Proposal

for

Inception and Establishment of New M. Sc. Program

M. Sc. Material Science

(Specialization in Energy Science)

Curriculum

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

SCHOOL OF ENERGY MATERIALS

MAHATMA GANDHI UNIVERISTY

KOTTAYAM

1. TITLE OF THE PROGRAMME:

The programme shall be called Master of Science (M.Sc. Material Science (Specialization in Energy Science).

2. ABOUT THE COURSE:

M.Sc. Material Science (Specialization in Energy Science) 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.

3. ELIGIBILITY FOR ADMISSION:

A pass in B.Sc. or B.S. in Chemistry/Physics/Materials Science/Nanoscience and Nanotechnology/Polymer Chemistry and Renewable Energy.

4. ADMISSION CRITERIA:

The admission is made on the basis of the performance in entrance test (objective type/ short answer questions). 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.

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. Material Science (Specialization in Energy Science) 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 practicals. 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 wit Course outcomes (COs)
Section A	Remembering/Understanding/Applying/Evaluating.	12 out of 15 questions;3 marks each	Minimum one question from each unit.	36	Aligned with COs
Section B	Applying/Analyzing/ Evaluating/Creating	4 out of 7 questions; 6 marks each	Minimum one question from each unit	24	Aligned with COs
Total Marks = 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 to70%

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 to30%
- Moderate: 55 to65%
- High: 15 to25%

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 the1st and2nd semesters, who have secured SGP A 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

Candidatesinthe1st and2nd 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.Candidateinthe3rd semester who has secured letter grade of 'F'or 'Ab'inany 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'inacourseinthe4th semester examination can re-appear course wise, along with the immediate lower batch. Candidates who secured the grade of only 'F' or'Ab'inacourseinthe3rd /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.

22. 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. Material Science (Specialization 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/Transdisciplinary 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.

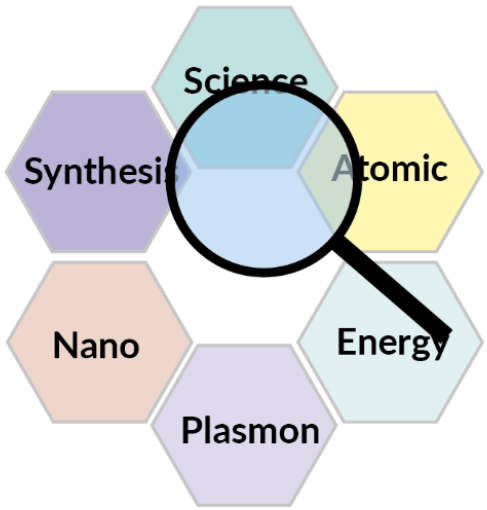
PO 7: Equity, Inclusiveness and Sustainability Appreciate equity, inclusiveness and sustainability and diversity; acquire ethical and moral reasoning and values of unity, secularism and national integration to enable to act as dignified citizens; able to understand and appreciate diversity, managing 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 issuesrelatedtoone'sworkandlivingasadignifiedpersoninthesociety.

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.

PO10: 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. Material Science (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 M.Tech 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 Advanced thermodynamics, material characterisation techniques, polymers and nano-composites, and Functional materials.

SCHOOL OF ENERGY MATERIALS

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

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

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

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	To develop in students, the knowledge in students about the importance and scope of the subject
2	The detailed functional knowledge of theoretical concepts and experimental aspects of chemistry, physics and material science.
3	Provide opportunities to excel in academics, research or Industry
4	Train students in the field of Material Science with specific emphasis on Energy Science and Technology to cater to the present demands of miniaturization and energy economy.
5	Solid understanding of the sciences and technology related to energy production, storage and conversion.
6	Understand the economic, environmental and policy impact of a sustainable energy practice for a sustainable society

7	Will learn basic to advanced aspects of Renewable Energy systems completely prepared to shift from fossil fuels to renewable sources.
8	Facilitate the students to be able to familiarise and to work with advanced experimental and computational techniques at various scales.
9	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.
10	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.

SCHEME AND CREDIT DISTRIBUTION

Semester I

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
1	EMM23C81	Fundamentals of Material Science	3	18	24
2	EMM23C82	Material Synthesis and Characterisation Techniques	3		
3	EMM23C83	Nanoscience and Nanotechnology	3		
4	EMM23C84	Advanced Thermodynamics	3		
5	EMM23C25	**LAB I** – Synthesis and Characterization of Advanced materials	3		
6	EMM23C85	Internship/Miniproject	3		
***Elective Courses**					
8	EMM23E51	Basics of Energy Science	3	6	
	EMM23E52	Energy policies and Management	3		
9	EMM23E23	Thin film science and Technology	2		
10	EMM23E24	Bioenergy Technology	2		
11	EMM23E25	Polymer Chemistry	2		
12	EMM23E53	Machine Learning for Energy Science	2		

Semester 2

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
13	EMM23C86	Optical and Magnetic Properties of Materials	3	18	

14	EMM23C87	Synthesis and Applications of Nanocomposites	3		24
15	EMM23C88	Advanced Functional Materials	3		
16	EMM23C60	Power Electronics and Applications	3		
17	EMM23C89	**LAB II**- Energy Conversion and Energy Storage	3		
18	EMM23C90	**LAB III**- Power Electronics and Applications	3		
***Elective Courses (Choose any two)**					
19	EMM23E26	Energy conversion, storage and transportation	3	6	
20	EMM23E52	MEMS and Nanofabrication	3		
21	EMM23E54	Solar, Photovoltaic Technology	2		
22	EMM23E29	Nuclear Energy and Technology	2		
23	EMM23E30	Energy from wind, geothermal and water	2		

Semester 3

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
24	EMM23C35	Advanced computation in Material science	3	15	24
25	EMM23C91	Processing and Designing of Materials	3		
26	EMM23C34	Advanced Solid State and Electrochemistry	3		
27	EMM23C92	**LAB IV**- Fabrication of Materials and Applications	3		
28	EMM23C93	Internship/Miniproject	3		
***Elective Courses (Choose any two)**					
29	EMM23E31	Energy device and fabrication	3	5	
	EMM23E21	Hydrogen and Fuel cells	3		

30	EMM23E32	Metal, ceramics and composites materials for Energy applications	3		
31	EMM23E34	Research Methodology	2		
32	EMM23E35	Nano sensors and nanodevices	2		
33	EMM23E36	Nanotechnology in Energy	2		
34		**Open Course**	4	4	

Semester 4

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
35	EMM23C94	Industrial visit	3	16	16
36	EMM23C95	Dissertation/Viva-voce	13		

SEMESTER I

	MAHATMA GANDHI UNIVERSITY
	Fundamentals of Material Science
School Name	**School of Energy Materials**
Programme	**M.Sc. Material Science (Specialization in Energy Science)**
Course Name	**Fundamentals of Material Science**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C81**

Course Summary & Justification	This course focuses on the fundamental aspects of materials science which every material scientist is supposed to be familiar with. The course discusses the basic structure of solids, classification of materials based on the structure and the correlation between the structure and properties. The evolution of properties based on the structure and its alteration is also dealt with.					
Semester	**I**					
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	Fundamental knowledge on the structure of solids and ceramics.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Identify the structure of solids and understand the imperfection in solids.	U,	2,9
2	Understanding the diffusion mechanism of solids.	U	2,6,10
3	Analyse the various nucleation mechanism	An	2,6
4	Impart idea about phase diagram and phase transformation of materials. Different heat treatment mechanisms.	A, An	2,6,8
5	Will discuss the detail study about ceramic materials and their applications.	U,Ap	2,6,7
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	**Structure of solids:** Introduction to engineering materials, Description of materials science tetrahedron, Force - interatomic distance curve, Structure - description of unit cell and space lattices, Coordination number, APF for cubic and hexagonal close packed structures, Miller indices, Non crystalline structures properties of crystalline and amorphous structures, Crystal imperfections Significance of structure property correlations in all classes of engineering materials.	**8 Hrs.**	**1**
Module 2	**Diffusion phenomenon:** Diffusion in ideal solutions, Kirkendall effect, Rate and mechanism of diffusion, Fick's first and second law of diffusion, Applications of diffusion, Concept of uphill diffusion.	**15 Hrs.**	**2**

Module 3	**Principles of solidification and phase equilibria**: Concept of free energy and entropy; Structure of liquid metals; Energetics of solidification; Nucleation and growth, Homogeneous and heterogeneous nucleation, Dendritic/Equiaxed growth, Origination of grain and grain boundaries, Cast structure; Significance of alloying, Intermediate alloy phases, solid solutions and its types.	**12 Hrs.**	**3**
Module 4	**Phase diagrams and phase transformations**: Basic definitions; Gibbs phase rule, Introductions to binary, ternary and quaternary system; Construction of binary isomorphous diagram from cooling curves, Time scale for phase diagrams, Transformations in steels, Precipitation process, recrystallization and growth. **Heat treatment:** TTT curves, CCT curves, Annealing, Normalising, Hardening, Tempering	**15 Hrs.**	**4**
Module 5	**Ceramics**: Introduction to ceramic materials; Classification of ceramics, Crystal structure and bonding of common advanced ceramic materials; Mechanical behavior of ceramics, Glass and glass ceramics, Preparation and characterisation of ceramics powders; Characterisation of ceramic materials; Applications of ceramics in advanced technologies.	**10 Hrs.**	**5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **1. Continuous Internal Assessment (CIA)** ***Internal Test*** ***Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature **2. Seminar Presentation** – A topic needs to be presented and discussed with the class **3. Semester End Examination**

References

1. R. Abbaschian, R.E. Reed-Hill, Physical Metallurgy Principles, 4th ed., Cengage Learning, 2009.
2. D.R. Askeland, P.P. Phule, W.J. Wright, The Science and Engineering of Materials, 6th ed., Cengage Learning, 2010.
3. W.D. Callister, D.G. Rethwisch, Materials science and Engineering: An Introduction, 8th ed., Wiley, 2010.
4. B.S. Mitchell, An Introduction to Materials Engineering and Science for Chemical and Materials Engineers, 1st ed., Wiley- Interscience, 2003.
5. C. Kittel, Introduction to Solid State Physics, 8th ed., Wiley, 2005.
6. V. Singh, Physical Metallurgy, 1st ed., 2008.
7. S.H. Avener, Introduction to Physical Metallurgy, 2nd ed., Tata McGraw-Hill Education, 2011.
8. V. Raghavan, Materials Science & Engineering: A first course, 5th ed., PHI Learning, 2004.
9. W.D. Kingery, Introduction to Ceramics, 2nd ed., John Wiley & Sons, 1999.

	MAHATMA GANDHI UNIVERSITY
	MATERIALS SYNTHESIS AND CHARACTERIZATION TECHNIQUES

School Name	School of Energy Materials					
Programme	M.Sc. Material Science (Specialization in Energy science)					
Course Name	**MATERIALS SYNTHESIS AND CHARACTERIZATION TECHNIQUES**					
Type of Course	Core					
Course Code	EMM23C82					
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. 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 Collaborative learning 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 *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	4,6,8
2	Explain the principles behind and the type of information that different characterisation techniques provide	U, A	2,7,8
3	Evaluate the strengths and limitations of various synthesis and characterisation methods	U, A	2,6,7
4	Propose technical applications for materials produced by different synthesis methods	An, E	1,2,7
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.
Module -1	Synthesis of nanomaterials: Gold, Silver, different types of Nano oxides, TiO2, 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.	12	1
Module–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.	8	2

Module -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
Module–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
Module–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.	15	2,3

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

REFERENCES:

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

2. B. D. Cullity, “Elements of X-ray Diffraction”, 4th Edition, Addison Wiley,1978.

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

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

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

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

7. D.A. Skoog, F.J. Holler, S. R. Crouch, Instrumental Analysis, Cengage Learning, 2007.

8. K. J. Klabunde and R.M. Richards (Eds.), Nanoscale Materials in Chemistry, 2nd Edn.,John Wiley & Sons, 2009.

	MAHATMA GANDHI UNIVERSITY
	Nanoscience and Nanotechnology
School Name	**School of Energy Materials**
Programme	**M.Sc. Material Science (Specialization in Energy Science)**
Course Name	**Nanoscience and Nanotechnology**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C83**

Course Summary & Justification	This provides an overview of nanomaterials, their synthesis, properties, and specific applications of nanotechnology in material science, biomedical fields, electronic devices, modelling and simulation, environmental solutions, and in energy production. This is to produce students that can apply fundamental knowledge of physics, chemistry, biology, material science, and computational science, to get fundamental knowledge in how to model and solve problems related to design, synthesis, characterization, fabrication, and optimization of functional nano materials.					
Semester	**I**					
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	Fundamental knowledge on the structure of solids and ceramics.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	To introduce the students to the world of nanoscience and provide knowledge of various synthesized/developed and natural nanomaterials and their possibilities.	U	1,2,7
2	To create understanding of the fundamentals of nanoscience and the properties of nanomaterials which are different from their bulk counterparts.	U,A	1,2,3,7
3	To create understanding of Size and shape dependence of properties at nanoscale.	U,R	2,3,7
4	Explain the properties of carbon nanomaterials.	U	2,3,7
5	Outline the structure, properties and applications of nanomaterials	U	3,7,10
6	Understand the various approaches for nanomaterials synthesis	U,A	4, 5,6,7
7	To understand the applications of nanomaterials in the fields of material science, biomedical fields, electronic devices, modeling and simulation, environmental solutions, and in energy production	U,A	4,5,6
8	Understand the toxicity and environmental Risks of Nanomaterials	U,A	1,2,7
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.
Module 1	Fundamentals of Nanoscience and Nanotechnology General introduction and history of nanomaterials, Feynmann's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic nanomaterials. Classification of nanostructures, Zero dimensional, one dimensional two dimensional nanostructures. Size	**8 Hrs.**	**1**

	and shape dependant properties and their uniqueness, energy at nanoscale - surface characteristics of nanomaterials, quantum confinement effect. Carbon based nanomaterials; properties and applications of fullerene, carbon nanotube, graphene, carbon onion, nanodiamond. Coreshells, quantum dots, nanoclusters, core-shells, organic, inorganic, hybrid nanomaterials, biomimetic nanomaterials.		
Module 2	Properties of Nanomaterials: General Introduction to electronic, optical, magnetic, catalytic, mechanical, and thermal properties of nanomaterials. Fundamental types of electronic nanomaterials. Microelectronics, Band structureconductor and semiconductor. Electrical conductivity in nanomaterials. Optical and photonic properties: Interaction of light with matter, the surface plasmon – SPR and scattering color generation from nanoparticles and nanostructures. Quantum dots – Optical properties related to quantum confinement. Magnetic Properties: Introduction – magnetic phenomena and their classical interpretation- the nanoperspective. Introduction to nanomagnetism-characteristics of nanomagnetic materials. Magnetization and nanostructures. Mechanical & Thermal properties: Nanomechanics- Introduction-lattice mechanics- linear elasticity relations	**15 Hrs.**	**2**

Module 3	Synthesis and Preparation of Nanomaterials: Understand the principles behind synthesis of nanomaterials such as top down, bottom up approaches, and solid-state synthesis methods. Fabrication of nanomaterials by physical methods: ball milling, physical vapor deposition, sputtering, laser ablation, ion sputtering, laser pyrolysis, molecular beam epitaxy, Langmuir-Blodgett growth, electrospinning. By chemical routes: chemical precipitation and coprecipitation, sol-gel methods, chemical vapour deposition (CVD). General methods for preparation, properties, and characterization of nanoparticle/polymeric blends and its applications. General methods for the preparation of bionanoparticle/polymeric blends and its applications. Surface modification of polymeric nanomaterials	**12 Hrs.**	**3**

Module 4	Characterization Methods and Analytical tools for Nanoparticles General introduction to spectroscopic techniques, Optical Microscopy, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunnelling Microscopy, Optical Absorption and Emission Spectroscopy, Thermo Gravimetric Analysis, Differential Scanning Calorimetry, Thermomechanical Analysis, X-Ray Diffraction, UV-Visible spectroscopy, Raman Spectroscopy, Dynamic Light Scattering (DLS), Differential Scanning Calorimeter (DSC), Differential Thermal Analyzer (DTA), Contact Angle Analysis, Scanning Probe Microscopy (SPM), X-ray Photoelectron Spectroscopy (XPS), electrochemical characterization measurements, Introduction to LASER spectroscopy and its applications.	**15 Hrs.**	**4,5**

Module 5	Applications of Nanoscience and Nanotechnology Applications of nanostructured materials for clean energy-related applications. Nanomaterials for photovoltaic solar energy conversion systems. Functional nanostructured materials for electrochemical energy storage systems, fuel cells, nanocatalyts, nanomagnetic materials and devices, nano sensors. Applications of nanobiotechnology in tissue engineering, biopolymers for tissue engineering, nanomedicines, wound healing, drug delivery, diagnostic and therapeutic applications of nanoformulations. Applications of nanotechnology in medicine and dentistry. Nanostructured materials for EMI shielding applications. Graphene Functionalization for Applications. Applications of conducting polymer nanocomposites, modeling of advanced nano energy materials, electronic structure of nanoparticles, Modeling, design and simulations of nanostructured materials. Photonic and opto-electronic properties and applications of nanoparticles. Environmental application of nanomaterials, water purification system.	**10 Hrs.**	**5,6**

Module 6	Health, Environmental risk, Toxicology and Safe Handling of Nanomaterials General introduction to Environmental risk, Toxicology of nanomaterials. Developing Environmental Regulations Pertinent to Nanotechnology, Analyses of Nanoparticles in the Environment, Ecological hazards of nanomaterials. Assessing nanotechnology health risk, treatment of nanoparticles in waste water, nanoparticles in pollution control, Development of sustainable nanotechnology. Toxicology and risk assessment, determination of potential toxicity, nanoparticles in work place, biodistribution and interaction of nanoparticles, nanoparticle dose in humans- issues and challenges.		**7,8**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **1. Continuous Internal Assessment (CIA)** ***Internal Test*** ***Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature **2. Seminar Presentation** – A topic needs to be presented and discussed with the class **3. Semester End Examination**

Reference:

1. H. S. Nalwa (Ed.), "Encyclopedia of Nanoscience & Nanotechnology", American Scientific Publishers, California, 2004

2. M. D. Ventra, S. Evoy and J. R. Heflin, “Introduction to Nanoscale Science and Technology”, Kluwer Academic Publishers, 2004.

3. Anke Krueger, Carbon Materials and Nanotechnology, Wiley-VCH Verlag GmbH & Co. KgaA, 2010.
4. B.P.S. Chauhan (Ed), Hybrid Nanomaterials: Synthesis, Characterization, and Applications,Wiley-VCH Verlag GmbH, 2011.
5. Cao, G., Nanostructures and Nanomaterials Synthesis, Properties, and Applications, Imperial College Press, 2004
6. M. A. Ratner and D. Ratner, “Nanotechnology: A Gentle Introduction to the Next Big Idea”, Prentice Hall, 2002.
7. M. D. Ventra, S. Evoy and J. R. Heflin, “Introduction to Nanoscale Science and Technology”, Kluwer Academic Publishers, 2004.

	MAHATMA GANDHI UNIVERSITY
	Advanced Thermodynamics
School Name	**School of Energy Materials**
Programme	**M.Sc. Material Science (Specialization in Energy Science)**
Course Name	**Advanced Thermodynamics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C84**

Course Summary & Justification	This course aims to provide a good platform to students to understand, model and appreciate concept of dynamics involved in thermal energy transformation. To prepare them to carry out experimental investigation and analysis at later stages of graduation.					
Semester	**I**					
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 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 *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	To apply the knowledge of mathematics, science and engineering fundamentals to model the energy conversion phenomenon.	U	2
2	To identify and formulate power production based on the fundamentals laws of thermal engineering.	U,An	2,6
3	To instill upon to envisage appropriate experiments related to heat engines.	A,An	2,6
4	To investigate the effectiveness of energy conversion process in mechanical power generation for the benefit of mankind.	U	2,6
5	To appreciate concepts learnt in fundamentals laws of thermodynamics from which learning ideas how to sustain in energy crisis and think beyond curriculum in the field of alternative and renewable sources of energy.	U, I, S	1,3,7
6	To communicate effectively the concepts of internal combustion engines and try to think beyond curriculum in alternative sources of energy.	An, C	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	**Classical Thermodynamics** Mathematical foundations for thermodynamics-variables of thermodynamics, extensive and intensive quantities, equation for total differential, conversion formulas, exact differentials, general formulation, reciprocity characteristics, homogeneous functions, Euler's theorem. Concepts of entropy and free energy: Entropy as measure of randomness and unavailable energy. Entropy changes in reversible and irreversible process and during various processes. Clausius inequality. Variation of entropy with T and P. Helmholtz and Gibbs free energies.	**15 Hrs.**	**1**

Module 2	Thermodynamic criteria of equilibrium and spontaneity. Variation of free energy with temperature and pressure. Maxwell's relations, Von't Hoff's reaction isotherm and isochore, Gibbs-Helmholtz equation. Determination of free energy changes. Nernst heat theorem and third law of thermodynamics- calculation of absolute entropies and residual entropy. Partial molar Properties: Physical significance, Partial molar volume and partial molar free energy (chemical potential). Determination of partial molar quantities by intercept method and slope methods. Physical significance of chemical potential. Variation of chemical potential with temperature and pressure. Formulation of the Gibbs Duhem equation. Derivation of DuhemMargules equation.	**15 Hrs.**	**2,3**
Module 3	**Statistical Mechanics** Brief history about the macroscopic and microscopic approach in science, permutation, probability, Stirling's approximation, macrostate and microstates, equal a priori principle and thermodynamic probability, thermodynamic probability and entropy, phase-space, ensemble, types of ensembles. Boltzmann distribution law, partition function and its physical significance, relation between molecular partition function and molar partition function, distinguishable and indistinguishable particles, partition function and thermodynamic functions, separation of partition function- translational, rotational, vibrational, and electronic partition functions, partition function for hydrogen. Thermal de-Broglie wavelength.	**15 Hrs.**	**3,4**

Module 4	Calculation of thermodynamic functions and equilibrium constants, Sackur-Tetrode equation, statistical formulation of third law of thermodynamics, residual entropy, heat capacity of gases - classical and quantum theories. Heat capacity of solids: the vibrational properties of solids, Dulong and Petit's law, Einstein's theory and its limitations, Debye theory and its limitations. Need for quantum statistics, Bosons and Fermions, Bose-Einstein statistics: Bose-Einstein distribution law, Bose-Einstein condensation, first order and higher order phase transitions, liquid helium, Fermi-Dirac statistics: Fermi-Dirac distribution law, application in electron gas, thermionic emission. Comparison of three statistic	**15 Hrs.**	**4,6**

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

	MAHATMA GANDHI UNIVERSITY
	LAB I- SYNTHESIS AND CHARACTERIZATION OF ADVANCED MATERIALS

School Name	School of Energy Materials		
Programme	M.Sc. Material Science (Specialization in Energy Science)		
Course Name	**LAB I- 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. 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 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** *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)*	
Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar Assignments Semester End examination

	MAHATMA GANDHI UNIVERSITY
	Internship/ Miniproject

School Name	**School of Energy Materials**
Programme	**M. Sc. Material Science (Specialization in Energy Science)**
Course Name	**Internship/ Miniproject**
Type of Course	**Core**
Course Code	EMM23C85

Course Summary & Justification	The candidate shall do 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	**I**		**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-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.						

ELECTIVE COURSES:

	MAHATMA GANDHI UNIVERSITY
	Basics of Energy Science
School Name	**School of Energy Materials**
Programme	**M.Sc. Material Science (Specialization in Energy Science)**
Course Name	**Basics of Energy Science**
Type of Course	**Elective**
Credit Value	**3**
Course Code	**EMM23E51**

Course Summary & Justification	This course looks at physics within the nucleus, exploring the consequences of quantum physics at the high energies, and short distances, explored by nuclear physics.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning 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 *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Understanding the different types of nuclear energy.	U, E	1,2
2	Understand the impact of radiation damages.	U,An	2,3,6
3	Illustrate different nuclear fuels.	A,An	2,4, 6
4	General ideas about future nuclear reactors.	U,I, S	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	**Basics of Solar Energy** Energy and development, Units and measurements, Solar spectrum – Electromagnetic spectrum. Energy balance of the earth, solar constant for earth, specialty and potential – Sun – Earth – Solar Radiation, beam and diffuse – measurement – estimation of average solar radiation on horizontal and tilted surfaces – problems – applications. Measurement of solar radiation – Pyranometer, Pyrheliometer, Sunshine recorder. Solar time - Local apparent time (LAT), equation of time (E), Solar radiation geometry - Earth-Sun angles – Solar angles. Calculation of angle of incidence - Surface facing due south, horizontal, inclined surface and vertical surface. Solar day length – Sun path diagram – Shadow determination. Estimation of Sunshine hours at different places in India. Calculation of total solar radiation on horizontal and tilted surfaces. Prediction of solar radiation availability, Capturing solar radiation – physical principles of collection – types – liquid flat plate collectors – construction details – performance analysis – concentrating collection – flat plate collectors with plane reflectors – cylindrical parabolic collectors – Orientation and tracking.	**15 Hrs.**	**1**

Module 2	**Basics of Energy Conversion** Energy Conversion routes, Direct and Indirect way of Energy Conversion, Principles of heat and mass transfer, Thermodynamics, Fluid statics and dynamics, Electricity generation and distribution	**15 Hrs.**	**2**
Module 3	**Energy Conversion** Introduction to Energy conservation, Approach and modem techniques, Benefits, Trend, Energy conservation technology (Thermal Energy), Energy conservation in Energy Intensive Industries, collection, Limitation and heat and its potential applications, Waste heat survey and measurements Data collection, Limitation and heat affecting factors Heat recovery equipment and systems, Heat Exchangers, Incinerators Regenerators and Recuperates. Need and importance of Energy storage in conventional and non-conventional Energy systems. Technical aspects (Measurements, Quantify), Various forms of Energy storage: thermal, chemical Mechanical, Electrical and Nuclear	**15 Hrs.**	**3**
Module 4	**Energy Demand and Utilization** Introduction and Historical Demand, Understanding Current Demand, Energy Markets, Energy and the rebound Effect, Residential Energy, Commercial Energy, Transportation **Energy and Environment** Impact of Energy on Environment, Flow of Energy in Ecological system, Environment Degradation due to Energy, Control of pollution from Energy.	**15 Hrs.**	**4**

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

Textbooks:

1. The Science of Energy, Roger G Newton, World Scientific.
2. Energy Recourses and Systems (Volume 1), Tushar Ghosh, Mark Prelas, Springer.
3. Energy Technology, O. P. Gupta, Khanna Publishing

	MAHATMA GANDHI UNIVERSITY
	ENERGY POLICIES AND MANAGEMENT
School Name	**School of Energy Materials (SEM)**
Programme	**MSc. Material Science (Specialization in Energy Science)**
Course Name	**ENERGY POLICIES AND MANAGEMENT**
Course Credit	**3**
Type of Course	**Elective**
Course Code	**EMM23E52**

Course Summary & Justification	This course provides an advanced introduction to the design and delivery of energy policy at various levels. Energy presents theoretical and practical challenges across many disciplines and professions, especially in the context of economic development and environmental sustainability at scales ranging from local to global. This course is intended to provide a broad overview of the institutions, legal frameworks, technologies, and markets involved in energy policy by exploring theories and case studies across these topics, with an emphasis on the energy transition necessitated by climate change.					
Semester	**1**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		30	30	0	30	90
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	To facilitate the students to achieve a clear conceptual understanding of technical and commercial aspects of energy conservation	U, R	1,2
2	Conceptual knowledge of the technology, economics and regulation related issues associated with energy conservation and energy auditing	U, C	2,4
3	Performance analysis of energy conservation opportunities.	U, I	2,3
4	A foundation for students who want to take additional courses on energy law, markets, technology, or policy.	A, S	3,6
5	Ability to analyse the viability of energy conservation projects	U, R	3,7

6	Analysis of economics of energy conservation opportunities in electrical and thermal utilities and reporting of energy audit	E, S	4,7
7	Advocacy of strategic and policy recommendations on energy conservation	An, I	6,8
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	**Basic principles of energy audit** Energy audit – Definition, concept, type of audit, energy index, cost index, pie charts, Sankey diagrams, load profiles, Energy conservation schemes – Energy audit of industries – Energy saving potential, energy audit of process industry, thermal power station and Building.	**10**	**1,2**
2	**Energy management** Principles of energy management -Organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting – Energy manager, Qualities and functions, Language, Questionnaire – Check list for top management.	**8**	**3,4**
3	**Economic aspects and analysis** Economic analysis – Depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, life cycle costing analysis - Energy efficient motors - Calculation of simple payback method, net present worth method- Power factor correction, lighting – Applications of life cycle cost analysis - Return on investment.	**10**	**5,7**
4	**Energy Policy Planning and Implementation Key Elements**: Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and Formulation. Format and Ratification, Organizing: Location of Energy Manager, Top Management Support, Managerial functions, Role and responsibilities of Energy Manager, Accountability. Motivating– Motivation of employees, Requirements for Energy Action Planning.	**10**	**5,6**

	Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning.		
5	**Energy Balance & MIS** First law of efficiency and Second law of efficiency, Facility as an Energy system, Methods for preparing process flow, Materials and Energy Balance diagram, Identification of losses, Improvements. Energy Balance sheet and Management Information System (MIS), Energy Modelling and Optimization. Instruments for Audit and Monitoring Energy and Energy Savings, Types of instruments and Accuracy	**12**	**6**

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

REFERENCES:

1. Energy Management by W.R.Murphy, G.Mckay. Butterworths.

2. Energy Management Principles by C.B.Smith, Pergamon Press.

3. Capehart B.L., Turner W.C., Kennedy W.J. (2011). Guide to Energy Management (7th Edition). Fairmont Press. ISBN: 1439883483.

4. Patrick D.R., Fardo S.W., Richardson R.E., Fardo B.W. (2014). Energy Conservation Guidebook (3rd Edition). Fairmont Press. ISBN: 1482255693.

	MAHATMA GANDHI UNIVERSITY
	Thin Film Science and Technology
School Name	**School of Energy Materials**
Programme	**MSc. Material Science (Specialization in Energy Science)**
Course Name	**Thin Film Science and Technology**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**EMM23E23**

Course Summary & Justification	To impart the modern ideas of thin film technologies used in various solid state physics and day today applications.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	20	0	30	80
Pre-requisite	Basic knowledge in vacuum science and electrical properties.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	To familiarise with the vacuum science and different thin film deposition methods.	U,R	1,2
2	To understand the nuclear theories of thin film formation.	U	2
3	To familiarise with the measurements techniques of the properties of thin films.	An,E	2,9
4	Awareness and knowledge of various applications of thin films in semiconductor devices and in day today life.	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.
Module 1	**Vacuum Technology**: High vacuum production: Mechanical pumps - Diffusion pumps-Cryogenic pumps - Getter pumps - ion pumps- basics of ultra-high vacuum Measurement of Vacuum: McLeod gauge - Thermal conductivity gauges - Cold cathode and hot cathode ionisation gauges Designing Vacuum system- vacuum leak detection: helium leak detector, residual gas analyzer.	**10 Hrs.**	**1**
Module 2	**Thin film growth techniques**: Physical Vapour Deposition: Vacuum evaporation – Evaporation theory - Rate of evaporation - Hertz-Kundsen equation - Free evaporation and effusion – Evaporation mechanisms - Directionality of evaporating molecules - vapour sources - wire and metal foils - Electron beam gun-sputtering - Glow discharge sputtering - Bias sputtering - Reactive sputtering - Magnetron sputtering - Ion beam sputtering - PLD- epitaxial films- MBE Chemical Vapour deposition: conventional CVD, Plasma enhance CVD, MOCVD, Atomic layer Deposition Film thickness measurements: Optical methods - basics of multilayer modelling- Ellipsometry -Other techniques: Electrical - Mechanical - Micro-balance - Quarts crystal monitor - X ray reflectivity.	**10 Hrs.**	**1,2**
Module 3	**Nucleation Theories**: Condensation process - Theories of Nucleation - Capillarity theory - Atomistic theory - Comparison - stages of film growth - Incorporation of defects during growth. Optical properties: Reflection and transmission at an interface - Reflection and transmission by a single film - Optical constants - Refractive index measurement techniques- Reflectivity variation with thickness Patterned films: lithography techniques - film etching methods.	**10 Hrs.**	**3**
Module 4	**Electrical Properties**: Electrical Properties: Sources of resistivity - sheet resistance – electron mobility- Hall Effect -TCR - Influence of thickness on resistance - Theories of size effect – Theories of conduction in discontinuous films - Electronic conduction in thin insulating films- MIS structure -Dielectric properties - D.C. conduction mechanisms - High and low field conduction - Temperature dependence - space charge limited conduction - A.C. conduction mechanisms Application of thin films: electrodes, transparent conducting oxides, thin film devices: LED, TFT, - Solar cells – optical and decorative coatings - dichroic coatings- biomedical coatings - tribological coatings.	**10 Hrs.**	**4**

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

Reference

1. Hand Book of Thin Film Technology, Maissel and Glang, McGraw Hill Higher Education (1970)
2. Materials science of thin films deposition and structures, Milton Ohring, Academic press, 2006.
3. Vacuum deposition of thin films, L. Holland, Chapman and Hall.4. Glow discharge processes, B. Chapman, Wiley, New York.
5. Physics of Non-Metallic Thin Films, Dupy and Kachard, Plenum Press (1976).
6. Scientific Foundations of Vacuum Technology, S. Dushman and J.M. Lafferty, John Wiley & Sons, Inc.; 2nd Ed. (1962).
7. Thin Film Phenomena, K.L. Choppra, McGraw-Hill Inc., US (1969.
8. O. S. Heavens, Optical Properties of Thin Films, by, Dover Publications, Newyork 1991
9. Donald L. Smith `Thin Film deposition principle and Practice's, McGraw Hill international Edition, 1995.
10. Various web resources and research papers.

	MAHATMA GANDHI UNIVERSITY					
	Bio Energy Technology					
School Name	**School of Energy Materials (SEM)**					
Programme	**MSc. Material Science (Specialization in Energy Science)**					
Course Name	**Bio Energy Technology**					
Course Credit	**2**					
Type of Course	**ELECTIVE**					
Course Code	**EMM23E24**					
Course Summary & Justification	This course aims to develop researchers who can provide fundamental inputs required to meet the challenges of a sustainable energy future. 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	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning	30	30	0	30	90

	Case based learning					
Pre-requisite	Basics of Energy: Energy and development, Units and measurements, Solar spectrum, Electromagnetic spectrum.					

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.	7,8,10
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**: Biomass- types, advantages and drawbacks, Indian scenario, characteristics, carbon neutrality, conversion mechanisms, fuel assessment studies	**8**	**1,2**
2	**Bio methanation**: 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.	**8**	**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	**8**	**4,5**

	Briquetting, merits and demerits, feed requirements and pre-processing, advantages, drawbacks.		
4	**Gasification**: Types, comparison, application, performance evaluation, economics, dual fuel engines, 100 % Gas Engines, engine characteristics on gas mode, gas cooling and cleaning train.	**8**	**6**
5	**Pyrolysis and Carbonization**: Types, process governing parameters, thermo gravimetric analysis, differential thermal analysis, differential scanning calorimetry, Typical yield rates.	**8**	**5,6**

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

MAHATMA GANDHI UNIVERSITY

Polymer Chemistry

School Name	**School of Energy Materials**
Programme	**M.Sc. Material Science (Specialization in Energy Science)**
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..	30	30	0	30	90
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. 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. 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**

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

MAHATMA GANDHI UNIVERSITY

Machine Learning for Energy Science

School Name	School of Energy Materials					
Programme	M.Sc. Material Science (Specialization in Energy science)					
Course Name	**Machine Learning for Energy Science**					
Type of Course	Core					
Course Code	**EMM23E53**					
Course Summary & Justification	With the increase of human society and its vital need for energy, energy systems play an important and decisive role in various sectors such as; residential, industry, and transportation. To accelerate the process and improve the methods of responding to this problem, the use of models and algorithms based on artificial intelligence has become common and mandatory. This course aims to provides basic understanding of machine learning and Artificial Intelligence, prospect of machine learning for energy efficiency and sustainability and Software knowledge on energy management					
Semester	1		**Credit**		2	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning	30	30	-	30	90

	Case based learning					
Pre-requisite	Basic computer knowledge, data analysis and fundamental knowledge in Energy parameters.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to**;***	**Learning Domains**	**PSO No.**
1	Understanding the fundamentals of machine learning and AI.	U, A	6,8
2	Familiarity with various methods of machine learning	U, A	2
3	Energy efficiency and Smart grid management by machine learning	U, A	2,7
4	Understanding of the renewable energy forecasting by machine learning	S, An, E	1,2,4
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	Background and theory of AI, machine learning for energy applications, available tools for AI applications in the energy sector, fundamental concepts of inference and prediction, opportunity and limitations of machine learning, Motivation and methods for inferential machine leaning methods, Dimensionality Reduction and Clustering, predictive machine learning methods, k Nearest Neighbors, Prediction: Tree-based Regression, ensemble methods, neural network.	15	1

2	Renewable Energy Forecasting, prediction model, statistical model, AI based model, hybrid model, prediction of solar irradiance, prediction of wind energy and hydro energy.	20	2
3	Machine learning for smart grid, Introduction to smart grid, Smart Grid–Need, Definitions, Concept, Functions & Barriers. Present development & International scenario in Smart Grid. Smart Grid – System architecture and Stakeholders. Communication Technologies for Smart Grid, Interoperability, Protocols, Standards for Information Exchange. Information Security in smart grid, Cyber Security standards. Smart grid management by machine learning, Future energy systems and software.	10	3
4	Case study or group project.	15	4

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 4. Continuous Internal Assessment (CIA) 5. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 6. Assignments 2. Semester End examination

References

1. Machine Learning for Energy Systems; ISBN 978-3-03943-382-7 (Hbk); ISBN 978-3-03943-383-4 (PDF);Denis N. Sidorov (Ed.) https://www.mdpi.com/books/pdfview/book/3201

2. Internet of Energy for Smart Cities; Machine Learning Models and Techniques; Edited By Anish Jindal, Neeraj Kumar, Gagangeet Singh Aujla; ISBN 9780367497750; July 20, 2021 Forthcoming by CRC Press; 322 Pages 112 B/W Illustrations

SEMESTER II

	MAHATMA GANDHI UNIVERSITY
	Optical and Magnetic Properties of Materials
School Name	**School of Energy Materials**
Programme	**M. Sc. Material Science (Specialization in Energy Science)**
Course Name	**Optical and Magnetic Properties of Materials**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C86**

Course Summary & Justification	The course aims to provide in-depth knowledge of physical properties of the solids and helps in developing creative skills among students by understanding the principles of lasers and applications. Topics include electronic and optical properties of solids, revising the basic principles of lasers, high power pulsed lasers like Q-switched nanosecond lasers and amplifiers. Also it elaborates the nonlinearity in materials					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	0	40	120
Pre-requisite	Fundamental knowledge in solid state laser and non-linear optics.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

CO No	Expected Course Outcome	Learning Domains	PSO No
1	Upon completion of this course, students will be able to; In-depth knowledge of physical properties of the solids	U, A	2,7
2	Fundamentals of lasers and illustrate pulse shortening mechanisms and chirped pulse amplification	An, E	2,9
3	To explain different types of interactions in a magnetic solid and ordered magnetic structures.	U, A, An	2,6, 9
4	Elaborate high power laser interaction with material and nonlinearity in 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.
Module 1	The Basics of Electrons in Solids: The electron; Problems with classical description; Wave-particle duality; De Broglie theorem; Bohr model for hydrogen; Born postulate; Schrödinger's equation; Solving the wave equation; Particle in a 1-D box & quantum tunneling; Electrons in a periodic potential; Bloch waves; Energy (E) versus wavevector (k) dispersion plots.	**15**	**1**
Module 2	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, Superconductivity- Meissner effect, brief discussion of Cooper theory of superconductivity; Low temperature and high temperature superconductivity	**15**	**1**

Module 4	Optical properties - photo conductivity, luminescence, colour centers, refraction & birefringence; Magnetic properties - diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism & ferrimagnetism; Thermal properties - thermal conductivity & specific heat Solid state reactions: Brief introduction.	**15**	**2**
Module 4	Basics of lasers (Population Inversion - Stimulated emission - Einstein Coefficients), Pulsed high power lasers, Q switching, Mode locking, Methods of producing mode locking, Pulse shortening by self-phase modulation, Group velocity dispersion, gratings or prisms.	**15**	**3**
Module 5	Nonlinear Optics, Nonlinear Wave equation, Optical rectification, Harmonic Generation, Phase matching, Third Harmonic generation, Parametric oscillator, B integral - self focusing, Two photon absorption.	**15**	**4**

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

References

1. Introduction to Atomic Spectra, H. E. White, McGraw-Hill Inc., US (1934).
2. Laser fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
3. Lasers Theory and Applications, 2nd Ed., K. Thayagarajan and A.K Ghatak, Springer (2011).
4. O. S. Heavens, Optical Properties of Thin Films, by, Dover Publications, Newyork 1991

5. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
6. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley-Blackwell (2010).
7. Solid State Physics by N W Ashcroft and N D Mermin
8. Magnetism in Condensed Matter by S. Blundell
9. Introduction to Magnetic Materials by B. D. Cullity

	MAHATMA GANDHI UNIVERSITY
	Synthesis and Applications of Nanocomposites
School Name	**School of Energy Materials**
Programme	**M. Sc Material Science (Specialization in Energy Science)**
Course Name	**Synthesis and Applications of Nanocomposites**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C87**

Course Summary & Justification	This course aims to impart basic knowledge on different polymerization process and techniques. To introduce the basic concepts on glass transition temperature, various measuring techniques, factors affecting glass transition temperature. To familiarize the molecular weight of polymers and specialty polymers. To give the concept of conducting polymers, discovery and its classification. Understanding the concept of polymer nanocomposites, different types of nanofillers, nanocomposites, and also the synthesis of nanocomposites and other metal matrix composites. The course deals with the study of the basic nature of different polymers and polymer composites and the manufacturing processes associated thereof. The classification of engineering materials and processing techniques, the structure and mechanical properties of plastics, thermoplastics and thermosets, the various processing techniques of polymers such as Extrusion, Injection molding, Thermoforming, Compression molding and Transfer molding have been explained with the relevant and specific examples. The fundamental concept and classification of composite materials, properties of composites and the primary as well as secondary processing methods of polymeric matrix composites have been explained in detail. The various issues, challenges and opportunities in primary and secondary processing of polymers and polymer composites has also been explained.					
Semester	**I**					
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.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Different kind of polymers and their properties.	U	2,7
2	Concept of Molecular Weight and distribution.	U, A, R	1,2,6,7
3	Variation of properties of polymer by crystallinity and glass transition temperature, process of polymer degradation.	U, R	1,2
4	Different techniques of polymerization of polymers.	U, R, A	2
5	Concept of conducting polymers	U, R, A	1,3,6
6	The student will able to understand various structure of polymers and their effect on different properties of polymers and polymer nanocomposite.	U, A, I	4
7	Will understand basic elements, operation and applications of various microscopy techniques such as SEM, TEM and XRD for analysis of surface and structure of plastic products.	U, R, S, I, An	2,4
8	Effect of variation in the quantities & type of curing agents, additives & curing condition on the properties of polymer composites	U, A, R, An	1,2,5
9	Upon completion of the course, the students will have the knowledge of formulation for manufacturing, properties and applications of variety of polymer composites	U, R, S, I, An, A	2,3
10	The candidate will get basic knowledge of the properties of polymer composites, the common application of such materials and the engineering principles including material selection, fundamental relations, analysis methods and manufacturing methods.	U, A, R, S, I, An C	1,2,3
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	**Basic Aspects** Classification, Some basic definitions, Addition and condensation polymerizations, and copolymerization, Mechanism of free radical, cationic and anionic polymerizations, Nomenclature, Tacticity, Glassy solids: Glass transition and melting temperatures and their determination by DSC - Factors affecting Tg, importance of Tg, relationship between Tm and Tg and their control - Crystallinity in polymers: Degree of crystallinity, factors affecting crystallinity of polymers, effect of crystallinity on the properties of polymers. Polymerization Techniques: Bulk, Solution, Suspension and Emulsion polymerizations- Polymerization using metal catalysts and surfactants.	**10 Hrs.**	**1, 6**
Module 2	**Molecular weight of polymers** Number average, weight average and viscosity average molecular weights of polymers - Determination of molecular weight of polymers by GPC and viscometry methods. Specialty polymers:Bio-polymers, Bio-degradable polymers, Fire retardant / Thermally stable polymers, Polymer electrolytes, Liquid armor polymers and Liquid crystalline polymers.	**13 Hrs.**	**2, 6**

Module 3	**Conducting Polymers** Discovery, Structural characteristics and doping concept, Charge carriers and conducting mechanism, Classification of conducting polymers: Intrinsic and extrinsic conducting polymers, Chemical and electrochemical methods of the synthesis of conducting polymers, Applications of conducting polymers in corrosion protection, sensors, electronic and electrochemical energy devices.	**12 Hrs.**	**5,6**
Module 4	**Polymer Nanocomposites** Definition of nanocomposites, Nanofillers, Classification of nanofillers, Synthesis and properties of nanofillers, Types of nanocomposites, Synthesis of nanocomposites: Direct mixing, solution mixing, In-situ polymerization, Polymer/ Metal oxide nanocomposites, diblockcopolymer-basednanocomposites, Polymer/CNTs and Polymer/Nanoclay based composites and their properties and functional applications.	**15 Hrs.**	**6, 7, 8, 9, 10**
Module 5	**Other Kinds of Nanocomposites** Fractal based Glass, metal nanocomposites, Core-shell structured nanocomposites, Super hard nanocomposites, Self-cleaning nanocomposites, Metal matrix nanocomposites: Metal with nanoceramic fillers such as SiC, CeO2, TiO2, ZrO2 PTFE, CNTs and their mechanical, corrosion resistance properties and functional applications.	**10 Hrs.**	**1, 6, 9, 10**

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

REFERENCES

1. Alfred Ruiden, Elements of Polymer Science and Engineering, Elsevier Science, 1998.
2. Bill Meyer, A Text Book of Polymer Chemistry, John Wiley & Sons, Singapore, 1994.
3. Gowariker and Viswanathan, Polymer Science, Wiley Eastern, 1986.
4. Nanostructured Conductive Polymers, Editor. Ali Eftekhari, Wiley, 2010.
5. Nanocomposites - Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun, WileyVCH, 2004.
6. GeorgeOdian, Principles of Polymerization, John Wiley & Sons, 1933
7. Conducting polymers with micro or nano meter structure, Meixiang Wan, Springer, 2008.
8. Polymer-Clay Nanocomposites, T.J. Pinnayain, G.W.Beall, Wiley, New York, 2001.
9. Composite Materials, Deborah D.L.Chung, Springer, 2002.

	MAHATMA GANDHI UNIVERSITY					
	Advanced Functional Materials					
School Name	**School of Energy Materials**					
Programme	**M.Sc. Material Science (Specialization in Energy Science)**					
Course Name	**Advanced Functional Materials**					
Course Credit	**3**					
Type of Course	**CORE**					
Course Code	**EMM23C88**					
Course Summary & Justification	The course provides a fundamental understanding of the physical principles responsible for the properties of important functional materials, with emphasis on the design of material properties emerging and potential applications and sustainability. The advanced chemical and physical aspects of modern materials and the transfer of skills in synthesis, development, analysis and manufacturing of functional materials are the key issues of the course Advanced Functional Materials. The research oriented extension and intensification of knowledge is based on advanced practical training in actual research fields in a modern laboratory environment. This course is designed as an interdisciplinary course that includes fundamental as well as in-depth knowledge of the advanced functional materials. The syllabus has been designed to cover the fundamental understanding of different functional materials with special emphasis on fullerenes, carbon nanotubes and graphene synthesis and related topics thereby enabling the students to work in frontier areas of novel materials.					
Semester	**2**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutoril	Practical	Othes	Total Learning Hours

		40	40	0	40	120
Pre-requisite	Basics of laws and principles of thermodynamics,entropy and energy changes of a system.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Demonstrate an understanding of the classical theories of electrical conduction and energy band/bandgap theory and be able to analyze the conduction property of complex materials	**U, I, A**	**1,2,4**
2	Apply the semiconducting mechanism to define intrinsic and extrinsic (p- and n-type) semiconductors, and critically evaluate doping effect and p-n junctions, demonstrate the ability to design common semiconductor devices, and microelectronic techniques.	**S, R**	**2,5,7**
3	Critically evaluate the newest development of nanomaterials and nanotechnology, demonstrates the ability to use this knowledge to design new nanostructures for required or special applications.	**U, I**	**3,8**
4	Create and design materials for environment cleaning and valuable materials recovery	**An**	**4,9**
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	Introduction: Definition of functional materials, Different kind of functional materials; Use of functionalities of materials in fabricating devices, Causes for observed functionality in a material; Functionality arising due to (i) electronic, (ii) spin, and (iii) ionic degrees of freedom; Exploitation of combined effects in designing new functional materials	**10**	**1**

2	Semiconducting Nanostructures**:** Metal oxide nanostructures: Background, Synthesis, Properties and Applications. Nano chalcogenides: Background, Synthesis, Properties and Applications, Organic Semiconductor Nanostructures: Background, Synthesis, Properties and Applications.	**10**	**2**
3	Carbon Nanomaterials**:** Introduction to Carbon allotropes and Carbon nanomaterials, Fullerenes: Structure of Higher Fullerenes, Growth Mechanisms; Production and Purification: Pyrolysis of Hydrocarbons, Partial Combustion of Hydrocarbons, Arc Discharge Methods, Resistive Heating, Rational Syntheses. Physical Properties, Spectroscopic Properties, Thermodynamic Properties. Chemical Properties: Hydrogenation, Halogenation, Nucleophilic Addition to Fullerenes, Applications.	**10**	**4**
4	Carbon nanotubes (CNT): The Structure of Carbon Nanotubes, Single Walled Carbon Nanotubes, Multiwalled Carbon Nanotubes. Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman Spectroscopy of CNTs. Purification and Functionalization of CNTs by Flame, CVD, Laser & Arc-discharge process, Fluidized bed reactor, Applications.	**8**	**3, 4**
5	Graphene: Structure of graphene, synthesis of graphene: Modified Hummer's method, electrochemical exfoliation and CVD method, Electronic Properties Band structure of Graphene -Mobility and Density of Carriers - Quantum Hall Effect -Spectroscopic Properties of graphene, Applications.	**8**	**4**

REFERENCE

1. Solid State Physics by N.W.Ashcroft and N.D. Mermin, Harcourt College Publishers
2. The Physics of Semiconductors: An Introduction Including Devices and Nanophysics by Marius Grundmann, Springer Berlin Heidelberg New York
3. Electronic Structure: Basic Theory and Practical Methods by R.M.Martin, Cambridge University Press
4. Encyclopaedia of Nanotechnology, M.Balakrishna rao and K.Krishna Reddy, Vol I to X Campus books (2006).

5. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology, T.Pradeep; TataMc.Graw Hill (2008).
6. Carbon Nanotubes: Properties and Application, Michael J. O'Connell, CRC Press (2018).
7. Nanotubes and Nanowires, CNR Rao and A Govindaraj, RCS Publishing (2005)
8. Carbon Nanotechnology: Recent Developments in Chemistry, Physics, Materials Science and Device Applications, Liming Dai, Elsevier Science (2006).
9. Carbon Materials and Nanotechnology, Anke Krueger, Wiley-VCH Verlag GmbH & Co. KGaA (2010).
10. Nanostructures and Nanomaterials Synthesis, Properties, and Applications, Cao, G, Imperial College Press (2004).
11. Handbook of Nanoscience, Engineering, and Technology, Goddard III W.A., et. al., Taylor & Francis Group (2007).
12. Hybrid Nanomaterials: Synthesis, Characterization, and Applications, B.P.S. Chauhan (Ed), Wiley-VCH Verlag GmbH (2011).

	MAHATMA GANDHI UNIVERSITY **POWER ELECTONICS AND APPLICATIONS**
SchoolName	**School of Energy Materials**
Programme	**M.Sc. Material Science (Specialization in Energy Science)**
Course Name	**POWER ELECTONICS AND APPLICATIONS**
Course Credit	**3**
Type of Course	**CORE**
Course Code	**EMM23C60**
Course Summary & Justification	The course focuses on presenting the fundamental concepts on conversion, control and monitoring of electric energy using power semiconductor devices. Methods for analyzing power electronic converters suitable for AC/DC, DC/DC and DC/AC electrical energy conversions are presented. This unit of study aims to

	provide the fundamentals of power electronics. It provides description of the operation principles and control of these blocks. Through analysis and design methodologies, it delivers an understanding of modern enabling technologies associated with energy conversion.					
Semester	**2**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutoril	Practical	Othes	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Basics of laws and principles of thermodynamics,entropy and energy changes of a system.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Compare the characteristics of power electronic devices	U, R	1,2
2	Describe the role of Power Electronics as an enabling technology in various applications such as flexible production systems and energy conservation.	U, A, C	2,4,6
3	Learn the basic concepts of operation of dc-ac converters	U, An	3,4
4	Understand, simulate and design single-phase and three-phase thyristor converters	A, S	3,6
5	Recognize the role power electronics play in the improvement of energy usage efficiency and the applications of power electronics in emerging areas.	U, R	3,5
6	Design and Analyze power converter circuits and learn to select suitable power electronic devices by assessing the requirements of application fields.	I, R	4,5

7	Learn the role of Power Electronics in utility-related applications which are becoming extremely important.	A, S	5,6
8	Design various application of power electronics for motor speed control in electric vehicles.	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	**Power Semiconductor Devices**: Introduction, Scope and Application- Construction and characteristics of Thyristors SCR, TRIAC, DIAC, SBS, UJT, MOSFET, IGBT, MCT and GTO, Comparison of Controllable switches.	**18**	**1,2**
2	**Phase Controlled Converters:** Principle of phase control, Full-wave controlled Converters. Single phase full wave converters, Single phase two pulse converters with discontinuous load and its performance, three phase thyristor converters: half wave, full and semi converters. Dual Converters. Effect of source impedance on performance of converter.	**15**	**2,3**
3	**DC to AC Converters** Introduction, Classification, single phase half and full bridge VSI, three phase VSI 120 and 180-degree conduction mode. Performance Parameters of Inverter, Voltage control of single phase and three phase Inverter, Series inverter, Parallel inverter, Current source inverter.	**12**	**3,4,6**
4	**AC Voltage Controllers:**	**15**	**5,7,8**

	Introduction, Principal of On-Off control and Phase Control, Single phase Bidirectional Controllers with R and R-L Loads, Three phase full wave controllers Cycloconverters- Single Phase and Three phase cycloconverters.		
5	**Application of Power Electronics:** UPS, Battery Charging, HVDC, DC, BLDC and PMS Motor Speed control, A.C. Drives-variable frequency drives. DC and AC Power supplies, Electric Vehicle.	**10**	**7,8**

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

REFERENCES

1. A Handbook of Nanotechnology, U. Kumar, AGROBIOS
2. Springer Handbook of Nanotechnology, B. Bhooshan, Springer
3. Advances in Nanomaterials, Zishan Husain Khan & M. Husain, Springer22
4. Recent Trends in Nanomaterials: Synthesis and Properties (Advanced Structured Materials), Zishan Husain Khan, Springer
5. Muhammad H. Rashid, “Power Electronics - circuits, devices and applications”, Prentice Hall of India, 2nd edition.
6. Power Electronics – Devices, Converters and Applications”, by Vedam Subramanyam Revised 2nd edition, New Age Publications.
7. Thyristorised controller by Dubey, Joshi & Doradla, New age Publication. 4. B. K. Bose, ‘Modern Power Electronics & AC Drives’, Prentice Hall India.
8. P. S. Bimbhra, "Power Electronics", Khanna Publishers, New Delhi.

	MAHATMA GANDHI UNIVERSITY
	LAB II - Energy conversion and Energy storage

School Name	School of Energy Materials					
Programme	M.Sc. Material Science (Specialization in Energy science)					
Course Name	**LAB II - Energy conversion and Energy storage**					
Type of Course	Core					
Course Code	**EMM23C89**					
Course Summary & Justification	The lab course will include detail on Energy conversion and Energy storage.					
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	Basic synthesis lab skills					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.

	*Upon completion of this course, students will be able to**;***		
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 energy storage application	U, A,R	2,7
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)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar Assignments Semester End examination

	MAHATMA GANDHI UNIVERSITY
	LAB III – Power Electronics and Applications

School Name	School of Energy Materials					
Programme	M.Sc. Material Science (Specialization in Energy science)					
Course Name	**LAB III – Power Electronics and Applications**					
Type of Course	Core					
Course Code	**EMM23C90**					
Course Summary & Justification	The lab course will include detail on Power Electronics and Applications**.**					
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	Basic synthesis lab skills					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

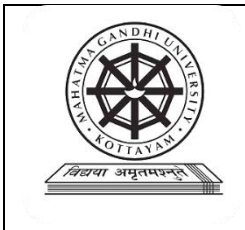
COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.

	*Upon completion of this course, students will be able to**;***		
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 energy storage application	U, A,R	2,7
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)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** Continuous Internal Assessment (CIA) Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar Assignments Semester End examination

ELECTIVES

<table>
<tr><td rowspan="2">  </td><td colspan="6">MAHATMA GANDHI UNIVERSITY</td></tr>
<tr><td colspan="6">ENERGY CONVERSION, STORAGE AND TRANSPORTATION</td></tr>
<tr><td>SchoolName</td><td colspan="6">School of Energy Materials</td></tr>
<tr><td>Programme</td><td colspan="6">M.Sc. Material Science (Specialization in Energy science)</td></tr>
<tr><td>Course Name</td><td colspan="6">ENERGY CONVERSION, STORAGE AND TRANSPORTATION</td></tr>
<tr><td>Course Credit</td><td colspan="6">3</td></tr>
<tr><td>Type of Course</td><td colspan="6">Elective</td></tr>
<tr><td>Course Code</td><td colspan="6">EMM23E26</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">Energy storage solutions are receiving high marks in the energy sector.

Energy storage is a useful tool to support grid electrical supply, transmission and distribution systems.

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.</td></tr>
<tr><td>Semester</td><td colspan="6">II</td></tr>
<tr><td rowspan="2">Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutoril</td><td>Practical</td><td>Othes</td><td>Total Learning Hours</td></tr>
<tr><td></td><td>40</td><td>40</td><td>0</td><td>40</td><td>120</td></tr>
<tr><td>Pre-requisite</td><td colspan="6">General Chemistry and Physics, Introductory Materials Science, Elementary Semiconductor Theory, Thermodynamics of Materials.</td></tr>
</table>

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** 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** 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** 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** 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** 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**

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

	MAHATMA GANDHI UNIVERSITY
	MEMS AND NANOFABRICATION
SchoolName	**School of Energy Materials**
Programme	**MSc. Material Science (Specialization in Energy Science)**
Course Name	**MEMS AND NANOFABRICATION**
Course Credit	**3**
Type of Course	**Elective**
Course Code	**EMM23E52**
Course Summary & Justification	This course is based on the manufacturing and characterization fundamentals of nano-scale materials for nano- and micro-electro-mechanical systems (N/MEMS). The students-who want to specialize on N/MEMS and CMOS devices and smart hybrid materials systems for nano and micro-electronics and nano-composites based structures-are targeted. There is a big demand from high-tech precision industry (medical and electronic) for the engineers having knowledge of fabrication and characterization of nano- and micro-systems.
Semester	**II**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	0	40	120
Pre-requisite	Basics concepts in Microsystems and Microelectronics.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understand the basic concept of nanoscience and nanotechnology.	U, R	1,2
2	Have a concept on the scope and recent development of the science and technology of micro- and nano-systems	U, A, C	2,4,6
3	Gain the physical knowledge underlying the operation principles and design of microand nano-systems.	U, An	3,4
4	to understand the operation of micro devices, micro systems and their applications	A, S	3,6
5	Gain a knowledge of basic approaches for various sensor design	U, R	3,5
6	Gain the technical knowledge required for computer-aided design, fabrication, analysis and characterization of nano-structured materials, micro- and nano-scale devices.	I, R	4,5
7	Select one or more suitable MEMS/NEMS integration and packaging approaches for a given application.	A, S	5,6
8	Exploring the fundamental working principle of bio-molecule sensing/sensors, and applying this knowledge to design solutions to probe biomedical and biology systems.	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	**Overview and working principles of MEMS** MEMS and Microsystems – Typical MEMS and Microsystems products – Microsystems and Microelectronics –Miniaturization – Applications of Microsystems –Microsensors, Micro actuators, Microgrippers, Micromotors, Microvalves, Micropumps and Micro accelerometers.	10	1,2
2	**Fabrication & microsystem design** Ions and Ionization – Doping – Scaling Laws for Electrical design – Substrate and wafers – Silicon as a substrate – Silicon compounds – Piezoresistors – Piezocrystals – Gallium Arsenide, Quartz -Polymers in MEMS –PMMA. Micro System Fabrication Processes – Photolithography, Ion Implantation, Diffusion, Oxidation, Chemical Vapour Deposition, Physical Vapour Deposition – Sputtering, Deposition by Epitaxy, Etching.	15	2,3
3	**Overview of Micromanufacturing** Bulk Micromanufacturing, Surface Micromachining and LIGA Process. Microsystem Design- Design Considerations – Use of CAD tool in Microsystem Design.	10	3,4,6
4	**Microsystem Packaging** General considerations in Packaging Design- Levels of Microsystem Packaging. Bonding Techniques for MEMS: Surface Bonding, Anodic bonding Wire Bonding. Overview of MEMS areas: RF MEMS, Bio- MEMS, MOEMS, NEMS.	10	5,7,8
5	**Introduction to Nanofabrication** Introduction to methods of fabrication of nano layers, different approaches, Fabrication of nano	15	6

	particle, Precipitation of quantum dots. Electron beam evaporation Sputtering, Cathodic Arc Deposition, Atomic Layer Deposition, Pulsed Laser Deposition, Molecular Beam Epitaxy, Lithography and their types, mechanical milling, Chemical Methods; Sol-Gel technique, self-assembly, colloidal method, hydro-thermal method, coprecipitation method, solid state synthesis, microwave method, micro-emulsion method.		

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

REFERENCE BOOKS:

1. "MEMS & Micro Systems Design and Manufacture" – Tai-Ran-Hsu, TMH, 2002 Edition.
2. Julian W Gardner, Microsensors: Principles and Applications- John Wiley & Sons, 1994
3. 2. Mark Madou, Fundamentals of Micro Fabrication, CRC Press, New York, 1997
4. 3. Stephen D Senturia, Microsystem design, Springer (India) ,2006
5. 4. Thomas B Jones, Electromechanics and MEMS, Cambridge University Press 2001
6. Chattopadhyay, Banerjee, Introduction to Nanoscience & Technology, PHI, 2012

7. George W. Hanson, Fundamentals of Nanoelectronics, Pearson Education, 2009.

	MAHATMA GANDHI UNIVERSITY
	SOLAR, PHOTOVOLTAIC TECHNOLOGY
School Name	**School of Energy Materials (SEM)**
Programme	**M. Sc. Material Science (Specialization in Energy Science)**
Course Name	**Solar, Photovoltaic Technology**
Course Credit	**2**
Type of Course	**ELECTIVE**
Course Code	**EMM23E54**
Course Summary & Justification	This course aims to develop researchers who can provide fundamental inputs required to meet the challenges of a sustainable energy future. This course is designed at providing students with concepts of photovoltaic (PV) systems Overview of PV usage in the world, basic structure and characteristics of solar cells, study about Solar Power Plant, its Components and Working and Types of Solar Power plant. The course also provide knowledge about solar power management This course offers an advanced knowledge within the field of photovoltaic system technology. By completing this course students can get a knowledge about the solar resource and how photovoltaic energy conversion is used to produce electric power. This course also provides fundamental starting point for the design and fabrication of different solar cell and module technologies, the various photovoltaic system components, how to design a photovoltaic cell etc.
Semester	2

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		30	30		30	90
Pre-requisite	Basics of Solar Energy: Energy and development, Units and measurements, Solar spectrum, Electromagnetic spectrum.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understanding the solar cell theory to improve and optimize its performance of solar cell device.	U, An	1,2
2	Identify the potential of energy harvesting systems.	U, I	2,4
3	To learn about fabrication of different types of solar cells.	U, C	2,3,5
4	Gain knowledge about photovoltaic technical parameters and emerging technologies.	A, S	3,6
5	Understand the components of solar powerplant and its working.	U, R	4,7
6	Deep understand in solar power management.	E, Ap.	7

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
1	**INTRODUCTION TO PHOTOVOLTAIC (PV) SYSTEMS**: Historical development of PV systems, Overview of PV usage in the world, Solar energy potential for PV, irradiance, solar radiation and spectrum of sun, geometric and	**10**	**1,2**

	atmospheric effects on sunlight, Photovoltaic effect, conversion of solar energy into electrical energy, behaviour of solar cells		
2	**SILICON WAFER BASED SOLAR CELL TECHNOLOGY** Photovoltaic Devices & Array and Modules, Technical Parameters: Solar cells, basic structure and characteristics: Single-crystalline, multicrystalline, Processes Used in Solar Cell Technologies-High Efficiency. Silicon Solar Cells-Passivated Emitter Solar Cells (PESC)-buried contact solar cells	**15**	**1,3**
3	**THIN FILM SOLAR CELL TECHNOLOGIES** Thin film deposition techniques-common features of thin film technologies Thin film silicon solar cells. Cadmium telluride solar cell technology-Perovskite solar cell technology-Emerging new technologies. silicon solar cell technologies.	**10**	**4,5**
4	**EMERGING SOLAR CELL TECHNOLOGIES** Need of emerging cell technologies-organic solar cells-dye sensitized solar cell (DSC) –GaAs solar cells- Thermo photovoltaic (TPV)-Crystalline Silicon Multifunction Solar Cells-Quantum Well Solar Cells-Hot Carrier Solar Cells	**15**	**6**
5	**BATTERIES AND CONVERTERS** Definition-types of batteries-parameters of batteries-batteries for photovoltaic systems -liquid vented and sealed- Types of Solar Power Plant: Off grid, Grid Connected, Hybrid, Interfacing PV modules to loads, direct connection of loads to PV modules, connection of PV modules to a battery and load together, DC-DC Converters, DC to AC converters (inverters)- PWM charge controller-maximum power point tracking (MPPT)	**10**	**5,6**

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

References

1. Chetan Singh Solanki, Solar Photovoltaic Technology And Systems

PHI Learning Private limited (2013)

3. Richard A.Dunlap, Sustainable energy, Cengage (2018)
4. Photovoltaics: Designs, Systems and Applications, Michael Stock, Larsen and Keller Education
5. Photovoltaics: Engineering and Technology for Solar Power, Catherine Waltz, Syrawood Publishing House

	MAHATMA GANDHI UNIVERSITY
	Nuclear Energy and Technology
School Name	**School of Energy Materials**
Programme	**M.Sc. Material Science (Specialization in Energy Science)**
Course Name	**Nuclear Energy and Technology**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**EMM23E29**

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 Collaborative learning 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 *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
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**
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**

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

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

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
		40	40	0	40	120
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, (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).	**10 Hrs.**	**1, 6**
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	**13 Hrs.**	**2, 6**

	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).		

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) 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 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.**	**5,6**
Module 4	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 and Environmental Benefit, Environmental Effects.	**15 Hrs.**	**6, 7,**

Module 5	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**

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

MAHATMA GANDHI UNIVERSITY

Advanced Computation in Materials Science

School Name	School of Energy Materials					
Programme	**M.Sc. Material Science (Specialization in Energy Science)**					
Course Name	**Advanced Computation in Materials Science**					
Type of Course	Core					
Course Code	EMM23C35					
Course Summary & Justification	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					
Semester	3		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based	40	40	-	40	120

	learning					
Pre-requisite	Basic knowledge in Numerical methods and algorithms.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *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

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

	MAHATMA GANDHI UNIVERSITY **Processing and designing of materials**
School Name	**School of Energy Materials**
Programme	**M.Sc. Material Science (Specialization in Energy Science)**
Course Name	**Processing and designing of materials**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C91**

Course Summary & Justification	This course focuses on the various processing techniques of metals, polymers and ceramics. The process parameters involved during processing and their influence on the final shape of the product is discussed. Design of tools and other accessories for manufacturing a healthy product is also included.					
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 on the manufacturing techniques of various materials					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	To impart knowledge about processing of polymers, ceramics and metals.	U,R	2,6,7
2	Understanding the rheology of polymer materials.	U	2
3	Identify and understand the various synthesis methods of ceramics.	U, An	2,6
4	Impart idea about metallic processing.	A, An	2,6
5	Will understand the basic concepts of material selection and design aspects.	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	**Introduction:** Materials processing science with special emphasis on processing of polymers, ceramics and metals.	**8 Hrs.**	**1**
Module 2	**Polymer processing:** Rheology of polymeric materials, Compounding of plastics, processing techniques: Compression, Transfer, injection, blow molding, Extrusion, Calendaring, Thermoforming, Rotational molding, Compounding and processing of rubber (both latex and dry rubber) with different formulations: Casting, rubber extrusion, Dip coating (gloves, balloons etc.), fibre spinning and manufacturing processes.	**15 Hrs.**	**2**

Module 3	**Ceramic processing:** Processing of traditional ceramics- spray granulation, Pressing, CIP, HIP, Slurry processing, Slip casting, Pressure casting, Tape casting, Gel casting, Injection molding, Extrusion; Rapid prototyping through Additive manufacturing, Electrophoretic deposition, Production of ceramic fibres, Electro-spinning; Drying, Binder burnout, Green machining, Sintering; Sol-gel processing, Thermal and plasma spraying, Thick and thin film coatings- PVD and CVD techniques; Vapor infiltration techniques.	**12 Hrs.**	**3**
Module 4	**Metallic processing:** Casting process- major casting techniques, Solidification and volume shrinkage, Casting design and defects, Fundamentals of deformation processing, Deformation work, Hot and cold working, Few forming processes and defects; Metal joining process- Concepts of Fusion and solid state welding processes, Brazing and soldering, Welding defects	**15 Hrs.**	**4**
Module 5	**Design aspects:** General principles of materials selection and design based on requirements of function, Property, Processability and cost; Quantitative methods of materials selection, Materials performance index; Design of engineering structures from the atomic- and nano-scales to macroscopic levels; Case studies- modern metallic, ceramic, polymeric and biomaterials devices and components	**10 Hrs.**	**5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative
Assessment Types	**Mode of Assessment** **1. Continuous Internal Assessment (CIA)** ***Internal Test*** ***Assignment*** – Every student needs to write an assignment on a given topic based on the available published literature **2. Seminar Presentation** – A topic needs to be presented and discussed with the class **3. Semester End Examination**

Reference Books:

1. P. Boch, J-C. Nièpce, *Ceramic Materials: Processes, Properties, and Applications*, Wiley-ISTE, 2007.
2. J-H. He, *Electrospun Nanofibres and Their Applications*, Smithers Rapra Technology, 2008.
3. Z. Tadmor, C.G. Gogos, *Principles of Polymer Processing*, 2nd ed., Wiley International, 2006.
4. T.A.Osswald, *Polymer Processing Fundamentals*, Hanser Publications, 1998.
5. M.N. Rahaman, *Ceramic Processing and Sintering*, 2nd ed.,, CRC press
6. F.C. Campbell, *Elements of Metallurgy and Engineering Alloys*, ASM International, 2008.
7. J. Beddoes, M.J. Bibby, *Principles of Metal Manufacturing Processes*, Elsevier, 2003.
8. G.E. Dieter, *Mechanical Metallurgy*, McGraw-Hill, 3rd ed., 1986.
9. E. Degarmo, J.T. Black and R.A. Kohser, *Materials and Processes in Manufacturing*, 9th ed., Wiley, 2002.
10. S. Kalpakjian, S.R. Schmid, *Manufacturing Engineering and Technology*, 6th ed., Pearson, 2009.

MAHATMA GANDHI UNIVERSITY

Advanced Solid State and Electrochemistry

School Name	School of Energy Materials					
Programme	M.Sc. Material Science (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 Collaborative learning 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 *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.	10	3

4	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.	15	2,3
5	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, Imperfections in solids - point, line and plane defects, non-stoichiometry.	10	3

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

	MAHATMA GANDHI UNIVERSITY
	LAB IV- Fabrication of Materials and Applications

School Name	School of Energy Materials
Programme	M.Sc. Material Science (Specialization in Energy Science)
Course Name	**LAB IV- Fabrication of Materials and Applications**
Type of Course	Core
Course Code	**EMM23C92**
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.

	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 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** *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
	Critically analyse how and why the nature of the chemical bonding in a material is influenced by the		2

2	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 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)

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

	MAHATMA GANDHI UNIVERSITY
	Internship/ Miniproject

School Name	**School of Energy Materials**					
Programme	**M. Sc. Material Science (Specialization in Energy Science)**					
Course Name	**Internship/ Miniproject**					
Type of Course	Core					
Course Code	**EMM23C93**					
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 Collaborative learning 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.						

Electives

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

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 Collaborative learning 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 *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. .	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.
Module 1	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**
Module 2	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 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)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 7. Continuous Internal Assessment (CIA) 8. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 9. Assignments 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).

	MAHATMA GANDHI UNIVERSITY					
	HYDROGEN AND FUEL CELLS					
School Name	**School of Energy Materials (SEM)**					
Programme	**MSc. Material Science (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** 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** Hydrogen – Physical and chemical properties - Salient characteristics - Production of hydrogen – Steam reforming – Water electrolysis – Gasification and	**8**	**3,4**

	woody biomass conversion – Biological hydrogen production – Photo dissociation – Direct thermal or catalytic splitting of water.		
3	**HYDROGEN STORAGE & TRANSPORT** 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** History – Principle - Working - Thermodynamics and kinetics of fuel cell process – Performance evaluation of fuel cell – Comparison on battery Vs fuel cell - Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – Relative merits and demerits.	**10**	**5,6**
5	**APPLICATION OF FUEL CELL** 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**

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

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

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

REFERENCES

01. Introduction to Materials Science and Engineering, William J Callister, John Wiley & Sons, Inc.
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.

MAHATMA GANDHI UNIVERSITY

RESEARCH METHODOLOGY

SchoolName	**School of Energy Science**
Programme	**MSc. Material Science (Specialization in Energy Science)**
Course Name	**RESEARCH METHODOLOGY**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**EMM23E34**

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 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. **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) **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**
Module 4	**Interpretation and report writing:** Meaning of Interpretation, Why Interpretation?	**15 Hrs**	**2,4,5**

	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.		

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **Continuous Internal Assessment (CIA)** Surprise test Internal Test – Objective and descriptive answer type Submitting assignments Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **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).
3. C.K Kothari. (2004), 2/e, Research Methodology- Methods and Techniques (New Age International, New Delhi).
4. B.L Garg,.,RKaradia., F Agarwal,. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
5. C.R Kothari., 1990. Research Methodology: Methods and Techniques. New Age International. 418p.
6. S.C Sinha. andA.K Dhiman,., 2002. Research Methodology, Ess Publications. V2.
7. W.M.K Trochim,., 2005. Research Methods: the concise knowledge base, Atomic Dog Publishing. 270p.
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.
10. Hering Lutz, Hering Heike, Springer, 2010How to write technical reports- Understandabble structure, Good Design, Convincing presentation –

	MAHATMA GANDHI UNIVERSITY
	NANOSENSORS AND NANODEVICES
School Name	**School of Energy Materials**
Programme	**MSc. Material Science (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
	Authentic learning Collaborative learning Independent learning	30	30	0	30	90
Pre-requisite	Basics of sensors and microelectronics.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the basics of a sensor.	U	1
2	Study the sensor characterization and modes of packaging.	U	1
3	Correlate and record data's of the medically significant measures using a biosensor	R	1
4	Apply the sensing of physical parameters sensed to fabricate appropriate sensors.	E	1
5	Understand the processing of input signals of sensors and applying it in electronics.	E	1
Remember(R),Understand(U),Apply(A),Analyse(An),Evaluate(E),Create(C),Skill(S),Interest (I)and Appreciation(Ap)			

COURSECONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	**Micro and nanosensors**: Fundamentals of sensors, biosensor, microfluids, MEMS and NEMS Packaging and characterization of sensors: Method of packaging at zero level, and first level. Active and Passive sensors – Static characteristic - Accuracy, offset and linearity – Dynamic characteristics – First and second order sensors–Physical effects involved in signal transduction.	**8 Hrs.**	**1**
Module 2	**Nano material based Sensors:** Nanomaterials in biochemical sensor design, application for nanoparticles based on gold and semiconductor materials (quantum dots). Synthesis of nanomaterials (nano rod, nanoclusters, nanodiamond and nano shells). Application of nanomaterial for analytical purpose, important functions of nanoparticles. Nanomaterials: Nanomaterial based colorimetric sensors, metallic nanoparticles in sensing, surface functionalization of gold nanoparticle, Fluorescence based sensoring, electrical and electrochemical sensing. Different type of sensors: Electrochemical,	**8 Hrs.**	**2**

	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:** 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.	**8 Hrs.**	**3**
Module 4	**Metal Insulators Quantum Structures and Devices:** Metal Insulator Semiconductor devices, molecular electronics, information storage, molecular switching, Schottky devices.	**8 Hrs.**	**4**
Module 5	**Quantum Structures and Devices:** Quantum layers, wells, dots and wires, Mesoscopic Devices, Nanoscale Transistors, Single Electron Transistors, MOSFET and Nano FET, Resonant Tunneling Devices, Carbon Nanotube based logic gates, optical devices. .Connection with quantum dots.	**8 Hrs.**	**5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contactclasses,Tutorials,Seminar,Assignments,Authenticlearning,Library work,independentstudies,Presentationby individual student
Assessment Types	**Mode of Assessment** **A.Continuous Internal Assessment (CIA)** o Surprise test o Internal Test–Objective and descriptive answer type o Submitting assignments o SeminarPresentation–selectatopicofchoiceintheconcernedareaandpres

	entintheseminar **B. Semester End examination**

REFERENCE BOOKS:

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, CRCPress.
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. Woodhead publishing.
7. Fundamentals of Nanoelectronics, George W.H, Pearson education india 2009.
8. Current at the Nanoscale, Colm Durkan, University of Cambridge, 2008.
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;NewYork, Chichester, 2002.
12. Biosensors: A Practical Approach, J.Cooper&C.Tass, Oxford UniversityPress,2004.
13. Nanomaterials for Biosensors,C S.Kumar,Wiley–VCH,2007.
14. Smart Biosensor Technology, G.K.Knoff, A.S.Bassi, CRCPress, 2006.

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

School Name	**School of Energy Materials**
Programme	MSc. Chemistry (Specialization in Energy Science)
Course Name	**Nanotechnology in Energy**
Type of Course	Elective
Course Code	**EMM23E36**
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. 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 Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite	Basics of Energy production, conversion and storage systems. (Graduate Level)					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *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 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 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 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 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 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**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.

Assessment Types	Mode of Assessment 7. Continuous Internal Assessment (CIA) 8. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 9. Assignments 6. Semester End examination

REFERENCES

1. Twidell. J. and Weir. T “Renewable Energy Resources”, E & F N Spon Ltd, 1986.
2. Martin A Green, “Solar cells: Operating principles, technology and system applications”, Prentice Hall Inc, Englewood Cliffs, 1981.
3. Moller. H J “Semiconductor for solar cells”, Artech House Inc, 1993. 4. Ben G Streetman, “Solid state electronic device”, Prentice Hall of India Pvt Ltd.,1995
4. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw- Hill, New York (1995).
5. Handbook of fuel cells: Fuel cell technology and applications by Vielstich. Wiley, CRC Press
6. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kulwer Acdemic Publishers, Dordrecht, Netherlands (2004).
7. J. Larmine and A, Dicks, Fuel Cell System Explained, John Wiley, New York (2000).
8. Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).
9. Hydrogen from Renewable Energy Sources by D. Infield 2004

	MAHATMA GANDHI UNIVERSITY
	Open Course

School Name	**School of Energy Materials**					
Programme	**M.Sc. Material Science (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 StudentLearningTime (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

	MAHATMA GANDHI UNIVERSITY
	Industrial visit

School Name	**School of Energy Materials**					
Programme	**M.Sc. Material Science (Specialization in Energy Science)**					
Course Name	**Industrial Visit**					
Course Credit	**3**					
Type of Course	**Core**					
Course Code	**EMM23C94**					
Course Summary & Justification	The Industrial visit shall be conducted by the School of Energy Materials. 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 StudentLearningTime (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)** 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.

	MAHATMA GANDHI UNIVERSITY
	Dissertation/Viva voce

School Name	**School of Energy Materials**					
Programme	**M. Sc. Material Science (Specialization in Energy Science)**					
Course Name	**Dissertation/Viva -voce**					
Type of Course	Core					
Course Code	**EMM23C95**					
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**		13	
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-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)			

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** 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** Evaluation of the presentation by both internal and external examiners.