CENTRAL UNIVERSITY OF HARYANA

(*Established under the Central Universities Act, 2009*)

(NAAC Accredited 'A' Grade)

CBCS Based

Curriculum and Syllabi
Of
Ph.D. Chemistry Course Work

(w.e.f. 2021)

DEPARTMENT OF CHEMISTRY
SCHOOL OF BASIC SCIENCES

Approved by :	**BOS**	**School Board**	**Academic Council**
Approval Status :	√	✓	✓
Approval Date :	09-09-2021	20-09-2021	12-10-2021

CENTRAL UNIVERSITY OF HARYANA (CUH)
DEPARTMENT OF CHEMISTRY
SCHOOL OF BASIC SCIENCES

Ph.D. (Chemistry)

Course Structure of Course Work for Ph.D. Degree in Chemistry

Sr. No	Course No	Course Name	Course Code	Course Type	Credit
CORE COURSES (CC)					
1	**CHP-01**	Research Methodology and Computer Applications for Chemistry	SBS CH 030101 C 5016	**CC**	**06**
ANY ONE OF THE FOLLOWING ELECTIVE COURSES(EC)					
2	**CHP-02**	Solid State and Supramolecular Chemistry	SBS CH 030101 E 5016	**EC**	**06**
3	**CHP-03**	Advanced Computational Chemistry	SBS CH 030102 E 5016	**EC**	**06**
4	**CHP-04**	Advanced Organic Synthesis	SBS CH 030103 E 5016	**EC**	**06**
5	**CHP-05**	Medicinal Chemistry	SBS CH 030104 E 5016	**EC**	**06**
6	**CHP-06**	Spectroscopic Techniques for Chemists	SBS CH 030105 E 5016	**EC**	**06**
7	**CHP-07**	Electroanalytical Techniques for Chemists	SBS CH 030106 E 5016	**EC**	**06**
UGC APPROVED TWO-CREDIT COMPULSORY COURSE FOR Ph.D./ M.Phil. STUDENTS					
8	**Offered by Central Library, CUH**	Research and Publication Ethics	CPE-RPE		**02**
				Total Credit	**14**

Central University of Haryana
Department of Chemistry

Course Type	**:**	**Core**
Course Name	**:**	**Research Methodology and Computer Applications for Chemistry**
Course Code	**:**	**SBS CH 030101 C 5016**
Contact Hrs per week	**:**	**6**
Credit	**:**	**6**

Course Objective and Learning Outcomes:

Guiding philosophy of knowledge creation and dissemination will be discussed in this course. Idea about various approaches to research, data collection, analysis and inference will be taught. Principles of formulating research problems, designing experiments and documentation will form a major part of the course. Specific objectives and techniques of chemical sciences research will also be presented. At the end of the course the students are expected to identify, design and plan research problems, prepare research proposals and contemplate publications and reports when presented with data.

UNIT I: METHODS AND TYPES OF RESEARCH

Research methods vs Methodology. Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical. Research proposals-design and components.

UNIT II: LITERATURE REVIEW

Defining and formulating the research problem - Selecting the problem - Necessity of defining the problem - Importance of literature review in defining a problem – Literature review – Primary and secondary sources – reviews, treatise, monographs-patents – web as a source – searching the web - Critical literature review – Identifying gap areas from literature review - Development of working hypothesis.

UNIT-III: SCIENTIFIC SOFTWARES IN RESAECRH DESIGN AND METHODS AS APPLIED

Data Analysis using Tools like MS Excel, ChemDraw and MATLAB

Digital Methods and Web Search: Internal basics, Internet protocols, pre-requisites, search engines – google scholar, chemspider, scifinder, scopus, reaxys, research gate; using

advanced search techniques, web resources, e-journals, e-books, journal access, subscribing TOC alerts, hot articles, citation index – h-index and i-index; Impact factor

Experiment design- monitoring- laboratory safety- Laboratory notebook keeping- data collection-coding of samples and experiments- storage of samples- Hypothesis-testing - Generalization and Interpretation.

UNIT-V: REPORTING, DOCUMENTATION AND PRESENTATION

Scientific Document; Organization and writing of research papers, short communications, review articles, monographs, technical and survey reports, authored book and edited books and dissertation.

Writing of Thesis: Format of a thesis: Review of literature, formulation, writing methods, results, preparation of tables, figures, writing discussion, summary and conclusion, synopsis, references citing and listing, bibliography, acknowledgement, avoiding plagiarism, Oral presentations-visual aids

Suggested Readings

1. A. Fink, Conducting Research Literature Reviews: From the Internet to Paper, Sage Publications, 2009.
2. M. Graziano, A.M. Anthony and M. L. Raulin, Research Methods: A Process of Inquiry, Allyn and Bacon., 2009.
3. W. M. K. Trochim, Research Methods: the concise knowledge base, Atomic Dog Publishing, 2005.
4. P. D. Leedy and J. E. Ormrod, Practical Research: Planning and Design, Prentice Hall, 2004.
5. B. L. Garg, R. Karadia, F. Agarwal and U. K. Agarwal, An introduction to Research Methodology, RBSA Publishers, 2002.
6. R. A. Day, How to Write and Publish a Scientific Paper, Cambridge University Press, 1992.
7. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International, 1990.
8. S. M. Coley and C. A. Scheinberg, Proposal Writing, Sage Publications, 1990.

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Department of Chemistry

Course Type	**:**	**Elective**
Course Title	**:**	**Solid State and Supramolecular Chemistry**
Course Code	**:**	**SBS CH 030101 E 5016**
Contact Hrs per week	**:**	**6**
Credit	**:**	**6**

Course Objective and Learning Outcomes:

In-depth understanding of the elements of symmetry and their importance in solid state chemistry will be discussed. Symmetry as the founding principle of crystal growth and design will be pursued. X-ray techniques to study crystals and their properties, supramolecular interactions and their importance in crystal growth and design, molecular recognition and self-assembly will be analysed in depth. Students are expected to analyse and design crystal structures at the end of the course.

SYMMETRY AND STRUCTURE IN SOLID STATE

UNIT I

Crystal symmetry – (i) point group elements and (ii) space group elements; 32 crystal classes, HM notations, distribution in different systems and stereographic projections.

Space group – HM notation, space groups in triclinic and monoclinic systems.

Indexing of lattice planes; Miller indeces.

UNIT II

X-ray, Cu Kα and Mo Kα radiation; X-ray diffraction; Bragg equation; Reciprocal lattice and its relation to direct lattice; Bragg reflection in terms of reciprocal lattice – sphere of reflection and limiting sphere; relation between d_{hkl} and lattice parameters.

SUPRAMOLECULAR CHEMISTRY

UNIT III

Origin of supramolecular chemistry - “Chemistry beyond the molecules”. Concepts and terminology of supramolecular chemistry.

Nature and types of supramolecular interactions (Hydrogen bonding, van der Waal interactions, π-stacking, C-H….π interactions etc.)

UNIT IV

Molecular recognition- Information and complementarity. Different types of receptors with special reference of Crown ethers, cryptates and Calix[4]arene. Anion recognition and anion coordination chemistry. Molecular self-assembly formation and examples.

Supramolecular chemistry of life, application of supramolecular chemistry in drug design. Application in material science-molecular machines.

Suggested Readings

1. C. Giacavazzo, Fundamentals of crystallography, 3rd Edition. 2011.
2. J. W. Steed and J. L. Atwood, SupramolecularChemistry, John Wiley, 2nd Edition. 2009.
3. J. P. Sauvage, Transition metals in supramolecular chemistry: John Wiley & sons: UK, 1st Edition. 1999.
4. J. D. Dunitz, X-ray analysis and the structure of organic molecules, 2nd Edition. 1995.
5. J. M. Lehn, Supramolecular Chemistry, VCH, Wienheim, 1995.
6. G. H. Stout and L. H. Jensen, X-ray structure determination: A practical guide, 2nd Edition. 1989.

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Department of Chemistry

Course Type	**:**	**Elective**
Course Title	**:**	**Advanced Computational Chemistry**
Course Code	**:**	**SBS CH 030102 E 5016**
Contact Hrs per week	**:**	**6**
Credit	**:**	**6**

Course Objective and Learning Outcomes:

The principles and applications of computational methods in chemistry will be covered in detail. Introduction of the theory of various mathematical approaches, approximation methods and basis sets will be discussed. Armed with this knowledge, further analysis of potential energy surfaces will be done. Hands on exercise on solving actual problems in computational chemistry will also be done. Students are expected to design, write and execute the calculations of various types by themselves at the end of this course.

UNIT-I: INTRODUCTION TO COMPUTATIONAL CHEMISTRY

Computational chemistry map, Scope of Computational Chemistry, Born-Oppenheimer approximation, Restricted and Unrestricted Hartree-Fock.

Density Functional Theory: Exchange-Correlation Functional, Local Density Approximation, Generalized Gradient Approximation, Hybrid Density Functional Methods.

UNIT-II: BASIS SETS

Definition, Slater and Gaussian Type Orbitals, Minimal, Double-zeta, Split-valence, Core-valence, Pople style basis sets, Polarization and Diffuse Functions, Calculation of Basis Functions for with suitable examples, Pseudopotentials or Effective Core Potentials.

UNIT-III: BASIC CONCEPTS OF POTENTIAL ENERGY SURFACES

Stationary Points, Geometry Optimization, Local and Global Minima, and Transition State Theory (TST).

UNIT-IV: HANDS ON EXERCISE

Computations of Single Point Energy, Formation Energy, Optimizations and Transition States of Polyatomic Molecules, Intrinsic Reaction Coordinate Analysis, Natural Bond Order, Electron Decomposition Analysis.

Suggested Readings

1. F. Jensen, Introduction to Computational Chemistry, John Wiley & Sons, 2007.
2. J. B. Foresman and A. Frisch, Exploring Chemistry with Electronic Structure Methods, 2nd Edition. Gaussian Inc., 2005.
3. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2nd Edition. John Wiley & Sons Ltd, 2004.
4. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2nd Edition. John Wiley & Sons Ltd, 2002.

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Course Type	**:**	**Elective**
Course Title	**:**	**Advanced Organic Synthesis**
Course Code	**:**	**SBS CH 030103 E 5016**
Contact Hrs per week	**:**	**6**
Credit	**:**	**6**

Course Objective and Learning Outcomes:

To provide the advance knowledge of organic synthesis in general and classical and modern reagents and methods in synthesis in particular. In-depth knowledge of metal-mediated reactions and common metal-based reagents, oxidation-reduction reactions and reagents and rearrangement reactions will be gained. At the end of the course students are expected to predict reagents and conditions needed for specific conversions.

UNIT I: TRANSITION METAL CATALYSIS IN SYNTHESIS

Overview of modern catalytic methods in organic synthesis, transition metal catalysis, details of homogeneous catalysis by palladium, copper, silver, gold, rhodium and ruthenium complexes. Olefin and alkyne metathesis reactions.

UNIT II: ORGANOCATALYSIS AND BIOCATALYSIS

Asymmetric catalysis. Organocatalysis. Iminium and enamine catalysis. N-heterocyclic carbenes (NHC). Enzyme catalysis and biocatalysis. Light mediated reactions.

UNIT III: MODERN ORGANIC REACTIONS

Modern methods of carbonyl olefinations. Boron, Tin and Silicon based reagents. Modern oxidation reactions. Hypervalent iodine reagents. Sharpless asymmetric epoxidation and dihydroxylation reactions. New methods of reduction. Super hydride. Selectrides. Catalytic asymmetric hydrogenations and hydrogen transfer reductions. CH- and C-C activations.

UNIT IV: TOTAL SYNTHESIS

Strategies and tactics in total synthesis. Classical examples. Woodward synthesis of Strychnine. Stork synthesis of reserpine. Corey synthesis of longifolene. Overman synthesis of morphine. Vollhardt synthesis of estrone. Baran synthesis of vinigrol.

Suggested Readings

1. J. Clayden, N. Geeves, S. Warren, Organic Chemistry, 2nd Edition. Oxford University Press, 2012.
2. M. B. Smith, Organic Synthesis, Academic Press, 2009.

3. K. C. Nicolaou and E. J. Sorensen, Classics in Total Synthesis, Wiley, 2008,
4. Carey and Sundberg, Advanced Organic Chemistry; Parts A and B, Springer 2007.
5. E. J. Corey and X.-M. Cheng, The logic of Chemical Synthesis, Wiley, 2005.
6. R. O. C. Norman and J. M. Coxon, Principles of Organic Synthesis 3rd Edition, CRC Press, 2004.

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Department of Chemistry

Course Type	**:**	**Elective**
Course Title	**:**	**Medicinal Chemistry**
Course Code	**:**	**SBS CH 030104 E 5016**
Contact Hrs per week	**:**	**6**
Credit	**:**	**6**

Course Objective and Learning Outcomes:

This course will provide a basic understanding and fundamentals of Medicinal Chemistry. At the end of this course, students will learn about the various stages involved in drug discovery & development process and challenges encounter during the course of development of new drug which finally comes into the market, various biological drug targets, drug-target binding, mode of actions of anticancer, antibiotics, psychoactive drugs and its chemical synthesis.

UNIT I: DRUG DESIGN

Introduction, Development of new drugs, Concept of lead compounds and lead modifications, structure-activity relationship (SAR), factors affecting bioactivity, resonance, inductive effect, isosterism, bio-isosterism. Theories of drug activity: occupancy theory, rate theory, induced fit theory. Quantitative structure activity relationship, Concepts of drugs receptor, Elementary treatment of drug receptor interactions, Physico-chemical parameters: lipophilicity, partition coefficient, electronic ionization constants, steric factors.

UNIT II: ANTICANCER AGENTS

Introduction, cancer chemotherapy, role of alkylating agents and antimetabolites in treatment of cancer. Synthesis of 6-mercapto purine, melphalan, mechlorethamine, cyclophosphamide and uracil, Recent development in cancer chemotherapy.

UNIT III: ANTI-INFECTIVE DRUGS

Introduction and general mode of action of antibiotic and antibacterial-, antiviral-, antifungal- and antiprotozoan drugs. Cell wall biosynthesis, inhibitors, β-lactam rings, antibiotics inhibiting protein synthesis. Synthesis of penicillin G, amoxycillin, cephalosporin, ciprofloxacin, furazolidone, dapsone, gluconazole, chloroquine, primaquin, Introductory idea of tetracycline and streptomycin.

UNIT IV: CARDIOVASCULAR DRUGS

Introduction and general mode of action. Synthesis of ditiazem, verapamil, methyldopa and atenolol.

Suggested Readings

1. G. L. Patrick, An Introduction to Medicinal Chemistry, 5th Edition. Oxford University Press, 2013.
2. D. Sriram and P. Yogeshwari, Medicinal Chemistry, 2nd Edition. Pearson, 2012.
3. R. B. Silverman, The Organic Chemistry of Drug Design and Drug Action, Academic Press, 2009.
4. Ed. Robert F. Dorge. Wilson and Gisvold's Text Book of Organic Medicinal and Pharmaceutical Chemistry, 2008.
5. Ed. M. E Wolff, Burger's Medicinal Chemistry and Drug Discovery, Vol. 1, John Wiley, 2007.
6. S. S. Pandeya and J. R. Dmmock, An Introduction to Drug Design, New Age International, 2004.

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Course Type	**:**	**Elective**
Course Title	**:**	**Spectroscopic Techniques for Chemists**
Course Code	**:**	**SBS CH 030105 E 5016**
Contact Hrs per week	**:**	**6**
Credit	**:**	**6**

Course Objective and Learning Outcomes:

To provide the advance knowledge and understanding of organic spectroscopy. At the end of this course, students will acquire both the theoretical and application aspect of various spectroscopic techniques (UV-Visible, IR, NMR spectroscopy and mass spectrometry) to the solve problems related to structure determination of organic compounds.

UNIT I: ULTRAVIOLET AND VISIBLE SPECTROSCOPY AND MASS SPECTROMETRY

UV-Visible spectroscopy: Various electronic transitions, Beer-Lambert law, visible spectrum & colour, effect of solvent on electronic transitions, ultraviolet bands for carbonyl compounds, unsaturated carbonyl compounds, dienes, conjugated polyenes. Fieser-Woodward rules for conjugated dienes and carbonyl compounds, ultraviolet spectra of aromatic and heterocyclic compounds.

Mass spectrometry: Introduction, ion production–EI, CI, FD and FAB, factors affecting fragmentation, ion analysis, ion abundance. Mass spectral fragmentation of organic compounds, common functional groups, molecular ion peak, metastable peak, McLafferty rearrangement. Nitrogen rule. High resolution mass spectrometry (HRMS).

UNIT II: INFRARED SPECTROSCOPY

Instrumentation and sample handling. Characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols and amines. Detailed study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, acids, anhydrides, lactones, lactams and conjugated carbonyl compounds). Effect of hydrogen bonding and solvent effect on vibrational frequencies, overtones, combination bands and Fermi resonance.

UNIT III: NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY

General introduction and definition, theory of NMR, chemical shift, shielding and deshielding mechanism, magnetic anisotropy, chemical shift values and correlation for protons bonded to carbon (aliphatic, olefinic, aldehydic and aromatic) and other nuclei (alcohols, phenols, enols, carboxylic acids, amines, amides & mercapto), spin-spin interaction, Spin systems, Pople notation, complex spin-spin interaction between two, three and four nuclei (first order spectra), virtual coupling. chemical exchange, effect of deuteration, Stereochemistry, hindred rotation, Karplus curve-variation of coupling constant with dihedral angle.

Simplification of complex spectra, nuclear magnetic double resonance, contact shift reagents. Fourier transform technique, nuclear Overhauser effect (nOe), COSY, NOESY, ROESY, TOCSY, HSQC, HMBC

UNIT IV: CARBON-13 NMR SPECTROSCOPY AND COMBINED APPLICATIONS

***Carbon-13 NMR Spectroscopy*:** General considerations, chemical shift (aliphatic, olefinic, alkyne, aromatic, heteroaromatic and carbonyl carbon), coupling constants and DEPT ^{13}C NMR spectra. General introduction to two-dimensional NMR spectroscopy- HETCOR and NOESY. Resonance of other nuclei-F, P.

***Combined problems*:** Combined problems relating to structure elucidation by UV, IR, NMR Spectroscopy and Mass Spectrometry.

Suggested Readings

1. D. L. Pavia, G. M. Lampman, G. S. Kriz and J. R. Vyvyan, Introduction to Spectroscopy, 5th Edition. Cengage India, 2015.
2. R. Kakkar, Atomic and Molecule Spectroscopy: Basic Concepts and Applications, Cambridge University Press, 2015.
3. W. Kemp, Organic Spectroscopy, Mac publishers, 3rd Edition. 2011.
4. D. H. Williams, I. Fleming, Spectroscopic Methods in Organic Chemistry, Tata McGraw-Hill, 2010.
5. J. R. Dyer, Application of Spectroscopy of Organic Compounds, Prentice Hall, 2009.
6. R. J. Abraham, J. Fisher and P. Loftus, Introduction to NMR Spectroscopy, Wiley, 2005.
7. J. Mohan, Organic Spectroscopy, Narosa Publishers, New Delhi, 2002.
8. R. M. Silverstein, G. C. Bassler and T. C. TMorrill, Spectrometric Identification of Organic Compounds, John Wiley, 1995.
9. C. N. Banwell and E. M. McCash; Fundamentals of Molecular Spectroscopy, 4th Edition. Tata McGraw Hill, 1994.

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Course Type	**:**	**Elective**
Course Title	**:**	**Electroanalytical Techniques for Chemists**
Course Code	**:**	**SBS CH 030106 E 5016**
Contact Hrs per week	**:**	**6**
Credit	**:**	**6**

Course Objective and Learning Outcomes:

To provide the knowledge and understanding of electroanalytical chemistry, modern electroanalytical techniques. At the end of this course, students will learn the fundamentals and uses of analytical chemistry, especially electrochemical polarization, impedance spectroscopy and Cyclic Voltammetry techniques.

UNIT I: ELECTROCHEMICAL POLARIZATION

Polarization of metal electrode, Anodic and cathodic polarization, Tafel plots, anodic and cathodic Tafel slopes, Mixed Potential Theory, Corrosion rate from corrosion current density, Corrosion inhibition efficiency, Galvanostatic and potentiostatic polarization, Importance of OCP in corrosion process, Equilibrium potential, Stern-Gerry equation, Open circuit potential. Impedance spectroscopy,

UNIT II: IMPEDANCE SPECTROSCOPY

AC impedance spectroscopy, Theory, principle and procedure of impedance spectroscopy, Nyquist plots, Bode plots, Bode phase angle plots, Applications of impedance spectroscopy in finding corrosion inhibition efficiency, double layer capacitance, charge transfer resistance, Equivalent circuit diagram. Structure of electrified interface from equivalent circuit diagram.

UNIT III: Cyclic Voltammetry and Chronoamperometry

Theory, principle, basics of Cyclic Voltammetry, Cyclic voltammogram, Application of cyclic voltammetry in qualitative and quantitative analysis, Pulse voltammetry.

Chronoamperometry, Potentiostatic and galvanostatic chronoamperometry, Charge-discharge cycle of rechargeable battery from chronoamperometry, Use of chemical and biosensors in environmental pollutant detection.

UNIT IV: SYNTHESIS, CHARACTERIZATION AND APPLICATIONS OF NANOPARTICLES

Introduction and properties (physical, electrical, mechanical, optical) of metal nanoparticles, Synthesis of metal nanoparticles by Sol-gel, coprecipitation, reverse micelle and hydrothermal methods. Characterization of metal nanoparticles by XRD, SEM, TEM, AFM, FTIR, TGA/DTA/DSC, and UV-visible techniques. Application study of metal nanoparticles. Merits and demerits of metal nanoparticles.

Books Suggested

1. S. L. Chopra and J. S. Kanwar, Analytical Agriculture Chemistry, *Kalyani Publishers,* 2008.
2. S. M. Khopkar, Concepts in Analytical Chemistry, 2nd Edition. New Age International Pub. 2004.
3. H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Settle, Instrumental methods of analysis, 7th Edition. *United States*, 1988.
4. D. A. Skoog and D. M. West, Principles of instrumental analysis, 2nd Edition. *Saunders College*, Philadelphia, 1980.
5. F. D. Snell and F. M. Biffen, Commercial Methods of Analysis, Tata McGraw Hill Book Company, New York, 1944.

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Course Type	**:**	**Core**
Course Name	**:**	**Research and Publication Ethics**
Course Code	**:**	**CPE-RPE**
Credits	**:**	**2**

Theory

RPE 01: Philosophy and Ethics (3 hrs.)

1. Introduction to philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgement and reactions

RPE 02: Scientific Conduct (5 hrs.)

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data

RPE 03: Publication Ethics (7 hrs.)

1. Publication ethics: definition, introduction and importance
2. Best practices / standards setting initiatives and guidance: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, types
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

Practice

RPE 04: Open Access Publishing (4 hrs.)

1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving polices
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

RPE 05: Publication Misconduct (4 hrs.)

A. Group Discussion (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools (2 hrs.)

1. Use of plagiarism software like Turnitin, Urkund and other open source software tools

RPE 06: Databases and Research Metrics (7 hrs.)

A. Databases (4 hrs,)

1. Indexing databases Research Metrics
2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics (3 hrs.)

1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IIP, Cite Score
2. Metrics: h index, g index, i10 index, almetrics

Suggested Readings:

1. Bird, A. (2006). *Philosophy of Science*. Routledge
2. MacIntyre, Alasdair (1967) *A Short History of Ethics*. London
3. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978-9387480865
4. National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. National Academics Press.
5. Resnik, D. B. (2011). What is ethics in research and why is it important. National Institute of Environmental Health Sciences, 1-10. Retrived from https://www.neihs.nih.gov/research/resources/bioethics/whatis/index.cfm
6. Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489 (7415), 179-179. https://doi.org/10.1038/489179a
7. Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (2019), ISBN:978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf