School of Energy Materials
Mahatma Gandhi University
Priyadarshini Hills P.O., Kottayam-686560

CURRICULUM STRUCTURE AND SYLLABI BASED ON OUTCOME BASED EDUCATION

FOR

M.Tech Energy Science and Technology

UNDER THE CSS REGULATIONS 2020 OF MAHATMA GANDHI UNIVERSITY

PREFACE

I am happy to present the revised curricula and syllabi of the M.Tech. Energy Science and Technology programme of the School of Energy Materials according to the OBE concept (with effect from 2020 admission onwards) for favour of approval by the Faculty and Academic Council of the University.

We have restructured the curriculum as per the Outcome Based Education (OBE) system. OBE is an educational approach that bases each part of the educational system with respect to goals set by the students. OBE aims to equip the students (learners) with knowledge, competency orientations required for achieving their goals when they depart the institution. Further empowers students to choose what they would like to study and how they would like to study it. The teaching methodologies and the evaluation system are also modified in par with the outcome-based approach. The programme Specific Outcomes (PSOs) and the Course Outcomes (COs) are presented in the syllabus. The PSOs and the COs are well correlated in the syllabus of each course.

About Mahatma Gandhi University

Mahatma Gandhi University, one of the four affiliating Universities in Kerala, is the premier educational institution that strives to fulfil the higher educational needs of the people of Central Kerala. Set over the 100-acre Priyadarshini Hills Campus at Athirampuzha, 13 km off Kottayam, the University also has ten satellite campuses. The University was established on 2nd October 1983 and has jurisdiction over the revenue districts of Kottayam, Ernakulam, Idukki, and parts of Pathanamthitta and Alappuzha

Vision

"Mahatma Gandhi University envisions to excel in the field of higher education and cater to the scholastic and developmental needs of the individual, through continuous creation of critical knowledge base for the society's sustained and inclusive growth."

Mission

- To conduct and support undergraduate, postgraduate and research-level programmes of quality in different disciplines
- To foster teaching, research and extension activities for the creation of new knowledge for the development of society
- To help in the creation and development of manpower that would provide intellectual leadership to the community
- To provide skilled manpower to the professional, industrial and service sectors in the country so as to meet global demands

- To help promote the cultural heritage of the nation and preserve the environmental sustainability and quality of life
- To cater to the holistic development of the region through academic leadership

About School of Energy Materials

Energy efficiency and sustainability are two important factors that will decide the choice of the energy technology of the 21st century. The School of Energy Materials (SEM) department was established in 2019 at Mahatma Gandhi University, Kottayam Kerala, India. The department specifically focuses the in-depth knowledge in energy science and technology and carrying out cutting-edge research and development in a variety of sectors of energy science. The department also aims to focus on the enhancement of research and higher studies in the various areas of energy science and polymeric materials. The department deals with modern energy technologies and conversion strategies in various domains such as nano sensors, nanodevices, nanophononics, nuclear energy, photovoltaics, batteries, fuel cells, etc. In addition, (SEM) expertise in research fields including nanomaterials synthesis, nanocomposites, polymer blend nanocomposites, systems, and polymer nanocomposites for energy and electronic related applications. The School of Energy Materials offers an M.Tech course in Energy Science which is expected to meet the growing demand for young researchers in the area. The M.Tech course will equip students with the skills necessary to be successful in the area of sustainable energy technology.

Our Vision

To emerge as a department of excellence in energy science and to be instrumental in the material discovery and development cut across the entire energy technology portfolio, i.e. from energy generation and storage to delivery and end-use. SEM hopes to lay the foundation of every clean energy innovation: advanced batteries, solar cells, low-energy semiconductors, thermal storage, coatings, and catalysts for the energy conversion, capture, and use of carbon dioxide. The novel materials developed at the SEM can be counted as one of the cornerstones of the global transition to a low-carbon future.

Our Mission

Advanced materials are the key elements in the development of improved high-efficiency, low-cost, clean energy technologies. The department will be a platform for the publication of original articles and comprehensive reviews on all aspects of fundamental science and applied research on materials used for harvesting, conversion, storage, transmission, and utilization of energy.

- Promote and coordinate interdisciplinary research programs in the development of improved high-efficiency, low-cost, clean energy technologies.

- As a platform in the development of Energy science and Nanotechnology leading to the technological development and fabrication of nano-devices.

- To serve as a department of educational excellence for students and researchers by offering academic programs to generate intellectual manpower in specialized areas for societal needs.

- To initiate and establish strong collaborations with industries and R&D sectors of the country and abroad by providing consultancy services and research projects in Energy Science and Nanotechnology.

- The department will be a platform for the publication of original articles and comprehensive reviews on all aspects of fundamental science and applied research on materials used for harvesting, conversion, storage, transmission, and utilization of energy.
- To pave more attention to studies focused on Social, Ethical, Legal, and Environmental (SELE) issues related to Energy Science

Preamble

Outcome Based Education (OBE) w.e.f. the Academic Year 2020-22
School of Energy Materials, Mahatma Gandhi University

Introduction

A high priority task in the context of education in India is improvement of quality of higher education for equipping young people with skills relevant for global and national standards and enhancing the opportunities for social mobility. Mahatma Gandhi University has initiated an Outcome Based Education (OBE) for enhancing employability of graduates through curriculum reforms based on a learning outcomes-based curriculum framework, upgrading academic resources and learning environment. Learning outcomes specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study. The fundamental premise underlying the learning outcomes-based approach to curriculum development is that higher education qualifications are awarded on the basis of demonstrated achievement of outcomes, expressed in terms of knowledge, understanding, skills, attitudes and values. Outcomes provide the basis for an effective interaction among the various stakeholders. It is the results-oriented thinking and is the opposite of input-based education where the emphasis is on the educational process.

Outcome Based Education (OBE) process

OBE is a comprehensive approach to organise and operate a curriculum that is focused on and defined by the successful demonstrations of learning sought from each learner. The term clearly means focusing and organising everything in an education system around “what is essential for all learners to be able to do successfully at the end of their learning experiences”. OBE is an approach to education in which decisions about the curriculum and instruction are driven by the exit learning outcomes that the students should display at the end of a programme or a course. By the end of educational experience, each student should have achieved the outcomes.

Benefits of OBE

The OBE Framework is a paradigm shift from traditional education system into OBE system where there is greater focus on programme and course outcomes. It guarantees that curriculum, teaching and learning strategies and assessment tools are continuously enhanced through a continuous improvement process. All decisions including those related to curriculum, delivery of instruction and assessment are based on the best way to achieve the predetermined outcomes. Traditionally, educators have measured learning in terms of 6 standardised tests. In contrast, outcome-based education defines learning as what students can demonstrate that they know.

Benefits of OBE:

- More directed & coherent curriculum.
- Graduates will be more “relevant” to industry & other stakeholders (more well-rounded Graduates)
- Continuous Quality Improvement is in place.
- OBE shifts from measuring input and process to include measuring the output (outcome)

Learning Outcomes based Curriculum Framework (LOCF) for Post Graduate Programmes: IQAC MG University

One of the main objectives of OBE is to ensure continuous improvement of programmes in terms of maintaining the relevance in curriculum as well as responding to the requirements of the stakeholders. an OBE system has been proposed and to be implemented at various Departments of Mahatma Gandhi University from 2020-21acdemic year onwards, as a quality-assurance approach to improve teaching and learning outcomes and processes. This OBE plan incorporates the “outcomes assessment” process to be followed in the departments. OBE should be a key driver of the curriculum management in all the departments of the university. Therefore, as envisaged by the IQAC of Mahatma Gandhi university, an OBE based curricular framework has been proposed for the Master programme of School of Energy Materials w.e.f. the academic year 2020- 2021 which is presented hereafter. In this regard, we have framed the syllabus in accordance with the programme outcomes of Mahatma Gandhi University listed below.

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 issues related to one's work and living as a dignified person in the society.

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

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

Eligibility for Admission

i)M. Sc in Nanoscience and Nanotechnology, Physics, Chemistry, Materials Science, Polymer science or an equivalent degree with not less than 50% Marks

ii) B. Tech in Nanoscience and Nanotechnology or Chemical Engineering/Technology or Polymer Engineering/Technology or Electronics and Communication or Biotechnology or Material Science or Mechanical, or Civil an equivalent degree with not less than 50% marks.

iii) Subject to the regulation relating to prescribed minimum of the respective qualifying examination, the minimum marks for the admission to the course of studies shall be a pass in the case of SC/ST candidates.

iv) Candidates belonging to Socially and Educationally backward classes (SEBC) referred to GO(P)208/66Edn dated 2-5-96 and subsequent amendments to the order issued by the Government shall be given a relaxation of 2% marks in the prescribed minimum for the admission

v) A relaxation of 5% marks from the prescribed minimum shall be allowed in the case of physically handicapped persons.

vi) Candidates who have passed the qualifying examination in more than one chance in the subject (excluding languages) will have their percentage marks de-rated at the rate of 5% for every additional appearance for the purpose of ranking.

Admission Procedure

Candidates have to appear for the Common Admission Test (CAT) conducted by the MG University in April/ May of every year. The questions will be of objective multiple-choice type. Any other conditions prescribed by MG University from time to time in this regard will be applicable. Relaxation of marks and Reservation of seats under SC/ST are based on University/ Government Rules. Admission may be based on the written test alone or written test and interview or on the basis of the marks obtained in the qualifying examinations as well as the marks obtained in the written test, the interview and/or the group discussion conducted by the respective Schools as decided by the Faculty Council of Schools/Centres/Institutes from time to time. The Rank list for admission will be prepared as per university guidelines. While preparing the rank list, if there is same index marks for more than one candidate, they will be ranked on the basis of actual marks obtained in the qualifying exam (CAT). Even after this, if there is a tie; they will be ranked on the basis of date of birth that is the older person is to be ranked higher. The duration of the M Tech programme of SEM is of two years consisting of four semesters. Each semester shall comprise of a minimum of 18 instructional weeks. Every semester will be adjusted to have at least 90 working days. Continuous Internal Assessment based evaluation during the course period and End Semester Examination at the end of each semester shall be conducted.

Course Registration

A student must register for the required number of courses as per specific curriculum of a programme, after the commencement of class of that semester. Each student shall have a course card for each semester, wherein the title of the courses and corresponding course codes are entered and signed by the student, the faculty member offering the course and countersigned by the Director/Head of the Department. Based on this, a consolidated statement of courses to which registration is granted for the semester is to be prepared by the department. This statement must be signed by the Director/Head of the department and has to be submitted to the CSS section of the examination branch of the University within 20 days after the commencement of class of each semester

Evaluation

There shall be continuous internal assessment as well as end semester examinations for all the courses. Evaluation of the first and third semester courses shall be done by the respective faculty members of SEM. End semester Examination of second and fourth semesters shall be conducted based on the question paper set by External Examiners. There will be double valuation of answer scripts of the end semester examination of the even semesters of the MTech programme. One valuation shall be conducted by External Examiner and the other by the faculty member who taught the course. External Examiner should be a competent person in the specified subject from other Universities/ Institutes. A panel of External Examiners is prepared based on recommendation of Faculty Council of SEM and approval of the same by Vice Chancellor.

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. Students have to secure a minimum attendance of 75% to appear for the end semester examination. A separate minimum of 40% of marks is required in the Continuous Assessment (CA) as well as End semester examination for a pass in a course. Students who fail to obtain minimum of 40% mark in the Continuous Assessment can request the faculty council for a chance to improve the marks. The faculty council may permit the student to secure the minimum mark in CA, by conducting written Tests. However, only one chance will be given to improve CA marks.

Process of Evaluation

The internal assessment will be a continuous assessment (CA) that accounts for 40% of the evaluation in both theory and practicals. 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. The evaluation of the end-semester examination of the first and third semesters shall be done by the faculty who taught the course. Evaluation of the 2nd and 4th semester courses based on questions set by external experts shall be evaluated by two examiners; one, the external (as far as possible the question paper setter shall evaluate the examination paper as well) and the other, internal examiner, the faculty who taught course. The Head of the School will make necessary arrangements for the evaluation of the answer scripts. The project report/dissertation shall be evaluated by two examiners, one the faculty member of the school and the other an external examiner to be decided by the HOD from a panel recommended by faculty council and approved by the Vice Chancellor. The comprehensive viva-voce will be carried out along with project evaluation.

Continuous Assessment (CA): The student’s participation and classroom performance as well as the feedback received from tests, tutorials, assignments and term papers shall form the basis for continuous assessment (CA). It accounts for 40% of the evaluation in both theory and practical. 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	25
3.	Punctuality and neatness	20
4.	Viva-voce	30

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 end of fourth semester: The evaluation of the project in the end of 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 and approval of the same by Vice Chancellor.

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

Pattern of Question papers for the End- Semester Written Examination

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

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

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

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

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

Section	Cognitive level	Choice and marks of questions	Question specification	Total Marks	Alignment with Course outcomes (COs)
Section A	Remembering/ Understanding/Applying/Evaluating	12 out of 15 questions; 3 marks each	Minimum one question from each unit	36	Aligned with COs
Section B	Applying/Analysing/ Evaluating/Creating	4 out of 7 questions; 6 marks each	minimum one question from each unit	24	Aligned with Cos
			Total	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 (Analysing/Evaluating/Creating): 60 to 70%

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

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

Grading System

The performance of a student in each course is evaluated in terms of percentage of 21 marks with a provision for conversion to grade points. 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 the Relative value of the Grades (Grade points)

Range of % of marks	Letter Grade	Performance	Grade points
95 to ≤100	O	Outstanding	10
85 to ≤ 95	A PLUS	Excellent	9
75 to ≤ 85	A ONLY	Very Good	8
65 to ≤ 75	B PLUS	Good	7
55 to ≤ 65	B ONLY	Above Average	6
45 to ≤ 55	C	Average	5
40 to ≤ 45	P	Pass	4
≤ 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.

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. There is no provision for revaluation or scrutiny of answer scripts for the End Semester Examinations for 2^{nd} and 4^{th} Semesters as double valuation is performed on the scripts. 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.

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.

Registration for Improvement

A candidate has to apply for registration for improvement by paying the requisite fee. Candidates are not permitted to register for improvement of grades for Individual course. Candidates in the 1^{st} and 2^{nd} semesters, who have secured SGPA letter grade 'P' or above in the End Semester Examination can improve their grade by reappearing for all the semester courses along with the next immediate batch. In such cases a candidate will be awarded a new grade only if there is an improvement in grade in the new examination; otherwise, the candidate is eligible to retain the grade already awarded. Candidates in the 3^{rd} 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 3^{rd} 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 4^{th} 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 (3^{rd} or 4^{th}) is to be improved; however, the grade given to the candidate shall be that obtained for the entire semester improvement examination. 1^{st} and 2^{nd} semester SGPA cannot be improved after the completion of the 4^{th} semester. Only 3^{rd} and 4^{th} 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 4^{th} semester can be improved only for the purpose of fulfilling the minimum CGPA requirement.

Reappearance

Candidates in the 1^{st} and 2^{nd} 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 23 examination, course wise, provided the candidate has applied for the same and paid the required fee. Candidate in the 3^{rd} semester who has secured letter grade of 'F' or 'Ab' in any of the courses can reappear for exams course-wise in the 3^{rd} semester supplementary examination, which will be conducted immediately after the completion of End Semester Examination of Fourth semester, provided the candidate has applied for the same and paid the required fee (fee for supplementary examination of any course shall be full semester examination fee irrespective of number of courses involved). Candidates who secured the grade of only 'F' or 'Ab' in a course in the 4^{th} semester examination can re-appear course wise, along with the immediate lower batch. Candidates who secured the grade of only 'F' or 'Ab' in a course in the 3rd/4thsemester 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).

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

MAHATMA GANDHI UNIVERSITY

SCHOOL OF ENERGY MATERIALS

PROGRAMME	M.Tech Energy Science and Technology
DURATION	2 years (2021 Admission Onwards)
Total credits required:	80 (for 4 semesters)
	[Core: 64; Elective: 16]

* The student has to secure minimum of 24 credits [12 Credits (Core) + 3 Credits (Practical) + 6 Credits (Elective) + 3 credits (Viva)].
* The student has to secure minimum of 24 credits [9 Credits (Core) + 3Credits (Practical) + 10 Credits (Elective) + 2 Credits (Minor project & Viva)]
* The student has to secure minimum of 32 credits for semester III and IV.

Program Specific Outcomes :(PSOs): At the completion of the M.Tech Energy Science and Technology program, the students from school of Energy Materials will be able to:

PSO	Expected outcome
1	Provide a strong foundation in Energy science and technology that emphasizes scientific reasoning and analytical problem solving.
2	Provide students with the skills required to succeed in M Tech., also enrich the students with a basic skill to perform in industry related to Energy
3	Promote research interest in students and enable them towards planning and execution of research in frontier areas of Energy storage conversion etc
4	Expose the students to a level of experimental techniques using modern instrumentation.
5	Demonstrate teamwork, communication, Time management and leadership skills across multicultural contexts
6	Acquire the ability to synthesize and characterize compounds using sophisticated instrumental techniques and related soft-wares, for the in-depth characterization of energy materials
7	Develop solid knowledge, understanding and expertise in the domain of energy materials.

SEMESTER I (24 credits)						
Course Code	**Course**	**Hours/Week**			**Credits**	**Total credits**
		L	T	P		
Core Courses						12
EMM20C01	Energy Science and Technology	2	2	-	3	
EMM20C02	Fundamentals of thermodynamics	2	2	-	3	
EMM20C03	Material Characterization Techniques	2	2	-	3	
EMM20C04	Basics of Nanoscience and Technology	2	2	-	3	
Elective Courses						
EMM20E01	Computational studies of energy materials	2	2	-	4	6
EMM20E02	Polymers and Nanocomposites	2	2	-	4	
EMM20E03	Nano photonics	2	2	-	4	
EMM20E04	Nano sensors and Nanodevices	2	2	-	2	
EMM20E05	Research Methodology	2	2	-	2	
Laboratory Courses						
EMM20C05	Lab1-Synthesis and Characterization of Advanced Materials for Energy Applications	40	60	-	3	3
Viva Voce						
EMM20C06	Comprehensive Viva voce	40	60	-	3	3

L- Lecture P-Practical C- Core E- Elective V-Viva

Out of the total credits, a student has to secure minimum of 24 credits [12 Credits (Core) + 3 Credits(Practical) + 6 Credits (Elective) + 3 credits (Viva)]

SEMESTER II (24 credits)						
Course Code	**Course**	**Hours/Week**			**Credits**	**Total credits**
		L	T	P		
			Core Courses			
EMM20C07	Nuclear Energy Technology	2	2	-	3	9
EMM20C08	Bio - Energy Technology	2	2	2	3	
EMM20C09	Materials and Devices for Energy Applications	2	2	-	3	
			Elective Courses			
EMM20E06	Energy Efficient Lighting and Displays	2	-	-	4	10
EMM20E07	Photovoltaic Techniques	2	-	-	4	
EMM20E08	Semiconductor Nanostructures for Optoelectronics	2	-	-	2	
EMM20E09	Metals, Ceramics and Composite Materials for Energy Applications	2	-	-	4	
EMM20E10	Statistical Mechanics	2	-	-	2	
			Laboratory Courses			
EMM20C10	Development of energy storage devices using Nanocomposites	-	-	6	3	3
			Viva Voce			
EMM20C11	Minor Project & Viva Voce	-	-	6	2	2

- **Out of the total credits, a student has to secure minimum of 24 credits [9 Credits (Core) + 3Credits (Practical) + 10 Credits (Elective) + 2 Credits (Minor project &Viva)]**

Semester III

Code	Subject	Credits
EMM20C12	**Project Work - Phase I**	16
	Total	**16**

SEMESTER IV

Code	Subject	Credits
EMM20C13	Comprehensive Viva Voce	4
EMM20C14	**Project Work - Phase II**	12
	Total	**16**

- **Total Min. Marks for the M.Tech. – 2100**
- **Total Min. credits for the M.Tech. – 80**

PROJECT SPECIFIC OUT COME M.TECH COURSE IN ENERGY SCIENCE AND TRCHNOLOGY

SEMSETER 1

Core Courses

	MAHATMA GANDHI UNIVERSITY
	EMM20C01 Energy Science and Technology
School Name	**School of Energy Materials**
Programme	**M. Tech. in Energy Science and Technology**
Course Name	**Energy Science and Technology**
Type of Course	**CORE**
Credit Value	**3**
Course Code	**EMM20C01**

Course Summary & Justification	Efficient energy conversion techniques are vital to our existence. This paper deals with modern technologies for energy conversion strategies and with the scientific principles underlying these technologies. Further, this curriculum is designed to allow students from a science, engineering, or other backgrounds with relevant experience, to gain the scientific knowledge needed to contribute to the energy sector. This can be through industry, business, academia, government policy or media communication. Students will examine the fundamental and applied science of how energy resources could be diversified from conventional polluting sources (e.g. CO_2, NO_X, SMOG) to renewable sources, where the sustainability of both the energy source and the conversion technology is presently unknown. The biggest benefit that student experience is the chance to significantly improve the world. Energy science professionals are able to increase the quality of life for millions of people and create the foundations for modern society. Whether you help a growing community expand or play a part in the energy systems of the future, this is a very fulfilling career choice.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		40	40	0	40	120
Pre-requisite	Deep knowledge on solar energy, fuel cell, photovoltaic, and renewable energy					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Possess sophisticated comprehension of the sources, utilisation technologies, storage and distribution modes of energy that presently power cities, buildings, transportation and consumer devices.	U	4,5
2	Hypothesise, using fundamental science, how alternative energy sources and technologies may disrupt conventional energy utilisation behaviours.	U, A, An	1,4, 7
3	Outline the impact of energy utilisation on the environment at local and global levels	U, An	5,7
4	Quantify the scale of local and global energy utilisation, contrast this to the geographical location of the energy source and understand how these factors relate to the economics of energy markets.	U, An, E	2,3
5	Use knowledge of scientific and technological challenges posed by distributed electricity/power generation with computer simulation to understand electricity distribution networks.	U, A, An	3,4,5
6	Apply science underlying conventional and sustainable energy sources including nuclear, fossil, wind, solar, biomass and biofuels to propose solutions to the clean and sustainable energy problem.	U, A, An, E, C	1,2,5
7	Understand the physical and chemical factors defining the carbon cycle and be able to relate these to global climate change, and to the readiness of carbon capture and storage technologies.	R, U, An	1,7
8	Describe how essential and consumer technologies rely on critical raw materials and have knowledge of the global impact of their extraction, refining, substitution and recovery.	U, A, An	2,3,4
9	Create and communicate original knowledge of Energy Science by directed independent research through a combination of experimental, computational and analytical means.	U, A, C, An, E	1,4,5,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	Basics of Solar Energy: Energy and development, Units and measurements, Solar spectrum, Electromagnetic spectrum. 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	**10 Hrs.**	**1,2,3**

	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.		
Module 2	Basics of Energy Conversion: Energy Conversion routes, Direct and Indirect way of Energy Conversion, Principles of heat and mass transfer, Fluid statics and dynamics, Electricity generation and distribution. 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.**	**4,5,6,7**

Module 3	Introduction to energy sources: Conventional and Non-Conventional Energy, Sources of Non-conventional energy, Historical, Economic and Environmental Perspective, Need of Non-conventional Energy Sources, Types of Non-conventional Energy Sources, Global and National scenario, Basics of Nonconventional Energy Sources, their distribution and limitations. **Hydroelectric power**: Types of hydropower plants and schemes, hydrology: runoff studies, flood estimation studies, assessment of hydropower potential of a basin, storage and pondage, load studies, elements of hydropower plants and their hydraulic design: dams, intakes, conveyance system, types of power house, hydraulic turbines and pumps, Components and design of hydraulic turbines, Standardization and selection of turbine, Components and design of hydraulic Pumps, Hydropower scenario; Global and Indian perspective, Policies, Environmental concerns, Sub classification of Hydropower projects, Conceptualization, Techno-commercial studies, Investigation & Planning, Design Principles, Project Management, Operational issues, Test cases of Hydropower Projects **Wind Energy:** Wind turbines, aerodynamics, types of turbines wind energy conversion system, Wind turbine generator types. Advantages and disadvantages **Tidal:** Principle, power calculation, Tidal modes of operation, **Thermal power plant:** Types of thermal power turbines, Gas turbines; Open and closed cycles, constant pressure and constant volume cycles, cycles with inter cooling, reheating and heat exchanger, compressor and turbine efficiencies, pressure losses, performance characteristics of various cycles, practical problems. Jet Propulsion: Calculation of thrust, Power, speed and efficiency, turbo - jet and turbo propulsion systems. Compressors, Combustion Systems, Steam turbines; Principle and working, type of turbines, stage to blade, speed ratio for optimum efficiency, diagram efficiency, steam s performance. Energy losses in steam turbine, turbine performance at various loads and governing of steam turbines. Constructional details and description of steam turbine, Thermal power scenario; Global and Indian perspective, Policies, Environmental concerns, Sub classification, Techno-commercial studies, Investigation & Planning, Design Principles, Project Management, Operational issues, Test cases. Nuclear Energy: Introduction to Nuclear Energy, Nuclear power scenario; Global and Indian	**15 Hrs.**	**8,9**
Module 4	Photo-voltaic cell – characteristics- cell arrays-power electric circuits for output of solar panels-choppers-inverters-batteries-charge regulators, Construction concepts. PV cell technologies 1st, 2nd and3rd generations, Electrical characteristics, PV module and array, PV system components and design Solar thermal power: Solar radiation characteristics, flat plate collector, Tubular Collector, solar air collector, solar concentrator.	**10 Hrs.**	**10**

Module 5	Biofuels: Biomass characteristics and their availability, Biofuel production processes: Biomethane, Biohydrogen, Alcoholic fermentation, Biodiesel, Microbial Fuel Cell, Biomass based steam power plant, combined cycle powerplant, cogeneration plant	**10 Hrs.**	

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

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	MAHATMA GANDHI UNIVERSITY **EMM20C02 Fundamentals of thermodynamics**
School Name	**School of Energy Materials**
Programme	**M. Tech. in Energy Science and Technology**
Course Name	**Energy Science and Technology**
Type of Course	**CORE**
Credit Value	**3**
Course Code	**EMM20C02**

Course Summary & Justification	The "fundamentals of thermodynamics" course explores the concepts of heat and how it can be converted to power, and covers all aspects of energy and energy transfer including power production, refrigeration and property relation of substances. This course aims to impart basic knowledge on laws of thermodynamics, entropy, energy changes, energy analysis. To familiarize different types of cycle analysis and optimization, thermodynamic optimization of irreversible systems. To give the concept of Finite time thermodynamics principles. Understanding the relationship between properties of heat, temperature, energy, and work. This course is designed at providing students with concepts of thermodynamics, entropy, energy changes, energy analysis. In depth knowledge on thermodynamic optimization, thermodynamic principles. Concept on thermodynamic reactive system, properties of gas mixtures, changes in entropy. Knowledge on laws of thermodynamics, energy analysis of industrial systems, cycle analysis and optimization.					
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 thermodynamics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the basic concepts of thermodynamic such as temperature, pressure, system, properties, process, state, cycles and equilibrium	U	1,2,5,7
2	To conduct experiments regarding the measurement and calibration of temperatures and pressures in groups.	U, A, An	3,4,5
3	To identify the properties of substances on property diagrams and obtain the data from property tables	U, An	1,5,7
4	Ability to define energy transfer through mass, heat and work for closed and control volume systems.	U, An, E	2,3,4
5	Ability to apply the first Law of Thermodynamics on closed and control volume systems.	U, A, An	5,7
6	Ability to apply Second Law of Thermodynamics and entropy concepts in analysing the thermal efficiencies of heat engines such as Carnot and Rankine cycles and the coefficients of performance for refrigerators.	U, A, An, E, C	1,3,6,7
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	Laws of thermodynamics, entropy, entropy balance for closed and open systems. Energy: Concept of reversible work & irreversibility, second law efficiency; Energy change of a system: closed & open systems, energy transfer by heat, work and mass, energy destruction, energy balance in closed & open systems. Energy analysis of industrial systems, power systems and refrigeration systems.	**15 Hrs.**	**1,2,3**
Module 2	Cycle analysis and optimization: Regenerative reheat, Rankine cycle and Brayton cycle, combined cycle power plants, multi-stage refrigeration systems.	**15 Hrs.**	**4,5,6,7**
Module 3	Thermodynamic optimization of irreversible systems: Finite time thermodynamics principles, optimization studies of various thermal systems, Minimization of entropy generation principle. Thermodynamics of Reactive System: Conditions of equilibrium of a multiphase, multicomponent system; Second law applied to a reactive system; Condition for reaction equilibrium.	**15 Hrs.**	**8,9**
Module 4	Properties of Gas Mixtures: Equation of state and properties of ideal gas mixtures; Change in entropy on mixing; Partial molal properties for non-ideal gas mixtures; Equations of state.	**15 Hrs.**	**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** **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

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	MAHATMA GANDHI UNIVERSITY
	EMM20C03 MATERIAL CHARACTERISATION TECHNIQUES

SchoolName	**School of Energy Materials**					
Programme	**M.Tech**					
Course Name	**MATERIAL CHARACTERISATION TECHNIQUES**					
Course Credit	**3**					
Type of Course	**CORE**					
Course Code	**EMM20C03**					
Course Summary & Justification	This course aims to impart basic knowledge on spectroscopic methods, different types of spectroscopies, microscopic techniques. To introduce the basic concepts on thermal analysis, theory, instrumentation and applications. To familiarize different types of nondestructive testing. To give the concept of analyzing the material properties by different microscopic techniques. Understanding the concept of various material characterization methods and also is important as it helps to analyze various materials. This course is designed at providing students with concepts of material characterization techniques, thermal analysis and nondestructive testing. In depth knowledge on spectroscopic methods, electron spectroscopies, optical microscopy, electron microscopy. Concept on thermal analysis, basic theory, instrumentation and applications. Knowledge on material's structure and properties.					
Semester	**I**					
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	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	Understand the concept of spectroscopic methods, thermal analysis, instrumentation and applications.	U, A	1,2,6
2	To learn about various electron spectroscopies.	U, A	1,2,4
3	Understand the concept of characterizing material properties by using different microscopic methods.	R, An, E	1,6
4	To impart knowledge on analyzing materials structure and properties.	E,S,An	1,4
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	**Spectroscopic methods:** UV-visible spectroscopy- Beer's law, Instrumentation, Quantitative analysis; Vibrational spectroscopy- Raman and Infrared, Principles of vibrational spectroscopy, Photoluminescence Spectroscopy, Electrochemical Impedance Spectroscopy, Polarized neutron Reflectivity, Infrared and Raman activity, Fourier transform infrared spectroscopy, instrumentation, X-ray diffraction (XRD), Raman spectroscopy, Micro Raman, Applications	**15**	**1**
2	**Electron spectroscopies:** X-ray photoelectron spectroscopy (XPS), Ultra-violet photoelectron spectroscopy (UPS), Auger electron spectroscopy (AES), Atomic model and electron configuration, Principles of XPS and AES, Chemical shift, Depth profiling, Instrumentation, Applications	**10**	**2**
3	**Optical Microscopy:** Image formation, Resolution, Aberrations, Imaging modes, Specimen preparation, Confocal microscopy	**5**	**3,4**
4	**Electron microscopy:** Scanning electron microscopy (SEM), Field Emission Scanning Electron Microscopy, Instrumentation, Electron beam-specimen interaction, Specimen preparation, Energy dispersive spectroscopy (EDS) in electron microscopes; Transmission electron microscopy (TEM) - Basics of TEM, Electron sources, Preparation of samples for electron microscopic studies, Image modes, Image contrast.	**15**	**3,4**
5	**Scanning Probe Microscopies:** Scanning tunneling microscope (STM) and Atomic force microscope (AFM) - Working principles, working modes, Image artifacts	**5**	**3,4**
6	**Thermal analysis**: Thermo gravimetric analysis (TGA), Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Dynamic mechanical analysis (DMA), Thermomechanical analysis (TMA) and Dynamic mechanical thermal analysis (DMTA), Basic theory, Instrumentation and applications, Other characterization methods: Universal Testing Machine, Vibrating sample Magnetometer, Vector network Analyzer, vibrating Sample Magnetometer, Brunauer-Emmett Teller surface areas, Zeta sizer	**15**	**1**

7	**Non-destructive testing:** Radiography, Ultrasonic, Acoustic emission, Thermography, Holography, Basic principles, Applications in airframe and rocketry.	**5**	**4**

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

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	MAHATMA GANDHI UNIVERSITY

	EMM20C04 BASICS OF NANOSCIENCE AND TECHNOLOGY
SchoolName	**School of Energy Materials**
Programme	**M. Tech in Energy Science and Technology**
Course Name	**BASICS OF NANOSCIENCE AND TECHNOLOGY**
Course Credit	**3**
Type of Course	**CORE**
Course Code	**EMM20C04**
Course Summary & Justification	To provide seamless education through the pioneering use of nanotechnology, in partnership with industry and society with a view to promote research, discovery and entrepreneurship and to prepare its students to be responsible citizens of the world and the leaders of technology and techno-innovation of the 21st Century by developing in them the desirable knowledge, skill and attitudes base for the world of work and by instilling in them a culture for seamlessness in all facets of life. This course aims to Understand various chemical and physical methods for the synthesis of diverse types of nanomaterials (0D, 1D and 2D) It will give decipher information on the specific details of both bottom up and top-down synthesis. Gather information on the different types of nanomaterials and their potential applications. The course will provide exposure in various specialization of Nanotechnology.
Semester	**I**

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 CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**

1	**General introduction and theory of nanomaterials-** History of nanomaterials; Size and shape dependant properties and their uniqueness; Energy at nanoscale - surface characteristics and electrostatic and steric stabilization - Quantum confinement - zero dimensional, one dimensional and two dimensional nanostructures Synthesis of nanomaterials- top down approach, bottom up approach, Physical Methods; Vacuum Evaporation, Electron beam evaporation Sputtering, 21 Cathodic Arc Deposition, Chemical Vapour 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. chemical vapour deposition (CVD) and wet chemical methods for the synthesis of zero dimensional one dimensional and two-dimensional nanostructures-metal nanoparticles, quantum dots, nanoclusters, nanowires and rods, thin films	**18**	**1,2**
2	**Functional nanomaterials** 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 Carbon Nanomaterials: Introduction to Carbon allotropes and Carbon nanomaterials Fullerenes: Background, Synthesis, Properties and Applications CNTs (SWNTs and MWCNTs,): Background, Synthesis, Properties and Applications Nano-diamonds: Background, Synthesis, Properties and Applications Graphene: Background, Synthesis, Properties and Applications Carbon nano-fibers and Carbon nano-yarns: Background, Synthesis, Properties and Applications	**15**	**2,3**
3	**Applications of nanomaterials-** Application of nanomaterials in healthcare, biosensor, coatings environment, catalysis, agriculture, automotive, sensors, electronics, photonics, information technology, quantum computing, energy and aerospace sectors	**12**	**3,4,6**
4	**Nanotechnology** Environmental and health effects Environmental pollutants in air, water, soil, hazardous and toxic wastes, application of nanotechnology in remediation of pollution. The challenge to occupational health and hygiene, toxicity of nanoparticles, effects of inhaled nanosized particles, skin exposure to nanoparticles, impact of CNTs on respiratory systems, hazards and risks of exposure to nanoparticles, monitoring nanoparticles in work place and sensors.	**15**	**5,7,8**

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	To synthesize nanomaterials using different fabrication process such as Vacuum Evaporation, Electron beam evaporation Sputtering, Cathodic Arc Deposition, Chemical Vapour Deposition, Atomic Layer Deposition, Pulsed Laser Deposition and Molecular Beam Epitaxy.	U, A, C	2,4,6
3	Understand the background, synthesis, properties and applications of organic semiconductor nanostructures.	U, An	3,4
4	Utilization and application of nanomaterials in various sectors and industries like healthcare, agriculture, automotive, electronics, photonics, information technology, quantum computing, energy and aerospace.	A, S	3,6
5	Understand the environmental safety aspect of nanotechnology.	U, R	3,5
6	To foster the creation of new and relevant technologies and to transfer them to industry for effective utilization.	I, R	4,5
7	To participate in the planning and solving of engineering and managerial problems of relevance to global industry and to society at large by conducting basic and applied research in the areas of technologies.	A, S	5,6
8	To impart awareness on significance of nanomaterials in the future technological applications. The programme provides adequate exposure to the students for pursuing higher education in the field of nanotechnology and other job opportunities in academia and industry.	E, Ap.	3,7
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)** 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

	○ Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **D. Semester End examination**

REFERENCES

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Elective Courses

	MAHATMA GANDHI UNIVERSITY
	EMM20E01 COMPUTATIONAL STUDIES OF ENERGY MATERIALS

SchoolName	**School of Energy Materials**					
Programme	**M.Tech in Energy Science and Technology**					
Course Name	**COMPUTATIONAL STUDIES OF ENERGY MATERIALS**					
Course Credit	**4**					
Type of Course	**ELECTIVE**					
Course Code	**EMM20E01**					
Course Summary & Justification	This course aims to impart the basic knowledge on the computational modelling techniques in the field of materials for energy technologies including hydrogen production and storage, energy storage and conversion, and light absorption and emission. To familiarize the current possibilities and limitations of each computational modelling techniques, as well as the criteria for selecting a particular technique and combining different techniques. To introduce the basic knowledge on different optimization methods used in the computational studies. Understanding the concept of computational modelling techniques is very important as it helps to study simple to complex chemical processes, complex structures and their reactivity. This course is designed at providing students with the basic knowledge on different computational modelling methods for studying materials on energy technologies including hydrogen production and storage, energy storage and conversion, and light absorption and emission. And it provided an in-depth knowledge on computational modelling techniques for phase transition under confinement. In addition to this, it helps to understand Density Functional Calculations, Thermal Systems Modelling, Optimization Methods and Electrical Energy Systems Modelling.					
Semester	**I**					
Total StudentLearning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	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	Understand the concept of computational modelling techniques in the field of materials for energy technologies	U, R	1,2,3
2	Understand computations of Phase Transition under Confinement	U, S, I	1, 5,7
3	Understand different optimization methods	U, R	1,3,4
4	To impart knowledge on density Functional Calculations and Electrical Energy Systems Modelling:	E, Ap, S	1,7
5	Understanding of Density Functional Calculations in Carbon Nanotubes	U, R, An	1,3,4,5
6	To impart knowledge of different Optimization Methods	U, R, S	1,5,6,7
7	To understand concepts of Electrical Energy Systems Modelling	U, R, An	1,3
8	Understand Developments and applications of computational modelling techniques in the field of materials	U,R,S	1,4,5
***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	Hours	CO.No.
1	**General introduction** Understanding current possibilities and limitations of each method, as well as the criteria for selecting a particular method and combining different methods. Becoming familiar with the theoretical, computational and application aspects of modelling. Solving a few selected real materials problems	**7.5**	**1,2**
2	Computer modelling methods for studying materials on a wide variety of length and time scales. Phase field methods, Background statistical mechanics, Quantum-level modelling, Molecular dynamics, Icing model, Cluster Variation Method, Monte Carlo techniques, Finite volume methods, discrete dislocation dynamics.	**7.5**	**1,2,3**

3	**Applications of nanomaterials:** Computations of Phase Transition under Confinement; General Basis for predicting physical properties of nanocrystals and large clusters; Quantum Confined Systems & computational techniques, Computational Electrodynamics Methods; Large Scale Electronic Transport Calculations.	**7.5**	**2,3,4**
4	Density Functional Calculations in Carbon Nanotubes; Time Dependent Density Functional Theory; Computational Study of Nanotubes; Excited State Properties (GW, BSE); Computing Mechanical Properties and Modeling Growth; Computation Vs Experiment, Present Day Scenario: regarding computation in the field. COMSOL Multiphysics, MATLAB	**7.5**	**4,5**
5	Thermal Systems Modelling, Design and Simulation Methodology for Heat exchangers, refrigerators and air conditioners Steady state system simulation, Non-linear Systems: Modelling and Simulation, Dynamic System Simulation, Numerical Integration, Parametric Estimation.	**7.5**	**1,4,5**
6	Optimization Methods: Lagrange Multiplier, Search Techniques, Geometric Programming Chemical Energy Systems Modelling, Non-isothermal Chemical Reaction Systems, Heating and Cooling of Reactors, Ignition and Extinction Temperatures, Multiplicity and HotSpot Formation in Reactors, Fossil Fuel Pyrolysis and Combustion Models, Adiabatic Combustion Temperature, Thermogravimetric Analysis, Design of Petroleum Refinery Distillation Heat Exchanger Network Analysis.	**7.5**	**4,5,6**
7	Electrical Energy Systems Modelling: Introduction to Electrical Systems and Electrical Elements, Lumped and	**7.5**	**1,4,7**

	Distributed Parameter Models, Laplace Transforms, Transfer Functions, Electrical and Electro-mechanical System Transfer Functions, Examples of Modelling and Transfer Functions, State variables and the State-Space Representation, Solving the equations of Time and Space Domain, State Equation examples Controllability and Observability.		
8	Developments and applications of computational modelling techniques in the field of materials for energy technologies including hydrogen production and storage, energy storage and conversion, and light absorption and emission.	**7.5**	**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** **E. 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 **F. Semester End examination**

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	MAHATMA GANDHI UNIVERSITY **POLYMERS AND NANOCOMPOSITES**
School Name	**School of Energy Materials**
Programme	**M.Tech in Energy Science and Technology**
Course Name	**Polymers and Nanocomposites**
Type of Course	**Elective**
Credit Value	**4**
Course Code	**EMM20E02**

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.	**10 Hrs.**	**1, 6**

	Polymerization Techniques: Bulk, Solution, Suspension and Emulsion polymerizations- Polymerization using metal catalysts and surfactants.		
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, CeO_2, TiO_2, ZrO_2 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** **E. 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 **F. Semester End examination**

REFERENCES

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	MAHATMA GANDHI UNIVERSITY
	Nano Photonics
School Name	**School of Energy Materials**
Programme	**.**
Course Name	**Nano Photonics**
Type of Course	**Elective**
Credit Value	**4**
Course Code	**EMM20E03**

Course Summary & Justification	This course shall introduce the basic principles, applications and latest advances in the area of Nanophotonics. Student shall have a clear view about this excited new area and ready to contribute to the advances of photonic technology in the broad area of applications such as light-matter interactions, lithography, nanophotonic devices, nanophotonics in medicine, etc. This course aims to provide a comprehensive view of nanoscale optical materials and photonics to undergraduate and graduate students by starting at a very elementary level, and gradually guiding the students to the very frontier of current research in nanophotonics. In addition to the basic concepts, you will learn experimental techniques and simulation methods on light interactions with nanostructures. It is expected that you can apply your new knowledge to read and understand the current scientific literature in the fields of nanophotonics after you complete this course.					
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	Basics of laws and principles of nanooptics, nano-photonics, and quantum confinement of a system.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand devices and general concepts used in nanooptics, nano-photonics and nano-opto electronics.	U, R, I	1, 7
2	Understand the basic concepts of quantum confined materials	U,R, S	1, 3, 4
3	Understand the interaction dynamics of quantum confined materials and the latest spectroscopic techniques.	U,A,An	1,2,4
4	Understand the basics of photonics, Building blocks of photonic circuits and its effects	U, An, A	1, 7
5	Explore the scientific discoveries lead to technological inventions with nanophotonics.	E, S	2, 5
6	Describe broadly about the impact of biomedical research in biotechnology.	R, A	2, 4,5
7	Apply the principles of bio-nanophotonics in to latest inventions of nano medicine.	U, A,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.
<u>Module 1</u>	**Foundation of Photonics & Photonic devices** Confinement of photons and electrons, propagation through a classically forbidden zone: tunneling, localization under a' periodic potential: bandgap, cooperative effects for photons and electrons, nanoscale optical interactions, axial and lateral nanoscopic localization, nanoscale confinement of electronic interactions, quantum confinement effects, nanoscopic interaction dynamics, nanoscale electronic energy transfer lasers, LEDs, Optical modulators (acousto-optic and electro-optic), Optical fibers and fiber optic components, Frequency conversion, Propagation and confinement of photons and electrons, tunnelling, band gap	**12 Hrs.**	**1**
<u>Module 2</u>	**Quantum confined materials & Effects** Quantum-confined materials: quantum wells, quantum wires, quantum dots quantum rings, manifestations of quantum confinement, optical properties, quantum-confined stark effect,	**18 Hrs.**	**2,3**

	dielectric confinement effect, single-molecule spectroscopy, quantum-confined structures as lasing media, metallic nanoparticles and nanorods, metallic nano shells, applications of metallic nano structures. Interaction dynamics, Electronic energy transfer and emission. Near-field optics and Near-fieldscanning optical microscopy, Single molecular spectroscopy and Nonlinear Optical Processes,Timer solved studies, Hetero structures.Quantum confinement effects, Interaction dynamics, Electronic energy transfer and emission.Near-field optics and Near-field scanning optical microscopy, Quantum Dots, Single molecularspectroscopy and Nonlinear Optical Processes, Timer solved studies, Hetero structures		
Module 3	**Photonic crystals** Basics concepts, theoretical modelling of photonic crystals, features of photonic crystals, methods of fabrication, photonic crystal optical circuitry nonlinear photonic crystals, photonic crystal fibers (pcf), photonic crystals and optical communications, photonic crystal sensors. Applications in communication and sensing**.**	**12 Hrs.**	**4,5**
Module 4	**Bionanophotonics and nanomedicine** Near-field imaging of biological systems, bio derived materials; bio inspired materials bio templates, bacteria as bio synthesizers, near-field bio imaging, nanoparticles for optical diagnostics and targeted therapy, upconverting nanophores forbioimaging. semiconductor quantum dots for bioimaging. Biosensing, nanoclinics for optical diagnostics and targeted therapy, nanoclinic gene delivery nanoclinics for photodynamic therapy	**18 Hrs.**	**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** **G. 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 **H. Semester End examination**

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12. Nanophotonics: Accessibility and Applicability, by National Research Council (ebook)

	MAHATMA GANDHI UNIVERSITY
	EMM20E04-Nanosensors and Nanodevices
School Name	**School of Energy Materials**
Programme	**M. Tech. Program in Energy Science**
Course Name	**Nanosensors and Nanodevices**
Type of Course	**ELECTIVE**
Credit Value	**2**
Course Code	**EMM20E04**

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	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	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	Understand the basics of a Nanosensors.	U	1, 2,7
2	Study the sensor characterization and modes of packaging.	U, An	1, 3,4
3	To learn about various Nanosensor materials	U, A, E	1,2,3,4
4	To design Nanomaterials in biochemical sensor and its application	U, A	3,4,5
5	Correlate and record data of the medically significant measures using a bio sensor	U, R, E	5,7
6	Apply the sensing of physical parameters sensed to fabricate appropriate sensors.	U, A, E	2,4,5
7	Understand the processing of input signals of sensors and applying it in electronics	U, A, Ap	4,5
8	To learn about various Nanodevice materials	U, I, An	1,7
9	State and apply basic concepts of Mechanical Sensors and Actuators	U, An, C	1,4,6
10	Find the connection between Metal Insulators, Quantum Structures and Devices	U, A, E	5,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

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

	(quantum dots). synthesis of nanomaterials (nano rod, nanoclusters, nanodiamond and nano shells). application of nano material for analytical purpose, Important functions of nanoparticles. **Nanomaterials:** Nanomaterial based colorimetric sensors, metallic nanoparticles in sensing, surface functionalization of gold nanoparticle, Fluorescence based sensing, electrical and electrochemical sensing. Different type of sensors: Electrochemical, Mass sensitive sensor, biochemical sensors and their applications. gold nanoparticle-based surface plasmon resonance sensors, physical properties of gold nano particle: size dependent electronic and optoelectronic properties, fluorescence quenching, limit of detection and limit of quantification, sensitivity of thesensor, 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. **Optical Sensors:** Photodiodes, phototransistors and photoresistors based sensors, Photomultipliers, light-to-light detectors, infrared sensors (thermal, PIR, AFIR, thermopiles), CCD sensors and detectors. Surface Plasmon sensors, SERS Sensors **Environmental monitoring sensors:** Mercury and arsenic contamination in water, atmospheric pollution monitoring sensors.	**15 Hrs.**	**8,9**
Module 4	Metal Insulator Semiconductor devices, molecular electronics, information storage, molecularswitching, Schottky devices **Quantum Structures and Devices:** Quantum layers, wells, dots and wires, Mesoscopic Devices, Nanoscale Transistors, Single Electron Transistors, MOSFET and NanoFET, Resonant TunnellingDevices, Carbon Nanotube based logic gates, optical devices, Connection with quantum dots	**15 Hrs.**	**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** **I. 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 **J. Semester End examination**

References

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4. Introduction to Nanoelectronics, Science, Nanotechnology, Engineering, and Applications,Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, Cambridge University Press, 2007.
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13. Nanomaterials for Biosensors, Cs. Kumar, Wiley – VCH, 2007.
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MAHATMA GANDHI UNIVERSITY

EMM20E05 RESEARCH METHODOLOGY

SchoolName	**School of Energy Materials**
Programme	**M. Tech in Energy Science and Technology**
Course Name	**RESEARCH METHODOLOGY**
Type of Course	**Elective**
Credit Value	**3**
Course Code	**EMM20E05**

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	**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 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. Data for Research : Primary data, Meaning, Collection methods, Observation, Interview, Questionnaire, Schedule, Pretest, Pilot study, Experimental and case studies, Secondary data, Meaning, Relevance, Limitations and cautions. Processing data: Checking, Editing, Coding, transcriptions and tabulation, Data analysis, Meaning and methods, Quantitative and qualitative analysis.	**15 Hrs**	**1,2**
Module 3	**Computer applications:** Spreadsheet Tool: Introduction to spreadsheet application, features and	**15 Hrs**	**2,3,4**

	functions, using formulas and functions, Data storing, Features for Statistical data analysis, Generating charts/ graph and other features. (Microsoft Excel or similar tool). **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.		
Module 4	**Interpretation and report writing:** Meaning of Interpretation, Why Interpretation? Technique of Interpretation: Precaution in Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Indexing, presenting footnotes, abbreviations, Presentation of tables and figures, Contents, Styles of reporting, Referencing, Oral Presentation, Mechanics of Writing a Research Report, Precautions for Writing Research Reports, Research-Scientific misconduct, Plagiarism, impact factor, h-index.	**15 Hrs**	**2,4,5**

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**

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Laboratory Courses

	MAHATMA GANDHI UNIVERSITY **SYNTHESIS AND CHARACTERIZATION OF ADVANCED MATERIALS FOR ENERGY APPLICATIONS**
School Name	**School of Energy Materials**
Programme	**M.Tech in Energy Science and Technology**
Course Name	**Synthesis and Characterization of Advanced Materials for Energy Applications**
Type of Course	**3**
Credit Value	**CORE**
Course Code	**EMM20C05**

Course Summary & Justification	Students will learn how to apply common laboratory techniques to determine the structure and the chemical properties of compounds. The lab will comprise hands-on materials synthesis experiments along with their characterization with focus on interpretation. Synthesis and characterization of materials. Understand the principles behind synthesis techniques, perform experiments, analyse obtained results and interpret outcomes (effects of synthesis conditions) of obtained materials, their structure and properties					
Semester	I					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		0	0	120	30	150
Pre-requisite	Basic knowledge of Chemistry. Any discipline of engineering, chemistry and physics can complete the course.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Able to perform experiments individually and gain knowledge about principles and techniques involved in various experiments	U	1
2	To learn about various characterization techniques	U, A	
3	Acquire Experimental skills & handling instruments.	A	3
4	Gain Knowledge in Prediction & verification of Experimental results	Ap	2
5	Understand the concept of materials for energy application	An	2, 3, 6
6	Understand the concept of synthesis of materials	U	6,7
7	Correlate the reactivity of a compound with its structure.	C	6
8	Evaluate the yield of a particular product in a mixture under a set of conditions	E	4, 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.
<u>Module 1</u>	**Synthesis and Characterization techniques** UV-visible spectroscopy, Vibrational spectroscopy- Raman and Infrared, Principles of vibrational spectroscopy, Photoluminescence Spectroscopy, Electrochemical Impedance	**50 Hrs.**	**1, 6**

	Spectroscopy, Polarized neutron Reflectivity, Infrared and Raman activity, Fourier transform infrared spectroscopy, instrumentation, X-ray diffraction (XRD), Raman spectroscopy, Micro Raman		
Module 2	X-ray photoelectron spectroscopy (XPS), Ultra-violet photoelectron spectroscopy (UPS), Auger electron spectroscopy (AES), Atomic model and electron configuration, Principles of XPS and AES, Chemical shift, Depth profiling, Instrumentation	**30 Hrs.**	**2, 6**
Module 3	Optical Microscopy: Image formation, Resolution, Aberrations, Imaging modes, Specimen preparation, Confocal microscopy, Thermal analysis: Thermo gravimetric analysis (TGA), Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Dynamic mechanical analysis (DMA), Thermomechanical analysis (TMA) and Dynamic mechanical thermal analysis (DMTA), Basic theory, Instrumentation and applications Other characterization methods: Universal Testing Machine, Vibrating sample Magnetometer, Vector network Analyzer, vibrating Sample Magnetometer, Brunauer-Emmett Teller surface areas, Zeta sizer Non-destructive testing: Radiography, Ultrasonic, Acoustic emission, Thermography, Holography, Basic principles, Applications in airframe and rocketry Electron microscopy: Scanning electron microscopy (SEM), Field Emission Scanning Electron Microscopy, Instrumentation, Electron beam-specimen interaction, Specimen preparation, Energy dispersive spectroscopy (EDS) in electron microscopes; Transmission electron microscopy (TEM) - Basics of TEM, Electron sources, Preparation of samples for electron microscopic studies, Image modes, Image contrast. Scanning Probe Microscopies: Scanning tunneling microscope (STM) and Atomic force microscope (AFM) - Working principles, working modes, Image artifacts	**70 Hrs.**	**5,6**

Assessment Types	Mode of Assessment • Lab/Experiment skills • Lab record/Report • Viva-voce • Lab Discipline (participation, punctuality, accuracy)

REFERENCES

01. B.S. Furniss, A.J. Hannaford, V. Rogers, P.W.G. Smith, A.R. Tatchell, Vogel's Text Book of Practical Organic Chemistry, ELBS, 2005.

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	MAHATMA GANDHI UNIVERSITY
	EMM20C06 Comprehensive Viva-Voce

SchoolName	**School of Energy Materials**					
Programme	**M.Tech in Energy Science and Technology**					
Course Name	**Comprehensive Viva-Voce**					
Course Credit	**3**					
Type of Course	**CORE**					
Course Code	**EMM20C06**					
Course Summary & Justification	The comprehensive viva-voce shall be conducted by the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner. Thorough understanding of all the M.Tech. level course contents and recent trends in the broad area of energy sciences are evaluated					
Semester	**I**					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total LearningHours

	Classroom studies, lab work, library Library work, independent learning etc.	-	-	-	-	-
Pre-requisite	Basic as well as in-depth knowledge in the coureses he/she studied					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
	At the end of the course the students are expected to		
1	Achieve fundamental and in-depth knowledge	A	3
2	Acquire more in-depth knowledge of the major subject of study	Ap	1,2,3,4,5,6, 7
3	Deeper knowledge of methods in the major subject of study.	A	1, 4
4	Able to contribute to research and development work.	U	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)** 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** Thorough understanding of all the M.Tech level course contents and recent trends in the broad area of energy sciences are evaluated. The candidate will be asked questions based on the whole syllabus he/she studied in the entire programme. How he/she answered or responded the questions asked will be considered for evaluation.

Semester II

Core courses

	MAHATMA GANDHI UNIVERSITY
	EMM20C07 – Nuclear Energy Technology
School Name	**School of Energy Materials**
Programme	**M. Tech. Program in Energy Science**
Course Name	**Nuclear Energy Technology**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM20C07**

Course Summary & Justification	In broadest sense, this course is designed to introduce students to the foundations of nuclear reactions and their effects on processes we use every day for energy, work, or discovery. It provided an in-depth knowledge on nuclear reactions and various nuclear reactor materials and fuels. This course helps to understand the basics of nuclear reprocessing and separation technologies. In addition to this, it provided a basic understanding of radioactivity and its effect on humans and their environment, as well as the techniques for their remediation and disposal.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
		37	0	0	60	97
Pre-requisite	The student has to have a scientific-technical background and profound knowledge in physics and mathematics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the theory and concept of nuclear reactions	R, U	1
2	To learn about various types of nuclear reactors	U	1
3	To learn about various nuclear reactor materials and fuels	U, A, E	1
4	To impart knowledge on nuclear reprocessing	A, E	1
5	To demonstrate knowledge on radioactive waste disposal and radiation protection	An, A	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	**Nuclear Reactions:** Nuclear energy conversion, Chemical and nuclear equations, nuclear reactions. Mechanism of Nuclear Fission and Fusion, Energy from fission and fuel burnup Nuclides, Radioactivity, Decay Chains, Neutron Reactions - the Fission Process, Reactors, Types of Fast Breeding Reactors, Design and Construction of Nuclear reactors, Heat Transfer Techniques in Nuclear Reactors, Reactor Shielding, Production of nuclear fuels	**15 Hrs.**	**1,2,3**
Module 2	Nuclear Reactor Materials and Fuels, Nuclear Fuel Cycles- Characteristics of Nuclear Fuels Uranium - Production and Purification of Uranium-Conversion to UF4 and UF6 Other Fuels like Zirconium Thorium-Berylium design of nuclear reactors and safety analysis Fuel rod design, Steam cycles for nuclear power plants reactor heat removal coolant channel orficing, Core thermal design, thermal shields, fins in nuclear plants, Core thermo-hydralic design, Safety analysis, Time scales of transient flow andheat transfer process, LOCA.	**15 Hrs.**	**4,5,6,7**

Module 3	**Reprocessing:** Nuclear Fuel Cycles - Spent Fuel Characteristics - Role of Solvent Extraction in Reprocessing - Solvent Extraction Equipment. Separation of Reactor Products: Process to be Considered - 'Fuel Element' Dissolution - Precipitation Process - Ion Exchange - Redox - Purex - TTA - Chelation - U235 - Hexone - TBP and Thorax Processes - Oxidative Slaging and Electro - Refining - Isotopes - Principles of IsotopeSeparation.	**15 Hrs.**	**8,9**
Module 4	**Waste Disposal and Radiation Protection:** Types of Nuclear Wastes, Safety Control and PollutionControl and Abatement, International Convention on Safety Aspects, Radiation Hazards Prevention.	**15 Hrs.**	**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** **K. 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 **L. Semester End examination**

References

1. Lamarsh, J.R. (1966) Introduction to Nuclear Reactor Theory, Wesley
2. Duderstadt, J.J. and Hamilton, L.J. (1976) Nuclear Reactor Analysis John Wiley
3. Walter, A.E. and Reynolds, A.B. (1981) Fast Breeder Reactors, Pergamon Press
4. Glasstone, S. and Sesonske, A. (1981) Nuclear Reactor Engineering (3r Edition), Von Nostrand
5. Winterton, R.H.S. (1981) Thermal Design of Nuclear Reactors—Pergamon Press
6. Essentials of Nuclear Chemistry - Hari Jeevan Arnikar, New age international,1995

	MAHATMA GANDHI UNIVERSITY **EMM20C08 Bio - Energy Technology**
School Name	**School of Energy Materials**
Programme	**M. Tech. in Energy Science and Technology**
Course Name	**Bio - Energy Technology**
Type of Course	**CORE**
Credit Value	**3**
Course Code	**EMM20C08**

Course Summary & Justification	Bioenergy is one of many diverse resources available to help meet our demand for energy. It is a form of renewable energy that is derived from recently living organic materials known as biomass, which can be used to produce transportation fuels, heat, electricity, and products. Abundant and renewable bioenergy can contribute to a more secure, sustainable, and economically sound future by, supplying domestic clean energy sources, reducing the dependence on oil, generating jobs, and revitalizing rural economies. The bioenergy industry is undergoing rapid growth due to the policy drivers underpinning the current interest in bioenergy, such as energy security and climate change. This module provides an overview of key topics on sustainable bioenergy production, including the main biomass systems for bioenergy generation and the wide range of bioenergy conversion and utilisation methods. This course adopts a whole systems approach and enables students to critically appraise the sustainability of various biomass energy production routes. The module teaching and learning will comprise lectures and a site visit. The coursework requires students to either design a biofuel/bioenergy production system, or critically review a biofuel/bioenergy production process.					
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 thermodynamics					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Summarise the main sources of biomass, and the framework within which biomass is considered as a renewable energy source	U	1,7
2	Calculate the energy generating potential of biomass as an energy source used in different system design choices	U, A, An	3,4,5
3	Distinguish between the different biomass conversion processes in terms of operating conditions, useful products and by-products.	U, An	2,5,7
4	Investigate the energy conversion efficiency quantitatively using a full life cycle approach in any particular context	U, An, E	1,2,4
5	Evaluate clearly and concisely the benefits and problems relating to the production and use of different forms of biomass energy	U, A, An	3,4,5
6	Select and design systems that work for the community, the environment and the client by making the appropriate assumptions and utilising the right tools and analyses	U, A, An, E,	1,2,4,7
7	Critically assess the quality of the data and the information source. Assess the framework within which biomass is considered as a renewable energy source, including the socioeconomic, political, historical, and environmental contexts that are relevant	U, A, An, E, C	2,3,4
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.
Module 1	Introduction: Biomass: types, advantages and drawbacks, Indian scenario, characteristics, carbon neutrality, conversion mechanisms, fuel assessment studies.	**12 Hrs.**	**1,2,3**
Module 2	Biomethanation: Microbial systems, phases in biogas production, parameters affecting gas production, effect of additives on biogas yield, possible feed stocks. Biogas plants, types, design, constructional details and comparison, biogas appliances, Burner, illumination and power generation, effect on engine performance.	**12 Hrs.**	**4,5,6,7**

Module 3	**Combustion:** Perfect, complete and incomplete, equivalence ratio, fixed Bed, fluid Bed, fuel and ash handling, steam cost comparison with conventional fuels. Briquetting: types of Briquetting, merits and demerits, feed requirements and pre-processing, advantages, drawbacks.	**12 Hrs.**	**8,9**
Module 4	Gasification: Types, comparison, application, performance evaluation, economics, dual fuel engines, 100 % Gas Engines, engine characteristics on gas mode, gas cooling and cleaning train.	**12 Hrs.**	**10**
Module 5	Pyrolysis and Carbonization: Types, process governing parameters, thermo gravimetric analysis, differential thermal analysis, differential scanning calorimetry, Typical yield rates.	**12 Hrs.**	

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** **M. 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 **N. Semester End examination**

REFERENCES

1. David Boyles, (1984) *Bio Energy Technology Thermodynamics and costs*, Ellis Hoknood Chichester
2. Khandelwal, K.C, Mahdi, S.S. (1986) *Biogas Technology* – A Practical Handbook, Tata 35 McGraw Hill
3. Mahaeswari, R.C. (1997) *Bio Energy for Rural Energisation*, Concepts Publication
4. Tom B Reed, (1981*) Biomass Gasification – Principles and Technology*, Noyce Data Corporation, Best Practises Manual for Biomass Briquetting, I R E D A, 1997
5. Eriksson S. and M. Prior, (1990) *The briquetting of Agricultural wastes for fuel*, FAO Energy and Environment paper
6. Iyer PVR et al, Thermochemical Characterization of Biomass, M N E S
7.

	MAHATMA GANDHI UNIVERSITY
	EMM20E09– Materials and devices for energy application
School Name	**School of Energy Materials (SEM)**
Programme	**M. Tech Energy Science and Technology**
Course Name	**Materials and Devices for Energy Application**
Course Credit	**3**
Type of Course	**ELECTIVE**
Course Code	**EMM20C09**
Course Summary & Justification	The students are introduced into basic principles of functioning of devices for electrochemical conversion and storage. They are acquainted with physical-chemical mechanisms that are exploited by such devices during their operation. They learn about the relationship between the structure, morphology, composition and functionality of materials constituting such devices. They are acquainted with additional effects occurring upon integration of active materials into electrode composites. They are introduced into techniques for investigation of individual components (active material, additives, supports) and interaction between these components. They get acquainted with the most important existing problems and drawbacks found in the novel energy devices and measures for their further improvements. Finally, they learn about wider aspects concerning the introduction of novel devices, impact on environment and sustainable development, safety aspects, price-performance, development of relevant infrastructure etc. This course is intended as a review of the challenges facing materials scientists working in renewable energy and sustainability science and technology. It aims to give the student a birds-eye view of the current topics in energy harvesting and storage materials. The potential of various energy harvesting approaches will be discussed in the context of energy needs facing the world. This will be done with particular focus on materials innovations required to improve the state of the art. After this thorough introduction, the course will discuss solar power and electrochemical energy storage in more depth.
Semester	**2**

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 CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Elements of Semiconductor Physics** Introduction to Semiconductors, Types of Semiconductors; Crystalline and Amorphous Semiconductors; Direct and Indirect Bandgap Semiconductors; Intrinsic and Extrinsic Semiconductors; Compound Semiconductors, Behaviour of the Chemical Potential, Metal–Semiconductor Junction, Rectifying Contact, Metal–Semiconductor Junction, Ohmic Contact, The p–n Junction, Bipolar Transistor, Field Effect Transistor, Metal Oxide Semiconductor Field Effect Transistor (MOSFET), CMOS, Processing of Semiconductor Devices Organic Semiconductors: Electronic Configuration and Concept of Atomic Orbital, Hybridization and Overlapping of orbitals, Molecular Orbital, LCAO theory, Bonding and Antibonding orbitals, sigma bonding and pi-bonding, Material Origin of bandgap in organic semiconductors, Charge transport in organic semiconductors, Types of organic semiconductors, Optical and Electrical Properties of Organic Semiconductors, Organic Semiconductor Devices: Principal and Concepts, Processing of Organic Semiconducting Materials and Devices.	**10**	**1,2**
2	**Materials for hydro power generation** Introduction: India' vast potential of hydro power; problem of high silt content of Himalayan rivers and its associated erosion damage, and high velocity streaming water causing cavitation. Size and shape of particles, hardness of particles and its concentration in water. Chemical composition, microstructure, mechanical properties like hardness, ductility, tensile strength, work-hardening rate and toughness. Materials for thermal power generation: Introduction to the constraints that are currently placed 36 on power generation plant in terms of environmental impact and developing of high efficiency, low emission systems. Measures to improve the efficiency of a power plant, Increasing the temperature and the pressure of the steam entering the turbine.	**8**	**3,4**
3	**Materials for photovoltaics** Principles of photovoltaic energy conversion (PV), Types of photovoltaics Cells, Physics of photovoltaic cells; First generation solar cell materials; single and polycrystalline Silicon, amorphous silicon: growth and wafer processing, contact materials, materials for surface engineering. Second generation solar cell materials; CdSe, CdTe, Copper Indium Gallium Selenide (CIGS), Gallium Arsenide for applications in photovoltaics, Materials for thin film solar cells, Thin film processing, and properties. Contact materials for second generation solar cells. Third generation solar cell materials; Quantum Dots, Organic materials,	**10**	**5**

	Composites, Dyes, Perovskites and their synthesis, characterization and properties, Interface energetics, photoactive layers and their materials, role of electron transport, hole transport, electron blocking and hole blocking materials and their processing. Contact materials and processing of contact layers.		
4	**Materials for energy harvesting** Piezoelectric, Pyroelectric and Thermo-electrics materials, Electrostatic (capacitive), Energy Harvesting and materials, energy from Magnetic Induction, Metamaterial, energy from atmospheric pressure changes, electroactive polymers (EAPs), nanogenerators, Ambient radiation sources and nanoantenna, energy from noise.	**10**	**5,6**
5	**Materials for Energy Storage** Primary and secondary batteries. Battery Management systems and System Performance Electrochemistry and electro-chemical Battery materials, Primary and Secondary Batteries, battery potential, charge figure of merit, Energy density, power density, price and market polarization losses, thermodynamics of battery materials, tortuosity and porosity of battery materials, reversible and irreversible interfacial reactions, battery architecture and design guidelines, Cathode and anode materials, Lead–acid battery, Nickel–cadmium battery (NiCd), Nickel–metal hydride battery (NiMH), Lithium-ion battery, Lithium-ion polymer battery, Organic radical batteries, redox flow batteries, Nanostructured Carbon-based materials, Nano-Oxides, Novel hybrid electrode materials. Conducting polymer as electrode materials for batteries and supercapacitors; Bi-functional polymeric binders, Electric vehicles and failure mechanisms of lithium batteries. 37 Super Capacitor, Electrochemical supercapacitors, Basic components of supercapacitors like 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, Current status and future trends. Hydrogen Storage materials for fuel cells: Physical and chemical properties, general storage methods, compressed storage-composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, Carbon based materials for hydrogen storage. Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles. Metal hybrids, Nanostructured metal hydrides, Non-metal hydrides, Liquid organic hydrogen carriers (LOHC), Amine borane complexes, Nano borohydrides and nano catalyst doping, imidazolium ionic liquids, hosphonium borate, Carbonite substances, Metal Organic frameworks, Activated Carbons, Carbon nanotubes, Clathrate hydrates, Glass capillary arrays.	**12**	**6**
6	**Materials for fuel cells** Fuel Cells, components of fuel cells, Types of fuel cells, Acid/alkaline fuel cells, polymer electrolyte fuel cell, phosphoric acid fuel cell, molten	**10**	**6,7**

	carbonate fuel cell, Solidoxide fuel cells (SOFC), Types of solid oxide fuel cells: High temperature, intermediate temperature Single chamber solid oxide fuel cells, nanomaterials design for Proton exchange membrane fuel cells (PEMFC); Direct methanol fuel cells (DMFC); Problems with fuel cells, applications of fuel cells, difference between batteries and fuel cells, principle of working of fuel cell, performance characteristics of fuel cells, efficiency of fuel cell, fuel cell stack, description of some commercially available fuel cell stacks, fuel cell cars and buses.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the basic elements of Semiconductor Physics and theory of band structure.	U, R	1,2
2	Identify the potential of energy harvesting materials and its applications in various sectors of the society.	U, C	2,4
3	Familiarise the concept of hydroelectric and thermoelectric power production and study its environmental impacts.	U, I	2,3
4	Gain knowledge in various photovoltaic materials, devices and systems.	A, S	3,6
5	To impart knowledge on energy storage materials and devices.	U, R	3,7
6	Development of a sustainable energy harvesting and storage system.	E, S	4,7
7	To impart awareness on significance of various energy materials 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)			

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. Introduction to Solid State Physics, 8th Ed., C. Kittel, J. Wiley & Son
2. Physics of Functional Materials, Hasse Fredriksson and Ulla Åkerlind, J. Wiley & Sons
3. Textbook of polymer science, Fred W Billmeyer, J. Wiley & Sons
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21. Springer Handbook of Nanotechnology, B. Bhooshan, Springer
22. Advances in Nanomaterials, Zishan Husain Khan & M. Husain, Springer
23. Recent Trends in Nanomaterials: Synthesis and Properties (Advanced Structured Materials), Zishan Husain Khan, Springer
24. Nanomaterials and Their Applications, Zishan Husain Khan, Springer
25. Detlef Stolten, "Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications", Wiley, 2010.
26. Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, Ru-Shi Liu, "Electrochemical 39 Technologies for Energy Storage and Conversion", John Wiley and Sons, 2012.
27. Francois Beguin and Elzbieta Frackowiak ,"Super capacitors", Wiley, 2013.
28. Doughty Liaw, Narayan and Srinivasan, "Batteries for Renewable Energy Storage", The Electrochemical Society, New Jersy,2010.

	MAHATMA GANDHI UNIVERSITY
	EMM20E06– Energy efficient lighting and displays

School Name	**School of Energy Materials (SEM)**					
Programme	**M. Tech Energy Science and Technology**					
Course Name	**Energy efficient lighting and displays**					
Course Credit	**4**					
Type of Course	**ELECTIVE**					
Course Code	**EMM20E06**					
Course Summary & Justification	This course is designed at providing students with technical aspects of different lighting techniques. The course also discusses about the conventional materials used for the preparation of organic light emitting diodes (OLED) and its working principle. Moreover, the course will provide a basic concepts of various display technologies and its applications. This course is aimed at imparting advanced knowledge in Lighting and Lighting System Elements, the need of energy efficiency in lightening technique, Methodology of Lighting System. These courses also provides basic concepts of different solid state lightening techniques and carry out research on the development of organic Light Emitting Diodes and conduct studies in energy conservation and environmental protection.					
Semester	2					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Others include: Research, Fieldworks, Independent Learning etc	37			60	97
Pre-requisite	Basics of organic light emitting diodes and their working principle					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	To study the basics of lighting and lighting system elements	U	1,7
2	To learn about solid state lighting technique	U	1,7
3	Understand the concept of organic light emitting diodes	U, A,S	2,7

4	To study the concept of fiber optic lighting materials	U, An, S	3,7
5	To study in depth about display technology	U, R	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.**
1	**Introduction to Lighting and Lighting System Elements:** Need for Energy Management, Illumination requirements for various tasks Activities/Locations, Basic Terms in Lighting System and Features, Light Sources, Luminaries, Ballasts, Lamp Types and their Features, Methodology of Lighting System, Day lighting, Lighting system controls, System maintenance, Operating schedule, Psychology of changeover, Lighting energy management in buildings: Case Studies, Some Good Practices in Lighting, History of Lighting	**20**	**1**
2	**Solid State Lighting:** Florescence, Phosphorescence, Electroluminescence, Inorganic Luminescent Materials and Devices (Light Emitting Diodes and Light Emitting,Transistors) Blue and Ultraviolet LEDs, White LEDs, RGB system Phosphor Based LEDs	**20**	**2**
3	**Organic Light Emitting Diodes:** Introduction to Organic Semiconductors, Classification of Organic Semiconductors, Florescence, Phosphorescence, Thermally Active Delayed Fluorescence and Hyperfluorescence in Organic Materials, Different generations of Organic Light Emitting Diodes and their processing, Blue OLEDs and White OLEDs, Technical aspects of OLEDs	**15**	**3**
4	**Fiber Optic Lighting:** Types of Fibers, Fabrication technology, Materials development for fibre optic, Transmission losses, Use of fibre in lighting	**15**	**4**
5	**Display Technology:** History of Display Technology, LCD display technologies and devices thin-film transistor (TFT) technology for LCD, Back lighting technologies for LCDs, Field-emissive, electro-chromic, and photo-chromic displays, Plasma Display, Electronic-ink, electronic paper (e-paper) and flexible display technologies and their applications, Laser based projection displays, Digital micromirror devices (DMD) and pico-projectors, Three-dimensional (3-D) display technologies, Micro displays, STEREOSCOPIC 3D displays, Integral imaging, Polarization based 3Ddisplays, HOLOGRAPHIC 3-D displays, Laser based 3D-TV	**20**	**5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** 1. Direct Instruction: Lecture, Explicit Teaching, E-learning 2. Interactive Instruction: Active co-operative learning, Seminar, Group Assignments Authentic learning 3. Flip classroom
Assessment Types	**Mode of Assessment** **A.** Formative Assessment **B.** Summative assessment

REFERENCES

01. Fundamentals of Solid-State Lighting: LEDs, OLEDs, and Their Applications in Illumination and Displays, Vinod Kumar Khanna, CRC Press
02. Materials for Solid-State Lighting and Displays, Adrian Kitai, John Wiley & Sons Ltd.
03. Handbook of Display Technology, Joseph A. Castellano, Gulf Professional Publishing
04. Handbook of Visual Display Technology, Janglin Chen, Wayne Cranton, Mark Fihn, Springer

	MAHATMA GANDHI UNIVERSITY
	EMM20E07– Photovoltaic Techniques
School Name	**School of Energy Materials (SEM)**
Programme	**M. Tech Energy Science and Technology**
Course Name	**Photovoltaic Techniques**
Course Credit	**4**
Type of Course	**ELECTIVE**
Course Code	**EMM20E07**

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
		40	40		40	120
Pre-requisite	Basics of Solar Energy: Energy and development, Units and measurements, Solar spectrum, Electromagnetic spectrum.					

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 atmospheric effects on sunlight, Photovoltaic effect, conversion of solar energy into electrical energy, behaviour of solar cells	**10**	**1,2**
2	**Photovoltaic devices, modules and technical parameters** Solar cells, basic structure and characteristics: Single-crystalline, multicrystalline, thin film silicon solar cells, emerging new technologies, Electrical characteristics of the solar cell, equivalent circuit, modeling of solar cells including the effects of temperature, irradiation and series/shunt resistances on the open-circuit voltage and short-circuit	**15**	**1,3**

	current. Solar cell arrays, PV modules, PV generators, shadow effects and bypass diodes, hot spot problem in a PV module and safe operating area. Terrestrial PV module modelling.		
3	**Solar Power Plant** Components and Working: 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, Inverters.	**10**	**4,5**
4	**Solar Power Management** Power conditioning and maximum power point tracking (MPPT) algorithms based on buck- and boost-converter topologies, Maximum power point tracking (MPPT) algorithms, Inverter topologies for stand-alone and grid-connected operation. Analysis of inverter at fundamental frequency and at switching frequency.	**15**	**6**
5	**Grid Codes and Standards** Grid Codes, Anti Islanding protection, LVRT protection, HVRT Protection, Active and Reactive Power Control, Advance Control for Inverters, Feasible operating region of inverter at different power factor values for grid-connected systems	**10**	**5,6**

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
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)** 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. Photovoltaics: Designs, Systems and Applications, Michael Stock, Larsen and Keller Education

2. Photovoltaics: Engineering and Technology for Solar Power, Catherine Waltz, Syrawood Publishing House

3. Principles of Solar Engineering, D. Goswami, CRC Press

4. Solanki S. Chetan. Solar Photovoltaics: Fundamentals, Technologies and Applications, New Delhi, PHI, 2012.

	MAHATMA GANDHI UNIVERSITY
	EMM20E08– Semiconductor nanostructures for optoelectronics

School Name	**School of Energy Materials (SEM)**
Programme	**M. Tech Energy Science and Technology**
Course Name	**Semiconductor nanostructures for optoelectronics**
Course Credit	**2**
Type of Course	**ELECTIVE**
Course Code	**EMM20E08**

Course Summary & Justification	This course is designed at providing students with concepts of quantum dots and the devices developed using the QD materials and preparation methods and device characterization techniques etc. Nanostructured semiconductors or quantum dots have attained great potential focus on the optoelectronic properties because of their excellent applications. Quantum dots are one of the eminent and innovative materials for applications such as LEDs, solar cell, biosensors, imaging, cancer therapy, etc. This course aims to impart basic knowledge on nanostructures like quantum dots.					
Semester	2					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Others include: Research, Fieldworks, Independent Learning etc	35			60	95
Pre-requisite	Basics of nanostructured materials, synthesis, application etc.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the concept of QD materials, optoelectronic devices	U,I	1,2
2	Understand the theory and & concept of QD lasers	R,U,I	1,2,3
3	To learn about various characteristics of QD Lasers	U, A,I	2,7
4	To impart knowledge on different optoelectronic devices based on fiber optic technology	R,U, An	2,3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Quantum Dot Infrared Photodetectors:** QD and QDIP Structure Growth and Characterization, GaAs Capped Large and Small InAs QDs, AlGaAs Capped Large InAs MQD QDIP Structures, QDIP Device Characteristics Device Structures Detectors	**20**	**1**
2	**Quantum Dot Lasers:** Theoretical Overview, Dimensionality and Laser Performance, Advantages of an Idealized QD Laser, Progress in fabricating QD Lasers, State-of the-Art Complications, High-Speed Quantum Dot Lasers, MBE Growth of Self-Organized QDs	**25**	**2**

3	**Characteristics:** Characteristics of High-Speed Tunneling-Injection QD Lasers, Room Temperature DC Characteristics, Temperature-Dependent DC Characteristics, High-Speed Modulation Characteristics	**20**	**3**
4	**Fiber Optic Lighting:** Zinc Oxide-Based Nanostructures, General Properties of ZnO, ZnO One-Dimensional Nanostructures, Growth Mechanisms, Growth Techniques, Structural Characterizations, Optical Characterizations, Optical Devices, Electronic Devices	**25**	**4**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Direct Instruction: Lecture, Explicit Teaching, E-learning, Interactive Instruction: Active co-operative learning, Seminar, Group Assignments Authentic learning, Flip classroom
Assessment Types	**Mode of Assessment** **C.** Formative Assessment **D.** Summative assessment

REFERENCES

01. Semiconductor nanostructures for optoelectronic applications: Todd D.Steiner
02. Semiconductor nanostructures for fundamental physics & optoelectronic applications: J.P.Reithmaier
03. Recent advances in quantum dot optoelectronic devices & future trends: S.Kim&M.Razeghi
04. Quantum photovoltaic devices based on Antimony compound semiconductors : Y.Wei, A.Gin&M.Razeghi
05. Mid -infrared optoelectronics: A.Keir
06. Semiconductor Nanostructures for Optoelectronic Devices, Yi, Gyu-Chul Springer 2012.
07. Optoelectronics, Emmanuel Rosencher , Cambridge University Press 2010
08. Optoelectronics, an introduction, J. Wilson,1983, Science.

	MAHATMA GANDHI UNIVERSITY **METALS, CERAMICS AND COMPOSITE MATERIALS FOR ENERGY APPLICATIONS**
School Name	**School of Energy Materials**
Programme	**M.Tech in Energy Science and Technology**
Course Name	**Metals, Ceramics and Composite Materials for Energy Applications**
Type of Course	**Core**
Credit Value	**4**
Course Code	**EMM20E09**

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	**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. 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** **O. 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 **P. 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
	EMM20E10– Statistical Mechanics

School Name	**School of Energy Materials (SEM)**
Programme	**M. Tech Energy Science and Technology**
Course Name	**Statistical Mechanics**
Course Credit	**2**
Type of Course	**ELECTIVE**
Course Code	**EMM20E10**
Course Summary & Justification	Statistical mechanics thus not only provides a foundation for thermodynamics and the properties of gases, but generally for condensed matter in the form of fluids, glasses, crystals, semiconductors, superconductors, polymers, biomaterials, etc. Its concepts find broad applications in astrophysics, geophysics, particle physics, chemistry, biology, and engineering science. This course offers an introduction to probability, statistical mechanics, and thermodynamics. Specific topics in probability include random variables, joint and conditional probability densities, and functions of a random variable. Concepts in statistical mechanics include macroscopic variables and thermodynamic equilibrium, fundamental assumptions of statistical mechanics, and microcanonical and canonical ensembles. Also covered are the first, second, and third laws of thermodynamics. Numerous examples illustrating a wide variety of physical phenomena such as magnetism, polyatomic gases, thermal radiation, electrons in solids, and noise in electronic devices are discussed.
Semester	2

Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Others include: Research,	37			60	97

	Fieldworks, Independent Learning etc					
Pre-requisite	Basics of thermodynamics and properties of different states of materials					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Students will have achieved the ability to find the connection between statistics and thermodynamics	U, R, I	1,3, 4
2	To learn the differentiate between different ensemble theories used to explain the behavior of the systems	U, S, I,A	1, 5,7
3	Differentiate between classical statistics and quantum statistics.	U, R, S, A	2,7
4	To explain the statistical behavior of ideal Bose and Fermi systems	U, R, An	3, 4
5	To understand physical significance of statistical quantities	U, R, A	2,4
6	To understand behaviour of ideal gas in quantum mechanical micro canonical ensemble and other quantum mechanical ensemble	U, R, S, I	1, 2, 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**Thermodynamics and Statistical theory** Laws of thermodynamics and their consequences. Thermodynamic potentials and Maxwell's relations. Chemical potential. Phase equilibriam. The macroscopic and microscopic states –contact between statistics and thermodynamics – the classical ideal gas – entropy of mixing and the Gibb's paradox – Phase space of a classical system – Liouville's theorem and it's consequences – The micro canonical ensemble – quantum states and phase space – The equi partition theoremThe Virial theorem	**15**	**1,2**
2	**The Canonical and grand canonical ensemble** Equilibrium between a system and heat reservoir – a system in the canonical ensemble – thermo dynamical relations in a canonical ensemble – the classical systems – energy fluctuations in the canonical ensemble: correspondence with micro canonical ensemble – equilibrium between a system and a particle energy reservoir – a system in the grand canonical ensemble – physical significance of statistical quantities – density and energy fluctuations in the grand canonical ensemble	**15**	**3,4**
3	**Quantum statistics** Quantum mechanical basis – statistical distribution – an ideal gas in quantum mechanical micro canonical ensemble and other quantum mechanical ensemble – Partition functions and other thermodynamic quantities of monatomic and diatomic molecules. Thermodynamic behavior of a Bose gas – thermodynamics of Black body radiation – Bose Einstein condensation	**15**	**4**
4	**Theory of Phase transition and fluctuations** Problem of condensation **-** Ginzburg – Landau theory – Ising model and it's solution for a linear chain – equivalence of Ising model to other models – Lattice gas and binary alloy. Fluctuations – Brownian motion – Langevin equation	**10**	**5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** 4. Direct Instruction: Lecture, Explicit Teaching, E-learning 5. Interactive Instruction: Active co-operative learning, Seminar, Group Assignments Authentic learning 6. Flip classroom
Assessment Types	**Mode of Assessment** **E.** Formative Assessment **F.** Summative assessment

REFERENCES

01. Introductory Statistical Mechanics, R. Bowley&M.Sanchez, 2nd Edn. 2007, Oxford University Press, Indian Edition, (Chaptr 11& 12)
02. Statistical Mechanics, R.K. Pathria, & P.D. Beale, 2nd Edn, B-H (Elsevier) (2004).
03. Statistical Mechanics, Kerson Huang, John Wiley and Sons (2003).
04. Statistical mechanics and properties of matter – E S R Gopal
05. Statistical thermodynamics - M C Gupta
06. An introduction to thermodynamics- Y V C Rao
07. Fundamentals of Statistical Mechanics, B. B. Laud, New Age International.
08. Statistical Mechanics, B.K. Agarwal and M. Eisner, Wiley Eastern
09. Elements of Statistical Mechanic, Kamal Singh, S P. Singh, S. Chand & Co

Viva Voce

	MAHATMA GANDHI UNIVERSITY
	EMM20C11 Mini Project & Viva Voce

School Name	**School of Energy Materials**
Programme	**M. Tech in Energy Science and Technology**

Course Name	**Mini Project & Viva Voce**					
Type of Course	Core					
Course Code	**EMM20C11**					
Course Summary & Justification	Train the student to assimilate research problems and research attitude by acquiring hands-on experience in either experimental/computational polymer materials or both. Relevance of scientific literature in knowledge addition and problem identification would be emphasised. Encourage the student to initiate the process of literature review and use of online research repositories. Research literature documentation and rudimentary research writing is envisaged in this course.					
Semester	2		**Credit**		2	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning			40	40	80
Pre-requisite	Fundamental understanding and knowledge of polymeric materials.					
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	Conceive a research problem in the area of polymer science by the application of scientific methodologies	U, C	1,2,3,4,5,7
2	Apply scientific methodologies to solve the problem either through experiments or simulation or applying both.	C, A	1,2,3,4, 7,8
3	Perform experiment or simulation or both to accomplish the outcome of the research.	An, E	4,7
4	Analyse results and arrive at inferences and conclusions drawn out of it. Also understand the documentation procedure for project report writing.	An, E	3, 7
5	Present the scientific insight and knowledge derived by performing research work before a board of experts in the field of polymer science.	S, An, Ap, I	3, 5,9
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)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – prepare mini project/review report and present in the seminar

<u>SEMSETER 3 and SEMSETER 4</u>

The M. Tech students will undergo rigorous research project training in leading industries or research laboratories for one full year. The projects are intended to carry out in leading institutions preferably in abroad.

	MAHATMA GANDHI UNIVERSITY
	EMM20C12 Project Work – Phase I

School Name	**School of Energy Materials**					
Programme	**MTech. Energy Science and Technology**					
Course Name	**Project Work – Phase I**					
Course Credit	**16**					
Type of Course	**CORE**					
Course Code	**EMM20C12**					
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 and the Internal Examiner.					
Semester	**III**					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Library work, lab work, Team work, independent learning	-	-	-	-	-
Pre-requisite	Excellent Lab skills and knowledge of different characterization techniques.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the course the students are expected to		
	To clearly present and discuss the research objectives, methodology, analysis, results and conclusions effectively.	A	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	6,9
7	Create, analyse and critically evaluate different problems and their solutions.	C	7,8
8	Gain a consciousness of 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 internal examiners.

SEMESTER IV

	MAHATMA GANDHI UNIVERSITY
	EMM20C13 Comprehensive Viva Voce

School Name	**School of Energy Materials**					
Programme	**M.Tech. in Energy Science and Technology**					
Course Name	**Comprehensive Viva Voce**					
Course Credit	**4**					
Type of Course	**CORE**					
Course Code	**EMM20C13**					
Course Summary & Justification	The comprehensive viva-voce shall be conducted by the Examination Board consisting of the Chairman and the Internal Examiner . The relevance and significant features will be analysed.					
Semester	**IV**					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Classroom studies, lab work, library Library work, independent learning etc.	-	-	-	-	-
Pre-requisite	Basic as well as in-depth knowledge in the coureses he/she studied					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the course the students are expected to		
1	Achieve fundamental and in-depth knowledge	A,C	3,4
2	Acquire more in-depth knowledge of the major subject of study	Ap	1,2,3,4,5,6,7
3	Deeper knowledge of methods in the major subject of study.	A	1, 4,8
4	Able to contribute to research and development work.	U	3,8,9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** 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** Thorough understanding of all the M.Tech. level course contents and recent trends in the broad area of chemical sciences are evaluated. The candidate will be asked questions based on the whole syllabus he/she studied in the entire programme. How he/she answered or responded the questions asked will be considered for evaluation.

	MAHATMA GANDHI UNIVERSITY

	EMM20C14 Project Work – Phase II

School Name	**School of Energy Materials**					
Programme	**MTech. Energy Science and Technology**					
Course Name	**Project Work – Phase II**					
Course Credit	**12**					
Type of Course	**CORE**					
Course Code	**EMM20C14**					
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 and the Internal Examiner.					
Semester	**IV**					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Library work, lab work, Team work, independent learning	-	-	-	-	-
Pre-requisite	Excellent Lab skills and knowledge of different characterization techniques.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	At the end of the course the students are expected to		
	To clearly present and discuss the research objectives, methodology, analysis, results and conclusions effectively.	A	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	6,9
7	Create, analyse and critically evaluate different problems and their solutions.	C	7,8
8	Gain a consciousness of 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 internal examiners.