



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

PhD ADMISSIONS

Second Semester, 2022-23

BROCHURE

INDEX

1. About BITS Pilani	2
2. PhD Admissions	3
3. Minimum eligibility criteria for admissions	4
4. Financial assistance	4-5
5. Important dates	5
6. Application Process	6
7. Written test details	7-8
8. Syllabus for Test	9
A. Biological Sciences	9
B. Chemistry	10
C. Mathematics	12
D. Physics	14
E. Humanities & Social Science	16
F. Economics	18
G. Management	20
H. Nanoscience & Nanotechnology	21
I. Chemical Engineering	23



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

About BITS Pilani

BITS Pilani offers UG, PG and PhD programs to over 17,500 students across its campuses in Pilani, Goa, Hyderabad, Mumbai and Dubai. BITS Pilani was declared as an Institution of Eminence by the Ministry of Education, Government of India in 2020.

QS World University Subject Rankings 2022 has ranked BITS Pilani globally at

- i) 101-150 in Pharmacy and Pharmacology
- ii) 301-350 in 2 subjects namely, EEE and Chemical Engineering
- iii) 351-400 in Mechanical Engineering
- iv) 401-450 in Computer Science
- v) 451-500 in 2 subjects (Mathematics and Business & Management Studies)
- vi) 501-550 in Chemistry
- vii) 551-600 in Physics & Astronomy

BITS Pilani has been ranked among the top 300 in QS World University Graduate Employability Rankings 2022 and within the top 8 in India. In the NIRF 2022 rankings, BITS Pilani has been ranked 5th in Pharmacy, 18th in the University category. In QS Asia University Rankings 2022, BITS Pilani has been ranked 194th, only private institute from India in the Asia Top 200, and at 18 in India.

The Institute has secured over Rs. 375 crore as external research grant in the last 5 years. State of the art facilities have been developed to support cutting edge research, led by students and about 925 faculty members. Scopus h-index of 140, about 20,905 publications with over 20,5012 citations as per Scopus Database. 40 patents were filed and 11 patents were granted in 2021.

Recently, BITS Pilani was chosen by the Department of Science and Technology, GoI to establish a Technology Innovation Hub on Bio-Cyber Physical Systems with a grant of Rs 125 Cr - the only non-Government institute amongst the 25 chosen nationally for this prestigious grant. Recent studies have identified BITS Pilani at #3 in terms of number of Indian start-ups founded by the graduates of an institute. Currently there are 12 BITSian Unicorns and 1 Decacorn. There are over 7500 BITSian founders and co-founders of enterprises.



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

PhD Admissions (Second Semester, 2022–2023)

Applications are invited for Second Semester admission to the PhD program (Full time and/or Part time) starting January 2023 in Pilani, Goa and Hyderabad campuses of BITS Pilani in the following Departments:

- Engineering: Chemical, Civil, Computer Science, Electrical & Electronics, Mechanical
- Science: Biological Sciences, Chemistry, Mathematics, Physics
- Pharmacy
- Economics & Finance, Humanities & Social Sciences, Management

Department openings with regard to Full and Part time student admission are tabulated below:

Department's Preference for Ph.D. Admission (Second Sem. 2022-23)						
Department	Pilani		Goa		Hyderabad	
	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time
Biological Sciences	Yes	No	Yes	Yes	Yes	Yes
Chemical Engg.	Yes	Yes	Yes	Yes	Yes	Yes
Chemistry	Yes	Yes	Yes	Yes	Yes	Yes
Civil	Yes	Yes	No	No	Yes	Yes
CSIS	Yes	Yes	Yes	Yes	Yes	Yes
EEE	Yes	Yes	Yes	Yes	Yes	Yes
Humanities & Social Sciences	Yes	No	Yes	No	Yes	Yes
Economics & Finance	Yes	Yes	Yes	No	Yes	Yes
Management	Yes	Yes	Yes	No	Yes*	No
Mathematics	Yes	No	Yes	No	Yes	Yes
Mechanical	Yes	Yes	Yes	Yes	Yes	Yes
Pharmacy	Yes	Yes	No	No	Yes	Yes
Physics	Yes	No	No	No	Yes	Yes

Yes – A Department intends to admit students under the specified scheme

No – A Department does not intend to admit students under the specified scheme

(*only in the area of entrepreneurship and strategy)



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

Information on specific Departments and related research activities is available on the Department website of respective campuses. Candidates are requested to visit the relevant website and if needed, further contact the concerned Head of Department (HOD) for details.

Full-time Students: Preferably individuals who would like to pursue Ph.D. in-house, residing on campus.

Part-time Students: Preferably individuals working in organizations providing basic facilities and environment for research.

Minimum eligibility qualifications

- M.E./M.Tech./M.Pharm./MBA/M.Phil. or an equivalent Degree with a minimum of 60% aggregate in the qualifying examination
- M.Sc./B.E./B.Pharm. or an equivalent degree with a minimum of 60% aggregate in the qualifying examination
- For admissions to Humanities and Social Sciences, candidates with an M.A. degree and a minimum of 55% aggregate may apply.

Meeting the minimum eligibility criteria does not guarantee admission into the PhD program. In addition, Departments may set specific admission criteria for shortlisting. Shortlisted candidates will have to appear for an admission test, which may comprise of a written exam and/or interview. Candidates admitted with qualifications like M.Sc., B.E., B.Pharm. etc., will be required to do course work on admission to the program.

Financial assistance

Full-time PhD students admitted into the PhD program are eligible to be considered for an Institute fellowship of Rs. 28,000 or Rs. 31,000 per month in the first year based on their qualifications at the time of admission.

Students admitted with M.E./M.Tech./M.Pharm./MBA/M.Phil. or an equivalent Degree are eligible to receive an Institute fellowship of Rs. 31,000/-.

Students admitted with M.Sc./B.E./B.Pharm. or an equivalent degree are eligible to receive an Institute fellowship of Rs. 28,000/-. These students on successful completion of coursework will receive Rs. 31,000/- from the Semester following the one in which the course work was completed.



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

Higher fellowship may be made available in subsequent years. Consideration for Institute fellowship will be as per Institute norms. It will be obligatory on the part of every admitted Full time student to undertake 8 to 10 hours (per week) of work as assigned to him/her by the institute.

Important Dates

ACTIVITY	DATE
Admission Portal Open	20-Oct-2022
Last Date for filling application form online	24-Nov-2022
Declaration of shortlisted candidates (on BITS admission website)	28-Nov-2022
Admission Test/Interview	5/7-Dec-2022
Result Notification	17-Dec-2022
Deadline for Fee Payment	6-Jan-2023
Student Reporting	16-Jan-2023
Student Registration	17-Jan-2023

The Institute reserves the right to change the above deadlines. Candidates will be informed in advance should there be such a change.



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

Application Process

1. The Admission portal to apply online opens on **20th October, 2022**.
2. Interested and eligible candidates should apply through the prescribed application form available online at <https://www.bitsadmission.com/phdmain.aspx>. Hard copy of the application form is not required to be sent. Candidates are advised to take a printout of the filled form and retain it for further reference.
3. Candidates will need to register online prior to filling the application form. A registered mobile number and email ID will be required to generate a username and password essential for filling the application form.
4. While filling the application form online, candidates are required to give preference of the campus or campuses to which they wish to apply for. Please refer to Department's Preference with regard to Full and Part-time student admission prior to filling the application form.
5. The completed application form along with the prescribed application fee should be submitted online by the prescribed deadline. Detail on modes of Fee Payment will be available while applying online. Campus preference and priority cannot be changed once the application form is submitted.
6. Deadline for submission of the completed application form online is 5:00 PM on **21st Nov, 2022**.
7. A non-refundable application fee of Rs. 2600/- is payable at the time of submission of the online form.
8. A candidate can submit only one application form for PhD admission. However, if a candidate discovers any mistake in the form to be submitted by him/her, there will be an edit option which will be made available before the final submission of the application form, which he/she can make use of to incorporate necessary changes. This option will be available only till the deadline for submission of the form which is 5:00 PM on **21st Nov, 2022**.
9. Final decision on admitting the candidates to the PhD program will be taken by the Admission Committee of the Institute and will be binding on all.



Written Test Details

A. Candidates shortlisted for test in any of the following Departments

Biological Sciences/Chemistry/Mathematics/Physics will have to write two tests. Test-I will be common to all disciplines and Test-II will be discipline specific. The details of the tests are as follows:

Test-I question paper consists of 30 multiple-choice type questions pertaining to General Science, Quantitative Reasoning & Analysis and Research Aptitude. The duration of Test – I will be 1 hr. Each correct answer will be awarded 2 marks while 0.5 marks will be deducted for every wrong answer.

Test-II will be subject-based and will consist of 70 multiple-choice type questions covering the prescribed syllabus of relevance to the candidate as given on Page 9. The duration of Test – II will be 1 or 2 hrs. Each correct answer will be awarded 2 marks while 0.5 marks will be deducted for every wrong answer.

Candidates with M.Phil. / M.E. / M.Tech. or with National level fellowships like CSIR NET-JRF, DBT-JRF, UGC NET-JRF etc. are exempted from writing the above test.

B. Candidates shortlisted for Test in any of the following Departments:

Humanities & Social Sciences/Economics will have to write two tests. Test-I will be common to both disciplines and Test-II will be discipline specific. The details of the tests are as follows:

Test-I will comprise of the following components:

S.No	Component	Number of Questions	Time (minutes)
1.	Reading Comprehension (2 Passages)	5 Questions for each passage (10 questions in total)	20
2.	Logical Reasoning	10 questions	10
3.	Analytical Reasoning	15 questions	15
4.	General Awareness	15 questions	15



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

Test-II for candidates shortlisted in Humanities & Social Sciences will be discipline specific and subjective in nature.

Candidates with a M.Phil. degree or with fellowships like CSIR NET-JRF, DBT-JRF, UGC NET-JRF etc. are exempted from writing the above test

- C.** All Candidates shortlisted for the PhD program in the Department of Management will be required to take a written test of duration 1 hr. The nature of the written test will be application-based in the areas of general management to testing basic technical knowledge, research aptitude and research orientation.
- D.** Candidates with a B.E./B.Pharm. or an equivalent degree, if shortlisted, will be required to appear for the written test.

Based on the test results, there may be shortlisting of candidates for Interview.

All notices/shortlists will be put on the admission website <https://www.bitsadmission.com/phdmain.aspx>. Candidates are advised to check this website regularly. No written communication will be sent to the candidates.



Syllabus for Test

A. Biological Sciences

Subject	Content	Reference Books
Genetics	Laws of inheritance and genetic interaction, Genetic mapping in Virus, Bacteria, & Eukaryotes, Gene expression in prokaryotes and eukaryotes, Control of gene expression in prokaryotes eukaryotes and Viruses., Population and evolutionary genetics	Principles of Genetics – Robert H. Tamarin, 7th edition, Tata McGraw–Hill, 2002.
Molecular Technique	Restriction endonucleases, Vectors and cloning, Blotting technique, PCR, Sequencing	Principles of Gene Manipulation- R. W. Old & S. B. Primrose, 7 th Edition
Biological Chemistry	Chemistry of Biomolecules, Enzymes, Vitamins & Coenzymes, Bioenergetics and biological oxidation, Metabolism of Biomolecules, Photosynthesis	Principle of Biochemistry- Lehninger, Macmillan Worth Publication, 3rd edition
Microbiology	Fundamentals of Microbiology, A survey of the microbial world, Host-Microbe interaction, Microbes and Human disease, Environmental and applied microbiology	Microbiology-An introduction (8th edition)- Tartora, Funk & Cane-Pearson publishing house.
Ecology	Abiotic factors, Ecosystem ecology and energy flow, Community ecology and population ecology, Regional Ecology (Terrestrial and Aquatic), Regional Ecology (Terrestrial and Aquatic)	Concepts of Ecology by E J Kormondy Fundamentals of ecology by E. P. Odum
Plant Physiology	Transport and translocation of water and solutes, Essential elements and their function, Plant development and PGRs, Ascent of sap and translocation in phloem, Movement in plants	Plant physiology, 3rd edition by Salisbury & Ross- CBS Publisher and Distributor.
Bio-Physics	Chemical properties of basic unit of life, energy forces, bonds., Conformation of Biomolecules, Biological membranes and Biomechaniques, Physiochemical techniques to study biomolecules, X-ray crystallography, NMR, molecular modeling.	Biophysical chemistry by Cantor and Schimmel. Biophysics by Rodney Cotteril.
Developmental Biology	Model systems- Vertebrates, Invertebrates and Plants, Axis and germ layers, The mesoderm and early nervous system, Morphogenesis and cell differentiation, Organogenesis, germ cells and sex.	Principles of Development – Lewis Wolpert-Oxford University Press, 2nd edition
Cell Biology	Preview of cell, cellular membranous systems, Transport, Mitochondria, Chloroplast, energy transducing organelle, Golgi, Nucleus, Cytoskeletal network, Cell growth & proliferation, Cell Immunity	Cell and Molecular Biology- Philip Sheeler & Donald E. Bianchi. 3rd edition, John Wiley Publication.
Animal Physiology	Digestive and Respiratory system, Circulatory system, Excretory system, Nervous and Endocrine system, Body Immune system	Animal Physiology by Sherwood et al, 1st edition- Thomson Publication. Animal Physiology by Sherwood et al, 1st edition- Thomson Publication.



B. Chemistry

Subject	Content	Reference Books
Physical Chemistry	<p>Basic principles and applications of quantum mechanics, angular momentum, hydrogen atom, atomic structure, chemical bonding, variational and perturbational methods, pure rotational spectroscopy, vibrational spectroscopy, vibrational-rotational spectroscopy, Raman spectroscopy, electronic spectroscopy, nuclear magnetic resonance spectroscopy, electron spin resonance spectroscopy, mass spectroscopy, fluorescence spectroscopy</p> <p>Concepts and laws of thermodynamics, entropy, free energy, calculation of changes in thermodynamic properties, partial molar properties, ideal and real gases, ideal and non-ideal solutions, electrolytic solutions, colligative properties, phase equilibria, chemical equilibria, electrochemistry and applications, kinetic theory of gases, statistical thermodynamics</p> <p>Chemical kinetics, rate laws, order and molecularity, determination of reaction mechanism, Arrhenius equation, theory of reaction rates, concept of catalysts, elementary reactions, consecutive elementary reactions, unimolecular reactions, polymerization kinetics, photochemical processes, quantum yield, enzyme kinetics, thermodynamic and kinetic control, physical and chemisorption, molecular interactions, self-assembly and transport processes</p>	<ol style="list-style-type: none"> 1. Donald A. McQuarrie, „Quantum Chemistry“, University Science Books (First Indian Edition 2003, Viva Books Private Limited). 2. Ira N. Levine, „Quantum Chemistry“, Pearson Education Inc. (2000) (First Indian Reprint, 2003). 3. P.W. Atkins and R.S. Friedman, „Molecular Quantum Mechanics“, 3rd Ed. OUP (1997). [4th ed. Has come out]. 4. F.L. Pillar, „Elementary Quantum Chemistry“, 2nd ed., McGraw Hill (1990). 5. John P. Lowe, „Quantum Chemistry“, 2nd ed., Pearson Education Inc. 6. Ira N. Levine, Physical Chemistry, Tata McGraw Hill, 2002, 5th edition 7. Donald A. McQuarrie & J. D. Simon, „Molecular Thermodynamics“, Viva Book Pvt Ltd., New Delhi, 2004 8. R. C. Srivastava, S K Saha, A K Jain, „Thermodynamics“, 2004
Inorganic Chemistry	<p>VSEPR Model, VB Theory, Ionic Crystal Structure, Structure of Complex Solids, Electronegativity, Acid-Base Chemistry, Chemistry in Aqueous and Non-Aqueous Solvents, Periodicity, Chemistry of transition metals, Redox chemistry.</p> <p>Character Table and its Applications in Infrared and Raman spectroscopy and in Bonding; Coordination Chemistry: Bonding - Valence Bond, Crystal Field, and Molecular Orbital theories; Complexes - Nomenclature, Isomerism, Coordination Numbers, Structure, Electronic Spectra, Magnetic Properties, Chelate Effect; Reactions - Nucleophilic Substitution Reactions, Kinetics, Mechanisms; Organometallic Chemistry: Structure and Reaction of Metal Carbonyls, Nitrosyls, Dinitrogen, Alkyls, Carbenes, Carbynes, Carbides, Alkenes, Alkynes, and Metallocenes; Catalysis by Organometallic Compounds; Stereochemically Non-Rigid Molecules. Bio-inorganic chemistry; metalloenzymes; metalloproteins; role of alkali and alkaline earth metal</p>	<ol style="list-style-type: none"> 1. Chemical Application of Group Theory, F. A. Cotton, 3rd edition, John Wiley and Sons, Inc. 2011. 2. J. A. Cowan, "Inorganic Biochemistry An Introduction", Wiley-VCH, 2nd edition 3. Inorganic Chemistry – Principles of Structure and Reactivity, Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi O. K.; 4th Edition, Pearson. 4. Concise Inorganic Chemistry, Lee, J.D. 5th Edition, Wiley India Edition. 5. Inorganic Chemistry, Shriver, D.F.; Atkins, P.W.; Overton T. L., Rourke, J. P.,



Birla Institute of Technology & Science, Pilani

Pilani | Goa| Hyderabad |

	ions, iron, copper, zinc, molybdenum etc. in life processes; Basic concepts in electronic, magnetic and photonic materials and nanomaterials.	Weller, M. T., Armstrong, F. A. 4th edition, Oxford.
Organic Chemistry	<p>Structure and Reactivity of Organic Compounds: IUPAC nomenclature of organic compounds, Reactive intermediates (carbocations, carbanions, free radicals, carbenes, benzyne and nitrenes), Aromaticity (Benzenoid and non-benzenoid compounds), Aliphatic & Aromatic Nucleophilic and Electrophilic Substitutions, Addition Reactions (carbon-carbon and carbon-hetero-multiple bonds) Elimination Reactions, Neighboring Group Participation</p> <p>Chemistry of Organic Compounds: Chemistry of functional groups, Structure, property and reactions of five and six membered heterocyclic (O, N and S) compounds, Organometallic compounds in organic synthesis, Natural products (carbohydrates, alkaloids, terpenes, amino acids).</p> <p>Stereochemistry of Organic Compounds: Stereochemistry (isomerism, chirality, origin of optical activity, stereochemistry of cyclic compounds, resolution), Selectivity (chemo-, regio-, and stereoselectivity), Conformations and configurational analysis of acyclic and cyclic compounds, Resolution and other asymmetric induction methods, Name reactions and rearrangements.</p> <p>Retrosynthetic Analysis: Disconnection approaches, Protecting Groups, Umpolung of reactivity, Ring synthesis and synthesis of Heterocyclic compounds</p> <p>Pericyclic Reactions and Photochemistry: Orbital symmetry, Electrocyclisation, Cycloaddition, Sigmatropic rearrangements and other related concerted reactions, Principles and applications of photochemical reactions in organic chemistry</p> <p>Spectroscopy of Organic Compounds: Structural elucidation of organic compounds using UV, IR, NMR (^1H & ^{13}C), Mass Spectrometry</p>	<p>1. March Jerry, Advanced Organic Chemistry, John Wiley & Sons, 4th edition, 1992.</p> <p>2. Morrison and Boyd, Organic Chemistry, Prentice & Hall, 6th edition, 1992.</p> <p>3. William Kemp, "Organic Spectroscopy", Macmillan, 3rd ed. 1991.</p> <p>4. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, Oxford University Press.</p> <p>5. Raj K Bansal, heterocyclic Chemistry, fifth edition (TB), New Age International publishers.</p> <p>6. I. L. Finar, Organic chemistry Vol. 2, 5th Ed.; Pearson</p> <p>7. Stuart Warren, Designing Organic Syntheses: A Programmed Introduction to the Synthon Approach, John Wiley and sons Ltd., 1978.</p> <p>8. W. Graham Solomons and Craig B. Fryhle, „Organic Chemistry“, 8th Edition, John Wiley & Sons, Inc. New York, 2004.</p> <p>9. F. A. Carey, Organic Chemistry, 5th Edition, Tata McGraw-Hill Publications Company Ltd., 2003.</p> <p>10. P. A. Bruice, Organic Chemistry, 3rd Edition, Reason Edution, Inc. 2001.</p>
Analytical Chemistry	<p>Instrumental methods of analysis: Magnetic Resonance Spectroscopy (^1H NMR, ^{13}C NMR, EPR), IR Spectroscopy, Mass Spectrometry, Ultraviolet and visible spectroscopy, fluorescence spectroscopy, chromatography and other separation techniques, Structure Resolution by combination of techniques.</p> <p>Chemical experimentation: Chemical Experimentation: Functional group identification and synthesis of organic compounds, Chromatography techniques (TLC & HPLC), Separation and qualitative analysis of mixture of organic Compounds. Acid base titrations, Complexometric titrations, Study of kinetics of chemical reactions, Determination of partition function, Adsorption isotherm, Synthesis and characterization of nanomaterials</p>	<p>William Kemp, "Organic Spectroscopy", Macmillan, 3rd ed, 1991</p> <p>Vogels textbook of practical organic chemistry 5th edition</p>



C. Mathematics

Subject	Content	Reference Books
Algebra	Permutations, combinations, pigeon-hole principle, inclusion-exclusion principle, derangements. Fundamental theorem of arithmetic, divisibility in congruences, Chinese Remainder Theorem, Euler - function, primitive roots. Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equation, Sylow's theorem. Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain. Polynomial rings and irreducibility criteria. Fields, finite fields, field extensions, Galois Theory.	Topics in Algebra by I.N. Herstein, Vikas Publishing House Pvt Ltd.
Analysis	Elementary set theory, finite, countable and uncountable sets, real number system as a complete ordered field, Archimedean property, supremum, infimum. Sequences and series, convergence, limsup, liminf. Bolzano Weierstrass theorem, Heine Borel theorem. Continuity, uniform continuity, differentiability, mean value theorem. Sequences and series of functions, uniform convergence. Riemann sums and Riemann integral, improper integrals and Riemann Stieltjes integral. Monotonic functions, types of discontinuity, functions of bounded variation. Lebesgue measure, measurable sets, measurable functions, Riemann and Lebesgue integral and their properties. Differentiations, functions of bounded variations, spaces, different modes of convergence, metric spaces, compactness, connectedness. Normed linear spaces, spaces of continuous functions as examples	Principle of Mathematical Analysis by W. Rudin, McGraw hill Publishers. Measure Theory and Integration by G. D. Barra, Wiley Eastern.
Topology	Topological spaces; special topologies, subspaces, product spaces and quotient spaces, continuity and homeomorphisms, connectedness and compactness, fundamental groups of surfaces	Topology by J.R. Munkres, Pearson Education publication. Introduction to Topology and Modern Analysis by G.F. Simmons, McGraw hill Publishers.
Ordinary Differential Equations (ODEs)	Existence and uniqueness of solutions of initial value problems for first order ODEs, singular solutions of first order ODEs, system of first order ODEs. General theory of homogeneous and non-homogeneous linear ODEs, variation of parameters, Sturm-Liouville boundary value problems, Green's function.	Differential Equations by G.F. Simmons. Elementary Differential Equations and Boundary Value Problems, 8th Edition, with ODE Architect CD by G. Krantz, Wiley.
Partial Differential Equations (PDEs)	Lagrange and Charpit's methods for solving first order PDEs, Cauchy problem for first order PDEs. Classification of second order PDEs, general solution of higher order PDEs with constant coefficients, method of separation of variables for Laplace, Heat and Wave equations	Elements of Partial Differential Equations by I.N. Sneddon, McGraw hill Publisher.



Birla Institute of Technology & Science, Pilani

Pilani | Goa| Hyderabad |

Linear Algebra	Vector spaces, subspaces, linear dependence, basis, dimension, algebra of linear transformations. Algebra of matrices, rank and determinant of matrices, linear equations. Eigenvalues and eigenvectors, Cayley-Hamilton's theorem. Matrix representation of linear transformations. Change of basis, canonical forms, diagonal forms, triangular forms, Jordan forms. Inner product spaces, orthonormal basis. Quadratic forms, reduction and classification of quadratic forms.	Linear Algebra by K. Hoffmann and R. Kunze, Prentice hall of India Pvt Ltd. Linear algebra and matrix theory by J. Gilbert and L. Gilbert, Brooks Cole. Introduction to linear algebra by G. Strang Wellesley Cabridge Press.
Complex Analysis	Algebra of complex numbers, the complex plane, polynomials, power series, transcendental functions such as exponential, trigonometric and hyperbolic functions. Analytic functions, Cauchy-Riemann equations. Contour integral, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem, maximum modulus principle, Schwarz lemma, open mapping theorem. Taylor's series, Laurents series, calculus of residues. Conformal mappings, Mobius transformations.	Complex Variables and Applications by James Brown, R. V Churchill.
Numerical Analysis	Computer arithmetic and errors, numerical solutions of algebraic equations, method of iteration and Newton-Raphson method, rate of convergence. Solution of systems of linear algebraic equations by using Gauss elimination and Gauss-Seidel methods. Finite differences, Lagrange, Hermite and spline interpolation, numerical differentiation and integration. Numerical solution of ODEs using Picard, Euler, modified Euler and Runge-Kutta methods.	Applied Numerical Analysis by Gerald and Wheatley 6/E, Pearson Education.
Probability	Sample space, discrete probability, independent events, Bayes' theorem. Random variables and distribution functions (univariate and multivariate); expectation and moments. Independent random variables, marginal and conditional distributions. Characteristic functions. Probability inequalities (Tchebycheff, Markov, Jensen). Modes of convergence, weak and strong laws of large numbers, central limit theorems (i.i.d. case).	Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences by J. Susan Milton. Schaum's Outline of Probability and Statistics by Murray R Spiegel, John J. Schiller, R. Alu Srinivasan.
Optimization	Modeling with linear programming, general L.P. solution, The simplex method, duality and post optimal analysis, transportation model and its variants, goal programming and integer linear programming, non linear programming algorithms.	Operations Research: An Introduction by Hamdy A Taha 8/E, Prentice Hall India/Pearson Education.
Operations Research	Queuing systems: Poisson queuing systems, Reliability: reliability and hazard rate function of series and parallel systems, inventory systems: single item inventory models, simulation and game theory, network models and deterministic dynamic programming.	Operations Research: An Introduction by Hamdy A Taha.
Advanced Calculus	Functions of several variables, directional derivative, partial derivative, and derivative as a linear transformation, inverse and implicit function theorems.	Thomas's Calculus (11th Edition) by George B. Thomas, Maurice D. Weir, Joel Hass and Frank R. Giordano, Pearson Publication.



D. Physics

Subject	Content	Reference Books
Modern Physics	Special Theory of Relativity, Particle-like Properties of Waves, Wave-like Properties of Particles, Heisenberg Uncertainty Relation, Bohrs Model of Hydrogen-like Atoms, Schrodinger Equation, Particle in One-dimensional Potential, Particle in One-dimensional Potential, Many Electrons Atoms, Physics of Molecules, Nuclear Transformations	R. Eisberg & R. Resnick, Quantum Physics of Atoms, Molecules & Solids, WSE, 2nd ed., 1985 Arthur Beiser, Concepts of Modern Physics, Tata McGraw-Hill, 6th ed., 2005
Thermodynamics & Properties of Matter	Thermometry, Thermal Expansion, Heat, Work and the First Law of Thermodynamics, Second Law of Thermodynamics, Heat Engines and Entropy, Kinetic Theory, Phase Transformations, General Properties of Matter	Zemansky & Dittman, Heat & Thermodynamics, 6th ed., McGraw-Hill, 1981
Classical Mechanics	Constraints, Generalized Coordinates, De-Alemberts principle, Lagranges Equations of Motion, Two-body Central force motion, Rigid Body Kinematics, Rigid Body Dynamics, Hamiltons Equations of Motion	H Goldstein, Classical Mechanics, Pearson Education, 3rd ed., 2002
Electromagnetic Theory	Electrostatics in Free Space, Electrostatics in Matter, Magnetostatics in Free Space, Magnetostatics in Matter, Faraday's Law of Electromagnetic Induction, Maxwells Equations, Conservation Laws, Electromagnetic Waves, Electromagnetic Potentials, Fields and Radiations	D. J. Griffiths, Introduction to Electrodynamics, Pearson Education, 3rd ed., 1999
Quantum Mechanics	Schrodinger Equation, Eigenvalues, Eigenfunctions, Eigenfunction Expansion, Dirac Notation, Operator Methods, Harmonic Oscillator, Angular Momentum, Central Force Problem, The Hydrogen Atom, Spin, Identical Particles, Time Independent Perturbation Theory	Richard L. Liboff, Introductory Quantum Mechanics, Pearson Education, 4th ed., 2003 Stephen Gisorowicz, Quantum Physics, John Wiley & Sons Inc., 3rd ed., 2003
Methods of Mathematical Physics	Vector Analysis, Curvilinear Coordinates, Matrices and Vector Spaces, Functions of Complex Variables, Ordinary Differential Equations, Sturm-Liouville Theory and Special Functions, Elements of Partial Differential Equations	Mathew Jon & R. Walker, Mathematical Methods of Physics, Pearson Education, 2nd ed., 1970 Arfken & Weber, Mathematical Methods for Physicists, Academic Press, 6th ed., 2005
Statistical Physics	Elements of Probability Theory, Elementary Kinetic Theory, Microcanonical, Canonical & Grand Canonical Ensembles and Their Applications, Quantum Statistics of Ideal Bose Gases, Quantum Statistics of Ideal Fermi Gases	Pathria R K, Statistical Mechanics, Elsevier, 2nd ed., 1996



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

Solid State Physics	X-ray Diffraction and Crystal Structure, Lattice Dynamics, Free Electron Theory of Metal, Electron in Periodic potential, Energy Bands, Semiconductors, Superconductivity	Kittel C., Introduction to Solid State Physics, WSE, 7th ed., 1995
Optics & Spectroscopy	Geometrical Optics, Interference, Diffraction, Polarization, Crystal Optics & Lasers, Atomic & Molecular Spectroscopy	Ghatak, A K, Optics, Tata McGraw-Hill, 3rd ed., 2005 Banwell C N, Fundamentals of Molecular Spectroscopy, Tata McGraw-Hill, 4th ed., 1994
Nuclear & Particle Physics	Nuclear Properties and Nuclear Models, Fission & Fusion, The Quark Model, Elementary Particles, their Classification and Interactions, Particle Accelerators, Conservation Laws of Elementary Particles and Fundamental Interactions	Krane K, Introductory Nuclear Physics, John Wiley & Sons, 1st ed., 1988 Griffiths, D J, Introduction to Elementary Particles, WIE, 1st ed., 1987



E. Humanities & Social Sciences

Subject	Content	Reference Books
Media Studies	Cinematic Art, Cinematic Adaptation, Understanding News, Current Affairs, Mass communication, Advertising, Media Writing, Content Design, Short Film Making	Hartley, J. Understanding News. London: Routledge. 1991 2nd Ed The Oxford Guide to Film Studies. Richard Dyer et al. A&C Black Publishers Ltd. London, 2008 Belch, George E. and Michael A. Belch. 1998. Advertising and Promotion. Sixth Ed. New Delhi: Tata McGraw-Hill.
Communication	Business Communication, Conflict Management, Technical Communication	Lesikar and Flatley. 2005. Basic Business Communication. New Delhi: Tata McGraw Hill 10th ed. The Dynamics of Conflict Resolution, San Francisco: Wiley Company, 2000
Phonetics, Language & Literature	English Language Teaching, English Usage, Phonetics and Language, English Literature: Elizabethans and Augustan, Pre-romantics and Romantics, Victorian Literature, Twentieth Century Literature: Poetry and Drama, Twentieth Century Literature: Prose and Fiction, Indian Writing in English, Applied Linguistics, American Literature, Women's Writing, Postcolonial Literature	The Oxford Companion To English Literature. A Critical History of English Literature (Vol – I & II) by David Daiches. Studying English Literature (A Practical Guide) by Tory Young. Murphy, R. (2012). English grammar in use. Cambridge: Cambridge University Press. Richards, J. C., & Rodgers, T. S. (2001). Approaches and methods in language teaching. Cambridge: Cambridge University Press. Nunan, David, & Newbury House Teacher Development. (1999). Second language teaching & learning. Boston, Mass: Heinle & Heinle.
Music	Logic and science working behind music, Schools of musical training, Musical forms and styles	SangeetRatnakar by Sharangdev
Other HSS areas	Test can also be conducted in these subjects depending upon the applications: Sociology, Public Policy, Gender Studies, History, Psychology, Philosophy, Political Science, Professional Ethics, Education	
Digital Humanities	"A Companion to Digital Humanities". Schreibman, S., Siemens, R., Unsworth, J. (Eds). Blackwell Companions to Literature and Culture. Paperback Edition, 2007. (Available freely online at http://www.digitalhumanities.org/companion/) "A Companion to Digital Literary Studies". Schreibman, S., and Siemens, R., (Eds). Blackwell Companions to Literature and Culture. 2008. (Available freely online at http://www.digitalhumanities.org/companionDLS/)	
Philosophy	Soccio, Douglas J. 2001. Archetypes of Wisdom: An Introduction to Philosophy. Wordsworth. Moore, Brooke Noel and Burder, Kenneth. 2005. Philosophy: The Power of Idea. Tata McGraw-Hill. The Essentials of Indian Philosophy, M. Hiriyanna, 2015, Motilal Banarsidass Publishers	
General Psychology	Robert A Baron, Psychology, Prentice Hall of India, 2005	
Cognitive Psychology	Levitin, D. J. 2002. Foundations of Cognitive Psychology. The MIT Press. Martine, M.W. 2013. Cognitive Psychology, John Wiley & Sons.	



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad | Dubai

Educational Psychology	Educational Psychology, 2nd edition, The Saylor Foundation (https://www.saylor.org/site/wp-content/uploads/2012/06/Educational-Psychology.pdf)
Education	Contemporary Issues in Higher Education, 2nd Edition, Richard Fossey, Kerry Brian Melear, and Joseph C. Beckham, eds. (2011) Issues and Challenges on Higher Education, (Eds. Doris Phillips Singh and Naveen Sameul Singh), Words Worth, 2012.
Organizational Behavior	Robins, Stephen; Judge, Thimonthy A; and Sanghi, Sooma. 2010. Essentials of Organizational Behavior. Pearson Education India
Spiritual Intelligence	Zohar and Marshall, Spiritual Intelligence The Ultimate Intelligence, Bloomsbury, 2001. Schuller, Peter A. ,Spiritual Intelligence, Author House, 2003.
Political Science	Robert E. Goodin, Philip Pettit and Thomas Pogge (Eds.) 2007. A Companion to Contemporary Political Philosophy (2nd edition), Oxford: Blackwell. Goodwin, Barbara (2014) Using Political Ideas (6th Edition). New York: John Wiley Bhargava, Rajeev & Acharya, Ashok (2008) Political Theory; An Introduction (2nd Edition). Pearson Education India
Development Economics	Misra, S. K. and Puri, V. K. (2005), Development and Planning: Theory and Practices (13th Revised Edition), Himalaya Publishing House, Bombay Todaro, M. (2000) Economic Development.7th Ed. Delhi: Pearson Education. 338.9 TOD.SMI Thirlwall, A. P. (2006) Growth and Development with Special Reference to Developing Economies. 8th ed. Hampshire: Palgrave Macmillan. 338.90091724 THI/Gro Meier, G. M. & Rauch, J. E. (2000) Leading Issues in Economic Development.7thed. New York: OUP. 338.9 MEI.RAU Ray, D. (1998) Economic Development. New Delhi: OUP 338.9 RAY/DEV
Introduction to Development Studies	Rapley, John. 2009. Understanding Development: Theory and Practice in the Third World (3rdEdition).Viva Books
International Relations	John Baylis;(2001). The Globalization of World Politics: An Introduction to International Relation; Oxford University Press; 2nd Edition. http://bit.ly/XhmCPF https://yfadukypyz.files.wordpress.com/.../the-globalization-of-world-pol... https://peaceandconflictstudiesblog.files.wordpress.com/.../the-globalizati... Students are also expected to be familiar with NCERTs Contemporary World Politics - http://www.ncert.nic.in/ncerts/textbook/textbook.htm?leps1=0-9
Ecocriticism	Garrard, Greg. Ecocriticism. London: Routledge, 2012. Print. Cheryll Glotfelty and Harold Fromm. Eds. The Ecocriticism Reader: Landmarks in Literary Ecology. Athens: University of Georgia Press, 1996. Print.
Science and Technology Studies	Felt, U., Fouche, R., Miler, C.A. & Smith-Doer, L. (Eds.) (2017) The Hand Book of Science and Technology Studies (Fourth Edition): MIT Press.



F. Economics

Subject	Content	Reference Books
Principles of Economics	Demand, Supply, Elasticity, Consumer Behavior, Analysis of Production and Cost Analysis, Markets, Basics of Macroeconomics, Economics of Public Goods	Case and Fair, Principles of Economics, Pearson Education, 2012
Fundamentals of Finance & Accounting	Basics of Accounting, Financial Statements and Analysis, Introduction to Securities, markets and analysis, Banking System, RBI, Non-bank financial intermediaries, Markets for Future, Options & Derivatives; Foreign Exchange Markets Capital market theory, Security valuation, Portfolio evaluation measures, Accounting analysis, Strategic analysis, Corporate strategies, Financial analysis, Valuation, Time value of money, Cost of capital, Capital structure, Dividend policy, Capital budgeting decision, Bond valuation, Stock valuation, Working capital management, Introduction to Risk & Derivatives Markets and Futures markets, Determination of forward and futures prices and Interest rate Futures, Hedging Strategies using Interest, Currency, Commodity, Stock and Index Futures, Mechanics of Swap contracts (Equity and Currency), Mechanics of Options Markets, Properties of Stock Options, Trading Strategies Involving Options, Option Pricing, Basic Greek Letters	Horngren, Sundem, and Elliott, Introduction to Financial Accounting, Pearson Education India Ltd. 8th ed. 2004 Bhole L.M, Financial Institution & Market Structure: Growth & Innovation, Tata McGraw Hill, 4th ed. 2004.
Microeconomics	Theory of Consumer Behaviour, Topics in Consumer Theory, Theory of Firm, Theory of Market Structure, General Equilibrium, Welfare Economics, Externalities, Common & Public Goods	Henderson J M and Quandt R E , Microeconomic Theory : A Mathematical Approach , McGraw Hill 3rd ed. 1980.
Macroeconomics	Macroeconomic System- Measurement, I-O System, Flow of Funds, Keynesian System – Demand, Money, Interest, Income, Output, Inflation& Unemployment, Money Supply, Consumption and Investment, Consumption and Investment	Froyen, Richard T Macroeconomics: Theories & Policies Pearson Education, Latest Edition.
Econometrics	Basics of Statistics, OLS, k-variable Linear Equation, General Linear Model, Violation of classical Assumptions, Heteroscedasticity, Autocorrelation, Multi co linearity, ARIMA Model, Time Series Analysis, Simultaneous Equation System	Johnston J and John Dinardo, Econometric Methods McGraw Hill International, 4th ed. 1997.
Money Banking & Financial Markets	Fundamentals of Financial Markets, Money and its Functions, Money Markets, Financial Markets and Financial Institutions, Foreign Exchange Markets,	Mishkin, Frederic S, Stanley G Eakins, Financial Markets and Institutions,



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

	International Financial System, Banking Business, Role of Central Bank in conduct of Monetary Policy, Management of Financial Institutions, Risk Management and Financial Derivatives.	Pearson Education, 8th Edition, 2016.
Public Finance – Theory and Practice	Scope of Public Finance, Allocation, Distribution & Public Choices, Equity in Distribution, Public Choice & Fiscal Policy, Public Expenditure – Structure, Growth & Evaluation, Public Revenue, Principles of Taxation, Role of Fiscal Policy in India, Budgeting in India	Musgrave, R.A and Musgrave, P.B Public Finance: Theory and Practice McGraw Hill Book Co. 1999.
Economics of Growth and Planning	Economic Growth Models – Harrod-Domar, Neo-classical, Two sector Models, The Feldman Model of Economic Growth, Samuelson Model of Economic Growth, Kaldors Model of Income, Population, Environment, Inequality and Development. Issues of Development Economics.	Jones H. G. An Introduction to Modern Theories of Economic Growth, McGraw Hill, Kogakusha Ltd. 1976., Devraj Ray Development Economics OUP, Delhi 1998
International Economics	International Economics, Trade Theories, International Trade – Comparative Advantage, Heckscher –Ohlin (H-O) Model, Modern Theories of International Trade, Commercial Policies; Tariffs, Quotas, FDI, BOP, GATT, WTO, International Monetary System	Salvatore. D. International Economics WSE 9th ed. 2014
Issues in Indian Economy	India's Economic Growth & Development, Significant Aspects of Indian Economy – Agriculture, Infrastructure, Private & Public Sector, Industrial Growth, Import- Exports, Unemployment, Commercial Banking & Finance, Inflation & Income Growth, Money Supply, Monetary Control, India's Trade, External Aid, Public Debt	Agarwal. A. N, Indian Economy – Problems of Development & Planning Wishwa Prakashan, A division of New Age International(P) Ltd.,2005



G. Management

Subject	Content	Reference Books
Marketing	Developing Marketing Strategies and Plans, Marketing Research, Creating customer value and customer relationships, Analyzing consumer markets, Analyzing Business Markets, Identifying Market Segments and Targets, Competitive Dynamics, Crafting the Brand position, Creating Brand Equity, Setting Product strategy, Designing and managing services, Developing Pricing strategies and Programs, Designing and Managing Integrated Marketing Channels, Designing and Managing Integrated Marketing Communications	Kotler Philip, Kevin Lane Keller, Abraham Koshy, Mithileswar Jha; "Marketing Management – A South Asian Perspective", Pearson Education India Limited, New Delhi, 14 th Ed., 2013. Malhotra Naresh K. and Dash Satyabhushan, Marketing Research: An Applied Orientation. Pearson Education, 2015, 7th Edition.
Production & Operations Management	Forecasting, Facility Location Planning, Facility Layout Planning, Aggregate Planning, Inventory Management, Statistical Process Control, Production scheduling, Materials Requirement Planning, Just in time and Lean Operations	Heizer, J.; Render, B. and Rajashekhar, J., Operations Management, Pearson Education, India, 9th Edition, 2009.
Finance & Accounting	Concepts and Relevance of Accounting Information in the Business, Golden Rules of Accounting, Journal Entries, Ledger and Trial Balance, Preparation of Financial Statement – Trading, Profit and Loss A/C, Balance Sheet, Cash flow statement. Analysis of Financial Statements – Ratio Analysis	Anthony Robert N., Hawkins David F., Merchant Kenneth A., Accounting: Text and cases, 12th edition-2007, Tata McGraw Hill
HR & OB	Personnel Planning and Recruitment, Selection, Testing and Interviews, Training and Development, Performance Management and Appraisal, Employee Retention, Engagement and Careers Compensation, Benefits and Services, Ethics, Employee Safety and Health, Labour Relations and Collective Bargaining, Personality, Motivation, Perception, Organizational Culture, Group behavior and leadership	Dessler Gary, Varkkey Biju (2015), Human Resource Management, 14th edition. Pearson Education Stephen P. Robbins, Organizational Behavior, 15th edition. Pearson Education



H. Nanoscience & Nanotechnology

Subject	Content	Reference Books
Fundamental of Materials (structure and properties)	Structures of materials: Metals, ceramics and polymers; Crystallographic directions and planes, Linear and planar densities, close-packed crystal structures, defects, dislocations, & diffusions. Polymers and composites, semiconducting materials; self-assembled monolayer, Phase transformations & phase diagrams: Basic thermodynamics & kinetics of nucleation and growth. Correlation of structure to properties: mechanical, chemical, electrical, magnetic and optical. Evolution of materials: functional materials, Biomimetic materials, energy saving materials, etc Criteria for material selection	Callister's Materials Sc & Engg, W.D. Callister & R. Balasubramaniam (Adapted), Wiley, 2nd. ed., 2014. Materials science and engineering by V. Raghavan, 5th edition, Prentice Hall of India, ISBN: 978-81-203-2455-8 Nano: The Essentials, Understanding Nanoscience and Nanotechnology, T. Pradeep, Tata McGraw-Hill Publishing Company Limited, New Delhi, First edition, 2007. ISBN 10 0070617880, ISBN 13 9780070617889
Synthesis of Nanomaterials	Bottom up methods: chemical reduction, solvothermal synthesis, photochemical, electrochemical, sonochemical, thermolysis, biological methods etc. Top down methods: Lithography, Electron beam lithography, Ion beam lithography, X-ray lithography, UV lithography, Synthesis of nanomaterials by Laser ablation etc. Chemical Vapor Deposition (CVD) Nanopolymer, carbon based nanostructures - carbon nanotube, graphene, fullerenes. Anisotropic metal nanoparticles, nanowires, quantum dots, nanoclusters, 2D nanostructure array, 3D Superlattice, Bimetallic nanoparticles. Self-assembled monolayer	Fundamentals of Nanoscience, S L Kakani & Shubhra Kakani, New Age International Publishers, 1st Edition, 2017, ISBN: 9789386286505 Nanostructures and Nanomaterials; Synthesis, Properties, and Applications. Guozhong Cao and Ying Wang, World Scientific Series in Nanoscience and Nanotechnology, 2nd edition, 2011, Nanomaterials Synthesis Design, Fabrication, and Applications, Yasir Beeran Pottathara et al, Elsevier, 1st edition, 2019, ISBN 978-0-12-815751-0



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

Characterization of Nanomaterials	<p>Diffraction Methods : XRD</p> <p>Microscopic Analysis: Principles and operational aspects of SEM, TEM, AFM, STM</p> <p>Spectroscopic Analysis: Principles and operational aspects of UV-Vis, FTIR, Raman, X-ray photoelectron spectroscopy (XPS), Photoelectron spectroscopy (PES)</p> <p>Adsorption Based Techniques: Physisorption (surface area, porosity, and textural analysis) and chemisorption (TPR, TPO, TPD, pulse-chemisorption, etc.) study</p>	<p>Nanomaterials Synthesis Design, Fabrication, and Applications, Yasir Beeran Pottathara et al, Elsevier, 1st edition, 2019, ISBN 978-0-12-815751-0.</p> <p>Introduction to Nanoscience and Nanotechnology, An Indian Adaptation, Charles P. Poole; Jr.; Frank J. Owens, Wiley India Pvt Ltd., ISBN-10 : 9354240208, ISBN-13 : 978-9354240201</p>
Application of Nanotechnology	<p>Use of nanomaterials in the</p> <ul style="list-style-type: none"> • catalysis, • medical, • food and agriculture industries, • automobile, • textile, • water-treatment, • nano-electronic devices, • biological, • MEMS, NEMS and sensors, • strategic use in energy, space and defense. 	<p>Nanomaterials Synthesis Design, Fabrication, and Applications, Yasir Beeran Pottathara et al, Elsevier, 1st edition, 2019, ISBN 978-0-12-815751-0.</p> <p>Introduction to Nanoscience and Nanotechnology, An Indian Adaptation, Charles P. Poole; Jr.; Frank J. Owens, Wiley India Pvt Ltd., ISBN-10 : 9354240208, ISBN-13 : 978-9354240201</p>



I. Chemical Engineering

Subject	Content	Reference Books
Chemical Process Calculations	Units and Dimensions, Chemical Equation and Stoichiometry, Thermodynamic properties of Gases, Vapors, Liquids and Solids, Steady and unsteady state mass and energy balances, Phase Equilibria (multiphase, multicomponent), reacting and non-reacting systems, recycle, bypass and purge calculations, Combustion Calculations.	Himmelblau, D. M. Riggs, J. B. "Basic principles & calculations in chemical Engg", PHI, 8th ed., 2015. Felder, R. M. & R. W. Rousseau, "Elementary Principles of Chemical Processes", John Wiley & Sons, Inc., 4th ed., 2011.
Fluid Mechanics	Fundamental Concepts and Fluid Statics, basic concept of Newtonian and non-Newtonian fluids, head losses, velocity and pressure drop calculation. Integral and Differential Analyses for Fluid Motion, Internal and External Fluid Flow and Flow through Packed & fluidized beds, Dimensional Analysis, flow meters, pumps and compressors.	R. W. Fox, A. T. McDonalds, and P. J. Pritchard, "Introduction to Fluid Mechanics", John Wiley and Sons Inc., 8th ed., 2013. W. L. McCabe, J. C. Smith, and P. Harriott, "Unit Operations of Chemical Engineering", McGraw Hill, Inc., 7th ed., 2014.
Chemical Engineering Thermodynamics	First and Second laws of thermodynamics. Applications of first law to close and open systems. Second law and Entropy. Thermodynamic properties of pure substances: Equation of State and residual properties, properties of mixtures: partial molar properties, fugacity, excess properties and activity coefficients; phase equilibria: predicting VLE of systems; chemical reaction equilibrium.	J. M. Smith, H.C. Ness, and M. Abbott, B Bhatt (Adapted), "Introduction to Chemical Engineering Thermodynamics", McGraw Hill Education, 7th ed., 2009. YVC Rao, "Chemical Engineering Thermodynamics", Universities Press, 1997. KV Narayanan, "A Textbook of Chemical Engineering Thermodynamics", Prentice Hall of India, 2nd ed., 2013.
Mass Transfer	Molecular diffusion and mass transfer coefficients Interphase mass transfer, heat and mass transfer analogies, design and operation of equipment for distillation, absorption, Adsorption, leaching, extraction, drying and adsorption, humidification, crystallization.	Treybal, R.E., "Mass Transfer Operations," 3rd ed., McGraw-Hill Education, 2012. Foust, A. S., Wenzel, L.A., Clump, C.W., Anderson, L.B., "Principles of Unit Operations," 2nd ed., John Wiley and Sons, New York, 2008.
Heat Transfer	Steady and Unsteady state heat	Holman, J. P.,



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

	conduction, Natural & Forced convection, Radiation, Condensation, boiling and evaporation, Heat Exchangers.	Bhattacharyya, S "Heat Transfer" 10th ed., McGraw-Hill, 2011. Frank P. Incropera, David P. DeWitt, "Fundamental of Heat & Mass Transfer" 6th ed., John Wiley & Sons, 2006. D. Q. Kern, "Process Heat Transfer", Tata McGraw Hill, 2001. McCabe & Smith, "Unit Operations of Chemical Engineering" 7th ed., McGraw Hill, 2014
Mechanical Operations	Properties and Handling of Particulate Solids, Mechanical Separations, particle size distribution, size reduction operation, operation of centrifuge and cyclones, filtration, agitation and mixing.	McCabe W. L., and Smith J. M., & Harriott P., Unit Operations of Chemical Engineering, 7th ed., McGraw Hill International Edition, 2014. J. M. Coulson, J. F. Richardson's Chemical Engineering, Vol. 1 (6th ed.,) & Vol. 6 (4th ed.,) Elsevier Butterworth-Heinemann, MA, USA, 2004 & 2005.
Chemical Engineering	Reaction Mole balances and reactor sizing, Rate laws and stoichiometry, Isothermal reactor design for single and multiple reactions, Analysis of laboratory reactor data, and reaction mechanisms for nonelementary reactions, Non isothermal reactor design, Heterogeneous reactors, Non Ideal reactors.	Scott Fogler "Elements of Chemical Reaction Engineering", PHI, 4th ed, 2015. O. Levenspiel, "Chemical Reaction Engineering", John Wiley, 3rd ed., 2006. M. Smith, "Chemical Engineering Kinetics", McGraw Hill, 3rd Ed., 2013.
Chemical Technology	Process Inorganic chemical industries (sulphuric acid, phosphoric acid); Fertilizer industries (Ammonia, Urea, SSP, TSP); Natural product industries (Pulp & paper, Sugar, Oils & fats); Petroleum Refining and Petrochemicals; Polymerization industries (polyethylene, polypropylene, polyester synthetic fibers, PVC).	Moulin A J., Makkee, M., Diepen, A V., "Chemical Process Technology", 2nd ed., Wiley, 2013. Rao M G., Sittig M., "Dryden's Outlines of Chemical Technology for the 21st Century", East West Press, 3rd ed., 2006. Austin G T., Shreve R.N., "Shreve's Chemical



Birla Institute of Technology & Science, Pilani

Pilani | Goa | Hyderabad |

		Process Industries", McGraw Hill, 5th ed., 2012.
Plant Design and Economics	Principles of process economics, depreciation calculation, cost indices, rate of return, payback period, discounted cash flow, optimization in process design and sizing of chemical engineering equipments such as evaporator, heat exchangers, multistage contactors.	James M. Douglas. Conceptual Design of Chemical Processes. McGraw-Hill International Editions (Chemical Engineering Series), McGraw Hill Book Company, New York, 1988. Max S. Peters, Klaus D. Timmerhaus, Ronald E. West, Max Peters. Plant Design and Economics for Chemical Engineers. 5th ed., McGraw Hill, New York, 2011. J. M. Coulson, J. F. Richardson's Chemical Engineering, Vol. 6 (4th ed.,) Elsevier Butterworth-Heinemann, MA, USA, 2005.
Process Dynamics and Control	Dynamic process modeling, Laplace transform, transfer functions, analysis of the dynamic behavior of chemical processes, Analysis and design aspect of feedback controllers (P, PI and PID), controller tuning, advanced control systems, measurement of process variables; sensors, transducers and their dynamics.	Stephanopoulos, G., "Chemical Process Control: An Introduction to Theory and Practice," Prentice-Hall, Englewood Cliffs, N.J., 2008 Seborg, D.E., Edgar, T.F., Mellichamp, D.A. and Doyle III F. J. "Process Dynamics and Control," 4th ed., Wiley, 2016. Coughnowr, D. R., Leblanc S., "Process Systems Analysis and Control," 3rd ed., McGraw-Hill, 2013.