



**UNIVERSITY OF CALICUT**

**Abstract**

General and Academic IV - Faculty of Science - Scheme and syllabus of M.Sc Chemistry (Nanoscience) programme ( CCSS ) , in accordance with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), w.e.f 2024 admission onwards -Approved I- Orders Issued

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**G & A - IV - J**

U.O.No. 13022/2024/Admn

Dated, Calicut University.P.O, 23.08.2024

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*Read:-*1. .UO No.3459/2024/Admn dated 27.02.2024

2. Minutes of the online meeting of the Board of Studies in Nanoscience and Technology held on the 17/05/2024
3. Remarks of the Dean, Faculty of Science dated 05/07/2024.
4. Orders of the Vice Chancellor in the file of even No and dated 11/07/2024.

**ORDER**

1. The Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024) were implemented w.e.f 2024 admission onwards, vide paper read as (1) above.
2. The Board of Studies in Nanoscience and Technology in the meeting held on 17/05/2024, vide paper read as (2), has approved the Scheme and Syllabus of M.Sc Chemistry (Nanoscience) (CCSS) Programme in tune with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), w.e.f 2024 admission onwards.
3. The Dean, Faculty of Science vide paper read as (3), has approved the above recommendation of the Board of Studies in Nanoscience and Technology.
4. Considering the urgency, the Vice Chancellor has approved the minutes of the meeting of Board of Studies in Nanoscience and Technology and accorded sanction to implement the Scheme and Syllabus of M.Sc Chemistry (Nanoscience) (CCSS) Programme in tune with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), w.e.f 2024 admission onwards, exercising the powers as per clause 10(13) of Calicut University Act 1975 .
5. The Scheme and Syllabus of M.Sc Chemistry (Nanoscience) (CCSS) Programme in tune with the Regulations for CCSS in the University Teaching Departments with Multiple entry and exit options (2024), is therefore implemented w.e.f 2024 admission onwards.
6. Orders are issued accordingly. ( Syllabus appended )

Ajayakumar T.K

Assistant Registrar

To

Head, Department of Nanoscience and Technology, University of Calicut,

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Forwarded / By Order

Section Officer

# DEPARTMENT OF NANOSCIENCE AND TECHNOLOGY

Programme:

1. **M.Sc. CHEMISTRY (NANOSCIENCE)**  
Program Code: **FSCNSCHMSC**

## SCHEME, CURRICULUM & SYLLABUS



## UNIVERSITY OF CALICUT

**(A State University Accredited with “A+” Grade by NAAC)**

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**MAY 2024**

**UNIVERSITY OF CALICUT**

Scheme and Syllabus for  
**M.Sc. Chemistry (Nanoscience) (Code: FSCNSCHMSC)**  
**Under (CCSS-PG-2024)**

Department of Nanoscience and Technology, School of Physical Sciences,  
University of Calicut, (w.e.f. 2024 admission onwards)

### **ELIGIBILITY FOR ADMISSION**

B.Sc. Degree in Chemistry of this university or an equivalent degree, with Mathematics and Physics as compulsory complementary, having 50% marks or equivalent grade in Part III (Core and complementary put together) are eligible to apply for this programme. OBC/OEC candidates are eligible for relaxation up to 5%. SC/ST candidates need only to get a pass.

### **ADMISSION PROCEDURE**

Admission to this MSc program shall be based on entrance examination conducted among eligible candidates and successful candidates shall be ranked according to the entrance test marks. Program structure, evaluation and grading will be as per the Choice-based Credit Semester System PG - CCSS Regulations for Post Graduate Programmes of Teaching Departments/Schools of the University of Calicut. Intake is 10.

### **SCHEME AND CURRICULUM OF THE PROGRAM**

- M.Sc. Chemistry (Nanoscience) is a PG program of 2 years duration with 4 semesters. The program includes Core, Elective and MOOC courses. The total credit of the program is **88**.
- Total credits for the core courses (Theory, Practical) shall be **36**.
- The Project work is compulsory for all students and the credit points assigned is **20**.
- Total credits for the elective courses shall be **20**
- Total credits for the MOOC courses shall be **12**
- Minimum credits required from core courses (Theory, Practical, Project) is **56**
- Minimum credits required from elective courses is **20**
- Minimum credits for the MOOC courses shall be **12**
- Accumulated minimum credits required for successful completion of the program is **88**
- Minimum attendance required is **75 %**
- Evaluation and grading will be done as per CCSS PG Regulations 2024 - Regulations for Post Graduate Programmes of Teaching Departments/Schools of the University of Calicut

## Program Specific Outcomes (PSOs)

The PG programme, **M.Sc. Chemistry (Nanoscience)** offers a well-balanced curriculum that ensures the career prospects of the students with due consideration is given to capacitate the students to face the challenges posed by the specialized areas of knowledge in the global arena. Since Nanoscience being an applied science and has application in various fields, in other words, being a vastly interdisciplinary area with great fluidity, the competence of the students can be improved with specialization and focus on chosen areas.

<b>PSO-1</b>	Recognise and relate the theories and principles of chemistry for understanding the scientific phenomenon in nano domain
<b>PSO-2</b>	Develop a comprehensive understanding of fundamental theories and concepts across all branches of chemistry, including organic, inorganic, physical, analytical, and biochemistry, enabling their application to advanced studies, problem-solving, understanding underlying principles, proposing mechanisms, identifying chemical species, and drawing logical conclusions.
<b>PSO-3</b>	Understand the quantum mechanical concepts and apply the same in various physical systems and processes at nano regime
<b>PSO-4</b>	Understand and apply the inter-disciplinary concepts and computational simulations to describe natural phenomenon.
<b>PSO-6</b>	Provide exposure in various specializations in the field of Nanoscience with frequent updates
<b>PSO-7</b>	Provide exposure to advanced experimental/theoretical methods for measurement, observation, and fundamental understanding of phenomenon at nanoscale and nanosystems.
<b>PSO-8</b>	Provide practical experience in chemical sciences with judiciously designed experiments for imparting the research attitude.
<b>PSO-9</b>	Contribute adaptive thinking and adaptability to protect the environment for sustainable development
<b>PSO-10</b>	Well-tempered professional ethics essential to maintain a transparent career
<b>PSO-11</b>	The basic understanding of how interdisciplinary science works to coordinate Nanoscience and Technology.
<b>PSO-12</b>	The vital awareness of computational/mathematical programs to solve the bottleneck issues in different aspects of science and technology.
<b>PSO-13</b>	New ideas to develop advanced nanomaterials for sustainable/eco-friendly energy, clean water, pollution-free air, and modern biology.

**University of Calicut, Kerala- 673635**

**M.Sc. Chemistry (Nanoscience)**

**Course and Credit Distribution Summary (2024 admission onwards)**

Semester	Course Code	Subject	Type	Total Marks	Credits
<b>First Semester</b>  <b>(500 Level)</b>	NSC7C 501	Conceptual Organic Chemistry	DSC(A) 1	100	4 (3+1)
	NSC7C 502	Chemistry of Transition Metals	DSC(A) 2	100	4 (3+1)
	NSC7C 503	Kinetics, Photochemistry and Catalysis	DSC(A) 3	100	4 (3+1)
	NSC7E 501	Physics and Chemistry of Solids	DSE(A) 1	100	4 (3+1)
	NSC7E 502	Thermodynamics and Surface Chemistry	DSE(A) 1	100	4 (3+1)
	NSC7E 503	Surface Energy and Growth Kinetics of Nanomaterials	DSE(A) 1	100	4 (3+1)
	NSC7E 504	Structure and Properties of Materials	DSE(A) 1	100	4
	NSC7E 505	Nanomaterials for Energy Production and Storage	DSE(A)2 OE	100	4
	NSC7M 501	MOOC -I	Online	100	4
		<b>TOTAL CREDITS</b>			<b>24</b>
<b>Second Semester</b>  <b>(500 Level)</b>	NSC8C 504	Organic Reactions and Rearrangements	DSC(A) 4	100	4 (3+1)
	NSC8C 505	Advanced Electrochemistry	DSC(A) 5	100	4 (3+1)
	NSC8C 506	Quantum Mechanics -I	DSC(A) 6	100	4 (3+1)
	NSC8E 506	Precision Nanoclusters: Origin and Applications	DSE(A) 3	100	4 (3+1)
	NSC8E 507	Nanostructured Solar Cells	DSE(A) 3	100	4
	NSC8M 502	MOOC- II	Online	100	4
			<b>TOTAL CREDITS</b>		
<b>Third Semester</b>  <b>(600 Level)</b>	NSC9C 601	Organometallic Chemistry, Bio-Inorganic Chemistry, and Applications of Spectroscopy	DSC(A) 7	100	4
	NSC9C 602	Quantum Mechanics -II	DSC(A) 8	100	4 (3+1)
	NSC9C 603	Molecular Spectroscopy	DSC(A) 9	100	4 (3+1)
	NSC9E 601	Advanced Analytical Techniques	DSE(A) 4	100	4
	NSC9E 602	Micro/Nano Electro-mechanical Systems (MEMS/NEMS)	DSE(A) 4	100	4
	NSC9E 603	Computational Nanotechnology	DSE(A) 5	100	4 (3+1)
	NSC9E 604	Design, Synthesis and Properties of Nanomaterials	DSE(A) 5	100	4 (3+1)
		<b>TOTAL CREDITS</b>			<b>20</b>

<b>Fourth Semester (600 Level)</b>	NSC10P 601	Project	Project	100	20
	NSC10M 601	MOOC -III	Online	100	4
		<b>TOTAL CREDITS</b>			<b>24</b>
		<b>Project OR 5 Core papers with total 20 credits (Applicable for FYUG – PG Students)</b>			
	NSC10C 604	Bio-Nanomaterials	DSC(A) 10	100	4
	NSC10C 605	Advanced Nanomaterials	DSC(A) 11	100	4
	NSC10C 606	Nanostructured Super Capacitors	DSC(A) 12	100	4
	NSC10C 607	Nanomaterials for Sustainable Technology	DSC(A) 13	100	4
	NSC10C 608	Computational Studies on Bio-active Compounds	DSC(A) 14	100	4
		<b>TOTAL CREDITS</b>			<b>20</b>
	<b>TOTAL CREDITS (I, II, III, IV Sem. ) : 88</b>				

**EVALUATION AND GRADING:** As per the Calicut University Regulations under Choice Based Credit Semester System for Postgraduate Programmes (CCSS-PG) of the University Campus Departments.

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**PATTERN OF QUESTION PAPER FOR CORE AND ELECTIVE COURSES:**

M.Sc. Chemistry (Nanoscience)

**Time: 3 hours**

**Total Marks = 50**

**Section A**

Ten Compulsory short answer type questions of one mark each  
(Total Marks = 10 x 1=10 Marks)

**Section B**

Eight paragraph answer type questions, the students shall answer 4 question each of four marks (Total Marks = 4 x 4 = 16 marks)

**Section C**

Eight essay/problem type questions, the students shall answer four questions, each of six marks  
(Total Marks = 4 x 6=24 marks)

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# **SYLLABUS**

**M.Sc. Chemistry (Nanoscience)  
(Code: FSCNSCHMSC)**

**Discipline Specific Courses  
DSC (A)  
&  
Discipline Specific Electives  
DSE (A)  
&  
MOOC – Online Courses**

<b>Course Code</b>	<b>NSC7C 501</b>	<b>CONCEPTUAL ORGANIC CHEMISTRY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general organic chemistry		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<p>The main objectives of the course are to:</p> <ul style="list-style-type: none"> <li>Understand the fundamental concepts and principles in organic chemistry.</li> <li>Learn different reactions and mechanism.</li> <li>Understand the concepts of stereochemistry and conformations.</li> <li>Learn synthesis and applications of different heterocyclic compounds</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>Remember the fundamentals of organic chemistry – K1</li> <li>Understand the applications of heterocyclic compounds and supramolecules – K2</li> <li>Understand the concepts of stereochemistry and conformations, and solving problems based on it – K2, K3, K5</li> <li>Understand the various reagents for oxidation and reduction reactions – K1</li> </ol>						
K1- Remember K2 – Understand K3 – Apply K4 – Analyse K5 – Evaluate						
<b>UNIT-I</b>	<b>Stereochemistry &amp; Conformations</b>	<b>11 Hours</b>				
<p>Configuration and conformation, Internal factors affecting the stability of molecules – dipole interaction, bond opposition strain, bond angle strain. Conformations of acyclic compounds – alkane dihalides, glycols, tartaric acid, erythro and threo isomers, aldehydes, and ketones (acetaldehyde, acetone). Conformations of mono- and di-substituted cyclohexanes, cis and trans decalins. Geometrical isomerism – E and Z notation of compounds with one and more double bonds in acyclic systems. Optical isomerism, optical rotation, specific rotation, optical isomerism of compounds with more than one chiral carbon atoms, meso-compounds, enantiomeric excess and diastereomeric excess, resolution, prochirality, prochiral groups and faces, Re/Si notation, enantiotopicity and diastereotopicity (definitions only). Axial chirality, optical isomerism of allenes, biphenyls and spiranes, atropisomerism, non-carbon chiral centers (Si, P and S). Effect of conformation on the course and rate of reactions in acyclic systems. Introduction to asymmetric synthesis.</p>						
<b>UNIT-II</b>	<b>Reactive Intermediates &amp; Reaction Mechanism</b>	<b>11 Hours</b>				
<p>Free radicals: Generation, characterization, stability, and detection. Structural and stereochemical properties. Rearrangement and fragmentation reactions. Applications, Gomberg-Bachmann reaction, Wohl-Ziegler reaction, Hunsdiecker reaction. Carbenes and nitrenes: Generation and stability, addition, cyclisation, insertion, and ring enlargement reactions, Skattebol rearrangement, Wolff rearrangement. Classification of organic reactions based on reaction mechanism, addition reaction – electrophilic addition, nucleophilic addition, radical addition. Elimination reaction- E1, E2, E1CB mechanism. Substitution reactions- aliphatic nucleophilic substitution, aromatic nucleophilic substitution, aromatic electrophilic substitution. Rearrangement reactions (introduction</p>						

only). Methods of determining reaction mechanisms, isotopic labelling, kinetic isotopic effects, crossover studies, detection of intermediates, linear free energy relationships (Hammett and Taft equations).		
<b>UNIT-III</b>	<b>Heterocyclic Compounds</b>	<b>11 Hours</b>
Aromatic heterocycles and nonaromatic heterocyclic compounds. Five membered ring compounds with one heteroatom. Synthesis, reactions and applications of pyrrole, furan, thiophene, indole, benzofuran. Synthesis and reactions of six membered ring compounds. Pyridine, quinoline, iso-quinoline, pyrylium salts. Five and six membered rings with two or more heteroatoms-pyrimidines and purines, quinazoline, imidazole.		
<b>UNIT-IV</b>	<b>Oxidation and Reduction Reactions</b>	<b>12 Hours</b>
<p>Oxidation Alcohols – chromium based, DMSO-based (Kornblum, Moffatt, Swern), hypervalent iodine-based and TEMPO-based oxidants, Oppenauer oxidation. Alkenes – DMDO, Sharpless asymmetric epoxidation, OsO<sub>4</sub>-NMO, NaIO<sub>4</sub>, Woodward and Prevost hydroxylations, ozonolysis, hydroboration-oxidation. Selenium/chromium based allylic oxidation.</p> <p>Reduction LiAlH<sub>4</sub>, NaBH<sub>4</sub>, Red Al and NaCNBH<sub>3</sub>. Lindlar catalysts and Rosenmund reduction. Birch reduction, pinacol formation, acyloin formation. Clemmensen, Wolff-Kishner and MPV reductions, hydrazine and diimide reductions. Trialkylsilane and trialkylstannane. Baker's yeast.</p>		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Distillation (fractional &amp; vacuum)</li> <li>2. Thin layer chromatography (natural samples)</li> <li>3. Extraction of caffeine from teal leaves</li> <li>4. Separation of binary mixture 1 (Weak Acid &amp; Neutral) by solvent extraction</li> <li>5. Separation of binary mixture 2 (Strong Acid &amp; Neutral) by solvent extraction</li> <li>6. Separation of binary mixture 3 (Basic &amp; Neutral) by solvent extraction</li> </ol>		
<b>Total Lecture + Practical Hours</b>		<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Reactive intermediates in organic chemistry, N. S. Issac, John Wiley &amp; Sons.</li> <li>2. Stereo chemistry of organic compounds, Nasipuri, New Age International.</li> <li>3. Stereochemistry of organic compounds, Kalsi, Wiley Eastern.</li> <li>4. Advanced organic chemistry, F. A. Carey, R. J. Sunberg, Plenum Press.</li> <li>5. Organic chemistry, P. Y. Bruice, Prentice Hall.</li> <li>6. Heterocyclic chemistry, Gilchrist, Pearson Education.</li> <li>7. Organic chemistry, I. L. Finar, Prentice Hall.</li> <li>8. Principles in organic synthesis, R. O. C. Norman and E. M. Coxon, CRC Press, New York.</li> <li>9. Organic Synthesis, M. B. Smith, McGraw Hill.</li> <li>10. Vogel's Textbook of practical organic chemistry, A. R. Tatchell, John Wiley.</li> </ol>		

<b>Course Code</b>	<b>NSC7C 502</b>	<b>CHEMISTRY OF TRANSITION METALS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general inorganic Chemistry	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
The main objectives of the course are to: <ul style="list-style-type: none"> <li>• Understand the importance of coordination chemistry.</li> <li>• Learn different kinds of spectral properties of coordination compounds.</li> <li>• Understand the importance of coordination compounds.</li> <li>• Learn reaction mechanism and photochemistry of inorganic compounds.</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Remember the fundamentals of coordination compounds – K1</li> <li>2. Understand the concepts of MOT in coordination chemistry– K2</li> <li>3. Understand different kinds of spectral and magnetic properties of coordination compounds – K2</li> <li>4. Understand reaction mechanism and photochemistry of inorganic compounds– K1</li> <li>5. Problem solving, evaluation and analysis capacity – K3, K4, K5</li> </ol>						
K1– Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate						
<b>UNIT-I</b>	<b>Introduction to Coordination Chemistry</b>				<b>11 Hours</b>	
Coordination compounds. HSAB principle, symbiosis - hard and soft ligands. Chelate, macrocyclic and macrobicyclic effects. Formation constants, stepwise and overall stability constants - factors affecting stability. Isomerism – ORD and circular dichroism. Crystal field and ligand field theories (orbital splitting in octahedral, tetrahedral, cubic, square planar, square pyramidal, and trigonal bipyramidal fields). Significance of 10Dq, factors affecting crystal field splitting, spectrochemical and nephelauxetic series, Jahn-Teller effect - causes and consequences.						
<b>UNIT-II</b>	<b>Molecular Orbital Theory, Electronic Spectra and Magnetic Properties of Coordination Compounds</b>				<b>11 Hours</b>	
Molecular orbital theory of coordination compounds (tetrahedral, octahedral, square planar complexes). Charge transfer spectra, charge transfer spectra of $\text{KMnO}_4$ . Electronic spectra of complexes – terms of $d^n$ configurations, selection rules for d-d transitions. Orgel diagrams, calculation of Dq, B, and $\beta$ . Correlation diagram. Tanabe-Sugano diagrams. Magnetic properties of transition metal complexes – types of magnetic properties. Paramagnetism – the Curie and Curie-Weiss law. $\mu_J$ , $\mu_{L+S}$ , and $\mu$ spin-only expressions, temperature independent paramagnetism. Antiferromagnetism – types and exchange pathways.						
<b>UNIT-III</b>	<b>Reaction Mechanism of Coordination Compounds</b>				<b>11 Hours</b>	
Reaction mechanisms of metal complexes, rate laws. Metal and ligand substitution reactions in octahedral complexes – A, D, and I mechanisms and associated energetic, aquation and base hydrolysis, stereochemical changes, isomerisation, and racemisation. Fuoss-Eigen equation and factors determining A and D mechanisms. Lability and inertness						

of the complexes, trans-effect – theories and applications, cis effect. Reactions of coordinated ligands – hydrolysis, acid dissociation, aldol condensation, template effect, and macrocyclization. Redox reaction mechanisms – classification, outer-sphere electron transfer, chemical activation, Marcus theory, and thermodynamics. Inner-sphere electron transfer – kinetics, the effect of the nature of metal and ligand, bridging group effects. Metal-ligand redox reactions. Two electrons, inner-sphere electron transfer processes.		
<b>UNIT-IV</b>	<b>Photochemistry and Spectroscopy of Coordination Compounds</b>	<b>12 Hours</b>
Prompt and delayed reactions. Excited states of metal complexes – intra-ligand, ligand field, charge transfer, and delocalized states. Charge transfer excited states and redox processes, communication between excited states, radical pair models. Properties of ligand field excited states, rules for photo substitution, photo-aquation, and ligand exchange reactions. Substitution and redox reactions of Cr (III) and Rh (III) complexes. Photo-isomerisation and photo-racemisation. Metal complex sensitizers, chemical actinometry, and photochromism. Water photolysis and dinitrogen splitting. IR spectroscopy of simple inorganic compounds and metal complexes - changes in ligand vibrations on coordination with metal ion. Vibrational spectra of metal carbonyls. NMR spectroscopy for structural studies of diamagnetic metal complexes from chemical shift and spin-spin coupling. ESR spectra of metal complexes – hyperfine splitting, g values, zero field – splitting, and Kramer's degeneracy, application to simple copper complexes. Mossbauer spectroscopy – Mossbauer effect, hyperfine interactions (qualitative treatment). Application to simple iron and tin complexes.		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Estimation of calcium and nickel – complexometric titration.</li> <li>2. Estimation of chromium – Iodometric titration.</li> <li>3. Estimation of hardness of water using complexometric titration (Tap water, well water, and bore well water).</li> <li>4. Estimation of Cr, Ni, and Fe by colorimetric method.</li> <li>5. Estimation of mixtures of metal ions - estimation of iron (gravimetric method) and chromium (colorimetric method).</li> <li>6. Estimation of mixtures of metal ions - estimation of iron (gravimetric method) and calcium (volumetric method).</li> </ol>		
<b>Total Lecture + Practical Hours</b>		<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Inorganic chemistry; Weller, Overton, Rourke, and Armstrong; Oxford University Press. (Formerly Shriver &amp; Atkin's Inorganic Chemistry).</li> <li>2. Inorganic chemistry principles of structure and reactivity; J. E. Huheey, E. A. Keiter and R. L. Keiter; Pearson Education.</li> <li>3. Inorganic chemistry; C. E. Housecroft and A. G. Sharpe; Pearson.</li> <li>4. Inorganic chemistry; J. E. House; Academic Press, Elsevier.</li> <li>5. Basic inorganic chemistry; F. A. Cotton; John Wiley.</li> <li>6. Advanced inorganic chemistry; F. A. Cotton and G. Wilkinson; John Wiley.</li> <li>7. Inorganic chemistry; G. Wulfsberg; Viva Books.</li> <li>8. Concepts and models of inorganic chemistry; B. E. Douglas, D. H. Mc Daniel, and J. J. Alexander; John Wiley.</li> <li>9. Inorganic chemistry; G. L. Miessler, P. J. Fischer, and D. A. Tarr; Pearson.</li> <li>10. Vogel's textbook of qualitative inorganic analysis; G. Svehla and B. Sivasankar; Longman Scientific &amp; Technical.</li> <li>11. Vogel's textbook of quantitative chemical analysis; G. H. Jeffery, J. Bassett, J. Mendham, and R. C. Denney; Longman Scientific &amp; Technical.</li> </ol>		

<b>Course Code</b>	<b>NSC7C 503</b>	<b>KINETICS, PHOTOCHEMISTRY, AND CATALYSIS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general physical chemistry		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
The main objectives of the course are to:						
<ul style="list-style-type: none"> <li>• Understand the fundamental concepts of physical chemistry.</li> <li>• Learn the method of solving problems mathematically.</li> <li>• Understand the concepts of kinetics, photochemistry, and catalysis.</li> <li>• Learn the method of evaluation of kinetics of chemical and photochemical reactions.</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Remember the fundamentals of kinetics – K1</li> <li>2. Understand some mathematical concepts – K2</li> <li>3. Understand different kinetic pathways and problems based on it – K2, K3</li> <li>4. Understand photochemistry of different systems – K1</li> <li>5. Problem solving, evaluation and analysis capacity – K3, K4, K5</li> </ol>						
K1- Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate						
<b>UNIT-I</b>	<b>Chemical Kinetics I</b>				<b>11 Hours</b>	
Reaction rate, Arrhenius equation, energy of activation, collision theory, transition state theory. Thermodynamic treatment of reaction rates. London equation. Various theories of unimolecular reactions. Lindemann – Hinshelwood and RRKM theories (in brief). Kinetics of complex reactions, chain reactions, rate laws of chain reactions. Explosions (in brief).						
<b>UNIT-II</b>	<b>Chemical Kinetics II</b>				<b>11 Hours</b>	
Kinetic of reaction in solution. Comparison of solution and gas kinetics. Diffusion controlled reactions. Influence of solvent on rate. Cage effect. Effect of dielectric constant on the rate. Primary and secondary kinetic salt effects, structural effects on rate. Study of fast reactions, flash photolysis, flow techniques, relaxation methods.						
<b>UNIT-III</b>	<b>Photochemical Reactions</b>				<b>11 Hours</b>	

Reactions of electronically excited species, laws of photochemistry, quantum yield and its determination. Radiative and non-radiative transitions. Jablonski diagram. Fluorescence: quantum efficiency of fluorescence, Stern-Volmer equation; delayed fluorescence. E-type and P-type phosphorescence. Laser photochemistry, multiphoton excitation. Effect of temperature, wavelength, and intensity of radiation on photochemical reaction. Different types of photochemical reactions. Kinetics of $H_2-Br_2$ and $H_2-Cl_2$ reaction, photo stationary states. Excimers and exciplexes. Photosensitization, photophysical phenomena. Luminescence, chemiluminescence and thermoluminescence. Radiation-chemical reactions – primary processes, pulse radiolysis, hydrated electrons.		
<b>UNIT-IV</b>	<b>Catalysis</b>	<b>12 Hours</b>
Theories of homogeneous catalysis. Acid-base catalysis, Bronsted catalysis law. Enzyme catalysis: Michaelis-Menten mechanism. Auto catalysis, oscillating reaction and BZ reaction. Heterogeneous catalysis: Kinetics and mechanism of surface catalyzed reactions. Unimolecular surface reaction: Eley – Rideal mechanism. Bimolecular reactions: Langmuir – Hinshelwood mechanism.		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Study the kinetics of hydrolysis of methyl acetate (ester) in the presence of an acid (<math>HCl</math> or <math>H_2SO_4</math>) at room temperature.</li> <li>2. Study the kinetics of saponification of an ester with sodium acetate.</li> <li>3. Determination of distribution coefficient of <math>I_2</math> between carbon tetrachloride and water.</li> <li>4. Study the equilibrium reaction <math>KI + I_2 \rightleftharpoons KI_3</math> and to determine its equilibrium constant.</li> <li>5. Determination of the concentration of unknown <math>KI</math> solution by partition method.</li> </ol>		
<b>Total Lecture + Practical Hours</b>		<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. K. K. Rohatgi and Mukherjee, fundamental of photochemistry, New Age International.</li> <li>2. Dupoy and Chapmann, molecular reactions and photochemistry, Prentice-Hall.</li> <li>3. Fundamental chemical kinetics, Margaret Robson Wright. Horwood publishing Limited.</li> <li>4. E. K. Rideal, concepts in catalysis, Academic press.</li> <li>5. Physical chemistry, Peter Atkins, Julio de Paula, Oxford University Press.</li> <li>6. A. Clark, theory of adsorption and catalysis, Academic press.</li> <li>7. Advanced practical physical chemistry; J. B. Yadav; Goel Publishing.</li> <li>8. Experimental physical chemistry; Gurtu &amp; Gurtu; Prgti Prakashan.</li> <li>9. Experimental physical chemistry; Gurdeep Raj; Krishna Prakasha.</li> <li>10. Experiments in physical chemistry; D. F. Schomaker and C. W. Garland; McGraw Hill.</li> </ol>		

<b>Course Code</b>	<b>NSC7E 501</b>	<b>PHYSICS AND CHEMISTRY OF SOLIDS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in crystals and solids		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<p>The main objectives of the course are to:</p> <ul style="list-style-type: none"> <li>• Understand the fundamental concepts and principles of material science.</li> <li>• Learn the method of solving problems mathematically.</li> <li>• Understand the concepts and theories describing the properties of solid-state materials.</li> <li>• Apply the knowledge to manipulate the working of solid-state electronic devices.</li> </ul>						
<b>Course Outcomes</b>						
<p>1. Identify crystallographic features and apply X-ray diffraction techniques for structure analysis (K2, K3)</p> <p>2. Analyze crystal packing, defects, and electronic properties, calculating carrier concentration and Fermi level in semiconductors (K4)</p> <p>3. Interpret electronic, dielectric, and thermal properties of solids (K4)</p> <p>4. Analyze the behaviour of different solids by evaluating the fundamental theories (K4, K5)</p>						
K1– Remember, K2 – Understand, K3 – Apply, K4 – Analyze, K5 – Evaluate						
<b>UNIT-I</b>	<b>Crystalline State</b>		<b>10 Hours</b>			
Crystal morphology: symmetry elements, crystal systems; Bravais lattices; Crystal planes and directions: Miller indices, interplanar separations. Crystal symmetry, Symmetry elements and symmetry operations. Structure analysis by X-rays: Atomic scattering factor; Laue conditions for diffraction and Bragg's law; Powder X-ray diffraction.						
<b>UNIT-II</b>	<b>Crystal Packing, Defects and Theories</b>		<b>10 Hours</b>			
Packing in a crystal: BCC, FCC, HCP structures with examples, Point defects, line defects, plane defects. Free electron theory of metals, Band theory of solids, Effective mass; Direct and Indirect bandgaps: Determination of bandgap; Donors and acceptors, carrier concentration at thermal equilibrium; Calculation of Fermi level; Degenerate and Non-degenerate semiconductors.						
<b>UNIT-III</b>	<b>Electronic and Dielectric Properties</b>		<b>13 Hours</b>			
Free electron gas in three dimensions, heat capacity of electron gas, electrical conductivity and Ohm's law, Experimental electrical resistivity of metals, Motion in magnetic fields, Hall effect, Thermal conductivity of metals (Wiedemann-Franz law), Nearly free electron model-origin of energy bands, Magnitude of energy gap, Bloch functions, Kronig Penny model, Semiconductor crystals: band gap, direct/indirect bad gap SCs, Equation of motion, Holes, Effective masses in semiconductors, Intrinsic carrier concentration, Impurity conductivity, Thermoelectric effects. Theory of Dielectrics: Polarisation, Dielectric constant, Local Electric field, Dielectric polarisability, Clausius- Mossotti relation, Polarisation from dipole orientation, Dielectric losses, Ferroelectric crystals, Order-disorder type ferroelectrics, Polarisation catastrophe, Displacive type ferroelectrics, Landau theory of ferroelectric phase						

transitions, Ferroelectric domain, Antiferroelectricity, Piezoelectricity, Applications of Piezoelectric Crystals.		
<b>UNIT-IV</b>	<b>Magnetic Properties</b>	<b>12 Hours</b>
Diamagnetism and Paramagnetism: Langevin's diamagnetism equation, Quantum theory of diamagnetism of mononuclear systems, Quantum theory of paramagnetism, Hund's rule, Paramagnetic susceptibility of conduction electrons, Ferro, Anti and Ferri magnetism: Curie point and the exchange integral, Magnons, Ferrimagnetic order, Curie temperature and susceptibility of ferrimagnets, Antiferromagnetic order. Weiss theory of ferromagnetism, Ferromagnetic domains, Bloch walls, Origin of domains.		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Study of energy band gap and diffusion potential of P-N junction.</li> <li>2. Determination of Particle size of Lycopodium powder using He-Ne laser.</li> <li>3. Temperature Dependence of Hall coefficient. Determination of Carrier concentration and mobility.</li> <li>4. Determination of band gap of a semiconductor by four probe method.</li> <li>5. Solar Power and I-V characteristics of semiconductor thin films.</li> <li>6. Determination of concentration of an unknown solution through UV-Vis spectrophotometer: Verification of Beer-Lambert Law.</li> <li>7. Analysis of crystal structure of a given sample using its XRD data.</li> </ol>		
<b>Total Lecture + Practical Hours : 75 Hours</b>		
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. D.A McQuarrie and J.D. Simon, Physical Chemistry, a molecular approach, University Science Books.</li> <li>2. Tareen and Kutty, Solid state chemistry.</li> <li>3. Lesley Smart &amp; Elaine Moore, SolidState Chemistry, nelson Thornes.</li> <li>4. A.K. Galway, Chemistry of Solids, Science Paperbacks and Chapman and Hall Ltd., London 91967).</li> <li>5. A.R. West, basic Solid State Chemsitry, John Wiley &amp; Sons Ltd. (1991).</li> <li>6. B.S.Skoog and D.M. West, Principles of Instrumental Analysis, Sanndes College, Philadelphia (1980).</li> <li>7. Atomic structure and chemical Bond, Manas Chanta <b>Publisher:</b> McGraw-Hill Inc.,US (1 December 1974) <b>ISBN-10:</b> 0070965110</li> <li>8. Concise Inorganic chemistry, J.D.Lee <b>Publisher:</b> Wiley; 5th edition edition (18 December 1998) <b>ISBN-10:</b> 0632052937</li> <li>9. Inorganic Chemistry, G. Wwfsberg Unit IV <b>Publisher:</b> Pearson; 4 edition (31 May 2012) <b>ISBN-10:</b> 0273742752</li> <li>10. Introduction to solids – L.V. Azaroff □ <b>Publisher:</b> McGraw Hill Education; New edition edition (14 June 2001) <b>ISBN-10:</b> 0070992193</li> <li>11. Introduction to solid state Physics – C. Kittel □ <b>Publisher:</b> John Wiley &amp; Sons Inc (23 July 1996) □ <b>ISBN-10:</b> 0471142867</li> <li>12. Elements of solids state physics, J.P. Srivastava □ <b>Publisher:</b> Prentice Hall India Learning Private Limited; 4th Revised edition edition (17 December 2014) <b>ISBN-10:</b> 8120350669</li> <li>13. Superconductivity and Superconducting Materials – A V Narlikar and S N Ekbote (South Asian Pub., 1983).</li> <li>14. Physics of high Tc superconductors – J C Phillips (Academic Press, 1989)</li> <li>15. Introduction to superconductivity – A C Rose-Innes and E H Rhoderick (Pergamon Press, 1978)</li> </ol>		

<b>Course Code</b>	<b>NSC7E 502</b>	<b>THERMODYNAMICS AND SURFACE CHEMISTRY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general physical chemistry	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
The main objectives of the course are to: <ul style="list-style-type: none"> <li>• Understand the fundamental concepts of thermodynamics.</li> <li>• Learn the method of solving problems mathematically.</li> <li>• Understand the concepts of statistical mechanics, and thermodynamics.</li> <li>• Understand and concepts of adsorption and colloids.</li> </ul>						
<b>Course Outcomes</b>						
The course outcomes can be as follows: <ol style="list-style-type: none"> <li>1. Remember the fundamentals of analytical methods – K1</li> <li>2. Understand some electrochemical systems – K2</li> <li>3. Understand different statistical systems – K1</li> <li>4. Problem solving, evaluation and analysis capacity – K3, K4, K5</li> <li>5. Describe various adsorption phenomena and apply the properties of colloidal systems and their applications – K2, K3, K5</li> </ol>						
K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate K6 – Create						
<b>UNIT-I</b>	<b>Equilibrium Thermodynamics</b>	<b>10 Hours</b>				
Basic concepts – laws. Maxwell's relations. Jacobian method of relating thermodynamic partial derivatives. Thermodynamics of solutions. Partial molar properties. Chemical potential and its significance. Gibbs – Duhem equation. Influence of pressure and temperature on chemical potential. Fugacity of gas and its determination. Gibbs-Duhem-Margules equation. Ideal and non-ideal solutions. Deviation from Raoult's law. Relation between Raoult's law & Henry's law. Activity and activity coefficient. Thermodynamics functions of mixing. Excess thermodynamic functions.						
<b>UNIT-II</b>	<b>Irreversible Thermodynamics</b>	<b>11 hours</b>				
Non-equilibrium thermodynamics. Thermodynamics of irreversible processes. Stationary state. Principle of local equilibrium. Forces and fluxes. The phenomenological relations. Onsager relations. Coupled flows. Direct and cross coefficients. Domination of direct coefficients – proof. Reciprocal relation (no derivation) – entropy production in simple irreversible systems (closed systems). Application of reciprocal relation to irreversible processes. Thermal diffusion - thermo-osmosis and thermo-molecular pressure difference. Electrokinetic phenomena. Entropy production in the process. Electro-osmosis, streaming potential, streaming current, and electro-osmotic pressure.						
<b>UNIT-III</b>	<b>Statistical Thermodynamics</b>	<b>12 Hours</b>				
Probability distribution. Ensembles. Microstates and macrostates. Statistical weight. Thermodynamic probability and entropy. Maxwell Boltzmann distribution law. Partition function and its relation to thermodynamic functions. Factorisation of the partition function into the translational, rotational, vibrational, and electronic parts. Perfect gas-ideal monatomic and diatomic gases. Sackur-Tetrode equation. Heat capacity of gases. Classical						

and quantum theories. Anomalous heat capacity of hydrogen. Heat capacity of solids. Imperfect gases, virial expressions, and virial coefficients, Configurational partition function, relation between virial coefficients and cluster integrals. Atomic crystal – Einstein theory of atomic crystals, Debye modification of Einstein model. Need for quantum statistics. Fermi-Dirac distribution law - ideal Fermi gas. Application to electrons in metals. Bose-Einstein distribution law. Ideal Bose gas. Gas Degeneracy. Bose-Einstein condensation. Application to liquid helium. Comparison of three statistics.		
<b>UNIT-IV</b>	<b>Surface Chemistry</b>	<b>12 Hours</b>
Structure and chemical nature of surfaces, adsorption at surfaces – adsorption isotherms, Langmuir isotherm, and its kinetic and statistical derivation. Freundlich equation, BET equation – derivation, determination of surface area and pore structure of adsorbents, heat of adsorption and its determination.		
Colloids – preparation and purification, stability of colloids, zeta potential and its determination. Electrokinetic phenomena – electrophoresis, electroosmosis, sedimentation, and streaming potential. Colloidal surfactants, micelles, HLB number. Stabilizing action of surfactants, practical importance of surfactants. Langmuir- Blodgett films.		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Determination of heat of solution of ammonium oxalate/ succinic acid from solubility data.</li> <li>2. Determination of molecular weight from depression in freezing point.</li> <li>3. Determination of critical solution temperature (CST) of phenol and water in the presence of (a) NaCl, (b) naphthalene, and (c) succinic acid.</li> <li>4. Construction of phase diagram of two components (eg: naphthalene – biphenyl or diphenylamine – benzophenone) system by cooling curve method.</li> <li>5. Construction of the triangular phase diagram of acetic acid, chloroform, and water.</li> <li>6. Evaluation of Freundlich and Langmuir adsorption isotherm of acetic acid or oxalic acid on activated charcoal.</li> </ol>		
	<b>Total Lecture + Practical Hours</b>	<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Molecular thermodynamics; D. A. McQuarrie, J. D. Simon; University Science Books.</li> <li>2. Advanced physical chemistry; G. Raj; Goel Publishing House.</li> <li>3. Physical chemistry; G. K. Vemulapalli; Prentice-Hall.</li> <li>4. Introduction to thermodynamics of irreversible processes; I. Prigogine; Interscience Publishers, John Wiley &amp; Sons.</li> <li>5. An introduction to statistical thermodynamics; T. L. Hill, Dover Publications, Inc.</li> <li>6. Elements of statistical thermodynamics; L. K. Nash; Addison Wesley Publishing Co.</li> <li>7. Physical chemistry of surfaces; A. W. Adamson and A. P. Gasi; Wiley-Interscience Publication.</li> <li>8. Adsorption and catalysis by solids; D. K. Chakrabarty; New Age International.</li> <li>9. Surface science: Foundations of catalysis and nanoscience; K. K. Kolasinski, John Wiley &amp; Sons Ltd.</li> <li>10. Advanced practical physical chemistry; J. B. Yadav; Goel Publishing.</li> <li>11. Experimental physical chemistry; Gurtu &amp; Gurtu; Prgti Prakashan.</li> <li>12. Experimental physical; Gurdeep Raj; Krishna Prakashan.</li> <li>13. Experiments in physical chemistry; D. F. Schomaker and C. W. Garland; McGraw Hill.</li> </ol>		

<b>Course Code</b>	<b>NSC7E 503</b>	<b>SURFACE ENERGY AND GROWTH KINETICS OF NANOMATERIALS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Fundamentals of Physics and Chemistry at Undergraduate level	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. Recognize the interdisciplinary area of Nanoscience and Technology</li> <li>2. Realize different nano systems and recognize the advanced tools used for their analysis</li> <li>3. Understand the reasons behind size dependent physical or chemical properties of nanomaterials</li> <li>4. Analyze the phase transformation process and understand how to control that process for nanostructure creation</li> <li>5. Introduce different methods available for the fabrication of nanostructures</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Recognize different nanosystems and the tools for their analysis (K2)</li> <li>2. Understand the size dependent physical phenomena observed in nanomaterials (K2)</li> <li>3. Realize the origin of surface energy, energy minimization and stabilization processes in nanosystems (K2)</li> <li>4. Understand and apply the kinetics of phase transformation in nanosystems (K2,K3)</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Introduction to Nano-systems</b>	<b>8 Hours</b>				
Feynmann's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic nanomaterials. Quantum confinement in nanostructures- size dependent physical phenomena in semiconductor and metal nanoparticles. Classification of nanostructures, 0D, 1D and 2D nanostructures. Visualization of nanostructures and techniques related.						
<b>UNIT-II</b>	<b>Surface Energy</b>	<b>13 Hours</b>				
Surface energy and surface stress-origin and estimation of surface energy. Surface Energy minimization:- Sintering Ostwald ripening and agglomeration. Energy minimization by Isotropic and anisotropic surfaces. Surface energy and surface curvature, Surface energy stabilization- electrostatic stabilization, steric stabilization, electro-steric stabilization..						
<b>UNIT-III</b>	<b>Growth Kinetics of Nanomaterials</b>	<b>13 Hours</b>				
Kinetics of phase transformations, Homogeneous & Heterogeneous nucleation. Controlling nucleation, growth and aggregation in nanoparticle growth. Growth Mechanisms:						

Spontaneous growth, Evaporation condensation growth, growth controlled by diffusion and surface process, VLS growth, fundamentals of thin film growth.		
<b>UNIT-IV</b>	<b>Special Nanostructures</b>	<b>11 Hours</b>
Carbon Nanostructures: Fullerenes, CNTs and Graphene- structure and physical properties. Micro & Mesoporous Materials, Ordered mesoporous structures, Random mesoporous structures, and crystalline microporous materials: zeolites. Core – Shell Structures - Metal-oxide structures, Metal-polymer structures, Oxide-polymer structures. Organic-Inorganic Hybrids- Class I hybrids, Class II hybrids, Intercalation Compounds.		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Synthesis of different sized Ag nanoparticles by aqueous method, Size distribution studies using DLS</li> <li>2. UV-Vis absorption studies of different sized Ag nanoparticles and calculation of particle size comparing with reported literature</li> <li>3. Synthesis of different sized Au nanoparticles by aqueous method, Size distribution studies using DLS</li> <li>4. UV-Vis absorption studies of different sized Au nanoparticles and calculation of particle size comparing with reported literature</li> <li>5. Green Synthesis of carbon nanodots and their optical characterization</li> <li>6. Polymer thin film preparation using spin coating method and thickness measurement using Profilometer</li> </ol>		
<b>Total Lecture + Practical Hours</b>		<b>75 Hours</b>
<b>Text Books/References</b>		
Text Books:		
<ol style="list-style-type: none"> <li>1. Nanostructures and Nanomaterials- Synthesis, Properties &amp; applications by Guozhong Cao, Imperial College Press, (2006). (for UNIT I &amp; II, 2<sup>nd</sup> Chapter, Unit III – Chapter 4 (3.2), Unit IV- Chapter 7</li> <li>2. Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani Springer-Verlag (2007). (For Unit III-Part I Chapter I)</li> <li>3. Materials Science and Engineering-An Introduction 7e, William D. Callister, (Wiley, 2007). (Chapter 10. section 1-.2 and 10.3) Unit II.</li> </ol>		
Reference:		
<ol style="list-style-type: none"> <li>1. Introduction to Nanoscience &amp; Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor &amp; Francis Group New York, 2009. <b>Publisher:</b> CRC Press (15 December 2008) <b>ISBN-13:</b> 978-1420047790</li> <li>2. Introduction to Nanoscale Science &amp; Technology, Di Ventra, Evoy, Heflin, Springer Science, NY, 2004. <b>Publisher:</b> Springer; 1 edition (30 June 2004) <b>Sold by:</b> Amazon Asia-Pacific Holdings Private Limited.</li> </ol>		

<b>Course Code</b>	<b>NSC7E 504</b>	<b>STRUCTURE AND PROPERTIES OF MATERIALS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Fundamentals of Physics and Chemistry at Undergraduate level	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. Understand the fundamental principles governing the structure and properties of materials.</li> <li>2. Explore the principles of metallurgy and phase transformations in materials.</li> <li>3. Examine the physics of semiconductors and their practical applications.</li> <li>4. Analyze the mechanical, optical, and magnetic properties of materials.</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Understand the atomic structure of materials, imperfections in solids, and apply microscopic techniques for material characterization (K2, K3)</li> <li>2. Analyze phase transformations in materials and interpret phase diagrams (K3, K4)</li> <li>3. Apply principles of semiconductor physics and evaluate diffusion processes in solids for industrial applications (K3, K5)</li> <li>4. Analyze mechanical properties and comprehend the optical and magnetic properties</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Structure of Materials</b>		<b>12 hours</b>			
Introduction and structure of materials, why study properties of materials? Structure of atoms - Quantum states-Atomic bonding in solids-binding energy-interatomic spacing - variation in bonding characteristics - Single crystals – polycrystalline - Non crystalline solids - Imperfection in solids – Vacancies – Interstitials - Geometry of dislocation - Schmid’s law - Surface imperfection - Importance of defects - Microscopic techniques - grain size distribution						
<b>UNIT-II</b>	<b>Metallurgy and Phase Transformations</b>		<b>14 hours</b>			
Solidification of Metals - Solidification of Single Crystals - Metallic Solid Solutions - Rate Processes in Solids - Diffusion in Solids, Industrial Applications of Diffusion Processes - Effect of Temperature on Diffusion in Solids - Phase diagrams - Gibbs phase rule - Single component systems – Eutectic phase diagram – lever rule - Study of properties of phase diagrams - Phase transformation - Nucleation kinetics and growth						
<b>UNIT-III</b>	<b>Physics of Semiconductors</b>		<b>12 hours</b>			
Band model of semiconductors - carrier concentrations in intrinsic, extrinsic semiconductors – organic semiconductors - Fermi level - variation of conductivity, mobility with temperature – law of mass action - Hall effect - Hall coefficients for intrinsic and extrinsic semiconductors – Hall effect devices. Application of diffusion in sintering, doping of semiconductors and surface hardening of metals.						

<b>UNIT-IV</b>	<b>Mechanical Properties of Materials</b>	<b>12 hours</b>
Mechanical Properties of Metals - Processing of Metals and Alloys - Stress and Strain in Metals, The Tensile Test and The Engineering Stress-Strain Diagram, Hardness and Hardness Testing, Plastic Deformation of Metal Single Crystals, Plastic Deformation of Polycrystalline Metals - Solid-Solution Strengthening of Metals, Recovery and Recrystallization of Plastically Deformed. Metals, Fracture of Metals - Fatigue of Metals - Creep and Stress Rupture of Metals. Tribology: wear of metals - mechanisms, factors influencing wear, wear resistance - protection against wear.		
<b>UNIT-V</b>	<b>Optical and Magnetic Properties of Materials</b>	<b>10 Hours</b>
Optical properties - Light interaction with solids - Atomic, electronic interaction, non – radiative transition - refraction, reflection, Absorption, Transmission, Insulators, luminescence. Magnetic properties - paramagnetism - ferromagnetism - domain theory - magnetic hysteresis, Weiss molecular field theory, Heisenberg's theory - magnetic anisotropy - domain walls - Exchange energy –antiferromagnetism		
	<b>Total Lecture Hours</b>	<b>60 Hours</b>
<b>Text Books/References</b>		
Text Books:		
<ol style="list-style-type: none"> <li>1. Materials Science and Engineering-An Introduction 7e, William D. Callister, (Wiley, 2007).</li> <li>2. K. Vijayamohan Pillai and Meera Parthasarathi Functional Materials: A Chemist's Perspective by, Orient Blackswan (21 November 2013).</li> <li>3. C. Kittel, "Introduction to Solid State Physics" Wiley Eastern Ltd, 2005.</li> <li>4. V. Raghavan, "Materials Science and Engineering: A First Course", Prentice Hall, 2006.</li> <li>5. A.J. Dekker, "Solid State Physics", Macmillan &amp; Co, 2000.</li> <li>6. Michael Shur, "Physics of Semiconductor Devices", Prentice Hall of India, 1995.</li> <li>7. Charles P Poole Jr., and Frank J. Ownes, Introduction to Nanotechnology, John Wiley Sons, Inc., 2003.</li> <li>8. H. S. Nalwa (Ed.), "Encyclopedia of Nanoscience &amp; Nanotechnology", American Scientific Publishers, California, 2004.</li> <li>9. V.R.Gowariker, "Polymer science ",New age international Publishers, 1986</li> <li>10. Introduction to magnetic materials, B. D. Cullity, C. D. Graham, Published by John Wiley &amp; Sons, Inc., Hoboken, New Jersey, 2009</li> </ol>		

<b>Course Code</b>	<b>NSC7E 505</b>	<b>NANOMATERIALS FOR ENERGY PRODUCTION AND STORAGE</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>OPEN ELECTIVE</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in science		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. Understand the fundamental properties of nanomaterials</li> <li>2. Explore the role of nanomaterials in energy production</li> <li>3. Investigate nanomaterials in energy storage systems</li> <li>4. Analyze the benefits and challenges of using nanomaterials in energy systems</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Comprehend the unique properties of nanomaterials - K1, K2</li> <li>2. Evaluate nanomaterial-based energy production and storage technologies - K3, K4, K5</li> <li>3. Identify emerging trends and research opportunities in nanomaterials for energy K4, K5</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Introduction to Nanomaterials and Energy</b>					<b>12 hours</b>
Nanomaterials: Definition, types (e.g., nanoparticles, nanotubes, nanowires, nanosheets, quantum dots), physical properties (size, shape, and surface area), chemical properties (reactivity and stability), optical properties (light absorption and emission) and mechanical properties (strength, flexibility, and durability). Energy sources: renewable vs. non-renewable, basics of energy conversion and storage, current challenges in energy production and storage.						
<b>UNIT-II</b>	<b>Electrochemical Energy Storage</b>					<b>12 hours</b>
Basics of electrochemical energy storage, Importance of energy storage in modern technology, batteries and supercapacitors - working principle, energy density, power density, nanostructured electrode materials (carbon-based materials, 2D materials and metal oxides). Advantages and challenges of nanomaterials in energy storage.						
<b>UNIT-III</b>	<b>Hydrogen Energy- Production and Storage</b>					<b>14 hours</b>
Hydrogen energy – basics and importance, hydrogen production methods, photocatalytic and electrochemical water splitting, nanomaterials for hydrogen production (carbon-based, oxides and metallic). Hydrogen storage- importance and challenges, nanomaterials for hydrogen storage (metal-organic frameworks and carbon-based materials).						
<b>UNIT-IV</b>	<b>Nanomaterials for Fuel Cell Application</b>					<b>12 hours</b>
. Fuel cell – introduction and type; Working principle of hydrogen fuel cells; Nanomaterials-based (carbon-based, metal oxide and metallic) electrodes and membranes in fuel cell. Future impact of nanomaterials on fuel cell technology and clean energy.						
<b>UNIT-V</b>	<b>Nanomaterials for Thermoelectric and Other Energy Conversion Technologies</b>					<b>10 Hours</b>

Basic principles of thermoelectric energy conversion, nanostructured thermoelectric materials: types, key properties and importance. Nanomaterials for bioenergy and biofuel production. Piezoelectric nanomaterials.

**Total Lecture Hours**

**60 Hours**

**Text Books/References**

Text Books:

1. Dinesh C. Agrawal; Introduction to Nanoscience and Nanomaterials; World Scientific Publishing Company.
2. Zishan H. Khan; Nanomaterials for Innovative Energy Systems and Devices; Springer.
3. Quan Li.; Nanomaterials for Sustainable Energy; Springer.
4. Amit Saxena, Bhaskar Bhattacharya, and Felipe Caballero-Briones; Applications of Nanomaterials for Energy Storage Devices; CRC Press.
5. Jude A. Okolie, Emmanuel I. Epelle, Alivia Mukherjee, and Alaa El Din Mahmoud; Nanomaterials for Sustainable Hydrogen Production and Storage; CRC Press.
6. Piyush Kumar Sonkar and Vellaichamy Ganesan; Nanomaterials for Sustainable Energy Applications; CRC Press.
7. Kenneth I. Ozoemena and Shaowei Chen; Nanomaterials for Fuel Cell Catalysis; Springer.
8. Sabu Thomas, El Hadji Mamour Sakho, Nandakumar Kalarikkal, Oluwatobi Samuel Oluwafemi, and Jihuai Wu; Nanomaterials for Solar Cell Applications; Elsevier.
9. Kunihiro Koumoto and Takao Mori; Thermoelectric Nanomaterials: Materials Design and Applications; Springer.

**NSC7M 501 MOOC I ONLINE Course - 4 Credits**

<b>Course Code</b>	<b>NSC8C 504</b>	<b>ORGANIC REACTIONS AND RE-ARRANGEMENTS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general organic chemistry	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<p>The main objectives of the course are to:</p> <ul style="list-style-type: none"> <li>• Understand molecular rearrangements.</li> <li>• Learn the concept of multistep organic synthesis.</li> <li>• Understand the mechanisms of different types of named reactions.</li> <li>• Learn the concepts of photochemistry and pericyclic reactions.</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Remember the fundamentals of molecular rearrangements – K1</li> <li>2. Understand some named organic reactions and their mechanisms – K2</li> <li>3. Understand different photochemical and pericyclic reactions – K1</li> <li>4. Problem solving, evaluation and analysis capacity with chemical reactions – K3, K4, K5</li> </ol>						
K1- Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate K6- Create						
<b>UNIT-I</b>	<b>Molecular Rearrangements</b>	<b>11 Hours</b>				
<p>Concepts, types of rearrangements, rearrangement to electron deficient carbon: (carbon migration) Wagner-Meerwein rearrangement, Pinacol-Pinacolone rearrangement. Rearrangement to electron rich carbon: Stevens rearrangement, Sommelet-Hauser rearrangement, Wittig rearrangement. Rearrangement to electron deficient nitrogen: Lossen rearrangement, Hofmann rearrangement, Curtius rearrangement, Schmidt rearrangement, Beckmann rearrangement. Rearrangement to electron deficient oxygen: Baeyer Villiger reaction, Dakin reaction. Intermolecular migration from nitrogen to carbon. Aromatic arrangements: Orton rearrangement, Fischer-Hepp rearrangement, Hofmann-Martius rearrangement, Bamberger rearrangement.</p>						
<b>UNIT-II</b>	<b>Named Organic Reactions</b>	<b>11 hours</b>				
<p>Baylis-Hillman reaction, Eschenmoser methenylation, Staudinger reaction, Horner – Wadsworth – Emmons reaction, McMurry coupling, Nazarov cyclization, Nef reaction, Ritter reaction, Eschenmoser – Tanabe fragmentation, Hofmann – Löffler – Freytag reaction, Julia – Lythgoe olefination, Koenig – Knorr glycosidation, Mitsunobu reaction, Peterson olefination, Shapiro reaction, Sommelet reaction, Von Braun reaction, Fischer-Indole synthesis, Ramberg – Bäcklund reaction. Hell – Volhard – Zelinski reaction. Claisen ester condensation, Darzen reaction, Dieckmann reaction, Perkin reaction, Prins reaction, Mannich reaction, Michael reaction, Robinson annulation, and Wittig reaction.</p>						
<b>UNIT-III</b>	<b>Photochemistry &amp; Pericyclic Reactions</b>	<b>11 Hours</b>				
<p>General principles, photosensitization and PET reactions, photochemistry of carbonyl compounds. photochemistry of alkenes, photochemistry of aromatic compounds, Norrish Type I and II, Paterno Buchi reaction, Barton reactions, chemi and bioluminescence reactions, Photochemical rearrangements: Dienone rearrangements, di – <math>\pi</math> methane rearrangements, photo – Fries rearrangements. Definition and types of reactions classified as pericyclic actions. (a) cycloaddition and reversion: Diels – Alder reaction, endo – exo selectivity, 1,3-dipolar additions (azide, diazo, nitrones). (b) Electrocyclic ring closing and</p>						

ring opening. (c) Sigmatropic rearrangements: Cope rearrangement, Claisen rearrangement, (2,3) – sigmatropic rearrangement. (d) Cheletropic reactions. Molecular orbital symmetry – based explanations of pericyclic reactions: FMO and PMO approaches.		
<b>UNIT-IV</b>	<b>Synthetic Reagents &amp; Multistep Organic Synthesis</b>	<b>12 Hours</b>
<p>N – Bromosuccinimide (NBS), diazomethane, dicyclohexyl carbodiimide (DCC), selenium dioxide, Dichloro – dicyano – benzoquinone (DDQ), di-isobutyl aluminium hydride (DIBAL), lithium diisopropylamide (LDA).</p> <p>Concept of retrosynthesis, synthons, and synthetic equivalents, protecting groups (hydroxyl, amino carbonyl and carboxylic acid protecting groups), activating groups, leaving groups, types of selectivities (chemo, regio and stereo selectivity). Stereospecific vs stereoselective reactions. Synthetic planning illustrated by simple molecules, disconnections and functional group inter conversions. Umpolung reactions and use in synthesis. Retro synthetic analysis of a complex molecule – a case study.</p>		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<b>A. Single Step Preparations</b>		
<ol style="list-style-type: none"> <li>1. Preparation of dibenzalacetone</li> <li>2. Preparation of phthalimide</li> <li>3. Preparation of glyptal resin</li> <li>4. Preparation of benzalaniline</li> <li>5. Preparation of benzoic acid and benzyl alcohol from benzaldehyde</li> </ol>		
<b>B. Multistep Organic Synthesis</b>		
<ol style="list-style-type: none"> <li>6. Preparation of phthalimide from phthalic acid</li> </ol>		
<b>Total Lecture + Practical Hours</b>		<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Advanced organic chemistry, J. March, Wiley Interscience, New York.</li> <li>2. Principles in organic synthesis, R. O. C. Norman and E. M. Coxon, CRC Press, New York.</li> <li>3. Name reactions: A collection of detailed mechanisms and synthetic applications, J. J. Li, Springer.</li> <li>4. Strategic applications of named reactions in organic synthesis, L. Kurti and B. Czako, Elsevier Academic Press.</li> <li>5. Photochemistry and pericyclic reactions, J. Singh, New Age International.</li> <li>6. Organic chemistry, J. McMurry, Brooks/Cole.</li> <li>7. Designing organic synthesis: Programmed introduction to the synthon approach, S. Warren, Wiley.</li> <li>8. Reagents for organic synthesis, Fieser &amp; Fieser, John Wiley &amp; Sons.</li> <li>9. Modern synthetic methods, Carruthers, Cambridge University Press.</li> <li>10. Vogel's textbook of practical organic chemistry, A. R. Tatchell, John Wiley.</li> </ol>		

<b>Course Code</b>	<b>NSC8C 505</b>	<b>ADVANCED ELECTROCHEMISTRY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in physical chemistry and electrochemistry		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
The main objectives of the course are to: <ul style="list-style-type: none"> <li>• Understand the fundamental concepts of electrochemistry.</li> <li>• Learn the method of solving problems mathematically.</li> <li>• Learn some important analytical methods based on electrochemistry.</li> <li>• Learn the chemistry behind advanced electrochemical devices.</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Remember the fundamentals of electrochemistry – K1</li> <li>2. Understand some electrochemical systems – K2</li> <li>3. Application of electrochemistry in analytical technique– K3</li> <li>4. Electrochemistry in energy production and storage devices – K2, K3, K5</li> </ol>						
K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6- Create						
<b>UNIT-I</b>	<b>Electrochemistry - I</b>				<b>11 Hours</b>	
Electrolytes and non-electrolytes. Activities and activity coefficients. Mean ionic activity and ionic strength. Debye-Hückel limiting law (qualitative and quantitative tests). Ionic strength, mechanism of electrolytic conductance. Debye-Hückel theory of ionic interactions. Asymmetry/relaxation effect and electrophoretic effect. Debye-Hückel-Onsager equation (validity and deviations). Electrolytic conductance – Kohlrausch's law and its applications, deviations from Onsager relation. Wien effect and Debye-Falkenhagen effect.						
<b>UNIT-II</b>	<b>Electrochemistry - II</b>				<b>13 hours</b>	
Electrochemical cells and reactions, energy levels of electrons and potential variation during redox processes, current-potential curves. Faradaic and non-Faradaic processes, polarization of electrodes, polarizable and non-polarizable electrodes and their I-V characteristics, factors affecting electrode reaction rate and current, effect of electrode potential on Gibbs free energy of activation, Butler-Volmer equation, exchange current density and activation over potential, Tafel equation and Tafel plot. Concentration cells. Electrode and electrolyte concentration cells. Electrical double layer and its different models, Liquid junction potential and its determination. Concentration polarization, dissolution, and decomposition potentials. Overvoltage. Hydrogen over-voltage, factors influencing overpotential.						
<b>UNIT-III</b>	<b>Electroanalytical Methods</b>				<b>13 Hours</b>	
General principles of potentiometry. Different types of electrodes. Microelectrode - potential and current variations at the microelectrode systems. Voltammetry, different potential types. Linear sweep, differential pulse, and cyclic voltammetry. Principle and application of chronopotentiometry, polarography, amperometry, coulometry, anodic stripping						

voltammetry, spectroelectrochemistry, electrochemical impedance spectroscopy, scanning electrochemical microscopy, and quartz crystal microbalance.		
<b>UNIT-IV</b>	<b>Applications of Electrochemistry</b>	<b>8 Hours</b>
Storage devices: working principle and storage mechanism in battery and supercapacitor. Fuel cell: working principle and different types. Electrocatalysis. Electrochemical sensors.		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Determination of equivalent conductance of (i) a strong electrolyte (KCl) and (ii) a weak electrolyte (acetic Acid) with concentration and to verify Debye - Hückel - Onsager equation.</li> <li>2. Conductometric titration: Strong acid vs strong base.</li> <li>3. Conductometric titration: Weak acid vs strong base.</li> <li>4. Conductometric titration: Weak acid vs weak base.</li> <li>5. Conductometric titration: Estimation of the amount of strong acid (HCl) and weak acid present in the given mixture against a strong base.</li> <li>6. To study the titration curve for an acid with alkali potentiometrically and to determine the normality of the given acid solution.</li> </ol>		
<b>Total Lecture + Practical Hours</b>		<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Electrochemical methods: Fundamentals and applications; A. J. Bard and L. Faulkner; Wiley.</li> <li>2. An introduction to electrochemistry; S. Glasstone; East-West Press Private Ltd.</li> <li>3. Fundamentals of electrochemistry; V. S. Bagotsky; Wiley.</li> <li>4. Modern electrochemistry - Volume 1, 2a and 2b; John O'M. Bockris and Amulya K. N. Reddy P; Kluwer Academic Publishers.</li> <li>5. Fundamentals of analytical chemistry; D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, Brooks/Cole, Cengage Learning.</li> <li>6. Analytical electrochemistry; J. Wang, Wiley.</li> <li>7. Energy storage devices for electronic systems: Rechargeable batteries and supercapacitors; N. Kularatna, Academic Press.</li> <li>8. Experimental physical; Gurdeep Raj; Krishna Prakasha.</li> <li>9. Experiments in physical chemistry; D. F. Schomaker and C. W. Garland; McGraw Hill.</li> <li>10. Vogel's textbook of quantitative chemical analysis; G. H. Jeffery, J Bassett, J. Mendham, and R. C. Denney; Longman Scientific &amp; Technical.</li> </ol>		

<b>Course Code</b>	<b>NSC8C 506</b>	<b>QUANTUM MECHANICS- I</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general physics, Chemistry, and mathematics.	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ul style="list-style-type: none"> <li>• Understand the evolution of quantum mechanics.</li> <li>• Introduce the quantum mechanical postulates in physical systems.</li> <li>• Learn quantum mechanical formalism for different physical systems</li> <li>• Learn the concepts of angular and spin moneta.</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Learn to describe the failure of classical mechanics for microscopic systems – K1, K2</li> <li>2. Understand different postulates and Learn to Solve Schrodinger equation for simple systems – K3, K4</li> <li>3. Understand angular momentum and spin dynamics of quantum systems and to solve angular momentum using CG coefficients – K3, K4</li> <li>4. Problem solving, evaluation and analysis capacity – K3, K4, K5</li> </ol>						
K1– Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate						
<b>UNIT-I</b>	<b>Origin of quantum mechanics</b>	<b>10 Hours</b>				
Blackbody radiation. Plank's quantum hypothesis, Einstein's photoelectric effect, wave particle duality-de Broglie matter waves, Electron diffraction, Heisenberg's Matrix Mechanics (brief mention), Schrodinger wave mechanics, Deduction of Schrodinger equation from classical wave equation.						
<b>UNIT-II</b>	<b>Postulates of quantum mechanics</b>	<b>10 hours</b>				
All postulates in detail. Wave function postulate. Operator postulate. Eigen value postulate. Expectation value postulate. Time dependent postulate. Formulation of quantum mechanical problem. Solving problems.						
<b>UNIT-III</b>	<b>Quantum mechanics in different systems</b>	<b>13 Hours</b>				
Quantum mechanics of translational motion- particle in 1D and 3D box. Tunneling. Vibrational motion- One-dimensional harmonic oscillator. Rotational motion- Rigid rotator. Spherical harmonics. Quantization of angular momentum, quantum mechanical operators corresponding to angular momenta ((Lx, Ly, Lz), commutation relations between these operators. Matrix Representation of Angular Momentum Operators. Addition of angular momenta. Clebsh-Gordon coefficients. Spin Angular Momentum- Spin 1/2 and the Pauli Matrices. Coupling of Orbital and Spin Angular Momenta.						
<b>UNIT-IV</b>	<b>Quantum mechanics of Hydrogen like atoms</b>	<b>12 Hours</b>				
Potential energy of hydrogen-like systems. The wave equation in spherical polar coordinates, Separation of variables. The R, Theta and Phi equations and their solutions. Wave functions and energies of hydrogen-like atoms, Orbitals. Radial functions and Radial distribution of functions and their plots Angular functions and their plots, Orbital diagrams. Hydrogen spectrum. The postulate of spin by Unlebeck and Goldsmith, Dirac's Relativistic Schrodinger equation for hydrogen atom and discovery of spin.						

<b>UNIT-V</b>	<b>Computational Lab I</b>	<b>30 Hours</b>
<ul style="list-style-type: none"> <li>• Use of different software for data analysis</li> <li>• Writing Z-matrix</li> <li>• Graph plotting</li> <li>• Familiarizing different software for reference management</li> <li>• Use of chemdraw/chemsketch/marvinsketch</li> </ul>		
	<b>Total Lecture Hours</b>	<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. A Textbook of Quantum Mechanics, P. M. Mathews &amp; K. Venkatesan, Tata McGraw Hill, (2010).</li> <li>2. Quantum Chemistry, D. A. McQuarrie, University Science Books, 1983 (first Indian edition, Viva books, 2003).</li> <li>3. Modern Quantum Mechanics, J. J. Sakurai and Jim Napolitano, Cambridge University Press, third edition, 2020.</li> <li>4. Problems and solutions in quantum mechanics, K. Tamvakis, Cambridge University Press, 2005.</li> <li>5. Quantum Physics, Florian Scheck, Springer Science &amp; Business Media, 2007.</li> <li>6. Introduction to Quantum Mechanics, D. J. Griffiths, Cambridge University Press.</li> <li>7. Quantum Chemistry, I. N. Levine, 6<sup>th</sup> Edition, Pearson Education Inc.,</li> <li>8. Molecular Quantum Mechanics, P. W. Atkins and R. S. Friedman, 4<sup>th</sup> Edition, Oxford University Press, 2005.</li> <li>9. Quantum Mechanics in Chemistry, M. W. Hanna, 2<sup>nd</sup> Edition, W. A. Benjamin Inc., 1969.</li> <li>10. Physical Chemistry – Quantum Mechanics, HoriaMetiu, Taylor &amp; Francis, 2006.</li> <li>11. Introduction to Quantum Mechanics, L. Pauling and E. B. Wilson, McGraw-Hill, 1935 (A good source book for many derivations).</li> <li>12. Quantum Chemistry, R. K. Prasad, 3<sup>rd</sup> Edition, New Age International, 2006.</li> <li>13. Lectures on Chemical Bonding and Quantum Chemistry, C. N. Datta, Prism Books Pvt. Ltd., 1998.</li> </ol>		

<b>Course Code</b>	<b>NSC8E 506</b>	<b>PRECISION NANOCLUSTERS: ORIGIN AND APPLICATIONS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>			<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
The main objectives of the course are to:						
<ol style="list-style-type: none"> <li>To understand the applications of various precision nanomaterials in different aspects of science.</li> <li>To Analyze the potentials of precision nanoprobe in cancer therapeutics.</li> <li>To evaluate the uses of different nanoprobe in catalysis, sensing, fabrication of solar cells and light-emitting devices.</li> <li>To create new functional nanoprobe for advanced applications.</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>This course is designed to understand (K1) the applications of precision nanomaterials in different aspects of science, including catalysis, sensing, fabrication of solar cells and light-emitting devices, and biology (K3, K6).</li> <li>This particular course module will help students to analyse (K2) each precision nanoprobe at the laboratory level.</li> <li>Towards the end of this course, students could evaluate (K3) which precision nanoprobe will be ideal for specific applications.</li> <li>Such experience will help to create (K4) novel precision materials during their Ph.D. career.</li> </ol>						
K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6-Create						
<b>UNIT-I</b>	<b>Precision Nanoclusters: Origin, Synthesis, &amp; Characterization</b>				<b>12 Hours</b>	
Polydisperse nanoparticles to monodisperse nanoparticles and monodisperse nanoparticles to atomically precise nanoclusters – Brust synthesis and beyond. Electronic and geometric stability of nanoclusters (magic numbers). Size-focused synthesis of gold nanoclusters (eg: Au <sub>25</sub> (SR) <sub>18</sub> ): chemical reduction method, LEIST methodology, carbon monoxide reduction method. Different isolation techniques: fractionated precipitation, recrystallization, solvent extraction, polyacrylamide gel electrophoresis, size exclusion chromatography, high performance liquid chromatography, thin layer chromatography. Crystal structure of nanoclusters (eg: Au <sub>25</sub> (SR) <sub>18</sub> ).						
<b>UNIT-II</b>	<b>Optical Properties of Nanoclusters</b>				<b>8 hours</b>	
Optical properties: Optical absorption and photoluminescence, aggregation-induced emission, electrochemical properties (Brief).						
<b>UNIT-III</b>	<b>Chemistry of Nanoclusters</b>				<b>13 Hours</b>	
Ligand exchange, ligand conjugation: coupling reaction (EDC or DCC) and click reaction. Self – assembly of nanoclusters using various molecular driving forces (eg: hydrogen bonding, electrostatic interactions, Van der Waals interactions, dipolar interactions, C-						

H $\cdots$ $\pi$ / $\pi\cdots\pi$ interactions, amphiphilicity, metal chelation, metal – metal interactions, light-triggered dipole – induced attractions, and external templates).		
<b>UNIT-IV</b>	<b>Applications of Nanoclusters</b>	<b>12 Hours</b>
Catalysis – oxidation (eg: CO, alcohol), hydrogenation (selective, alkyne, nitro compounds), electron – transfer catalysis, electrocatalysis, photocatalysis. Sensors: cation or anion sensing, biosensing (eg; glucose, ATP, protein, and nucleic acid). Applications in solar cells and light – emitting devices. Biological applications: biolabeling, bioimaging, and cancer therapeutics: photodynamic, and photothermal therapy.		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Estimation of ferrous ions by cerimetry titration</li> <li>2. Estimation of nitrite ion by cerimetry titration</li> <li>3. Determination of viscosity of pure liquids</li> <li>4. Determination of composition of binary liquid mixture using viscometer</li> <li>5. Preparation of salicylaldehyde from phenol</li> <li>6. Preparation of <i>p</i>-nitroaniline from acetanilide</li> </ol>		
	<b>Total Lecture + Practical Hours</b>	<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Atomically precise nanoclusters, Zhu, Y.; and Jin, R. Jenny Stanford Publishing Ltd., (2021).</li> <li>2. Atomically precise metal nanoclusters, Wu, Z.; and Jin, R.; Morgan &amp; Claypool (2020).</li> <li>3. Protected metal clusters from fundamentals to applications, Tsukuda, T.; Häkkinen, H. Elsevier (2015).</li> <li>4. Precision nanoclusters, Pradeep et al. Elsevier (2022).</li> <li>5. Chakraborty, I.; Pradeep, T. Atomically precise clusters of noble metals: Emerging link between atoms and nanoparticles. Chem. Rev. 2017, 117, 8208-8271.</li> <li>6. Jin, R.; Zeng, C.; Zhou, M.; Chen, Y. Atomically precise colloidal metal nanoclusters and nanoparticles: Fundamentals and opportunities. Chem. Rev. 2016, 116, 10346-10413.</li> <li>7. Kang, X.; Zhu, M. Tailoring the photoluminescence of atomically precise nanoclusters. Chem. Soc. Rev. 2019, 48, 2422-2457.</li> <li>8. Rival, J. V.; Mymoona, P.; Lakshmi, K. M.; Nonappa; Pradeep, T.; Shibu, E. S. Self-assembly of precision noble metal nanoclusters: Hierarchical structural complexity, colloidal superstructures, and applications. Small 2021, 17, 2005718.</li> <li>9. Vogel's textbook of qualitative inorganic analysis; G. Svehla and B. Sivasankar; Longman Scientific &amp; Technical.</li> <li>10. Experiments in physical chemistry; D. F. Schomaker and C. W. Garland; McGraw Hill.</li> <li>11. Experimental physical chemistry; Gurdeep Raj; Krishna Prakasha.</li> <li>12. Vogel's textbook of practical organic chemistry, A. R. Tatchell, John Wiley.</li> </ol>		

<b>Course Code</b>	<b>NSC8E 507</b>	<b>NANOSTRUCTURED SOLAR CELLS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in Nanoscience		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. Conscious of energy crisis, its reason, current status and possible solutions</li> <li>2. Recognize renewable and non-renewable energy resources and their contribution towards global energy production</li> <li>3. Importance of re-newable energy resources and tapping such energies</li> <li>4. Role of Nanoscience or nanotechnology in producing novel materials and designs for efficient production of energy using renewable resources</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Analyze the reasons for energy crisis and understand the importance of sustainable energy development (K4,K2)</li> <li>2. Understand Hydrogen economy and advantages and challenges of Hydrogen fuel and its production (K2)</li> <li>3. Understand the possibilities of solar energy production using nanostructured materials and create awareness on using solar panels for house hold and other energy usages. (K2,K6)</li> <li>4. Analyze the importance of different design architectures for efficient tapping of solar energy using nanoscience (K4)</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Primary Perspective in Energy Conversion</b>		<b>10 Hours</b>			
Current energy scenario; Energy and climate: - Greenhouse effect, conventional energy sources Vs non-conventional energy sources. Outline of alternative energy schemes – solar, wind, biomass, hydro, and nuclear. Clean low cost, sustainable energy development, prospects of renewable energy.						
<b>UNIT-II</b>	<b>Photovoltaic Solar Energy Conversion</b>		<b>14 Hours</b>			
Properties of sunlight: Solar radiation at earth's surface- Air Mass. Semiconductors and junctions, carrier generation, Recombination, Carrier Transport, Solar cell operation, Principles of photovoltaic energy conversion (PV), Solar cell parameters, Factors affecting the solar cell efficiency, Types of photovoltaic Cells.						
<b>UNIT-III</b>	<b>Silicon Solar Cells</b>		<b>16 Hours</b>			
Si solar cells- Structure, and working. Optical properties, optical losses, antireflection coating, light trapping. Reducing recombination, Silicon solar cell manufacturing, Silicon wafers, processing technologies, solar cell fabrication technologies, Modules and arrays, inter connection issues, temperature effects and other effects. Efficiency measurements, IV						

Characterization, Life time etc. General materials properties of silicon. Types of silicon solar cells.		
<b>UNIT-IV</b>	<b>Nanostructured Solar Cells</b>	<b>15 Hours</b>
Fundamentals of nanostructured solar cells, nanostructures in conventional thin film solar cells. Dye sensitized solar cells (DSSC), Design and working. Quantum dot sensitized solar cells (QDSSC), Design, working and charge transfer kinetics. Organic solar cell, Organic-Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Nanostructured ETA solar cells, Current status and future direction.		
<b>UNIT-V</b>	<b>Contemporary Issues</b>	<b>5 Hrs.</b>
Expert lectures, General Seminars, online seminars – webinars		
	<b>Total Lecture Hours</b>	<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Nanostructured Materials for Solar Energy Conversion, By Tetsuo Soga, 2006 Elsevier B.V. All rights reserved.</li> <li>2. PVCDROM, "<a href="http://www.pveducation.org">www.pveducation.org</a>",</li> <li>3. Aldo V. da Rosa, <i>Fundamentals of Renewable Energy Processes, 2nd Edition</i> (Elsevier Academic Press, 2009).</li> <li>4. Green Chemistry and Chemical Engineering, Proton Exchange Membrane Fuel Cells Contamination and Mitigation Strategies, By hui Li, Shanna Knights, Zheng Shi, John W. Van Zee, Jin Jun Zhang, Taylor and Francis Group, 2010, USA.</li> <li>5. Martin A. Green, <i>Solar Cells: Operating Principles, Technology, and System Approaches</i> (Prentice-Hall, 1998)</li> <li>6. Jenny Nelson, <i>The Physics of Solar Cells</i> (Imperial College Press, 2003)</li> <li>7. D. Linden Ed., <i>Handbook of Batteries</i>, 2<sup>nd</sup> edition, McGraw-Hill, New York (1995)</li> <li>8. G.A. Nazri and G. Pistoia, <i>Lithium Batteries: Science and Technology</i>, Kulwer Academic Publishers, Dordrecht, Netherlands (2004).</li> <li>9. J. Larminie and A. Dicks, <i>Fuel Cell System Explained</i>, John Wiley, New York (2000).</li> </ol>		

**NSC8M 502 MOOC II ONLINE Course - 4 Credits**

<b>Course Code</b>	<b>NSC9C 601</b>	<b>ORGANOMETALLIC CHEMISTRY, BIO-INORGANIC CHEMISTRY, AND APPLICATIONS OF SPECTROSCOPY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general inorganic chemistry		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<p>The main objectives of the course are to:</p> <ul style="list-style-type: none"> <li>• Understand the importance of organometallic compounds.</li> <li>• Learn the importance of elements in biological systems.</li> <li>• Learn different kinds of metallic and non-metallic clusters.</li> <li>• Learn basics of organometallic compounds.</li> <li>• Understand the applications of spectroscopy in the characterization of organic molecules</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Remember the fundamentals of organometallic compounds – K1</li> <li>2. Understand some organometallic compounds – K2, K3</li> <li>3. Understand and evaluate different metallic and non-metallic clusters – K2, K5</li> <li>4. Understand the importance of elements in biological systems – K1, K4</li> <li>5. Evaluate the overall structure of unknown molecules – K4, K5</li> </ol>						
K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6- Create						
<b>UNIT-I</b>	<b>Metallic &amp; Non-metallic Clusters</b>				<b>13 hours</b>	
<p>General electronic aspects and bonding in metal-metal single, double, triple and quadruple bonded complexes of non-carbonyl clusters. Carbonyl clusters. Carbonyl clusters-LNCCS and HNCCS. Capping rule. Reactions of metal carbonyl clusters, Wade-Mingos rules. IR spectral studies of bridging and non-bridging CO ligands, Isoelectronic and isolobal analogy. Non-metallic clusters. Boron hydrides and borazine. Styx numbers. closo, nido, arachno polyhedral structures. Wade's rule. Structure and bonding of carboranes. Medical applications of boron clusters. Structure and bonding in sulphur phosphorous, phosphorous-sulphur, and sulphur-nitrogen compounds. General features of silicates, alumino-silicates, zeolites, silcones, carbides and silicides.</p>						
<b>UNIT-II</b>	<b>Organometallic Compounds I</b>				<b>12 Hours</b>	
<p>Organometallic compounds. 16 and 18 electron rules, main group organometallics with alkyl and aryl ligands, groups 1, 2, 11,12, 13, 14 and 15 (general features), <math>\sigma</math> – bonded complexes, cyclopentadienyl complexes and bis (arene) complexes. Metal carbenes – Fischer and Schrock carbenes (synthesis and properties), Tebbe's reagent. Transition metal complexes with chain <math>\pi</math> ligands (ethylene, acetylene, allyl and butadiene ligands). Complexes of ring <math>\pi</math> donor ligands (cyclobutadiene, <math>C_5H_5</math>, <math>C_6H_6</math>). Fluxional organometallic compounds.</p>						
<b>UNIT-III</b>	<b>Organometallic Compounds II</b>				<b>11 Hours</b>	
<p>Applications of organometallic compounds. Oxidative addition, reductive elimination, and insertion reactions. Carbonylation by Collman's reagent. Hydrozirconation of alkenes and</p>						

alkynes. Hydrogenation, hydrosilation, isomerization of alkenes, alkyne, cycloadditions, Zeigler-Natta catalysis, hydroformylation of alkenes, Monsanto acetic acid process and Wacker process. Suzuki reaction, Stille coupling reaction and Heck reaction.		
<b>UNIT-IV</b>	<b>Bioinorganic Chemistry</b>	<b>13 Hours</b>
Bulk-and trace metal ions, role of metal ions in biological functions. Biological role of some trace nonmetals. (B, Si, S, Se, As, Cl, Br, I), biological importance of nitric oxide. Ion transport across membranes - Sodium/potassium pump, structural role of calcium. Storage and transport of metal ions-ferritin, transferrin and siderophores. Oxygen transport by heme proteins-hemoglobin and myoglobin, structure of the O <sub>2</sub> binding site, nature of heme-dioxygen binding, cooperativity. Hemerythrin and hemocyanin. A brief idea on structure and function of copper proteins in electron transport process, cytochromes, iron-sulphur proteins, tyrosinase, superoxide, dismutase. Lewis acid role of Zn (II) and Mn (II) containing enzymes, carboxy peptidase, vitamin B <sub>12</sub> and coenzymes. Chlorophyll photosystems I and II. Nitrogen fixation – nitrogenase, anticancer drugs.		
<b>UNIT-V</b>	<b>Applications of Spectroscopy in Organic Compounds</b>	<b>11 Hours</b>
IR absorptions of common functional groups and interpretation of IR spectra of organic molecules, interpretation of mass spectra of organic molecules, base peak and molecular ion, fragmentation patterns of common functional groups, structural determination of organic molecules using <sup>1</sup> H NMR spectroscopy, TMS and chemical shifts, Integration and number of protons, spin – spin splitting and coupling constants, diamagnetic anisotropy, assigning chemical structures from <sup>1</sup> H NMR spectra (aliphatic and aromatic small molecules). Applications of <sup>13</sup> C NMR spectroscopy, chemical shift correlations in <sup>13</sup> C NMR, UV-Vis absorption of conjugated molecules, the effect of conjugation on absorption spectra. Combined spectroscopic problems in the characterization of organic molecules.		
<b>Total Lecture Hours</b>		<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. The organometallic chemistry of the transition metals, R. H. Crabtree, Wiley–Blackwell.</li> <li>2. Basic organometallic chemistry - concepts, synthesis and applications, B. D. Gupta, A. J. Elias, University Press.</li> <li>3. Bioinorganic chemistry, D. E. Fenton, Oxford science publications.</li> <li>4. Principles of bioinorganic chemistry, S. J. Lippard and J. M. Berg, University Science Books, U. S.</li> <li>5. Inorganic chemistry-principles, structure and reactivity, J. E. Huheey, Pearson Education.</li> <li>6. Physical methods in inorganic chemistry, R. S. Drago, Affiliated East West Press.</li> <li>7. Bioinorganic chemistry, R. W. Hay, Ellis Horwood Limited, UK.</li> <li>8. Principles of organometallic chemistry, P. Powell, Chapman and Hall, London.</li> <li>9. Concise co-ordination chemistry, S. F. A. Kettle, Nelson.</li> <li>10. Bioinorganic chemistry, John Wiley &amp; Sons, R. M. Roat-Malone.</li> <li>11. Spectroscopy of organic compounds, P. S. Kalsi, New Age International Private Limited.</li> <li>12. Spectrometric identification of organic compounds, Silverstein, Bassler and T. Morrill, John Wiley.</li> </ol>		

<b>Course Code</b>	<b>NSC9C 602</b>	<b>QUANTUM MECHANICS II</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general physics, Chemistry, and mathematics.	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<p>The main objectives of the course are to:</p> <ul style="list-style-type: none"> <li>Understand various approximation techniques &amp; relativistic quantum mechanics to solve simple systems.</li> <li>Learn the concepts of group theory and symmetry for different chemical systems.</li> <li>Describe the spectra and bonding in compounds in connection with group theory.</li> <li>Learn different computational software and solve simple molecular systems.</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>Solve different molecular systems by suitable approximations – K2, K3, K4</li> <li>Understand the fundamentals spectral transitions and bonding at the molecular level – K3, K4, K5</li> <li>Learn to use different computational softwares – K2, K3, K6</li> <li>Solve simple chemical problems computationally – K3, K6</li> </ol>						
K1– Remember, K2 – Understand, K3 – Apply, K4 – Analysis, K5 – Evaluate, K6- Create						
<b>UNIT-I</b>	<b>Approximation Methods</b>	<b>11 hours</b>				
<p>Perturbation theorem: The WKB approximation, Connection formulae, Barrier tunneling, Application to decay- bound states, Penetration of a potential barrier, Time- independent perturbation theory. Illustration by application to particle in 1D-box with slanted bottom, Perturbation treatment of the ground state of the helium atom. Transition probability. Variation theorem: The variational equation with proof, ground state and excited states, the variation method for bound states, Application to ground state of the hydrogen and helium atoms. HFSCF Method.</p>						
<b>UNIT-II</b>	<b>Relativistic Quantum Mechanics</b>	<b>11 Hours</b>				
<p>The Dirac equation, Dirac matrices, Solution of the free-particle Dirac equation. Spin-orbit coupling, Covariance of the Dirac equation, Bilinear covariants, Hole theory, The Weyl equation equation for the neutrino, Nonconservation of parity, The Klein Gordon equation, Charge and current densities, The Klein- Gordon equation, Charge and current densities, The Klein –Gordon equation equation with potentials, Wave equation for the photon, Charge conjugation for the Dirac, Weyl and Klein Gordon equation.</p>						
<b>UNIT-III</b>	<b>Theories of molecular symmetry</b>	<b>11 Hours</b>				
<p>Introduction to symmetry and point groups. Group multiplication tables. Similarity transformation. Reducible and irreducible representations. Construction of irreducible representations by reduction (similarity transformation). Great orthogonality theorem (GOT) and properties of irreducible representations using GOT, Construction of character Table (C<sub>2v</sub>, C<sub>3v</sub>, C<sub>2h</sub>, C<sub>4v</sub>). Nomenclature of irreducible representations - Mulliken symbols, Symmetry species. Reduction formula using GOT.</p>						

<b>UNIT- IV</b>	<b>Applications of Group Theory</b>	<b>12 Hours</b>
<p>a. Vanishing and non-vanishing integrals. Transition moment integral and selection rules. Overlap integrals and conditions for overlap. Electronic transitions and selection rules, Laporte selection rule for Centro symmetric molecules.</p> <p>b. Molecular vibrations, Selection of rules for IR and Raman activities, complementary character of IR and Raman spectra, Determination of IR active and Raman active modes of molecules.</p> <p>c. Molecular orbital treatment of molecules using Group theory. Treatment of H<sub>2</sub>O.</p> <p>d. Group theoretical treatment of hybridization, Construction of hybrid orbital in BF<sub>3</sub> and Inverse transformation.</p>		
<b>UNIT-V</b>	<b>Computational Lab-II</b>	<b>30 Hours</b>
<ul style="list-style-type: none"> <li>• Use of different graphical user face</li> <li>• Plotting experimental data by different software</li> <li>• PES and Geometry optimization of small molecules</li> </ul> <p>Computing quantum chemical descriptors</p>		
	<b>Total Lecture Hours</b>	<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>5. A Textbook of Quantum Mechanics, P.M. Mathews &amp; K. Venkatesan, Tata McGraw Hill, (2010).</li> <li>6. Quantum Chemistry, Donald, A. McQuarrie, University Science Books, 1983 (first Indian edition, Viva books, 2003).</li> <li>7. Modern Quantum Mechanics, J. J. Sakurai and Jim Napolitano, Cambridge University Press, third edition, 2020.</li> <li>8. Problems and solutions in quantum mechanics, K. Tamvakis, Cambridge University Press, 2005.</li> <li>9. Quantum Physics, Florian Scheck, Springer Science &amp; Business Media, 2007.</li> <li>10. Introduction to Quantum Mechanics, David J. Griffiths, Cambridge University Press.</li> <li>11. Quantum Chemistry, I.N. Levine, 6th Edition, Pearson Education Inc.,</li> <li>12. Molecular Quantum Mechanics, P.W. Atkins and R.S. Friedman, 4th Edition, Oxford University Press, 2005.</li> <li>13. Quantum Mechanics in Chemistry, M.W. Hanna, 2nd Edition, W.A. Benjamin Inc., 1969.</li> <li>14. Physical Chemistry – Quantum Mechanics, HoriaMetiu, Taylor &amp; Francis, 2006.</li> <li>15. Introduction to Quantum Mechanics, L. Pauling and E.B. Wilson, McGraw-Hill, 1935 (A good source book for many derivations).</li> <li>16. Quantum Chemistry, R.K. Prasad, 3rd Edition, New Age International, 2006.</li> <li>17. Lectures on Chemical Bonding and Quantum Chemistry, C.N. Datta, Prism Books Pvt. Ltd., 1998.</li> </ol>		

<b>Course Code</b>	<b>NSC9C 603</b>	<b>MOLECULAR SPECTROSCOPY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general spectroscopy		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
The main objectives of the course are to:						
<ol style="list-style-type: none"> <li>1. Understand the fundamental concepts and principles in molecular spectroscopy.</li> <li>2. Learn the method of solving problems for different molecular systems.</li> <li>3. Understand the concepts of different types of spectra.</li> <li>4. Learn the method of evaluation of chemical problems spectroscopically.</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Remember the fundamentals of concepts and principles in molecular spectroscopy – K1</li> <li>2. Understand concepts of different types of spectra – K2</li> <li>3. Understand different chemical systems with different types of spectra and solving problems based on it – K2, K3</li> <li>4. Problem solving, evaluation and analysis capacity – K3, K4, K5</li> </ol>						
K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6- Create						
<b>UNIT-I</b>	<b>Microwave Spectroscopy</b>	<b>11 hours</b>				
General theory of spectra: Electromagnetic radiation and its different regions, quantization of energy, interaction of matter with radiation and its effect on the energy of the molecule. Origin of molecular spectra. Rotation spectra of diatomic and polyatomic molecules, rigid and non-rigid rotator models, asymmetric, symmetric, and spherical tops. Isotope effect on rotation spectra, Stark effect, nuclear and electron spin interactions. Rotational transitions and selection rules. Microwave spectrometer - principle & applications.						
<b>UNIT-II</b>	<b>IR and Raman Spectroscopy</b>	<b>11 Hours</b>				
Vibrational spectra of diatomic and polyatomic molecules, harmonic oscillator model, anharmonicity. Vibrational transitions and selection rules. Morse potential, fundamentals, overtones, hot bands, combination bands, difference bands. Vibrational spectra of diatomic and polyatomic molecules, P, Q, R branches. IR and FT-IR spectrophotometer – principle, instrumentation, and applications. Pure rotational, pure vibrational Raman spectra, vibrational, rotational Raman spectra, selection rules, mutual exclusion principle. Raman spectrophotometer – principle, instrumentation. Laser Raman spectroscopy, and applications.						
<b>UNIT-III</b>	<b>Electronic Spectroscopy</b>	<b>11 Hours</b>				
Basic principle, Beer-Lambert's law, Molar extinction coefficient, intensity of electronic transitions. Types of electronic transitions. Franck – Condon principle, ground, and excited electronic states of diatomic molecules. Electronic spectra of polyatomic molecules. The fate of electronically excited state species – vibrational relaxation, external conversion, internal conversion, fluorescence, phosphorescence, Jablonski diagram. Electronic spectra of conjugated molecules – dissociation and predissociation spectra. UV-Visible and fluorescence spectrophotometer – principle and applications.						

<b>UNIT-IV</b>	<b>Resonance Spectroscopy</b>	<b>12 Hours</b>
Interaction between nuclear spin and magnetic field, level population, Larmor precession, resonance condition, Bloch equations, relaxation times, spin-spin and spin-lattice relaxation, chemical shift, instrumentation for NMR spectroscopy, electron spin resonance spectroscopy (ESR/EPR) of the unpaired electron, total Hamiltonian, fine structure, electron-nucleus coupling and hyperfine structure.		
<b>UNIT-V</b>	<b>Practical</b>	<b>30 Hours</b>
<ol style="list-style-type: none"> <li>1. Characterization of Cu (II) coordination complexes using FT-IR, Raman, NMR, UV-Vis absorption and fluorescence spectroscopies and XRD analysis</li> <li>2. Characterization of Ni (II) coordination complexes using FT-IR, Raman, NMR, UV-Vis absorption and fluorescence spectroscopies and XRD analysis</li> <li>3. Characterization of organic small molecules using NMR, mass, FT-IR, UV-Vis absorption, and fluorescence spectroscopic technics</li> </ol>		
	<b>Total Lecture + Practical Hours</b>	<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Straughan &amp; Walker; For Mossbauer Effect: Aruldas and G. K. Wertheim.</li> <li>2. Gunther K. Wertheim: "Mossbauer Effect: Principles and applications, (Academic Press).</li> <li>3. Straughan and Walker (Eds): "Spectroscopy"- Vol. I and II (Chapman and Hall).</li> <li>4. G. M. Barrow: "Introduction to molecular spectroscopy", (McGraw Hill).</li> <li>5. D. A. Long: "Raman spectroscopy" McGraw Hill (1977).</li> <li>6. C. N. Banwell &amp; E. N. McCash, Fundamentals of molecular spectroscopy, Tata, McGraw Hill.</li> <li>7. Aruldas, Molecular structure &amp; spectroscopy, Prentice Hall, India.</li> <li>8. F. W. Atkins, Physical chemistry, Oxford University Press.</li> <li>9. Silverstein, Bassler, Monill – Spectroscopic identification of organic compound; John Wiley &amp; Sons, 1991.</li> <li>10. Kemp – Organic spectroscopy; McMillan, 1996.</li> <li>11. R. S. Drago, Physical methods for chemists, W. B. Saunders (1992).</li> <li>12. Pavia, Spectroscopy of organic compounds, Sounde Publications.</li> <li>13. J. B. Lambert, H. F., Shurvell, D. A. Lightner and R. G. Cooks, Organic structured spectroscopy, Prentice Hall.</li> <li>14. NMR Spectroscopy: Basic principle, concepts, and applications in chemistry by Harald Gunther; John Wiley &amp; Sons, <b>2013</b>; ISBN: 9783527330003.</li> <li>15. Modern spectroscopy by J. Mixhael Hollas; John Wiley &amp; Sons, <b>2004</b>, ISBN: 9780470844168.</li> <li>16. Vogel's textbook of practical organic chemistry, A. R. Tatchell, John Wiley.</li> <li>17. Vogel's textbook of qualitative inorganic analysis; G. Svehla and B. Sivasankar; Longman Scientific &amp; Technical.</li> <li>18. Vogel's textbook of quantitative chemical analysis; G. H. Jeffery, J Bassett, J. Mendham and R. C. Denney; Longman Scientific &amp; Technical.</li> </ol>		

<b>Course Code</b>	<b>NSC9E 601</b>	<b>ADVANCED ANALYTICAL TECHNIQUES</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in, Physical, Chemical or Biological sciences	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. To familiarize and understand the fundamental principles and concepts of characterization of nanostructured materials.</li> <li>2. To categorize and understand the different techniques used for studying the structural, optical, morphological, thermal, magnetic and electrochemical properties of nanomaterials.</li> <li>3. To understand the working principle and instrumentation of the characterization instruments.</li> <li>4. Evaluation and analysis of experimental data obtained from different instrumentation techniques</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Recognize various characterization techniques available for the studying different properties of nanostructured materials (K1)</li> <li>2. Apply the knowledge gained to correctly choose the most suitable characterization technique for studying the properties of nanomaterials (K3)</li> <li>3. Effectively use the knowledge gained in analyzing the obtained characterization data. (K4, K5)</li> <li>4. Evaluate the characterization data and nurture the ability to explain the underlying mechanism. (K5)</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT - I</b>	<b>Electron Microscopy</b>	<b>13 Hours</b>				
Scanning Electron Microscopy (SEM): Instrumentation – Mechanism of image formation and its processing; Transmission Electron Microscopy (TEM): Instrumentation – Bright field and dark field imaging – Analysis of Micrographs – HRTEM – Selected Area Electron Diffraction						
<b>UNIT - II</b>	<b>Probe and Optical Microscopy</b>	<b>14 Hours</b>				
Atomic Force Microscopy: Instrumentation – analysis of surface roughness of thin films; Scanning Tunnelling Microscopy (STM): Instrumentation – analysis of conductivity of thin films; Near field scanning optical microscopy (NSOM); Principles of Fluorescence microscopy; Confocal Laser Scanning Microscopy						
<b>UNIT - III</b>	<b>Thermal, Mechanical and Magnetic Techniques</b>	<b>14 Hours</b>				
Thermal Analysis: TGA, DTG, DTA, DSC - combustion calorimetry – Thermal diffusivity by						

the laser flash technique – simultaneous techniques including analysis for gaseous products. Mechanical testing: Introduction – tension testing – High strain rate testing of materials – Fracture Toughness testing methods – Hardness testing; Magnetic Vibrating Sample Magnetometer,		
<b>UNIT - IV</b>	<b>Structure and Surface Analysis and Electrochemical Techniques</b>	<b>14 Hours</b>
X-ray powder diffraction: principles and practices. Small angle X-ray diffraction, GIXRD, and Single crystalline X-ray diffraction. Hydrophobic and hydrophilic surfaces, Super hydrophobicity, and hydrophilicity, contact angle. Photoelectron spectroscopy (X-ray and Ultraviolet). BET surface area and porosity analysis; Electrochemical Techniques: Cyclic voltammetry – Electrochemical Impedance		
<b>UNIT - V</b>	<b>Contemporary Issues</b>	<b>5 Hrs.</b>
Expert lectures, General Seminars, online seminars – webinars		
<b>Total Lecture Hours</b>		<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, <b>ISBN-13:</b> 978-81-203-3608-7.</li> <li>2. Characterization of Materials Vol 1 &amp;2, by Elton N. Kaufmann, John Wiley and Sons Publication, 2003. New Jersey.</li> <li>3. Principles of instrumental analysis, Douglas A Skoog, Donald M West, Saunders College, Philadelphia. □ <b>Publisher:</b> Cengage; 6 edition (1 November 2014) <b>ISBN-13:</b> 978-81-315-25579.</li> <li>4. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi ) <b>ISBN-13:</b> 978-0-07-061788-9</li> <li>5. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander, <b>Publisher:</b> Wiley-Blackwell; 2nd Revised edition edition (1 January 1974) <b>ISBN-13:</b> 978-0471493693</li> <li>6. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter, <b>Publisher:</b> Springer; 1st ed. 1996. Corr.6<sup>th</sup> printing edition (15 April 2005) <b>ISBN-13:</b> 978-0306453243</li> <li>7. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton , <b>Publisher:</b> Springer; Softcover reprint of hardcover 1st ed. 2005 edition (12 October 2010) <b>ISBN-13:</b> 978-1441938374</li> <li>8. Springer handbook of Nanotechnology ed. Bharat Bhushan (Springer), <b>Publisher:</b> Springer-Verlag (15 May 2006) <b>ISBN-13:</b> 978-3540343660.</li> <li>9. Handbook of Analytical Techniques by Helmut Gunzler and Alex Williams, <b>Publisher:</b> Wiley-VCH, <b>2001</b>; ISBN: 9783527301652.</li> <li>10. 2. Surface Analysis Methods in Materials Science by J. O'Connor, B. Sexton, R. Smart, <b>Publisher:</b> Springer, <b>2003</b>; ISBN: 9783540413301.</li> <li>11. Modern Techniques of Surface Science by D.P. Woodruff, <b>Publisher:</b> Cambridge University Press, <b>2016</b>; ISBN: 9781139149716.</li> </ol>		

<b>Course Code</b>	<b>NSC9E 602</b>	<b>MICRO/NANO ELECTRO-MECHANICAL SYSTEMS (MEMS/NEMS)</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in nanoscience and nanodevices		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. Understand an overview of MEMS and NEMS</li> <li>2. Understand different fabrication methods of MEMS/NEMS</li> <li>3. Identify the applications of MEMS/NEMS</li> <li>4. Understand different materials used for MEMS/NEMS</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Understand the basics and working principles of MEMS/NEMS (K2)</li> <li>2. Recognize different application potential of MEMS/NEMS (K2)</li> <li>3. Compare the various methods of fabrication of MEMS/NEMS (K4)</li> <li>4. Use MEMS and NEMS for sensing purpose (K5)</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Overview and introduction</b>		<b>12 Hours</b>			
New trends in Engineering and Science: Micro and Nanoscale systems, Overview of Nano and Microelectromechanical Systems, Introduction to Design of MEMS and NEMS, Applications of Micro and Nanoelectromechanical systems, Micro-electromechanical systems, devices and structures Definitions, Microfabrication: Introduction						
<b>UNIT-II</b>	<b>Materials for MEMS and Microsystem</b>		<b>12 Hours</b>			
Introduction, Substrates and Wafers, Silicon as Substrate materials, Silicon Compounds, Silicon Piezo-resistors, Gallium Arsenide, Quartz, Piezoelectric crystals, Polymers.						
<b>UNIT-III</b>	<b>Fundamentals of MEMS Fabrication</b>		<b>12 Hours</b>			
Introduction, Photolithography, ion implantation, Diffusion, Oxidation, Chemical vapor deposition, sputtering, Deposition by Epitaxy, Etching, MEMS fabrication technologies-bulk micromachining, Surface micromachining, High-aspect-ratio (LIGA and LIGA-Like) technology						
<b>UNIT-IV</b>	<b>Working Principles of microsystems</b>		<b>14 Hours</b>			
Introduction, Microsensors - Acoustic wave sensors, Biomedical and biosensors, chemical sensors, optical sensors, pressure sensors, thermal sensors, Microactuation-Actuation using thermal forces, piezoelectric effect, electrostatic effect. MEMS with microactuators-microgrippers, miniature microphones, micromotors.						
<b>UNIT-V</b>	<b>Microsystem Design</b>		<b>10 Hrs.</b>			
Design considerations-materials, manufacturing processes, Signal transduction, Process design-Photolithography, Thin-film fabrication, Geometry shaping, Mechanical design.						

	<b>Total Lecture Hours</b>	<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Tai-Ran Hsu, MEMS and Microsystems- Design, Manufacture and Nanoscale Engineering, John Wiley &amp; Sons, INC. 2008. <b>ISBN:</b> 978-0-470-08301-7.</li> <li>2. MEMS and NEMS: Systems, Devices, and Structures Sergey Edward Lyshevski . CRC PRESS ISBN: 0-8493-1262-0</li> <li>3. Mohamed Gad – el – Hak, “The MEMS Handbook”, Second Edition, CRC Press, 2005.</li> <li>4. James J. Allen, “Micro Electro Mechanical System Design”, CRC, 2005.</li> <li>5. K. Subramanian, “Micro Electro Mechanical Systems: A Design Approach”, Springer, 2008.</li> </ol>		

<b>Course Code</b>	<b>NSC9E 603</b>	<b>COMPUTATIONAL NANOTECHNOLOGY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general physics, Chemistry and mathematics.		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
The main objectives of the course are to: <ul style="list-style-type: none"> <li>• Understand different computational tools.</li> <li>• Learn to write z-matrix for simple systems.</li> <li>• Understand different kinds of modelling and simulations.</li> <li>• Evaluate different computed results through various methods.</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Introduction to different computational tools – K2</li> <li>2. Understand the need and importance of computational studies in supporting scientific results – K3, K4</li> <li>3. Learn to write inputs for computational calculations – K2, K3, K6</li> <li>4. Understand different simulations and applications by using through software – K3, K5, K6</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Basic principles</b>		<b>9 Hours</b>			
Potential energy scanning, saddle points, Stable conformer-local and global minima. Geometry optimization, Molecular orbital, charges, electron density. RA approximation. Van der waal's corrections. Frequency calculation. Interaction energy. ESP map. Solvent Continuum models. Fock matrices.						
<b>UNIT-II</b>	<b>Computational Methods and Basis sets</b>		<b>12 Hours</b>			
Basis sets- different types: Basis set truncation error. Correlation energy. Basis set limit. Slater type orbitals and Gaussian type orbitals; z-matrix- basic idea and construction. General classification- Classical and quantum mechanical. Molecular mechanics. Semi-Empirical method. Ab initio method. Density functional theory method. Molecular dynamics. ONIOM method. Simulations.						
<b>UNIT-III</b>	<b>Computational Analysis</b>		<b>12 Hours</b>			
Z-matrix of small molecules like H <sub>2</sub> O, HCHO, CH <sub>3</sub> OH and H <sub>2</sub> O <sub>2</sub> . Global reactive descriptors. Fukui descriptors. QSAR/QSPR study; TDDFT. Analysis of MOs; NBO analysis. Thermal properties. Marcus theory (Detailed analysis). Restricted and unrestricted analysis.						
<b>UNIT - IV</b>	<b>Computational Nanotechnology</b>		<b>12 Hours</b>			

Quantum confinement; change in properties with size. Applications of computational studies in nanotechnology. Simulations-different types-Monte Carlo Methods. Nano-computing and modelling. Computing transport in materials. Nanodesign-Nano-CAD. Nanomedicine (brief study only)		
<b>UNIT-V</b>	<b>Computational Lab - III</b>	<b>30 Hrs.</b>
<ul style="list-style-type: none"> <li>• PES and geometry optimizations of large molecules</li> <li>• Spectroscopic analysis of compounds</li> <li>• Thermochemical analysis</li> <li>• Correlation study - Statistical analysis</li> <li>• 2D-QSAR modelling</li> <li>• Monte Carlo Simulation</li> <li>• BDE calculation</li> <li>• pKa calculation</li> </ul>		
	<b>Total Lecture Hours</b>	<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. D. Frenkel and B. Smith, —Understanding molecular simulation from algorithm to applicationsII, Kluwar Academic Press, 1999.</li> <li>2. K. Ohno, K. Esfarjani and Y. Kawazoe, —Introduction to Computational Materials Science from ab initio to Monte Carlo MethodsII, Springer-Verlag, 1999.</li> <li>3. Jenson F, Introduction to Computational Chemistry – John Wiley</li> <li>4. Cramer C.J., Essentials of Computational Chemistry – John Wiley</li> <li>5. Young, Computational Chemistry – Wiley Inter Science</li> <li>6. Andrews R. Leach, Molecular Modeling – Pearson</li> <li>7. Ramachandran K.I et al computational Chemistry and Molecular Modeling Springer.</li> <li>8. Schlick. T., Molecular Modeling and Simulations, Springer.</li> <li>9. Python for Education, Ajith Kumar B.P. IUAC, New Delhi; free e-book.</li> <li>10. Introduction to Python for Engineers and Scientists by Dr.Sandeep Nagar, Apress publications</li> </ol>		

<b>Course Code</b>	<b>NSC9E 604</b>	<b>DESIGN, SYNTHESIS AND PROPERTIES OF NANOMATERIALS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Elective</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in physics, chemistry and nanoscience	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<p>The main objectives of the course are to:</p> <ol style="list-style-type: none"> <li>1. Understand different top-down and bottom-up approaches available for nanomaterials synthesis.</li> <li>2. Apply the knowledge on synthesis to properly design an experiment for tuning the size, shape and properties of the nanostructures</li> <li>3. Understand and apply different lithographic techniques for the fabrication of nanostructures</li> <li>4. Understand the fundamental principles and concepts related to the optical, electrical, magnetic, thermal and mechanical properties</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Understand physical, chemical, and lithographic techniques available for the preparation of nanoparticles or nanostructures and apply the knowledge to select a proper synthetic approach for a specific application (K2, K5)</li> <li>2. Create experimental design to control the size, shape, distribution and properties of nanoparticles (K6)</li> <li>3. Apply and analyze the design criteria for the fabrication of nanostructures by lithography (K3,K4)</li> <li>4. Evaluate and correlate the structure-property optimization using the data collected from different analysis (K5,K6)</li> <li>5. Apply the size and shape dependence of materials properties for tuning the material for various applications (K3)</li> <li>6. Review the advantages of using nanostructured materials for various applications and the challenges that will face while using nanomaterials (K5)</li> </ol>						
K1 – Remember K2 – Understand K3 – Apply K4 – Analyze K5 – Evaluate, K6- Create						
<b>UNIT-I</b>	<b>Physical and Chemical Methods</b>				<b>15 Hours</b>	
<p>Physical Vapour deposition techniques (PVD): Sputtering &amp; e-beam Evaporation. Atomic layer deposition, Chemical vapour deposition method (CVD), Molecular beam epitaxy(MBE), &amp; Electrospinning, Ball Milling. Chemical Methods: Nanoparticles through homogeneous &amp; heterogenous nucleation in solution:-Co-precipitation method, Hydrothermal/ Solvothermal synthesis, Template based synthesis, Electrochemical synthesis, Sonochemical routes, Sol- gel, Micelles and microemulsions. Self-assembly methods and Langmuir Blodgett (LB) method.</p>						

<b>UNIT-II</b>	<b>Lithographic Techniques</b>	<b>10 hours</b>
Lithography- Photolithography- Laser lithography and SPM based lithography (AFM & STM), Dip pen lithography and nanomanipulation. E-beam/SEM lithography. X-ray Lithography, Focused Ion beam lithography.		
<b>UNIT-III</b>	<b>Optical Properties of Nanostructures</b>	<b>10 Hours</b>
Interaction of light with matter. The nano perspective. The surface plasmon resonance-applications of nano plasmonics. Quantum dots – Optical properties related to quantum confinement. Special luminescent materials - electroluminescence- photochromic and electrochromic nanomaterials.		
<b>UNIT-IV</b>	<b>Electrical properties of Nanostructures</b>	<b>10 Hours</b>
Electrical conductivity in one dimensional nanostructure (CNTs). Electronic transport in nanostructures, single electron transfer devices (SETs). Molecular electronics: transport properties of molecular wires. Molecular devices.		
<b>UNIT-V</b>	<b>Practical Experiments</b>	<b>30 Hrs.</b>
<ol style="list-style-type: none"> <li>1. Chemical synthesis of CdSe Quantum dots with five different sizes.</li> <li>2. Band gap determination and size estimation of CdSe quantum dots by using optical spectroscopy</li> <li>3. Emission behaviour of CdSe QDs by using Spectrofluorometer</li> <li>4. Chemical Synthesis of Two different magnetic nanoparticles and size determination from XRD.</li> <li>5. Metal chalcogenide film with different thickness via SILAR method and thickness measurements by profilometer</li> <li>6. Wet chemical synthesis of ZnO nanoparticles and optical studies using UV-Vis Spectroscopy</li> <li>7. Au nano rod preparation and record the SPR spectrum using UV-Vis Spectroscopy</li> <li>8. Polyaniline synthesis and study the chemical structure using FTIR spectroscopy</li> </ol>		
<b>Total Lecture Hours</b>		<b>75 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Nanostructures and Nanomaterials- Synthesis, Properties &amp; applications by GuozhongCao , Imperial college Press, (2006). <b>Publisher:</b> World Scientific Publishing Company; 2 edition (4 January 2011) <b>ISBN-13:</b> 978-9814324557</li> <li>2. An introduction to Electrospinning and Nanofibers by Seeram Ramakrishna, KazutoshiFujihara, Wee Eong Tee, Teck Cheng Lim, Zaveri Ma, World Sci. Pub. Ltd. Singapore, 2005, <b>Publisher:</b> World Scientific Publishing Co Pte Ltd (8 May 2005) <b>ISBN-13:</b> 978-9812564542</li> <li>3. Springer Handbook of Nanotechnology - Bharat Bhusan, <b>Publisher:</b> Springer-Verlag (15 May 2006) <b>ISBN-13:</b> 978-3540343660</li> <li>4. Introduction to Nanoscience &amp; Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor &amp; Francis Group New York, 2009. <b>Publisher:</b> CRC Press (15 December 2008) <b>ISBN-13:</b> 978-1420047790</li> <li>5. Introduction to Nanoscale Science &amp; Technology, Di Ventra, Evoy, Heflin, Springer Science, NY, 2004, <b>Publisher:</b> Springer; 1 edition (30 June 2004)</li> </ol>		

**Sold by:** Amazon Asia-Pacific Holdings Private Limited

6. Nanofabrication- Fundamentals and Applications, By Ampere A Tseng, World Scientific, Singapore 2008. □ **Publisher:** World Scientific Publishing Co Pte Ltd (18 March 2008) **ISBN-13:** 978-9812705426
7. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998, **Publisher:** Wiley VCH (28 May 1998) **ISBN-13:** 978-3527294435
8. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens, **Publisher:** Wiley-Interscience; 1 edition (30 May 2003) **Sold by:** Amazon Asia-Pacific Holdings Private Limited.
9. Nanomaterials – An Introduction to synthesis, Properties and Applications, by Dieter Vollath, Wiley – VCH Verlag GmbH & Co. Germany, 2008.
10. Properties of nanomaterials by Charles P. Poole.
11. The Physics & Chemistry of Nanosolids by Frank J. Owens and Charles P. Poole Jr. , John Wiley & Sons, Inc. New Jersey 2008.
1. Introduction to Nanoelectronics, by V. Mitin, V. Kochelap, M. Stroscio, **Cambridge University Press (2008).**
2. Nanoelectronics and Photonics: From Atoms to Materials, Devices, and Architectures by Anatoli Korokin I Federico Rosei, **2008 Springer Science, Business Media, LLC.**
3. Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices, by Rainer Waser, **Wiley-VCH (2003).**
4. Nanoelectronics and Nanosystems, by Karl Gosser, Peter Glosekotter, Jan Dienstuhl, **Springer (2004).**
5. Nanotechnology & Nanoelectronics, Materials, devices, measurement techniques, by W. R. Fahrner(Editor), **Springer, 2005**
6. Principles of Nanophotonics, by Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe, Takashi Yatsui, Makoto Naruse, **CRC press 2008 by Taylor & Francis Group**
7. Semiconductor Quantum Dots, L. Banyai and S.W.Koch, **World Scientific (1993).**
8. NanoBiophotonics, H. Masuhara, S. Kawata and F. Tokunga, **Elsevier Science, (2007).**
9. Fundamentals of Photonics, B. E. A. Saleh and A. C. Teich, John Wiley and Sons, New York, (1993).
10. Introduction to Biophotonics, P. N. Prasad **John Wiley and Sons, (2003).**
11. Molecular Nanomagnets, Dante Gatteschi, Roberta Sessoli, Jacques Villain, Oxford **University Press 2006, USA.**
12. Concepts in Spin Electronics, Sadamichi Maekawa, **Oxford University Press (2006).**
13. Nanomagnetism and Spintronics: Fabrication, Materials, Characterization and Applications
14. Farzad Nasirpouri , Alain Nogaret □ **Publisher:** World Scientific Publishing Company; edition (December 21, 2010) **ISBN-10:** 9814273058
15. Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Edward L. **Wolf Wiley-VCH (2006).**
16. Biomineralization: Principles and Concepts in Bioinorganic Materials Chemistry. Mann, S., **2001. New York, Oxford University Press.**

17. Nanoscale Technology in Biological Systems, Edited by Ralph S. Greco, Fritz B. Prinz, R. Lane Smith, **CRC Press, USA, 2005.**
18. Nanoparticle Technology for Drug delivery, Ram B.Gupta, Uday, B.Compella, **2006 Taylor & Francis Group, LLC, NY.**
19. Nanoparticulates as Drug Carriers, Vladimir Ptorchilin, **Imperial College Press, London, 2006.**
20. Hybrid Nanocomposites for Nanotechnology, Electronic, Magnetic, Optical and Biomedical Applications,byLhadiMerhari, **Springer USA 2009.**

<b>Course Code</b>	<b>NSC10P 601</b>	<b>PROJECT</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Project</b>			<b>0</b>	<b>0</b>	<b>20</b>	<b>20</b>
<b>Pre-requisite</b>	Basic knowledge on nanoscience and nanomaterials		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. Inculcate and improve the research attitude of the student</li> <li>2. To understand the process of literature review and use of online research resources</li> <li>3. Train to design a research problem and to understand how to fix the objectives and methodologies to solve the problem</li> <li>4. Documentation practices and improvement of communication and presentation skills</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Apply the scientific concepts to identify and design a research problem in the area of nanoscience (K3)</li> <li>2. Understand and analyze the results or data obtained from experiments or simulation using data analysis softwares (K2,K4)</li> <li>3. Apply the theoretical knowledge to explain the data collected from different advanced characterization techniques (K3)</li> <li>4. Understand the importance of documentation procedure and research publication. (K2)</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						

**NSC10M 601 MOOC III ONLINE Course - 4 Credits**

<b>Course Code</b>	<b>NSC10C 604</b>	<b>BIO-NANOMATERIALS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core Course</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in physical, chemical and biological sciences	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. To understand the applications of various nanomaterials in biology</li> <li>2. To analyze the potentials of nanoprobes</li> <li>3. To evaluate the uses of different nanoprobes</li> <li>4. To create new functional nanoprobes for advanced applications</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. This course is designed to understand (K1) the applications of different nanomaterials in biology.</li> <li>2. The detailed description of this particular course module will help students to analyze (K2) each nanomaterials' uses at the laboratory level.</li> <li>3. Towards the end of this course, students could evaluate (K3) which nanoprobes will be ideal for specific applications.</li> <li>4. Such experience will help to create (K4) novel materials during their Ph.D. career.</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Nanomaterials for Bio-labeling and Bio-imaging</b>	<b>16 Hours</b>				
Different methods for bio-labeling, bio-conjugate chemistry, and variety of nanoprobes (carbon nanomaterials, semiconductor quantum dots, metal nanoclusters, polymer nanoparticles, up conversion nanoparticles, plasmonic nanoparticles), etc. Raman imaging, fluorescence imaging, magnetic resonance imaging, positron emission tomography, photoacoustic imaging, ultrasound imaging, X-ray computed tomography, etc.						
<b>UNIT-II</b>	<b>Nanomaterials for Delivery and Therapeutics</b>	<b>13 Hours</b>				
Different techniques to deliver drugs, gene, mRNA, etc. Photothermal therapy, photodynamic therapy, chemotherapeutics, etc.						
<b>UNIT-III</b>	<b>Nanomaterials for Tissue Engineering</b>	<b>14 Hours</b>				
Introduction, Artificial implants, scaffolds used for tissue engineering based on nanomaterials – bones, skin and neurons.						
<b>UNIT-IV</b>	<b>Nanomaterials for bioelectronics</b>	<b>12 Hours</b>				

Nanoparticle-biomaterial hybrid systems for bioelectronic devices, nanoparticle-enzyme hybrids; bio-recognition. Biomaterial based metallic nanowires, networks and circuitry. DNA as functional template for nanocircuitry; Protein based nanocircuitry.		
<b>UNIT-V</b>	<b>Contemporary Issues</b>	<b>5 Hrs.</b>
Expert lectures, General Seminars, online seminars – webinars		
	<b>Total Lecture Hours</b>	<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Nanomaterials and Their Applications in Bio-imaging (Plant nanobiotics) by Prasad, R. <b>Publisher:</b> Springer, <b>2019</b>, ISBN: 9783030164386.</li> <li>2. Carbon Nanomaterials for Bio-imaging, Bio-analysis, and Therapy in Nanocarbon Chemistry and Interfaces by Hui, Y. Y.; Chang, H.-C.; Dong, H.; Zhang, X. <b>Publisher:</b> John Wiley &amp; Sons, <b>2018</b>, ISBN: 978-1119373452.</li> <li>3. Nanotechnology for Biomedical Imaging and Diagnostics: From Nanoparticle Design to Clinical Applications by Berezin, M. Y. <b>Publisher:</b> John Wiley &amp; Sons, <b>2014</b>, ISBN: 9781118121184.</li> <li>4. Nanofabrication towards biomedical application: Techniques, tools, Application and impact by Challa S., Kumar, S. R.; Carola. <b>Publisher:</b> J. H. John Wiley &amp; Sons, <b>2005</b>; ISBN: 9783527311156.</li> <li>5. Tissue Engineering, Palsson, B. O.; Bhatia, S. N. <b>Publisher:</b> Prentice Hall, 2003; ISBN:</li> <li>6. Lanza, R.; Langer, R.; Joseph, P. Principles of Tissue Engineering. <b>Publisher:</b> Academic Press. <b>2013</b>; ISBN-10: 0130416967.</li> <li>7. Nanobioelectronics for Electronics, Biology, and Medicine by Offenhäusser, Andreas, Rinaldi, Ross, <b>Publisher:</b> Springer, <b>2009</b>; ISBN: 9781441918574.</li> </ol>		

<b>Course Code</b>	<b>NSC10C 605</b>	<b>ADVANCED NANOMATERIALS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core Course</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic Knowledge in Nanoscience and Nanomaterials	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. To understand the importance of advanced nanostructured materials and their properties.</li> <li>2. To understand the concepts of functionalization of carbon nanotubes and analyze the change in the physical and chemical properties.</li> <li>3. To understand the properties of micro and mesoporous materials and their applications.</li> <li>4. To understand the properties of ultrahard smart materials and nanocomposites.</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. To remember the various type of advanced nanostructured materials that could be utilized for various applications.(K1)</li> <li>2. To apply the concepts of functionalization while designing CNT composites for a specific application. (K3)</li> <li>3. To apply the knowledge gained while designing novel nanocomposites.(K3)</li> <li>4. To nurture the ability of critical thinking towards the design and development nanostructured materials for a specific application.(K6)</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Carbon Nanostructures</b>	<b>14 Hours</b>				
Introduction:- Diamond – Graphite- Fullerenes, CNTs and Graphene. Synthesis: CVD, Laser and Electrochemical and other methods. Functionalization and reactivity of CNTs, Covalent Functionalization -Oxidative Purification, Defect Functionalization –Sidewall Functionalization, Noncovalent Exohedral Functionalization, Endohedral Functionalization.						
<b>UNIT-II</b>	<b>Special Nanomaterials</b>	<b>14 Hours</b>				
Micro & Mesoporous Materials - Ordered mesoporous structures, Random mesoporous structures, and crystalline microporous materials: zeolites. Core – Shell Structures - Metal-oxide structures, Metal-polymer structures, Oxide-polymer structures. Organic-Inorganic Hybrids- Class I hybrids, Class I1 hybrids, Intercalation Compounds.						
<b>UNIT-III</b>	<b>Ultra Hard Smart Materials</b>	<b>14 Hours</b>				

Introduction- synthesis properties and applications of ultra nanocrystalline diamond-growth, electronic properties and application of nanodiamond. Diamond like materials- CNTs and Nitrides, C <sub>3</sub> N <sub>4</sub> -Boron nitride etc.		
<b>UNIT-IV</b>	<b>Nanocomposites</b>	<b>14 Hours</b>
Introduction to Nanocomposites – Layered Silicates-Polyamide-clay nanocomposites. Epoxy nanocomposites based on layered silicates and other nanostructured fillers. Biodegradable polymer silicate nanocomposites. Metal Polymer Nanocomposites-synthesis- Ex-situ and in-situ approaches-Optically anisotropic metal –polymer nanocomposites. Conducting nanocomposite systems- Introduction, classification and host guest materials for nanocomposite systems.		
<b>UNIT-V</b>	<b>Contemporary Issues</b>	<b>4 Hrs.</b>
Expert lectures, General Seminars, online seminars – webinars		
	<b>Total Lecture Hours</b>	<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Carbon Materials &amp; Nanotechnology, By Anke Krueger, Wiley VCH Verlag GmbH &amp; Co. KGaA, 2010, Weinheim.</li> <li>2. Diamond Nanotechnology- Synthesis and Applications, by James Sung, Pan Stanford Publishing (July 31, 2009)</li> <li>3. Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong, Imperial college press, 2004.</li> <li>4. Polymer nanocomposites, Edited by Yiu-Wing Mai and Zhong-Zhen Yu, CRC Press, Woodhead Publishing Limited, 2006.</li> <li>5. The New Frontiers of Organic and Composite Nanotechnology, Victor Erokhin, Manoj Kumar Ram and Ozlem Yavuz, 2008 Elsevier Ltd.</li> <li>6. Metal – Polymer nanocomposites by Luigi Nicolais and Gianfranco Carotenuto, John Wiley &amp; Sons, Inc. 2005.</li> <li>7. Nanoscale materials -Liz Marzan and Kamat Publisher: Wiley; 2 edition ( 2009)</li> <li>8. Synthesis functionalization and surface treatment of nanoparticles - Marie Isabelle Baraton</li> <li>9. Physical properties of Carbon Nanotube-R Satio Publisher: Am. Sci. Publishers ( 2002)</li> <li>10. Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport devices , S. Subramony &amp; S.V. Rotkins Publisher: Springer; 2005 edition.</li> <li>11. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell Publisher: CRC Press; edition (2006)</li> <li>12. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing Publisher: Royal Society of Chemistry.</li> <li>13. Nanosilicon by Vijay Kumar, Elsevier Ltd. UK ,2007. Publisher: Elsevier Science (2014)</li> </ol>		

<b>Course Code</b>	<b>NSC10C 606</b>	<b>NANOSTRUCTURED SUPERCAPACITORS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in Nanoscience		<b>Syllabus Version</b>		<b>2024</b>	
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. Conscious of energy crisis, its reason, current status and possible solutions</li> <li>2. Recognize the significance of energy storage</li> <li>3. Importance of efficient storage and release of energy</li> <li>4. Role of Nanoscience or nanotechnology in producing novel materials and designs for efficient storage of energy using renewable resources</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Analyze the performance of electric capacitors and understand their advantages and disadvantages (K4, K2)</li> <li>2. Understand different electrochemical techniques to know better the electrode-electrolyte interface (K2)</li> <li>3. Understand the possibilities of electrochemical double layer supercapacitors for efficient energy storage and create awareness on using such advanced technologies (K2, K6)</li> <li>4. Analyze the importance of novel energy storage devices with improved performance using nanoscience (K4)</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Fundamentals of Electric Capacitors</b>		<b>13 Hours</b>			
Introduction, energy storage in capacitor, types and structures of capacitors. General principles of electrochemistry, equilibrium electrochemistry, dynamic electrochemistry. General properties of electrochemical capacitors. Electrochemical cell, electrochemical interfaces, different electrochemical techniques.						
<b>UNIT-II</b>	<b>Electrochemical Double-Layer Supercapacitors</b>		<b>14 Hours</b>			
Introduction, Electrode-Electrolyte interfaces, Electrode Potential and double layer potential windows. Electrochemical double layer supercapacitors: structure and capacitance, equivalent series resistance, leakage resistance, supercapacitor charging and discharging, energy and power densities of EDL supercapacitors. EDLC electrode Materials.						
<b>UNIT-III</b>	<b>Electrochemical Pseudo capacitors</b>		<b>14 Hours</b>			
Introduction, Electrochemical pseudo capacitors, interfaces of electrode and electrolyte. Electrochemical Impedance spectroscopy and equivalent circuits. Electrode materials and Cell Designs. Pseudo capacitive materials, Asymmetric structures. Electrolyte structures and materials.						

<b>UNIT-IV</b>	<b>Characterization &amp; Applications of Electrochemical Supercapacitors</b>	<b>14 Hours</b>
Electrochemical cell design and fabrication. Cyclic voltammetry, Charging Discharging curve, electrochemical impedance spectroscopy, Physical Characterization methods. Applications of Electrochemical supercapacitors: power electronics, portable energy systems, hybrid electric vehicle etc. Perspectives and challenges of electrochemical super capacitors		
<b>UNIT-V</b>	<b>Contemporary Issues</b>	<b>5 Hrs.</b>
Expert lectures, General Seminars, online seminars – webinars		
	<b>Total Lecture Hours</b>	<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Electrochemical Supercapacitors for Energy Storage and Delivery: Fundamentals and Applications, by Aiping Yu, Victor Chabot and Jiujun Zhang, CRC Press, Tylor &amp; Francis Group, New York (2013).</li> <li>2. Supercapacitors: Materials, Systems and Applications, Max Lu, Francois Beguin, Elzbieta Frackowiak.</li> </ol>		

<b>Course Code</b>	<b>NSC10C 607</b>	<b>NANOMATERIALS FOR SUSTAINABLE TECHNOLOGY</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>3</b>	<b>0</b>	<b>1</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in nanomaterials and their synthesis		<b>Syllabus Version</b>	<b>2024</b>		
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
<ol style="list-style-type: none"> <li>1. Familiarize students the importance of nanomaterials for sustainable development.</li> <li>2. Enhancing the student's knowledge on nanomaterials for environmental remediation.</li> <li>3. Understand the photocatalysis reactions for solar fuel generation.</li> <li>4. Apply the knowledge gained for developing efficient nanostructured photocatalysts.</li> </ol>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Understand the benefits of nanomaterials for sustainable development (K2)</li> <li>2. Analyze the concepts of photocatalysis and its technological significance. (K4)</li> <li>3. Apply the photocatalysis reaction mechanisms towards contaminant degradation, hydrogen evolution and carbon dioxide reduction. (K3)</li> <li>4. Create strategies for developing efficient nanostructured photocatalysts.(K6)</li> </ol>						
K1=Remember, K2= Understand, K3= Apply, K4= Analyze, K5= Evaluate, K6= Create						
<b>UNIT-I</b>	<b>Photocatalysis</b>	<b>13 Hours</b>				
Introduction; Light and matter interaction; Principles of Photocatalysis; Electronic band structure of semiconductors; Mechanisms of charge formation, separation and transfer; Basic principles of photocatalytic water splitting for hydrogen generation; Basic principles of photocatalytic reduction of CO <sub>2</sub> ; Photocatalysis surface and active species.						
<b>UNIT-II</b>	<b>Environmental Remediation</b>	<b>14 Hours</b>				
Introduction; Fabrication of nanostructured photocatalysts; Methods of improving photocatalytic activity: Design parameters; Photodegradation of dyes; Photodegradation of persistent organic pollutants; Photodegradation of Inorganic pollutants; Photodegradation of emerging contaminants; Photodegradation of gaseous pollutants; Characterization and analysis of acquired data.						
<b>UNIT-III</b>	<b>Hydrogen Evolution and Carbondioxide Reduction</b>	<b>14 Hours</b>				
Introduction; Electronic band structure considerations; Photocatalytic reaction mechanism and charge transfer; Fabrication of nanostructured photocatalysts and design parameters: H <sub>2</sub> generation and CO <sub>2</sub> reduction; Z-scheme heterojunction photocatalysts; Quantification and calculation of efficiency; Characterization						

<b>UNIT-IV</b>	<b>Strategies for Improving Performance of Photocatalysts</b>	<b>14 Hours</b>
Introduction; Issues related to single-component photocatalysts; Microstructure modulation; Influence of facet and defects; Integration of noble metal nanostructures; Carbonaceous materials compounding – rGO, CNTs, CQDs; Integration with other semiconductor nanostructures.		
<b>UNIT-V</b>	<b>Contemporary Issues</b>	<b>5 Hrs.</b>
Expert lectures, General Seminars, online seminars – webinars		
	<b>Total Lecture Hours</b>	<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. Gianluca Li Puma, Detlef W. Bahnemann, Dionysios D. Dionysiou, Jinhua Ye and Jenny Schneider, Photocatalysis: Fundamentals and Perspectives, Publisher: Royal Society of Chemistry, ISBN: 9781782620419, 1782620419.</li> <li>2. Umar Ibrahim Gaya, Heterogeneous Photocatalysis Using Inorganic Semiconductor Solids, Publisher: Springer Netherlands, ISBN: 9789400777750, 9400777752</li> <li>3. Kazuya Nakata and Akira Fujishima, TiO<sub>2</sub> photocatalysis: Design and applications, Journal of Photochemistry and Photobiology C: Photochemistry Reviews 2012, 13, 169-189, <a href="https://doi.org/10.1016/j.jphotochemrev.2012.06.001">https://doi.org/10.1016/j.jphotochemrev.2012.06.001</a></li> <li>4. Chunping Xu, Prasaanth Ravi Anusuyadevi, Cyril Aymonier, Rafael Luque and Samuel Marre, Nanostructured materials for photocatalysis, Chemical Society Reviews, 2019,48, 3868-3902, <a href="https://doi.org/10.1039/C9CS00102F">https://doi.org/10.1039/C9CS00102F</a></li> </ol>		

<b>Course Code</b>	<b>NSC10C 608</b>	<b>COMPUTATIONAL STUDIES ON BIO-ACTIVE COMPOUNDS</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>Core</b>			<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>Pre-requisite</b>	Basic knowledge in general Chemistry and mathematics.	<b>Syllabus Version</b>	<b>2024</b>			
L= Lecture, T= Tutorial, P- Practical, C= Credits						
<b>Course Objectives</b>						
The main objectives of the course are to: <ul style="list-style-type: none"> <li>• Understand different statistical tools in data analysis.</li> <li>• Learn different bio-active compounds.</li> <li>• Learn the pathway for drug discovery.</li> <li>• Employ different computational tools to evaluate different bio-active compounds.</li> </ul>						
<b>Course Outcomes</b>						
<ol style="list-style-type: none"> <li>1. Understand different tools for data analysis – K3, K4, K5</li> <li>2. Understand the need and importance of computational studies in supporting scientific results – K1, K4</li> <li>3. Learn drug likeness and related parameters for drug discovery – K2, K3, K6</li> <li>4. Understand different computational tools for evaluating drug-target interactions– K3, K4, K5</li> </ol>						
K2 – Understand K3 – Apply K4 – Analyze K6 - Create						
<b>UNIT-I</b>	<b>Errors and Statistical Tools in Data Analysis</b>				<b>12 Hours</b>	
Significant figures. Errors and classification; accuracy and precision; significant figures and rules; selection of data- T-test; F-test; Q-test; Euler's theorem- exact and inexact differentials.						
<b>UNIT-II</b>	<b>Bio-active Compounds &amp; Metals in Medicine</b>				<b>12 hours</b>	
Bio-active compounds: Structure and general characteristics. Medicinal importance of bio-active compounds. Bio-activities. ED50, IC50, TD50 and LD50. Metal toxicity and homeostasis. Metal deficiency and diseases. Toxicity due to non-essential elements. Chelation therapy and chemotherapy. Metal complexes as drugs (brief only).						
<b>UNIT-III</b>	<b>Medicinal Chemistry I</b>				<b>12 Hours</b>	
Features of Drug like molecules. Drug classification: synthetic, semi-synthetic and nonsynthetic drugs. Drug classification according to medicinal use: pharmacodynamic medicinal use. Pharmacodynamic agents and chemotherapeutic agents. Lipinski's rule of 5. Physicochemical properties determining biological activity such as solubility, acidity and reactivity. Importance of liphophilicity constant (logP).						
<b>UNIT-IV</b>	<b>Medicinal chemistry II</b>				<b>12 Hours</b>	
Isosterism and bioisosterism. A brief introduction on the following terms: Pharmacology, Pharmacodynamics, Pharmacokinetics and ADME, pharmacotherapeutics,						

pharmacogeny, toxicology, Basic steps in drug discovery: from lead discovery to commercialization (a brief introduction only).		
<b>UNIT-V</b>	<b>Computation of Bio-active Compounds</b>	<b>12 Hrs.</b>
Combinatorial chemistry. QSAR/QSPR study. Molecular docking. Donar-acceptor interactions. Different biological assays (brief idea only). Experimental versus computational studies. UV filtering and metal chelation capacity. Multi target interactions. Molecular simulations		
	<b>Total Lecture Hours</b>	<b>60 Hours</b>
<b>Text Books/References</b>		
<ol style="list-style-type: none"> <li>1. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 8<sup>th</sup> Edn., Saunders College Pub., 2007.</li> <li>2. Jenson F, Introduction to Computational Chemistry – John Wiley</li> <li>3. Cramer C.J., Essentials of Computational Chemistry – John Wiley</li> <li>4. Young, Computational Chemistry – Wiley Inter Science</li> <li>5. S.S. Sastry (SS), Introductory Methods of Numerical Analysis, PHI</li> <li>6. J. B. Scarborough (SB), Numerical Mathematical Analysis, Oxford &amp; IBH</li> <li>7. Wilson and text book of Organic Medicinal and Pharmaceutical Chemistry. Author(s): John M Beale Jr., PhD, John Block, ISBN/ISSN: 9780781779296, Edition: Twelfth, 2010</li> <li>8. Gareth Thomas, Fundamentals of Medicinal Chemistry, ISBN: 9780470 84307-9, Wiley Blackwell.</li> </ol>		