MAHATMA GANDHI UNIVERSITY

Kottayam, Kerala

Undergraduate Programmes (HONOURS)
2024 Admission Onwards

SYLLABUS						
SIGNATURE COURSE						
Name of the College	Marthoma College, Kuttapuzha P.O, Tiruvalla					
Faculty/ Discipline	Chemistry					
Programme	BSc (Hons) Chemistry					
Course Coordinator	Dr.SHAJI					
Contributors	Dr. Neema Ani Mangalam, Dr. Ajesh K Zachariah, Dr. Nebu John, Dr. Shaji Varghese, Dr. Sharon Achamma Abraham, Dr. Anitha George Varghese, Dr. Merin Sara Thomas, Dr. Reenamole G, Dr. Josmin P Jose, Dr. Reni George, Dr. Sereen Thomas, Dr. Surya Philip					
Course Name	Fundamentals of Nanochemistry					
Type of Course	DSE					
Specialization title	Nanochemistry and Technology					
Course Code	To be prepared by the University					
Course Level	200					
Course Summary	The course introduces into the world of nanomaterials covering their fundamental aspects, classification, synthesis of nanomaterials, methodologies and various types of nanomaterials.					
Semester	3	**Credits**			4	**Total Hours**
Course Details	**Learning Approach**	Lecture	Tutorial	Practical	Others	
		4	0	0	0	60
Pre-requisites, if any						

Course Outcomes (CO)

Number of COs		**6**	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
1	Explain the fundamental concepts of Nanomaterials	U	PO1, PO2, PO3
2	Compare the top-down and button-up methods of nanomaterial synthesis.	AN	PO1, PO2, PO3
3	Explain the synthesis of different types of nanomaterials using various physico-chemical methods	AN	PO1, PO2, PO3
4	Describe the synthesis and properties of hybrid nanomaterials	AN	PO1, PO2, PO3
5	Describe the properties of different types of carbon nanomaterials	U	PO1, PO2, PO3
6	Explain the properties of 2D nanomaterials and quantum dots	AN	PO1, PO2, PO3

**Remember (K), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*

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CO-PO Articulation Matrix

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	3	3	3	-	-	-	-	-	-	-
CO 2	3	3	2	-	-	-	-	-	-	-
CO 3	3	3	2	-	-	-	-	-	-	-
CO 4	3	3	3	-	-	-	-	-	-	-
CO 5	3	3	2	-	-	-	-	-	-	-
CO 6	3	3	2	-	-	-	-	-	-	-

'0' is No Correlation, '1' is Slight Correlation (Low level), '2' is Moderate Correlation (Medium level) and '3' is Substantial Correlation (High level).

Course Content

Content for Classroom transaction (Units)

Module	Units	Course Description	Hrs	CO No.
1	Why Nano?			
	1.1	Nanomaterials , History of nanoparticles, Scale of nanoparticles, definitions of nanoparticle, Surface to volume ratio, change in properties when became nano (physical, chemical, electronic and optical properties)	5	["1"]
	1.2	Classifications of nanomaterials-0D,1D, 2D,3D nanostructured materials, quantum dots, quantum wires, quantum wells,Surface Plasmon resonance, Origin of fluorescence, Quantum tunneling	6	["1"]
	1.3	Introduction of nature inspired nanomaterials and its features-(hydrophilic and hydrophobic surfaces) fundamental ideas only	4	["1"]
2	Synthesis of Nanomaterials			
	2.1	Introduction of synthesis methods, top down and bottom up approach, self assembly process	4	["2"]
	2.2	CVD, PVD, reduction technique, solution growth technique, sol-gel methods, template assisted synthesis, Gas phase synthesis of nano powders, spray pyrolysis,Green synthesis	8	["3"]
	2.3	Preparation of nanocomposites, bionanomaterials, electrospinning	3	["3"]

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Module	Units	Course Description	Hrs	CO No.
3	Metal, metal oxide and hybrid nanomaterials			
	3.1	Metal oxide nanomaterials- TiO2, ZnO2, ZrO2, iron oxide nanomaterials, SiO2, Superparamagnetic Magnetic Iron oxide nanoparticle	5	["3"]
	3.2	Metal nanoparticles: Noble metal nanoparticles and magnetic nanoparticles	4	["3"]
	3.3	Hybrid Nanomaterials, organic- inorganic hybrid nanomaterials, Janus particles, surface functionalization, smart material	6	["4"]
4	Carbon based nanomaterials and 2D nanomaterials			
	4.1	Carbon based nanomaterials, single walled and multiwalled carbon nanotubes and its properties, introduction to fullerenes, carbon dots	4	["5"]
	4.2	2D nanomaterials- Graphene, hexagonal boron nitride, transition metal dichalcogenides, MXenes, LDHs and nanoclays,Phosphorene,black phosphorus	6	["6"]
	4.3	Quantum dots: fluorescence properties, semiconductor and core shell QDs, examples	5	["6"]

Teaching and Learning Approach	Classroom Procedure (Mode of transaction)
	Interactive instruction Peer teaching Group discussion Experiential Learning

Assessment Types	
	MODE OF ASSESSMENT Mode of Assessment: Theory
	A. Continuous Comprehensive Assessment (CCA) **• Theory – 30 Marks** Assignments/MCQ/Class test/Viva
	B. End Semester Evaluation (ESE) **• Theory – 70 Marks** Assessment Methods – Written Examination Duration of Examination – 2.00 Hrs Pattern of examination for Theory – Non-MCQ Different parts of written examination – Part - A , B , C Answer Type: ◦ PART - A ◦ Short answer - (5 out of 7) – 5 × 4 = 20 ◦ PART - B ◦ Short Essays - (5 out of 7) – 5 × 7 = 35 ◦ PART - C ◦ Essays - (1 out of 2) – 1 × 15 = 15

References

- 1. Pradeep, T. (2007). Nano: The essentials – Understanding nanoscience and nanotechnology. McGraw Hill Education India.

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Charles P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology, John Wiley & Sons, Inc (2003) 3. Shah, M. A., & Ahmad, T. (2010). Principles of nanoscience and nanotechnology. Narosa Publishing House. 4. Hornyak, G. L., Dutta, J., Tibbals, H. F., & Rao, A. (2008). Introduction to nanoscience and nanotechnology (1st ed.). CRC Press. 5. Rao, C. N. R., Müller, A., & Cheetham, A. K. (Eds.). (2004). The chemistry of nanomaterials: Synthesis, properties and applications. Wiley-VCH. 6. Schmid, G. (2010). Nanoparticles: From theory to applications (2nd ed.). Wiley-VCH Verlag. 7. O'Connell, M. J. (Ed.). (2006). Carbon nanotubes: Properties and applications. CRC Press. 8. Avouris, Phaedon, Tony F. Heinz, and Tony Low, editors. 2D Materials. Cambridge University Press, 2017. 9. Weibo Cai, Xiaoyuan Chen, Hybrid Nanomaterials: Design, Synthesis, and Biomedical Applications CRC Press, 2018 10. Ahmad Umar, Yoon-Bong Hahn, Metal Oxide Nanostructures and Their Applications" (5-Volume Series), American Scientific Publishers, 2010.

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Faculty/ Discipline	Chemistry					
Programme	BSc (Hons) Chemistry					
Course Coordinator	Dr.SHAJI					
Contributors	Dr. Neema Ani Mangalam, Dr. Ajesh K Zachariah, Dr. Nebu John, Dr. Shaji Varghese, Dr. Sharon Achamma Abraham, Dr. Anitha George Varghese, Dr. Merin Sara Thomas, Dr. Reenamole G, Dr. Josmin P Jose, Dr. Reni George, Dr. Sereen Thomas, Dr. Surya Philip					
Course Name	Characterization of Nanomaterials					
Type of Course	DSE					
Specialization title	Nanochemistry and Technology					
Course Code	To be prepared by the University					
Course Level	200					
Course Summary	The course explores the spectroscopic and microscopic studies of nanomaterials and different techniques for characterizing nanomaterials. Additionally, it familiarises how to interpret the data from these characterization techniques using various softwares.					
Semester	4	**Credits**			4	**Total Hours**
Course Details	**Learning Approach**	Lecture	Tutorial	Practical	Others	
		4	0	0	0	60
Pre-requisites, if any						

Course Outcomes (CO)

Number of COs		**6**	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
1	Describe, illustrate and interpret the characterization of nanomaterials using the electron probe method.	U, A, AN	PO1, PO2, PO3, PO10
2	Describe, illustrate and interpret the characterization of nanomaterials using Scanning probe microscopy method.	U, A, AN	PO1, PO2, PO3, PO10
3	Describe, illustrate and interpret the characterization of nanomaterials using spectroscopic methods.	U, A, AN	PO1, PO2, PO3, PO10
4	Describe, illustrate and interpret the characterization of nanomaterials using XRD, Surface area measurements, Thermal analysis.	U, A, AN	PO1, PO2, PO3, PO9, PO10
5	Define and extend the electrochemical aspects of nanomaterials.	K, U	PO1, PO2, PO3

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Number of COs		6	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
6	Develop skills for data interpretation using softwares (origin/image J /J mol)	U, C, S	PO1, PO2, PO3, PO10

**Remember (K), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*

CO-PO Articulation Matrix

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	3	3	3	-	-	-	-	-	-	3
CO 2	3	3	3	-	-	-	-	-	-	2
CO 3	3	3	3	-	-	-	-	-	-	2
CO 4	3	3	3	-	-	-	-	-	1	2
CO 5	3	3	3	-	-	-	-	-	-	-
CO 6	3	3	3	-	-	-	-	-	-	2

'0' is No Correlation, '1' is Slight Correlation (Low level), '2' is Moderate Correlation (Medium level) and '3' is Substantial Correlation (High level).

Course Content

Content for Classroom transaction (Units)

Module	Units	Course Description	Hrs	CO No.
1	Characterization using Electron probe method			
	1.1	SEM: Morphological Analysis of Metal oxides, Polymer nano composites and Biomaterials (Any two materials).	4	["1"]
	1.2	FESEM: Basic Principle, Comparison with SEM, Advantages and Applications, Basic Instrumental features, micro and nano structures (Any one material).	4	["1"]
	1.3	TEM: Morphological analysis and particle size distribution of Ag /Au nanoparticles, Quantum dots, Graphene oxide (Any two materials). Analysis using origin and Image- J software.	4	["1", "6"]
	1.4	HRTEM: Principle and Instrumental features (Basic idea only), Comparison with TEM, Advantages and Applications, Imaging and Diffraction patterns, SAED pattern. Analysis using origin and Image- J software.	4	["1", "6"]

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Module	Units	Course Description	Hrs	CO No.
2	Characterization using Scanning Probe Microscopy method			
	2.1	AFM: Analysis of biological molecules, polymers and nanostructures (Any one) Different modes of operation – Contact mode and Non-contact mode.	5	["2"]
	2.2	STM: Surface friction, surface roughness, defects surface reactions in catalyst, polymers, semiconductors (any one nanomaterial).	5	["2"]
3	Characterization using Spectroscopic methods			
	3.1	UV-Visible Spectroscopy : Basic Principle, and Applications. Analysis of nanostructures and its mechanism.-Surface Plasmon Resonance	3	["3"]
	3.2	Fluorescence Spectroscopy and its mechanism.	3	["3"]
	3.3	FT-IR, Raman, SERS, TERS and CARS,(Basic Principle and Applications). Analysis of material CNTs and MWCNTs, Graphene (Different bands in Raman spectra).	3	["3"]
	3.4	XPS: Oxidation state, Binding Energy, Deconvolution and fitting using origin software (Any one example)	4	["3"]
	3.5	Auger, SIMS and EPMA (Basic principle and application)	4	["3"]
4	Other Characterization Techniques			
	4.1	XRD, SAXS: Crystalline size, Analysis using J Mol software	4	["4", "6"]
	4.2	Surface Area Analysis: BET analysis, Surface Area and Porosity measurements Contact angle and Visco Elastic Studies - Fundamentals of contact angle measurements, hydrophilic and hydrophobic surfaces through contact angle measurements, variation of viscoelastic behaviour of nanocomposites due to nanofillers	4	["4"]
	4.3	Thermal Analysis: TGA,DTA and DSC- Basic ideas and its uses for nanomaterial characterization using any two examples for each	3	["4"]
	4.4	Significance of electrochemical measurements (Basic idea only) Cyclic voltammetry (CV), Polarography Electrochemical Impedance spectroscopy(EIS). Zeta potential and its applications (used to characterize the surface charge of materials like polymers , nano particles and solid surface, to measure the stability of colloidal dispersion). DLS : Basic principle and applications in nanomaterial characterization	6	["5"]

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Teaching and Learning Approach	Classroom Procedure (Mode of transaction) Interactive instruction Flipped classroom Interactive discussions Demonstrations

Assessment Types	**MODE OF ASSESSMENT** Mode of Assessment: Theory **A. Continuous Comprehensive Assessment (CCA)** **• Theory – 30 Marks** Assignments/ Interactive Activities/ Class test/ Viva The CCA will be based on the structural interpretations of materials using characterization techniques studied. **B. End Semester Evaluation (ESE)** **• Theory – 70 Marks** Assessment Methods – Written Examination Duration of Examination – 2.00 Hrs Pattern of examination for Theory – Non-MCQ Different parts of written examination – Part - A , B , C Answer Type: ◦ PART - A ◦ Short answer - (5 out of 7) – 5 × 4 = 20 ◦ PART - B ◦ Short Essays - (5 out of 7) – 5 × 7 = 35 ◦ PART - C ◦ Essays - (1 out of 2) – 1 × 15 = 15

References

- 1. Charles P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology, John Wiley & Sons, Inc (2003) 2. Skoog, D. A., Holler, F. J., & Crouch, S. R. (2017). Principles of instrumental analysis (7th ed.) 3. Salvi, F. (2012). Introduction to X-ray photoelectron spectroscopy (2nd ed.). CRC Press. 4. Goldstein, J. I., Newbury, D. E., Echlin, P., & Joy, D. C. (2017). Scanning electron microscopy and X-ray microanalysis (4th ed.). Springer. 5. Binnig, G., & Rohrer, H. (1982). Scanning tunneling microscopy. Surface Science, 126(1), 236–244 6. Binnig, G., Quate, C. F., & Gerber, C. (1986). Atomic force microscope. Physical Review Letters, 56(9), 930–933 7. Hollas, J. M. (2004). Modern spectroscopy (4th ed.). Wiley. 8. Leng, Y. (2013). Materials characterization: Introduction to microscopic and spectroscopic methods (2nd ed.). Wiley. 9. Walkenbach, J. (2015). Excel 2016 Bible. Wiley. 10. Higham, N. J. (2002). MATLAB guide. SIAM. 11. Sabu Thomas,Raju Thomas, Ajesh K. Zachariah, Raghvendra Kumar Mishra (eds.) Thermal and Rheological Measurement Techniques for Nanomaterials Characterization, Elsevier Inc.,2017 12. Sabu Thomas, Raju Thomas, Ajesh K. Zachariah, Raghvendra Kumar Mishra (eds.) Microscopy Methods in Nanomaterials Characterization, Elsevier Inc.,2017 13. Sabu Thomas, Raju Thomas, Ajesh K. Zachariah, Raghvendra Kumar Mishra (eds.)Spectroscopic Methods for Nanomaterials Characterization,Elsevier Inc.,2017

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2024 Admission Onwards

SYLLABUS						
SIGNATURE COURSE						
Name of the College	Marthoma College, Kuttapuzha P.O, Tiruvalla					
Faculty/ Discipline	Chemistry					
Programme	BSc (Hons) Chemistry					
Course Coordinator	Dr.SHAJI					
Contributors	Dr. Neema Ani Mangalam, Dr. Ajesh K Zachariah, Dr. Nebu John, Dr. Shaji Varghese, Dr. Sharon Achamma Abraham, Dr. Anitha George Varghese, Dr. Merin Sara Thomas, Dr. Reenamole G, Dr. Josmin P Jose, Dr. Reni George, Dr. Sereen Thomas, Dr. Surya Philip					
Course Name	Applications of nanomaterials-I					
Type of Course	DSE					
Specialization title	Nanochemistry and Technology					
Course Code	To be prepared by the University					
Course Level	300					
Course Summary	The course provides a comprehensive understanding of electrochemical, optoelectronic, catalytic and biological applications of nanomaterials.					
Semester	5	**Credits**			4	**Total Hours**
Course Details	**Learning Approach**	Lecture	Tutorial	Practical	Others	
		4	0	0	0	60
Pre-requisites, if any						

Course Outcomes (CO)

Number of COs		**6**	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
1	Explain the fundamental concepts of portable energy storage devices	U	PO1, PO2, PO3
2	Explain the fundamentals of electrochemical energy storage devices	U	PO1, PO2, PO3
3	Analyse the applications of electrochemical energy storage devices	AN	PO1, PO2, PO3, PO10
4	Explain the optoelectronic applications of nanomaterials	AN	PO1, PO2, PO3, PO10
5	Explain and analyse the applications of nanomaterials in energy and environmental applications	AN	PO1, PO2, PO3, PO10
6	Explain and analyse the applications of nanomaterials in biological applications	AN	PO1, PO2, PO3, PO10

**Remember (K), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*

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CO-PO Articulation Matrix

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	3	3	3	-	-	-	-	-	-	-
CO 2	3	3	3	-	-	-	-	-	-	-
CO 3	3	3	3	-	-	-	-	-	-	3
CO 4	3	3	3	-	-	-	-	-	-	3
CO 5	3	3	3	-	-	-	-	-	-	3
CO 6	3	3	3	-	-	-	-	-	-	3

'0' is No Correlation, '1' is Slight Correlation (Low level), '2' is Moderate Correlation (Medium level) and '3' is Substantial Correlation (High level).

Course Content

Content for Classroom transaction (Units)

Module	Units	Course Description	Hrs	CO No.
1	Electrochemical Applications			
	1.1	Batteries and supercapacitors- Need of portable energy storage devices. components of batteries, different type batteries:-Li-ion,Na-ion, Zn-Air, Li-MH. Types of nanomaterials used as electrodes in batteries.	4	["1"]
	1.2	Supercapacitors- definition and classification of capacitors, Components of capacitors, charging and discharging mechanisms	4	["2"]
	1.3	Fuel cells- definition and classification of fuel cells, Proton Exchange Membrane (PEM), Solid Oxide (SOFC), Alkaline (AFC), Phosphoric Acid (PAFC), Molten Carbonate (MCFC), and Direct Methanol (DMFC), working principle, advantages and energy efficiency compared to internal combustion engines. portable applications of fuels cells.	4	["3"]
	1.4	Other electrochemical applications- as electrochemical sensors	3	["3"]
2	Optoelectronic Applications			
	2.1	Superlattices, Dielectric constant of nanoscale silicon, excitonic binding, capacitance of nanoparticle (Only basic level ideas of all the topic mentioned)	6	["4"]
	2.2	Nonlinear optical properties - second order NLO, Third order NLO (basic concepts only), applications	3	["4"]
	2.3	Nanomaterials as LEDs- porous silicon-based diodes, photoluminescent superlattices Nanomaterials as single electron transistor, QD lasers (Only general ideas are needed for all the mentioned topics)	6	["4"]
3	Nanomaterials as catalysts and Adsorbents			
	3.1	Catalysis and photocatalysis- nanomaterials as catalyst and catalytic processes (general ideas only).	5	["5"]
	3.2	Catalysts for energy conversion (basic ideas only)- Catalysts in fuel cells, biomass production, hydrogen production Catalytic processes for environment- Advanced oxidation processes (AOPs) (Basic idea and mechanism)	6	["5"]
	3.3	Adsorption- different types of adsorbents, Membrane process- basic ideas only	4	["5"]

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Module	Units	Course Description	Hrs	CO No.
4	Biological Applications of nanomaterials			
	4.1	Biomedical Applications: Drug delivery systems, immunogold labelling	7	["6"]
	4.2	Tissue engineering - nanofibers as scaffolds, biosensors	4	["6"]
	4.3	Brief idea on DNA nanomaterials and polymeric nanomaterials	4	["6"]

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Lecture-based approach Peer teaching Quizzes Collaborative learning

Assessment Types	**MODE OF ASSESSMENT** Mode of Assessment: Theory **A. Continuous Comprehensive Assessment (CCA)** **• Theory – 30 Marks** Theory Assessment Methods Assignment/ Quiz/ Class test – written/ Oral Presentations **B. End Semester Evaluation (ESE)** **• Theory – 70 Marks** Assessment Methods – Written Examination Duration of Examination – 2.00 Hrs Pattern of examination for Theory – Non-MCQ Different parts of written examination – Part - A , B , C , D Answer Type: ◦ PART - A ◦ MCQ - (10 out of 10) – 10 × 1 = 10 ◦ PART - B ◦ Short answer - (8 out of 10) – 8 × 3 = 24 ◦ PART - C ◦ Short Essays - (3 out of 5) – 3 × 7 = 21 ◦ PART - D ◦ Essays - (1 out of 2) – 1 × 15 = 15

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References

- 1. Charles P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology, John Wiley & Sons, Inc (2003) 2. O'Hayre, R., Cha, S. W., Colella, W., & Prinz, F. B. (2016).Fuel Cell Fundamentals (3rd ed.). Hoboken, NJ: Wiley. 3. Murty, Budaraju S., P. Shankar, Baldev Raj, B. B. Rath, and James Murday. Textbook of nanoscience and nanotechnology. Springer Science & Business Media, 2013. 4. Sattler, Klaus D. Handbook of nanophysics: nanomedicine and nanorobotics. CRC press, 2010. 5. Patrick T. Moseley, Jurgen Garche, Electrochemical Energy Storage for Renewable Sources and Grid Balancing, Elsevier (2015) 6. Francois Beguin, Elzbieta Frackowiak, Supercapacitors: Materials, Systems, and Applications" Wiley-VCH (2013) 7. Ryan O'Hayre, Suk-Won Cha, Whitney Colella, Fritz B. Prinz, Fuel Cell Fundamentals, Wiley, 3rd Edition, 2016.ISBN: 978-1119113805 8. Shripad T. Revanka, Fuel Cells: Principles, Design, and Analysis" , CRC Press (2021) 9. Klaus D. Sattler, Handbook of Nanophysics: Nanoelectronics and Nanophotonics, CRC Press (2010). 10. Nick Serpone, Ezio Pelizzetti, Photocatalysis: Fundamentals and Applications" Wiley-Interscience (1989)

Suggested Readings

- 1. Pierre Pichat, Photocatalysis and Water Purification: From Fundamentals to Recent Applications" Publisher: Wiley-VCH (2013) 2. Grassian, V. H. (Ed.). (2004). Environmental catalysis. CRC Press 3. Carl C. Koch (Ed.) (2002), Nanostructured Materials Processing, Properties and Potential Applications, Noyes Publications / William Andrew Publishing

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Course Coordinator	Dr.SHAJI					
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Course Name	Applications of Nanomaterials-II					
Type of Course	DSE					
Specialization title	Nanochemistry and Technology					
Course Code	To be prepared by the University					
Course Level	300					
Course Summary	The course provides an insight on nanotechnology and circular economy, quantum nanotechnology and also addresses advanced applications of nanomaterials.					
Semester	6	**Credits**			4	**Total Hours**
Course Details	**Learning Approach**	Lecture	Tutorial	Practical	Others	
		4	0	0	0	60
Pre-requisites, if any						

Course Outcomes (CO)

Number of COs		**8**	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
1	Define circular economy and its principles.	K, U	PO1, PO2, PO3
2	Describe the relation between circular economy and SDGs.	K, U	PO1, PO2, PO3
3	Evaluate the application of nanomaterials in textile industry, benefits of nanofibers, strength and durability	U, AN, E	PO1, PO2, PO3, PO10
4	Explain nanomaterials used in construction materials /nano cement and in sustainable agriculture	K, U, AN	PO1, PO2, PO3, PO10
5	Explain the principle of MRAM & its advantages and fundamental principle of quantum computing /quantum sensing.	U, AN	PO1, PO2, PO3, PO10
6	Analyze spintronic devices and quantum computing systems.	U, AN	PO1, PO2, PO3

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Number of COs		8	
CO No.	**Expected Course Outcome**	**Learning Domains ***	**PO No**
7	Formulate the remediation solutions of nanomaterials in water/air/soil pollution.	U, A, AN, E, C	PO1, PO2, PO3, PO6, PO9, PO10
8	Describe the benefits of Smart materials and Nanorobots for biological application and flexible electronic materials	K, U	PO1, PO2, PO3, PO10

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CO 2	3	3	3	-	-	-	-	-	-	-
CO 3	3	3	3	-	-	-	-	-	-	3
CO 4	3	3	3	-	-	-	-	-	-	3
CO 5	3	3	3	-	-	-	-	-	-	3
CO 6	3	3	3	-	-	-	-	-	-	-
CO 7	3	3	3	-	-	1	-	-	2	3
CO 8	3	3	3	-	-	-	-	-	-	3

'0' is No Correlation, '1' is Slight Correlation (Low level), '2' is Moderate Correlation (Medium level) and '3' is Substantial Correlation (High level).

Course Content

Content for Classroom transaction (Units)

Module	Units	Course Description	Hrs	CO No.
1	Nanotechnology and circular economy			
	1.1	Introduction to circular economy- basic ideas, working of the circular economy, relationship between SDG and circular economy.	5	["1", "2"]
	1.2	Nanomaterials and circular economy- waste derived nanomaterials, circular resources and its flows.	5	["1"]
	1.3	Nanomaterials in sustainable agriculture, food systems, fabrics, construction.	5	["3", "4"]
2	Quantum nanotechnology			
	2.1	Spintronics - Basic idea Applications of nanomaterials in MRAM, Quantum computing (basic ideas only).	8	["5", "6"]
	2.2	Quantum Sensing (fundamental ideas only)- diamond magnetic nanoscale sensing, superconducting nanowire single photon detectors.	7	["5"]

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Module	Units	Course Description	Hrs	CO No.
3	Environmental Applications			
	3.1	Water purification (different nanomaterials and methods)-adsorption, disinfection, nanofiltration, degradation, emerging contaminant removal	6	["7"]
	3.2	Air pollution control -catalysts for emission control, adsorbents, sensors for air quality monitoring	4	["7"]
	3.3	Soil pollution remedies- removal of contaminants Nano pesticides and fertilizers, heavy metal immobilization	5	["7"]
4	Advanced Nanotechnology			
	4.1	Smart materials- Self cleaning materials, OLEDs, shape memory systems, smart coating systems, pH responsive nanomaterials	5	["8"]
	4.2	Flexible and wearable electronics-smart systems and applications of nanotechnology	5	["8"]
	4.3	Nanorobots for biological applications, nanoscale materials for NEMS devices	5	["8"]

Teaching and Learning Approach	Classroom Procedure (Mode of transaction) Interactive instruction Flipped classroom Industry Visit Applied learning

Assessment Types	**MODE OF ASSESSMENT** Mode of Assessment: Theory **A. Continuous Comprehensive Assessment (CCA)** **• Theory – 30 Marks** Quiz /Assignment /Classroom Activity/Class Test **B. End Semester Evaluation (ESE)** **• Theory – 70 Marks** Assessment Methods – Written Examination Duration of Examination – 2.00 Hrs Pattern of examination for Theory – Non-MCQ Different parts of written examination – Part - A , B , C Answer Type: ◦ PART - A ◦ Short answer - (5 out of 7) – 5 × 4 = 20 ◦ PART - B ◦ Short Essays - (5 out of 7) – 5 × 7 = 35 ◦ PART - C ◦ Essays - (1 out of 2) – 1 × 15 = 15

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- 1. Savage, N., & Diallo, M. S. (2005).Nanomaterials and water purification: Opportunities and challenges. Journal of Nanoparticle Research, 7(4-5), 331–342. 2. Lacy, P., Long, J., & Spindler, W. (2020). The circular economy handbook: Realizing the circular advantage. Palgrave Macmillan. 3. Grumezescu, A. M., & Holban, A. M. (Eds.). (2019). Materials for sustainable energy applications: Conversion, storage, transmission, and consumption. Elsevier. 4. Kuila, T. (Ed.). (2023). Nanotechnology in the textile industry: Advances in fibers, finishing and sustainability. Elsevier. 5. Rai, M., & Ribeiro, C. (Eds.). (2021). Nanotechnology in sustainable agriculture: Recent advances and future prospects. Springer.ISBN: 9783030582766 6. Awschalom, D. D., Loss, D., & Samarth, N. (Eds.). (2002). Semiconductor spintronics and quantum computation. Springer. 7. Quantum Sensing: From Fundamentals to Applications, Andreas Braun, Wiley-VCH, 2024, ISBN: 9783527347179 8. Harper, C. A. (Ed.). (2009). Handbook of smart materials. Wiley, ISBN: 9780471214574 9. Mark Wiesner,

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Jean-Yves Bottero, Environmental Nanotechnology: Applications and Impacts of Nanomaterials, McGraw-Hill (2007) 10. Boris I. Kharisov, Oxana V. Kharissova, & U. Ortiz-Mendez, Nanomaterials in Environmental Protection, Springer, 2014. 11. Kumar, C. S. S. R. (Ed.). (2006). Smart materials (Vol. 1, Nanomaterials for the Life Sciences). Wiley-VCH.

Suggested Readings

- 1. Bhushan, B. (2010). Springer, Handbook of nanotechnology (3rd ed.). Springer. 2. Cavalcanti, A., Freitas Jr., R. A., Hogg, T., & Lobo, F. P. (2015). Nanorobotics: Current approaches and techniques. Springer. 3. Carl C. Koch (Ed.) (2002), Nanostructured Materials Processing, Properties and Potential Applications, Noyes Publications / William Andrew Publishing

Affidavit

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