# M. Sc. Chemistry
# (Specialization in Energy Science)

## Curriculum
## (Under Credit and Semester System w.e.f. 2023 Admission)

**SCHOOL OF ENERGY MATERIALS**
**MAHATMA GANDHI UNIVERSITY**
**KOTTAYAM**

1. **TITLE OF THE PROGRAMME:**

   The programme shall be called Master of Science (M.Sc.) Chemistry (Specialisation in Energy Science)

2. **ABOUT THE COURSE:**

   M.Sc. Chemistry (Specialisation in Energy) programme has been proposed to offer students high level interdisciplinary education and training in novel materials and its technological applications. The course will focus on the science and technology related to various energy sectors giving emphasis to the renewable energy. The course has immense job potential in industries and research organizations working on battery, fuel cell and power generation (hydroelectric, thermal, geothermal, tidal, wind, biofuel and nuclear) in India and abroad. The syllabus of the said program is envisaged to ensure eligibility and equivalency for the new course with that of existing M.Sc. Chemistry program of Mahatma Gandhi University by matching 75 percentage of the syllabus of the new course with that of the M.Sc. Chemistry and the rest 20 % on advanced topics in Energy Science.

3. **ELIGIBILITY FOR ADMISSION**:

   A pass in B.Sc. Chemistry from Mahatma Gandhi University or equivalent from other Universities.

4. **ADMISSION CRITERIA:**

   The admission is made on the basis of the performance in entrance test (objective type/ short answer questions) based on the B.Sc. Chemistry syllabus. Admission to the said M.Sc. Course will follow the rules and regulations, which are currently as per the CSS regulations of Mahatma Gandhi University for admission to postgraduate course. Selection of the students will be made from the rank list of the entrance examination for M.Sc. Chemistry conducted by CSS.

5. **STUDENT INTAKE:**

   10 Seats + 2 (International)

6. **DURATION OF THE COURSE**:

   Two years course with Four Semesters, each of 6 months.

7. **SCHEME OF CLASSES:**

   Every semester will have the course distribution with appropriate number of theory and practicals. The fourth semester will accommodate the project work also.

8. **PROJECT WORK:**

   Every candidate must do a project work in the 4 th semester under a supervisor (approved by the Course Coordinator) in a topic having relevance to the application in energy industry. The project thesis should be carried out either at energy laboratory of internationally or nationally renowned institution OR at relevant industry in the energy sector.

## 9. FEE STRUCTURE:

Proposed fee structure of M.Sc. Chemistry (Specialisation in Energy) can be as follows;

| Description | Amount in (Rupees) |
|---|---|
| 1. Admission Fee | 200 |
| 2. Tuition fee per semester | 15000 |
| 3. Library Fee | 200 |
| 4. Affiliation Fee | 200 |
| 5. Stationery Fee | 500 |
| 6. Internet and Audio-Visual Fee | 500 |
| 7. Sports and Athletic Fee | 200 |
| 8. Student Aid Fund | 500 |
| 9. Medical inspection Fee | 500 |
| 10. Student Care Fund (Per Year) | 500 |
| 11. DDF | 2000 |
| 12. Caution Deposit | 1000 |
| 13. PTA Fund | 1000 |
| 14. Lab Fee (per semester) | 7500 |
| 15. Miscellaneous (Examination/mark list/viva) | 2000 |
| Total | 31,800/- |

## 10. COURSES AND CREDITS

Three kinds of courses are offered – Core Courses, Elective Courses and Laboratory courses. Core Courses and Laboratory courses are offered by the school conducting the program. Each course is allotted credits varying from 2 to 4 depending on the hours of instruction / practical. (A 3- credit course, in general, is one, which normally involves three hours per week of classroom teaching or lecture / seminar/ practical lessons).

**Credit Requirements**: The minimum total credits required for the successful completion of the M. Sc. program shall be 80.

**Course Teaching**: Courses shall generally be taught by the faculty who designed the course, though it is possible for the Faculty Council to assign the teaching of a course to more than one faculty.

**Internal Assessment**: The student's attendance and classroom performance as well as the feedback received from tests, tutorials, assignments and term papers shall form basis for internal assessment. The internal assessment will account for 40% of evaluation. The internal assessment marks shall be distributed as follows and as per regulation in 8 and 10 of CSS regulations 2020 of Mahatma Gandhi University.

**A. Theory**

Components' % of internal marks

1) Two test papers - 60%

2) Assignments/Book Review/debates - 20%

3) Seminars/Presentation of case study - 20%

**B. Practical's**

Components' % of internal marks

1) Two test papers - 40%

2) Lab Skill - 25%

3) Records/Viva - 25%

4) Attendance - 10%

## 11. EVALUATION

All work pertaining to the Examinations shall be held in the Schools/ Departments of study and research under the direct control and supervision of the Directors/ Heads of the Departments. There shall be continuous internal assessment as well as end semester examinations for all the courses. Evaluation of the courses shall be conducted by the respective faculty members of School of Energy Materials. Indirect Grading is employed for the evaluation of courses. The performance of a student in each course is evaluated in terms of percentage of marks converted to grade points.

A candidate will be deemed to have completed the requirements of study of any semester and permitted to appear each University end semester examinations (ESE) only if,

1. The candidate has not less than 75% of attendance in each of the subjects of the total number of working days of the concerned semester.
2. His/her progress has been good
3. His/her character and conduct has been good
4. She/he has minimum of 50 % of sessional marks for each subject.

A student who has an attendance and sessional marks lower than 75% and 50% respectively will not be permitted to appear for the ESE and he/she has to redo the semester at the next available opportunity. However, a candidate can repeat the course or avail condonation of attendance for temporary break of study, only once during entire programme as per existing University rules.

## 12. PROCESS OF EVALUATION

The internal assessment will be a continuous assessment (CA) that accounts for 40% of the evaluation in both theory and practical's. The end semester examination will account for the remaining 60% of the evaluation.

**End-Semester Examination:** The end semester examination will account for 60% of the evaluation

**Continuous Assessment (CA):** The student's participation and classroom performance as well as the feedback received from tests, tutorials, assignments and term papers shall form the basis for continuous assessment (CA). It accounts for 40% of the evaluation in both theory and practical's. This assessment shall be based on a predetermined transparent system involving periodic written tests, assignments and seminars in respect of theory courses and based on tests, lab skill, records/viva and attendance in respect of practical courses.

The percentage of marks assigned to various components for internal evaluation is as follows:

**a. Theory**

| Sl. No | Components | % of marks |
|---|---|---|
| 1. | Test Papers (2) | 60 |
| 2. | Assignment / Debates/Book review | 20 |
| 3. | Seminar/ Presentation of Case study | 20 |

**b. Practical's**

| Sl. No | Components | % of internal marks |
|---|---|---|
| 1. | Lab skill | 25 |
| 2. | Observation and recording results | 40 |
| 3. | Punctuality and neatness | 10 |
| 4. | Viva-voce | 25 |

**Test Papers:** For each course there shall be at least three class tests during a semester. Average of the marks obtained in the best two tests will be counted as the internal test component of CAS. Valued answer scripts shall be made available to the students for perusal within 10 working days from the date of the tests.

**Assignments:** Each student shall be required to do 2 assignments for each course. Assignments after valuation must be returned to the students. The teacher shall define the expected quality of the above in terms of structure, content, presentation and the like, and inform the same to the students. Punctuality in submission of assignments/records is to be given a weightage in the internal evaluation.

**Seminar:** Every student shall deliver one seminar as an internal component of every course and must be evaluated by the respective course teacher in terms of structure, content, presentation and interaction. The soft and hard copies of the seminar report are to be submitted to the teacher in charge.

**Results of Continuous Assessment:** The results of the CA counter-signed by Head of the school/Centre shall be displayed on the notice board 5 days before the end semester examinations. The marks awarded for various components of the CA shall not be rounded off, if it has a decimal part. The total marks of the CA shall be rounded off to the nearest whole number. Relevant records of continuous assessment (CA) must be kept in the department and that must be made available for verification.

**Project Work:** There shall be a project to be undertaken by all students. The dissertation entails field work, lab work, report writing, presentation and viva voce. The class hours allotted for project work may be clustered into a single slot so that students can do their work at parent school or other institution for a continuous period of time. However, appropriate changes can be made by the faculty council in this regard. Project/dissertation shall be carried out under the supervision of a teacher in the parent School/Centre/Institute or other research institutes or industrial establishment or university departments if they permit the students to do so, after getting permission from the Department Head. In such cases, one of the teachers from the schools/centres/institutes would be the co-supervisor/internal guide and an expert from the industry/ research organization concerned shall act as supervisor/ external guide.

**Process of evaluation of project work in the fourth semester:** The evaluation of the project in the fourth semester will be done by external examiner, based on the work done by the student, content, presentation of the project work and a viva voce. A panel of External Examiners is prepared based on recommendation of Faculty Council of School of Energy Materials and approval of the same by Vice Chancellor.

There is no provision for improving the continuous assessment/ final evaluation of the project.

## 13. PATTERN OF QUESTION PAPERS FOR THE END- SEMESTER WRITTEN EXAMINATION

The question papers set for the end-semester written examination will have three sections and carry 60 marks as detailed below:

**Section A** – Fifteen short answer questions, minimum one from each Unit. Students will have to answer any twelve. Each question will carry three marks (Total 36 marks).

**Section B** – Six short essay questions, minimum one from each Unit. Students will have to answer any four. Each question will carry 6 marks (Total 24 marks).

Both sections will contain questions covering all the cognitive levels Remembering/ Understanding/Applying/Analysing/ Evaluating and Creating. There will be questions of higher levels of learning for at least 10 marks.

The End Semester Examination (ESE) will be of three hours duration and carry 60 marks. The ESE for the core and elective courses shall be conducted based on the following pattern of question paper.

| Section | Cognitive level | Choice and marks of questions | Question specification | Total Marks | Alignment with Course outcomes (COs) |
|---|---|---|---|---|---|
| Section A | Remembering/ Understanding/ Applying /Evaluating. | 12 outof 15 questions; 3 marks each | Minimum one question from each unit. | 36 | Aligned with COs |
| Section B | Applying/Analysing/ Evaluating/Creating | 4 out of 7 questions; 6 marks each | Minimum one question from each unit | 24 | Aligned with COs |
| | | | | 60 | |

The cognitive levels of questions in the End Semester Examinations are summarised as :

- **Lower levels** of learning (Remembering/Understanding/Applying) :30 to 40%
- **Higher Levels** of Learning (Analyzing/Evaluating/Creating) : 60 to 70%

The **difficulty levels** of questions in the End Semester Examinations are categorised as Low, Medium and High. The percentage of questions in each level of difficulty are given below:

- Low: 20 to 30%
- Moderate: 55 to 65%
- High: 15 to 25%

## 14. GRADING SYSTEM

The grading system followed is that of relative grading on a ten-point scale. The following table indicates the performance range and the relative value of the grades (grade points) on the scale.

**Performance range and relative value of the Grades (Grade points)**

| Range of % of Marks | Grade | Performance | Grade Point |
|---|---|---|---|
| 95 % ≤ 100 | O | Outstanding | 10 |
| 85 % < 95 | A Plus | Excellent | 9 |
| 75 % < 85 | A Only | Very Good | 8 |
| 65 % < 75 | B Plus | Good | 7 |

| | | | |
|---|---|---|---|
| 55 % < 65 | B Only | Above Average | 6 |
| 45 % < 55 | C Only | Average | 5 |
| 40 % < 45 | P Only | Pass | 4 |
| Below 40 | F | Fail | 0 |
| Absent | Ab | Absent | 0 |

**Minimum grade for passing in a course or programme:** The minimum for a pass in a course is 'P' grade. The minimum credit point requirement (CGPA) for the programme is four.

## 15. CONSOLIDATION AND DECLARATION OF RESULTS AND ISSUE OF GRADE CARDS

All work pertaining to the Examinations shall be held in the Schools/ Departments of study and research under the direct control and supervision of the Directors/ Heads of the Departments. The Director of each School will, in consultation with the Faculty Council, nominate a senior teacher as the Chief Examiner who will help him/her in the matter. The marks awarded for internal assessment will be displayed in the school's notice board at the end of each semester. The Pass Board will consist entirely of the faculty of the Centre and will be constituted by the director on the advice of the Faculty Council. The tabulated Grade sheets will be forwarded after each end – semester examination to the office of the Controller of the Examinations. The CSS section in the Controller's office will check the Grade Card for any errors and notify the results after consolidating them. On completion of the final semester, a consolidated Grade Card showing the details of all the courses taken during the programme will be issued to the students. The consolidated Grade Card will contain the details of all the courses with their titles, credits, grades obtained, the total credits earned, the SGPA and the CGPA.

## 16. REVALUATION

The answer scripts of examinations under CSS shall have provisions for revaluation. Evaluation or Scrutiny of answer scripts for the first and third semester is provided. The application for scrutiny and revaluation of answer scripts shall be submitted to the Head of the concerned School/ Department/ Centre within 15 days from the date of publication of the results.

## 17. REAPPEARANCE AND IMPROVEMENT IN EXAMINATIONS:

A student who failed for a course in a semester can register for Reappearance in the forthcoming examination, subject to the conditions set forth in these regulations. Improvement of marks/grades in the forthcoming examination can be done, subject to the conditions set forth in these regulations.

## 18. REGISTRATION FOR IMPROVEMENT

A candidate has to apply for registration for improvement by paying the requisite fee. Candidates are not permitted to register for improvement of grades for Individual course.

Candidates in the 1st and 2nd semesters, who have secured SGPA letter grade ‘P’ or above in the End Semester Examination can improve their grade by reappearing for all the semester courses along with the next immediate batch. In such cases a candidate will be awarded a new grade only if there is an improvement in grade in the new examination; otherwise, the candidate is eligible to retain the grade already awarded. Candidates in the 3rd semester, who have secured the SGPA letter grade ‘P’ or above in the End Semester Examination, can improve their grade by reappearing for all the semester courses, along with the 3rd semester supplementary examination being conducted for failed candidates immediately after the completion of End Semester Examination of Fourth semester. This provision is applicable only for third semester. Improvement of the 4th semester can be done along with the immediate lower batch. If the improvement is meant to obtain minimum CGPA requirement, a candidate has the option to decide which semester (3rd or 4th) is to be improved; however, the grade given to the candidate shall be that obtained for the entire semester improvement examination. 1st and 2nd semester SGPA cannot be improved after the completion of the 4th semester. Only 3rd and 4th semester SGPA can be improved after the completion of a programme. The marks/grades awarded for Continuous assessment and that for the Project/dissertation cannot be improved. SGPA secured in the 4th semester can be improved only for the purpose of fulfilling the minimum CGPA requirement.

## 19. REAPPEARANCE

Candidates in the 1st and 2nd semesters who have secured a letter grade of ‘F’ or ‘Ab’ in any of the courses can avail two immediate consecutive chances to reappear for the examination, course wise, provided the candidate has applied for the same and paid the required fee. Candidate in the 3rd semester who has secured letter grade of ‘F’ or ‘Ab’ in any of the courses can reappear for exams course-wise in the 3rd semester supplementary examination, which will be conducted immediately after the completion of End Semester Examination of Fourth semester, provided the candidate has applied for the same and paid the required fee (fee for supplementary examination of any course shall be full semester examination fee irrespective of number of courses involved). Candidates who secured the grade of only ‘F’ or ‘Ab’ in a course in the 4th semester examination can re-appear course wise, along with the immediate lower batch. Candidates who secured the grade of only ‘F’ or ‘Ab’ in a course in the 3rd /4th semester examinations will be given two additional chances for course-wise reappearance even after the completion of the programme; but it has to be done within a period of two years after the completion. In such cases a candidate has to apply for the same as a supplementary exam and pay the required fee (Fee for supplementary examination of any course shall be full semester examination fee irrespective of number of courses involved).

## 20. REQUIREMENTS OF ATTENDANCE AND PROGRESS

A candidate will be deemed to have completed the requirements of study of any semester and permitted to appear each University end semester examinations (ESE) only if,

1. The candidate has not less than 75% of attendance in each of the subjects of the total number of working days of the concerned semester.
2. His/her progress has been good

3. His/her character and conduct has been good
4. She/he has minimum of 50 % of sessional marks for each subject. A student who has an attendance and sessional marks lower than 75% and 50% respectively will not be permitted to appear for the ESE and he/she has to redo the semester at the next available opportunity. However, a candidate can repeat the course or avail condonation of attendance for temporary break of study, only once during entire programme as per existing University rules.

**21. PROCEDURE FOR COMPLETING COURSE**

The academic year will be divided into four semesters, the odd semester normally commencing at the beginning of the academic year and even semester ending with the academic year. A candidate can proceed to the course of study of any semester (other than first semester) if and only if he has completed the course in the previous semester and has registered for the examination of the previous semester. A candidate who is required to repeat the course of any semester for want of attendance / progress or who desires to rejoin the semester after a period of discontinuance or who upon his own request is specially permitted to repeat the semester in order to improve his performance, may join the semester for which he is eligible or permitted to join. On discontinuation of the course, the student should refund the entire stipend he/she received from the University within one year. The transfer certificate and other certificates will be issued only after refunding the stipend.

**21. ADD-ON COURSES**

In addition to Core, elective and practical courses the school will offer add-on courses such as;

- Green Energy Technologies
- Energy Economics
- Hydrogen Generation and Storage
- Nanotechnology for clean energy
- Materials Recycling and Waste Management

The course structure and syllabus will be announced before commencement of each semester. The lectures will be delivered by reputed Professors/ Scientists from other Universities/ Institutions in India or Abroad.

**Faculty**

Upon successful completion of two years in the program the candidates will be awarded a Master’s Degree under the Faculty of Science.

(As per the M G University CSS regulations amended from time to time.)

**23. CURRICULUM**

**M.Sc. CHEMISTRY (Specialisation in Energy Science)**

**Career Opportunities:** This Masters programme provides students with knowledge and skills required for modern science and technology. Graduates will be prepared for careers within academia or industry in materials-related research and development. The demand for talents in this field is large both in research institutes and industries. For example, wide-bandgap semiconductors, high-performance soft matters, materials modelling, advanced multifunctional materials as well as hybrid smart materials are of high interest in the industries in India and other countries.

The proposed course is an amalgamation of conventional and non-conventional energy related courses focusing on emerging energy source and economical aspects, basics of materials for energy engineering with focus towards renewable energy related studies, computational methodologies etc. This curriculum envisages to prepare the students for a professional or research career either in industries or academia after the completion of the program.

**Features of this program**

- Courses with in-depth understanding of chemistry aspects of energy materials along with hands-on experimental facilities
- Detailed chemical synthesis and characterization-based laboratory experiments
- Computational methods-oriented laboratory course which is a must for modern material scientists
- Vast choice of discipline electives to be chosen from pool of courses of School of Energy Materials pertaining to Energy Science
- Scope of focused research on materials-energy-materials for energy nexus.
- 20 days internship is provided in first two semesters.
- Prospect to receive foreign university fellowship for excellent students to pursue research project in Semester IV.
- Opportunity for highly motivated students to pursue PhD in reputed foreign universities.

**Programme Outcomes (PO) of Mahatma Gandhi University**

**PO 1:** Critical Thinking and Analytical Reasoning Capability to analyse, evaluate and interpret evidence, arguments, claims, beliefs on the basis of empirical evidence; reflect relevant implications to the reality; formulate logical arguments; critically evaluate practices, policies and theories to develop knowledge and understanding; able to envisage the reflective thought to the implication on the society.

**PO 2**: Scientific Reasoning and Problem-Solving Ability to analyse, discuss, interpret and draw conclusions from quantitative/qualitative data and experimental evidences; and critically evaluate ideas, evidence and experiences from an unprejudiced and reasoned perspective; capacity to extrapolate from what one has learned and apply their competencies to solve problems and contextualise into research and apply one's learning to real life situations.

**PO3:** Multidisciplinary/Interdisciplinary/Trans disciplinary Approach Acquire interdisciplinary/ multidisciplinary/transdisciplinary knowledge base as a consequence of the learning they engage with their programme of study; develop a collaborative- multidisciplinary/ interdisciplinary/transdisciplinary-approach for formulate constructive arguments and rational analysis for achieving common goals and objectives.

**PO 4:** Communication Skills Ability to reflect and express thoughts and ideas effectively in verbal and nonverbal way; Communicate with others using appropriate channel; confidently share one's views and express herself/himself; demonstrate the ability to listen carefully, read and write analytically, and present complex information in a clear and concise manner and articulate in a specific context of communication.

**PO 5:** Leadership Skills Ability to work effectively and lead respectfully with diverse teams; setting direction, formulating a goal, building a team who can help achieve the goal, motivating and inspiring team members to engage with that goal, and using management skills to guide people to the right destination, in a smooth and efficient way.

**PO 6:** Social Consciousness and Responsibility Ability to contemplate of the impact of research findings on conventional practices, and a clear understanding of responsibility towards societal needs and reaching the targets for 12 attaining inclusive and sustainable development.

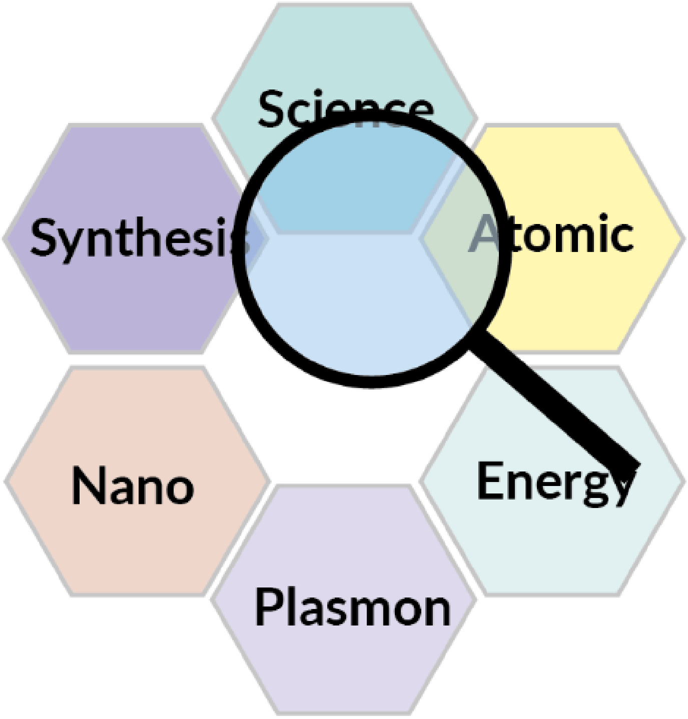
**PO 7:** Equity, Inclusiveness and Sustainability Appreciate equity, inclusiveness and sustainability and diversity; acquire ethical and moral reasoning and values of unity, secularism and national integration to enable to act as dignified citizens; able to understand and appreciate diversity, managing diversity and use of an inclusive approach to the extent possible.

**PO 8:** Moral and Ethical Reasoning Ability to embrace moral/ethical values in conducting one's life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work. Capable of demonstrating the ability to identify ethical issues related to one's work and living as a dignified person in the society.

**PO 9:** Networking and Collaboration Acquire skills to be able to collaborate and network with scholars in an educational institution, professional organizations, research organizations and individuals in India and abroad.

**PO 10:** Lifelong Learning Ability to acquire knowledge and skills, including "learning how to learn", that are necessary for participating in learning activities throughout life, through self- paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/skill development/reskilling

**Learning Outcomes-based Curriculum Framework (LOCF) for Post-graduate Programme**



# M.Sc. Chemistry (Specialization in Energy Science)

# (Syllabus effective from 2023 Admission onwards)

# School of Energy Materials

# Mahatma Gandhi University Kottayam

## PREAMBLE

The role of higher education is vital in securing the gainful employment and providing further access to higher education comparable to the best available in the world-class institutions elsewhere. The improvement in the quality of higher education, therefore, deserves to be given tom-most priority to enable the young generation of students to acquire skill, training and knowledge to enhance their thinking, comprehension and application abilities and prepare them to compete, succeed and excel globally. Sustained initiatives are required to reform the present higher education system for improving and upgrading the academic resources and learning environments by raising the quality of teaching and standards of achievements in learning outcomes across all undergraduate programs in science, humanities, commerce and professional streams of higher education. One of the significant reforms in the undergraduate education is to introduce the Learning Outcomes based Curriculum Framework (LOCF) which makes it student-centric, interactive and outcome-oriented with well-defined aims, objectives and goals to achieve. The University Grants Commission (UGC) took the initiative of implementing the LOCF in the Colleges and the Universities of the country. Accordingly, the Mahatma Gandhi University has decided to implement the LOCF in all its departments under the auspices of Internal Quality Assurance Cell (IQAC). A series of teacher training workshops were organised by IQAC and the office of the Credit and Semester System (CSS), and the departments have revised the syllabus accordingly, through workshops and in consultation with academic experts in the field.

## BRIEF HISTORY OF THE DEPARTMENT

The School of Energy Materials (SEM) was envisioned to address the increasing demand for trained professionals and researchers in the field of energy science. The School of Energy Materials (SEM) offers MTech and PhD programs in Energy Science and Technology. It also creates synergy between academia and industry by entering into several agreements with industrial organisations in India.

Programs offered by the School of Energy Materials will equip students with skills necessary to be successful in the area of sustainable energy science, thereby bridging the gap of trained manpower in the energy sector. Some of the areas of study include fundamentals of thermodynamics, material characterisation techniques, polymers and nano-composites, basics of nanoscience and technology, and nuclear energy technology.

## SCHOOL OF ENERGY MATERIALS

**PROGRAMME** : **M. Sc. Chemistry (Specialization in Energy Science)**

**DURATION** : **2 years (2023 Admission onwards)**

**Credits** : **Core : 67, Elective: 17, Open course: 4**

**Total: 88 credits**

**Program Specific Outcomes (PSOs):** This is an interdisciplinary subject offers knowledge, understanding and output that is integrated and cross-disciplinary in nature. The programme specific outcome (PSO) envisaged in this post graduate programme would be;

| PSO No: | PSOs |
|---|---|
| 1 | The detailed functional knowledge of theoretical concepts and experimental aspects of chemistry. |
| 2 | Provide opportunities to excel in academics, research or Industry |
| 3 | Train students in the field of Chemical sciences with specific emphasis on Energy Science and Technology to cater to the present demands of miniaturization and energy economy. |
| 4 | Solid understanding of the sciences and technology related to energy production, storage, conversion. |
| 5 | Understand the economic, environmental and policy impact of a sustainable energy practice for a sustainable society |
| 6 | Will learn basic to advanced aspects of Renewable Energy systems completely prepared to shift from fossil fuels to renewable sources. |
| 7 | Facilitate the students to be able to familiarise and to work with advanced experimental and computational techniques at various scales. |
| 8 | Nurture the quality of rationality and inquisitiveness, so that the students are capable of free and critical thinking to steer clear judgemental and social biases. |
| 9 | Inspire the students to be committed to deliver good to the society by judicious application of scientific skill sets they acquire doing physics at the nanoscale. |

**Semester 1**

| Sl. No. | Course Code | Name of the Course | Credits | Credits Required | Total Credits |
|---|---|---|---|---|---|
| 1 | EMM23C21 | Quantum Chemistry | 3 | 18 | 24 |
| 2 | EMM23C22 | Structural Inorganic chemistry | 3 | | |
| 3 | EMM23C23 | Statistical and Equilibrium Thermodynamics | 3 | | |
| 4 | EMM23C24 | Stereochemistry, organic photochemistry, pericyclic reactions | 3 | | |
| 5 | EMM23C25 | LAB I – Synthesis and Characterization of Advanced materials | 3 | | |
| 6 | EMM23C26 | Internship/Miniproject | 3 | | |
| ***Elective Courses (Choose any Two)** | | | | | |
| 7 | **EMM23E21** | Hydrogen and Fuel cells | 3 | 6 | |
| 8 | EMM23E22 | Material Synthesis and Characterisation Techniques | 3 | | |
| 9 | EMM23E23 | Thin film science and Technology | 2 | | |
| 10 | EMM23E24 | Bioenergy Technology | 2 | | |
| 11 | EMM23E25 | Polymer Chemistry | 2 | | |

**Semester 2**

| Sl. No. | Course Code | Name of the Course | Credits | Credits Required | Total Credits |
|---|---|---|---|---|---|
| 12 | EMM23C27 | Group theory and spectroscopy | 3 | 18 | 24 |
| 13 | EMM23C28 | Chemical kinetics and surface chemistry | 3 | | |
| 14 | EMM23C29 | Reagents, organic synthesis & organic spectroscopy | 3 | | |
| 15 | EMM23C30 | Coordination Chemistry | 3 | | |
| 16 | EMM23C31 | LAB II- Advanced experiments in Chemistry | 3 | | |
| 17 | EMM23C32 | Internship/Miniproject | 3 | | |
| ***Elective Courses (Choose any two)** | | | | | |
| 18 | EMM23E26 | Energy conversion, storage and transportation | 3 | 6 | |
| 19 | EMM23E27 | Green Chemistry | 2 | | |
| 20 | EMM23E28 | Advances in Catalysis | 3 | | |
| 21 | EMM23E29 | Nuclear Energy and Technology | 2 | | |
| 22 | EMM23E30 | Energy from wind, geothermal and water | 2 | | |

**Semester 3**

| Sl. No. | Course Code | Name of the Course | Credits | Credits Required | Total Credits |
|---|---|---|---|---|---|
| 23 | EMM23C33 | Organometallic and bioinorganic chemistry | 3 | 15 | 24 |
| 24 | EMM23C34 | Advanced solid state & electrochemistry | 3 | | |
| 25 | EMM23C35 | Advanced computation in Material science | 3 | | |
| 26 | EMM23C36 | Chemistry of Natural products | 3 | | |
| 27 | EMM23C37 | **LAB III**- Energy device and fabrication | 3 | | |
| ***Elective Courses (Choose any two)** | | | | | |
| 24 | EMM23E31 | Energy device and fabrication | 3 | 5 | |
| 25 | EMM23E32 | Metal, ceramics and composites materials for Energy applications | 3 | | |
| 26 | EMM23E33 | Bioinorganic photochemistry | 2 | | |
| 27 | EMM23E34 | Research Methodology | 2 | | |
| 28 | EMM23E35 | Nano sensors and nanodevices | 2 | | |
| 29 | EMM23E36 | Nanotechnology in Energy | 2 | | |
| 30 | | **Open Course** | 4 | 4 | |

**Semester 4**

| Sl. No. | Course Code | Name of the Course | Credits | Credits Required | Total Credits |
|---|---|---|---|---|---|
| 31 | EMM23C38 | Industrial visit | 3 | 16 | 16 |
| 32 | EMM23C39 | Dissertation/Viva-voce | 13 | | |

## SEMESTER I

| | |
|---|---|
| | **MAHATMA GANDHI UNIVERSITY** |
| | **QUANTUM CHEMISTRY** |

<table>
<tr><td>School Name</td><td colspan="6">School of Energy Materials</td></tr>
<tr><td>Programme</td><td colspan="6">MSc. Chemistry (Specialization in Energy Science)</td></tr>
<tr><td>Course Name</td><td colspan="6">QUANTUM CHEMISTRY</td></tr>
<tr><td>Type of Course</td><td colspan="6">Core</td></tr>
<tr><td>Course Code</td><td colspan="6">EMM23C21</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">Quantum chemistry uses high-level mathematics as a tool to understand atomic and molecular structure and properties, as well as chemical reactivity. The aim of the course is to give a detailed understanding of molecular orbital theory with research-level applications. During the course, basic and advanced methods in quantum chemistry are presented. An important part of the course is the practical computer exercises, in which you get hands-on experience with simple quantum chemical calculations, such as Hartree-Fock and density functional theory. Furthermore, you learn how to approach a chemical reaction from a quantum chemical perspective by determining potential minima, transition states, force constants, zero-point energy, and other relevant reaction parameters.</td></tr>
<tr><td>Semester</td><td colspan="2">1</td><td colspan="2">Credit</td><td colspan="2">3</td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total Learning Hours</td></tr>
<tr><td></td><td>Authentic learning<br>Collaborative learning<br>Case based learning</td><td>40</td><td>40</td><td>-</td><td>40</td><td>120</td></tr>
<tr><td>Pre-requisite</td><td colspan="6">Strong background in Mathematics and quantum mechanics (undergraduate level)</td></tr>
<tr><td colspan="7">Others- Library, seminar and assignment preparations, test, journal, discussion etc.</td></tr>
</table>

## COURSE OUTCOMES (CO)

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | To understand the fundamentals and mathematical aspects of quantum mechanics | U, A | 6,8 |
| 2 | Apply the postulates of quantum mechanics to simple systems of chemical interest, such as the particle-in-a-box, harmonic oscillator and rigid rotor, | U, A | 2,9 |
| 3 | Hydrogen atom, To calculate properties for simple systems of chemical interest | U, A | 2,3,7 |
| 4 | Derive the variational principle. Use perturbation theory to calculate properties for simple systems of chemical interest. | An, E | 2,7 |
| 5 | Define and explain the Hartree-Fock self-consistent field method. | S, An, E | 1, 2, 5 |
| ****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

## COURSE CONTENT

| Module No: | Module Content | Hrs | CO.No. |
|---|---|---|---|
| 1 | Wave-particle duality, uncertainty principle, postulates of quantum mechanics, Schrödinger equation, Time dependent and time independent Schrodinger wave equation. Its application on some model systems viz., free particle, particle in one, two and three-dimensional box (rectangular and cubical), separation of variables, concept of degeneracy, introduction to quantum mechanical tunneling. | 15 | 1 |
| 2 | Vibrational motion, Harmonic oscillator, Method of power series, Hermite equation and Hermite Polynomials, Recursion formula, wave function and energy. Rigid rotator, Wave function in spherical polar coordinates, Planar rotator, phi equation, theta equation and solutions Lagendre equation and Lagendre polynomials, Spherical harmonics, Angular momentum operator $L^2$ and Lz, Space quantization. | 20 | 2 |

| | | | |
|---|---|---|---|
| 3 | H atom, separation into three equations and solutions, Laguerre equation and Laguerre polynomials wave equation and energy of H like systems, quantum numbers and their importance, Radial wave function and radial distribution functions, angular wave function, Shapes of s, p, d and f atomic orbitals. Postulate of electron spin-orbital and spin functions. Zeeman effect. | 10 | 3 |
| 4 | Many electron atoms. Approximate methods in quantum mechanics: The variation theorem, linear variation principle and perturbation theory (first order and nondegenerate), application of variation method and perturbation theory to the Helium atom, antisymmetry, Pauli exclusion principle, Slatter determinantal wave functions. Electron spin | 15 | 4 |
| 5 | Hartree-Fock Self Consistent Field method, The Coulomb and Exchange Operators, The Fock Operator, Koopmans' theorem, Brillouin's theorem, The Roothaan Equations, Slater's treatment of complex atoms, Slater orbitals. Pauli principle, Slater determinant and wave function. | 10 | 3,5 |

| | |
|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>1. Continuous Internal Assessment (CIA)<br>2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>3. Assignments<br>A. Semester End examination |

**References:**


1. D. A. McQuarrie, Quantum Chemistry, 3rd ed., Univ. Sci. Books, MillValley, California, 1983.
2. I. N. Levine, Quantum Chemistry, 6th ed., Pearson Education, London, 2008.
3. P. W. Atkins, R.S Friedman, Molecular Quantum Mechanics, 5th ed., OUP, Oxford, 2012.
4. J. P. Lowe, Quantum Chemistry 3rd ed., Academic Press, New York, 2008.
5. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Book ed., Mc.Graw-Hill, New York, 1982.

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|---|---|
| | **MAHATMA GANDHI UNIVERSITY** |
| | **STRUCTURAL INORGANIC CHEMISTRY** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **School Name** | **School of Energy Materials** | | | | | |
| **Programme** | **M.Sc. Chemistry (Specialization in Energy science)** | | | | | |
| **Course Name** | **STRUCTURAL INORGANIC CHEMISTRY** | | | | | |
| **Type of Course** | **Core** | | | | | |
| **Course Code** | **EMM23C22** | | | | | |
| **Course Summary & Justification** | The course gives an introduction to symmetry of periodical structures. Fundamental principles of inorganic chemistry will be discussed. Topics to be discussed will include nucleogenesis, bonding theory, molecular symmetry and its relationship to vibrational spectroscopy and bonding. Where appropriate, emphasis will be placed on the mechanisms of reactions and the relationship between structure and reactivity. Time permitting, this class may also examine additional topics, for example, the role that inorganic compounds play in biochemistry (bioinorganic chemistry), or the formation of covalent bonds in metal-carbon compounds (organometallic chemistry). | | | | | |
| **Semester** | **1** | | **Credit** | | **3** | |
| **Total Student Learning Time (SLT)** | **Learning Approach** | **Lecture** | **Tutorial** | **Practical** | **Others** | **Total Learning Hours** |
| | **Authentic learning**<br>**Collaborative learning**<br>**Case based learning** | **40** | **40** | **-** | **40** | **120** |
| **Pre-requisite** | Strong understanding on Fundamental inorganic chemistry (Graduate level) | | | | | |
| ***Others- Library, seminar and assignment preparations, test, journal, discussion etc.*** | | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Identify the structure-activity relationship of simple molecules based on their qualitative molecular orbitals | U, A | 6,8 |
| 2 | Predict the stability and topology of different polyhedral boranes and related compounds. | U, A | 1, 2 |
| 3 | Assess the strength of various acids and bases and their reactivity. | U, A | 2,7 |
| 4 | Explain behavior of different non-aqueous solvent systems towards different reactions. | An, E | 2,7 |
| 5 | Interpret the structure and properties of compounds of sulfur, nitrogen, phosphorous and group 14 elements. | S, An | 3,9 |
| ****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO.No. |
|---|---|---|---|
| 1 | Qualitative molecular orbital theory, symmetry of molecular orbitals, MOs for homo and heteronuclear diatomic molecules, H2 to F2, HF, CO, NO, BeH2, $CO_2$, $H_2O$, $BH_3$, $NH_3$, $B_2H_6$, $B_3N_3H_6$, $S_3N_3$, $N_3P_3Cl_6$, $Si_2H_2$. Importance of frontier molecular orbitals, Shape, energy and reactivity of molecules. | 15 | 1 |
| 2 | Electronic structure and allotropes of boron, boron halides, boron heterocycles, borazine Structure and bonding in polyhedral boranes and carboranes, styx notation; electron count in polyhedral boranes; Wade's rule; topological approach to boron hydride structure. Importance of icosahedral framework of boron atoms in boron chemistry. Closo, nido and arachno structures. Synthesis of polyhedral boranes; electron counting in polycondensed polyhedral boranes, mno rule. Carboranes, metallocarboranes; Boron halides, boron heterocycles, borazine. | 20 | 2 |

| | | | |
|---|---|---|---|
| **3** | Relative strength of acids, Pauling rules, Lux-Flood concept, Lewis concept, Generalized acid-base concept, Measurement of acid base strength, Lewis acid –base interactions, steric and solvation effects, acid–base anomalies, Pearson's HSAB concept, acid-base strength and hardness and softness, Symbiosis, theoretical basis of hardness and softness, electronegativity and hardness. | **10** | **3** |
| **4** | Chemistry in non-aqueous solvents reactions in $NH_3$, liquid $SO_2$, solvent character, reactions in $SO_2$, acetic acid, solvent character, reactions in $H_2SO_4$ and some other solvents. Molten salts, Green solvent: supercritical $CO_2$, Ionic liquids and deep eutectic solvents. | **15** | **4** |
| **5** | Sulphur-Nitrogen compounds: Tetrasulphur tetranitride, disulphur dinitride and polythiazyl. SxNy compounds. S-N cations and anions. Sulphur-phosphorus compounds: Molecular sulphides such as $P_4S_3$, $P_4S_7$, $P_4S_9$ and $P_4S_{10}$. Phosphorusnitrogen compounds: Phosphazenes and poly phosphazenes. Transition metal dichalcogenides, $MoS_2$. Structure, bonding and reactivity of 2D and 3D Carbon, Silicon and Germanium materials. Carbon nitrides, fullerenes, carbon nanotubes (CNT's) and graphenes. | **10** | **2,3,5** |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>**Authentic learning, case-based learning, collaborative learning, seminar, group activities.** |
| **Assessment Types** | **Mode of Assessment**<br>**Continuous Internal Assessment (CIA)**<br>**Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar**<br>**Assignments**<br>**Semester End examination** |

**References**


1. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
2. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of Structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
3. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann, Advanced Inorganic Chemistry, 6th ed., Wiley-Interscience: New York, 1999.
4. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3 rd ed., ELBS, 1999.
5. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3 rd ed., Wiley, 1994

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **STATISTICAL AND EQUILIBRIUM THERMODYNAMICS** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **School Name** | School of Energy Materials | | | | | |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) | | | | | |
| **Course Name** | **STATISTICAL AND EQUILIBRIUM THERMODYNAMICS** | | | | | |
| **Type of Course** | Core | | | | | |
| **Course Code** | EMM23C23 | | | | | |
| **Course Summary & Justification** | Basic Info This is an advanced post undergraduate course on thermodynamics and statistical physics. Topics include basics of temperature, heat, and work; state-counting, probability, entropy, and the second law; partition functions and the Boltzmann distribution; applications to engines, refrigerators, and computation; phase transitions; basic quantum statistical mechanics and some advanced topics. | | | | | |
| **Semester** | 1 | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | 40 | 40 | - | 40 | 120 |
| **Pre-requisite** | Strong background in Thermodynamics | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome**<br>*Upon completion of this course, students will be able to;* | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| 1 | To predict changes in thermodynamic parameters during | U, A | 6,8 |

| | | | |
|---|---|---|---|
| | a process and predict the spontaneity. | | |
| 2 | To understand the significance of Partition function and its relation to thermodynamic properties | U, A | 2,3,4 |
| 3 | Describe the significance of different statistics | U, A | 2,5 |
| 4 | Understand thermodynamics of phase transitions and interpret phase diagram of a given system. | An, E | 2,7 |
| 5 | Understand thermodynamics of Binary systems | An, E | 2,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| **Module No:** | **Module Content** | **Hrs** | **CO.No.** |
|---|---|---|---|
| 1 | Kinetic Theory of gases, Maxwell Distribution of velocity, Boltzmann distribution, Types of molecular velocities- r.m.s, most probable and mean velocity, Molecular Collisions, Mean free path, Transport properties- Diffusion, effusion, Viscosity, Thermal conductivity. Thermodynamic probability, microstate and macrostate, entropy and probability, most probable distribution, residual entropy and its calculation. Ensembles, Maxwell - Boltzmann statistics. | 15 | 1 |
| 2 | Partition function and its relation to thermodynamic properties, Translational, rotational and Vibrational partition function. Molecular partition function for delocalized systems, calculation of equilibrium constant using partition functions. Heat capacity of gases, Anomalous heat capacity of $H_2$, Heat capacity of solids: Dulong - Petits law, Einstein's theory and its modification, Debye's theory of heat capacity of solids. | 20 | 2,3 |
| 3 | Quantum statistics, Bose - Einstein statistics, Fermi - Dirac statistics, Comparison of Maxell - Boltzman, Bose- Einstein and Fermi - Dirac Statistics, Dilute Systems. Application of Bose -Einstein Statistics, Gas degeneration, Application to liquid helium, Bose Einstein Condensation. Application of Fermi -Dirac Statistics to electrons in metals, Extreme Gas Degeneration, Electron gas in metals and its contribution to pressure and heat capacity. | 10 | 3,4 |

| | | | |
|---|---|---|---|
| 4 | Physical transformation of Pure substances- Stability of a phase, Phase transitions and phase boundaries- Thermodynamic aspects, Ehrenfest Classification of Phase transitions. Phase rule – Application to one component systems- Water, S, $CO_2$ and He. | 15 | 4 |
| 5 | Thermodynamics of Binary systems: Binary liquids- Ideal solutions, Raoults law, Henry's Law, Deviations from ideality, Real and Regular solutions, Excess functions, Ideal Dilute Solutions- Colligative Properties- van't Hoff factor. Liquid-vapour equilibria of binary systems – Vapour pressure-composition diagrams and Temperature composition diagrams. Distillation of binary mixtures –Azeotrope formation. Liquid-liquid equilibria- Partially miscible and immiscible liquids- CST, Nernst Distribution Law, Partition co-efficient, Principle of Steam distillation. Solid-liquid Equilibria-Cooling curve, Eutectic system, Deep Eutectic solvents, Application. | 10 | 5 |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

**References**


1. F.W. Sears, Introductions to Thermodynamics, Kinetic Theory of Gases and Statistical Mechanics, Addision Wesley Pub. Cambridge, 1998.
2. F.C. Andrews, Equilibrium to Statistical Mechanics, John Wiley, New York, 2002.
3. L.K. Nash, Statistical Thermodynamics, Addison Wesley, New York, 1999.
4. P. W. Atkins, J. de Paula, Physical Chemistry 8 th ed., 9 th edn. Wiley, New York, 2006
5. D. A. McQuarrie, Physical Chemistry- A Molecular Approach, South Asian Edn., 2008

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|---|---|
| | **MAHATMA GANDHI UNIVERSITY** |
| | **Stereochemistry, organic photochemistry, pericyclic reactions** |

<table>
<tr><td>School Name</td><td colspan="6">School of Energy Materials</td></tr>
<tr><td>Programme</td><td colspan="6">M.Sc. Chemistry (Specialization in Energy science)</td></tr>
<tr><td>Course Name</td><td colspan="6">Stereochemistry, organic photochemistry, pericyclic reactions</td></tr>
<tr><td>Type of Course</td><td colspan="6">Core</td></tr>
<tr><td>Course Code</td><td colspan="6">EMM23C24</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">The aim of the course is to make students familiar with the concepts and applications in two important topics in advanced organic chemistry, namely concerted organic reactions and organic photochemistry.<br>Pericyclic reactions are concerted organic reactions and are governed by Woodward-Hoffmann rules. Different methods of analysis of pericyclic reactions to arrive at the Woodward-Hoffmann rules will be presented. Synthetic applications and mechanisms of various pericyclic reactions will be discussed. Similarly the concepts involved in understanding organic photochemical reactions, their mechansims and applications in organic synthesis will be presented.</td></tr>
<tr><td>Semester</td><td colspan="2">1</td><td colspan="2">Credit</td><td colspan="2">3</td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total Learning Hours</td></tr>
<tr><td></td><td>Authentic learning<br>Collaborative learning<br>Case based learning</td><td>40</td><td>40</td><td>-</td><td>40</td><td>120</td></tr>
<tr><td>Pre-requisite</td><td colspan="6">Understanding of organic reaction mechanism (Graduate level)</td></tr>
<tr><td colspan="7">Others- Library, seminar and assignment preparations, test, journal, discussion etc.</td></tr>
</table>

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | To learn and apply various concepts such as stereochemistry and fundamental principles of stereo selectivity in organic chemistry. | U, A | 6,8 |
| 2 | Comprehend and predict the role of temperature, solvents, and catalysts in organic reactions Elucidate reaction mechanisms using isotope effects | U, A | 2 |
| 3 | Identify and differentiate prochirality and chirality at centers, axis, planes and helices and determine the absolute configuration | U, A | 2,7 |
| 4 | Understand the significance of organic photochemical reactions | An, E | 2,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO.No. |
|---|---|---|---|
| 1 | **Stereochemistry**: Molecular symmetry and chirality: symmetry operations and symmetry elements, point group classification and symmetry number. Stereoisomerism: Classification, racemic modification, molecules with one, two or more chiral centres. Configuration, nomenclature, D, L, R, S and E, Z nomenclature. Axial and planar chirality and helicity (P & M); stereochemistry and configurations of allenes, spiranes, alkylidene, cycloalkanes, adamantanes, catenanes, biphenyls (atropisomerism), bridged biphenyls, ansa compounds and cyclophanes. | 15 | 1 |
| 2 | Topicity and prostereoisomerism: Topicity of ligands and faces and their nomenclature, stereogenicity, cyclostereoisomerism; configurations, conformations and stability of cyclohexanes, (mono-, di- and tri-substituted), cyclohexenes, cyclohexanones, halocyclohexanones, decalines, decalols, decalones. Assymetric induction; Cram’s, Prelog’s and Horeaus rules. | 20 | 2 |

| | | | |
|---|---|---|---|
| 3 | **Pericyclic Reactions:** Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene and allyl system. Classification of pericyclic reactions. Woodward Hoffmann correlation diagrams. FMO and PMO approach. Electrocyclic reactions- conrotatory and disrotatory motions, 4n, 4n+2 and allyl system. Cycloadditions- antarafacial and suprafacial additions, 4n and 4n+2 systems, 2+2 addition of ketenes, 1,3- dipolar cycloadditions and cheleotropic reactions. Sigmatropic rearrangements- suprafacial and antarafacial shifts of H, Sigmatropic shifts involving carbon moieties, 3,3- and 5,5 sigmatropic rearrangements. Claisen, Cope and Aza-Cope rearrangements. Fluxional tautomerism, Ene reaction. | 10 | 3 |
| 4 | **Organic photochemistry** Photochemical processes. Energy transfer, sensitization and quenching. Singlet and triplet states and their reactivity. Photoreactions of carbonyl compounds, enes, dienes and arenes. Norrish Type I and Type II reactions of acyclic ketones. Free radical reactions: Patterno-Buchi and Barton reactions, photo-Fries and Di-π methane rearrangements. Photoreactions of Vitamin D. Photosynthesis, photochemistry of vision.Singlet oxygen generation and their reactions. Introduction to chemiluminescence. Applications of photochemistry. | 15 | 4 |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

**References**

1. S. Sankararaman, Pericyclic Reactions – A textbook. Wiley-VCH, 2005.
2. I. Fleming, Pericyclic Reactions, Oxford University Press, 1999.
3. N. J. Turro, V. Ramamurthy and J. C. Scaiano, Modern molecular photochemistry of organic compounds, University Science Books, 2010.
4. D. G. Morris, Stereochemistry Royal Society of chemistry; 2001.
5. D.Nasipuri, Stereochemistry of organic compounds New Age International ,1994.
6. R.J. Sundberg and F. A. Carey, Advanced Organic Chemistry Part B: Reaction and Synthesis, Springer, 2008 (Fifth Edition).

**MAHATMA GANDHI UNIVERSITY**

**LAB -I**

**SYNTHESIS AND CHARACTERIZATION OF ADVANCED MATERIALS**

| | | | | | | |
|---|---|---|---|---|---|---|
| **School Name** | School of Energy Materials | | | | | |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) | | | | | |
| **Course Name** | **LAB -I**<br>**SYNTHESIS AND CHARACTERIZATION OF ADVANCED MATERIALS** | | | | | |
| **Type of Course** | Core | | | | | |
| **Course Code** | EMM23C25 | | | | | |
| **Course Summary & Justification** | The lab course will include detail on solid state synthesis, solution-based synthesis (co-precipitation, solvothermal, sol-gel, microwave synthesis), synthesis from the melt, combustion synthesis, gas phase synthesis for thin films (PVD, CVD, sputtering), and polymer synthesis.<br>It will also cover scattering techniques (e.g. XRD, PDF), spectroscopic techniques (e.g. IR, Raman, XPS, XAS, UV-vis), imaging (e.g. SEM, AFM, TEM), methods for studying materials properties such as electrochemical, mechanical and magnetic characterisation. | | | | | |
| **Semester** | 1 | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | 40 | 40 | - | 40 | 120 |
| **Pre-requisite** | Basic synthesis lab skills | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Synthesise a material by a variety of different synthesis routes, having assessed their suitability | U, A | 6,8 |
| 2 | Critically analyse how and why the nature of the chemical bonding in a material is influenced by the synthetic pathway and how it impacts the resulting material properties | U, A | 2 |
| 3 | evaluate the suitability of synthesis and characterisation methodologies for a material targeted towards a particular application | U, A | 2,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Internship/ Miniproject** |

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|---|---|---|---|---|---|---|
| **School Name** | **School of Energy Materials** | | | | | |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** | | | | | |
| **Course Name** | **Internship/ Miniproject** | | | | | |
| **Type of Course** | Core | | | | | |
| **Course Code** | EMM23C26 | | | | | |
| **Course Summary & Justification** | The candidate shall do a 20 days internship in any of the industries or do a miniproject. The report will be evaluated by internal panel of experts authorized by director of the department. | | | | | |
| **Semester** | 1 | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | - | 40 | 40 | 40 | 120 |
| **Pre-requisites** | Aptitude for research work in one of the interdisciplinary areas in the realm of interface between physical science and nanotechnology. Literature survey. | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **HYDROGEN AND FUEL CELLS** |
| **School Name** | **School of Energy Materials (SEM)** |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) |
| **Course Name** | **HYDROGEN AND FUEL CELLS** |
| **Course Credit** | **3** |
| **Type of Course** | **Elective** |
| **Course Code** | **EMM23E21** |
| **Course Summary & Justification** | In this course, we will cover various concepts, reactions and applications of Fuel Cells. The main focuses are; Electrochemistry Basics - Chemical concepts to understand the foundation of Fuel Cells, Definitions and History - Simple definitions, history connected to political and economic motivations, Fuel Cell Chemistry - Fundamental processes in a Fuel Cell and their efficiency |
| **Semester** | **1** |

| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
|---|---|---|---|---|---|---|
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | General Chemistry and Physics, Introductory Materials Science, Elementary Semiconductor Theory, Thermodynamics of Materials. | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome** | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| 1 | Understand the basic elements of fuel cells | U, R | 1,2 |
| 2 | Identify the potential of hydrogen fuel cells and its applications in various sectors of the society. | U, C | 2,4 |
| 3 | Familiarise the concept of hydrogen production techniques | U, I | 2,3 |
| 4 | Gain knowledge in various fuel cells, devices and systems. | A, S | 3,6 |

| | | | |
|---|---|---|---|
| 5 | To impart knowledge on learning and facts of usage in fuel cells | U, R | 3,7 |
| 6 | Exposure to different fuel cells | E, S | 4,7 |
| 7 | To impart awareness on significance of various application knowledge in fuel cells in the future technological applications. | E, Ap. | 3,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| **Module No:** | **Module Content** | **Hrs** | **CO. No.** |
|---|---|---|---|
| **1** | **HYDROGEN ENERGY ECONOMY**<br>Hydrogen Energy Economy – Conception - Present status and a vision – Applications of Hydrogen - Transport application - cars, light trucks, buses - Stationary and Portable - Electronic gadgets. | **10** | **1,2** |
| **2** | **HYDROGEN AND PRODUCTION TECHNIQUES**<br>Hydrogen – Physical and chemical properties - Salient characteristics - Production of hydrogen – Steam reforming – Water electrolysis – Gasification and woody biomass conversion – Biological hydrogen production – Photo<br>dissociation – Direct thermal or catalytic splitting of water. | **8** | **3,4** |
| **3** | **HYDROGEN STORAGE & TRANSPORT**<br>Hydrogen storage options – Compressed gas – Liquid hydrogen – Hydride – Chemical Storage – Comparisons - Transport of Hydrogen - Pipelines, Gaseous, Liquid and Compound materials. | **10** | **5** |
| **4** | **FUEL CELLS**<br>History – Principle - Working - Thermodynamics and kinetics of fuel cell process – Performance evaluation of fuel cell – Comparison on battery Vs<br>fuel cell - Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – Relative merits and demerits. | **10** | **5,6** |
| **5** | **APPLICATION OF FUEL CELL**<br>Fuel cell usage for domestic power systems - Large scale power generation –Automobile - Space - Environmental analysis of usage of Hydrogen in Fuel cell - Future trends in fuel cells. | **12** | **6,7** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**A. Continuous Internal Assessment (CIA)**<br>o Surprise test<br>o Internal Test – Objective and descriptive answer type<br>o Submitting assignments<br>o Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**B. Semester End examination** |

**REFERENCES**


1. Hydrogen and Fuel Cells: A Comprehensive Guide, Rebecca L. and Busby, Penn Well Corporation, Oklahoma, (2005).
2. Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorensen (Sorensen), Elsevier, UK, (2005).
3. Fuel Cell and Their Applications, Kordesch, K and G.Simader, WileyVch, Germany, (1996).
4. Fuel Cells: Theory and Application, Hart, A. B and G.J.Womack, Prentice Hall, New York Ltd., London, (1989).

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **MATERIALS SYNTHESIS AND CHARACTERIZATION TECHNIQUES** |

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|---|---|---|---|---|---|---|
| **School Name** | School of Energy Materials | | | | | |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) | | | | | |
| **Course Name** | **Materials synthesis and characterization techniques** | | | | | |
| **Type of Course** | Elective | | | | | |
| **Course Code** | EMM23E22 | | | | | |
| **Course Summary & Justification** | The course will include detail on solid state synthesis, solution-based synthesis (co-precipitation, solvothermal, sol-gel, microwave synthesis), synthesis from the melt, combustion synthesis, gas phase synthesis for thin films (PVD, CVD, sputtering), and polymer synthesis.<br>It will also cover scattering techniques (e.g. XRD, PDF), spectroscopic techniques (e.g. IR, Raman, XPS, XAS, UV-vis), imaging (e.g. SEM, AFM, TEM), methods for studying materials properties such as electrochemical, mechanical and magnetic characterisation . | | | | | |
| **Semester** | 1 | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | 40 | 40 | - | 40 | 120 |
| **Pre-requisite** | Basic understanding on solid state (Graduate level) | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

## COURSE OUTCOMES (CO)

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Explain the principles of synthesising solid materials by various routes, e.g. from solid phase, solution, melts, gas phase | U, A | 6,8 |

| | | | |
|---|---|---|---|
| 2 | Explain the principles behind and the type of information that different characterisation techniques provide | U, A | 2 |
| 3 | Evaluate the strengths and limitations of various synthesis and characterisation methods | U, A | 2,7 |
| 4 | Propose technical applications for materials produced by different synthesis methods | An, E | 2,7 |
| 5 | Propose and critically evaluate the suitability of synthesis and characterisation methodologies for a material targeted towards a particular application | U,A, S | 2,3,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO.No. |
|---|---|---|---|
| 1 | Synthesis of nanomaterials: Gold, Silver, different types of Nano oxides, $TiO_2$, ZnO by using sol-gel method, Co-precipitation, Hydrothermal, Microwave, Solvothermaland bio synthesis methods, Nanotubes and Nanowires, Carbon nanotubes, Graphene preparation, powder syntheses, crystal growth techniques, zone refining, properties and applications. | 15 | 1 |
| 2 | Top down and bottom-up synthesis- mechanical alloying, Mechanical ball-milling, Ion implantation, Inert gas condensation, Arc discharge, RF-plasma arc technique, Laser ablation, Template assisted synthesis, Clusters, Colloids, Zeolites, Porous silicon. | 20 | 2,3 |
| 3 | Deposition techniques: Chemical vapour deposition (CVD), Metal Organic chemical vapour deposition (MOCVD), Epitaxial growth techniques: Molecular beam epitaxy, Atomic layer deposition, Pulsed laser deposition, Pulsed electrochemical deposition, Magnetron sputtering, Spin coating, Introduction to Lithography techniques | 10 | 3,4 |

| | | | |
|---|---|---|---|
| 4 | Principle, Theory, Working and Application; X-Ray Diffraction, Field Emission Scanning Electron Microscopy, High Resolution-Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunnelling Microscopy. | 15 | 4,5 |
| 5 | Photoluminescence Spectroscopy, Raman Spectroscopy, X-Ray Photoelectron Spectroscopy (XPS), Thermal analysis – Differential Scanning Calorimetry (DSC) – Thermogravimetric Analysis (TGA) – Differential Thermal Analysis (DTA) – Dynamic Mechanical Analysis (DMA), Mechanical Testing- Nano Indentation -Vibrating Sample Magnetometer, Zeta Potential and Particle size measurement. | 9 | 2,3 |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

**REFERENCES**


**1.** S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.

2. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate (Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.

3. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.

4. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties &Applications, Imperial College Press, 2004.

5. J. George, Preparation of Thin Films, Marcel Dekker, Inc., New York.2005.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **THIN FILM SCIENCE AND TECHNOLOGY** |

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|---|---|---|---|---|---|---|
| **School Name** | School of Energy Materials | | | | | |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) | | | | | |
| **Course Name** | **THIN FILM SCIENCE AND TECHNOLOGY** | | | | | |
| **Type of Course** | Elective | | | | | |
| **Course Code** | EMM23E23 | | | | | |
| **Course Summary & Justification** | This course aims at developing comprehensive understanding on thin film deposition principles and techniques. You will gain a fundamental view on the thin film growth process as well as the microstructure that has been developed during the deposition process. The course will help you develop the skills to design thin film systems and select appropriate deposition techniques based upon materials composition, microstructures and properties. | | | | | |
| **Semester** | 1 | | **Credit** | | 2 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | 30 | 30 | - | 30 | 90 |
| **Pre-requisite** | Basic knowledge on material synthesis | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome**<br>*Upon completion of this course, students will be able to;* | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| 1 | Explain the molecular behaviours in different vacuum conditions for gas-phase deposition techniques of thin films. | U, A | 6,8 |
| | Propose appropriate deposition methods for a targeting | | 2 |

| | | | |
|---|---|---|---|
| 2 | thin film structure with desirable properties. | U, A | |
| 3 | Explain the principles of different film deposition techniques. | U, A | 2,7 |
| 4 | Describe the general thin film growth process and evaluate the microstructure evolution during deposition. | An, E | 2,7 |
| 5 | Choose the right tools to perform thickness measurement of different thin films and characterize their optical properties. | S, An, E | 2,4,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO.No. |
|---|---|---|---|
| 1 | Growth and structure of films: General features. Nucleation theories Effect of electron bombardment on film structure. Post- nucleation growth Epitaxial films and growth. Structural defects. Preparation methods: Electrolytic deposition, cathodic and anodic films, thermal evaporation, cathodic sputtering, chemical vapour deposition. Molecular beam epitaxy and laser ablution methods. | 15 | 1 |
| 2 | Vacuum science and techniques: Vacuum principles; Vacuum generation – Rotary vane pump, Diffusion Pump, Turbomolecular Pump (TMP), Cryo-Pump; Vacuum measurement - Thermal conductivity vacuum gauges, Ionization vacuum gauges. | 20 | 2 |
| 3 | Thickness measurement and monitoring: Electrical, mechanical, optical interference, microbalance, quartz crystal methods. Analytical techniques of characterization: Small angle X-ray diffraction, electron microscopy, high and low energy electron diffraction, Auger emission spectroscopy. | 10 | 3 |

| | | | |
|---|---|---|---|
| 4 | Mechanical properties of films: Elastic and plastic behavior. Optical properties. Reflectance and transmittance spectra. Absorbing films. Optical constants of film material, Multilayer films, Anisotropic and gyrotropic films. | 15 | 4 |
| 5 | Electric properties to films: Conductivity in metal, semiconductor and insulating films. Discontinuous films. Superconducting films. Dielectric properties. Magnetism of films: Molecular field theory. Spin wave theory. Anisotropy in magnetic films, Domains in films, Applications of magnetic films. Thin film devices: Fabrication and applications. | | 5 |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

**References**


1. K.L. Chopra, Thin Film Phenomena; McGraw-Hill

2.A. Goswami; Thin Film Fundamentals; New Age International Pvt. Ltd.

3. Milton Ohring, Materials science of thin films; Academic Press

4. Thin Films; Heavens; Dover Publications Inc.; 1991

5. Thin-Film Deposition: Principles and Practice; Smith; McGraw-Hill; 1995.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Bio Energy Technology** |
| **School Name** | **School of Energy Materials (SEM)** |
| **Programme** | **M.Sc. Chemistry (Specialization in Energy science)** |
| **Course Name** | **Bio Energy Technology** |
| **Course Credit** | **2** |
| **Type of Course** | **Elective** |
| **Course Code** | **EMM23E24** |
| **Course Summary & Justification** | Bioenergy is seen as an important component in the future sustainable energy system, which itself requires knowledge and understandings for sustainable utilisations of biomass fuels. The course provides in-depth knowledge of fuel characterisation, treatement and conversion technologies, environmental consequences, and resource utilisations related to bioenergy. Moreover, the course gives insight into different bioenergy systems, including bioheat, biopower, biofuel and biogas, and their combinations, with consideration of process integration for heat and material recovery. For biomass conversion technologies, emphasis will be placed on the thermochemcial approaches, which include combustion, gasification and pyrolysis. The biological approaches, bioethanol and biogas productions, are also be treated in the course, but to a lesser extent. System design and process simulation is an important part of the course. |
| **Semester** | **1** |

| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
|---|---|---|---|---|---|---|
| | | 30 | 30 | | 30 | 90 |

| | |
|---|---|
| **Pre-requisite** | Basics of Energy: Energy and development, Units and measurements, Solar spectrum, Electromagnetic spectrum. |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **1** | **Introduction**: Biomass- types, advantages and drawbacks, Indian scenario, characteristics, carbon neutrality, conversion mechanisms, fuel assessment studies | **10** | **1,2** |
| **2** | **Biomethanation**: Microbial systems, phases in biogas production, parameters affecting gas production, effect of additives on biogas yield, possible feed stocks. Biogas plants, types, design, constructional details and comparison, biogas appliances, Burner, illumination and power generation, effect on engine performance. | **10** | **1,3** |
| **3** | Combustion: Perfect, complete and incomplete, equivalence ratio, fixed Bed, fluid Bed, fuel and ash handling, steam cost comparison with conventional fuels. Briquetting: types of Briquetting, merits and demerits, feed requirements and pre-processing, advantages, drawbacks. | **20** | **4,5** |
| **4** | **Gasification**: Types, comparison, application, performance evaluation, economics, dual fuel engines, 100 % Gas Engines, engine characteristics on gas mode, gas cooling and cleaning train. | **10** | **6** |
| **5** | **Pyrolysis and Carbonization**: Types, process governing parameters, thermo gravimetric analysis, differential thermal analysis, differential scanning calorimetry, Typical yield rates. | **20** | **5,6** |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Acquiring the knowledge of biomass energy | U, An | 1,2 |
| 2 | To design bio-energy systems | U, I | 2,4 |
| 3 | Understanding Biomass as a renewable energy and its importance | U, C | 2,3,5 |

| | | | |
|---|---|---|---|
| 4 | Develop knowledge on historical background and scope of geothermal systems. | A, S | 3,6 |
| 5 | Understand the concepts on Bio Gas these subjects for further learning. | U, R | 4,7 |
| 6 | Understand the concepts on Bio Gas these subjects for further learning. | E, Ap. | 7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

| | |
|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**C. Continuous Internal Assessment (CIA)**<br>o Surprise test<br>o Internal Test – Objective and descriptive answer type<br>o Submitting assignments<br>o Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**D. Semester End examination** |

**REFERENCES**


1. David Boyles, (1984) Bio Energy Technology Thermodynamics and costs, Ellis Hoknood Chichester
2. Khandelwal, K.C, Mahdi, S.S. (1986) Biogas Technology – A Practical Handbook, Tata 35 McGraw Hill
3. Mahaeswari, R.C. (1997) Bio Energy for Rural Energisation, Concepts Publication
4. Tom B Reed, (1981) Biomass Gasification – Principles and Technology, Noyce Data Corporation, Best Practises Manual for Biomass Briquetting, I R E D A, 1997
5. Eriksson S. and M. Prior, (1990) The briquetting of Agricultural wastes for fuel, FAO Energy and Environment paper
6. Iyer PVR et al, Thermochemical Characterization of Biomass, M N E S

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Polymer Chemistry** |

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| **School Name** | **School of Energy Materials** |
| **Programme** | **M.Sc.** |
| **Course Name** | **Polymer Chemistry** |
| **Type of Course** | **Elective** |
| **Credit Value** | 2 |
| **Course Code** | **EMM23E25** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Course Summary & Justification** | Polymer chemistry is a distinctive topic in chemistry having many inter as well as multidisciplinary components. This course is designed as an interdisciplinary course that includes fundamental as well as in-depth knowledge of the polymer science. The syllabus has been designed to cover the fundamental understanding of different fields of polymer chemistry with special emphasis on polymer synthesis and related topics thereby enable the students to work in frontier areas of polymer sciences. This comprises of the history of polymer science and its relevance in the development of human civilization. The syllabus covers the significance polymer molecular weight and its relation with structure and property of various polymers. This course also covers detailed study of the polymerisation reactions and techniques for polymer synthesis. This course further offers an awareness and understanding of the contemporary trends and growth in the field of polymer science. After the completion of this course, students will be able to understand the basics associated with polymer materials and the method/mechanism of its synthesis. | | | | | |
| **Semester** | **I** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Lectures, Group discussions, Seminars, Independant Learning etc.. | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Understanding of Organic Chemistry (Undergraduate level). | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | To Acquire a sound knowledge about the fundamentals and importance of Polymer chemistry. | R, U, An | 1,2,3, 7 |
| 2 | To compare and correlate various polymerization reactions and techniques. | U, A, An | 1,2,3 |
| 3 | To understand the peculiarities of polymer molecular weight and various determination techniques. | U, A | 1,2 |
| 3 | To Correlate the structure and property relationship in polymeric materials. | An,S | 1,4,5 |
| | To outline the basic concepts of thermal transitions in polymers and the determination methods for it. | U, A, An | 1,2,3 |
| 5 | To understand and explore properties and advance applications of different polymers in diverse areas. | U, A, An, E,C, I | 1,2,3, 6,7,8, 9 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | Concept of polymer & macromolecules, definition, functionality, classification of polymers.<br>Polymerization reactions: Addition (free radical polymerization reaction, anionic and cationic polymerization, coordination polymerization, Ziegler Natta polymerization) and Condensation polymerization, Co-polymerization. Polymerization techniques: Bulk, solution, suspension, emulsion polymerizations, melt and interfacial polycondensations. | **15 Hrs.** | **1, 2** |
| **Module 2** | **Concept of molecular weight of polymers**: number average, weight average, Z average and viscosity average molecular weight, molecular weight distribution and polydispersity index (PDI). Determination of molecular weight of polymers: Light scattering technique, Membrane Osmometry, Gel permeation chromatography (GPC), viscometry, etc. | **15 Hrs.** | **3, 4** |

| | | | |
|---|---|---|---|
| **Module 3** | Crystalline and amorphous polymers, Factors affecting crystallinity and chain flexibility of polymers. Effect of Crystallinity on the properties of polymers.<br>Thermal transitions in polymers: Glass transition temperature ($T_g$) and crystalline melting points ($T_m$), Factors affecting Glass transition temperature, methods to determine $T_g$ and $T_m$: DSC, TMA, DMA etc. | **15 Hrs.** | **4** |
| **Module 4** | Properties and Applications of: Specialty Polymers, Poly electrolytes, ionomers (ion containing polymers), conducting polymers, electroluminescent polymers, fluoropolymers, polymer colloids, thermoplastic elastomers (TPE), polymer blends (heterogeneous plastics), thermally stable polymers, biomedical polymers. | **15 Hrs.** | **5** |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**A. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**B. Semester End examination** |

**REFERENCES**


1. V.R. Gowariker, N.V. Viswanathan, J. Sreedhar, Polymer Science, New Age International, 2010
2. P. Bahadur, N. V. Sastry, Principles of Polymer Science, Narosa publishing house Pvt. Ltd., New Delhi, 2005.
3. M. S. Bhatnagar, A Textbook of Polymers, Vol II, S. Chand & Company Ltd., 2004.
4. Premamoy Ghosh, Fibre Science & Technology, McGraw-Hill professional, 2004.
5. D. C. Blackley, Polymer lattices: Science and Technology, Springer Netherlands, 2012
6. J.M.G. Cowie, V. Arrighi, Polymers: Chemistry &Physics of Modern Materials, 3rd Edn., CRC Press, 2008.
7. G.G. Odian, Principles of Polymerization, 4th Edn, John Wiley & Sons, 2004.
8. P.J. Flory, Principles of Polymer Chemistry, Cornel University Press. London, 1953.
9. F.W.Billmeyer, Text Book of Polymer Science, Wiley interscience, 1976.

**SEMESTER II**

| | |
|---|---|
| | **MAHATMA GANDHI UNIVERSITY** |
| | **GROUP THEORY AND SPECTROSCOPY** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **GROUP THEORY AND SPECTROSCOPY** |
| **Type of Course** | **Core** |
| **Credit Value** | **3** |
| **Course Code** | **EMM23C27** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Course Summary & Justification** | Learning the principles behind chemical bonding and the basics of group theory along with the applications. This course helps in familiarising the symmetry elements and symmetry operations and also identification of point group associated with a molecule. It also helps to determine the molecular orbitals and hybridisation of molecules.<br>This course is designed at providing students with theoretical concepts of various spectroscopy, i.e., Atomic, Molecular, Vibrational, Raman, Mossbauer and electronic to analyses the molecular and electronic structure of atoms and molecules. Interaction of light with molecules, spectral transitions, and theoretical explanation of spectral data will be discussed. | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge in Quantum Mechanics,<br>Basic knowledge about spectroscopy at the Bachelor's level | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome** | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| 1 | An insight to chemical bonding | U | 1&3 |
| 2 | An insight to group theory | U | 1,2,4&5 |
| 3 | Understand bonding in diatomic molecules | A | 1,6&7 |
| 4 | Identify point groups of the molecules | A | 1,3,5 |

| | | | |
|---|---|---|---|
| 5 | Determining the molecular orbitals of molecules using group theory | A | 4&5 |
| 6 | Deriving hybridization of molecules using group theory | A | 4,5,6&7 |
| 7 | Understand the interaction light with matter and the key concepts spectroscopy to probe the structure of molecules. | U | 1 |
| 8 | Apply quantum mechanics and group theory principles to understand molecular spectra | A | 3 |
| 9 | Identify the relationship between molecular spectra and molecular properties | Ap | 2,4,5 |
| 10 | Analyses and explain the structure of atoms and molecules using various spectral data. | A | 2,4,5 |
| 11 | Evaluate the utility of various spectroscopy as a qualitative and quantitative method. | U | 6 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| **Module No:** | **Module Content** | **Hrs** | **CO. No.** |
|---|---|---|---|
| **Module 1** | **Microwave Spectroscopy**<br>The Electromagnetic radiation, Absorption and emission spectra, Effect of radiation on atoms and molecules, Subdivisions of spectroscopy. Rigid rotor model and rotational spectra, diatomic and polyatomic molecules, chemical analysis by microwave spectroscopy. Non-rigid rotator model. Instrumentation techniques for Microwave spectroscopy | **10 Hrs.** | **1, 2,3, 6** |
| **Module 2** | **Infrared and Raman Spectroscopy**<br>Basics of molecular vibration and Harmonic oscillator, Anharmonicity, Ro-vibrational spectra. Polarization of light and and scattering. The Raman Effect, pure rotational Raman, vibrational Raman spectra, ro-vibrational Raman spectra structure determination from combined Raman and IR spectroscopy. Rotational fine structure of electronic-vibration transitions. Instrumentation of Infra red and Raman spectroscopy. | **13 Hrs.** | **2, 6** |

| | | | |
|---|---|---|---|
| **Module 3** | **Module 3: Electronic Spectroscopy of Atoms and Molecules**<br>Atomic structure and spectroscopy: term symbols; many-electron systems and antisymmetry principle. electronic spectra of diatomic molecules, vibrational coarse structure, progressions, intensity of vibrational-electronic spectra: the Franck-Condon Principle, oscillator strengths, spectroscopic and equilibrium dissociation energies, Molecular term symbol, n →π, π → π transition. Kasha's rule, photophysics of radiative and non-radiative transitions, energy transfer processes, Excimers and exciplexes, Fluorescence and phosphorescence, Quantum yield, life time and anisotropy, static and dynamic quenching, Stern-Volmer analysis. | **12 Hrs.** | **4,5,6** |
| **Module 4** | **Photoluminescence Spectroscopy**<br>Steady state Fluorescence: Principles, Jablonski diagram, application of fluorescene spectroscopy, Basic instrumentation, Effect of solvents on fluorescence spectra (general and specific), Chemical and biochemical applications of anisotropy measurements. Flash photolysis, laser flash photolysis. | **15 Hrs.** | **6, 7, 8, 9, 10** |
| **Module 5** | **Group Theory**<br>Reducible and irreducible representations, classes and characters, Great Orthogonality and related theorems, Projection operator, Direct product representation Applications: SALC, Spectroscopic selection rules, Polyatomic vibration and normal modes. | **10 Hrs.** | **1, 6, 9,11** |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**A. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**B. Semester End examination** |

**REFERENCES**


1. C.N. Banwell, E.M. McCash, Fundamentals of Molecular Spectroscopy, 4th Edn., Tata McGraw Hill, 1994.
2. G. Aruldhas, Molecular Structure and Spectroscopy, Prentice Hall of India, 2001.
3. H. Kaur, Spectroscopy, 6th Edn., Pragati Prakashan, 2011.
4. R.S. Drago, Physical Methods in Chemistry, Saunders College, 1992.
5. K.J. Laidler, J.H. Meiser, Physical Chemistry, 2nd Edn., CBS, 1999.
5. D.N. Sathyanarayana, Electronic Absorption Spectroscopy and Related Techniques, Universities Press, 2001.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **CHEMICAL KINETICS AND SURFACE CHEMISTRY** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Chemical kinetics and surface chemistry** |
| **Type of Course** | **Core** |
| **Credit Value** | **3** |
| **Course Code** | **EMM23C28** |

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|---|---|---|---|---|---|---|
| **Course Summary & Justification** | After the completion of the course the student will be able to Interpret the basic reaction dynamics and obtain the rate constants for reactions in gaseous state and solutions. Calculate thermodynamic parameters from kinetic data. Interpret the kinetics of unimolecular, termolecular and fast reactions. Identify isotope effects in reactions. Apply the principles of acid-base and enzyme catalysis to solve any given kinetic data. | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Any discipline of mechanical engineering, production engineering, polymer technology, chemical engineering, chemistry and physics can complete the course. | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | After the completion of the course the student will be able to Interpret the basic reaction dynamics and obtain the rate constants for reactions in gaseous state and solutions. reactions. | U | 2,7 |
| 2 | Calculate thermodynamic parameters from kinetic data. | U, A, R | 1,2,6,7 |
| 3 | Interpret the kinetics of unimolecular, termolecular and fast . | U, R | 1,2 |
| 4 | Identify isotope effects in reactions | U, R, A | 2 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

## COURSE CONTENT

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | **Theories of reaction rate**<br>Scope, laws of chemical kinetics, stoichiometry; time and true order; determination of order of reaction. Influence of temperature on reaction rate; potential energy surface, contour diagrams. Kinetic theory of collisions; ARRT, derivation of rate equations; application of ARRT<br>to reactions between (i) atoms (ii) molecules (iii) atoms and molecules. | **10 Hrs.** | **1** |
| **Module 2** | Unimolecular reactions, Lindemann - Christiansen hypothesis; bimolecular reactions in gas phase (involving atoms and free radicals), Factors determining reaction rates in solution; primary and secondary salt effects - influence of ionic strength and dielectric constant on reactions involving (i) ions (ii) dipoles (iii) ion and dipole. Electrostriction; influence of hydrostatic pressure; volume of activation. Linear free energy relationship, Hammett and Taft equations | **13 Hrs.** | **2** |
| **Module 3** | General catalytic mechanisms. Equilibrium and steady state treatments Enzyme catalysis; Michalis-Menten kinetics; activation energies of enzyme-catalyzed reaction<br>Acid - base catalysis - protolytic and prototropic mechanisms. Acidity functions - Kinetic methods of analysis. Chemisorption and Physisorption; Langmuir's adsorption isotherm; competitive adsorption-Mechanisms of reactions on surfaces (Langmuir, Rideal and LangmuirHinshelwood mechanisms); Activation energies Non-ideal adsorption; multiplayer adsorption; capillary condensation; measurement of surface area, BET equation | **12 Hrs.** | **3** |
| **Module 4** | Rate expressions for opposing, parallel and consecutive reactions; Chain reactions - Thermal and photochemical reactions; steady-state approximations; Stern-Volmer<br>equation; Reactions between hydrogen and halogens - Gas phase auto oxidation; explosion and explosion limits.<br>Flow techniques - relaxation theory and relaxation techniques - Temperature, Pressure, electric field and magnetic field jump methods; Flash photolysis and pulse<br>radiolysis | **15 Hrs.** | **4** |
| **Module 5** | **Surface Chemistry**<br>Different types of interfaces, molecular and atomic surface structure, surface chemical reactions, surface tension of solutions, surface excess, thermodynamics of surfaces, Gibbs equation and its derivation, surface films, surface potential, adsorption by solids, Langmuir isotherm - its kinetic and statistical derivation, Freundlich equation, multilayer adsorption, BET isotherm - its kinetic derivation, measurement of surface area. Colloids - their preparation, purification, stability & electro kinetic phenomena, Donnan membrane equilibrium, micro and nano emulsions. Surface analysis using photoelectron spectroscopy, surface imaging techniques like SEM, TEM, AFM etc., sputter coating, ion beam principles, design of surfaces with novel properties | **10 Hrs.** | **4,5** |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**C. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**D. Semester End examination** |

**REFERENCES**


1. A.A. Frost and R.G. Pearson, " Kinetics and Mechanism",(2nd edn), 1963, John Wiley and sons INC
2. K.B. Ytsiimiriski, " Kinetic Methods of Analysis" 1996, Pergamom press.
3. K.K.Rohatgi Mukherjee, "Fundamentals of Photochemistry", Revised edition 1978, New Age International Publishers, New Delhi.
4. Donald A.McQuarrie and John D.Simon, "Physical Chemistry-A Molecular Approach" 1st Edition 1998, Viva Books Private Limited, New Delhi.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **REAGENTS, ORGANIC SYNTHESIS & ORGANIC SPECTROSCOPY** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Reagents, organic synthesis & organic spectroscopy** |
| **Type of Course** | **Core** |
| **Credit Value** | **3** |
| **Course Code** | **EMM23C29** |

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|---|---|---|---|---|---|---|
| **Course Summary & Justification** | This course is to provide a comprehensive and contemporary introduction to the diverse and fascinating spectroscopic methods in organic chemistry. All students will be trained in interpreting individual spectra and sets of spectra obtained by different methods, so that molecular compounds and materials are quickly and efficiently characterized with respect to their structure, potential dynamics, and stereochemistry. Special emphasis will be placed on discussing and documenting the data. | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge of Organic reactions. | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome** | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| 1 | Interpret the differences in reactivity of various reducing and oxidizing agents with mechanistic illustrations. | U | 2,7 |
| 2 | Analyse the reagents and conditions for the synthesis of specific target molecules. | U, A, R | 1,2,6,7 |
| 3 | Describe strategies for the stereospecific/stereo selective organic transformations towards chiral target molecules. | U, R | 1,2 |
| 4 | Different techniques of polymerization of polymers. | U, R, A | 2 |
| 5 | Construct a synthetic pathway for simple to complex organic molecules by retrosynthetic approach. | U, R, A | 1,3,6 |
| 6 | Identify structures of unknown organic compounds based on the data from UV-Vis, IR, Mass Spectrometry 1HNMR and 13CNMR spectroscopy. | U, A, I | 4 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | Organometallic Reagents: Preparation and properties of Organolithium and organomagnesium compounds. Their uses in organic synthesis and in the preparation of Organometallic compounds. Methods of preparation, properties, reactivity and reactions of Organozinc, Organocadmium, Organomercury Organoindium, Organoaluminium and Organotellurium reagents. Silicon containing Reagents: Introduction, preparation reactions & stereochemistry, Petersonreaction. Boron containing Reagents: Introduction, preparations, Hydroborations, reactions of Organoboranes- Isomerization, oxidation, protonolysis, carbonylation, cyanidation. Synthesis of esters, E and Z alkenes, conjugated dienes and alkynes. Organotin Compounds: Synthesis of Organostannanes and their utility in C-C bond formingreactions. Tributyltin hydride, Barton decarboxylation reaction, Barton deoxygenation, Stelly-Kelly coupling reaction. | **10 Hrs.** | **1, 2,3** |
| **Module 2** | Use of the following reagents in Organic synthesis and functional group transformation: Gillman's reagent, Lithium diisopropylamide (LDA), Dicyclohexyl carbodiimide (DCC), 1,3- dithiane (reactivity-umpolong), Trimethyl silyliodide, DDQ, Selenium dioxide, Wilkinsons catalyst, Phase transfer catalysts, Baker's yeast, Polyphosphoric acid. Trimethyl silyl cyanide, Hydrosilanes, Chloramine-T, Aluminiumiso-propoxide. Woodward and Prevost hydroxylation, Zeigler-Natta catalyst, Phase transfer catalysts, Crown ethers. | **13 Hrs.** | **2, 3** |

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|---|---|---|---|
| **Module 3** | IR,1H NMR and 13C-NMR: Characteristic vibrational frequencies of alkanes, alkenes,alkynes, aromatic compounds, alcohols, ethers, phenols and amines. Detailed study of vibrational frequencies of carbonyl compounds (Ketones, aldehydes, esters, amides, acids, anhydrides, lactones, lactams and conjugated carbonyl compounds). Effect of H-bonding & solvent effect on vibrational frequencies. Chemical shift of different class of organic compounds. Spin-spin coupling – illustrate with different examples. AB, AX-Spin system. Chemical exchange, effct of deuteration, complex spin-spin interaction between two, three, four and five nuclei. Stereochemistry, hindered rotation; Karplus-Curve. Variation of coupling constant with dihedral angle. Pulse techniques,Techniques for simplication of spectra, Heteronuclear coupling, INDOR, 2DNMR, FT-NMR. Applications of NMR<br>Composite problems involving the application of UV, IR,1H NMR and 13C-NMR and Mass spectroscopy technique in the structural elucidation of organic molecules.<br>Green Techniques: Crown Ethers: Introduction, Nomenclature, Synthesis of Dibenzo[18]crown-6, Azacrown, Cryptates, Synthetic applications like esterification, saponification, elimation reactions, superoxide anion, generation of carbenes.<br>Microwave induced reactions: Introduction, advantages, limitations, precautions, application like Deprotection, Hydrolysis, Condensation, ortho ester Claisen rearrangement. Ionic Liquids: Introduction, properties, types, preparation, applications like Epoxidation,Alkene Metathesis, Oxidation, Reduction and Enzyme catalysed synthesis. | **12 Hrs.** | **4,5,6** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**E. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**F. Semester End examination** |

**REFERENCES**


1. Advanced Organic chemistry 5th edition -J. March (John Wiley and sons).
2. Organic Chemistry- J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford University Press).
3. E. Eliel and S.H. Wilen, Stereochemistry of Organic compounds, John Wiley.
4. Organic Spectroscopy- William Kemp(Palgrave)2005.
5. Advanced Organic Chemistry – Part A& B, 3rd edition- F.A. Carey and Sundberg, (Plenum Press) 1990.
6. Advanced General Organic Chemistry-S.K. Ghosh (Book and Alleied (P) Ltd) 1998.
7. Organic Synthesis, special Techniques -V.K. Ahluwalia and Renu Agrawal (Narosa Publications).
8. Spectrometric Identification of Organic Compounds - Silverstein, Bassler & Monnill (Wiley)1981.
9. Spectroscopy of Organic Compounds-3 rd Ed.-P.S.Kalsi (New Age, New Delhi) 2000.
10. Spectroscopic Methods in Organic Chemistry - Williams and Fleming, TMH.
11. Spectroscopy, Donald L.Pavia (Cengage learning India Pvt.Ltd., Delhi), 2007.
12. Organic Spectroscopy-3 rd ed.-W.Kemp (Pagrave Publishers, New York), 1991.

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| | **MAHATMA GANDHI UNIVERSITY**<br><br>**COORDINATION CHEMISTRY** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Coordination Chemistry** |
| **Type of Course** | **Core** |
| **Credit Value** | **3** |
| **Course Code** | **EMM23C30** |

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|---|---|---|---|---|---|---|
| **Course Summary & Justification** | It will give an excellent opportunity to study the advanced knowledge of coordination chemistry. The study will also lead to understand the difference between a coordinated ligand and charge balancing ion in a coordination compound. Complexation reactions, stability constants, structures, geometrical and optical isomerism, bonding, reactions and reactivity will be discussed. Color and electronic, and magnetic properties will be delineated with respect to their application in analytical chemistry, industry and medicine. Use of coordination compounds of some precious metal ions will be explained in relation to homogeneous catalysis for the production of useful organic and pharmaceutically important substances. | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge of Chemistry. Any discipline of mechanical engineering, production engineering, polymer technology, chemical engineering, chemistry and physics can complete the course. | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Apply the various theories of coordinate bonding to predict the geometry and properties of complexes | U | 2,7 |
| 2 | Interpret the electronic spectra and magnetic properties of complexes. | U, A, R | 1,2,6,7 |
| 3 | Improve their analytical and critical thinking through the reaction mechanism and stereochemistry of reactions. | U, R | 1,2 |
| 4 | Obtain a sound theoretical knowledge in bonding, reactivity and geometry of f-block metal coordination compounds. | U, R, A | 2 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | Theories and Concepts on d-block Coordination Compounds Introduction - ligands, nomenclature of coordination compounds, coordination compounds of d-block ions with coordination numbers of 2, 3, 4, 5, 6, 7 and 8. Werner's coordination theory, Valence bond theory (VBT), Crystal field theory (CFT), CFSE, effects of CFSE on hydration energies and spinel groups (normal and inverse), types of ligands – spectrochemical series, spectral and magnetic properties (spin-only magnetic moments), nephelauxetic effect. Crystal field splitting patterns in complexes having Oh, Td, square planar, square pyramidal and trigonal pyramid geometries, factors affecting the magnitude of CFSE, various types of isomerism in coordination complexes, Jahn-Teller (JT) distortion, manifestation of JT on spectral properties. Molecular orbital theory (MOT), ligand field theory (LFT), molecular orbital energy level diagram for octahedral complexes without pi-bonding, metal-ligand pi-bonding, metal-metal multiple bonds, d-orbital based metal-metal σ, π and δ bonds in compounds like [Re2Cl8]2-, [Os2Cl8]2-, Cr2(CH3COO)4 and R-Cr(I)-Cr(I)-R. Application of group theory to coordination compounds. | **10 Hrs.** | **1** |
| **Module 2** | Reaction Mechanism<br>Complex equilibrium - formation constants, chelate and macrocyclic effects, factors affecting stability of complexes, methods of determination of stability constants, stability of complex ions in solutions, inert and labile complexes, mechanisms of ligand displacement and addition reactions in octahedral complexes and square planar complexes of platinum cis- and trans-effect, substitution reactions, mechanisms of substitution, kinetic consequences of reaction pathways, dissociation, interchange, association, dissociation, linear free energy relationships, conjugate base mechanism, stereochemistry of reactions (substitution in trans-complexes and substitution in cis-complexes), isomerisation of chelate rings, sigma-bonding and pibonding effects, oxidation-reduction reactions, inner and outer sphere electron transfer reactions, conditions for high and low oxidations numbers, reactions of coordinated ligands, hydrolysis of esters, amides and peptides, template reactions, electrophilic substitution, photochemical reactions of coordination compounds. | **13 Hrs.** | **2** |

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|---|---|---|---|
| **Module 3** | Coordination Chemistry of Inner-transition (f-block) Elements f-block metal ions – oxidation states preferences, ligand preferences, coordination numbers and the geometry of the complexes, influence of lanthanide contraction and actinide contraction in their coordination behaviour, shapes of f-orbitals (4f and 5f), nature of bonding of f-orbitals with ligands, various types of coordination compounds of lanthanides and actinides, stereochemistry and reaction mechanism of f-block metal complexes. | **12 Hrs.** | **3** |
| **Module 4** | Spectral Properties<br>Stabilization of unusual oxidation states, electronic spectra of transition metal complexes – color wheel, Russell-Saunders coupling schemes, term symbols for various d n ions, Orgel diagrams for d b n systems, ligand field parameters, Dq, Racah parameter B and nephelauxetic constant b, Tanabe-Sugano (TS) diagrams, evaluation of Dq and other parameters from electronic spectra of transition metal complexes using TS diagrams, charge-transfer transitions, MLCT and LMCT, selection rules and band intensities, Laporte- and spin- selection rules, symmetry, spin-orbit and vibronic coupling effects. Photochemistry of transition metal complexes like [Ru(bipy)3]2+, spectral behaviour of f-block coordination complexes, special features of their absorption and emission properties. | **15 Hrs.** | **4** |
| **Module 5** | Magnetic Properties<br>Magnetic properties of coordination complexes - magnetic susceptibility, contribution of spin-orbit coupling on μeff, types of magnetic behavior - para-, ferro, anti-ferro and ferri-magnetic systems, Curie law, Curie-Wise law, Guoy, Faraday and superconducting quantum interference device (SQUID) methods, Kotani plots, giant magnetoresistance (GMR), anisotropic magnetoresistance (AMR) effect, effects of temperature on magnetic behavior, tunnelling magnetoresistance (TMR). Magnetism of coordination complexes by multinuclear homo- and heterometallic 3d systems (also with exclusive 4d and 5d metal ions), mixed 3d-4f systems, importance of 4f-metal ions for functional applications. Nanoscale magnetic systems based on coordination complexes - Single Molecule Magnets (SMMs), Single Ion Magnets (SIMs), Single Chain Magnets (SCMs), Spin-crossover complexes, magnetic refringents (magnetic coolers), magnetic storage systems - magnetic random access memory (MRAM) | **10 Hrs.** | **3,4** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**G. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**H. Semester End examination** |

**REFERENCES**


1. F. A. Cotton and G. Wilkinson, 'Advanced Inorganic Chemistry', John Wiley & Sons, 2009.
2. James E. Huheey, Ellen A. Keiter and Richard L.Keiter, 'Inorganic Chemistry, Principles of Structure and Reactivity', Pearson education, 5th edition, 2009.
3. J. D. Lee, 'Concise Inorganic Chemistry', 5th edition, John Wiley & Sons, 2009.
4. P Atkins, T. Overton, J. Rourke, M.Weller, F. Armstrong, "Shriver & Atkins Inorganic chemistry", 4th Edition, Oxford University Press, 2008.
5. B. Douglas, D. McDaniel and J. Alexander "Concepts and Models in Inorganic Chemistry", 3rd Edition, Wiley, 2006.
6. Sushanta Dattagupta, 'A Paradigm Called Magnetism', World Scientific Publishing Co. Pte. Ltd., 2008.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **LAB II Advanced experiments in Chemistry** |

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|---|---|---|---|---|---|---|
| **School Name** | School of Energy Materials | | | | | |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) | | | | | |
| **Course Name** | **LAB II - Advanced experiments in Chemistry** | | | | | |
| **Type of Course** | Core | | | | | |
| **Course Code** | EMM23C31 | | | | | |
| **Course Summary & Justification** | The lab course will include detail on advanced synthesis, characterization studies. | | | | | |
| **Semester** | II | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning Collaborative learning Case based learning | | 40 | 40 | 40 | 120 |
| **Pre-requisite** | Basic synthesis lab skills | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Synthesise a material by a variety of different synthesis routes, having assessed their suitability | U, A | 6,8 |
| 2 | Critically analyse how and why the nature of the chemical bonding in a material is influenced by the synthetic pathway and how it impacts the resulting material properties | U, A | 2 |

| | | | |
|---|---|---|---|
| 3 | evaluate the suitability of synthesis and characterisation methodologies for a material targeted towards a particular application | U, A | 2,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Internship/ Miniproject** |

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|---|---|---|---|---|---|---|
| **School Name** | **School of Energy Materials** | | | | | |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** | | | | | |
| **Course Name** | **Internship/ Miniproject** | | | | | |
| **Type of Course** | Core | | | | | |
| **Course Code** | EMM23C32 | | | | | |
| **Course Summary & Justification** | The candidate shall do a 20 days internship in any of the industries or do a miniproject. The report will be evaluated by internal panel of experts authorized by director of the department. | | | | | |
| **Semester** | 2 | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | - | 40 | 40 | 40 | 120 |
| **Pre-requisites** | Aptitude for research work in one of the interdisciplinary areas in the realm of interface between physical science and nanotechnology. Literature survey. | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

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| | **MAHATMA GANDHI UNIVERSITY** |

| | ENERGY CONVERSION, STORAGE AND TRANSPORTATION | | | | | |
|---|---|---|---|---|---|---|
| **SchoolName** | **School of Energy Materials** | | | | | |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) | | | | | |
| **Course Name** | **ENERGY CONVERSION, STORAGE AND TRANSPORTATION** | | | | | |
| **Course Credit** | **3** | | | | | |
| **Type of Course** | **CORE** | | | | | |
| **Course Code** | **EMM23E26** | | | | | |
| **Course Summary & Justification** | Energy storage solutions are receiving high marks in the energy sector.<br>Energy storage is a useful tool to support grid electrical supply, transmission and distribution systems.<br>This course covers a variety of topics in Energy Storage such as: Basics of energy storage systems, application of energy storage in electrical engineering, application of energy storage in transportation, energy storage in photovoltaic (PV) systems, energy storage applications in mobile applications, micro-power application of energy storage, hydrogen and thermal storage, lead acid batteries, fuel cell principles, electrochemical storage, and super capacitors. | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutoril | Practical | Othes | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | General Chemistry and Physics, Introductory Materials Science, Elementary Semiconductor Theory, Thermodynamics of Materials. | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Understand the basic concept of energy storage devices | U, R | 1,2 |
| 2 | Students will have the ideas in energy conversion methods. | U, A, C | 2,4,6 |
| 3 | Understand the background, synthesis, properties and applications of energy storage devices and perform the selection based on techno economic view point | U, An | 3,4 |
| 4 | Utilization and application of energy storage systems in various sectors and industries like automotive, electronics and energy | A, S | 3,6 |
| 5 | To foster the creation of new and relevant technologies and to transfer them to industry for effective utilization. | I, R | 4,5 |
| 6 | Detail practical knowledge in energy storage systems and conversion process of battery electric vehicles | A, S | 5,6 |
| 7 | To impart awareness on significance of Types and usage of hydrogen fuel cells in the future technological applications. | E, Ap. | 3,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **1** | **PRINCIPLES OF ENERGY CONVERSION**<br>Introduction to power system and technologies. Demand variation and forecasting. Grid features. Siting and costing. Renewable energy: solar, geothermal, wind, biomass, ocean, fuel cells, unique features of decentralized systems. Co-generation systems. Environmental issues, sustainability and future scenarios. | **18** | **1,2** |
| **2** | **HOME HEATING COOLING AND TRANSPORTATION**<br>Furnace efficiency-heat pumps- air conditioning-integrated HVAC systems minimizing heat loss-insulation, windows, and air leaks-residential lighting transportation-FUEL Economy-hybrid vehicles. | **15** | **2,3** |

| | | | |
|---|---|---|---|
| **3** | **ENERGY STORAGE**<br><br>Introduction-pumped hydroelectric power-bath country pumped hydroelectric facility-compressed air energy storage-implementation of compressed air energy storage-fly wheels-superconducting magnetic energy storage (SMES). | **12** | **3,4,6** |
| **4** | **BATTERY ELECTRIC VEHICLES**<br><br>BEVs- Introduction-battery types-the cost of electricity-BEV requirements and design-flow batteries-history of BEVs-rechargeable sodium batteries-super capacitors. | **15** | **5,7** |
| **5** | **HYDROGEN FUELS**<br><br>Introduction-properties of hydrogen-hydrogen production methods – electrolysis-Thermal Decomposition of Water-Chemical Reactions-Storage and Transportation of Hydrogen-Hydrogen Internal Combustion Vehicles Fuel Cells-Fuel Vehicles-Hydrogen Present and Future-Efficiency of Different Transportation Technologies. | | **6,7** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student. |
| **Assessment Types** | **Mode of Assessment**<br>**C. Continuous Internal Assessment (CIA)**<br>o Surprise test<br>o Internal Test – Objective and descriptive answer type<br>o Submitting assignments<br>o Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**D. Semester End examination** |

## REFERENCE BOOK


1. Jochen Fricke, Walter L. Borst, Essentials of Energy Technology: Sources, Transport, Storage, Conservation 1st Edition, Wiley, (2014)
2. Richard a. Dunlap sustainable energy, Cengage Learning; 1st edition (2014)
3. Linden D. and Reddy Thomas B., "Handbook of Batteries", 2001, McGraw Hill Publications.
4. S. Srinivasan, Fuel Cells: From Fundamentals to Applications, Springer (2006)
5. Jochen Fricke, Walter L. Borst, Essentials of Energy Technology: Sources, Transport, Storage, Conservation 1st Edition, Wiley, (2014).
6. O'Hayre, S. W. Cha, W. Colella and F. B. Prinz, Fuel Cell Fundamentals, Wiley (2005)
7. J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, 2nd Edition.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Green Chemistry** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Green Chemistry** |
| **Type of Course** | **Elective** |
| **Credit Value** | **2** |
| **Course Code** | **EMM23E27** |

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| **Course Summary & Justification** | On completion of the course, the student should be able to: discuss the principles behind energy conversion in solar cells and solar fuel systems. discuss different methods for solar fuel production. Explain the conditions for photobiological fuel production, and discuss strategies for enhancing the photosynthetic yield. explain the function of different kinds of solar cells and their mechanisms for charge separation. | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 30 | 30 | 0 | 30 | 90 |
| **Pre-requisite** | Basic knowledge of Chemistry . | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | To understand the environmental status and evolution | U | 2,7 |
| 2 | To know about the Pollution and its prevention measures | U, A, R | 1,2,6,7 |
| 3 | To familiarise the green chemistry | U, R | 1,2 |
| 4 | To learn about the bio-catalytic reactions | U, R, A | 2 |
| 5 | To understand about the vitamins and antiobiotics | U, R, A | 1,3,6 |
| 6 | To expertise the global warming and its effects | U, A, I | 4 |
| 7 | To learn about the control and remedial measures of green house effect | U, R, S, I, An | 2,4 |
| 8 | To know about the various analytical green methods | U, A, R, An | 1,2,5 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | Our environment and its protection, chemical pollution and environmental regulations, environmental chemistry, pollution prevention strategies, challenges to the sustainability of chemical industry, Pollution Prevention Act 1990, USA, Green Chemistry and its 12 principles, toxicity of chemicals, material safety data sheet (MSDS), concept of zero pollution technologies, atom economy, functional toxicity vs non-functional toxicity, alternative solvents, energy minimization, microwave and sonochemical reactions, renewable feed stock, carbon dioxide as a feed stock. | **10 Hrs.** | **1, 2,3,4** |
| **Module 2** | Greener strategies of the synthesis of ibuprofen synthesis, teriphthalic acid etc. phase behaviour and solvent attributes of supercritical $CO_2$, use of supercritical carbon dioxide as a medium chemical industry, use of ionic liquids as a synthetic medium, gas expanded solvents, superheated water, etc. Synthesis of various chemicals from bio mass, polycarbonate synthesis and $CO_2$ fixation, green plastics, green oxidations, etc. | **13 Hrs.** | **4,5,6** |
| **Module 3** | Processes involving solid catalysts – zeolites, ion exchange resins, Nafion/silica nano composites and enhanced activity. Polymer supported reagents, green oxidations using TAML catalyst, membrane reactors. Green chemistry in material science, synthesis of porous polymers, green nanotechnology. | **12 Hrs.** | **7,8** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**I. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**J. Semester End examination** |

**REFERENCES**


1. Anastas, P. T., Warner, J. C. Green Chemistry: Theory and Practice, Oxford University Press Inc., New York, 1998.

2. Matlack, A. S. Introduction to Green Chemistry Marcel Dekker: New York, NY, 2001

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| | **MAHATMA GANDHI UNIVERSITY**<br><br>**ADVANCES IN CATALYSIS** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Advances in Catalysis** |
| **Type of Course** | **Elective** |
| **Credit Value** | **3** |
| **Course Code** | **EMM23E28** |

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|---|---|---|---|---|---|---|
| **Course Summary & Justification** | The course is an introduction to important principles and methods of heterogeneous and homogeneous catalysis. The importance of catalysis as a key technology in sustainable chemical process industry, in energy production and in environmental processes. Definition of catalysis, elementary reactions, chain reactions and catalytic sequences. Adsorption, desorption, surface area and porosity. Langmuir-Hinshelwood kinetics. Kinetic modelling, including model fitting and data treatment. Catalyst preparation and characterisation. Modern theories for surfaces and surface reactions. Internal and external mass and heat transfer in catalyst particles. The effect of diffusion on reaction kinetics. Multifunctional catalysis. Catalysis by transition metal complexes. | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge of Chemistry (Graduate level) | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | To be able to apply the acquired knowledge to address the study of new catalytic transformations. | U | 2,7 |
| 2 | To be able to apply concepts acquired in the field of inorganic, organic and organometallic chemistry to the design of catalysts | U, A, R | 1,2,6,7 |
| 3 | To be able to apply the fundamentals of catalysis to the synthesis of chemicals following sustainable and environmentally friendly procedures. | U, R | 1,2 |

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|---|---|---|---|
| 4 | To identify and use the most useful literature sources in the scientific research field of catalysis. | U, R, A | 2 |
| 5 | To appreciate the potential of the catalysis to face up the new challenges for a sustainable development | U, R, A | 1,3,6 |
| 6 | To be able to communicate conclusions of a scientific research work in the field of catalysis. | U, A, I | 4 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)** | | | |

**COURSE CONTENT**

| **Module No:** | **Module Content** | **Hrs** | **CO. No.** |
|---|---|---|---|
| **Module 1** | Basic Concepts: General Introduction: Catalysis and activation energy. Homogeneous and heterogeneous reactions with suitable illustrations. Catalytic activity. selectivity and stability. Types of catalytic reactors. Steps in a heterogeneous catalytic reaction. Factors affecting rate of reaction such as temperature, flow rates, molar composition etc. TOF in catalysis. Adsorption and Surface Area: Cause of adsorption. No of molecules striking the surface and sticking probability. Types of adsorption and potential energy profiles for adsorption of $H_2$. Adsorption isotherms for gases and solutes. Basic types of BET isotherms. Gibbs adsorption equation and changes in surface tension. Free energy, enthalpy and entropy of adsorption. Chemisorption of $H_2$, $O_2$ and CO. Surface area and Porosity: Determination of surface area. Porosity and pore size distribution. Mercury porosimeter. Classification of catalysts based on electrical conduction. Adsorption on specific crystal planes; geometric factor in catalysis: Balandin's multiplet theory and Valence angle conservation. Electronic effect in catalysis by metals. Catalysis by semiconductors and solid acids (zeolites etc). Role of diffusion in catalysis. | **10 Hrs.** | **1, 2** |
| **Module 2** | Catalysis in Energy and Environment. Use of fossil fuels and role of catalysts in controlling pollution. Biomass and Synthesis of methanol. FT synthesis. Zeolite catalysts and MTG process. Production of biodiesel. Role of semiconductors and zeolites in auto-exhaust catalysts. CFCs and role of catalysts in their mitigation. Atom economy in catalysis. | **13 Hrs.** | **2, 3** |

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| **Module 3** | Kinetics and mechanisms of catalysed reactions Kinetics of catalysed reactions and rate expressions. Temperature dependence of catalysed reaction rates. Mechanism of catalysed reactions such as hydrogenation of ethene, oxidation of CO, decomposition of $N_2O$, decomposition of isopropanol.<br>Electrocatalysis. Basic electrocatalytic concepts, comparison of electrocatalysts, Electrosorption. Porous gas diffusion electrodes. Electrolysis of water and role of electrocatalysts. Hydrogen evolution reaction and investigation of its detailed mechanisms. Choice of electrocatalysts. Oxygen reduction reaction and electro-organic oxidation e.g. methanol. Special features of electro-catalysis. Principles of electrosysnthesis. | **12 Hrs.** | **3,4** |
| **Module 4** | Preparation of Catalysts. Various methods for preparation of bulk catalysts: Precipitation method, Impregnation method catalyst impregnation with or without interaction between support and catalyst. Synthesis of microporous solids. Synthesis of mesoporous solids. Thermal and Spectroscopic Methods in Heterogeneous Catalysis. Characterization of the catalysts by temperature programmed desorption using probes such as ammonia and pyridine molecules. Characterization of adsorbed molecules/intermediates by IR spectroscopic techniques. Application of spectroscopic methods such as XPS, EXAFS, EPR, NMR and Moessbauer in characterization. | **15 Hrs.** | **5,6** |
| **Module 5** | Zeolite Catalysis Structure building in zeolities such as A, X, Y and ZSM-5, producing Zeolite acidity and Zeolite modification. Nature of active sites and their characterization. Shape Selectivity. Identification of Zeolite structures through modern instrumental techniques, adsorption and acidity measurements. Photocatalysis Introduction to semi-conductor surface and catalysis. Catalytic reactions on illuminated semi-conductors. Principles of photocatalytic reactions, photocatalytic decomposition of water at semi-conductor electrodes. Solar energy conversion by photochemical process. | **10 Hrs.** | **5,6** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**K. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**L. Semester End examination** |

**REFERENCES**


1. B. Viswanathan, Catalysis: Selected Applications, Narosa Publishing House
2. G.A. Somorjai ,Introduction to Surface Chemistry and Catalysis, John Wiley, N.Y
4. J.M. Thomas W.J. Thomas, Principles and Practice of Heterogeneous Catalysis, 1996; VCH, New York.
5. R.A. van Santen, Theoretical Heterogeneous Catalysis, 1991; World Sc, Singapore.
6. J.W. Niemants verdriet, Spectroscopy in Catalysis, 1995, VCH, New York.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Nuclear Energy and Technology** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M.Sc.** |
| **Course Name** | **Nuclear Energy and Technology** |
| **Type of Course** | **Elective** |
| **Credit Value** | **2** |
| **Course Code** | **EMM23E29** |

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| **Course Summary & Justification** | The objective of this class is to provide students with an overview of the fundamental technical and societal aspects of nuclear energy. Emphasis is on nuclear fission as an energy source, with a study of the basic physics of the nuclear fission process followed by detailed discussions of issues related to the control, radioactivity management, thermal energy management, fuel production, and spent fuel management. A discussion of the various reactor types in use around the world will include analysis of safety and nuclear proliferation issues surrounding the various technologies. Case studies of some reactor accidents and other nuclear-related incidents will be included | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Independent learning | 30 | 30 | 0 | 30 | 90 |
| **Pre-requisite** | Basic knowledge on atomic and nuclear forces. | | | | | |
| *Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome**<br>*Upon completion of this course, students will be able to;* | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| 1 | Understanding the different types of nuclear energy. | U | 2 |
| 2 | Understand the impact of radiation damages. | U,An | 2,6 |
| 3 | Understand basic theoretical concepts of nuclear physics, reactor physics, and energy removal | U, S | 3 |

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|---|---|---|---|
| 4 | Describe radiation damage mechanisms in materials and biological tissue, estimate radiation dose, understand radiation shielding | An,A | 4,5 |
| 5 | understand the concepts of chain reaction, neutron balance, criticality, reactivity, and reactivity control | E, C | 6,7 |
| 6 | understand the fundamental aspects of used fuel reprocessing and disposal | U | 2,3 |
| 7 | Illustrate different nuclear fuels. | A,An | 2,6 |
| 8 | General ideas about future nuclear reactors. | U | 2,6 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO.No. |
|---|---|---|---|
| **Module 1** | **Types of Nuclear Energy**: Nuclear Fission Energy, Nuclear Fusion Energy, Radioisotopic Energy; Neutron Classification, Neutron Sources, Interactions of Neutrons with Matter: Fission Chain Reaction, Neutron Flux and Fluence, Neutron Cross Section: Reactor Flux Spectrum, Nuclear heat energy, Types of Reactors: A Simple Reactor Design, Generation-I,II,III and IV Reactors, Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), CANDU Reactor, RMBK Reactor, Fast Breeder Test Reactor, Fusion Reactor, Materials Selection Criteria, Reactor Components: Structural/Fuel Cladding Materials, Moderators and Reflectors, Control Materials, Coolants, Shielding Materials, Fusion Reactors. | **10 Hrs.** | **1,2,3** |
| **Module 2** | Radiation Damage, Radiation Effects on non-fuel reactor Materials: Microstructural Changes: Cluster Formation, Extended Defects, Nucleation and Growth of Dislocation Loops, Void/Bubble Formation and Consequent Effects, Radiation-Induced Segregation, Radiation-Induced Precipitation or Dissolution; Mechanical Properties: Radiation Hardening, Saturation Radiation Hardening, Radiation Anneal Hardening (RAH), Channeling: Plastic Instability, Radiation Embrittlement, Effect of Composition and Fluence, Effect of Irradiation Temperature, Effect of Thermal Annealing, Helium Embrittlement, Irradiation Creep, Radiation Effect on Fatigue Properties; Radiation Effects on Physical Properties: Density, Elastic Constants, Thermal Conductivity, Thermal Expansion Coefficient; Radiation Effects on Corrosion Properties: Metal/Alloy, Protective Layer, Corrodent, Irradiation-Assisted Stress Corrosion Cracking (IASCC) | **10 Hrs.** | **2,4,5** |
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| **Module 3** | Nuclear Fuels: Metallic Fuels: Uranium, Plutonium and Thorium, and their fabrication structure, physical, mechanical and corrosion properties, Ceramic Fuels: Ceramic Uranium Fuels, Uranium Dioxide, Uranium Carbide, Uranium Nitride, Plutonium-Bearing Ceramic Fuels, Thorium-Bearing Ceramic Fuels. | **10 Hrs.** | **3,6** |
| **Module 4** | **Future Nuclear Reactors:** General Considerations for Future Reactors (The End of the First Era of Nuclear Power, Important Attributes of Future Reactors, Reactor Size, U.S. Licensing Procedures); Survey of Future Reactors (Classification of Reactors by Generation, U.S. DOE Near-Term Deployment Roadmap, Illustrative Compilations of Reactor Designs); Individual Light Water Reactors (Evolutionary Reactors Licensed by the U.S. NRC, Innovative Light Water Reactors); High-Temperature, Gas-Cooled Reactors (HTGR Options, Historical Background of Graphite-ModeratedReactors, General Features of Present HTGR Designs, HTGR Configurations); Liquid-Metal Reactors (Recent United States Programs, Safety Features of LMRs); The Generation IV Program (Overview of the Program, Systems Emphasized in the United States); Radical Nuclear Alternatives to Present Reactors (Fusion, Accelerator-Driven Fission). | **10 Hrs.** | **4,5,8** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

**References**


1. Lamarsh, J.R. and Baratta, A.J., 2001. Introduction to nuclear engineering (Vol. 3). Upper Saddle River, NJ: Prentice hall.
2. Murty, K.L. and Charit, I., 2013. An introduction to nuclear materials: fundamentals and applications. John Wiley & Sons.
3. Murray, R.L. and Holbert, K.E., 2008. An Introduction to the Concepts, Systems, and Applications of Nuclear Processes. Nuclear Energy.
4. David Bodansky, Nuclear Energy: Principles, Practices, and Prospects, Springer 2004.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **ENERGY FROM WIND, GEOTHERMAL AND WATER** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Energy from Wind, Geothermal and Water** |
| **Type of Course** | **Elective** |
| **Credit Value** | **2** |
| **Course Code** | **EMM23E30** |

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| **Course Summary & Justification** | On completion of the course, the student should be able to: discuss the principles behind energy conversion in solar cells and solar fuel systems. discuss different methods for solar fuel production.<br>Explain the conditions for photobiological fuel production, and discuss strategies for enhancing the photosynthetic yield.<br>explain the function of different kinds of solar cells and their mechanisms for charge separation. | | | | | |
| **Semester** | **II** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 30 | 30 | 0 | 30 | 90 |
| **Pre-requisite** | Basic knowledge of Renewable energy resources. | | | | | |

## COURSE OUTCOMES (CO)

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| **1** | Understanding the principles of extraction of energy from wind, geothermal and water | **A, S, U** | **2,3** |
| **2** | Illustrate bio, hydro, hydrogen and ocean power generation systems | **S** | **3,4** |
| **3** | Model hydro power extraction from oceans | **An** | **5** |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

## COURSE CONTENT

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | Introduction (History of wind energy, Current status and future prospects). Basics of Wind Energy Conversion:Power available in the wind spectra, Wind turbine power and torque, Classification of wind turbines, | **10 Hrs.** | **1** |

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|---|---|---|---|
| | (Horizontal axis wind turbines, Vertical axis wind turbines, Darrieus rotor, Savonius rotor, Musgrove rotor), Characteristics of wind rotors, Aerodynamics of wind turbines(Airfoil, Aerodynamic theories, Axial momentum theory, Blade element theory, Strip theory), Rotor design, Rotor performance. Analysis of wind regimes: The wind (Local effects, Wind shear, Turbulence, Acceleration effect, Time variation), Measurement of wind (Ecological indicators, Anemometers, Cup anemometer, Propeller anemometer, Pressure plate anemometer, Pressure tube anemometers, Sonic anemometer, Wind direction), Analysis of wind data (Average wind speed, Distribution of wind velocity, Statistical models for wind data analysis; Weibull distribution, Rayleigh distribution), Energy estimation of wind regimes (Weibull based approach, Rayleigh based approach). | | |
| **Module 2** | Wind energy conversion systems: Wind electric generators (Tower, Rotor, Gear box, Power regulation, Safety brakes, Generator; Induction generator, Synchronous generator. Fixed and variable speed operations, Grid integration), Wind farms, Offshore wind farms, Wind pumps (Wind powered piston pumps, Limitations of wind driven piston pumps; The hysteresis effect, Mismatch between the rotor and pump characteristics, Dynamic loading of the pump's lift rod, Double acting pump, Wind driven roto-dynamic pumps, Wind electric pumps) Performance of wind energy conversion systems: Power curve of the wind turbine, Energy generated by the wind turbine (Weibull based approach, Rayleigh based approach), Capacity factor, Matching the turbine with wind regime, Performance of wind powered pumping systems (Wind driven piston pumps, Wind driven roto-dynamic pumps, Wind electric pumping systems). | **13 Hrs.** | **2** |
| **Module 3** | Wind energy and Environment: Environmental benefits of wind energy, Life cycle analysis (Net energy analysis, Life cycle emission), Environmental problems of wind energy (Avian issues, Noise emission, Visual impact)<br>Economics of wind energy: Factors influencing the wind energy economics (Site specific factors, Machine parameters, Energy market, Incentives and exemptions, The 'present worth' approach, Cost of wind energy; Initial investment, Operation and maintenance costs, Present<br>value of annual costs), Benefits of wind energy, Yardsticks of economic merit (Net present value, Benefit cost ratio, Pay back period, Internal rate of return), Tax deduction due to investment depreciation | **12 Hrs.** | **1,3** |
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| **<u>Module 4</u>** | Geothermal Energy: Introduction (Geothermal Resources), Geothermal Power Plants (Dry Steam Units, Single-Flashing Units, Dual Flashing Units, Several Flashing Processes: A Useful Theoretical, Binary Units, Hybrid Geothermal-Fossil Power Units), Effects of Impurities in the Geothermal Fluid, Cooling Systems, Geothermal District Heating: An Example of Exergy Savings<br>and Environmental Benefit, Environmental Effects. | **15 Hrs.** | **1,2,3** |
| **<u>Module 5</u>** | Power from the Water: Hydroelectric Power (Global Hydroelectric Energy Production, Planned Hydroelectric Installations and Future Expansion, Environmental Impacts and Safety Concerns), Tidal Power (Systems for Tidal Power Utilization, Environmental Effects of Tidal Systems, Ocean Currents), Wave Power (Wave Mechanics and Wave Power, Systems for Wave Power Utilization, Environmental Effects of Wave Power and Other Considerations), Ocean Thermal Energy Conversion (OTEC) (Two Systems for OTEC, Environmental Effects of OTEC and Other Considerations), Types of Water Power Turbines, Concluding Remarks on Water Power. | **9 Hrs.** | **2,4,5** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**Semester End examination** |

**REFERENCES**


1. Wind Energy: Fundamentals, Resource Analysis and Economics, Sathyajith Mathew, Springer, 2006.
2. Renewable Energy Sources, Efstathios E. (Stathis) Michaelides, Springer, 2012.

SEMESTER III

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **ORGANOMETALLIC AND BIOINORGANIC CHEMISTRY** |

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|---|---|---|---|---|---|---|
| **School Name** | **School of Energy Materials** | | | | | |
| **Programme** | **M.Sc. Chemistry (Specialization in Energy science)** | | | | | |
| **Course Name** | **ORGANOMETALLIC AND BIOINORGANIC CHEMISTRY** | | | | | |
| **Type of Course** | **Core** | | | | | |
| **Course Code** | **EMM23C33** | | | | | |
| **Course Summary & Justification** | Introduces the chemistry of carbon to transition-metal bonds beginning with rules governing structure and stability; effects of metal and ancillary ligand environment; general mechanistic steps; NMR and IR spectroscopy; fluxional processes. Followed by applications in homogeneous catalysis and stoichiometric organic synthesis | | | | | |
| **Semester** | **3** | | **Credit** | | **3** | |
| **Total Student Learning Time (SLT)** | **Learning Approach** | **Lecture** | **Tutorial** | **Practical** | **Others** | **Total Learning Hours** |
| | **Authentic learning Collaborative learning Case based learning** | **40** | **40** | **-** | **40** | **120** |
| **Pre-requisite** | Understanding on properties of transition metals, complexes etc. | | | | | |
| ***Others- Library, seminar and assignment preparations, test, journal, discussion etc.*** | | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome**<br>***Upon completion of this course, students will be able to;*** | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| **1** | Examine the basic principles that govern the electronics, structure and bonding in inorganic and organometallic complexes | **U, A** | **6,8** |

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| **2** | Explore the fundamental and experimental aspects of elementary organometallic transformations | **U, A** | **2** |
| **3** | Apply elementary organometallic reactions in the context of catalysis and new reactivity | **U, A** | **2,7** |
| **4** | Demonstrate and predict the reactivity pattern of organometallic complexes | **An, E** | **2,7** |
| **5** | Have a background to apply organometallics to other fields: organic synthesis, polymerization, bioinorganic chemistry, etc. | **U, A** | **2,4** |
| **6** | understand how metal ions interact with biological environments and how these interaction influences the properties of metal centers | **S, C** | |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| **Module No:** | **Module Content** | **Hrs** | **CO.No.** |
|---|---|---|---|
| **1** | Compounds with transition metal to carbon bonds: eighteen electron rule; classification of ligands, nomenclature, σ donor ligands – metal alkyl, arylcomplexes; σ donor/π acceptor ligands, – metal alkenyls, alkynyls, carbenes, carbynes, carbonyls, isocyanide, fluxionality of ligands – structure, bonding, spectra, preparation and reactions. | **15** | **1,3** |
| **2** | σ, π donor/π acceptor ligands – olefin complexes, alkyne, allyl, enyl complexes, metallocene- ferrocene, titanocene, zircanocene, arene complexes, cycloheptatriene, cyclooctatetraene, cyclobutadiene complexes, fluxionality of ligands – structure, bonding, preparation, reactions and spectroscopy | **20** | **2,3,4** |
| **3** | Metal–Metal bonds and Transition metal clusters; preparation, properties and spectroscopy. Parallels with non-metal chemistry- isolobal analogy. Application of Wade-Mingos-Lauher rules in predicting the structure of organometallic clusters | **10** | **4** |
| **4** | Reactions of organometallic complexes – Ligand cone angle, oxidative addition, reductive elimination, insertion, nucleophilic and electrophilic attack of coordinated ligands. Homogeneous catalysis using organometallic compounds: olefin hydrogenation, hydroformylation, Wacker process, Ziegler-Natta polymerisation, cyclo oligomerisation, olefin isomerisation, olefin metathesis, Monsanto acetic acid synthesis, Fischer-Tropsch process, hydrosilylation, coupling reactions in organic chemistry | **15** | **4,5** |

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|---|---|---|---|
| **5** | Metal ions in biological systems: Heme proteins – hemoglobin, myoglobin Non-Heme Iron Proteins: Iron storage and transfer – ferritin, transferrin; electron transfer (Iron-sulfur protein) – rubredoxin, ferredoxin; O2 transport – hemerythrin Copper proteins and Enzymes – Hemocyanin, superoxide dismutase, ceruloplasmin, cytochrome co-oxidase; Zinc and Cobalt enzymes – carbonic anhydrase, carboxypeptidase, interchangeability of zinc and cobalt enzymes; Vitamin B12 and B12 Photosynthesis and N2 fixation Metals in medicines and therapy. | | **5,6** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>**Authentic learning, case-based learning, collaborative learning, seminar, group activities.** |
| **Assessment Types** | **Mode of Assessment**<br>**Continuous Internal Assessment (CIA)**<br>**Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar**<br>**Assignments**<br>**B. Semester End examination** |

**References**


1. Ch. Elschenbroich, A. Salzer, Organometallics – A Concise Introduction, VCH Publishers, 1989.
2. B. D. Gupta, A. J. Elias, "Basic Organometallic Chemistry", University Press,2010.
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5. E.-I. Ochiai. Bioinorganic Chemistry – An Introduction, Allyn and Bacon Inc.,1977.
6. N. Kaim, B. Schwederski. Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, John Wiley, 1994.
7. Bertini, H. B. Gray, S. J. Lippard, J. S. Valentine, Bioinorganic Chemistry, Viva Books, 1998.
8. R. W. Hay, Bio Inorganic Chemistry, Ellis Horwood, 1987.
9. J. A. Cowan, Inorganic Biochemistry – An Introduction, 2nd ed., VCH, 1997.
10. N. S. Hosmane (Ed) Boron Science: New Technologies and Applications, CRCPress, 2011.
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12. M. N. Hughes, The Inorganic Chemistry of Biological Processes, Wiley, 1981.

## MAHATMA GANDHI UNIVERSITY

### Advanced Solid State and Electrochemistry

| | | | | | | |
|---|---|---|---|---|---|---|
| **School Name** | School of Energy Materials | | | | | |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) | | | | | |
| **Course Name** | **Advanced Solid State and Electrochemistry** | | | | | |
| **Type of Course** | Core | | | | | |
| **Course Code** | EMM23C34 | | | | | |
| **Course Summary & Justification** | Solid-state electrochemical devices play a crucial role in the society. The contribution of the devices ranges from semiconductor to energy devices. The core of the lecture lies in the understandings of the response of electrons and ions under an electric field. | | | | | |
| **Semester** | 3 | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | 40 | 40 | - | 40 | 120 |
| **Pre-requisite** | Fundamental knowledge in Solid state and electrochemical reactions. | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome**<br>*Upon completion of this course, students will be able to;* | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| 1 | Understand solids from both chemistry and physics point of view. | U, A | 6,8 |
| 2 | Explain the working principles and the prospects of semiconductor and energy devices. | U, A | 2 |
| 3 | To know the physical properties of the solid and liquid state and electrochemical processes at the solid/liquid interface. | U, A | 2,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO.No. |
|---|---|---|---|
| 1 | Activity and Activity coefficient of electrolytes, Ionic strength, Debye Huckel theory of strong electrolytes, Debye Huckel limiting law equation, Application of Debye Huckel theory to conductance bahaviour, Relaxation and electrophoretic effect, Debye-Huckel- Onsager equation and its derivation- Application of Debye Huckel equation for the determination of thermodynamic equilibrium constants, Calculation of effect of ionic strength on the reaction rates in solutions. Debye Falkenhagen effect. Wein effect. | 15 | 1 |
| 2 | Equilibrium Electrochemistry-EMF Phenomena, Cell Potential and its measurement, reference electrodes, Electrochemical series, Calculation of thermodynamic properties and activities, Cells without liquid junction potential, Liquid junction potential and its determination, Determination of solubility. Conductometric, Potentiometric and pH titrations,Redox indicators and redox titrations. | 20 | 2 |
| 3 | Dynamic Electrochemistry- Electrical double layer, Various models of electrical double layer, Electrode polarization. Electrolytic polarization, Dissolution and deposition potential, Overpotential and its theories, Butler Volmer equation, Tafel equation. Tafel plot and its significance, Overvoltage- hydrogen overvoltage and oxygen overvoltage, Theories of hydrogen overvoltage. Corrosion and methods for prevention. Porbaux diagram and Evans diagrams. Storage cells- Lithium ion battery. Fuel Cell. Theory and working of fuel cell. $H_2$-$O_2$ fuel cell, Methanol fuel cell, Solid oxide fuel cells, alkaline and polymer electrolyte fuel cells. Introduction to electrocatalysis. | 10 | 3 |
| 4 | Review of Crystal symmetry and symmetry elements and symmetry operations, crystal systems, Bravais lattices and crystal classes, Crystallographic point groups - Schönflies & Hermann– Mauguin notations, Stereographic projections of the 27 axial point groups, translational symmetry elements & symmetry operations - screw axes and glide planes, Introduction to space groups. Bragg's law and applications, lattice planes and miller indices, *d*-spacing formulae, crystal densities and unit cell contents,<br>Imperfections in solids - point, line and plane defects, non-stoichiometry. | 15 | 2,3 |

| | | | |
|---|---|---|---|
| 5 | Electronic structure of solids – free electron theory, band theory & Zone theory, density of states,band structure, direct and indirect band gaps, Brillouin zones; Electrical properties - electrical conductivity, Hall effect, dielectric properties, piezo electricity, ferro-electricity and ionic conductivity; Superconductivity- Meissner effect, brief discussion of Cooper theory of superconductivity; Low temperature and high temperature superconductivity, Optical properties - photo conductivity, luminescence, colour centers, lasers, refraction & birefringence; Magnetic properties - diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism & ferrimagnetism; Thermal properties - thermal conductivity & specific heat<br>Solid state reactions: Brief introduction. | 10 | 3 |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

**References**


1. J. Bockris and A.K.N. Reddy, Modern Electrochemistry, 2nd Edn., Wiley, New York, 1998
2. 2. R. Crow, Principles and Applications of Electrochemistry, Paper back edn, 4th edn, 1994.
3. S.Glasstone, An Introduction to Electrochemistry, Paperback edn., 2007
4. L.V.Azaroff, Introduction to Solids, Mc Graw Hill, 1960.
5. A. R. West, Solid State Chemistry, Wiley Student (Indian) Ed., (2014)
6. A.K. Galwey, Chemistry of Solids, Chapman and Hall, London, 1967.
7. Lesley Smart and Elaine Moore, Solid State Chemistry, Chapman and Hall, 1995.
8. H. V. Keer, Principles of the Solid State Wiley Eastern Ltd, New Delhi, 1993.
9. C. N. R. Rao and J. Gopalakrishnan, New Directions in Solid State Chemistry. 2nd edn,Cambridge Uty Press, 1997.

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|---|---|
| | **MAHATMA GANDHI UNIVERSITY**<br>**Advanced Computation in Materials Science** |

<table>
<tr><td>School Name</td><td colspan="6">School of Energy Materials</td></tr>
<tr><td>Programme</td><td colspan="6">M.Sc. Chemistry (Specialization in Energy science)</td></tr>
<tr><td>Course Name</td><td colspan="6">Advanced Computation in Materials Science</td></tr>
<tr><td>Type of Course</td><td colspan="6">Core</td></tr>
<tr><td>Course Code</td><td colspan="6">EMM23C35</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">The basic microscopic constituents of materials being atoms and inter atomic interactions being responsible the macroscopic behaviour and properties of a material, performing computer simulations in materials across several characteristic length and time scales has obvious appeal as a valid tool aiding technological innovation. This basic course is framed so as to benefit science students who aim at material discoveries and technologists who seek optimised materials for their application of choice. The course will bring out the various facets of computational materials science such as acting as the link between analytic theory and experiment, a tool to scrutinize theories, and as an exploratory research tool for predicting experiments in a laboratory which are difficult to realise physically. The topics are chosen and hierarchically arranged so as to lay strong foundations of computational science in students of graduate and post graduate level</td></tr>
<tr><td>Semester</td><td colspan="2">3</td><td colspan="2">Credit</td><td colspan="2">3</td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total Learning Hours</td></tr>
<tr><td></td><td>Authentic learning<br>Collaborative learning<br>Case based learning</td><td>40</td><td>40</td><td>-</td><td>40</td><td>120</td></tr>
<tr><td>Pre-requisite</td><td colspan="6">Basic knowledge in Numerical methods and algorithms.</td></tr>
<tr><td colspan="7">Others- Library, seminar and assignment preparations, test, journal, discussion etc.</td></tr>
</table>

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | To introduce students to the fundamental aspects of computational science and its increasing role in the development and optimization of materials. | U, A | 6,8 |
| 2 | Provide a combination of theory and laboratory activities for establishing the potential of computational tools in novel materials' design. | U, A | 2 |
| 3 | To help students become aware of the various tools available for materials discovery and optimization. | U, A,I | 2,7 |
| 4 | Students will get introduced to the new interdisciplinary field of computational materials science and engineering | An, E | 2,7 |
| 5 | Students gain an understanding of the theory behind computations and various tools relevant to the design of future materials. | U, I | 1,3,4 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| 1 | Introduction to computational modeling and simulation for Materials Science, First principle methods: the beginnings of Quantum mechanics, Schrodinger wave equation, time-independent wave equation, Molecular mechanics- Force Field Methods, Postulates of quantum mechanics, Energy Hamiltonian, early first principles calculation, Born-Oppenheimer approximation, Hartree method (one electron), HartreeFock molecular orbital theory, Self-consistent-field (SCF) procedure; | 15 | 1 |
| 2 | Density functional theory (DFT): electron density in DFT, Hohenberg-Kohn theorems, Kohn-Sham approach, exchange correlation functionals, solving Kohn-Sham equations, DFT extensions and limitations. DFT exercises using software (VASP/Gaussian). | 20 | 2 |

| | | | |
|---|---|---|---|
| 3 | Molecular dynamics (MD): Atomic model in MD, Molecular mechanics, potentials, solutions for newton's equation of motion, running MD: initialization, pre-set ups, periodic boundary condition, positions and velocity, time steps, ensembles, integration equilibration, minimisation in static MD run – steepest descent method, conjugate gradients method, run analysis. MD analysis exercises using software (LAMMPS/ XMD) | 10 | 3 |
| 4 | Monte Carlo (MC) methods: Basis of MC methods, stochastic processes, Markov's process, ergodicity; Algorithms for MC simulations, random numbers, sampling techniques. Applications of MC methods: System of classical particles, percolation, polymer systems, nucleation, crystal growth, fractal systems. Limitations of MC methods, introduction to quantum MC methods. | 15 | 4 |
| 5 | Materials genomics: High through-put combinatorial algorithms for materials design. | 8 | 2,4,5 |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

**References**


1. Richard LeSar, Introduction to Computational Materials Science: Fundamentals to Applications, Cambridge University Press, 2013.
2. June Gunn Lee, Computational Materials Science: An Introduction, CRC Press, 2012.
3. Kaoru Ohno, KeivanEsfarjani, Yoshiyuki Kawazoe, Computational Materials Science: From Ab Initio to Monte Carlo Methods, 2nd Ed., Springer, 2018.
4. I.N. Levine, Quantum Chemistry, 6th ed., Prentice Hall, 2009.
5. J.A. Dantzig, C.L. Tucker, Modeling in Materials Processing, 1sted., Cambridge University Press, 2001
6. Guillermo Bozzolo, Ronald D. Noebe, Phillip B. Abel (Editors), Applied Computational Materials Modeling: Theory, Simulation and Experiment, Springer, 2007.
7. A.R. Leach, Molecular modeling: Principles and Applications, 2nd ed., Pearson-Prentice Hall, 2001.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **CHEMISTRY OF NATURAL PRODUCTS** |

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|---|---|---|---|---|---|---|
| **School Name** | School of Energy Materials | | | | | |
| **Programme** | M.Sc. Chemistry (Specialization in Energy science) | | | | | |
| **Course Name** | **CHEMISTRY OF NATURAL PRODUCTS** | | | | | |
| **Type of Course** | Core | | | | | |
| **Course Code** | EMM23C36 | | | | | |
| **Course Summary & Justification** | This course (Chemistry of Natural Products) focuses on the biosynthesis, isolation of new natural products, rational structural modifications of known natural products scaffolds for new lead discovery, total synthesis of complex natural products and green chemistry. Special emphasis is given to the development of synthetic methodologies to facilitate generation of diversity around the scaffolds, which can be utilized as key intermediates for total synthesis. The new molecular entities generated are screened for pharmacological activities with focus on cancer and anti-bacterial properties | | | | | |
| **Semester** | 3 | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | 40 | 40 | - | 40 | 120 |
| **Pre-requisite** | General understanding on biosynthesis, isolation of new natural products. | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Device synthesis scheme fornonaromatic organic compounds. | U, A | 6,8 |
| 2 | Elucidate structure and device synthesis for important naturalproducts. | U, A | 2 |
| 3 | Describe molecular structure of carbohydrates, proteins, DNA,RNA and synthesis of vitamin C and shikimic acid. | U, A | 2,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO.No. |
|---|---|---|---|
| 1 | Nomenclature and general characteristics of heterocyclic compounds. Structure, properties, synthesis and reactivity of three and four-membered ring heterocycles containing one heteroatom. | 15 | 1 |
| 2 | Heteroaromatic compounds (five and six-membered rings) containing one or two heteroatoms. Fused ring compounds: Synthesis and properties of indole, quinoline, isoquinoline, coumarin, flavone, purine and pyrimidine bases present in nucleosides. | 20 | 2 |
| 3 | Terpenoids: Classification, biosynthesis. Structure elucidation and synthesis of abietic acid. Steroids: classification, biosynthesis. Structure elucidation of cholesterol, conversion of cholesterol to progesterone, androsterone and testosterone. Fatty acids: structure, biosynthesis. Prostaglandins-classification, structure, biosynthesis and synthesis.Alkaloids: Classification, isolation, structure elucidation based on degradative reactions (quinine and atropine). Biosynthesis of quinine and papaverine. | 10 | 3 |

| | | | |
|---|---|---|---|
| 4 | Carbohydrates: Structure of ribose, glucose, fructose, maltose, sucrose, lactose, starch cellulose and cyclodextrins. Preparation of alditols, glycosides (O, C, and N), deoxysugars. Synthesis of Vitamin C from glucose. Nucleic acids: Structure and synthesis, genetic code, recombinant DNA, biosynthesis of shikimic acid. | 15 | 4 |
| 5 | Amino acids, peptides and enzymes: Synthesis of amino acids – Strecker and azalactone synthesis, enantioselective synthesis of amino acids, reactions of aminoacids. Structure of proteins, introduction to enzymes and coenzymes with special reference to the function of chymotrypsin, NAD, thiamine, pyridoxal. In vitro and in vivo synthesis of peptides, solid phase synthesis. | | |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

## References


1. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
2. I. L. Finar, Organic Chemistry Volumes 1 & 2, 6th ed., Pearson Education Asia, 2004.
3. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
4. N. R. Krishnaswamy, Chemistry of Natural Products; A Unified Approach, Universities Press, 1999.
5. R. J. Simmonds, Chemistry of Biomolecules: An Introduction, RSC, 1992.
6. R. O. C. Norman, Principles of Organic Synthesis, 2nd ed., Chapman and Hall, 1978.
7. J. A. Joule, K. Mills, Heterocyclic Chemistry, 5th ed., Wiley, 1998.
8. J. J. Li, E. J. Corey, Total Synthesis of Natural Products: At the Frontiers of Organic Chemistry, Springer, 2012.
9. T. Eicher, S. Hauptmann, The Chemistry of Heterocycles, 2nd ed., Wiley, 2003.
10. K. C. Nicolaou, S. A. Snyder, Classics in Total Synthesis II: More Targets, Strategies, Methods, Wiley, 2003.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **LAB -III Energy devices and Fabrication** |

<table>
<tr><td>School Name</td><td colspan="6">School of Energy Materials</td></tr>
<tr><td>Programme</td><td colspan="6">M.Sc. Chemistry (Specialization in Energy science)</td></tr>
<tr><td>Course Name</td><td colspan="6">LAB -III<br>Energy devices and Fabrication</td></tr>
<tr><td>Type of Course</td><td colspan="6">Core</td></tr>
<tr><td>Course Code</td><td colspan="6">EMM23C37</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">The lab course will include detail on Fabrication of Energy devices</td></tr>
<tr><td>Semester</td><td colspan="2">3</td><td colspan="2">Credit</td><td colspan="2">3</td></tr>
<tr><td rowspan="2">Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total Learning Hours</td></tr>
<tr><td>Authentic learning<br>Collaborative learning<br>Case based learning</td><td>40</td><td>40</td><td>-</td><td>40</td><td>120</td></tr>
<tr><td>Pre-requisite</td><td colspan="6">Basic synthesis lab skills</td></tr>
<tr><td colspan="7">Others- Library, seminar and assignment preparations, test, journal, discussion etc.</td></tr>
</table>

## COURSE OUTCOMES (CO)

<table>
<tr><td rowspan="2">CO No.</td><td>Expected Course Outcome</td><td rowspan="2">Learning Domains</td><td rowspan="2">PSO No.</td></tr>
<tr><td>Upon completion of this course, students will be able to;</td></tr>
<tr><td>1</td><td>Synthesise a material by a variety of different synthesis routes, having assessed their suitability</td><td>U, A</td><td>6,8</td></tr>
<tr><td></td><td>Critically analyse how and why the nature of the</td><td></td><td>2</td></tr>
</table>

| | | | |
|---|---|---|---|
| 2 | chemical bonding in a material is influenced by the synthetic pathway and how it impacts the resulting material properties | U, A | |
| 3 | evaluate the suitability of synthesis and characterisation methodologies for a material targeted towards energy storage application | U, A | 2,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>Continuous Internal Assessment (CIA)<br>Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>Assignments<br>Semester End examination |

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Energy device and fabrication** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **MSc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Energy device and fabrication** |
| **Type of Course** | **Elective** |
| **Credit Value** | **3** |
| **Course Code** | **EMM23E31** |

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|---|---|---|---|---|---|---|
| **Course Summary & Justification** | This course aims to introduce materials that revolutionize the current world with various energy options. The materials that control the performance of various energy sources such as photovoltaic devices, fuel cells and energy storage are explored. This course covers the theory, design, fabrication and applications of materials and devices for energy applications. Device processing topics include crystal growth, substrate engineering, thin film deposition, etching and process integration for silicon and compound semiconductor materials. The course also covers different material characterization techniques and working principles of various measuring devices. This course will introduce students to the rapidly developing field of nano-engineered materials with special focus on energy related applications. | | | | | |
| **Semester** | **III** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge in photovoltaic and energy storage devices.. | | | | | |
| *Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

## COURSE OUTCOMES (CO)

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | To understanding the concepts of device fabrication technologies. | U,R | 1 |
| 2 | To analyze the material design and relate to photovoltaic device and analyze their quantum efficiency.<br>. | U,An | 4 |
| 3 | To develop an attitude of innovation/creativity towards material design for various energy harvesting devices. | An, Ap | 2,9 |
| 4 | Understanding of principles of operation of modern devices for electrochemical energy conversion and storage. Super Capacitor, Electrochemical supercapacitors. Nanostructured Carbon-based materials. | U, An | 2,6 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

## COURSE CONTENT

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **<u>Module 1</u>** | Device fabrication technologies: diffusion, oxidation, photolithography, sputtering, physical vapor deposition, chemical vapor deposition (CVD), plasma enhanced CVD (PECVD), hot wire CVD (HWCVD) | **10 Hrs.** | **1** |
| **<u>Module 2</u>** | High efficiency solar cells, PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, solar PV concentrator cells and systems, III - V, II - VI thin film solar cells; Amorphous silicon thin film (and/or flexible) technologies, multi-junction (tandem) solar cells, organic/flexible solar cells, polymer composites for solar cells, Spectral response of solar cells, quantum efficiency analysis, dark conductivity, I-V characterization | **10 Hrs.** | **2** |

| | | | |
|---|---|---|---|
| **Module 3** | Materials and devices for energy storage; Batteries, Carbon Nano Tubes (CNT), fabrication of CNTs, CNTs for hydrogen storage, CNT polymer composites, ultra capacitor; Polymer membranes for fuel cells, PEM fuel cell, Acid/alkaline fuel cells | **10 Hrs.** | **3** |
| **Module 4** | Super Capacitor, Electrochemical supercapacitors , Basic components of supercapacitors, types of electrodes like high surface area, activated carbons, metal oxide and conducting polymers, aqueous and organic electrolytes, Nanostructured Carbon-based materials<br>Electrical double layer model - Principles and materials design Redox capacitor Nano Oxides , Conducting polymers-based materials | **10 Hrs.** | **4** |

| | |
|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>7. Continuous Internal Assessment (CIA)<br>8. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>9. Assignments<br>C. Semester End examination |

## Text Books:


[1] Robert F.P.(2002).*Advanced Semiconductor Fundamentals*,2nd Edition, Pearson
[2] Duncan W.B., Dermot O., and Richard I.W.(2011).*Energy Materials*,1st Edition, Wiley
[3] Linden D. and Reddy Thomas B., "Handbook of Batteries", 2001, McGraw Hill Publications 5. Larminie and A. Dicks, Fuel Cell Systems Explained, 2nd Edition, Wiley (2003)


## Reference Books:


[1] Fahren bruch A.L. and Bube R.H.(1983);*Fundamentals of Solar Cells: PV Solar Energy Conversion*, Academic Press
[2] Tom M. and Luis C. (2005). *Solar Cells: Materials, Manufacture and Operation,*1st Edition, Elsevier Science
[3] Christoph B., Ullrich S. and VladimirD.(2014).*Organic Photovoltaics: Materials, Device Physics, and Manufacturing Technologies*, 2nd Edition, Wiley-VCH
[4] San P.J. and Pei K.S. (2013). *Nanostructured and Advanced Materials for Fuel Cells*,1st Edition, CRC Press
[5] Daniel C. And Besen hard J.O.(2011).*Handbook of Battery Materials*,1st Edition Wiley-VCH
[6] Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, Ru-Shi Liu, "Electrochemical Technologies for Energy Storage and Conversion", John Wiley and Sons, 2012.
[1] Francois Beguin and ElzbietaFrackowiak ,"Super capacitors", Wiley, 2013
**[2]** Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **METALS, CERAMICS AND COMPOSITE MATERIALS FOR ENERGY APPLICATIONS** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M.Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Metals, Ceramics and Composite Materials for Energy Applications** |
| **Type of Course** | **Elective** |
| **Credit Value** | **3** |
| **Course Code** | **EMM23E32** |

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|---|---|---|---|---|---|---|
| **Course Summary & Justification** | This course is designed at providing students with concepts of atomic defects, electrical properties. In depth knowledge on dielectrics, magnetic properties. Concept on sintering, densification, thermal and mechanical properties. Knowledge on composite interface, metal, ceramic composites. This course aims to impart basic knowledge on atomic structure, diffusion mechanism, electrical properties. To introduce the basic concepts on magnetic properties, dielectrics, magnetism, solid state sintering, densification and coarsening processes. To familiarize thermal expansion, creep and thermal stress. To give the concept of analysing the thermal and mechanical properties. Understanding the concept of composites, bonding interfacial properties and also metal matrix, ceramic matrix composites for energy applications. | | | | | |
| **Semester** | **III** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge of Chemistry (1st year level). Any discipline of mechanical engineering, production engineering, polymer technology, chemical engineering, chemistry and physics can complete the course. Basics of different properties such as electric, magnteic, thermal, and mechanical properties. | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome** | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| 1 | Understand the concept of electrical, magnetic, thermal, mechanical properties of metals, composites for energy applications | U | 1 |
| 2 | To learn about various properties for energy applications | U, A, R, An | 1 |

| | | | |
|---|---|---|---|
| 3 | To impart knowledge on analyzing the properties of materials used for energy applications. | U, R, A | 3 |
| 4 | To understand the fundamentals, basics and properties of materials | U, R, I | 1,3,6 |
| 5 | To study the basics of polymers and their application in energy systems and devices. | U, A, R, S, I, An C | 4 |
| 6 | Will understand Superconducting nano-materials & their properties and applications | U, R, S, I, An | 2,4 |
| 7 | Will understand in depth knowledge in mechanical and thermal properties | U, A, R, An | 1,2,5 |
| 8 | Upon completion of the course, the students will have the knowledge of composite materials, interfaces, reinforcements | U, R, S, I, An, A | 2,3 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | **Atomic structure:** Atomic structure and bonding, Crystal structures lattices, indices etc with examples of atomic structures and bonding types, Order and disorder, Diffusion mechanisms, Deformation mechanisms, Classes of metals, Point defects, line defects, surface and volume defects, Strengthening mechanisms, Simple alloys and intermetallics | **10 Hrs.** | **4** |
| **Module 2** | **Ceramic crystal structures:** Ceramic crystal structures, Atomic defects including intrinsic and extrinsic point defects, Electrical properties including ferroelectrics, thermistors, electrical conductors, dielectrics, Magnetic properties including ferromagnetic and ferromagnetic materials. | **12 Hrs.** | **1,2,3,4** |
| **Module 3** | **Dielectrics:** Dielectrics, ferroelectrics and magnetoceramics, Magnetism: Dia-, Para, Ferro-, Antiferro-, Ferri-magnetism, Magnetic properties: Gaint magnetoresistance, Tunneling magnetoresistance, Colossal magnetoresistance, Superparamagnetism, High Tc materials: YBCO and Bi-systems (Brief idea), Superconducting nano-materials & their properties and applications. | **13 Hrs.** | **1,3,6** |
| **Module 4** | **Solid state sintering:** Solid state sintering, Densification and coarsening processes, Grain boundary mobility, Porosity evolution (stability/entrapment), Thermal properties including thermal expansion, creep, and 44 thermal stress, Mechanical properties including strength, toughness, and microstructural design | **12 Hrs.** | **1,7** |
| **Module 5** | **Composites:** Composite Interfaces, Bonding Mechanisms, Other Interfacial properties, Polymer Matrix Composites, Metal Matrix Composites, Ceramic Matrix Composites, Composite Strengths, Fibers as reinforcements | **13 Hrs.** | **1,5,7,8** |

| Teaching and Learning Approach | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
|---|---|
| **Assessment Types** | **Mode of Assessment**<br>**M. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**N. Semester End examination** |

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02. K. Vijayamohanan Pillai and Meera Parthasarathi Functional Materials: A Chemist's Perspective by, Orient Blackswan (21 November 2013)
03. Physical Metallurgy Principles Reed-Hill - R. E., and R. Abbaschian, 3rd ed. Boston: PWS-Kent, 1992.
04. Structure and Properties of Engineering Alloys - Smith, W. F., McGrawHill, 1981.
05. Introduction to Ceramics W. D. Kingery, H.K. Bowen, D.R. Ulhmann.
06. Treatise on Inorganic Chemistry, Vol. II: Subgroups of the periodic table and general topics, Preparation of Metals - H. Remy, Elsevier, 1956.
07. Synthesis of Advanced Ceramic Materials David Segal.
08. Fundamentals of Polymer Science: An Introductory Text - P. Painter and M. Coleman, Technomic, 1997
09. Composite Materials: Engineering and Science - F. L. Matthews and R. D. Rawlings, Chapman & Hall 1994
10. Ceramic Processing and Sintering - M.N. Rahman, Marcel Dekker, Inc.

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|---|---|
| | **MAHATMA GANDHI UNIVERSITY** |
| | **BIOINORGANIC PHOTOCHEMISTRY** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M.Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Bioinorganic photochemistry** |
| **Type of Course** | **Elective** |
| **Credit Value** | **2** |
| **Course Code** | **EMM23E33** |

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|---|---|---|---|---|---|---|
| **Course Summary & Justification** | Bioinorganic photochemistry is a rapidly evolving field integrating inorganic photochemistry with biological, medical and environmental sciences. The interactions of light with inorganic species in natural systems, and the applications in artificial systems of medical or environmental importance, form the basis of this challenging inter-disciplinary research area. *Bioinorganic Photochemistry* provides a comprehensive overview of the concepts and reactions fundamental to the field, illustrating important applications in biological, medical and environmental sciences. | | | | | |
| **Semester** | **III** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge of bioinorganic chemistry and photochemical reactions. | | | | | |

## COURSE OUTCOMES (CO)

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Basic concepts of photochemistry and photochemical reactions. | U | 1 |
| 2 | Understand many organometallic compounds as fluroscent agents in the detection of cations, anions and toxic ions in the living system | U, A, R, An | 1 |
| 3 | Theory of photodynamics, and photocatalysis. | U, R, I | 1,3,6 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

## COURSE CONTENT

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | Introduction, Philosophy of bioinorganic photochemistry<br>Fundamentals: Light and matter. Nature of light, Accessible light sources and Interaction between light and matter.<br>Formation and properties of electronic excited states: Wave mechanics and quantum numbers and Electronic excitation.<br>Photophysical deactivation of electronic excited states: Spontaneous deactivation, Quenching and Coordination and organometallic compounds | **10 Hrs.** | **1** |
| **Module 2** | Photochemical reactions: Photochemical reaction channels, Intramolecular photoreactions, Photodissociation and photoionization, Photoisomerization, Intermolecular photoreactions, the coordination compound specificity. Ligand field photochemistry, Photochemistry from LC or LLCT states, Inner-sphere charge transfer photochemistry, Outer-sphere charge transfer photochemistry, Photosensitized reactions, Homogeneous photocatalysis. Natural photo-processes involving inorganic compounds From interstellar space to planetary atmospheres: Homogeneous systems: from interstellar space to planetary atmospheres and primitive soup models. Heterogeneous photochemistry in ice phases. | **12 Hrs.** | **1,2** |

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|---|---|---|---|
| **Module 3** | Applications: Fluorescent and chromogenic sensing and labeling: Cations as targets in biochemical sensing Cations common in biological systems, Fluorescent detection of toxic cations, Fluorescent and chromogenic sensing of anions, Common anions and Toxic anions. Optical detection of neutral molecules. Nanoparticles in biochemical sensing and labeling. Therapeutic strategies; Photobio-stimulation, Photo-activation of drugs, Photodynamic therapy, Mechanisms of PDT and PTT. Photosensitizers, Inorganic photosensitizers, Supporting role of metal ions in photodynamic therapy, and Combination of polypyrrolic photosensitizers and metallo-pharmaceuticals, Recent PDT development and Nanomedical methods. | **13 Hrs.** | **1,3** |
| **Module 4** | Photodynamic inactivation of microorganisms: Bacteria, Viruses, Fungi and Parasites. Phototoxicity and photoprotection: Chemical and physical photoprotection. Inorganic sunscreens. Photocatalysis in environmental protection: Development of homo- and heterogeneous methods. Homogeneous photocatalysis and heterogeneous photocatalysis. Water and air detoxification. Other applications of photocatalysis. | **12 Hrs.** | **1,2,3** |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**O. Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**P. Semester End examination** |

**REFERENCES**


1. Bioinorganic Photochemistry- Grazyna Stochel, Malgorzata Brindell, Wojciech Macyk, Zofia Stasicka, Konrad Szacilowski. Wiley Publishers (2009).
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3. Photochemistry and Photophysics of Coordination Compounds II - Volume Editors: Balzani, V., Campagna, Springer Publications.Vol.281, 2007.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **RESEARCH METHODOLOGY** |

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|---|---|
| **SchoolName** | **School of Energy Science** |
| **Programme** | **M.Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **RESEARCH METHODOLOGY** |
| **Type of Course** | **Elective** |
| **Credit Value** | **2** |
| **Course Code** | **EMM23E34** |

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|---|---|---|---|---|---|---|
| **Course Summary & Justification** | This course provides introduction, meaning, objectives and motivation of research. It also helps the students to understand how research is done, research process, criteria of good research, and problems encountered by researchers in India. Students will be able to study the formulation of hypothesis and review of literature. Learning this course will provide a strong foundation in sampling theory, types and steps in sampling and advantages and limitations of sampling. The course will also provide a deep awareness on computer applications spreadsheet tool, data storing, and features for statistical data analysis. The students will learn about the presentation tool, features and functions, creating presentation, customizing presentation, showing presentation and also about use of Internet, WWW, search engine like Google, Yahoo etc, advanced search techniques. It also describes about interpretation and report writing, presentation of tables and figures, research-scientific misconduct, plagiarism, impact factor, and h-index. | | | | | |
| **Semester** | **III** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning, collaborative learning, independent learning | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge about conducting research works | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome<br>Upon completion of this course, students will be able to; | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Understand the meaning, objectives, types, significance of research, and importance of knowing how research is done | R,U | 1,2,3 |
| 2 | Able to acquire the knowledge about sampling technique and computer applications | U,A | 2,3,4 |
| 3 | Learn about presentation tool, features and functions, creating presentation | A,C,An | 2,3,5 |
| 4 | Gather information about use of Internet, WWW, search engine and advanced search techniques. | U,An,E | 1,6,7 |
| 5 | Learn the interpretation, significance of report writing, different steps in writing report | An,S,I | 2,3,9 |
| ***Remember I, Understand (U), Apply (A), Analyse (An), Evaluate I, Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | **Research methodology:** An Introduction, Meaning of Research, Objectives of Research, Motivation in Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Importance of Knowing How Research is Done, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India Questions- Research design- Formulation of hypothesis- Review of literature. | 15 Hrs | **1,2** |
| **Module 2** | **Sampling technique:** Sampling theory, Types of sampling, Steps in sampling-Sampling and Non-sampling error, Sample size, Advantages and limitations of sampling.<br>**Computer applications:** Spreadsheet Tool: Introduction to spreadsheet application, features and functions, using formulas and functions, Data storing, Features for Statistical data analysis, Generating charts/ graph and other features. (Microsoft Excel or similar tool). | **15 Hrs** | **1,2** |
| **Module 3** | **Presentation tool:** Introduction to presentation tool, features and functions, creating presentation, customizing presentation, showing presentation. (Microsoft Power Point)<br>**Web Search:** Introduction to Internet, Use of Internet and WWW, Using search engine like Google, Yahoo etc, advanced search techniques. | **15 Hrs** | **2,3,4** |

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|---|---|---|---|
| **<u>Module 4</u>** | **Interpretation and report writing:** Meaning of Interpretation, Why Interpretation? Technique of Interpretation: Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Indexing, presenting footnotes, abbreviations, Presentation of tables and figures, Contents, Styles of reporting, Referencing, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports, Research-Scientific misconduct, Plagiarism, impact factor, h-index. | **15 Hrs** | **2,4,5** |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
| **Assessment Types** | **Mode of Assessment**<br>**Continuous Internal Assessment (CIA)**<br>Surprise test<br>Internal Test – Objective and descriptive answer type<br>Submitting assignments<br>Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**Semester End examination** |

**REFERENCES**


1. Montgomery, C Douglas (2007), 5/e, Design and Analysis of Experiments, (Wiley India).
2. Montgomery, C Douglas. &Runger, George C. (2007), 3/e, Applied Statistics &Probability for Engineers (Wiley India).
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8. B.L Wadehra,. 2000. Law relating to patents, trademarks, copyright designs and geographical indications. Universal Law Publishing. How to write a Technical report – AlamSmithee, Fictitious Institute of Technology, 1999.
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|---|---|
| | **MAHATMA GANDHI UNIVERSITY** |
| | **NANOSENSORS AND NANODEVICES** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Nanosensors and Nanodevices** |
| **Type of Course** | **ELECTIVE** |
| **Credit Value** | **2** |
| **Course Code** | **EMM23E35** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Course Summary & Justification** | In the broadest sense, nanosensors and nanodevices are the critical enablers that will allow mankind to exploit the ultimate technological capabilities of electronic, magnetic, mechanical, and biological systems. While the best examples of nanodevices at present are clearly associated with the information technology industry, the potential for such devices is much broader. Nanosensors and Nanodevices will ultimately have an enormous impact on our ability to enhance energy conversion, control pollution, produce food, and improve human health and longevity. This course summarizes the different types of nanosensors and nanodevices which have application in wide variety of fields | | | | | |
| **Semester** | **III** | | | | | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | | 40 | 40 | 0 | 40 | 120 |
| **Pre-requisite** | Basic knowledge in basic electronics and instrumentation. | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | Understand the basics of a Nanosensors. | U | 1, 2,7 |
| 2 | Study the sensor characterization and modes of packaging. | U, An | 1, 3,4 |
| 3 | To learn about various Nanosensor materials | U, A, E | 1,2,3,4 |
| 4 | To design Nanomaterials in biochemical sensor and its application | U, A | 3,4,5 |
| 5 | Correlate and record data of the medically significant measures using a bio sensor | U, R, E | 5,7 |
| 6 | Apply the sensing of physical parameters sensed to fabricate appropriate sensors. | U, A, E | 2,4,5 |
| 7 | Understand the processing of input signals of sensors and applying it in electronics | U, A, Ap | 4,5 |
| 8 | To learn about various Nanodevice materials | U, I, An | 1,7 |
| 9 | State and apply basic concepts of Mechanical Sensors and Actuators | U, An, C | 1,4,6 |
| 10 | Find the connection between Metal Insulators, Quantum Structures and Devices | U, A, E | 5,7 |
| ****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | **Micro and nano-sensors:** Fundamentals of sensors, biosensor, micro fluids, MEMS and NEMS, Packaging and characterization of sensors: Method of packaging at zero level, dye level and firstlevel. Active and Passive sensors – Static characteristic - Accuracy, offset and linearity – Dynamiccharacteristics - First and second order sensors – Physical effects involved in signal transduction. | **15 Hrs.** | **1,2,3** |
| **Module 2** | **Nanomaterial based Sensors:** Nanomaterials in biochemical sensor design, application for nanoparticles based on gold and semiconductor materials (quantum dots). synthesis of | **15 Hrs.** | **4,5,6,7** |

| | | | |
|---|---|---|---|
| | nanomaterials (nano rod, nanoclusters, nanodiamond and nano shells). application of nano material for analytical purpose, Important functions of nanoparticles.<br>**Nanomaterials:** Nanomaterial based colorimetric sensors, metallic nanoparticles in sensing, surface functionalization of gold nanoparticle, Fluorescence based sensing, electrical and electrochemical sensing. Different type of sensors: Electrochemical, Mass sensitive sensor, biochemical sensors and their applications. gold nanoparticle-based surface plasmon resonance sensors, physical properties of gold nano particle: size dependent electronic and optoelectronic properties, fluorescence quenching, limit of detection and limit of quantification, sensitivity of the sensor, selectivity of measurements, linear range. | | |
| **Module 3** | **Mechanical Sensors and Actuators:**<br>Accelerometers (capacitive, piezoelectric, piezoresistive, thermal), Force sensors (strain gauges, tactile sensors), Pressure sensors (semiconductor, piezoresistive, capacitive, VRP), Gyroscopes (mechanical, optical, fiber-optics). Night Vision, System, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry, For other civil applications: metrology, bridges etc., gas sensors.<br>**Optical Sensors:**<br>Photodiodes, phototransistors and photoresistors based sensors, Photomultipliers, light-to-light detectors, infrared sensors (thermal, PIR, AFIR, thermopiles), CCD sensors and detectors. Surface Plasmon sensors, SERS Sensors<br>**Environmental monitoring sensors:**<br>Mercury and arsenic contamination in water, atmospheric pollution monitoring sensors. | **15 Hrs.** | **6,7** |
| **Module 4** | Metal Insulator Semiconductor devices, molecular electronics, information storage, molecular switching, Schottky devices<br>**Quantum Structures and Devices:**<br>Quantum layers, wells, dots and wires, Mesoscopic Devices, Nanoscale Transistors, Single Electron Transistors, MOSFET and NanoFET, Resonant Tunnelling Devices, Carbon Nanotube based logic gates, optical devices, Connection with quantum dots | **15 Hrs.** | **4,6,7** |

| Teaching and Learning Approach | **Classroom Procedure (Mode of transaction)**<br><br>Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student |
|---|---|
| **Assessment Types** | **Mode of Assessment**<br><br>**Continuous Internal Assessment (CIA)**<br>➢ Surprise test<br>➢ Internal Test – Objective and descriptive answer type<br>➢ Submitting assignments<br>➢ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar<br>**Semester End examination** |

## REFERENCES


1. Nanosensors: Physical, Chemical, and Biological, Vinod Kumar Khanna,CRC Press, 2011.
2. Chemical Sensors: An Introduction for Scientists and Engineers, Peter Grundler, Springer**.**
3. Smart Sensors for industrial Applications, KrzysztofIniewski,CRC Press**.**
4. Introduction to Nanoelectronics, Science, Nanotechnology, Engineering, and Applications, Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, Cambridge University Press, 2007**.**
5. Nanotechnology and Nanoelectronics, Fahrner, Wolfgang (Ed.), 2005, Springer.
6. Introduction to the Physics of Nanoelectronics, Tan & Jalil 2012. Wood head publishing.
7. Fundamentals of Nanoelectronics, George W. H, Pearson education India 2009.
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9. Nanotechnology and Nanoelectronics, - Prof. Dr. W. R. Fahrner, Springer, 2005
10. Nanoelectronics and information technology, Rainer Weiser, 2012, Wiley.
11. Chemical Sensors and Biosensors; Brian, R Eggins; Wiley; New York, Chichester, 2002.
12. Biosensors: A Practical Approach, J. Cooper & C. Tass, Oxford University Press, 2004.
13. Nanomaterials for Biosensors, Cs. Kumar, Wiley – VCH, 2007.
14. Smart Biosensor Technology, G.K. Knoff, A.S. Bassi, CRC Press, 2006.

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Nanotechnology in Energy** |
| **School Name** | **School of Energy Materials** |
| **Programme** | **MSc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Nanotechnology in Energy** |
| **Type of Course** | **Elective** |
| **Credit Value** | **2** |
| **Course Code** | **EMM23E36** |

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|---|---|---|---|---|---|---|
| **School Name** | **School of Energy Materials** | | | | | |
| **Programme** | MSc. Chemistry (Specialization in Energy Science) | | | | | |
| **Course Name** | **Nanotechnology in Energy** | | | | | |
| **Type of Course** | Elective | | | | | |
| **Course Code** | | | | | | |
| **Course Summary & Justification** | This main objective of this course is to give a theoretical and practical overview of nanotechnology with applications in energy production, conversion and storage. The specific objectives of this course are to familiarize with nanomaterials, manufacturing processes, characterization and also reliability characteristics. Upon completion of the course on Nanotechnology in Energy, students will understand the fundamental laws governing energy conversion and storage efficiency, the importance of favourable nanomaterials in the energy conversion, and storage application and reliability of materials.<br>This paper encompasses a detailed exposure to the alternative energy technologies with a special focus on solar-photovoltaic, batteries and hydrogen-fuel cell technologies. The proposed course will be one of the elective courses to introduce students to applications of nanotechnology through five different modules. The modules are selected in order to have hierarchy in student learning in three different areas (renewable energy technologies, batteries, fuel cells, hydrogen storage and solar photovoltaics) of alternative energy technologies. | | | | | |
| **Semester** | 3 | | **Credit** | | 3 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning<br>Collaborative learning<br>Case based learning | 40 | 40 | - | 40 | 120 |
| **Pre-requisite** | Basics of Energy production, conversion and storage systems.<br>(Graduate Level) | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome<br>*Upon completion of this course, students will be able to;* | Learning Domains | PSO No. |
|---|---|---|---|
| 1 | The module encompasses a detailed exposure to energy challenges, development and implementation of renewable energy technologies. Nanotechnology enabled renewable energy technologies are also be discussed (Module 1) | U, A | 1,2,7 |
| 2 | This module discusses Nanomaterials for Energy Storage Systems. The student will able to understand principles and material design of different nanostructured carbon-based materials. Current status and future trends on energy storage systems are also discussed. (Module 2) | U, A | 1,2,3,7 |
| 3 | This module is to designed to help the students to provide adequate knowledge regarding nanomaterials in fuel cells, hydrogen Storage, thermoelectric materials (in nano scale), supercapacitors (Module 3). | An, E | 2,3,7 |
| 4 | Understanding of application of nanomaterials for hydrogen storage and photocatalysis. | E | 2,3 |
| 5 | This module gives an insights of role of various nanomaterials for Photovoltaic Solar Energy Conversion Systems. | An, E | 2,3,7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)** | | | |

**COURSE CONTENT**

| Module No: | Module Content | Hrs | CO. No. |
|---|---|---|---|
| **Module 1** | Renewable Energy Technology<br>Energy challenges, development and implementation of renewable energy technologies, nanotechnology enabled renewable energy technologies, Energy transport, conversion and storage- Nano, micro, and poly crystalline and amorphous Si for solar cells, Nano-micro Si-composite structure, various techniques of Si deposition | **15** | **1,2** |
| **Module 2** | Nanomaterials for Energy Storage Systems<br>Issues and Challenges of functional Nanostructured Materials for electrochemical Energy Storage Systems, Primary and Secondary Batteries (Lithium ion Batteries), Cathode and anode materials, Capacitor Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon-based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends. | **15** | **2,3** |

| | | | |
|---|---|---|---|
| | | | |
| **Module 3** | Nanomaterials in Fuel Cell and Storage Technology<br>Micro-fuel cell technologies, integration and performance for micro-fuel cell systems, thin film and microfabrication methods, design methodologies, micro-fuel cell power sources, Supercapacitors, Specific energy, charging/ discharging, EIS analysis. | | |
| **Module 4** | Nanomaterials for Hydrogen Storage and Photocatalysis<br>Hydrogen storage methods, metal hydrides, size effects, hydrogen storage capacity, hydrogen reaction kinetics, carbon-free cycle, gravimetric and volumetric storage capacities, hydriding/dehydriding kinetics, multiple catalytic effects, degradation of the dye, nanomaterials based photocatalyst design, kinetics of degradation. | **15** | **3,4** |
| **Module 5** | Nanomaterials for Photovoltaic Solar Energy Conversion Systems<br>Principles of photovoltaic energy conversion (PV), Types of photovoltaics Cells, Physics of Photovoltaic cells, Organic photovoltaic cell cells, thin film Dye Sensitized Solar Cells, Quantum dot (QD) Sensitized Solar Cells (QD-SSC), Organic- Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Current status and future trends. | **15** | **4,5** |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Authentic learning, case-based learning, collaborative learning, seminar, group activities. |
| **Assessment Types** | **Mode of Assessment**<br>4. Continuous Internal Assessment (CIA)<br>5. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar<br>6. Assignments<br>C. Semester End examination |

## REFERENCES


1. Twidell. J. and Weir. T “Renewable Energy Resources”, E & F N Spon Ltd, 1986.

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|---|---|
| | **MAHATMA GANDHI UNIVERSITY** |
| | **Open Course** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **School Name** | **School of Energy Materials** | | | | | |
| **Programme** | **M.Sc. Chemistry (Specialization in Energy Science)** | | | | | |
| **Course Name** | **Open Course** | | | | | |
| **Course Credit** | **4** | | | | | |
| **Type of Course** | **Core** | | | | | |
| **Course Code** | | | | | | |
| **Course Summary & Justification** | The students can opt. a general course offered by any of the department as open course. It aims to provides the interdisciplinary knowledge on various topics. | | | | | |
| **Semester** | **III** | | | | | |
| **Total StudentLearning Ti me (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Visiting other department and interact with expertises | - | - | - | - | - |
| **Pre-requisite** | Basic knowledge in Science and Arts topics. | | | | | |

| | | | |
|---|---|---|---|
| 1 | To obtain interdisciplinary knowledge on a topic other than students specific area. | A,S,I | 1, 2, 3 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

| | |
|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Main aim of industrial visit is to provide an exposure to students about practical working environment. They also provide students a good opportunity to gain full awareness about industrial practices. Through industrial visit students get awareness about new technologies. |
| **Assessment Types** | **Mode of Assessment** The report shall be evaluated by the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner. |

**SEMESTER IV**

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| | **MAHATMA GANDHI UNIVERSITY** |
| | **Industrial visit** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **School Name** | **School of Energy Materials** | | | | | |
| **Programme** | **M.Sc. Chemistry (Specialization in Energy Science)** | | | | | |
| **Course Name** | **Industrial Visit** | | | | | |
| **Course Credit** | **3** | | | | | |
| **Type of Course** | **Core** | | | | | |
| **Course Code** | **EMM23C38** | | | | | |
| **Course Summary & Justification** | The Industrial visit shall be conducted by the School of Nanoscience and Nanotechnology. The students have to visit an industry in the presence of a faculty member of the School during the programme and submit a report on the same at the end of the fourth semester. | | | | | |
| **Semester** | **IV** | | | | | |
| **Total StudentLearning Ti me (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Visiting the industry and interacting with the personnel | - | - | - | - | - |
| **Pre-requisite** | Basic knowledge in chemistry practicals and industrial chemistry | | | | | |

| | | | |
|---|---|---|---|
| 1 | Demonstrate the applications of chemical concepts and principles learned in classroom. | A | 1, 2, 3 |
| 2 | Illustrate processes and products manufactured in the chemical industries. | A | 2, 4 |
| 3 | Develop awareness of the principles and technological aspects in the chemical industries. | C | 2 |
| 4 | Improve interpersonal skill by communicating directly with industrial personnel. | S | 5 |
| 5 | Aware of the impacts of industrial processes on health, safety, environment and society. | E | 6, 7 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

| | |
|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>Main aim of industrial visit is to provide an exposure to students about practical working environment. They also provide students a good opportunity to gain full awareness about industrial practices. Through industrial visit students get awareness about new technologies. |
| **Assessment Types** | **Mode of Assessment**<br>The report shall be evaluated by the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner. |

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|---|---|
| | **MAHATMA GANDHI UNIVERSITY** |
| | **Industrial visit** |

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|---|---|---|---|---|---|---|
| **School Name** | **School of Energy Materials** | | | | | |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** | | | | | |
| **Course Name** | **Dissertation** | | | | | |
| **Type of Course** | Core | | | | | |
| **Course Code** | EMM23C39 | | | | | |
| **Course Summary & Justification** | The candidate shall do a research project in any of the research institute. This follows discussion with the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner. | | | | | |
| **Semester** | 4 | | **Credit** | | 9 | |
| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
| | Authentic learning Collaborative learning Case based learning | | | | | |
| **Pre-requisites** | Aptitude for research work in one of the interdisciplinary areas in the realm of interface between physical science and nanotechnology. Literature survey. | | | | | |
| *Others- Library, seminar and assignment preparations, test, journal, discussion etc.* | | | | | | |

**COURSE OUTCOMES (CO)**

| CO No. | Expected Course Outcome | Learning Domains | PSO No. |
|---|---|---|---|
| | At the end of the course the students are expected to | | |
| 1 | Clearly present and discuss the research objectives, methodology, analysis, results and conclusions effectively. | A | 1, 2, 3, 4, 5 |
| 2 | Acquire a comprehensive knowledge of the area subject of study | Ap | 1, 7 |
| 3 | Gain deeper knowledge of methods in the topic of study. | A | 6 |
| 4 | Able to contribute to research and development work. | U | 3 |
| 5 | Undertake independent, original and critical research on a relevant topic. | U | 5 |
| 6 | Able to plan and use adequate methods to conduct specific tasks in given frameworks and to evaluate this work. | U | 6 |
| 7 | Create, analyse and critically evaluate different problems and their solutions. | C | 7,8 |
| 8 | Gain consciousness about the ethical aspects of research. | E | 6,9 |
| ***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

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|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>E-learning, interactive Instruction: Seminar, Authentic learning, , Library work, laboratory work, Team work, independent learning and Group discussion, Presentation of research work. |
| **Assessment Types** | **Mode of Assessment**<br>Evaluation of the presentation by both internal and external examiners. |

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|---|---|
| **School Name** | **School of Energy Materials** |
| **Programme** | **M. Sc. Chemistry (Specialization in Energy Science)** |
| **Course Name** | **Viva-Voce** |
| **Course Credit** | **4** |
| **Type of Course** | **CORE** |
| **Course Code** | NSM21C30 |
| **Course Summary & Justification** | The Examination Board consisting of the Chairman and examiners shall conduct the comprehensive viva-voce. Thorough understanding of all the M. Sc. level course contents and of the recent trends in the broad area of Physics and Nanotechnology are evaluated |
| **Semester** | **4** |

| **Total Student Learning Time (SLT)** | Learning Approach | Lecture | Tutorial | Practical | Others | Total Learning Hours |
|---|---|---|---|---|---|---|
| | Classroom studies, lab work, library Library work, independent learning etc. | - | - | - | - | - |
| **Pre-requisite** | Basic as well as in-depth knowledge in the courses he/she studied | | | | | |

**COURSE OUTCOMES (CO)**

| **CO No.** | **Expected Course Outcome** | **Learning Domains** | **PSO No.** |
|---|---|---|---|
| | At the end of the course the students are expected to; | | |
| 1 | Achieve fundamental and in-depth knowledge of the subject | A | 1, 3 |
| 2 | Acquire more profound knowledge of the methods of all the major areas of the programme | Ap | 1,2,3,4,5, 6, 7 |
| 3 | Obtain objective understanding and knowledge of physics with an emphasis on nanotechnology | A | 1, 4 |
| 4 | Be able to contribute to research and development work. | U, S | 3, 8, 9 |
| ****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** | | | |

| | |
|---|---|
| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**<br>E-learning, interactive Instruction:, Seminar, Authentic learning, , Library work<br>, laboratory work, Team work, independent learning and Group discussion, Presentation of research work |
| **Assessment Types** | **Mode of Assessment**<br>Thorough understanding of all the M.Sc. level course contents and recent trends in the broad area of chemical sciences are evaluated. The candidate will be asked questions based on the whole syllabus he/she studied in the entire programme. How he/she answered or responded the questions asked will be<br>considered for evaluation. |

## MODEL QUESTION PAPER

**SCHOOL OF ENERGY MATERIALS**

**MAHATMA GANDHI UNIVERSITY**

**SEMESTER**

**PROGRAMME**

**EXTERNAL EXAMINATION (YEAR/ MONTH)**

**COURSE CODE: COURSE NAME**

**Time: 3 Hours** **Max. Marks: 60**

**Part A. Answer any 10 Questions (Each question carries 2 marks)**

1. ……………………………………………………………………………………
2. ……………………………………………………………………………………
3. ……………………………………………………………………………………
4. ……………………………………………………………………………………
5. ……………………………………………………………………………………
6. ……………………………………………………………………………………
7. ……………………………………………………………………………………
8. ……………………………………………………………………………………
9. ……………………………………………………………………………………
10. ……………………………………………………………………………………
11. ……………………………………………………………………………………
12. ……………………………………………………………………………………
13. ……………………………………………………………………………………
14. ……………………………………………………………………………………

**Part B. Answer any 4 Questions (Each question carries 5 marks)**

1. ……………………………………………………………………………………
2. ……………………………………………………………………………………
3. ……………………………………………………………………………………
4. ……………………………………………………………………………………
5. ……………………………………………………………………………………
6. ……………………………………………………………………………………
7. ……………………………………………………………………………………

**Part C. Answer any 2 Question (Each question carries 10 marks)**

1. ……………………………………………………………………………………
2. ……………………………………………………………………………………
3. ……………………………………………………………………………………
4. ……………………………………………………………………………………
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