaum 2. Cellular and Molecular Neurophysiology, 3rd Edition, Constance Hammond 3. From Molecules to Networks: An Introduction to Cellular and Molecular 4. Neuroscience, 3rd Edition, John H. Byrne, Ruth Heidelberger, M. Neal Wexham

Elective Course

1	**Title of the course** (L-T-P-C)	**Enzyme and protein engineering** **(3-0-0-3)**
2	**Pre-requisite courses(s)**	
3	**Course content**	Kinetics of enzyme-catalyzed reactions. The Michaelis-Menten and the Briggs-Haldane model. Enzyme inhibitors: competitive, non- competitive, uncompetitive. Activity assays.Definitions of enzyme unit and the marketing of enzymes. Molecular mechanisms of selected enzymes: α-chymotrypsin, DNA polymerases,and lactate dehydrogenase. Rational design of artificial proteins. Principles and practice of rational protein engineering. Construction of enzyme variants featuring improved thermostability or altered catalytic performances. Introduction of artificial disulfide bonds and thermostability. Grafting of the seryl-proteases catalytic triad into target proteins and construction of artificial proteases. Multifunctional enzymes. Directed evolution of enzymes. Principles and practice of directed evolution. Generation and recombination of mutant libraries by means of mutagenic PCR, DNA shuffling, STEP (staggered extensionprocess). Screening and selection strategies. Construction of thermostable enzymes by meansof directed evolution. Bacterial mutator strains asa tool for the construction of random mutant libraries.
4	**Texts/References**	1. Daniel Purich, Enzyme kinetics: catalysis and control, 2010, Elsevier 2. Sheldon J. Park & Jennifer R. Cochran,Protein Engineering and design, 2009, CRC Press 3. Biochemistry: Lubert Stryer; W. H. Freeman; 7th Edition; 2010. 4. Biochemistry by Donald Voet, Judith 5. G. Voet; Wiley; 4th edition; 2010.

Elective Course

1	**Title of the course** (L-T-P-C)	Applications of Mass Transfer (3-0-0-6)
2	**Pre-requisite courses(s)**	CL 203 (Mass Trasfer)
3	**Course content**	**Liquid-Liquid Extraction**: Liquid equilibria, single-stage and multi-stageextraction, Fractional extraction, emulsions, and dispersions. **Cooling tower:** saturated and unsaturated vapor-gas mixtures, Air-watersystem, gas-liquid contact operations, adiabatic, non-adiabatic operations. **Adsorption**: Types of adsorptions, Adsorption Equilibria, Heat of adsorption, adsorption operations, single stage and multistage operations, Ion exchange. **Drying:** Drying Operations, Batch drying and mechanisms, continuous drying **Leaching:** Steady and unsteady state operation, methods of calculations, stage efficiency, single and multi-stage leaching
4	**Texts/References**	**1.** R.E.Treybal, Mass Transfer Operations, 3rd Edition, McGraw Hill, New Delhi, 1983. **2.** E.D. Cussler, Diffusion - Mass Transfer in Fluid Systems, Cambridge University Press, Cambridge 1984. **3.** A. S. Foust, Principles of Unit Operations, 2nd Edition, Wiley, New York, 1980. **4.** C.J. Geankoplis, Transport Processes and Unit Operations, 3rd Edition, PrenticeHall, India, 1993.

Elective Course

1	**Title of the course** (L-T-P-C)	**Advanced computational chemistry** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Introduction to computer programming in Fortran, Elementary programming methods, arrays, do loops, functions and subroutines. Elementary numerical methods, error analysis, interpolations, matrix methods, integration, differential equations, integral transforms and random numbers. Use of Scilab in numerical methods and graphics. Classical molecular dynamics and Monte Carlo Simulations. Use of Gromacs software for classical molecular dynamics
4	**Texts/References**	1. T. R. McCalla, Introduction to Numerical Methods and Fortran Programming (1967), Amazon Book 2. M. P. Allen and D. J. Tildesley, Computer Simulation of Liquids, Oxford University Press (1990) 3. NPTEL/MOOCS videos and course materials on Computational Chemistry Gromacs manual

Elective Course

1	**Title of the course** (L-T-P-C)	**Coordination chemistry, Organometallics and organometallic reagents** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	1. Coordination chemistry: Fundamentals, theory and applications. 2. History and types of Organometallic compounds, 18 Valence Electron Rule and Classification. 3. Sigma-Donor ligands: Preparation and Properties and its application. 4. C−H activation, characterization and bonding. C−C Bond activation, Transition Metal Perfluoroalkyl (RF−TM) Complexes and its preparation. C−F Activation 5. Transition Metal Alkenyl/Aryl/Alkyne/Carbene/carbynes Complexes 6. Transition Metal Carbonyls: Bonding properties, Reactivity, Carbonyl Metallates, Carbonyl Hydrides and its application, application of Metal Halides and Metal Alkenes 7. Transition Metal Olefin Complexes: Reactivity, Bonding Properties. 8. Transition Alkyne Complexes: Reactivity.
4	**Texts/References**	Organometallics by Christoph Elschenbroich Organometallic Chemistry of Transition Metals by Robert H Crabtree.

Elective Course

1	**Title of the course** (L-T-P-C)	**Organic reactions and mechanisms** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	Reactive Intermediates**:** An overview and revision of the chemistry of carbenes, nitrenes, radicals, carbocations, carbanions and benzynes. Classification of reactions: A brief introduction to substitution, elimination, addition, oxidation, reduction, rearrangement and pericyclic reactions. Named reactions, mechanisms and applications: Aldol reaction, alkene and alkyne metathesis, Baeyer-Villiger oxidation, Barton reaction, Beckmann rearrangement, benzilic acid rearrangement, benzoin and acyloin condensation, Bergman cycloaromatization reaction, Birch reduction, Brown hydroboration, Buchner reaction, Buchwald-Hartwig cross- coupling, Burgess dehydration, Cannizzaro reaction, Claisen condensation, Claisen rearrangement (including Johnson, Ireland and Eschenmoser modifications), Cope reaction, Cope rearrangement (including aza-Cope and oxy Cope), Corey and related reactions, Criegee oxidation, Curtius rearrangement, Dakin oxidation, Darzens condensation, Danishefsky's diene cycloaddition, Dess-Martin oxidation, Dieckmann condensation, Diels-Alder cycloaddition, Ene reaction, Eschenmoser-Tanabe Fragmentation, Favorskii rearrangement, Fischer indole synthesis, Friedel- Crafts reaction, Fries rearrangement, Gabriel synthesis, Grignard reaction, Heck reaction, HVZ reaction, Hoffmann reaction and elimination, Hoffman rearrangement, Jacobsen epoxidation, Jones oxidation, Julia olefination, Knoevenagel condensation, Kolbe-Schmitt reaction, Lossen rearrangement, Mannich reaction, McMurry coupling, MPV reduction, Michael addition, Mitsunobu reaction, Negishi cross coupling, Oppenauer oxidation, Paterno-Buchi reaction, Perkin reaction, Peterson olefination, Pictet-Spengler reaction, Pinacol rearrangement, Prevost reaction, Pummerer rearrangement, Reformatsky reaction, Reimer-Tiemann reaction, Robinson annulation, Schmidt reaction, Sandmeyer reaction, Sharpless epoxidation and dihydroxylation, Shapiro reaction, Smiles rearrangement, Sonogashira cross-coupling, Staundinger reaction, Stevens rearrangement, Stille coupling, Stobbe condensation, Strecker reaction, Suzuki cross-coupling, Swern oxidation, Tebbe olefination, Tsuji-Trost reaction, Ugi reaction, Ullmann reaction, Wacker oxidation, Wagner- Meerwein rearrangement, Williamson ether synthesis, Wolff rearrangement, Wollf-Kishner reduction, Wurtz coupling, Witting reaction and Wittig rearrangement
4	**Texts/References**	**1.** Jerry March and Michael Smith, "Advanced Organic Chemistry", 7th Ed.,Wiley. **2.** F. A. Carey and R. J. Sundburg, "Advanced Organic Chemistry, Part A and B", Fifth Ed., Plenum Press. **3.** J. Clayden, N. Greeves, S. Warren and P. Wothers, "Organic Chemistry",2nd Ed., Oxford University Press. **4.** W. Carruthers, "Some Methods of Organic Synthesis", CambridgeUniversity Press. **5.** Laszlo Kurti and Barbara Czako, "Strategic applications of named reactions in organic synthesis" **6.** Norman and Coxon, "Principles of organic synthesis, 3rd edition, CRC press 7.Robert Grossman, "Art of writing reasonable organic reaction mechanisms", 2nd edition **7.** Organic chemistry by Paula Bruice/ Wade Jr/Solomons

Elective Course

1	**Title of the course** (L-T-P-C)	**3D Concrete Printing Technology (2-0-2-6)**
2	**Pre-requisite courses(s)**	CE 201 Building and Construction Materials CE203 Building Planning and Drawing CE 205 Structural Analysis
3	**Course content**	UNIT – I: Introduction to 3D Concrete Printing History and evolution of concrete printing, types of 3D concrete printers and their capabilities, various 3D printing technologies, advantages, and challenges of 3D concrete printing, and problem facing in the construction industry. UNIT – II: Material Sciences, Process, and Sustainability Materials properties, materials characterization, concrete mix design for 3D printing, fibre reinforcement and additives, sustainable materials for 3D printing. Components of 3D concrete printing system, on-site printing vs. Factory printing. On- site mixing systems; delivering print materials to the site. Economic Breakdown and life cycle assessment of to achieve sustainability. UNIT – III: Structural Design and Analysis Design considerations for 3D printed structures, mechanical properties, engineering properties of 3D printed concrete, durability aspects of 3D printed concrete, finite element analysis (FEA) for 3D printed elements. Case studies on 3D printed buildings. UNIT – IV: Automation and Robotics Robotics systems in 3D concrete printing; sensors and feedback control, programming, and scripting for automation; Building Information Modelling (BIM) for sustainable design of 3D concrete printing. 5D modelling of 3D printing concrete structure. Technology prospectives and insights. Practice Sessions: □ Operating 3D concrete printers □ Designing and 3D printing small-scale projects □ Troubleshooting and maintenance
4	**Texts/References**	1. Sanjayan, J. G., Nazari, A., & Nematollahi, B. (2019) D concrete printing technology: construction and building applications. Butterworth-Heinemann. 2. Miryousefi Ata, Sara; Kazemian, Ali; Jafari, Amirhosein (March 7, 2022) "Application of Concrete 3D Printing for Bridge Construction: Current Challenges and Future Directions". Construction Research Congress 2022. American Society of Civil Engineers. pp. 869–879. 3. Mohammad, Malek; Masad, Eyad; Al-Ghamdi, Sami G. (December 17, 2020). "3D Concrete Printing Sustainability: A Comparative Life Cycle Assessment of Four Construction Method Scenarios". Buildings. 10 (12): 245. doi:10.3390/buildings10120245. 4. Academic Papers 5. 3D concrete printing equipment and facilities

Elective Course

1	**Title of the course** (L-T-P-C)	**Advanced Soil Mechanics (2-1-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Module 1 (Introduction): Soil Composition, Index Properties, Soil Classification, Soil Structure Module 2 (Shear Strength of Soils): Mohr-Coulomb Failure Theory, Response of Soils to Shearing Force, Drained and Undrained Strength, Laboratory and Field Tests, Factors Affecting Shear Strength, Useful Correlations. Module 3 (Slope Instability): Introduction, Infinite Slope, Finite Slope, Stability analyses: General, Ordinary & Bishop's Methods of slices, Spencer & Janbu Metods of Slope Stability Analysis, Application of software: SLOPE/W, Wedge Method, Stability Charts Module 4 (Theory of Elasticity): Stress-Strain Relationship for various loading conditions, Elastic Stress Analysis, Introduction to Computer Program SIGMAW. Module 5 (Theory of Plasticity and Models for Soils): Elements of Plasticity, Yield Criteria, Post-yield Behavior, Elastic-Perfectly Plastic Model, Hardening Plasticity Based Model. Introduction to computer program PLAXIS
4	**Texts/References**	**Textbooks:** 1. Das, B.M., Advanced Soil Mechanics (5th edition), CRC Press, Taylor and Francis Group, 2020 2. Atkinson, J.H.. An Introduction to the Mechanics of Soil and Foundations. McGraw Hill, 1993 **Reference Books:** 1. Budhu, M., Soil Mechanics and Foundation (3rd edition), John Wiley & Sons Inc, 2011 2. Lambe, T.W. and Whitman, R.V. Soil mechanics, John Wiley and Sons, New York, 1979. 3. A.P.S. Salvadori, Plasticity & Geomechanics, Cambridge University Press, 2002

Elective Course

1	**Title of the course** (L-T-P-C)	**Theory of Vibrations and Structural Dynamics (2-1-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	**Module 1 (Introduction):**Basics of Structural Dynamics Introduction of Structural Dynamics Equation of Motion Types of Analysis/Static and Dynamic load Degrees of Freedom (Ex: Generation of Stiffness matrix) Dynamic Equilibrium Equation Solution of Equilibrium Equation Free Vibration of SDOF Undamped free Vibration Solution, Natural Period/Frequency Energy in Free Vibration Damped Free Vibration Types of damping Logarithmic decrement equation **Module 2 Forced Vibration of SDOF** Undamped Forced vibration Amplitude & Phase Angle Dynamic amplification factor for deflection (Rd) Damped Forced vibration Relationship between Rd, Rv and Ra Force Transmission, Vibration Measurement Resonant frequency and Half power band width Force Transmission and Isolation Design of Vibration Measuring Instruments **Module 3 Response to Arbitrary Motions** Response to Unit Impulse Response to Arbitrary Force (Duhamel's Integral) Response to Step and Ramp Forces Response to Rectangular Pulse, Half Sinusoidal wave Numerical Methods of Solution Time Stepping Methods Central Difference Method Newmark's Method **Module 4 Response Spectrum** Concept of Response Spectrum Uses of Response Spectrum Special Cases in Spectrum Development of Tripartite Plot Example: Base Shear and Base Moment Response of Structure in Frequency Domain Multi-Degree of Freedom Systems Equation of Motion for MDOF System Solution of Equation, Natural Frequencies and mode Shapes Modal Orthogonality Approximate Method for finding Natural frequency **Module 5 Earthquake Response of MDOF Systems**

Elective Course

		Time History Analysis Response Spectrum Analysis 3D Dynamic Analysis Dynamic Response of Continuous Systems Vibration of Continuous systems Shear behavior and bending behavior Generalized SDOF Dynamics of Rigid Blocks Dynamics of Rigid Blocks Non Structural Elements Floor Response Spectrum Vibration Control Introduction to Vibration Control Active Control Passive Control Design of Tuned Mass Damper
4	**Texts/References**	Textbooks: 1. “Dynamics of structures” by Anil K Chopra 2. “Structural Dynamics” by Clough & Penzin 3. “Theory of Vibrations” by Thompson Reference Books: 1. “Elements of vibration analysis” by Leonard Mirovitch 2. “Structural dynamics” by Madhujit Mukhopadyay

Elective Course

1	**Title of the course** (L-T-P-C)	**Advanced Software Development Laboratory (1-0-4-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Editing: Vim/emacs, Presentation: latex, beamer, Build, Integration and Deployment, Version Control, and Documentation: make, GitHub and git, doxygen Programming: HTML, CSS, Shell scripting, AWK, SED Exploring features of IDE (e.g. eclipse, vscode) using a high-level programming language such as Java, Python, C++, Debugging (using gdb, using IDE). Unix/Linux basics: shell, file system, permissions, process hierarchy, process monitoring, ssh, scp, rsync, grep, find, head, tail, tar, cut, sort, I/O redirection, pipes Profiling tools: (e.g., gprof, prof, perf, valgrind) A medium-sized project with significant weight.
4	**Texts/References**	1. Online tutorials for HTML/CSS, Inkscape, OODrawUnix Man Pages for all unix tools, Advanced Bash Scripting Guide from the Linux Documentation Project (www.tldp.org). 2. The Python Tutorial Online Book (http://docs.python.org/3/tutorial/index.html). 3. The Java Tutorials (http://docs.oracle.com/javase/tutorial/). 4. Latex - A document preparation system, 2/e, by Leslie Lamport, Addison Wesley, 1994. 5. Make - https://www.gnu.org/software/make/manual/html_node/index.html#Top 6 Git - Git - Book (git-scm.com) 7. GDB Documentation (sourceware.org) 8. Valgrind 9. Doxygen - My Project: Documenting the code (doxygen.nl) . 10. Gprof - GNU gprof

Elective Course

1	**Title of the course** (L-T-P-C)	**Advanced Data Structures and Algorithms Lab (0-0-3-3)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Module 1: Basics: asymptotic notations, recurrences, basic data structures Module 2: Advanced data structures: heaps, priority queues, hash tables, data structures based on trees Module 3: Design paradigms and complexity analysis: divide and conquer, dynamic programming, greedy algorithms, amortized analysis Module 4: Advanced topics: graph algorithms, string algorithms, geometric algorithms, complexity lower bounds, coping up with hard problems.
4	**Texts/References**	Introduction to algorithms: Cormen, Leiserson, Rivest, and Stein (Main textbook) Online lecture notes by Jeff Erickson The Algorithm Design Manual: Steven Skiena Algorithm Design: Kleinberg and Tardos Data structures and algorithm analysis in C++(Java): Mark Weiss

Elective Course

1	**Title of the course** (L-T-P-C)	**Advanced Data Structure and Algorithms (3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Module 1: Basics: asymptotic notations, recurrences, basic data structures Module 2: Advanced data structures: heaps, priority queues, hash tables, data structures based on trees Module 3: Design paradigms and complexity analysis: divide and conquer, dynamic programming, greedy algorithms, amortized analysis Module 4: Advanced topics: graph algorithms, string algorithms, geometric algorithms, complexity lower bounds, coping up with hard problems.
4	**Texts/References**	Introduction to algorithms: Cormen, Leiserson, Rivest, and Stein (Main textbook) Online lecture notes by Jeff Erickson The Algorithm Design Manual: Steven Skiena Algorithm Design: Kleinberg and Tardos Data structures and algorithm analysis in C++(Java): Mark Weiss

Elective Course

1	**Title of the course** (L-T-P-C)	**Combinatorics and Probability** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Combinatorics: Principles of counting : rule of sum, rule of product, permutations, combinations. partition, modular arithmetic. double counting, generating functions. Binomial coefficients, binomial theorem, multinomial theorem Probability theory: probability axioms and laws, random variables, binomial distribution, Poisson, exponential and normal distributions, expectations and moments, joint distribution, conditional distribution , conditional expectations, convergence of random variables, law of large numbers, central limit theorem, Markov chains.
4	**Texts/References**	(1) W. Feller, W: An Introduction to Probability Theory and its Applications, Vol.1, John Wiley. (2) G. R. Grimmett and D. R. Stirzaker: Probability and Random Processes, Oxford Science Publications. (3) Biggs, N. L., Discrete Mathematics, Oxford Science Publications, 1989. (4) Invitation to Discrete Mathematics, Jiří Matoušek, Jaroslav Nešetřil, Oxford University Press.

Elective Course

1	**Title of the course** (L-T-P-C)	**Scalable Data Mining (3-0-0-6)**
2	**Pre-requisite courses(s)**	NA
3	**Course content**	**Module 1: MapReduce and Software Stack**: Introduction to MapReduce. Apache Software Stack for distributed file systems and data processing. MapReduce for Matrix Vector Multiplication, Relational Algebra Operations, Set operations, Matrix Multiplication, MapReduce and Spark as tools for creating parallel algorithms that can process very large amounts of data. **Module 2: Finding similar items:** Shingles, Min-hashing, Locality Sensitive Hashing families. **Module 3: Mining Data Streams:** Sampling, Bloom filtering, Counting elements in a window-Datar-Gionis-Indyk-Motwani Algorithm, Flajolet-Martin Algorithm, **Module 4: Link Analysis:** PageRank, Efficient Computation of PageRank using Map Reduce, Topic-Sensitive Page Rank **Module 5: Frequent Item sets:** Market-Basket Model, A-Priori Algorithm, Handling Larger Datasets in the Main Memory, Limited Pass Algorithms, Counting Frequent Items in a Stream: Sampling Methods, Frequent Item sets in Decaying Windows **Module 5: Mining Social-Network Graphs:** Clustering, Discovery of Communities, Direct Discovery of Communities **Module 6: Dimensionality reduction:** Eigen Values and Eigen Vectors, Principal Component Analysis, Singular Value Decomposition, CUR Decomposition **Module 7: Large-Scale Machine Learning:** Parallel design of Perceptron, Support Vector Machines, Decision Trees, Deep Learning Learning from Nearest Neighbors Hierarchical Clustering, K-means Clustering, Clustering for Streams and Parallelism. Algorithms for distributed optimization: Distributed stochastic gradient descent and related methods. Alternating direction method of multipliers (ADMM) and decomposition methods. **Module 8: Recommendation Systems:** Content Based, Collaborative Filtering, The Netflix Challenge, UV Decomposition Algorithm
4	**Texts/References**	Mining of Massive Datasets. 2nd edition. - Jure Leskovec, Anand Rajaraman, Jeff Ullman. Cambridge University Press (2016). http://www.mmds.org/ Hadoop: The Definitive Guide, 4th Edition by Tom White Released April 2015 Publisher(s): O'Reilly Media, Inc. ISBN: 9781491901632 Introduction to Data Mining. 2nd edition – Pang-Ning Tan, Michael Steinbach, Anuj Karpatne and Vipin Kumar, Addison-Wesley Longman Publishing Co., Inc (2018).

Elective Course

		Adaptive Stream Mining: Pattern Learning and Mining from Evolving Data Streams, 1st edition. - Albert Bifet, IOS Press (2010), ISBN: 1607500906, 9781607500902 Spark: The Definitive Guide Big Data Processing Made Simple, 1st. ed. by Bill Chambers and Matei Zaharia Released February 2018. Publisher(s): O'Reilly Media, Inc. Data-Intensive Text Processing with MapReduce. Jimmy Lin and Chris Dyer. Morgan and Claypool. http://lintool.github.io/MapReduceAlgorithms/index.html Distributed optimization and statistical learning via the alternating direction method of multipliers. S. Boyd, N. Parikh, E. Chu, B. Peleato, and J. Eckstein, 2011.

Elective Course

1	**Title of the course** (L-T-P-C)	**Software Defined Networking (SDN) and Network Function Virtualization (NFV)** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Computer Networks
3	**Course content**	History and evolution of SDN; SDN Architecture (Application, Control, Infrastructure Layer); SDN Interfaces (East/West/North/South-bound interfaces); SDN Security; SDN routing; SDN standards; SDN Controllers; Network Operating Systems and Languages; OpenFlow; Software Switches (e.g. OpenVSwitch); SDN Simulation/Emulation Platforms (e.g. Mininet); Federated SDN networks; SDN Applications and Use Cases; Programming assignment/project; Need for NFV; NFV and SDN Relationship; Virtual Network Functions; Service Function Chaining; NFV Specifications; NFV Architecture; NFV Use Cases; NFV Management and orchestration (MANO); Open-source NFV; Hands-on exercises based on OpenStack/Docker.
4	**Texts/References**	● Software Defined Networks: A Comprehensive Approach by Paul Goransson and Chuck Black, Morgan Kaufmann Publications, 2014 ● SDN – Software Defined Networks by Thomas D. Nadeau & Ken Gray, O'Reilly, 2013 ● Software Defined Networking with OpenFlow, By Siamak Azodolmolky, Packt Publishing, 2013 ● Gray, Ken, and Thomas D. Nadeau. Network function virtualization. Morgan Kaufmann, 2016. ● Zhang, Ying. Network Function Virtualization: Concepts and Applicability in 5G Networks. John Wiley & Sons, 2018. ● Foundations of modern networking- SDN, NFV, QoE, IoT, and Cloud, William Stallings ● James Kurose and Keith Ross, "Computer Networking, A Top-Down Approach"

Elective Course

1	**Title of the course** (L-T-P-C)	**Software Development for Scientific Computing (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Data Structures and Algorithms, C / C++ / Java / Matlab
3	**Course content**	Algorithmic Patterns in Scientific Computing: dense and sparse linear algebra, structured and unstructured grid methods, particle methods (N-body, Particle-Particle, Particle-in-cell, Particle-in-a- mesh), Fast Fourier Transforms, Implementing PDEs, C++ standard template library (STL), Introduction to debugging using GDB, GMake, Doxygen, Version Control System, Profiling and Optimization, asymptotic analysis and algorithmic complexity. Mixed-language programming using C, Fortran, Matlab, and Python, Performance analysis and high-performance code, Data locality and auto tuning, Introduction to the parallel programming world.
4	**Texts/References**	• Stroustrup C++ Language Reference (https://www.stroustrup.com/4th.html) • Suely Oliveira, David Steward: Writing Scientific Software: A Guide to Good Style. Cambridge University Press, 2006 • Web references to GNU Make, GDB, Git, GProf, Gcov. • Code Complete: A Practical Handbook of Software Construction • https://www2.eecs.berkeley.edu/Pubs/TechRpts/2006/EECS -2006-183.html

Elective Course

1	**Title of the course** (L-T-P-C)	**Statistical Pattern Recognition Laboratory (0-0-3-3)**
2	**Pre-requisite courses(s)**	Currently taking statistical pattern recognition theory course
3	**Course content**	The lab will closely follow the theory course. The idea is to have the students implement the basic algorithms on different topics studied in the statistical pattern recognition theory course.
4	**Texts/References**	**1.** R.O.Duda, P.E.Hart and D.G.Stork, Pattern Classification, John Wiley, 2001. **2.** C.M.Bishop, Pattern Recognition and Machine Learning, Springer, 2006.

Elective Course

1	**Title of the course** (L-T-P-C)	**Deep Learning (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Calculus, Linear Algebra, Probability, Random Processes, Ability to code in Python
3	**Course content**	**Introductory Concepts of DNN** (a) Linear regression, logistic regression – penultimate layers of a neural network (b) Dealing with nonlinearity – Kernal Trick (c) Data-driven kernel learning using NNs **DNN Training** (a) Issues in training practical deep networks, Vanishing/Exploding gradients (b) Regularization for Deep Learning – Early stopping, weight regularization, activity regularization, dropout (c) Optimization methods for training deep networks – Stochastic gradient descent, rmsprop, adam (d) Convolutional Neural networks **Sequence Modeling** (a) Recurrent neural networks (b) LSTMs ans BLSTMs **Unsupervised Learning** (a) Autoendcoders (b) Variational autoencoders (c) Generative adversial networks (GANs) (d) Representation learning and feature extraction
4	**Texts/References**	**1.** Ian Goodfellow and Yoshua Bengio and Aaron Courville, "Deep Learning," MIT Press **2.** Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995. **3.** B Yegnanarayana, "Artificial Neural Networks," PHI.

Elective Course

1	**Title of the course** (L-T-P-C)	**Graph Theory and Combinatorics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Discrete Structures (CS 203)
3	**Course content**	Fundamentals of graph theory. Topics include: connectivity, planarity, perfect graphs, coloring, matchings and extremal problems. Basic concepts in Combinatorics. Topics include: counting techniques, inclusion-exclusion principles, permutations, combinations and pigeon-hole principle.
4	**Texts/References**	1. D. B. West, ``Introduction to Graph Theory" 2nd edition. Prentice Hall. 2. Martin C. Golumbic, ``Algorithmic Graph Theory and Perfect Graphs." 2nd edition. 3. R. Diestel, ``Graph Theory", 5th edition.

Elective Course

1	**Title of the course** (L-T-P-C)	**Philosophy (3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	**1.** What is Philosophy? (Philosophy in India and West) **2.** Main Branches of Philosophy **3.** Three Laws of Thought **4.** Epistemology and Logic (Indian and Western) **5.** Metaphysics (Universal and Particular, Substance and Attributes, Causality, Space, Time, Soul, God, Freedom) **6.** Three Great Greek Philosophers: Socrates, Plato and Aristotle **7.** Modern Philosophy: Rationalism and Empiricism (Descartes, Locke, Berkeley and Hume) **8.** Ethics (Utilitarianism, Categorical Imperative of Kant, Ethical Relativism, Bio-Medical Ethics, Ethical Issues) **9.** Indian Philosophy Component (Nishkama-karma of Gita, Virtue Ethics of Buddhism, Advaita Vedanta). **10.** Meaning of Life.
4	**Texts/References**	**1.** Ganeri, Jonardon, Philosophy in Classical India: An Introduction and Analysis (London: Routledge, 2001). **2.** Maritain, Jacques, An Introduction of Philosophy (New York and Oxford: Rowman & Littlefield, 2005). **3.** Mohanty, J. N. Classical Indian Philosophy: An Introductory Text (New York and Oxford: Rowman & Littlefield, 2000). **4.** Nagel, Thomas, What Does It All Mean? A Short Introduction to Philosophy (Oxford: Oxford University Press, 2004). **5.** Russel, Bertrand, The Problems of Philosophy (Oxford: Oxford University Press, Reprint by Kalpaz Publication, 2017). **6.** Sharma, Chandradhar, A Critical Survey of Indian Philosophy (Delhi: Motilal Banarsidass, 2016). **7.** Thilly, Frank, A History of Philosophy (New Delhi: SBW Publishers, 2018). **8.** Williams, Bernard, Morality: An Introduction to Ethics (Cambridge: Cambridge University Press, 2012).

Elective Course

1	**Title of the course** (L-T-P-C)	**Modernism and the 'Hero'** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Fiction/Non-Fiction of Franz Kafka, Albert Camus, Saadat Hasan Manto, Samuel Beckett, among others.
4	**Texts/References**	--

Elective Course

1	**Title of the course** (L-T-P-C)	**Introduction to Industrial Organization (3-0-0-6)**
2	**Pre-requisite courses(s)**	Economics (HS201)
3	**Course content**	1. Introduction to Industrial Economics: Overview of Industrial Economics. Theoretical foundations of Industrial Economics, Basic economic concepts and their relevance to Industrial Economics 2. Introductory Microeconomics: Consumer behaviour and demand, Production functions, Cost functions, Economies of scale and scope, Short-run and Long-run Cost Analysis 3. Game Theory and Strategic Behaviour: Normal Form Games, Extensive Form Games, Repeated Games, Games with Imperfect Information 4. Market Structures: Perfect Competition, Monopoly, Oligopoly, Monopolistic Competition, Collusion, Market Structure and Market Power 5. Pricing Strategies: Price discrimination, Price skimming, Penetration pricing, Bundling 6. Vertical Relations: Double Marginalization and Two-Part Tariffs, Retailer Competition, Investment Externalities, Manufacturer Competition 7. Product Differentiation: Horizontal and vertical differentiation, Product differentiation and market power, Product positioning 8. Strategic Behaviour, Entry and Exit: Entry costs and market structure, Free entry and social welfare, Entry deterrence, Predation, Mergers and acquisitions 9. Research and Development: Market structure and incentive for R&D, Dynamics of R&D competition, Patent races and welfare analysis of patent protection, 10. Network effects, platforms, search and standards
4	**Texts/References**	1. Industrial Organization, Markets and Strategies (Cambridge University Press (2nd Edition 2015)) by Paul Belleflamme and Martin Peitz 2. Industrial Organization: Theory and Applications (The MIT Press, 1st Edition, 6th reprint) By Oz Shy 3. The Theory of Industrial Organization (Prentice Hall India Learning Private Limited; 1st Edition) by Jean Tirole 4. A Course in Microeconomic Theory. (Princeton University Press (Illustrated Edition 2020)) by D. Kreps 5. An Introduction to Game Theory. (Oxford University Press (1st Edition, 2005)) by Martin J. Osborne

Elective Course

1	**Title of the course** (L-T-P-C)	Visual Narratives **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Module 1: Visual Narratives-Definitions, Approaches Module 2: Meta-Narratives- Form, Viewing and Meaning making Module 3: Being and Languagein Visual Narratives Module 4: Issues of Technology, Ethics and Identity Module 5: Gender, Visibility and Choice Module 6: Global Politics and Visual Narratives Module 7: Texts and Contexts from India
4	**Texts/References**	**1.** Mannay, Dawn. 2015. Visual, Narrative and Creative Research Methods: Application, reflection and ethics. Routledge, New York. **2.** Mulvey, Laura.2019. Afterimages: On Cinema, Women and Changing Times. Reaktion Books. **3.** Garrett, Brian. 2006. What is this thing Called Metaphysics?Routledge, New York. **4.** MacKinnon, Barbara, and Andrew Fiala. 2015. Ethics Theory and Contemporary Issues. CT: Cengage Learning, Stamford, USA. **5.** Shaw, Dan. 2012. Morality and the Movies:Reading ethics through film.Continuum International Publishing Group, New York.

Elective Course

1	**Title of the course** (L-T-P-C)	**Introduction to Indian Knowledge systems-2 (IIKS-2)** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	A broad overview of disciplines included in the IKS, and historical developments. The present course will consider Number system and units of measurement, Mathematics, Metals & Metal working, Town planning & Architecture, Irrigation & water management, and Aeronautics. The emphasis on different topics will be based on students' interests. **Module-1: Introduction**Indian Knowledge System – An Introduction, Organization, and importance of IKS. Historicity and some salient aspects of IKS. **Module 2: Number Systems and Units of Measurement:** Number systems in India - Historical evidence, Salient aspects of Indian Mathematics, Bhūta-Saṃkhyā system,Kaṭapayādi system, Measurements for time, distance, and weight, Piṅgala and the Binary system. **Module 3: Mathematics** Introduction to Indian Mathematics, Unique aspects of Indian Mathematics, Indian Mathematicians and their Contributio ns, Algebra, Geometry Trigonometry, Binary mathematics & combinatorial problems in Chandaḥ Śāstra and concept of Magic squares. **Module 4: Applications of Engineering: Metal and Metal processing** Wootz Steel: The rise and fall of a great Indian technology, The Indian heritage, Mining and ore extraction, Metals and metal processing technology, Iron and steel in India, Lost wax casting of idols and artefacts, Apparatuses used for extraction of metallic components. **Module 5: Applications of Engineering: Civil Engineering** Irrigation & water Management, Irrigation systems & practices in ancient India, Perspective on town planning, Vāstu-śāstra – The science of architecture, Eight limbs of Vāstu, Temples in India, Temple architecture in India. **Module 6: Aeronautics** Airplane parts, Materials used in construction of Airplane, Propulsion, Yantras or Machinery, Varieties of airplanes, Rukma Vimana, Shakuna Vimana, Sundara Vimana, Tripura Vimana.
4	**Texts/References**	1. An Introduction to Indian Knowledge Systems: Concepts and Applications, B Mahadevan, V R Bhat, and Nagendra Pavana R N; (Prentice Hall of India), 2022. 2. Indian Knowledge Systems: Vol I and II, Kapil Kapoor and A K Singh; (D.K.Print World Ltd), 2005. 3. Early Indian Architecture: Cities and City-Gates, Coomaraswamy, Ananda K., Munshiram Manoharlal Publishers, 2002.

		4. https://www.drishtiias.com/printpdf/temple-architecture 5. Mathematics in ancient and medieval India, Bag A K(Chaukhamba Orientalia),1979. 6. History of Hindu mathematics, part I&II, Datta B and Singh A N,(Asia Publishing House),1962. 7. Vymaanik shastra-Aeronautics, Maharshi Bharadwaj translated by Subbaraya Shastry (Coronation Press), 1973.

Elective Course

1	**Title of the course** (L-T-P-C)	Sanskrit-1 (3-0-0-6)
2	**Pre-requisite courses(s)**	None
3	**Course content**	Introduction to Sanskrit grammar and literature Epic and Purana literature, Vedas and Upanishads (selected passages and a small Upanishad such as Ishopanishad and chapters from the Bhagavadgeeta) Sanskrit prose and poetry (with examples from Kalidasa, Bhavabhuti, Magha and Bharavi) Sanskrit dramas (Selected acts from plays such as Abhidnyan Shakuntalam) Popular tales, fables and nibanandas Selected Sanskrit Maxims (Aphorisims) Modern Sanskrit Literature Translations of technical works into and from Sanskrit
4	**Texts/References**	Outlines of Sanskrit Literature, M. N. Joshi, Roopa Publications, Dharwad, 2016 Sanskrit Kavya, K. Krishnamurthy, Vidyut Prakashana, Mysore, 2003 The ten classical Upanishads Vol-1, P. B. Gajendragadkar, Bharatiya Vidya Bhavan, 2014 Essentials of Rigveda, SAKSI, Bangalore, 2013 The history of Sanskrit Literature, C. V. Vaidya, Parimala Publications, Delhi, 2013 The Bhagavadgeeta with English Translation, Swami Chidbhavananda, Tapovana Publishing House, Thirucarapalli, 1965

Elective Course

1	**Title of the course** (L-T-P-C)	**Introduction Music-1** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Theory: History of Indian Music. Popular Folk and Classical Music Origin and development of Hindustani and Carnatic Music Shrutis, Swaras and Saptakas, Notation systems Thats, Ragas and a few common Talas. Ten common Thats and one raga in each that: Bhairav, Bhimpalas, Kalyan and Bhairavi Musical Instruments and their pitches Western Classial Music: Melody and Harmony Popular music Practicals: One raga in each of the four That's mentioned above either vocal or in any musical instrument:
4	**Texts/References**	1. Hindustani music - by G.H.Ranade, Popular Prakashan, 1951 2. Indian music - by B.V.Keskar, Popular Prakashan, 1967 3. Melodic types of Hindustan by Narendra Kumar Bose, Jaico Publishing House, 1960. 4.. Musical instruments of India – e-Book, Ministry of Information and Broadcasting, 2015 5. Bhatakande Sangeet Shastra – by Pandit V.N.Bhatakande (part I to IV), Sangeet Karyalaya, Hatharas, 2000 6.. Sangeet Visharad – edited by L. N. Garg, Sangeet Karyalaya, Hatharas, 1998 7. Tabla - by Aravind Mulgaokar, Maharashtra Text Book Board, 1975 8. Raag Bodh Parts 1 to V1, B. R. Deodhar, Popular Publications (2011)

Elective Course

1	**Title of the course** (L-T-P-C)	**Communication Skills**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Why Communication Skills? , Types of Communication, Communication and Research: Academic Reading, Writing, Listening and Appreciation, Grammar and Style, Research Ethics, Gender and Cultural Issues.
4	**Texts/References**	1. The Craft of Research by Wayne C. Booth, Gregory G.Colomb, Joseph M. Williams. 2. A Manual for Writers of Research Papers, Theses, and Dissertations, Eighth Edition, 3. The Elements of Style by William Strunk Jr., 4. Communication Skills for Engineers and Scientists Sangeeta Sharma & Binod Mishra. 5. A New Approach to Research Ethics: Using Guided Dialogue to Strengthen Research Communities by Henriikka Mustajoki, Arto Mustajoki.

Elective Course

1	**Title of the course** (L-T-P-C)	**Macroeconomics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	HS201
3	**Course content**	1. Introduction: The major macroeconomic issues-Economic Growth, Inflation, Unemployment, Inequalities in Distribution of Income and Wealth, Financial Stability, Sustainable Balance of payments. 2. National Income (NI): Concepts, Definitions and Identities, Approaches to measurement of NI, Limitations and Omissions in Measurement of NI 3. Major Schools of thought in Macroeconomics: 3.1. Classical and Neoclassical Schools of Thought: Theories of output, employment, prices and interest rate, Quantity theory of money, Cash Transactions and Cash Balance versions, Classical dichotomy. 3.2. Keynes and Keynesians-Aggregate Demand, Aggregate Supply, Consumption (Savings) Function and Investment Multiplier, Output Determination, Role of Government-Monetary and Fiscal Policies in Growth Promotion, Demand for Money: Active and Idle cash balances, Liquidity Preference and Liquidity Trap, Phillips Curve, Inflation-Unemployment trade-off, IS-LM Model and Policy Effectiveness 3.3. Monetarism: Restatement of Quantity Theory of Money, Stability of Demand Function for Money, Expectations Augmented Phillips Curve, Adaptive Expectations, Short-run vs Long-run Phillips Curve 3.4. New Classicists: Rational Expectations, Lucas Critique and Policy Ineffectiveness, Rules vs Discretion, Monetary Policy Rules: Friedman, Taylor and McCallum Rules 3.5. New Keynesians: Sticky Wages and Prices and Coordination Failures, Asymmetric Information and Moral Hazard, Adverse Selection 3.6. New Consensus Macroeconomics. 4. Inflation: Measurement, Causes, Consequences and Remedies 5. Fiscal Policy: Growth and Equity, concepts of deficits, internal and external debt, debt vs money financing, sustainability of debt. 6. Opening Up the Economy: Balance of payments, Exchange rates-nominal and real, bilateral and effective, exchange rate systems, fixed vs flexible exchange rates

Elective Course

4	**Texts/References**	1. Dilip M. Nachane, 2019, Critique of the New Consensus Macroeconomics and Implications for India, Springer Nature Switzerland AG 2. Macroeconomics by G. Mankiw, Worth Publishers, 7th edition (2009). 3. Macroeconomics by R. Dornbusch, S. Fisher & R. Startz, McGraw- Hill education, 11th edition (2017). 4. Errol D'Souza, Macroeconomics, 2/e, Pearson Education, 2012. Macroeconomics Theories and Practices by R. T. Froyen, Pearson Education India, 10th edition (2013

Elective Course

1	**Title of the course** (L-T-P-C)	Principles of Microeconomics **(3-0-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	Rational choice theory, Consumer theory: Preferences and utility, the consumers' problem, indirect utility and expenditure function, Slutsky equation, Shephard's Lemma and Roy's Identity, properties of demand function Producer theory: Production and cost functions, profit maximisation Perfectly competitive markets: Market equilibrium in short and long run Decisions under risk and uncertainty: contingent commodities, expected utility and attitude towardrisk, choice under uncertainty, demand for insurance, demand for risky asset, price of information General Equilibrium and welfare, Monopoly and monopolistic behaviour: pure monopoly, inefficiency and regulation, monopsony, price discrimination Duopoly and Oligopoly: Cournot, Stackelberg and Bertrand models, Asymmetric information: hidden characteristics and adverseselection, Signalling, hidden action and moral hazard problem, principal-agent models Externalities and public goods: externalities and efficiency loss, property rights and Coase theorem, common property resources, public goods and efficiency, free riding problem
4	**Texts/References**	**1.** Microeconomic Theory: Basic Principles and Extensions by Walter Nicholson and Christopher Snyder, 12th ed. (2017), Cengage Learning India Pvt. Ltd. **2.** The Structure of Economics: A Mathematical Analysisby Eugene Silberberg and Wing Suen, 3rd edition. **3.** Microeconomic Analysis by Hal R. Varian, 8th ed. (2010), W. W. Norton & Company **4.** Advanced Microeconomic Theory by Geoffrey A. Jehle and Philip J. Reny, 3rd ed. (2011), Pearson. **5.** Microeconomics Theory by Mas Colell, Indian ed. (2012), Oxford University Publication.

Elective Course

1	**Title of the course** (L-T-P-C)	Principles of Microeconomics **(3-0-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	Rational choice theory, Consumer theory: Preferences and utility, the consumers' problem, indirect utility and expenditure function, Slutsky equation, Shephard's Lemma and Roy's Identity, properties of demand function Producer theory: Production and cost functions, profit maximisation Perfectly competitive markets: Market equilibrium in short and long run Decisions under risk and uncertainty: contingent commodities, expected utility and attitude towardrisk, choice under uncertainty, demand for insurance, demand for risky asset, price of information General Equilibrium and welfare, Monopoly and monopolistic behaviour: pure monopoly, inefficiency and regulation, monopsony, price discrimination Duopoly and Oligopoly: Cournot, Stackelberg and Bertrand models, Asymmetric information: hidden characteristics and adverseselection, Signalling, hidden action and moral hazard problem, principal-agent models Externalities and public goods: externalities and efficiency loss, property rights and Coase theorem, common property resources, public goods and efficiency, free riding problem
4	**Texts/References**	**6.** Microeconomic Theory: Basic Principles and Extensions by Walter Nicholson and Christopher Snyder, 12th ed. (2017), Cengage Learning India Pvt. Ltd. **7.** The Structure of Economics: A Mathematical Analysisby Eugene Silberberg and Wing Suen, 3rd edition. **8.** Microeconomic Analysis by Hal R. Varian, 8th ed. (2010), W. W. Norton & Company **9.** Advanced Microeconomic Theory by Geoffrey A. Jehle and Philip J. Reny, 3rd ed. (2011), Pearson. **10.** Microeconomics Theory by Mas Colell, Indian ed. (2012), Oxford University Publication.

Elective Course

1	**Title of the course** (L-T-P-C)	Meta-ethics **(4-0-0-8)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Meta-ethics is that branch of Moral Philosophy or Ethics that is concerned with the nature of morality or moral properties. Some of the questions in meta-ethics would be the following. Are moral standards relative or absolute? Answer to this question will lead to the debate between **Moral Realism** and **Moral Relativism**. Can moral judgments or statements be true or false? Are moral judgements or statements truth-apt? This will lead to the debate between **Cognitivism** (Moral statements are truth-apt) **and Non-cognitivism** (Moral statements are not truth-apt. They are neither true nor false.) If moral statements are truth-apt, then can they be known? This will lead to the debate between **Moral Rationalism** (Moral judgments are known a priori) and Moral Skepticism (Moral judgments cannot be known at all). Can there be ethical properties? This will lead to the debate between **Ethical Naturalism** (There are ethical properties which are reducible to the non-ethical but natural properties.) and **Ethical Non-naturalism**(There are ethical properties which are irreducible.) The following topics also will be discussed Moral Explanations and Moral Disagreement.
4	**Texts/References**	**1.** Russ Shafer-Landau (ed.) 2013. Ethical Theory: an Anthology. Wiley-Blackwell, Oxford, UK. **2.** Sher, George (ed.) 2012. Ethics: Essential Readings in Moral Theory. Routledge. New York. **3.** Hugh LaFollette (ed.) 2000. The Blackwell Guide to Ethical Theory. Blackwell Publishers, Oxford, UK. **4.** Peter Singer (ed.) 1991. A Companion to Ethics. Blackwell Publishers, Oxford, UK. **5.** Sturgeon, Nicholas. "Moral Explanations." In Ethics: Essential Readings in Moral Theory. 2012. Routledge.NY. **6.** Geoffrey, Sayre-McCord. 1988. Essays on Moral Realism. Cornell University Press. NY. **7.** Foot, Philippa. "Morality as a System of Hypothetical Imperatives." In Ethical Theory: An Anthology. 2013. Wiley-Blackwell, Oxford, UK.

Elective Course

1	**Title of the course** (L-T-P-C)	**Normative Ethics (4-0-0-8)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Under what conditions could one say that an action is morally right or morally wrong? What gives an act moral worth? Prima facie this question could be answered in at least three possible ways. One response could be that the effect/consequence determines the moral worth of the act. Thus, we have Consequentialist Theories of morality. Under consequentialism, we discuss mainly Extreme and Restricted Utilitarianism. Jeremy Benthan and J S Mill are the important philosophers. As opposed to utilitarians, deontologists would say that acts are morally right or morally wrong irrespective of the consequences that the act would produce. Deontologists would say that the moral worth of the action is dependent on the intention of the agent who performs the action and certain absolute moral principles. Immanuel Kant proposes deontology. Virtue ethical theorists would say that mere satisfaction of the principle (whether it is utilitarian or deontological principle) is not something that gives an act moral worth. The moral worth of the act depends on whether the act being performed is the exemplification of virtue.Aristotle proposes some versions of virtue ethics. Apart from these ethical theories, the course will also discuss Social contract theory.
4	**Texts/References**	**1.** Barbara MacKinnon and Andrew Fiala. 2015. Ethics Theory and Contemporary Issues. **2.** Foot, Philippa. 1978. Virtues and Vices, Blackwell. **3.** Russ Shafer-Landau (ed.) 2013. Ethical Theory: an Anthology. Wiley-Blackwell. **4.** Scanlon T.1999. 'Reasons', in What We Owe to Each Other, Belknap Press. **5.** George Sher (ed.) 2012. Ethics: Essential Readings in Moral Theory .Routledge. **6.** Hugh LaFollette (ed.) 2000. The Blackwell Guide to Ethical Theory. Blackwell. **7.** Peter Singer (ed.) 1991. A Companion to Ethics. Wiley- Blackwell.

Elective Course

1	**Title of the course** (L-T-P-C)	**Literary Theory and Criticism (4-0-0-8)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Introduction to Theories of Literature, Important Literary and Critical Concepts, Overview of Literary history and Approaches, Understanding 'Texts' and Contexts.
4	**Texts/References**	**1.** The Norton Introduction to Literature- Twelth Edition by Kelly J Mays. **2.** Contemporary Literary and Cultural Theory: From Structuralism to Ecocriticism by Pramod Nayar. **3.** The Reach of Criticism: Method and Perception in Literary Theory by Paul H. Fry. **4.** Companion to Comparative Literature, World Literatures and Comparative Cultural Studies by Steven Totosy De Zepetnek, Tuntun MukherjeeLiterary Theory and Criticism by Patricia Waugh.

Elective Course

1	**Title of the course** (L-T-P-C)	Interdisciplinary Approaches to Literary Research **(4-0-0-8)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	Aims and Scope of Literary Research, Literary Research and Interdisciplinarity, Methods of Interdisciplinary Research, Literary Research and the Question of 'Outcome'
4	**Texts/References**	**1.** Inter disciplinarily by Joe Moran, 2nd edition, (Routledge) 2010 **2.** Prospecting: From Reader Response to Literary Anthropology by Iser Wand Wolfgang Aser(The Johns Hopkins University Press, February 1, 1993) **3.** The Oxford Handbook of Interdisciplinarity edited by Robert Frodeman, Julie Thompson Klein (Oxford University Press) Reprint edition (March 21,2012) **4.** Literary Theories: A Case Study in Critical Performance by William Baker (Red Globe Press) 1996 edition (October 25,1996), **5.** The Handbook to Literary Research edited by Delia da SousaCorrea, **6.** W. R. Owens (Routledge) 2nd edition (20 August 2009)

Elective Course

1	**Title of the course** (L-T-P-C)	**Postmodernism: Theory and Literature (3-0-1-8)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Defining the 'Postmodern': Understanding the 'Post' in Postmodernism, Postmodernism and Postmodernity, Postmodernist Theory and Culture, Postmodernist Literature.
4	**Texts/References**	**1.** The Idea of the Postmodern: A History by Hans Bertens, Routledge (London & New York),1995. **2.** The Blind Assassin by Margaret Atwood, Anchor, 2001. **3.** White Teeth by Zadie Smith, Random House (New York),2000Selected Poems byJorge Luis Borges, Penguin Books, 2000. **4.** The White Tiger by Arvind Adiga, Free Press (New York),2008 **5.** Postmodernism, or, The Cultural Logic of Late Capitalism by Fredric Jameson, Duke University Press (Durham),1990. **6.** Intimations of Postmodernity by Zygmunt Bauman, Routledge (London & New York), 2003. **7.** Philosophers on Art from Kant to the Postmodernists: A Critical Reader, edited by Christopher Kul-Want Columbia University Press (New York),2010.

Elective Course

1	**Title of the course** (L-T-P-C)	**Research Methodology in Humanities and Social Sciences** **(4-0-0-8)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Research design and methods including qualitative, quantitative, and mixed- methods designs. Data- collection methods, data-analysis, exposure to critical thinking, research ethics and different schools of critical theories.
4	**Texts/References**	1.Bergmann, Merrie, Moor, James and Jack Nelson. 2008. The Logic Book. 5th edition, McGraw-Hill, Primis,US. 2.Copi, Irving M, Cohen, Carl and Kenneth McMahon. 2014. Introduction to Logic. 14th edition, Routledge, London & NewYork. 3.Susan T. Gooden and Rajade Berry-James,Why Research Methods Matter, Melvin & Leigh, Publishers, Irvine, California(2018) 4.Claire Lemercier, Claire Zalc, Quantitative Methods in the Humanities: AnIntroduction, University of Virginia Press, University of Virginia,2019 5.Bridget Somekh, Cathy Lewin, Research Methods in the Social Sciences, SAGE, London,California, New Delhi(2004) 6.Kalpana Kannabiran, Padmini Swaminathan, Re- Presenting Feminist Methodologies: Interdisciplinary Explorations, 2017, Routledge, London and New York. 7.Geoff Payne, Judy Payne, Key Concepts in Social Research, 2004, Sage, London, Thousand Oaks, New Delhi

Elective Course

1	Title of the course (L-T-P-C)	**Literature and Philosophy** **(4-0-0-8)**
2	Pre-requisite courses(s)	--
3	Course content	Relationship between Literature and Philosophy- from Classical to the Contemporary, Important Philosophical Concepts and their Literary Relevance, Writers and their philosophical attitudes.
4	Texts/References	1. Literature and Philosophy: A Guide to Contemporary Debates edited by D. Rudrum. 2. Literature and Philosophy in Dialogue: Essays in German Literary Theory by Hans-Georg Gadamer. 3. Literature as philosophy/philosophy as literature by Donald G. Marshall. 1.4. Future Crossings: Literature Between Philosophy and Cultural Studies edited by Krzysztof Ziarek, Seamus Deane.

Elective Course

1	**Title of the course** (L-T-P-C)	**Digital Communication and Coding Theory** **(2-0-2-6)**
2	**Pre-requisite courses(s)**	Signals and Systems, Introduction to Communication Systems, Introduction to Probability
3	**Course content**	Digital Modulation - Signal constellations, Nyquist's Sampling Theorem and Criterion for ISI Avoidance, Linear modulation Optimal D*emodul*ation – Review of Hypothesis Testing, ML and MAP decision rules, Signal Space Concepts, Optimal Reception in AWGN and performance analysis of various modulation schemes. Source Coding - Entropy, Shannon's source coding theorem (without proof), Huffman Codes Channel Coding – Mutual information, Shannon's channel coding theorem (without proof), Linear codes, soft decisions and introduction to cyclic codes Lab Component: Practical experiments in-line with the content of "Digital Communication and Coding Theory"course covering transmission and reception mechanisms corresponding to digital communication. ● Digital modulation and demodulation – PSK and QAM ● Channel Modelling ● Performance analysis of Huffman codingPerformance Analysis of linear and cyclic codes
4	**Texts/References**	*1.* Upamanyu Madhow, ``Introduction to Communication Systems," Cambridge university press, 2008 edition. 2. Cover and Thomas, "Elements of Information Theory," Wiley India Pvt. Ltd., 2006.

Elective Course

1	**Title of the course** (L-T-P-C)	**Next Generation Wireless Systems / Wireless Networks** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Principles/Fundamentals of Communications
3	**Course content**	Theory, design techniques, and analytical tools for characterizing next generation wireless systems. Performance analysis of digital communication systems over fading channels, rate and power adaptation, and multi-user diversity techniques; study of the fourth generation (4G) long term evolution (LTE) standard, its air interface, physical and logical channels, and physical layer procedures; introduction to fifth generation (5G) wireless communication and the 5G new radio (NR) standard, survey of non-orthogonal multiple access (NOMA) and the internet-of-things (IoT) related changes in 4G/5G..
4	**Texts/References**	1. Stefaniz Sesia, Issam Toufik, Matthew Baker, "LTE - The UMTS Long Term Evolution," John Wiley and Sons, 1st ed., 2009. 2. 3GPP technical specifications available online at http://www.3gpp.org/ 3. David Tse and Pramod Viswanath, "Fundamentals Of Wireless Communication," Cambridge University Press, 2005. 4. 4. QUEUEING SYSTEMS, VOLUME 1: THEORY by Leonard Kleinrock John Wiley & Sons, Inc., New York, 1975

Elective Course

1	**Title of the course** (L-T-P-C)	**Analog IC design** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Electronic Devices, Analog Electronics
3	**Course content**	Active and passive CMOS devices, MOS transistors and small signal models, Noise sources, current mirrors, Single stage opamp, cascode amplifier, folded cascode amplifier, 2 stage opamp and compensation, Negative feedback, fully differential amplifiers, Common mode feedback, PLL's.
4	**Texts/References**	1) Jacob Baker, CMOS Circuit Design, Layout, andSimulation, Wiley; 1 edition (2009) 2) Behzad Razavi, Design of Analog CMOS Integrated Circuits,McGraw Hill Education; Second edition 3) Hurst, Lewis, Meyer Gray Analysis and Design ofAnalog Integrated Circuits, Wiley; 5 edition

Elective Course

1	**Title of the course** (L-T-P-C)	**Power System Dynamics and Control** **(2-0-1-6)**
2	**Pre-requisite courses(s)**	Power System, Electrical Machines
3	**Course content**	Modelling of Synchronous Machines, Modelling of Exciters, Small Signal Stability Analysis, Modellingof Turbine and Governors, Simulation of Power System Dynamic Response, Improvement of Stability, Sub-synchronous Oscillations.
4	**Texts/References**	1. Power System Dynamics and Stability: With Synchrophasor Measurement and Power System Toolbox, 2nd Edition 2. Power System Stability and Control: Prabha Kundur Mc GrawHill 3. Power System Dynamics and Stability, J Machowski; J Bialek, J Bumby, John Wiley & Sons

Elective Course

1	**Title of the course** (L-T-P-C)	**VLSI Design** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to basic concepts in calculus and probability
3	**Course content**	Review of MOS transistor models, Technology scaling, CMOS logic families including static, dynamic and dual rail logic. Integrated circuit layout; design rules, parasitics. low power design, high performance design, logical effort, Interconnect aware design, clocking techniques. VLSI design: data and control path design, floor planning, Design Technology: introduction to hardware description languages(VHDL), logic, circuit and layout verification.
4	**Texts/References**	1. *N. Weste and D. M. Harris, "CMOS VLSI Design, A circuits and systems perspective" Pearson, 2010* 2. *S. Kang and Y. Leblebici, "CMOS Digital Integrated circuits", Tata McGraw Hill edition, 2003* 3. *Jan M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated circuits" Pearson , 2016*

Elective Course

1	**Title of the course** (L-T-P-C)	Multivariable Control Systems **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to control systems
3	**Course content**	**Review of basic mathematics:** Review of differential equations, Fourier and Laplace transform, basic linear algebra: matrices, rank, inverses, decompositions etc., **Review of frequency domain modelling:** revision of frequency domain modelling, transfer functions **Introduction to State Variables:** Motivation for State Variables, Implementation of Differential Equations, Formal Definitions **Basic Realization Theory:** Similarity Transformation, Canonical Realizations: Jordan and real canonical forms, Minimal realization **Connections to Transfer Functions:** Characteristic/Minimal Polynomials, matrix exponentials, Markov parameters and other invariants **Review of frequency domain analysis:** Recall root locus, stability analysis using Routh-Hurwitz criteria, bode plots, Nyquist plots etc. **Observability, Controllability:** Canonical Realizations, Decomposition of Uncontrollable and Unobservable realizations, State Feedback, Asymptotic Observers, Separation Principle and Pole Placement Theorem **Extensions to MIMO systems:** Transfer matrices, Controllability, Observability and Pole Placement, Controller/Observer forms, Minimality and relations to Controllability and observability, MIMO Realization theory
4	**Texts/References**	1. T. Kailath, Linear Systems, Prentice-Hall, New Jersey, 1st edition, (11 February 1980) 2. Richard Dorf and Robert Bishop, Modern Control Systems, Pearson; 13th edition (5 January 2016) 3. Karl Johan Aström, Richard M. Murray, Feedback Systems:An Introduction for Scientists and Engineers, Princeton

		University Press (21 April 2008) 4. João P. Hespanha, Linear Systems Theory, Princeton University Press (2 October 2009) 5. Karl Johan Aström, Richard M. Murray, Feedback Systems: An Introduction for Scientists and Engineers, Princeton University Press, 2nd edition (2 March 2021) 6. João P. Hespanha, Linear Systems Theory, Princeton University Press (2 October 2009), 2nd edition, 13 February 2018

Elective Course

1	**Title of the course** (L-T-P-C)	**Design of Power Converters** **(2-0-2-6)**
2	**Pre-requisite courses(s)**	EE222: Introduction to Power Electronics or equivalent as determinedby the instructor or faculty advisor.
3	**Course content**	Rectifier analysis and design: Analysis and design of buck, boost; Intro to single-phase and 3-phase inverter: Intro to PWM generation and gate-drive basics; Intro to Flyback, Forward, Full Bridge; Switching and conduction loss calculation; Magnetics Design; Basics of Gate Drivers and PWM ICs; Basics of Snubbers.
4	**Texts/References**	1. L Umanand Power Electronics: Essentials & Applications.,, Wiley 2009. 2. Robert W Erickson and Dragan Maksimovic, Fundamentals of Power Electronics, Springer, 3ed, 2020. 3. Daniel W Hart, Introduction to Power ElectroniPrentice-Hall, 1997. 4. Mohan, N., et al, Power Electronics, John Wiley, 1989. 5. Daniel W Hart, Power Electronics, McGraw Hill Higher Education, 2010 6. Mohan, N., et al., Power Electronics, John Wiley, 3rd edition, 2007

Elective Course

1	**Title of the course** (L-T-P-C)	**Probability Models and Applications (PMA)** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Data analysis and Introduction to probability (6 credits course that all batches are currently doing as core)
3	**Course content**	**Introduction to** Probability theory. **Review of** sample space, events, axioms of probability, introduction to probability as a measure, Random variables, Notion of independence and mutually exclusive events Probability Space, limits and sequence of events, continuity of probability, measurable functions, notions of induced measures, connection with cdf, change of measure, conditional probability and conditional expectation, simulating discrete and continuous random variables - accept-reject method, importance sampling. **Random vectors and Stochastic processes:** Introduction to random vectors, Gaussian vectors, notion of i.i.d random variables introduction to elementary stochastic processes like Bernoulli process and Poisson process. **Markov Process.** Discrete time and continuous time Markov chains**,** classification of states, notion of stationary distribution. Simulating stochastic processes like Gaussian process, Poisson process, Markov chains and Brownian motion. Introduction to Markov chain monte carlo methods, Hidden Markov chain and Markov decision process, Introduction to Brownian motion and stationary process. **Statistics:** MLE, MAP and Bayesian Estimation, sufficient statistics, Cramer-Rao bound
4	**Texts/References**	1. Sheldon Ross "Introduction to probability models" 9th Ed., Elsevier AP 2. Sheldon Ross, 'Stochastic process', John Wiley, 2nd Ed., April 1996. 3. David Stirzaker, 'Stochastic process and models', Oxford press.

Elective Course

1	**Title of the course** (L-T-P-C)	**Linear Algebra and its applications** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Basic calculus.
3	**Course content**	The following topics will be covered: Vector spaces, linear dependence, basis; Representation of linear transformations with respect to a basis.; Inner product spaces, Hilbert spaces, linear functions; Riesz representation theorem and adjoints.; Orthogonal projections, products of projections, orthogonal direct sums; Unitary and orthogonal transformations, complete orthonormal sets and Parseval's identity; Closed subspaces and the projection theorem for Hilbert spaces.; Polynomials: The algebra of polynomials, matrix polynomials, annihilating polynomials and invariant subspaces, forms, Solution of state equations in linear system theory; Relation between the rational and Jordan forms.; Numerical linear algebra: Direct and iterative methods of solutions of linear equations; Matrices, norms, complete metric spaces and complete normal linear spaces (Banach spaces); Least squares problems (constrained and unconstrained); Eigenvalue problem and SVD.
4	**Texts/References**	1. K. Hoffman and R. Kunze, Linear Algebra, Prentice-Hall, (1986). 2. G.H. Golub and C.F. Van Loan, Matrix Computations, Academic, 1983.

Elective Course

1	**Title of the course** (L-T-P-C)	**Physics of Transistors** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Not-applicable
3	**Course content**	Semiconductor Physics Review. **The MOS transistor:** MOS Capacitor Fundamentals, Fixed Oxide and Interface Charge Effects, Carrier Transport in MOS capacitor, Basic MOSFET operation, Measurement of MOS transistor parameters, Small Signal Equivalent Circuit, Non-ideal effects, MOSFET scaling and Short channel effects, Advanced MOSFET structures (High-k gate, SOI MOSFET and FinFET), Radiation and Hot-electron effects in transistors, MOSFET reliability, CMOS technology, Charged Coupled Device (CCD). **Bipolar transistor:** Basic BJT operation, Minority carrier distribution, Ideal current-voltage characteristics, Non-ideal effects, Base width modulation, High injection, Emitter bandgap narrowing, Current crowding, Nonuniform base doping, Breakdown voltage, Equivalent circuit models, Switching characteristics, Insulated-gate bipolar transistor (IGBT). **Heterojunction Transistors:** Heterostructure fundamentals, High electron mobility transistor (HEMT), and Heterojunction bipolar transistor (HBT).
4	**Texts/References**	**References:** 1. Tsividis Y. and Mcandrew C., **The MOS Transistor**, New York, Oxford University Press, 2012. 2. Taur Y. and Ning T. H., **Fundamentals of Modern VLSI Devices**, 2nd edition, New Delhi, Cambridge University Press, 2009. 3. Sze S. M. and Ng K. K., **Physics of Semiconductor Devices**, 3rd edition, New Jersey, John Wiley & Sons, 2007. 4. Shur M., **Physics of Semiconductor Devices**, Noida, Pearson, 2019. 5. Neamen D. A., **Semiconductor Physics and Technology: Basic Principles**, 4th edition, New York, McGraw Hill, 2012

Elective Course

1	**Title of the course** (L-T-P-C)	Irrational and Transcendental Numbers (3-0-0-6)
2	**Pre-requisite courses(s)**	Linear Algebra, Complex Analysis, and prior knowledge of Field andGalois theory over Q is helpful
3	**Course content**	Hermite Pade-Approximation, Transcendence of e and pi, Lindemann Weierstrass Theorem, Gelfond-Schneider Theorem, Six-Exponential Theorem, Schneider-Lang Theorem and its applications, Baker's theory oflinear form in logarithm of algebraic numbers. Criterion for linear independence – Siegel and Nesterenko's methods, Irrationality of Reimann Zeta function at odd positive integers: Apery's irrationality proof of zeta(3) and Beukers's proof, Ball-Rivoal theorem, recentresults about infinitely many odd zeta values are irrational due to Fischler-Zudilin-Sprang
4	**Texts/References**	1. Baker A., Transcendental Number Theory, Cambridge University Press,1975. 2. Burger E. B. and Tubbs R., Making Transcendence Transparent: An intuitive approach to classical transcendental number theory, Springer NewYork, 2004. 3. Ram Murty M. and Rath P., Transcendental numbers, 1st Edition, Springer, New York (2014). 4. Natarajan S. and Thangadurai R., Pillars of Transcendental number theory,1st Edition, Springer Verlag (2020). 5. Ball, K. and Tanguy R., Irrationality of infinitely many values of the zetafunction at odd integers, Invent. Math. (2001) Fischler S., Johannes S. and Zudilin W., Many odd zeta values areirrational, Compos. Math. (2019)

Elective Course

1	**Title of the course** (L-T-P-C)	**Introduction to Representation Theory** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	A course in (graduate) algebra
3	**Course content**	Basic notions of representation theory that includes irreducible modules and complete reducibility theorem. Character theory, Schur's orthogonality relations, isotopic components and the canonical decomposition. Group algebra and integrality, and the degree of an irreducible representation. Induced representations, Frobenius reciprocity, and Mackey theory. Various examples: Abelian groups, Dihedral groups, Symmetric groups in 3,4, and 5 letters.
4	**Texts/References**	J.-P.Serre, Linear representations of finite groups, Graduate Texts in Mathematics, Vol. 42, Springer-Verlag, New York-Heidelberg 1977 W. Fulton and J. Harris, Representation theory, A first course, Graduate Texts in Mathematics, 129. Readings in Mathematics, Springer-Verlag, New York, 1991 1. Benjamin Steinberg, Representation theory of finite groups : introductory approach, Springer-Verlag, New York, 2012.

Elective Course

1	**Title of the course** (L-T-P-C)	**Differential Topology** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Multivariable Calculus, General Topology and Linear Algebra
3	**Course content**	Differentiable manifolds, smooth maps between manifolds, Tangent spaces and cotangent spaces, Vector fields, tangent and cotangent bundles, Vector bundles, Sub manifolds, submersion and immersions, Basic notion of Lie groups, Tensors and differential forms, Integration on manifolds and de Rham theory
4	**Texts/References**	John M. Lee, Introduction to Smooth Manifolds, Springer Verlag, New York, 2003. Frank Warner, Foundations of Differentiable Manifolds and Lie Groups, Springer Verlag, New York, 1983 . Glen Bredon, Topology and Geometry, Springer Verlag, New York, 1993.

Elective Course

1	**Title of the course** (L-T-P-C)	**Introduction to Graduate Algebra** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	Basics of Group Theory, Ring Theory and Module Theory, Linear Algebra, Field Theory and Galois Theory
3	**Course content**	Review of Group theory: Sylow's theorem and Group Actions, Ring theory: Euclidean Domains, PID and UFD's, Module theory: structure theorem of modules over PID Review of field and Galois theory, Infinite Galois extensions, Fundamental Theorem of Galois theory for infinite extensions, Transcendental extensions, Luroth`s theorem Review of integral ring extensions, prime ideals in integral ring extensions, Dedekind domains, discrete valuations rings, Categories and functors, Basic Homological algebra: Complexes and homology, long exact sequences, homotopy, resolutions, derived functors, Ext, Tor, cohomology of groups
4	**Texts/References**	M. Artin, Algebra, 2nd Edition, Prentice Hall of India, Delhi, 1994. N. Jacobson, Basic Algebra, Vol. 1, 2nd Edition, Hindustan Publishing Corporation, Delhi, 1985. N. Jacobson, Basic Algebra, Vol. 2, 2nd Edition, Hindustan Publishing Corporation, Delhi, 1989. S. Lang, Algebra, 3rd Edition, Addison Wesley, Boston, 1993. O. Zariski and P. Samuel, Commutative Algebra, Vol.1, Corrected reprinting of the 1958 edition, Springer-Verlag, New York, 1975. O. Zariski and P. Samuel, Commutative Algebra, Vol.2, Reprint of the 1960 edition, Springer-Verlag, New York, 1975.

Elective Course

1	**Title of the course** (L-T-P-C)	**Introduction to Computational Fluid Dynamics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	ME 203 Fluid Mechanics; Numerical Analysis; Computer Programming
3	**Course content**	1. Review of Governing Equations: General conservation equation; specific mass, momentum, energy conservation equations. 2. Fundamentals of Numerical Methods: Direct and iterative solvers for linear equations; PDE, Classification, Basics of finite-difference, finite- volume finite-volume methods; Notion of accuracy, consistency, stability, convergence; Verification and validation. 3. Diffusion Equation: 1-D steady conduction; Source terms and non-linearity; 2-D steady conduction; Unsteady conduction; Non-trivial boundary conditions. 4. Advection-Diffusion Equation: Steady 1-D advection- diffusion equation; Upwinding, numerical diffusion, higher-order schemes; 2-D advection-diffusion equation 5. Incompressible Navier-Stokes equations, Incompressibility and pressure-velocity coupling; Staggered vs collocated grids; SIMPLE and PISO algorithms. 6. Special Topics: Non-Cartesian coordinate systems; Curvilinear grids; Unstructured grids; Advancedlinear solution methods such as multigrid methods, preconditioning; Use of numerical libraries; Introduction to parallel programming for CFD. 7. Mesoscopic approaches to discrete simulation of fluid dynamics 8. Tutorial on a commercial CFD code & an open-source code (e.g. OpenFOAM).
4	**Texts/References**	1. "An Introduction to Computational Fluid Dynamics", by H. W. Versteeg and W. Malalasekera; 2nd edition, Pearson Education Ltd., 2007. (ISBN: 9780131274983) "Introduction to Computational Fluid Dynamics: Development, Application and Analysis", by Atul Sharma; Wiley, 2016. (ISBN: 9781119002994)

Elective Course

1	**Title of the course** (L-T-P-C)	**Rocket Propulsion** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Calculus, Linear Algebra, Probability, Random Processes, Ability to code in Python
3	**Course content**	**Motion in Space: Introduction, Motion in space. Rotational frame of reference and orbital velocities, Velocity requirements(4hr)** **Theory of Rockets: Theory of rocket propulsion,Specific impulse,Rocket equation and Staging of rocket,Review of rocket principles, Propulsion efficiency,Examples illustrating theory of rocket propulsion(3hr)** **Nozzles Introduction to nozzles,Therory of nozzles, Nozzle shape, Area ratio of nozzles: Under expansion and over expansion,characteristics velocity and thrust coefficient,Divergence loss in conical nozzles and Bell nozzles,Unconventional nozzles and problems in nozzles(7hr)** **Solid Propellant Rockets: Introduction to solid propellant rockets,Burn rate of solid propellants and equilibrium pressure in solid propellant grains, Ignition of solid propellant rockets,Review of solid propellant rockets(6hr)** **Liquied Propellant Rockets: Feed systems for liquid Propellant rockets, feed system cycles for pump fed liquid propellant rockets,Analysis of gas generator and staged combustion cycles and introduction to injectors,injector configurations, Cooling of chambers and mixture ratio distribution Efficiencies due to mixture ratio distribution and incomplete vaporization, Pumps and Turbines:Propellant feed system at zero'g' conditions, Review of liquid be -propellant rockets and introductions to mono-propellant rockets, instability in liquid propellant rockets,instability in liquid propellant rockets(8hr)** **Hybrid Rockets: Introduction to hybrid rockets and simple illustration of combustion(3hr)** **Electrical,Nuclear Rockets: Principles of electrostatic and electromagnetic rockets Electrical thrusters.Electrical and nuclear rockets,Advanced propulsion(4hr)**
4	**Texts/References**	1. 1.Hill,P.G and Peterson,C.R..,Mechanics and Thermodynamics of Propulsion,2nd ed.,Reading Massachusetts:Addison Wesley Publishing Company,1992. 2. 2.Sutton,G.P.and Biblarz,O.,Rocket Propulsion Elements, 9th Ed., New York: Wiley Intescience pulications,2001. 3. 3.Mukunda,H.S..,Understanding Aerospace Propulsion, Bangalore:Interline Publishing,2004. 4. 4.Turner, M.J.L.., Rocket and Spacecraft propulsion,Springer Praxis Publishing. 2004. 5. 5.Ramamurthi.K..,Rocket Propulsion, Macmillan 210

Elective Course

1	**Title of the course** (L-T-P-C)	**Additive and Forming Manufacturing Processes** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	**Module 1:** Introduction to Smart manufacturing, various Smart Manufacturing Technologies, Smart foundry, Reverseengineering, Traditional manufacturing, Rapid Tooling, Rapid Manufacturing; Indirect Processes - Indirect Prototyping, Indirect Tooling, Indirect Manufacturing. Introduction to Additive Manufacturing (AM): Overview of Additive Manufacturing (AM), Introduction to flexible manufacturing processes **Module 2:** AM technologies, classification of AM processes: Sheet Lamination, Material Extrusion, Photo- polymerization, Powder Bed Fusion, Binder Jetting, and Direct Energy Deposition, Popular AM processes. Additivemanufacturing of different materials **Module 3:** Advance in welding techniques, Robotic welding, characterization, Non-traditional Manufacturing processes, **Module 4:** Introduction: CAD/CAM, NC/CNC, CNC machines, Industrial applications of CNC, economic benefits of CNC. CNC Machine Tools, CNC tooling: Qualified and pre-set tooling, tooling systems, tool setting, automatic tool changers, work holding and setting. Programming: Part programming language, programming procedures, proving part programmes, computer aided part programming **Module 5:** Metal forming: Bulk and sheet metal forming processes, Fundamentals of plasticity, yield and flow, anisotropy, instability, yield criterion for isotropic materials, plastic stress strain relations for isotropic materials. Force equilibrium method and its application to metal forming processes. Introduction to incremental sheet and bulkmetal forming **Module 6:** Industry 4.0 cases studies of manufacturing
4	**Texts/References**	1. Gibson, D. W. Rosen, and B. Stucker, Additive Manufacturing Technologies: Rapid Prototypingto DirectDigital Manufacturing. Springer, 2014. 2. C. K. Chua and K. F. Leong, Rapid Prototyping: Principles and Applications in Manufacturing.WorldScientific, 2003. 3. Theory of Plasticity by J. Chakrabarty, McGrawHill Book Co., InternationalEdition, 19874. 4. Messler, R. W. (2008). Principles of Welding: Processes, Physics, Chemistry, and Metallurgy.Germany:Wiley. 5. Ibrahim Zaid, R. Sivasubramanian, CAD/CAM: Theory and Practice. McGraw Hill Education,2nd edition,2009. 6. M. P. Groover, E. W. Zimmers, CAD/CAM: Computer-aided design and manufacturing.Pearson, 2013.

Elective Course

1	**Title of the course** (L-T-P-C)	**Advanced Solid Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Module 1: Analysis of Stress:** Concept of traction, Cauchy Stress formula: Traction on arbitrary planes, Equality of cross-shears, Principal stresses and Principal Planes, Stress invariants, State of Stress Referred to Principal Axes – Octahedral stresses, Mohr's Circles for 3D State of Stress, Equations of equilibrium – Cartesian and Cylindrical coordinate systems. **Module 2: Analysis of Strain:** Displacement field, Deformation gradient, Change in length of a linear element andits linearization and physical interpretation, State of Strain at a point, Change in thedirection of a linear element, cubical dilatation, change in the angle between two linear elements – shear strain, Principal axes of strain and Principal strains, Strains in cylindrical coordinate systems, compatibility of linear strains. **Module 3: Stress-strain Relations – Linear Elastic Solids:** Generalized Hooke's Law, Material Symmetry Planes – Monoclinic, Orthotropic and Isotropic, Lames's constants, Bounds on moduli. **Module 4: Formulations, General theorems and Solution Strategies:** Stress formulation – Beltrami-Michell Compatibility relations, Navier-Lame Equations of equilibrium, Strain Energy Concept, Saint Venants principle, Principle of Superposition, Uniqueness theorem; General Solution strategies. **Module 5: Plane elasticity:** Plane stress, Pane strain, 2D stress formulation in Cartesian and Polar Coordinates: Airy stress function. **Module 6: 2D Problems:** Cartesian coordinate Problems: Using Polynomials and Fourier series , Polar coordinateProblems: Axisymmetric problems - Lame, Rotating Disk, curved beams under pure moments, Infinite/Semi-infinitebody subjected to concentrated loads – Kelvin and Flamant problems, Stress concentration in an infinite plate with a small hole – Kirsch problem. **Module 7: Extension, Flexure and Torsion of Prismatic bars:** Extension formulation; Torsion formulation: SaintVenants semi-inverse approach, Prandtl's stress function approach, Membrane analogy, Solution using Fourier series, Torsion of thin-walled tubes – Bredt-Batho formula; Flexure formulation without twist.
4	**Texts/References**	**Text-books: 1.** M.H.Sadd,"Elasticity: Theory, Applications and Numerics",Academic Press, 2013. **2.** J. R. Barber, Elasticty, Springer, 2010. **3.** L.S.Srinath,"Advanced Mechanics of Solids" Tata McGraw Hill, 2007. **References: 1.** S.P. Timoshenko and J.N. Goodier, "Theory of Elasticity," McGraw-Hill, Third Ed., New York,1970. 2. Allan F. Bower, Applied mechanics of Solids.. CRC press, 2009. 3. Adel S. Saada , Elasticity: Theory andApplications, Second Edition, Revised & Updated.. J. Ross Publishing, ,2009. 4. Robert William Soutas-Little,Elasticity, Courier Corporation, 2012.

Elective Course

1	**Title of the course** (L-T-P-C)	**Advanced Mechanisms and Dynamics ofMechanical Systems** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	

3	**Course content**	• Review of Grashof criterion and its derivation
		• Synthesis of Mechanisms - Four bar linkage and Slider crank mechanisms
		  ○ Two position Double rocker design
		  ○ Two position motion generation
		  ○ Three position motion generation
		  ○ Function Generation
		  ○ Synthesis of crank-rocker for a specified rocker amplitude
		• Path synthesis -- practical Approaches
		  ○ Roberts Cognate Theorem
		• Review of Special Mechanisms
		  ○ Straight Line generating mechanisms
		  ○ Ackermann Steering Mechanism
		  ○ Pantograph Mechanism and its derivation
		• Brief introduction to spatial linkages
		  ○ Serial Chain
		  ○ Closed loop linkages
		• Review of Dynamics of particles
		  ○ Newton's laws, Impulse Momentum
		  ○ Moment of a force and Angular Momentum, Work and Energy
		  ○ System of particles
		• Fundamentals of Analytical Mechanics
		  ○ Degrees of freedom and generalized coordinates
		  ○ Systems with constraints
		  ○ The stationary value of a function and a definite integral
		  ○ The principle of virtual work
		  ○ D' Alembert's principle
		  ○ Hamilton's principle
		  ○ Lagrange's equation of motion
		  ○ Lagrange's equations for impulsive forces
		  ○ Conservation laws
		  ○ Routh's method for ignoration of coordinates
		  ○ Rayleigh's dissipation Function
		  ○ Hamilton's equations

4	**Texts/References**	TEXTBOOKS 1. "Kinematics Dynamics and Design of Machinery", Kenneth Waldron and Gary L. KInzel,Second Edition, John Wiley and Sons. 2. "Analytical Dynamics", Leonard Meirovitch, First Edition, McGraw Hill.

Elective Course

1	**Title of the course** (L-T-P-C)	**Advanced Fluid Mechanics and Heat Transfer** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	Boundary layer theory: fundamentals, derivation of N-S equations, exact solutions of N-S equations,Boundary-layer equations in plane flow, coupling of thermal boundary layers and velocity field of the temperature field, internal flows Potential flow and flow past immersed bodies Turbulence: high Re flows, energy-transfer concepts, turbulent boundary layers, free-shear flows like jets, wakes, andmixing layers, turbulence modelling Compressible flows: energy equation, assumptions, compressible flows, stagnation properties, speed of sound, isentropic and non-isentropic flows, potential and rotational flows, effect of area change, shaft work, heat addition, mass addition and friction on flow states in a compressible (channel) flow. Pool Boiling: Nukiyama curve, boiling regimes, correlations, enhancement of boiling heat transfer Two phase flow and heat transfer: liquid-vapor interface, contact angle hysteresis, bubble formation,flow regimes,flow models, condensation. Radiation: Intensity, radiosity, irradiance, view factor geometry and algebra, radiative heat transfer equation, extinctionand scattering properties of gases and aerosols, overview of solution methods and applications. Radiation in Enclosures – Gas Radiation – Diffusion and Convective Mass Transfer – Combined Heat and Mass Transfer
4	**Texts/References**	**Texts:** 1. Hermann Schlichting, and Klaus Gersten. Boundary layer theory. 9th edition. Springer, 2017. 2. Tennekes, Hendrik, and John L. Lumley. A first course in turbulence. MIT press, 2018. 3. Anderson, John D. Modern compressible flow. Tata McGraw-Hill Education, 2003. 4. Carey, Van P. Liquid-vapor phase-change phenomena: an introduction to the thermophysics ofvaporizationand condensation processes in heat transfer equipment. CRC Press, 2018. 5. Incropera, Frank P., et al. Fundamentals of heat and mass transfer. Wiley, 2007. 6. Modest, Michael F. Radiative heat transfer. Academic press, 2013. **References:** 7. Davidson, Peter Alan. Turbulence: an introduction for scientists and engineers. Oxford universitypress, 2015. 8. Pope, Stephen B. "Turbulent flows." (2001): 2020. 9. Bejan, Adrian. Convection heat transfer. John wiley & sons, 2013. 10. Kays, William Morrow. Convective heat and mass transfer. Tata McGraw-Hill Education,2011.

Elective Course

1	**Title of the course** (L-T-P-C)	**Fundamentals of Acoustics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Fluid Mechanics
3	**Course content**	**Review of classical acoustics**: review of classical acoustics, linearized equations of motion, classical wave equation. Speed of sound, harmonic waves, acoustic energy/intensity, decibel scale. Acoustic impedance and admittance, reflection and transmission at the interface of two media, Impedance tube technique. **Sound propagation:** plane and spherical waves, Travelling and standing waves, boundary conditions, Eigen frequency and Eigen modes. Effects of area variation, reflection and transmission of waves in pipes. Acoustic wave propagation in homogeneous and inhomogeneous media; **Models for acoustic sound sources:** point sources, monopoles, dipoles and quadrupoles, Aero-acoustic sources: Lighthill's acoustic analogy, integral solutions and far-field approximations; effect of solid surface; **Losses:** Viscous and thermal conduction losses, absorption coefficient, sound absorption in pipes **Measurement** of sound signals, microphones, time series analysis using Fast Fourier Transform, Discrete Fourier Transform, Transfer function, and Bode plots. Solving numerical problems. **Applications to engineering problems**: Aero-acoustic jet noise, Thermoacoustic instability, fan/rotor noise and numerical evaluation
4	**Texts/References**	1. Lawrence E. Kinsler, Austin R. Frey, and Alan B. Coppens, 2000. Fundamentals of acoustics. 4th edn. John-Wiley & Sons, Inc. 2. Pierce, Allan D. Acoustics: an introduction to its physical principles and applications. Springer, 2019. 3. Munjal, M. L. (1987). Acoustics of ducts and mufflers with application to exhaust and ventilation system design. John Wiley & Sons. 4. Tim C. Lieuwen, 2012. Unsteady combustor physics. 1st edn. Cambridge University Press.

Elective Course

1	**Title of the course** (L-T-P-C)	**Finite Element Analysis** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Mechanics of Materials
3	**Course content**	Approximate solution of differential equations - - Weighted residual techniques. Collocation, Least Squares and Galerkin methods. Piecewise approximations. Basis of Finite Element Method. Formulation of the matrix method -- "stiffness matrix"; transformation and assembly concepts. Example problems in one dimensional structural analysis, heat transfer and fluid flow. Elements of Variational calculus. Minimisation of a functional. Principle of minimum total potential. Piecewise Rayleigh - Ritz method and FEM. Comparison with weighted residual method. Two dimensional finite element formulation. Isoparametry and numerical integration. Algorithms for solution of equations. Convergence criteria, patch test and errors in finite element analysis. Finite element formulation of dynamics. Applications to free vibration problems. Lumped
4	**Texts/References**	1. Bathe, K. J., Finite element procedures in Engineering Analysis, Prentice Hall of India, 1990. 2. Cook, R.D., D. S. Malkus and M. E. Plesha, Concepts and Applications ofFinite element analysis, John Wiley, 1989. 3. Reddy, J. N., An Introduction to the Finite Element Method, 2nd ed., McGraw Hill, 1993. 4. Seshu, P. Finite Element Method, Prentice Hall of India, New Delhi, 2003. 5. Zienkiewicz, O. C., and K. Morgan, Finite elements and approximation, John Wiley, 1983. 6. Zienkiewicz, O. C., and R. L. Taylor, The

Elective Course

1	**Title of the course** (L-T-P-C)	**Fatigue and Fracture Mechanics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Strength of Materials/Mechanics of Materials (& Theory of Elasticity)
3	**Course content**	Module 1(10 hours): Introduction and historical overview, Types of fatigue – low cycle fatigue, highcycle fatigue, very high cycle (giga cycle) fatigue, Fatigue test methods and equipment, Totallife approaches based on cyclic stress and cyclic strain, Cyclic hardening and softening in single crystals and polycrystals. Module 2(10 hours): Crack initiation and propagation, Mechanisms, Macro-structural and microstructural aspects, Use of fracture mechanics in fatigue Module 3(10 hours): Local strain approach, effect of different factors on fatigue – Stress concentration, Size, Surface, Temperature, Frequency, Environment, Microstructure, Residual stresses, Fretting, Creep-fatigue interaction, Multiaxial stresses, Thermomechanical loading, Variable amplitude loading, Load sequence, Crack closure Module 4(10 hours): Fatigue behaviour of different materials – Metallic materials and weldments, Ceramics, Polymers, Composites, Metallic glasses, Shape memory alloys, Ultrafine grained materials, Nanocrystalline materials, Biomaterials, Metallic foams, Case studies on fatigue failures, Design considerations, Methods for fatigue life improvement
4	**Texts/References**	1. Fatigue of Materials, Suresh, Cambridge India, 2015 2. Fracture Mechanics, Fundamentals and Applications, T.L. Anderson, CRC Press 2017

Elective Course

1	**Title of the course** (L-T-P-C)	BIO ENERGY CONVERSION **(3-0-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	**Introduction**: Global and Indian energy scenario, Issues with conventional energy sources, climate change, alternative energy sources **Bio Energy sources:** Photosynthesis, Biomass characteristics, Energy content of various bio energy sources, Biomass conversion methodologies **Physical conversion:** Briquetting, Pelletization **Thermo chemical conversion**: Direct combustion, Working principal of high efficiency stoves **Gasification:** Chemical reaction in gasification, Producer gas, Types of gasifiers, Working principal of fixed bed and fluidized bed gasifiers, Application of producer gas in engines **Pyrolysis:** Liquefaction of biomass through pyrolysis, Methanol production **Bio chemical conversion:** Anaerobic digestion, Bio gas production, Factors affecting bio gas yield, Types of bio digestors, Bio fermentation for ethanol production, Application of ethanol in engines **Chemical conversion:** Bio diesel, Sources of bio diesel, methods of bio diesel production, Transesterification of bio oil, Application of bio diesel in engines **Introduction to Algal Biofuel:** Sources and methodologies of utilization

Elective Course

4	**Texts/References**	**Textbooks:** • Understanding Clean Energy and Fuels from Biomass, H. S. Mukunda, Wiley-India, 2011 • Introduction to Biomass Energy Conversions, Sergio Capareda, CRC Press Inc, 2013 • Bio Gas Technology, B. T. Nijaguna, New Age International, 2006 • Renewable Energy Engineering and Technology, A Knowledge Compendium, Edited by VVN Kishore, TERI Press, 2009 • Algal Biofuel: Sustainable Solution, Editors, Richa Kothari, Vinayak V Pathak and and V V Tyagi, TERI Press, 2023 **References:** • Renewable Energy Resources, Joh, W. Twidell, Anthony, D. Weir, EC BG-2001 • Sustainable Energy, Choosing Among Options, Jefferson W. Tester et.al., PHI Publications, Second Edition, 2012 • Gasification, Christopher Higman, Maarten van der Burgt, 2nd Edition, Elsevier Publications, 2008

Elective Course

1	**Title of the course** (L-T-P-C)	**Practicum** **(0-0-3-3)**
2	**Pre-requisite courses(s)**	None for M. Tech SSM. For others, instructor consent is required
3	**Course content**	Pre-mid semester: 1. Overview on components, subsystems in EV 2. Reverse Engineering: a. Two/Three/Four Wheel EV, b. Conventional IC Vehicle 3. Site visits to testing and manufacturing centers or colloquium with Industry experts Post-mid semester: 1. Hands-on on fabrication, manufacturing, machining and metrology a. Sheet metal b. Welding processes c. Machining processes d. 3D Printing e. Material characterization; static and dynamic loading f. Impact tests
4	**Texts/References**	TEXTBOOKS a. Elements of Workshop Technology Vol. 1 (2015), S. K. Hajra Choudhary, A. K. Hajra Choudhary and Nirjhar Roy, Media Promoters and Publishers Pvt. Ltd. b. W. A. J. Chapman, Workshop Technology, Vol. 1 (2006), Vol 2 (2007), and (1995), CBS Publishers. c. Handbooks of Convenctional IC Engine Vehicle and EV vehicles

Elective Course

1	**Title of the course** (L-T-P-C)	**Astrophysics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Successfully finishing first 3 semesters
3	**Course content**	1. a. An inventory of the Universe, b. Celestial sphere, Coordinates c. Units, sizes, masses and distance scale 2. Electromagnetic spectrum a. Radio, Microwave, Infrared, Optical, X-ray and Gamma Ray b. Telescopes and Detectors 3. Stars A. General a. Sun, Planets, (Mother Earth) b. Mass, Radius, Luminosity, Temperature, Chemistry, Age and Types of stars c. Hertzsprung-Russell Diagram d. Birth and Evolution of stars c. Limits on Mass - Quantum mechanism at large scale: Brown Dwarf B. : Structure of a star: a. Virial Theorem (qualitative) b. Nuclear Energy, Pressure, Interaction with radiation. c. Basic Equations of Stellar Structure d. Thermal Equilibrium, Radiation and Convection - Schwarzchild Criterion e. Helioseismology 4. Galactic and Extragalactic Astronomy a. The Milky Way and Andromeda b. Rotation Curve - Dark Matter c. Structures within 500 mega light years d. Clusters of Galaxies, Superclusters, Filaments and Voids 5. Special Topics: a. White Dwarf - Quantum Mechanics and Gravitation: Chandrasekhar limit b. Supernova, Neutron Stars, (Pulsar astronomy), c. Black Holes, Gravitational Wave Astronomy d. Gamma Ray Burst e. Quasars and Active Galactic Nuclei 6. Topics in Cosmology (This will be decided after discussing certain issues with Department members) a. Hubble Expansion - Cosmic Distance Scale - Age of the Universe b. Standard Model of Cosmology c. Cosmic Microwave Background d. Supernova Cosmology Project and Dark Energy e. Gravitational Lens 7. Major Astronomical facilities where India is involved: GMRT, SKA, Thirty Metre Telescope, LIGO, ASTROSAT 8. Open questions in Astrophysics and Cosmology
4	**Texts/References**	1. The New Cosmos: An introduction to Astronomy and Astrophysics, A. Unsold and B. Baschek, Springer, 5th edition, 2010. 2. An Introduction to Modern Astrophysics, B.W. Carroll and D.A. Ostlie, Cambridge University Press, 2nd edition, 2017. 3. Elements of Cosmology, J.V. Narlikar, University Press, 1996.

Elective Course

1	**Title of the course** (L-T-P-C)	**Introduction to Quantum Information and Computation** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	PH101 – Quantum Physics and Application MA102 - Linear Algebra
3	**Course content**	Framework of Quantum Mechanics: Quantum States, Dirac notation and Hilbert Space, Operators, Spectral Theorem, Functions of operators, Tensor Products, Schmidt Decomposition theorem; Time-evolution of a closed system; composite systems, measurement, pure and mixed states and general quantum operations. Quantum systems: Qubits, qudits, bipartite and multipartite systems, Continuous variable states. Quantum Entanglement: Definition, detection, quantification in various quantum systems Quantum Communication: no-go theorems, quantum teleportation, quantum dense coding, and other quantum communication protocols without security. Quantum Cryptography: essentials of classical cryptography, quantum protocols with security like, BB84, B92, Ekert, etc. Quantum Computation: Quantum gates, quantum algorithms, D-wave quantum computer. Status update for experimental realization on some of these protocols.
4	**Texts/References**	1. Quantum Computation and Quantum Information, M. A. Nielsen & I. L. Chuang, 10th Edition, Cambridge University Press, NY, USA (2011). 2. Quantum Information Theory, M. M. Wilde, Cambridge University Press, 2nd edition, 2017. 3. An introduction to Quantum Computing, P. Kaye, R. Laflamme and M. Mosca, Oxford University Press, (2010). 4. Preskill's lecture notes on Quantum Information and Quantum Computation, http://www.theory.caltech.edu/people/preskill/ph229/ 5. Principles of Quantum Computation and Information (Vol.-1), G. Benenti, G. Casati, and G. Strini, World Scientific, 2004. Classical and Quantum Computation, A. Yu. Kitaev, A. H. Shen, and M. N. Vyalyi, American Mathematical Society, 2002 7. Quantum Computation and Quantum Communication -Theory and Experiments, M. Pavicic, Springer, 2006. 8. Quantum Computer Science, N. D. Mermin, Cambridge, 2007. 9. Lectures on Quantum Information, Edited by D. Bruss and G. Leuchs, Wiley-VCH Verlag, 2007.