

Comilla University
Post-Graduate Program Handbook
Department of Chemistry
Doctoral Program in Chemistry
(Academic Session: 2025-26, 2026-27 and 2027-28)

Doctoral program involves substantial and independent research in advanced areas of knowledge and emerging issues. The conduct of research resulting in a thesis in a **field of study** is vital at this level. The graduate should provide effective leadership in his/her field of research, share ideas, and adhere and deal with complex ethical issues. S/he should continue to contribute towards social, technological and cultural progress in the academic and professional contexts.

Pursuing a Ph.D. in chemistry at Chemistry of CoU prepares you to transform the field of teaching and learning chemistry. You'll gain expertise in chemistry, education, methodologies, and research tools from According to Bangladesh National Qualification Framework (BNQF), a Master's degree involves significantly specialized knowledge in a specific area or discipline, which is current, and at the forefront of knowledge. Critical, systematic and creative thinking skills, research practice or advance professional practice, interpersonal skills with leadership and managerial skills are critical competencies particularly within multicultural or transnational work and learning environments. The learners should be able to inform or advise, improve innovations, and share views on contemporary and new issues in related fields or professional practice to relevant audience. While the above competencies are expected as outcomes of a Master's study, the differences generally are in the output, in the form of substantial thesis, dissertation, long case study, project report, new technical solutions/practices and art forms.

- (i) PhD by Mixed-Mode
- (ii) PhD by Research

Eligibility for Admission:

Program Description:

The Chemistry PhD program focuses on all areas of modern chemistry with faculty actively engaged in research in the often-interdisciplinary fields of Physical Chemistry, Inorganic & material Chemistry, Organic chemistry and Chemistry Education Research. The training prepares future scientists and educators for research within contemporary subjects which yield graduates that are very competitive when entering the workforce in industry, government, and academic positions.

The PhD program in Chemistry provides a doctoral education in the following technical focal areas: Physical Chemistry, Inorganic & Material Chemistry, Organic Chemistry, Analytical & Environmental and Chemistry Education Research, drawing upon the strengths of the Department of Chemistry. These areas meet the ever-pressing demand for the development of new materials, the increasing urgency of addressing crucial environmental and security problems, and new methods and understanding for STEM education. The curriculum has been formulated in collaboration with industrial, government, and academic scientists and represents a response to current and projected competencies needed by industry and the scientific community. The purpose of the program is to develop scientists and educators capable of conducting research to solve important problems in contemporary fields of the chemical sciences while preparing a highly skilled work force to ensure the technological/economic health and competitiveness in national and international level.

The Chemistry PhD program requires **minimum 15 credit hours courseworks**, an original research project, and **dissertation presentation** (non-credit bearing).

Learner Profile

At this level, a learner will demonstrate critical understanding and application skills, which are at the frontier of a field of study or professional practice. S/he will be able to independently conduct, manage, and lead research that contributes to substantial, new and original knowledge, and/or professional practice and global citizenship. S/he will possess a strong sense of ethics aligned to national aspirations and global citizenship. S/he will be able to function in an environment of broad degree of autonomy.

Table: Main Competences Category

Learning Outcome Domains	Level Descriptors
Fundamental Skills	<ol style="list-style-type: none"> 1. Demonstrate understanding which is comprehensive, systematic, integrated and undertake critical analysis and synthesis of new, complex and abstract ideas of current critical issues in the most advanced frontiers of knowledge of a field of study, or discipline, or practice and related principles, theories, practice or techniques/ technology; 2. Make substantial / significant contribution/ through the creation/production/innovation of new knowledge/theories/practice/solutions which can satisfy peer reviews, meeting international standards through communications in internationally refereed publications; 3. Analyse, evaluate and synthesise expert knowledge in specific fields and practice; 4. Demonstrate mastery of practical, technical skills/practices and scientific skills which is at the forefront of one or more area of specialization and develop new complex skills or techniques and solutions to resolve new highly complex and emerging problems; 5. Design and implement or adapt highly advanced, specialized research methodologies which are at the forefront of one or more areas of specialization; 6. Initiate, conduct, manage, supervise and lead future independent original research initiatives; 7. Provide informed expert/professional opinion and judgment on new and emerging issues in the related fields; and 8. Use/select/improve existing or develop new appropriate software to support and enhance research activities.
Social Skills	<ol style="list-style-type: none"> 1. Communicate effectively research findings to peers, scholarly community and society at large in the relevant field of expertise in Bangla and advanced English; 2. Work with different people in learning and working community and other groups and networks; 3. Convey information, insights, ideas, problems and present solutions cogently/coherently to peers, scholarly community and society at large in the field of expertise; 4. Contribute to the technical, social and cultural progress in the academic and professional practices to the society on emerging issues; and 5. Demonstrate expert/professional knowledge of cultural, governmental, and environmental issues at a regional and international level, in relation to issues within Bangladesh and actively advocating for and initiating changes/solutions for the betterment of the nation.
Thinking Skills	<ol style="list-style-type: none"> 1. Be independent and individually responsible for work, professional practice, systems, processes and decision-making on complex problematic matters or issues within the academic, professional or technical settings (a field of study and/or professional practice and/or in multi-disciplinary context); 2. Demonstrate autonomy, leadership qualities, interpersonal skill and responsibilities - (planning, resource management, supervision and problem solving) in managing work within a team and others; 3. Be independent original research initiatives with the view to resolve an existing issue; and 4. Display expert judgment, and responsibility to promote/contribute towards technological, social and cultural development
Personal Skills	<ol style="list-style-type: none"> 1. Take full responsibility for own work and where relevant be accountable for overall management of the research; 2. Adhere to legal, ethical and professional codes of practice as a natural part of her/his personality; 3. Integrate knowledge for lifelong learning, development of new ideas, solutions and systems; and 4. Demonstrate appreciation of cultural diversity in Bangladesh in contributing to the society.

Doctoral Graduate Attributes

1. *In-depth Mastery knowledge and skills in the field of study*

- In-depth knowledge Have in-depth knowledge on Physical/Organic/Inorganic & Analytical Chemistry.
- An appreciation of the link between theory and practice

2. *Specialized Knowledge*

- The graduate demonstrates expert, specialized, and in-depth current knowledge of a specific area of research, which will be evident in the thesis or equivalent.

3. *Insight into related Fields:*

- The graduate demonstrates awareness of how the specific area of research relates, or is relatable, to other fields of study and practice which will be evident in the doctoral work.

4. *Ethical Awareness*

- The graduate demonstrates awareness of, and compliance with, the principles of ethics in research and, where relevant, professional protocols, which will be evident in the in-depth discussion in the thesis or equivalent. knowledge and respect of ethics and ethical standards in relation to a major area of study

5. *Original Contribution*

- The graduate shows evidence of original and innovative thinking in research and, where applicable, creative practice and/or performance, which makes a special and novel contribution to the field of study

6. *Appropriate Methodologies*

- The graduate demonstrates knowledge of, and the ability to create and introduce, where appropriate, and to evaluate, select and apply relevant research designs, approaches, methodologies, instruments, and procedures, appropriate for the doctoral work undertaken

7. *Reflection and Autonomy*

- The graduate demonstrates ability to conceptualize and reflect critically, work independently, and arrive at defensible conclusions and solutions, based on appropriately-substantiated and defensible premises and analysis.

8. *Communication and Digital Literacy Skills*

- The graduate demonstrates an advanced level of communicative competence through capacity for rigorous academic writing, including relevant digital literacy skills, and ability to relate individual research with reference to, and critical analysis of, related research by scholars in the relevant knowledge domain(s). The graduate is able to communicate, defend and disseminate their research findings effectively to expert and non-expert audiences.

9. *Critical Thinking for Problem Solving*

- The graduate demonstrates ability to conduct research-related critical and analytical thinking, which shows an intellectual competence for problem-solving in diverse contexts, both familiar and unfamiliar.

10. Program Educational Objectives (PEOs)

PE01	Organizing a quality and reputable chemistry doctoral education program so as to gain recognition at the regional and international levels
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PE02	To produce doctor of chemistry graduates with competence in chemistry and its applications focusing on energy, environment, and health, who are competitive at the national and international levels
PE03	Comprehensively correlate the scientific field of chemistry in order to solve problems in society through an inter, multi, and/or trans-disciplinary approach
PE04	To provide socially & professionally responsible, ethical and life-long learner doctorate

11. Program Learning Outcomes (PLOs)

PLO1	Able to demonstrate a comprehensive knowledge and perform skills in the field of chemistry or professional practice through research with greater depth demonstrated in at least one sub-discipline.
PLO2	PhD students should demonstrate focused and deep expertise in their areas of scholarly exploration, including an understanding of the current status of the topic.
PLO3	Apply critical thinking skills in the evaluation of scientific work, by analyzing, organizing, and evaluation scientific data and knowledge
PLO4	Generate hypotheses, design strategies, perform studies, and interpret results that lead to new knowledge in the field,
PLO5	Communicate scientific information with effectiveness to both experts and novices in oral and written form, including methods, results, and conclusions.
PLO6	Able to perform as ethical, societal, and environmentally aware life-long learner as doctorate

12. Mapping mission of the university with PEOs

PEOs	Mission-1	Mission-2	Mission-3	Mission-4
PEO1				
PEO2				
PEO3				
PEO4				

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low)

13. Mapping PLO with PEOs

PEOs	PEO-1	PEO-2	PEO-3	PEO-4
PLO1				
PLO2				
PLO3				
PLO4				
PLO5				
PLO6				

14. Evaluation Strategy

Each theoretical course offered should be composed of either 50 (for 02 credits) or 100 (for 03 credits) marks. Grades will be calculated as per the university grading structure and individual students will be evaluated based on the following criteria with respective weights.

Descriptions	Evaluation (%)
Class Test and/or Quiz and/or In-course and/or Sudden test and/or tutorial	10%
Assignment and/or Presentation with Rubrics	10%
Mid Semester Examination (At least 2 mid-semester examinations). An average of all examinations will be calculated.	20%
Semester-Final Examination: An Average of the marks given by the internal and	60%

external examiners will be calculated.	
Total:	100%

Comilla University
Department of Chemistry
Academic Session: 2025-26, 2026-27 and 2027-28
Semester Wise Course Distribution
Name of the Program: Doctor of Philosophy (Mixed-Mode) in Chemistry
Curriculum Structure

PhD Coursework			
Course Code	Course Title	Credit Value	Contact Hours/Week
0531-14-611	Scientific Writing	4.0	04
0531-14-612	Chemistry Education Research	4.0	04
0531-14-613	New Energy Materials	4.0	04
0531-14-614	Nanomaterials and Technology	4.0	04
0531-14-615	Semiconductor Technology	4.0	04
0531-14-616	Aquatic Toxicology Assessment	4.0	04
0531-14-617	Organometallic Synthesis and Development	4.0	04
0531-14-618	Water Quality Assessment and Pollution Control	4.0	04
0531-14-619	Advanced Organic Reaction Mechanisms	4.0	04
0531-14-620	Advanced Spectroscopic Tools and Separation Techniques	4.0	04
<i>Any four theory courses will be offered* (Coursework will be offered in first 2 semesters but must be completed before Pre-defense)</i>			
Total Credits of Coursework		16.0	
Course Code	Course Title	Credit Value	Contact Hours/Week
Common Specialized Course			
0531-14-621	Research Proposal Defense	Non-credit Bearing	Has to pass
0531-14-622	Graduate Chemistry Seminar-I	Non-credit Bearing	Has to pass
0531-14-623	Research Publication and Pre-defense	Non-credit Bearing	Has to pass
0531-14-624	Graduate Chemistry Seminar-II	Non-credit Bearing	Has to pass
0531-14-625	Thesis Submission and Defense	Non-credit Bearing	Has to award

<i>Thesis and Defense for Doctor of Philosophy (Mixed-Mode) in Chemistry</i>	<i>Non-credit Bearing</i>	<i>Has to award</i>
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<u>Course Code</u>	<u>Course Title</u>	<u>Credit Hours</u>
0531-14-611	Scientific Writing	4.0
Continuous Internal Evaluation (CIE) Marks: 40 Semester Final Examination (SFE) Marks: 60 Final Exam Hours: 3.0		
<p>(a) Rationale: It is important to decide how your <i>research</i> work compares to other <i>studies</i> of its kind by familiarizing yourself with previous <i>research</i> on the <i>topic</i>. Even, writing for peer-reviewed publication is an important part of the careers of many scientists and engineers. It is also an essential part of the scientific enterprise. Something this important should be done well. However, many scientists and engineers do not consider themselves good writers, so how can the average scientist write a good scientific paper? The good news is you do not have to be a good writer to write a good science paper, but you do have to be a careful writer. In particular, writing for a peer-reviewed science or engineering journal requires learning and executing a specific formula for presenting scientific work.</p>		
<p>(b) Course Objectives (COs):</p> <ul style="list-style-type: none"> ➤ To train professionals with high competences within this program ➤ To develop your writing skills and thinking level ➤ To evaluate communicating research findings and reports of research activities ➤ To provide research indicators, easy methodology and theories on the selected topic for the preparation of plan/strategy on how to handle the research information 		

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(c) Course Contents	
1.	Research Status: Quality (high/low) of article; number of publications, SCI (science citation index)/EI (engineering index), impact factor, high submission and low quality, international editor says what, publishing advice, interest of research publication, field of publication, requirements of publication.
2.	Why do Scientist Publish: Why should publish; worthless of article, citation of article, article as gateway of the community, submission and invest, how to write good manuscript; check originality at the beginning, types of manuscript, choice of right journal, guide for authors.
3.	Contents of Manuscript: Manuscript details; novelty, scientific soundness, reproducibility, readability, standardization, elements of manuscript; title, authorship and its affiliation, abstract, keyword, introduction, materials and methods, results and discussion, conclusion, funding and acknowledgements, references, order of writing papers, review process.

4.	Authors Guideline: Manuscript layout; text layout, length of article, abbreviation, cover letter, revision before submission, editor and reviewers, editorial review, rejection by editor or send to the reviewers, ethical issues, deadly sins; multiple submission, redundant publication, plagiarism, data fabrication and falsification, improper use of human subjects and animals in research, improper author contribution, attention to deadline.
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(d) Course Learning Outcomes (CLOs):	
Upon successful completion of this course, graduates will have the knowledge and skills to-	
CLO-1:	Evaluate the quality of article, impact factor, quartile, field and requirements of publication, <i>etc.</i>
CLO-2:	Judge why should publish SCI/EI article along with how to write quality/types manuscript, choice of right journal, citation, <i>etc.</i>
CLO-3:	Evaluate novelty, scientific soundness, reproducibility, readability, standardization, elements and order of writing papers, <i>etc.</i>
CLO-4:	Prepare a well-furnished article having main manuscript, cover letter, probability of rejection by editor/reviewers, ethical issues, probability of acceptance, <i>etc.</i>
CLO-5:	Concentrate on deadly sins like multiple submission, redundant publication, plagiarism, data fabrication and falsification, improper objectives/contribution (author), attention to deadline, <i>etc.</i>

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):						
	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	2	1	-	-	-
CLO2	3	2	2	-	-	-
CLO3	3	2	1	-	-	-
CLO4	3	2	1	-	-	-
CLO5	3	2	1	2		2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

(g) Learning Materials
(i) Recommended Readings

- Turabian K.L., Manual for Writers of Research Papers, Theses, and Dissertations, **9th edition**, 2018; Chicago Style for Students and Researchers
- Schimel J., Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded Illustrated Edition; Amazon Book Clubs
- Day R.A., Gastel B., How to Write & Publish a Scientific Paper 7th Edition
- Mack C.A., How to Write a Good Scientific Paper, Published by SPIE Press, Bellingham, Washington 98227-0010 USA

(ii) Supplementary Readings:

- Hoogenboom B.J., Manske R.C., How to Write a Scientific Article, Int J Sports Phys Ther. 2012 Oct; 7(5): 512–517
- SCI/EI published articles from world prestigious journals

<u>Course Code</u>	<u>Course Title</u>	<u>Credit Hours</u>
0531-14-612	Chemistry Education Research	4.0
Continuous Internal Evaluation (CIE) Marks: 40 Semester Final Examination (SFE) Marks: 60 Final Exam Hours: 3.0		
<p>(a) Rationale: Chemical education and research course aims to improve student learning, retention and belonging in the field of chemistry by applying concepts from educational, cognitive, and social psychology to chemistry learning environments. Chemical education research course aims to improve student. Models of learning will be developed and refined throughout the semester on the basis of primary literature discussed in-class. How theories of cognition could and should inform learning objectives and assessments in chemistry learning environments will be explored. Substantial emphasis will be placed on critically reading and analyzing studies in the chemistry education research literature with an eye toward the implicit and explicit theories of cognition informing the work. No prior experience with coursework in the learning sciences is assumed. Appropriate for students engaged in discipline-based education research as part of a graduate degree, those interested in pursuing academic careers. CER is conducted both in the field (i.e., in a classroom setting) and in controlled laboratory settings.</p>		
<p>(b) Course Objectives (COs):</p> <ul style="list-style-type: none"> ➤ To train professionals with high competences within this program ➤ To develop your writing skills and thinking level ➤ To evaluate communicating research findings and reports of research activities ➤ To provide research indicators, easy methodology and theories on the selected topic for the preparation of plan/strategy on how to handle the research information 		

(c) Course Contents	
1.	Practical Work in Higher Level Chemistry Education
2.	Early theories of learning
3.	Context- and Problem-based Learning in Higher Level Chemistry Education
4.	Cooperative Learning in Higher Level Chemistry Education

5.	What should students know and be able to do after a course in chemistry?
6.	Learning from Industry and Employment
7.	Assessment in Higher Level Chemistry Education
8.	Curricular Transformations
9.	Online Support and Online Assessment for Teaching and Learning Chemistry
10.	Research-based Teaching in Higher Level Chemistry Education

(d) Course Learning Outcomes (CLOs):

Upon successful completion of this course, graduates will have the knowledge and skills to-

CLO-1: Develop and refine a model of learning based on discussion and analysis of the primary chemistry education and science education literature

CLO-2: Articulate outcome(s) for a chemistry course and justify why they are worthwhile

CLO-3: Assess coherently content knowledge throughout an entire undergraduate career represents a significant advantage for programmatic assessment strategies.

CLO-4: Assess the validity of conclusions in the literature

CLO-5: Design a plan for investigating whether a chemistry learning environment is supporting students' progress toward your desired outcome(s)

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	1	-	-	-	-
CLO2	3	1	-	-	-	-
CLO3	3	-	-	-	-	-
CLO4	3	-	-	-	-	-
CLO5	3	1	2	2	-	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

(g) Learning Materials

(i) Recommended Readings

- Ingo Eilks and Bill Byers (2009). Innovative Methods of Teaching and Learning Chemistry in Higher Education, Royal Society of Chemistry
- Keith S. Taber (2024). Chemical Pedagogy: Instructional Approaches and Teaching Techniques in Chemistry, Advances in Chemistry Education Series No. 12, Royal Society of Chemistry

(ii) Supplementary Readings:

- Relevant journals from google, google scholar, Research Gate, etc.
- Relevant journals from web of science.

<u>Course Code</u>	<u>Course Title</u>	<u>Credit Hours</u>
0531-14-613	New Energy Materials	4.0
Continuous Internal Evaluation (CIE) Marks: 40 Semester Final Examination (SFE) Marks: 60 Final Exam Hours: 3.0		
<p>(a) Rationale:</p> <p>Due to global population growth and expansion of the middle class, it is expected that demand for chemicals and materials will quadruple by 2050. Today's global energy, materials and infrastructure sectors are characterized by significant shifts that are creating new opportunities. New trends and technologies are changing energy production, delivery and consumption. Today, some 83% of primary energy is fossil fuels, while wind and solar PV account for 1.3%. In our Green Scenario, which prioritizes clean electricity and green hydrogen, wind and solar grow to 15% of primary energy in 2030, 47% by 2040 and 70% in 2050, split 62% wind and 38% PV.</p>		
<p>(b) Course Objectives (COs):</p> <ul style="list-style-type: none"> ➤ To train professionals with high competences within this program ➤ To reduce air pollution and mitigate global warming by fossil energy ➤ To develop the methods of renewable and sustainable energy systems ➤ To innovate the energy storage devices for the production of green energy ➤ To ensure the energy storage for next generation of 21st century ➤ To produce skilled research team with higher education system of Bangladesh 		

(c) Course Contents	
1.	Energy Status of the World: Energy; types of energy, energy revolution, sources of energy, fossil fuel energy, bad impact of fossil fuel, future of fossil fuel, alternative of fossil energy, renewable and sustainable energy; solar plant; sun, solar cell, wind plant, tidal plant, geothermal energy plant, nanotechnology revolution.
2.	Energy Storage Devices: Energy storage and its types; lithium-ion battery, sodium-ion battery, ultrafast rechargeable aluminium-ion battery, lithium-sulphur battery, electrochemical double layer capacitor (EDLC), lithium-O ₂ battery. Challenges; higher energy density, high-voltage cathode materials, 5V-LiNi _{0.5} Mn _{1.5} O ₄ , nano-structured cathode materials; Li-ion batteries for mobile electronics, nano-structures Mn-based oxides, advanced cathode materials, high-capacity anode; bottleneck volume expansion, hollow/porous structure; α -Fe ₂ O ₃ multi-shelled hollow spheres (MSHSs), electrochemical performance, structural stability, multi-shelled hollow micro-/nanostructures, ZnMn ₂ O ₄ hollow spheres, CoMn ₂ O ₄ hollow cubes, Fe ₂ O ₃ porous nanorods, porous mixed metal-oxides, nanocomposites, Fe ₂ O ₃ -g-C, integrated solution, Yolk-shell FeO _x @C, ZnFe ₂ O ₄ @PPY, Si-oxide based anode.
3.	Solar Cell: Photoelectric cell; Si solar cell, band structure of <i>c</i> -Si, <i>p-n</i> junction; band diagram, <i>J-V</i> curve, <i>n</i> -type and <i>p</i> -type contact metal, quantum efficiency, key aims for high power, resistance parameters, efficiency loss, CIS/CdTe solar cell, solar cell efficiency, solar radiation, solar spectrum, optical parameters; dielectric constant, absorption coefficient, extinction coefficient, refractive index.

4.	Catalytic Water Splitting: Water splitting (WS); photochemical/chemical/electrochemical catalysis, requirements of WS, ligands, catalysts; homo-/heterogeneous catalysts, electrolysis; cyclic voltammetry, pourbaix diagram, diffusion-controlled electrolysis, bulk electrolysis (controlled potential electrolysis), Faradaic efficiency, catalyst stability and its homo-/heterogeneous nature; instrumental techniques; UV-vis, FT-IR, SEM/EDX, ESI/MS, MALDI-TOF/MS, etc.
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(d) Course Learning Outcomes (CLOs):

Upon successful completion of this course, graduates will have the knowledge and skills to-

CLO-1: Predict the energy update of the globe and discover its alternatives.

CLO-2: Design energy storage devices in the context of new energy materials.

CLO-3: Innovate photoelectric cell to mitigate the world globalization.

CLO-4: Synthesis robust catalysts as the cost effective, available and sustainable.

CLO-5: Perform bottleneck of catalytic water splitting using robust catalysts.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	-	-	-	-	-
CLO2	3	-	-	-	-	2
CLO3	2	2	2	1	-	-
CLO4	2	1	2	1	-	-
CLO5	2	2	2	2	-	-

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

(g) Learning Materials

(i) Recommended Readings

- Likodimos V., *Advanced Photocatalytic Materials*, MDPI, Switzerland
- Elisa I. Garcia Lopez, Leonardo Palmisano, *Materials Science in Photocatalysis*, Elsevier
- Naushad M., Rajendran S., Lichtfouse E., *Green Photocatalysts*, Springer
- Glasstone L., *Introduction to Electrochemistry*
- Bard A. J., *Electroanalytical Methods*

(ii) Supplementary Readings:

- SCI/EI published articles from world prestigious journals

<u>Course Code</u>	<u>Course Title</u>	<u>Credit Hours</u>
0531-14-614	Nanomaterials and Technology	4.0
Continuous Internal Evaluation (CIE) Marks: 40 Semester Final Examination (SFE) Marks: 60 Final Exam Hours: 3.0		
<p>(a) Rationale:</p> <p>Nanomaterials and technology deal with innovation by delivering diverse electronics devices, drug delivery as well as energy production and storage. In the beginning of this chapter, students will learn about history to basic nanomaterials with their properties. In the 2nd chapter, synthesis and characterizations of nanomaterials will be discussed. In the 3rd and 4th chapter, Biosynthetic and natural nanocarbon production and polymer nanocomposites will be focused. In the 5th chapter, their application as well as device fabrication will be deliberated. All these understandings are vital in advanced study of Nanomaterials and technology.</p>		
<p>(b) Course Objectives (COs):</p> <ul style="list-style-type: none"> ➤ To provide information about Nanomaterials for next generation use. ➤ To convey knowledge regarding the properties and characterization of nanomaterials. ➤ To understand the generation of nanomaterials for the betterment of society or country. 		

(c) Course Contents	
1.	Introduction: Characteristics of nano particles, types of nano particles, synthesis process: tops down, bottom-up process, Nanocomposites, diverse nano structures, Uses of nano technology in engineering sectors. Chemistry in nano technology.
2.	Synthesis and characterization: Chemical synthesis (SILAR, colloidal, sol-gel, microemulsion); Physical & chemical vapor deposition (CVD); Laser ablation. Lithography (Photo, E-beam, Nanoimprint); Etching techniques; hydrothermal, Electro-deposition, Sol-gel, Spin coating, Vacuum deposition: Sputtering, PLD, MBE etc. Characterizations: Scanning Probe Microscopy (STM, AFM); X-ray Diffraction (XRD). Electron Microscopy (SEM, TEM, STEM); Spectroscopy (Raman, FTIR, UV-Vis, Photoluminescence); X-ray Photoelectron Spectroscopy (XPS)
3.	Biosynthetic and natural nanocarbon production: Introduction, Types of nanocarbon: Fullerenes, Carbon nanotubes, Carbon nanofiber, Carbon nanohorns, Nanodiamonds, Graphene/graphene oxides, Graphene Quantum Dots, Nanocarbon production: pyrolysis, hydrothermal, Microwave synthesis, cyclic oxidation, combustion method, and CVD etc. Recent advances by nanocarbon: battery, catalysts, molecular imaging, supercapacitors, photovoltaics, Therapeutic agents, sensors etc.
4.	Polymer nanocomposite membranes: Introduction, Membrane behavior: permeability, fouling resistance, technology processes, Demulsification techniques: Chemical, Magnetic, Carbonous, Ionic liquid and nanocomposite membrane demulsification, Mechanism of separation by polymeric nanocomposite membrane, Nano-composite membranes: Polymer nanotube composite, polymer@CNT nanohybrid, nanofiber membranes, nanocomposite film, nanoparticle composite etc.
5.	Application of Nanomaterials with their toxicology: Current developments of nanomaterials, Economic benefits, Industrial progress around the world: Photovoltaics; Batteries & Supercapacitors; Drug delivery; Theranostics; Catalysis; Environmental remediation. Toxicity mechanisms; Risk assessment; Responsible innovation; Ethical, Legal, and Social Implications (ELSI).

<p>(d) Course Learning Outcomes (CLOs):</p> <p>After completion of the Course, the Student will be able to –</p>

CLO-1: Understanding of nanomaterials with their current advancements
CLO-2: Describe the synthesis and processing of nanomaterials.
CLO-3: Predict and pronounce the natural nanomaterials for device fabrication
CLO-4: Describe modern research results about the properties of nanomaterials and technology.
CLO-5: Applying techniques to use different nanomaterials with their toxicological knowledges.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):						
	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	-	-	-	-	-
CLO2	3	1	-	-	-	-
CLO3	3	-	-	-	-	-
CLO4	3	1	-	-	-	-
CLO5	3	2	2	2	-	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

(g) Learning Materials
(i) Recommended Readings
<ul style="list-style-type: none"> Advanced Nanocarbon Polymer Biocomposites, M. R. Rahman, M. K. Bin Bakri (Elsevier) Polymer Nanocomposite Membranes in Water Treatment & Desalination, M. R. Rahman, M. K. Bin Bakri
(ii) Supplementary Readings:
<ul style="list-style-type: none"> Nanomaterials: An Introduction to Synthesis, Properties, and Applications by Dieter Vollath. (Wiley-VCH) Nanotechnology: Principles and Practices by Sulabha K. Kulkarni (Springer). Introduction to Nanotechnology by Charles P. Poole Jr. and Frank J. Owens (Wiley). Nanostructures and Nanomaterials: Synthesis, Properties, and Applications by Guozhong Cao (World Scientific)

<u>Course Code</u>	<u>Course Title</u>	<u>Credit Hours</u>
0531-14-615	Semiconductor Technology	4.0
Continuous Internal Evaluation (CIE) Marks: 40		

(a) Rationale:

Semiconductor materials deal with innovation by delivering diverse electronics devices. In the beginning of this chapter, students will learn about history to basic material properties of semiconductors. In the 2nd chapter, semiconductor characterizations as well as already studied semiconductors will be discussed. In the 3rd chapter, surface science and growth techniques of semiconductors will be focused. In the 4th chapter, their application as well as device fabrication will be deliberated. All these understandings are vital in advanced study of semiconductor materials. This course is intended to furnish well-developed ideas about modern renewable energy materials.

(b) Course Objectives (COs):

- To provide information about semiconductors for next generation use.
- To convey knowledge regarding the properties and characterization of semiconductor materials.
- To understand the generation of renewable energy or the minimal use of it for the betterment of society or country.

(c) Course Contents

1.	Basics of Semiconductor: History of Semiconductors, physics, and chemistry of Semiconductors, Semiconductor processing. Crystal growth of diverse semiconductors, band structure, carrier transport properties, point defects, optical properties, and device physics/ chemistry of semiconductors.
2.	Semiconductor Properties: The electronics field associated with optical devices such as sensors, solar cells, supercapacitors, LED, photocathodes, photoanodes etc. semiconductors related to the optical devices, semiconductor characterizations, and processes including crystal growth and impurity doping. Properties of Si or Si like compounds, Compound semiconductors like GaAs, ZnO, ITO, FTO, TiO ₂ , Cu ₂ O, CuO, Cu ₃ N, CZTS, Oxide or nitride semiconductors etc.
3.	Surface Science and growth techniques of Semiconductors: Theoretical and experimental aspects of the electronic semiconductors, geometric structure of surfaces of semiconductors. Modern ultrahigh vacuum experimental methods will be also discussed such as SILAR, hydrothermal, Electro-deposition, Sol-gel, Spin coating, Sputtering, Vacuum deposition, CVD, PLD, MBE etc.
4.	Application of Semiconductors: Current developments of semiconductors, Economic benefits, Industrial progress around the world, device fabrication like photovoltaic cell, H ₂ evaluation, sensors, and detectors.

(d) Course Learning Outcomes (CLOs):

After completion of the Course, the Student will be able to –

CLO-1: Understanding of semiconductor materials with their current advancements as renewable energy

CLO-1: Describe the physics, chemistry, and processing of semiconductor materials.

CLO-1: Predict and pronounce the theoretical and experimental aspects of semiconductor growth

CLO-1: Describe modern research results about the properties of semiconductors.

Using techniques to deposit different layers of semiconductor materials.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):						
	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	-	-	-	-	-
CLO2	3	1	-	-	-	-
CLO3	3	-	-	-	-	-
CLO4	3	-	-	2	-	-
CLO5	3	-	2	2	-	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

(g) Learning Materials

(i) Recommended Readings

- Thin Films - Deposition Methods and Applications, Edited by Dongfang Yang
- Donald Neamen, *Semiconductor Physics and Devices*

Supplementary Readings:

- Stephen A. Campbell, *The Science and Engineering of Microelectronic Fabrication*
- Tsuneno bu Kimoto and James Cooper, *Wide Bandgap Semiconductor Power Devices: Materials, Physics, Design, and Applications*
- Jia-Ming Liu, *Photonic Devices*.
- Simon M. Sze and Yiming Li, *Physics of Semiconductor Devices*
- Robert F. Pierret, *Semiconductor Fundamentals" (Vol. 1)*

Course Code	Course Title	Credit Hours
0531-14-616	Aquatic Toxicology Assessment	4.0
Continuous Internal Evaluation (CIE) Marks: 40 Semester Final Examination (SFE) Marks: 60 Final Exam Hours: 3.0		
Rationale:		
<p>Aquatic Toxicology mainly focuses on identifying effects of toxicants/toxins for aquatic organisms at different levels, including acute effects and sublethal effects. Achievements from aquatic toxicology have contributed for establishing limited levels of toxicants/toxins in aquatic environment for risk assessment and protection health of aquatic organisms as well as health of aquatic ecosystem.</p>		
Course Objectives (COs):		
<p>➤ To focus on training students to understand the fate, bioavailability, and biological</p>		

effects of contaminants on aquatic organisms and ecosystems.

➤ Students learn to conduct toxicity tests, analyze data, and evaluate risks for environmental management.

(c) Course Contents

1.	General Introduction to Aquatic Toxicology 1. History of aquatic toxicology and concepts in aquatic toxicology, 2. Factors affect to toxicity of toxicants 3. Contributions of aquatic toxicology
2.	Common Toxicants in water bodies 1. Metals; 2. Pesticides; 3. Organic and Inorganics; 4. Others (Aflatoxins...)
3.	Uptake, biotransformation, elimination and accumulation of toxicants in aquatic organisms 1. Uptake, 2. Biotransformation 3. Elimination 4. Accumulation
4.	Mode of actions of common toxicants: 1. Metals 2. Pesticides 3. Organic and Inorganics
5.	Risk assessment: 1. Hazard identification 2. Exposure assessment 3. Effect assessment 4. Risk Characterization

(d) Course Learning Outcomes (CLOs):
 Students after attending the course, he/she should be able to-
 CLO-1: Demonstrate Basic fundamentals of toxicology.
 CLO-2: Explain uptake, bio-transformation, elimination and bio-accumulation of toxicants.
 CLO-3: Articulate the mode of actions of common toxicants for organisms.
 CLO-4: Assess the risk assessment of toxicants for aquatic organisms.
 CLO-5: Design and carry out experiment to identify acute toxicity of toxicant for aquatic organism.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	2	1	-	-	-
CLO2	3	-	1	-	-	-
CLO3	3	2	1	-	-	-
CLO4	3	1	-	1	-	-
CLO5	3	3	2	2	-	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

(g) Learning Materials

(i) Recommended Readings

<ul style="list-style-type: none"> Muhammed Atamanalp, Gonca Alak, Arzu Ucar, Veysel Parlak. Aquatic Toxicology in Fresh Water; The Multiple Biomarker Approach, Springer Nature Switzerland.
(ii) Supplementary Readings:
<ul style="list-style-type: none"> Richardson M. (Ed.), 1995. Environmental Toxicity Assessment. Taylor & Francis. Rand G.M. (Ed.), 1995. Fundamentals of Aquatic Toxicology, 2nd edition. Taylor & Francis. London and New York. Connell D., Lamm P., Richardson R., and Wu R., 1999. Introduction to Ecotoxicology. Blackwell Science. Masson C. F., 1996. Biology of Freshwater Pollution. Third edition. Longman Peakall D. 1992. Animal Biomarkers as Pollution Indicators. Chapman & Hall. London. Sprague J.B. 1971. Review paper: Measurement of pollution toxicity to fish-III, Sub-lethal effects and “safe” concentrations. Water Research Pergamon Press. Vol. 5, p. 245-266

<u>Course Code</u> 0531-14-617	<u>Course Title</u> Organometallic Synthesis and Development	<u>Credit Hours</u> 4.0
(a) Rationale: This course aims to enable the students to learn the state-of art development in organometallic synthesis in addition with deep understanding about structure/bonding and mechanistic aspects of organometallic chemistry in metal-organic framework, catalysis, and biology.		
(b) Course Objectives (COs): ➤ The course will allow the student to appreciate and understand the vast field of organometallic chemistry. It will allow students to learn the state-of-art development in the field. This course aims to enable the students to understand the structure/bonding and mechanistic aspects of organometallic chemistry in catalysis, materials, and biology.		

(c) Course Contents	
1.	Overview of different types of ligand frameworks.
2.	Lewis’s acidity and capacity of those ligands.
3.	Different ligands coordination and chemistry: alkyls, aryls, alkene, alkynes, allyl, carbenes, carbynes, carbonyls, NHC, phosphines, and nitrosyl complexes.
4.	Oxidative addition, reductive elimination, insertion and elimination reactions, and agnostic interaction.
5.	Homogeneous and heterogeneous catalysis, fluxional molecules, bio-organometallics, and optoelectronics organometallic compounds
6.	Special topics from recent developments

<p>(d) Course Learning Outcomes (CLOs): After completion of the Course, the Student will be able to –</p> <p>CLO-1: Explain the metal-ligand frameworks and mechanistic aspects of organometallic chemistry of molecular transformations</p> <p>CLO-2: Explore the properties of specific organometallic compounds from structure-property-activity relationships.</p> <p>CLO-3: Compare the properties of different organometallic compounds for their intended application</p> <p>CLO-4: Design and develop the synthetic scheme of specific organometallic compounds for their specific applications</p>
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(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):						
	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	1	1	-	-	-
CLO2	3	2	1	-	-	-
CLO3	3	1	1	-	-	-
CLO4	3	2	2	-	-	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

(g) Learning Materials
(i) Recommended Readings
<ul style="list-style-type: none"> • Basic Organometallic Chemistry, Anil Elias and B D Gupta • Inorganic Chemistry: Principles of Structure and Reactivity by J. E. Huheey, E. A. Keiter, and R. L. Keiter, 4th ed. Harper Collins 1993 • Inorganic Chemistry by Gary L Miessler and Donald A. Tarr, 3rd ed. Organometallics, Christoph Elschenbroich • Organotransition Metal Chemistry: From Bonding to Catalysis; John F. Hartwig • The Organometallic Chemistry of the Transition Metals; Robert H. Crabtree • Organometallic Chemistry, G O Spessard and G L Miessler
(i) Supplementary Readings
<ul style="list-style-type: none"> • SCI/EI scientific journal from google or google-scholar or research gate.

<u>Course Code</u>	<u>Course Title</u>	<u>Credit Hours</u>
0531-14-618	Water Quality Assessment and Pollution Control	4.0
(a) Rationale:		
<p>Water quality assessment and pollution control course provide learners with a comprehensive understanding of water quality monitoring principles, pollution control strategies and regulatory frameworks. It focuses on both scientific and policy makers, equipping professionals with the skills to analyze, manage and mitigate water pollution. including an overview of the main pollutants and their effects, typical wastewater characteristics (both municipal and industrial wastewater) and how those characteristics may affect relevant unit operations (physical, chemical and biological). It also focuses on how to combine these operations to control water pollution and to meet effluent requirements.</p>		

(b) Course Objectives (COs):

- Demonstrate how to interpret laboratory analysis to establish whether the water fulfils the quality requirements for different uses.
- Show how to look at the major water pollutants, their sources, physical, chemical and biological transformations and impacts.
- Assist with exploring how natural ecosystems respond to changes in water characteristics, including the self-purification capacity of oxygen-demanding materials and filtration of solid components.
- Facilitate the learning of strategies to control common water pollutants in municipal and industrial wastewater.

(c) Course Contents

1.	Introduction to water quality monitoring
2.	Sampling Design and Field Techniques
3.	Water Pollution Control Technology
4.	Waste Water Treatment and Reuse
5.	Emerging Contaminants and challenges
6.	Water Quality data Management and reporting system

(d) Course Learning Outcomes (CLOs):

After completion of the Course, the Student will be able to –

CLO-1: Discuss several types of water pollution problems and the chemistry and physics affecting them

CLO-2: Develop a broad overview understanding of the strategies, regulations and policies to manage water pollution in the European context.

CLO-3: Interpret the results of laboratory analysis for water characterization.

CLO-4: Select methods to control and prevent water pollution to meet effluent requirements within realistic constraints, such as economic, environmental and social aspects, health and safety, manufacturability, and sustainability.

CLO-5: Design and optimize various unit operations and unit processes used in water treatment and configure processes in a treatment plant. This includes obtaining and applying appropriate design values and making appropriate assumptions when needed

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	1	-	-	-	-
CLO2	3	-	-	-	-	-
CLO3	3	1	-	-	-	-
CLO4	3	-	-	-	-	-
CLO5	3	2	2	1	-	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation

CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

(g) Learning Materials
(i) Recommended Readings
<ul style="list-style-type: none"> Water Pollution Control: A Guide to the Use of Water Quality Management Principles – Richard Helmer and Ivanildo Hespanhol: Focuses on managing water resources and pollution prevention. Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring – Edited by Deborah Chapman: Covers practical monitoring techniques and assessments. Clean Water: An Introduction to Water Quality and Water Pollution Control – Kenneth M. Vigil: A comprehensive, accessible guide suitable for students and the public. Handbook of Water Pollution – Inamuddin, Tariq Altalhi, Arwa Alrooqi: Discusses various contaminants affecting water bodies. Physicochemical Processes for Water Quality Control – Walter J. Weber Jr.: Focuses on the technical aspects of treating water. Water Quality: Monitoring and Assessment – Various authors, BoD – Books on Demand: A broad overview of monitoring techniques.
(ii) Supplementary Readings:
<ul style="list-style-type: none"> SCI/EI published articles from world prestigious journals

<u>Course Code</u>	<u>Course Title</u>	<u>Credit Hours</u>
0531-14-619	Advanced Organic Reaction Mechanism	4.0
(a) Rationale:		
This course focuses knowledge and techniques for different organic reaction mechanism at different conditions.		
(b) Course Objectives (COs):		
<ul style="list-style-type: none"> ➤ To provide knowledge about the substitution, elimination and photochemical reaction mechanism. ➤ To impart knowledge about the designing of a new reaction. ➤ To provide an idea of the stereochemistry of organic compounds 		

(c) Course Contents	
1.	Substitution Reaction: <ol style="list-style-type: none"> Nucleophilic Substitution at a Saturated Carbons: Mechanism of S_N1, S_N2, S_Nⁱ reactions, kinetics, thermodynamics and effect of structure, solvent, leaving group, attacking group, neighboring group in substitution reactions. Nucleophilic Substitution in Aromatic System: Nucleophilic substitution in pyridine and diazonium salts, nucleophilic substitution in substituted benzene through benzyne intermediate.

2.	Elimination Reaction: E1 and E2 reactions, stereo selectivity of E2 reactions, mechanism of E1CB reaction, orientation in E2 reaction, elimination vs. substitution reaction, Saytzev vs. Hofmann product in elimination reactions.
3.	Pericyclic reactions: Concept of HOMO, LUMO, symmetry properties of MO. Electrocyclic and cycloaddition both in thermal and photochemical methods, Stereochemistry and mechanisms. Woodward-Hofmann rule, sigmatropic changes (both carbon and H-shift). Conrotation, disrotations.
4.	Photochemistry: Light absorption, fluorescence and phosphorescence, singlet and triplet states, photosensitization reactions. Example of photochemical reaction: (i) photorearrangement, (ii) photoaddition, (iii) photosubstitution, (iv) photooxidation/reduction, photocyclization, (v) photoelimination, Norrish I & II type reactions, (vi) photochemistry of aromatic compounds.
5.	Methods of determining reaction mechanism: Kinetic & non-kinetic methods of determining reaction mechanism. Linear free energy relationships. Application and limitation of Hammett equation. Yukawa-Tsuno equation and its application. Introduction to Taft equation.
6.	Mechanism of Some Important Reactions: Benzoin condensation, Fries rearrangement, Dienone-phenol rearrangement, Pinacol-pinacolone rearrangement, Hofmann, Lossen, Schmidt, Beckmann, Curtius, Claisen, Cope and related rearrangements & stereochemistry.

(d) Course Learning Outcomes (CLOs):

After completion of the Course, the Student will be able to-

CLO-1: Demonstrate the mechanism of nucleophilic substitution and elimination reactions in aliphatic and aromatic compounds.

CLO-2: Describe the mechanism of electrocyclic reaction, cycloaddition and sigma-tropic rearrangement in thermal and photochemical conditions.

CLO-3: Know and understand about fluorescence, phosphorescence, photosensitization and the different types of photochemical reactions and its mechanism.

CLO-4: Describe the kinetic & non-kinetic methods of determining reaction mechanism.

CLO-5: Explore some important name reactions.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	1	2	-	-	-
CLO2	3	2	2	-	-	-
CLO3	3	1	2	-	-	-
CLO4	3	1	2	2	-	-
CLO5	3	1	2	2	-	3

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with Teaching-Learning & Assessment Strategy

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Semester Final, Assignment and Presentation
CLO2	Lecturing and video presenting	Summative (Mid-Semester-1) and

		Semester Final, Presentation
CLO3	Lecturing and Demonstration	Summative (Mid-Semester-2) and Semester Final, Presentation
CLO4	Lecturing and project-based learning	Semester Final, Assignment and Presentation
CLO5	Lecturing and Students Activity	Semester Final, Assignment and Presentation

(g) Learning Materials

(i) Recommended Readings

- Peter Sykes, A Guide Book to Mechanism in Organic Chemistry, 6th edition, Pearson: New York, 2016
- Finar I. L., Organic Chemistry (Volume II), 5th edition, Pearson
- Elial E. L., Stereochemistry for Carbon Compounds, McGraw-Hill, 1962

(ii) Supplementary Readings:

- Gould E. S., Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston, 1962
- Morrison R. T. and Boyd's R. N., Organic Chemistry, 6th edition, Prentice Hall, 1962
- SCI/EI published articles from world prestigious journals

<u>Course Code</u>	<u>Course Title</u>	<u>Credit Hours</u>
0531-14-620	Advanced Spectroscopic Tools and Separation Techniques	4.0
(a) Rationale: This course focuses knowledge and techniques for forming and unearthing chemical structure of unknown organic compounds.		
(b) Course Objectives (COs): <ul style="list-style-type: none"> ➤ To learn the principles of a few spectroscopic techniques (e.g., UV-Visible, IR, Raman, ESR, NMR, and mass spectrometry) ➤ To apply these spectroscopic techniques in identifying the structure of an unknown compound and in their research. ➤ To impart knowledge on chromatographic techniques and use these for chemical analysis 		

(d) Course Contents

1.	UV and IR: Review of theory and experimental techniques. Applications in the identification of organic molecules.
2.	Raman Spectroscopy: Classical and quantum theory of Raman scattering. Criterion of Raman activity. Raman spectrometers, use of laser in Raman spectroscopy, effect of nuclear spin, molecules without a centre of symmetry, vibrational and rotational Raman spectra, mutual exclusion principles, use of polarized light and applications of Raman spectroscopy.
3.	ESR spectroscopy: Introduction, principles, instrumentation, spectrum, the g-factor, relation between hyperfine splitting and unpaired electron density, radicals, anions of aromatic hydrocarbons, interpretation of ESR spectra, ESR spectra of transition metal complexes as single crystal, determination of electron density from ESR spectroscopic studies
4.	Nuclear magnetic Resonance (NMR) ¹H NMR Spectroscopy: Review of basic NMR principles, instrumentation and experimental principles, advanced ideas of chemical shift, chemical exchange, effect of deuteration, stereochemistry, hindered rotation, first and second order spectra, identification of spin systems: A ₂ , AB, AX, AB ₂ , AX ₂ , A ₂ B ₂ , A ₂ X ₂ , ABC, ABX, ABX ₂ and AMX systems.

	<p>different types of couplings (one, two and three bond coupling, vicinal and germinal coupling, virtual, long range and allylic coupling), magnitude of coupling constant, factors affecting the coupling constant, Karplus equation, simplification of complex spectra (Nuclear double resonance, nuclear overhauser effect (NOE), ROE, and shifts reagents), internal rotation and the equivalence and non-equivalence of nuclear polarization, relaxation effect, spin-lattice relaxation, measurement of T_1, mechanism of spin-lattice relaxation, application of dipolar relaxation times, spin-spin relaxation, the multiple irradiation techniques, elimination of quadruple effects, multiple pulse sequence, measurement of T_2, spectral editing, signal and resolution enhancement, connectivity, solid state NMR, applications of ^1H-NMR in the structure elucidation of organic compounds and medical science.</p> <p>^{13}C NMR Spectroscopy: Resolution and multiplicity of ^{13}C NMR, instrumentation, chemical shifts (aliphatic, olefinic, alkyne, aromatic, heteroaromatic and carbonyl carbons), effect of substituents on chemical shifts, theoretical calculation of ^{13}C value, ^1H-decoupling, noise decoupling, broad band decoupling, NOE and origin of nuclear overhauser effect, off-resonance, proton decoupling, DEPT, INEPT, DANTE, structural applications of ^{13}C NMR.</p> <p>Two-dimensional (2D) NMR: Homo- and heteronuclear correlation (COSY, COLOC, HSQC, DEPT, HMBC & HETCOR experiments), measurement of the nuclear Overhauser effect (NOESY, ROSEY), J resolved 2D NMR spectroscopy (TOCSY, SECSY, EXTASY, INADEQUATE and RELAY experiments), introduction to tactics strategies of structure elucidation by one and two-dimensional NMR skeletal structure (atom connectivities) by NMR experiments, relative configuration and conformation by NMR.</p>
5.	NMR Spectroscopy of some other Nuclei: ^{15}N , ^{19}F , ^{31}P and D and ^{11}B .
6.	Mass Spectroscopy (MS): Review of basic mass spectrometry principles and instrumentation, Ionization methods: Electron Impact (EI) & Chemical Ionization (CI), Desorption Ionization Techniques: Fast Atom Bombardment (FAB), Secondary Ion Mass Spectroscopy (SIMS), Matrix Assisted Laser Desorption/ Ionization (MALDI), Electrospray ionization (ESI) & Thermo Spray (TS) spectra, , Field Desorption (FD) & Plasma Desorption (PD), Tandem Mass Spectroscopy (MS-MS/MS-MS-MS). Analyzer: Magnetic Sector, Double-Focusing, Quadruple, Ion Trap, Time-of-Flight (TOF), Fourier Trans-formation Cyclotron Resonance (FTICR or FTMS). Structural study of simple and complex organic compounds and application to macromolecules.
8.	Advanced chromatographic techniques: Theory, principles, instrumentation and applications of separation methods for chemical analysis: LC, GLC, HPLC, GC, combined techniques (GC/MS, LC/MS), GPC, Ion-exchange and supercritical fluid chromatography.

(d) Course Learning Outcomes (CLOs):

After completion of the Course, the Student will be able to-

CLO-1: Describe the basic principles of UV, IR, NMR, Raman and ESR spectroscopic techniques and Mass spectrometry.

CLO-2: Explain the factors affecting the λ_{max} , stretching frequency, chemical shift.

CLO-3: Calculate λ_{max} value, stretching frequency, chemical shift and mass/charge ratio and natural abundances of elements.

CLO-4: Interpret of UV, IR, NMR, Raman and ESR spectroscopic techniques and Mass spectrometry.

CLO-5: Identify unknown molecules using a combination of all the spectroscopic techniques.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):

	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	1	1	-	-	-

CLO2	3	1	1	-	-	-
CLO3	3	1	1	-	-	-
CLO4	3	2	2	-	-	-
CLO5	3	1	2	2	-	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Demonstration	Summative (Mid-Semester-1) and Semester Final
CLO2	Lecturing and Discussion	Summative (Mid-Semester-1) and Semester Final
CLO3	Lecturing and Students activity	Summative (Mid-Semester-1I) and Semester Final
CLO4	Lecturing and Project Based Learning	Summative (Mid-Semester-1I) and Semester Final
CLO5	Lecturing and Group Discussion	Assignment and Semester Final

(g) Learning Materials
(i) Recommended Readings
<ul style="list-style-type: none"> • D. L. Pavia, G. M. Lampman and G. S. C. Kriz, Introduction to Spectroscopy • D. H. William and Ian Flemming, Spectroscopic Methods in Organic Chemistry, 4th edition • T. C. Morrill, R. S. Silverstein & G. C. Bessler, Spectrometric Identification of Organic Compounds, 4th edition. • H. Gunther, NMR Spectroscopy • J. K. M. Sanders and B. K. Hunter, Modern NMR Spectroscopy
(ii) Supplementary Readings:
<ul style="list-style-type: none"> • D. Campbell and R. A. Dwek, Biological Spectroscopy • E. A. V. Ebsworth, D. W. H. Roukin & S. Croadock, Structural Methods in Inorganic Chemistry. • P. S. Kalsi, Spectroscopy of Organic Compounds • SCI/EI published articles from world prestigious journals

Course Code	Course Title	Credit Hours
0531-14-622/0531-14-624	Graduate Chemistry Seminar	4.0
Continuous Internal Evaluation (CIE) Marks: 40 Semester Final Examination (SFE) Marks: 60 Final Exam Hours: 3.0		
(a) Rationale:		
Graduate chemistry seminar is vital on developing professional scientific communication skills, fostering critical thinking, and keeping researchers abreast of cutting-edge developments in the field. It serves as a crucial bridge between academic study and professional research by training students to defend their data, interpret complex literature, and present findings to a peer audience.		
(b) Course Objectives (COs):		
Develop an overall understanding of the principles of oral communication in science including accepted presentation techniques, listening skills, critical analysis of scientific presentations, participation in scientific discussions and introduction of speakers and invited guests.		

(c) Course Contents	
1.	Ability to present scientific material
2.	Ability to critically evaluate the research presented in a peer reviewed article
3.	Ability to defend research approaches and conclusions
4.	Ability to listen to a scientific presentation and to ask pertinent questions regarding the material
5.	Actively participate in a discussion of strengths and weaknesses of a speaker's presentation and/or the scientific merit of the research presented
6.	Research and/or journal presentations with respect to presentation style, multimedia and content.

(d) Course Learning Outcomes (CLOs):	
Upon successful completion of this course, graduates will have the knowledge and skills to-	
CLO-1:	Demonstrate the ability to present scientific material during a 40-minute presentation of a peer-reviewed research article.
CLO-2:	Demonstrate the ability to critically evaluate the research presented in a peer reviewed article and to answer questions posed by the audience on this research at the end of the presentation.
CLO-3:	Demonstrate an ability to defend research approaches and conclusions by providing answers to questions on experimental rational and alternate interpretations of data.
CLO-4:	Demonstrate an ability to listen to a scientific presentation and to ask pertinent questions regarding the material presented.
CLO-5:	Actively participate in a discussion of strengths and weaknesses of a speaker's presentation and/or the scientific merit of the research presented.
CLO-6:	Provide clear concise written critiques of research and/or journal presentations with respect to presentation style, multimedia and content.

(e) Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs):						
	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6
CLO1	3	2	1	2	-	-
CLO2	3	2	1	2	-	-
CLO3	3	2	2	2	-	1
CLO4	3	2	1	2	-	2
CLO5	3	2	2	2	-	2

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low can be used)

(f) Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy		
CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO1	Lecturing and Discussion	Summative (Mid-Semester)
CLO2	Lecturing and Video Presentation with material studio	Assignment and Presentation
CLO3	Lecturing and Power-point Presentation and Discussion	Summative (Mid-Semester)
CLO4	Lecturing and Discussion	Summative (Final Exam)
CLO5	Tutorial on Gaussian Software	Project and Presentation

<i>(g) Learning Materials</i>
<i>(i) Recommended Readings</i>
<ul style="list-style-type: none"> • SCI/EI published articles from world prestigious journals

Orientation

The Departmental orientation for graduate students takes place at the beginning of each semester. Attendance is mandatory. Topics typically include a general description of the graduate program, courses taught in that semester, and a questions and answer session.

Semester 1

- Complete 3 compulsory courses earning a GPA of 3.0 or higher
- Take Research and Teaching Practice and Ethics
- Complete Laboratory Rotations and select the doctoral research advisor (Supervising Professor)
- Attend departmental seminars
- Select Doctoral Studies Committee

Semester 2

- Take Research Proposal Development
- Complete coursework (electives)
- Begin writing Dissertation Research Proposal
- Submit Program of Study
- Attend departmental seminars and research colloquia
- Continue dissertation research
- Submit and defend Dissertation Research Proposal
- Admission to Candidacy

Semester 3

- Conduct research as specified in the Dissertation Research Proposal
- Attend departmental seminars and research colloquia
- Take Scientific Presentations
- Continue dissertation research

Semester 4

- Take Scientific Presentations
- Attend departmental seminars and research colloquia
- Complete dissertation research
- Write Dissertation
- Submit Dissertation to Doctoral Studies Committee for approval

- Defend Dissertation (Oral examination)
- Submit Dissertation to Graduate School

Roles & Responsibilities of Graduate Teaching Assistants in the Department of Chemistry

The professional development acquired through serving as a Graduate Teaching Assistant (GTA) is a major component of the education of Chemistry graduate students. GTAs assume diverse teaching-related responsibilities, such as serving as laboratory assistants, grading laboratory protocols, quizzes, and exams, assisting with course development, leading discussion sections, acting as lead teaching assistants, and fulfilling other duties in support of the primary instructor or at the request of the Department Chair and/or Assistant Chair

Responsibilities of Graduate Teaching Assistants

Upon accepting the role, GTAs are obligated to conscientiously carry out all duties associated with the position. This includes ensuring sufficient preparation for teaching, timely attendance of all scheduled classes, teaching assistant meetings, labs practice sessions, and office hours, diligent and timely evaluation of student work, and prompt communication with students, faculty, or university administrators in case of any concerns, as appropriate to the situation. If a teaching assistant cannot fulfill a scheduled obligation (e.g., attend a meeting or office hours), they must make arrangements for alternative coverage or rescheduling by obtaining prior approval from their lab coordinator

In the cases of repeated or egregious failures to fulfill the designated responsibilities associated with the teaching role, GTAs may be released from their duties and lose their teaching assistantship. Furthermore, since teaching is a major component of the academic requirements of the Chemistry Graduate Program, failing to meet the obligations of the role may have serious implications for a graduate student's standing in the Program.

GTAs are required to adhere to the CoU Student Conduct and Community Standards at all times. It is strictly forbidden for GTAs to abuse their position of authority for personal benefits. They must maintain the integrity of their role and refrain from engaging in situations that could result in a conflict of interest. For example, GTAs must carefully examine their class roster(s) and report to the designated course instructor any potential conflicts of interest involving students in the class, such as romantic or business relationships.

Considerations

GTAs will be provided with a desk in a tutoring room assigned by the Department and located in the Department Building for conducting office hours. Office hours comprised of a total of two hours per week for all assigned courses are required of each GTA and should be conducted only in the assigned tutoring room in the department.

Grievance Procedures

If a graduate student has a grievance regarding teaching assignments or related issues, all efforts should be made to resolve them with the course instructor or supervisor of the GTA. If the complaint cannot be resolved satisfactorily at this level, the graduate student may bring this issue before the Assistant Chairman of the Department. If there still is no satisfactory resolution, the grievance can be brought to the Department Chairman, which will be the final avenue of appeal.

Teaching/Research Assistantship Guidelines

PhD Students will receive funding through teaching assistantships or research assistantships. The only exception is for students who are in their final Semester prior to graduation, during which registration for the final dissertation course will be considered a full-time course load. Doctoral students serving as GTAs should limit teaching activities during the specific semester so that they can focus on research.

**Doctoral Dissertation
Written Communication Rubric**

<i>Student Outcome</i>	<i>Excellent 4</i>	<i>Good 3</i>	<i>Acceptable 2</i>	<i>Needs Improvement 1</i>
Ability to summarize prior research and contextualize research goals Score: _____	The introduction provides a critical and thorough review of the relevant literature that leads to a clear, concise and accurate description of the research problem(s) and aims, significance of the work, and the research design.	The introduction provides a thorough review of the relevant literature that provides some well formulated critical analysis and leads to a mostly clear, concise and accurate description of the research problem(s) and aims, significance of the work, and the research design.	The introduction provides a reasonably detailed review of the literature with enough critical analysis that leads to sufficiently clear, concise and accurate description of the research problem(s) and aims, significance of the work, and the research design but somewhat lacks in clarity or relevance, and omits some key points.	The introduction does not provide a sufficiently detailed review of the literature with little or no critical analysis and incoherent, inaccurate, or lacking description of the research problem(s) and aims, significance of the work, and the research design.
Research design and execution Score: _____	The research design is well-reasoned and appropriate, as evidenced by a large body of research results that are supported by detailed, well-organized, and extensive scientific data, demonstrating a deep understanding of methods, research strategies, and potential problems.	The research design is mostly well-reasoned and appropriate, as evidenced by a significant body of research results that are supported by reasonably well-organized and detailed scientific data, demonstrating a good understanding of methods, research strategies, and potential problems.	The research design is sufficiently well-formulated, as evidenced by research results that are supported by sufficient scientific data, demonstrating appropriate understanding of methods, research strategies, and potential problems.	The research design has significant weaknesses and is inappropriate, as evidenced by minimal research results that are supported by insufficient and poorly organized or lacking scientific data, demonstrating poor understanding of methods, research strategies, and potential problems.
Ability to summarize the research project(s) Score: _____	Demonstrates outstanding subject knowledge and mature critical thinking in summarizing key points, significance and innovation of the research project(s)	Demonstrates broad knowledge and well-developed critical thinking in summarizing key points, significance and innovation of the research project(s)	Demonstrates acceptable knowledge and critical thinking in summarizing key points, significance and innovation of the research project(s), with some minor points missing or unclear	Demonstrates minimal subject knowledge and critical thinking in summarizing key points, significance and innovation of the research project(s), with many key points missing unclear
Quality of writing, graphics, and formatting Score: _____	The writing is compelling, concise, accurate, and effective. Graphics are appropriately sized, clear, virtually error-free, and easily understandable. The text and references are also well-formatted and virtually error-free.	The writing is sufficiently compelling, concise, accurate, and mostly effective. Graphics are mostly appropriately sized, clear, easily understandable, and contain few errors. The text and references are also well-formatted and contain few errors.	The writing is reasonable but somewhat lacking in accuracy and effectiveness. Graphics are somewhat unclear and disorganized and contain a significant number of errors. The text and references are somewhat lacking in attention to appropriate format and contain some errors.	The writing is ineffective, mundane, and inaccurate. Graphics are too small, unclear, poorly organized, and contain many errors. The text and references are not appropriately formatted and contain many errors

**Doctoral Dissertation
Oral Communication Rubric**

<i>Student Outcome</i>	<i>Excellent 4</i>	<i>Good 3</i>	<i>Acceptable 2</i>	<i>Needs Improvement 1</i>
Quality of presentation materials Score: _____	Content is original, accurate in facts and evidence. Presentation is orderly, purposeful, topics are clearly identified, and presentation flows smoothly. Graphics are appropriately sized and positioned, clear, and easily understandable.	Content is mostly original and accurate in facts and evidence. Presentation is mostly orderly and purposeful, topics are clearly identified, and presentation for the most part flows smoothly. Graphics are mostly appropriately sized and positioned, clear, and easily understandable.	Content reveals sufficient effort in originality and accuracy of facts and evidence. Presentation is reasonably orderly and purposeful, topics are clearly identified, and the presentation flow is sufficiently smooth. Graphics are sufficiently well-prepared but are somewhat misaligned, ineffective, unclear, or understandable.	Content reveals minimal effort in originality and accuracy of facts and evidence. Presentation is not orderly and purposeful, topics are not clearly identified, and the presentation flow is not smooth. Graphics are poorly prepared, misaligned, ineffective, unclear, and are not easily understandable
Mastery of the subject Score: _____	Presentation reveals outstanding depth of subject knowledge, exceptionally well developed critical thinking skills, and a substantial ability to interconnect and extend knowledge from the literature to the dissertation research.	Presentation reveals good depth of subject knowledge, well developed critical thinking skills, and a notable ability to interconnect and extend knowledge from the literature to the dissertation research.	Presentation reveals a sufficient depth of subject knowledge, fairly well developed critical thinking skills, and a reasonable ability to interconnect and extend knowledge from the literature to the dissertation research.	Presentation reveals a minimal knowledge of the subject, undeveloped critical thinking skills, and a lack of the ability to interconnect and extend knowledge from the literature to the dissertation research.
responses to questions Score: _____	Questions are handled skillfully and answered thoroughly	Answers reveal a significant skill and are mostly thorough.	Questions are handled sufficiently skillfully and are answered reasonably well	Questions are answered poorly or mostly not answered
Delivery preparation and techniques Score: _____	The speaker appears polished and confident; has obviously practiced delivery multiple times. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation compelling.	The speaker appears comfortable and has likely practiced several times. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation interesting.	The speaker appears somewhat uncomfortable and somewhat lacking in practice but is sufficiently well prepared. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation understandable.	The speaker appears uncomfortable, obviously has not practiced and is does not seem to know the content. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) detract from the understandability of the presentation.

Doctoral Research Proposal Written Communication Rubric

<i>Student Outcome</i>	<i>Excellent 4</i>	<i>Good 3</i>	<i>Acceptable 2</i>	<i>Needs Improvement 1</i>
Abstract Score: _____	The abstract provides a clear, concise and accurate description of the research problem(s) and aims, significance of the work, and the research design.	The abstract provides a mostly clear, concise and accurate description of the research problem(s) and aims, significance of the work, and the research design.	The abstract provides a reasonably accurate description of the research problem(s) and aims, significance of the work, and the research design but somewhat lacks in clarity or omits some key points.	The abstract lacks in clarity and does not provide an accurate description of the research problem(s) and aims, significance of the work, and the research design.
Specific aims and/objectives Score: _____	Specific aims are clearly stated, skillfully crafted and accurately describe the purpose and goals of the proposed research.	Specific aims are mostly well written and describe the purpose and goals of the proposed research with sufficient clarity.	Specific aims provide a reasonably clear description of the purpose and goals of the proposed research.	Specific aims provide a minimal and inaccurate description of the purpose and goals of the proposed research or demonstrate minimal understanding of the research goals.
Delivery preparation and techniques Score: _____	The speaker appears polished and confident; has obviously practiced delivery multiple times. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation compelling.	The speaker appears comfortable and has likely practiced several times. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation interesting.	The speaker appears somewhat uncomfortable and somewhat lacking in practice but is sufficiently well prepared. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation understandable	The speaker appears uncomfortable, obviously has not practiced and is does not seem to know the content. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) detract from the understandability of the presentation.
Significance and impact of the proposed research Score: _____	Significance and impact of the proposed research are clearly articulated, demonstrating a deep understanding of the research problem(s) and the potential outcomes of the proposed work.	Significance and impact of the proposed research are mostly clearly articulated, demonstrating a good understanding of the research problem(s) and the potential outcomes of the proposed work.	Significance and impact of the proposed research are reasonably clearly articulated, demonstrating some understanding of the research problem(s) and the potential outcomes of the proposed work.	Significance and impact of the proposed research are not well described and demonstrate minimal understanding of the research problem(s) and the potential outcomes of the proposed work.
Research design Score: _____	The research design is well-reasoned and appropriate for accomplishing the	The research design is mostly well-reasoned and appropriate for accomplishing the	The research design is reasonable and mostly appropriate for accomplishing the	The research design has significant weaknesses and is inappropriate to accomplish the specific

	specific aims, demonstrating a deep understanding of methods, research strategies, and potential problems.	specific aims, demonstrating a good understanding of methods, research strategies, and potential problems.	specific aims, demonstrating some understanding of methods, research strategies, and potential problems.	aims, demonstrating minimal understanding of methods, research strategies, and potential problems.
Literature Score: _____	Demonstrates skillful use of the relevant literature to support the proposed research and discuss prior art.	Demonstrates thoughtful use of the literature to support the proposed research and discuss prior art. The literature is mostly relevant and carefully selected.	Demonstrates an attempt to use the relevant literature to support the proposed research and discuss prior art. The literature is reasonably relevant and selected.	Barely demonstrates an attempt to use credible sources to support the proposed research and discuss prior art. Key references are missing or the literature is not relevant
Quality of writing, graphics, and formatting Score: _____	The writing is compelling, concise, accurate, and effective. Graphics are appropriately sized, clear, virtually error-free, and easily understandable. The text and references are also well-formatted and virtually error-free.	The writing is sufficiently compelling, concise, accurate, and mostly effective. Graphics are mostly appropriately sized, clear, easily understandable, and contain few errors. The text and references are also well-formatted and contain few errors.	The writing is reasonable but somewhat lacking in accuracy and effectiveness. Graphics are somewhat unclear and disorganized and contain a significant number of errors. The text and references are somewhat lacking in attention to appropriate format and contain some errors.	The writing is ineffective, mundane, and inaccurate. Graphics are too small, unclear, poorly organized, and contain many errors. The text and references are not appropriately formatted and contain many errors.

Doctoral Dissertation Oral Communication Rubric

<i>Student Outcome</i>	<i>Excellent 4</i>	<i>Good 3</i>	<i>Acceptable 2</i>	<i>Needs Improvement 1</i>
Quality of presentation materials Score: _____	Content is original, accurate in facts and evidence. Presentation is orderly, purposeful, topics are clearly identified, and presentation flows smoothly. Graphics are appropriately sized and positioned, clear, and easily understandable.	Content is mostly original and accurate in facts and evidence. Presentation is mostly orderly and purposeful, topics are clearly identified, and presentation for the most part flows smoothly. Graphics are mostly appropriately sized and positioned, clear, and easily understandable.	Content reveals sufficient effort in originality and accuracy of facts and evidence. Presentation is reasonably orderly and purposeful, topics are clearly identified, and the presentation flow is sufficiently smooth. Graphics are sufficiently well-prepared but are somewhat misaligned, ineffective, unclear, or understandable.	Content reveals minimal effort in originality and accuracy of facts and evidence. Presentation is not orderly and purposeful, topics are not clearly identified, and the presentation flow is not smooth. Graphics are poorly prepared, misaligned, ineffective, unclear, and are not easily understandable.
Mastery of the subject Score: _____	Presentation reveals outstanding depth of subject knowledge, exceptionally well developed critical thinking skills, and a substantial ability to interconnect and extend knowledge from the literature to the dissertation research.	Presentation reveals good depth of subject knowledge, well developed critical thinking skills, and a notable ability to interconnect and extend knowledge from the literature to the dissertation research.	Presentation reveals a sufficient depth of subject knowledge, fairly well developed critical thinking skills, and a reasonable ability to interconnect and extend knowledge from the literature to the dissertation research.	Presentation reveals a minimal knowledge of the subject, undeveloped critical thinking skills, and a lack of the ability to interconnect and extend knowledge from the literature to the dissertation research.
Quality of responses to questions Score: _____	Questions are handled skillfully and answered thoroughly	Answers reveal a significant skill and are mostly thorough.	Questions are handled sufficiently skillfully and are answered reasonably well	Questions are answered poorly or mostly not answered

<p>Delivery preparation and techniques Score: _____</p>	<p>The speaker appears polished and confident; has obviously practiced delivery multiple times. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation compelling.</p>	<p>The speaker appears comfortable and has likely practiced several times. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation interesting.</p>	<p>The speaker appears somewhat uncomfortable and somewhat lacking in practice but is sufficiently well prepared. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation understandable</p>	<p>The speaker appears uncomfortable, obviously has not practiced and is does not seem to know the content. Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) detract from the understandability of the presentation.</p>
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