M. Sc. Physics

(Specialization in Energy Science)

Curriculum

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

SCHOOL OF ENERGY MATERIALS

MAHATMA GANDHI UNIVERISTY

KOTTAYAM

1. **TITLE OF THE PROGRAMME:**

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

2. **ABOUT THE COURSE:**

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

3. **ELIGIBILITY FOR ADMISSION**:

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

4. **ADMISSION CRITERIA:**

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

5. **STUDENT INTAKE:**

10 Seats + 2 (International)

6. **DURATION OF THE COURSE**:

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

7. **SCHEME OF CLASSES:**

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

8. **PROJECT WORK:**

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

9. FEE STRUCTURE:

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

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

10. COURSES AND CREDITS

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

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

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

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

A. Theory

Components' % of internal marks

1) Two test papers - 60%

2) Assignments/Book Review/debates - 20%

3) Seminars/Presentation of case study - 20%

B. Practical's

Components' % of internal marks

1) Two test papers - 40%

2) Lab Skill - 25%

3) Records/Viva - 25%

4) Attendance - 10%

11. EVALUATION

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

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

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

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

12. PROCESS OF EVALUATION

The internal assessment will be a continuous assessment (CA) that accounts for 40% of the evaluation in both theory and 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

Continuous Assessment (CA): The student's participation and classroom performance as well as the feedback received from tests, tutorials, assignments and term papers shall form the basis for continuous assessment (CA). It accounts for 40% of the evaluation in both theory and practical's.

This assessment shall be based on a predetermined transparent system involving periodic written tests, assignments and seminars in respect of theory courses and based on tests, lab skill, records/viva and attendance in respect of practical courses.

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

a. Theory

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

b. Practical's

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

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

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/ externalguide.

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

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

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

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

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

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

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

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

Section	Cognitive level	Choice and marks of questions	Question specification	Total Marks	Alignment with Cours outcomes (COs)
Section A	Remembering/Understa ding/Applying/Evaluati g.	12 outof 15 questions;3 marks each	Minimum one question from eachunit.	36	Aligned with COs

Section B	Applying/Analysing/ Evaluating/Creating	4 out of 7 questions; 6 marks each	Minimum one question from eachunit	24	Aligned with COs
				60	

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

- **Lower levels** of learning (Remembering/Understanding/Applying) :30 to40%
- **Higher Levels** of Learning (Analyzing/Evaluating/Creating) : 60 to70%

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

- Low: 20 to30%
- Moderate: 55 to65%
- High: 15 to25%

14. 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 relative value of the Grades (Grade points)

Range of % of Marks	Grade	Performance	Grade Point
95 % ≤ 100	O	Outstanding	10
85 % < 95	A Plus	Excellent	9
75 % < 85	A Only	Very Good	8
65 % < 75	B Plus	Good	7
55 % < 65	B Only	Above Average	6
45 % < 55	C Only	Average	5
40 % < 45	P Only	Pass	4
Below 40	F	Fail	0
Absent	Ab	Absent	0

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

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

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

16. REVALUATION

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

17. REAPPEARANCE AND IMPROVEMENT IN EXAMINATIONS:

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

18. REGISTRATION FOR IMPROVEMENT

A candidate has to apply for registration for improvement by paying the requisite fee. Candidates are not permitted to register for improvement of grades for Individual course. Candidates in the1st and 2nd semesters, who have secured SGPA letter grade 'P' or above in the End Semester Examination can improve their grade by reappearing for all the semester courses along with the next immediate batch. In such cases a candidate will be awarded a new grade only if there is an improvement in grade in the new examination; otherwise, the candidate is eligible to retain the grade already awarded. Candidates in the 3rd semester, who have secured the SGPA letter grade 'P' or above in the End Semester Examination, can improve their grade by reappearing for all the semester courses, along with the 3rd semester supplementary examination being conducted for failed candidates immediately after the completion of End Semester Examination of Fourth semester. This provision is applicable only for third semester. Improvement of the 4th semester can be done along with the immediate lower batch. If the improvement is meant to obtain minimum CGPA requirement, a candidate has the option to decide which semester (3rd or 4th) is to be improved; however, the grade given to the candidate shall be that obtained for the entire semester improvement examination. 1st and 2nd semester SGPA cannot be improved after the completion of the 4th semester. Only 3rd and 4th semester SGPA can be improved after the completion of a programme. The marks/grades awarded for Continuous assessment and that for the Project/dissertation cannot be improved. SGPA secured in the 4th semester can be improved only for the purpose of fulfilling the minimum CGPA requirement.

19. REAPPEARANCE

Candidates in the 1st and 2nd semesters who have secured a letter grade of‛ F' or 'Ab' in any of the courses can avail two immediate consecutive chances to reappear for 23 examination, course wise, provided the candidate has applied for the same and paid the required fee. Candidate in the3rd semester who has secured letter grade of 'F' or'Ab' in any of the courses can reappear for exams course-wise in the 3rd semester supplementary examination, which will be conducted immediately after the completion of End Semester Examination of Fourth semester, provided the candidate has applied for the same and paid the required fee (fee for supplementary examination of any course shall be full semester examination fee irrespective of number of courses involved). Candidates who secured the grade of only 'F' or 'Ab' in a course in the 4th semester examination can re-appear course wise, along with the immediate lower batch. Candidates who secured the grade of only 'F' or 'Ab' in a course in the 3rd /4th semester examinations will be given two additional chances for course-wise reappearance even after the completion of the programme; but it has to be done within a period of two years after the completion. In such cases a candidate has to apply for the same as a supplementary exam and pay the required fee (Fee for supplementary examination of any course shall be full semester examination fee irrespective of number of coursesinvolved).

20. REQUIREMENTS OF ATTENDANCE AND PROGRESS

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

1. The candidate has not less than 75% of attendance in each of the subjects of the total number of working days of the concerned semester.

2. His/her progress has been good

3. His/her character and conduct has been good

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

21. PROCEDURE FOR COMPLETING COURSE

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

22. ADD-ON COURSES

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

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

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

Faculty

Upon successful completion of two years in the program the candidates will be awarded a Master's Degree under the Faculty of Science. (As per the M G University CSS regulations amended from time to time)

23. CURRICULUM

M.Sc. PHYSICS (Specialisation in Energy)

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

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

Features of this program

- Courses with in-depth understanding of physics aspects of energy materials along with hands-on experimental facilities

- Detailed chemical synthesis and characterization-based laboratory experiments
- Computational methods-oriented laboratory course which is a must for modern material scientists
- Vast choice of discipline electives to be chosen from pool of courses of School of Energy Materials pertaining to Energy Science
- Scope of focused research on materials-energy-materials for energy nexus
- Prospect to receive foreign university fellowship for excellent students to pursue research project in Semester IV.
- Opportunity for highly motivated students to pursue PhD in reputed foreign universities.

Programme Outcomes (PO) of Mahatma Gandhi University

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

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

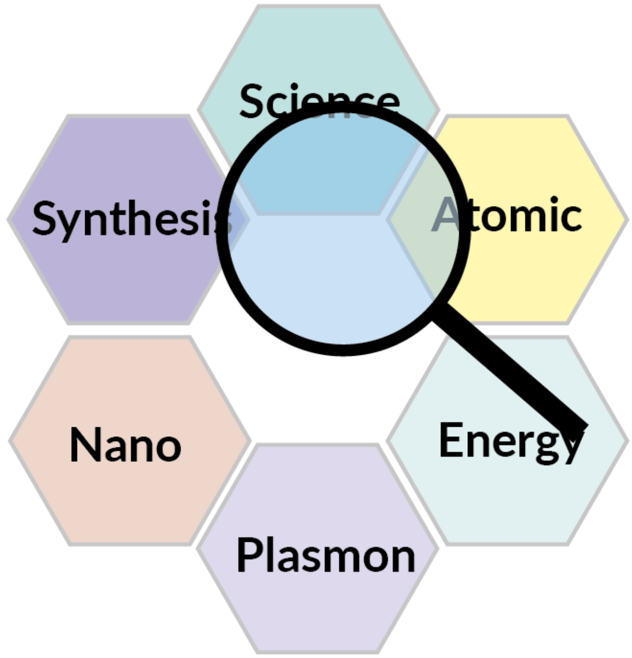
PO 7: Equity, Inclusiveness and Sustainability Appreciate equity, inclusiveness and sustainability and diversity; acquire ethical and moral reasoning and values of unity, secularism and national integration to enable to act as dignified citizens; able to understand and appreciate diversity, managing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

PO10: Lifelong Learning Ability to acquire knowledge and skills, including "learning how to learn", that are necessary for participating in learning activities throughout life, through self- paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/skill development/re skilling

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



M.Sc. Programme in Physics (Specialization in Energy)

(Syllabus effective from 2023 Admission onwards)

School of Energy Materials

Mahatma Gandhi University Kottayam

PREAMBLE

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

BRIEF HISTORY OF THE DEPARTMENT

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

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

SCHOOL OF ENERGY MATERIALS

PROGRAMME : M. Sc. Physics (Specialization in Energy Science)

DURATION : 2 years (2023 Admission onwards)

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

Total : 88 credits

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

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

SEMESTER I

Semester 1

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
1	**EMM23C51**	Mathematical Physics	3	15+3	24
2	**EMM23C52**	Classical Mechanics	3		
3	**EMM23C53**	Quantum Mechanics I	3		
4	**EMM23C54**	Advanced Electronics	3		
5	**EMM23C55**	**LAB I** – Advanced Electronics Lab	3		
6	**EMM23C56**	Internship/Miniproject	3		
***Elective Courses**					
7	**EMM23E21**	Hydrogen and Fuel cells	3	6	
8	EMM23E22	Material Synthesis and Characterisation Techniques	3		
9	EMM23E23	Thin film science and Technology	2		
10	EMM23E24	Bioenergy Technology	2		
11	EMM23E51	Laser and Non-linear optics	2		

Semester 2

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
12	**EMM23C57**	Statistical Mechanics	3	15+3	24
13	**EMM23C58**	Quantum Mechanics II	3		
14	**EMM23C59**	Electrodynamics	3		
15	**EMM23C60**	Power Electronics and Applications	3		
16	**EMM23C61**	**LAB II**- Advanced Experiments - Physics	3		
17	EMM23C62	Internship/Miniproject	3		
***Elective Courses**					
18	**EMM23E26**	Energy conversion, storage and transportation	3	6	
19	**EMM23E52**	MEMS and Nanofabrication	3		
20	EMM23E53	Advanced Magnetism and Magnetic Materials	2		

21	EMM23E29	Nuclear Energy and Technology	2		
22	EMM23E30	Energy from wind, geothermal and water	2		

<u>Semester 3</u>

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
23	**EMM23C63**	Nuclear and Particle Physics	3	15	24
24	**EMM23C64**	Condensed Matter Physics	3		
25	**EMM23C35**	Advanced computation in Material science	3		
26	**EMM23C65**	Atomic and Molecular Physics	3		
27	**EMM23C36**	**LAB III -** Energy device and fabrication	3		
***Elective Courses**					
28	**EMM23E31**	Energy device and fabrication	3	5	
29	EMM23E32	Metal, ceramics and composites materials for Energy applications	3		
30	EMM23E54	Astrophysics	2		
31	EMM23E34	Research Methodology	2		
32	EMM23E35	Nano sensors and nanodevices	2		
33	EMM23E36	Nanotechnology in Energy	2		
34		**Open Course**	4	4	

<u>Semester 4</u>

Sl. No.	Course Code	Name of the Course	Credits	Credits Required	Total Credits
34	**EMM23C66**	Dissertation/Viva-voce	13	16	16
36	**EMM23C67**	Industrial visit	3		

SEMESTER I

	MAHATMA GANDHI UNIVERSITY
	Mathematical Physics
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Mathematical Physics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C51**

Course Summary & Justification	This course introduces different mathematical tools used in physics to the students. The course aims to prepare the students for understanding and applying various mathematical formalisms used in physics. The material covered in this course is very important for students as the mathematical techniques introduced find applications in every branch of physics and other quantitative sciences.					
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	Introductory mathematical knowledge of algebra, trigonometry, calculus; basic knowledge of problem solving.					
Others- Library, field work, 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	Categorize physical properties according to the medium of their occurrence.	U,R	2,3
2	Demonstrate an understanding of basic tensor analysis	U, An	2,6
3	Comprehend the linear algebra underlying many of the numerical simulation algorithms	E	1,8

4	Solve problems involving calculus of functions of a complex variable	E,S	9,4
5	Identify the applicability of special functions and polynomials.	A,An	6,2
6	Customize differential equations to depict various real-world problems	A	1,8
7	Solve basic problems in probability and demonstrate an understanding of the Binomial, Poisson and Gaussian probability distributions.	E,S	9,4
***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	Matrices and vector spaces: Vector spaces, linear operators, matrices, basic matrix algebra, functions of matrices, transpose, Hermitian conjugate, trace, determinant, inverse and rank. Special types of square matrices, Eigenvectors and eigenvalues, Change of basis and similarity transformation, diagonalisation, simultaneous linear equations.	**15 Hrs.**	**1**
Module 2	Review of vector calculus. Orthogonal curvilinear coordinates cylindrical and spherical polar coordinates. Vector integration and integral theorems. Tensor analysis: Contravariant and covariant vectors, Basic operations with tensors, Quotient law, The line element and metric tensor.	**10 Hrs.**	**2,3**
Module 3	Complex numbers, functions of a complex variable, mapping, branch lines and Riemann surface. Calculus of functions of a complex variable, elementary functions of z. Complex integration. Series representations of analytic functions. Integration by the method of residues, evaluation of real definite integrals.	**15 Hrs.**	**4**
Module 4	Gamma functions – Gauss λ functions, values of Γ1/2 – β functions- connection between β and Γ functions- Error function – Dirac delta function – representation of δ function – properties.	**10 Hrs.**	**5**
Module 4	Solution of linear second order differential equations. The Euler linear equation. Solutions in power series - Frobenius method, Bessel's equation. Simultaneous equations. Partial differential equations, Solutions of Laplace's and wave equation, solution Poisson's equation - Green's function method, Laplace and Fourier Transform methods.	**10 Hrs.**	**6,7**

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

Reference Books:

1. George Arfken, Mathematical Methods for Physicists, Fourth (Prism Indian) 7th Edition, Elsevier (2012).
2. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).
3. Mathematical Physics, B.D.Gupta, 4th edition, Vikas Publishing House Pvt.Ltd., 2010.
4. Mathematical Physics, Satya Prakash, S.Chand and Sons, 6th edition, 2021
5. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001).
6. Schaum's outline series, Mcgraw Hill, 1964: (i) Vector and tensor analysis (ii) Linear Algebra (iii) Differential Equations.
7. E. Kreyszig, Advanced Engineering Mathematics, Wiley Eastern, 5th Edition, 1991
8. E. Kreyszig, Introductory Functional Analysis and Applications, John Wiley, 1978.
9. M. Boas, Mathematical Methods in Physics Sciences, 2nd Edition, Wiley International Edition, 1983.

	MAHATMA GANDHI UNIVERSITY
	Classical Mechanics
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Classical Mechanics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C52**

Course Summary & Justification	The course aims to develop an understanding of Lagrangian and Hamiltonian formulation which enable the students for simplified treatments of many complex problems in classical mechanics and provides the foundation for the modern understanding of dynamics. In a detailed way, since this course forms the foundation for the study of many areas of Physics, it apprises the students about Lagrangian and Hamiltonian formulations.					
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	Introductory mathematical knowledge of algebra, trigonometry, vector and tensor analysis, calculus; basic knowledge of Newtonian mechanics.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Get exposure to the Newtonian mechanics and variational formulation.	U,R	4,6,7
2	Comprehend and learn more abstract Lagrangian and Hamiltonian mechanics.	E	2,6,7

3	Identify generalized coordinates and coordinate transformations of a rigid body. Comprehend various aspects of rigid body dynamics.	An	2,6
4	Be able to solve some real-world problems using canonical transformations.	A,An	2,6
5	Understanding the basic features of non-linear dynamics	U	2,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	**Lagrangian formulation** Mechanics of a system of particles (brief review) - Constraints - Generalized coordinates - D'Alembert's principle and Lagrange's equations -Calculus of variations and Derivation of Lagrange's equations form it. Symmetry properties and Noether's theorem. Application of Lagranges equation to Central force problem - equivalent one dimensional problem - classiffication of orbits - the differential equation for orbits - Kepler problem.	**15 Hrs.**	**1,2**
Module 2	**Hamiltonian Mechanics** Derivation of Hamilton's equation form variation of principle (Principle of least action with fixed end points), cyclic coordinates. Equations of canonical transformation - examples. Poisson Brackets- Equations of motion, angular momentum Poisson Bracket relations. Hamilton-Jacobi equation - harmonic oscillator problem - Hamilton's characteristic function.	**15 Hrs.**	**2,3,4**
Module 3	**Rotational dynamics** Independent co-ordinates of a rigid body. Orthogonal transformations - Euler angles - rigid body equations of motion- angular momentum and kinetic energy of motion about a point- inertia tensor- Solving rigid body problems and Euler equations of motion- torque free motion of a rigid body symmetric top. Rate of change of a vector, centrifugal and Coriolis forces.	**15 Hrs.**	**3,4**
Module 4	**Nonlinear dynamics and chaos** Chaotic trajectories and Liapunov exponents. Poincare maps. Logistic maps. Bifurcations, driven damped harmonic oscillator, parametric resonance. Logistic equation. Fractals and dimensionality: Cantor set, Sierpinski carpet.	**15 Hrs.**	**5**

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

Reference Books:

1. H. Goldstein, C. Poole and J. Safko , Classical Mechanics, Third Edition, Pearson (2011).
2. N. C. Rana and P.S. Joag: Classical Mechanics, TMH, 1994
3. Michael Tabor, Chaos and Integrability in Nonlinear Dynamics, Wiley (1989).
4. V. B. Bhatia , Classical Mechanics, Narosa (1997).
5. Landau and Lifshitz, Mechanics Vol. I, 3rd Edition, Butterworth-Heinemann (1976).

	MAHATMA GANDHI UNIVERSITY
	Quantum Mechanics I
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Quantum Mechanics I**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C53**
Course Summary & Justification	This course provides a substantive introduction to the mathematical setting to the formulation of quantum mechanics and explains the basic concepts and elementary theory. It discusses the most important 1D and 3D quantum mechanical problems which helps to analyse the concept of quantum mechanics in potential practical applications. It also discusses Schrodinger and Heisenberg formulations of quantum mechanics.
Semester	**I**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Students will get an understanding of linear vector spaces that are fundamental to quantum mechanics. They will also learn concepts and properties of inner-product, basis, linear operators and Hermitian operators etc. (Module 1)	U, A	6,8
2	Students will be able to understand the postulates of quantum mechanics	U, A	2

3	Students will solve various 1-dimensional time independent problems in quantum physics. This will help them to formulate such problems and understand the general properties of solutions. (Module 3)	U, A	2,7
4	The student will learn to solve various 3-dimensional time independent problems like Hydrogen atom in Quantum Mechanics. Study of angular momentum and atomic structure will be crucial to understand other subjects like spectroscopy (Module 4).	An, E	2,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT:

Module No:	**Module Content**	**Hrs.**	**CO No.**
Module 1	Linear Vector Spaces de Broglie's hypothesis: matter waves and experimental confirmation, wave packets; Linear vector spaces: inner product, Hilbert space, Wave Functions; Linear operators: Hermitian operators, Projection operators, Commutator algebra, Unitary operators, Eigenvalues and Eigen vectors of a Hermitian operator; Basis: Representation in discrete bases, Matrix representation of kets, bras, and operators, Change of bases and unitary transformations, Matrix representation of the eigenvalue problem, Representation in position bases.	**15 Hrs.**	**1**
Module 2	Postulates of Quantum Mechanics: State of a System, Probability Density, Superposition Principle, Observables as Operators, Position and Momentum operators, Position and Momentum representation of state vector, Connecting the position and momentum representations, Measurement in quantum mechanics, Expectation values, Commuting operators and Uncertainty relations; Time evolution of the state: Time-independent potentials and Stationary States, Time evolution operator, infinitesimal and finite Unitary Transformations; Conservation of probability; Time evolution of expectation values: Ehrenfest theorem; Poisson's brackets and commutators; Matrix and Wave mechanics	**18 Hrs.**	**2**
Module 3	Discrete, continuous and mixed spectrum; symmetric potentials and parity; Infinite square well potential; Symmetric potential well; Finite square well potential: Scattering and bound state solutions; Free particle; Delta	**12 Hrs.**	**3**

	function potential; Harmonic oscillator.		
Module 4	Free particle in 3-dimensions: spherically symmetric solution; Particle in a 3D box; Schrodinger equation in presence of central Potential; Orbital angular momentum: eigen values and eigen functions of L^2 and L_z; Hydrogen Atom; Scattering: Cross Section, Amplitude and Differential Cross Section, Scattering of Spin-less Particles, The Born Approximation, Validity of the Born Approximation	**15 Hrs.**	**4**

Teaching and Learning Approach		Classroom Procedure (Mode of transaction) Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types		Mode of Assessment 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

Reference Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009.
2. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004
3. G. Aruldhas, Quantum Mechanics, PHI learning Pvt Ltd, second edition, 2009
4. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley, 1994
5. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994
6. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill, 2010
7. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985
8. E. Merzbacher, Quantum Mechanics, 2nd Edition, Wiley International Edition, 1970
9. NouredineZettili, Quantum Mechanics: Concepts and Applications, Wiley India, 2016
10. V. K. Thankappan, Quantum Mechanics, Wiley Eastern, 1985
11. R. P. Feynman, R. B. Leighton and M. Sands, the Feynman Lectures on Physics, Vol. 3, Narosa Pub. House, 1992.
12. P. M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw-Hill, 1977.
13. Linus Pauling, E. Bright Wilson, Introduction to Quantum Mechanics with Applications to Chemistry, Dover Publications, 2012.

	MAHATMA GANDHI UNIVERSITY					
	ADVANCED ELECTRONICS					
School Name	**School of Energy Materials**					
Programme	**MSc. Physics (Specialization in Energy Science)**					
Course Name	**ADVANCED ELECTRONICS**					
Course Credit	**3**					
Type of Course	**Core**					
Course Code	**EMM23C54**					
Course Summary & Justification	The students completing this course will understand basic analog, including semiconductor properties, operational amplifiers and analog-to-digital digital-to-analog conversion techniques. Analogue electronic components and circuits are building blocks for any electronic device used in industries or in daily life. It is therefore necessary to understand clearly the principles and functioning of the basic analogue components and circuits. This course will enable the students to understand the basics of construction, working, and applications of various types of electronic components such as UJT, JFET, MOSFET and circuits such as oscillators, power amplifiers, operational amplifier, and timers using linear ICs. Practical exercises of this course would enable students to maintain such circuits and in turn maintain equipment having such circuits.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	0	40	120
Pre-requisite	Basics knowledge in discrete electronics components.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Explain the ideal and practical Op-Amp characteristics	U, An	1,2
2	Perform the various Op-Amp circuits in different applications	U, I	2,4
3	Explain the basic concepts of linear and nonlinear wave shaping circuits	U, C	2,3,5
4	Analyze the concepts, write and simulate the concepts of AM and FM demodulation process in Communication.	A, S	3,6
5	Discriminate the AM and FM functionalities	U, R	4,7
6	Design & analyze the design and fabrication of integrated circuits.	E, Ap.	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	**Operational Amplifiers** Operational Amplifiers, Block diagram representation of a typical op-amp – schematic symbol - A general purpose IC Op amp – IC 741 and its features, Op-Amp parameters - input offset voltage and current, input bias current, differential input resistance, output resistance, output voltage swing, common mode rejection ratio (CMMR), slew rate and gain-bandwidth product, ideal and practical op-amps – Equivalent circuit of an op-amp, Open-loop op-amp configurations, Frequency response of an op-amp.	**10**	**1,2**
Module 2	**Op-Amp Linear Applications** Review of differential amplifiers - review of operational amplifiers - differential amplifier with one and two op amps - Frequency response of an op amp - Summing, Scaling, averaging amplifiers – Instrumentation amplifier using transducer bridge – Differential input and differential output amplifier –Voltage to current converter– Current to voltage	**15**	**1,3**

	converter –integrator and differentiator.		
Module 3	**Active Filters, Oscillators, Comparators and Converters** Active filters – First order and second order low pass Butterworth filter - First order and second order high pass Butterworth filter- wide and narrow band pass filter - wide and narrow band reject filter - All pass filter – Oscillators: Phase shift and Wien bridge oscillators – square, triangular and saw tooth wave generators- Voltage controlled oscillator. Basic comparator - Zero crossing detector - Schmitt Trigger – Comparator characteristics - D/A and A/D converters- Peak detector – Sample and Hold circuit.	**10**	**4,5**
Module 4	**Analog modulation and digital modulation** Amplitude Modulation –Single sideband techniques – Frequency modulation and Demodulation techniques – Bandwidth requirements – Pulse communication – Pulse width, Pulse position and Pulse amplitude modulation, Digital modulation- Pulse Code Modulation, Sampling process, Performance comparison of various sampling techniques, Aliasing, Reconstruction, PAM, Quantization, Noise in PCM system, Modifications of PCM: Delta modulation, DPCM, ADPCM.	**15**	**6**
Module 5	**Integrated Circuits** Advantages of ICs- Limitations of ICs- Scale of Integration-Classification of ICs By Structure- Monolithic ICs- Thick Film and Thin Film ICs- Hybrid ICs - Monolithic IC Technology-Planar Processes. Crystal Growth of The Wafer -Epitaxial Growth- Oxidation- Photolithography and Chemical Etching-Diffusion- Ion Implantation- Metallization-Fabrication of a Bipolar Junction Transistor.	**10**	**5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **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

Reference Books:

1. Op Amps and Linear Integrated Circuits by Ramakant A Gayakwad.
2. Integrated Electronics by Jacob Millman & C Halkias (Tata McGraw Hill).
3. Electronic Devices and Circuits by Allan Mottershed PHI
4. Integrated Circuits by Botkar.

	MAHATMA GANDHI UNIVERSITY
	Lab -1 Advanced Electronics
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Lab I - Advanced Electronics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C56**

Course Summary & Justification	The lab course will include detail on advanced electronics experiments. At the end of this course students should acquire skills in designing and testing analog and power electronics circuits.					
Semester	I		**Credit**		3	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	-	40	40	40	120
Pre-requisite	Basic synthesis lab skills					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	To design and implement basic Op Amp circuits	U, A	6,8
2	To design and implement various wave generation circuits and applications	U, A	2
3	Design and demonstrate functioning of various analog and power electronic circuits	U, A	2,7
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

Sl.No:	Experiments	Course outcome
1	Measurement of Op-amp parameters.	1
2	Differential amplifier - using op-amp	1
3	Low pass filter frequency response	2
4	High pass filter- frequency response and roll off rate	2
5	Band pass filter using op-amp-frequency response and bandwidth	2
6	Wein-bridge Oscillator using op-amp with amplitude stabilization	2
7	RC phase shift oscillator	2
8	AM generation and demodulation	2
9	FM generation	2
10	Current to voltage and voltage to current converter (IC 741)	2
11	Interfacing analog to digital convertor ADC 0808	3
12	Characteristics of SCR and DIAC.	3
13	Controlled HWR and FWR using RC Triggering circuit	3
14	Generation of firing signals for Thyristors/Triacs using digital Circuit	3
15	AC voltage controller using Triac – Diac combination	3
16	Single phase fully controlled bridge converter	3
17	Speed control of DC motor	3
18	Parallel/ Series Inverters.	3

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

MAHATMA GANDHI UNIVERSITY

Internship/ Miniproject

School Name	**School of Energy Materials**					
Programme	**M. Sc. Physics (Specialization in Energy Science)**					
Course Name	**Internship/ Miniproject**					
Type of Course	**Core**					
Course Code	EMM23C56					
Course Summary & Justification	The candidate shall do 20 days internship in any of the industries or do a miniproject. The report will be evaluated by internal panel of experts authorized by director of the department.					
Semester	**I**		**Credit**		**3**	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours

	Authentic learning Collaborative learning Case based learning	-	40	40	40	120
Pre-requisites	Aptitude for research work in one of the interdisciplinary areas in the realm of interface between physical science and nanotechnology. Literature survey.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

ELECTIVE COURSES

	MAHATMA GANDHI UNIVERSITY					
	HYDROGEN AND FUEL CELLS					
School Name	**School of Energy Materials (SEM)**					
Programme	**MSc. Physics (Specialization in Energy Science)**					
Course Name	**HYDROGEN AND FUEL CELLS**					
Course Credit	**3**					
Type of Course	**ELECTIVE**					
Course Code	**EMM23E21**					
Course Summary & Justification	In this course, we will cover various concepts, reactions and applications of Fuel Cells. The main focuses are; Electrochemistry Basics - Chemical concepts to understand the foundation of Fuel Cells, Definitions and History - Simple definitions, history connected to political and economic motivations, Fuel Cell Chemistry - Fundamental processes in a Fuel Cell and their efficiency					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative	40	40	0	40	120

	learning Independent learning					
Pre-requisite	General Chemistry and Physics, Introductory Materials Science, Elementary Semiconductor Theory, Thermodynamics of Materials.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the basic elements of fuel cells	U, R	1,2
2	Identify the potential of hydrogen fuel cells and its applications in various sectors of the society.	U, C	2,4
3	Familiarise the concept of hydrogen production techniques	U, I	2,3
4	Gain knowledge in various fuel cells, devices and systems.	A, S	3,6
5	To impart knowledge on learning and facts of usage in fuel cells	U, R	3,7
6	Exposure to different fuel cells	E, S	4,7
7	To impart awareness on significance of various application knowledge in fuel cells in the future technological applications.	E, Ap.	3,7
****Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)***			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**HYDROGEN ENERGY ECONOMY** Hydrogen Energy Economy – Conception - Present status and a vision –Applications of Hydrogen - Transport application - cars, light trucks, buses -Stationary and Portable - Electronic gadgets.	**10**	**1,2**
2	**HYDROGEN AND PRODUCTION TECHNIQUES** Hydrogen – Physical and chemical properties - Salient characteristics - Production of hydrogen – Steam reforming – Water electrolysis – Gasification and woody biomass conversion – Biological hydrogen production – Photo dissociation – Direct	**8**	**3,4**

	thermal or catalytic splitting of water.		
3	**HYDROGEN STORAGE & TRANSPORT** Hydrogen storage options – Compressed gas – Liquid hydrogen – Hydride – Chemical Storage – Comparisons - Transport of Hydrogen - Pipelines, Gaseous, Liquid and Compound materials.	**15**	**5**
4	**FUEL CELLS** History – Principle - Working - Thermodynamics and kinetics of fuel cell process – Performance evaluation of fuel cell – Comparison on battery Vs fuel cell - Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC – Relative merits and demerits.	**15**	**5,6**
5	**APPLICATION OF FUEL CELL** Fuel cell usage for domestic power systems - Large scale power generation – Automobile - Space - Environmental analysis of usage of Hydrogen in Fuel cell - Future trends in fuel cells.	**12**	**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** **1. 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 **2. Semester End examination**

REFERENCE BOOKS:

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

	MAHATMA GANDHI UNIVERSITY
	MATERIALS SYNTHESIS AND CHARACTERIZATION TECHNIQUES
School Name	**School of Energy Materials (SEM)**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**MATERIALS SYNTHESIS AND CHARACTERIZATION TECHNIQUES**
Course Credit	**3**
Type of Course	**ELECTIVE**
Course Code	**EMM23E22**

Course Summary & Justification	The course will include detail on solid state synthesis, solution-based synthesis (co-precipitation, solvothermal, sol-gel, microwave synthesis), synthesis from the melt, combustion synthesis, gas phase synthesis for thin films (PVD, CVD, sputtering), and polymer synthesis. It will also cover scattering techniques (e.g. XRD, PDF), spectroscopic techniques (e.g. IR, Raman, XPS, XAS, UV-vis), imaging (e.g. SEM, AFM, TEM), methods for studying materials properties such as electrochemical, mechanical and magnetic characterisation.					
Semester	**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 understanding on solid state (Graduate level)					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

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

	phase		
2	Explain the principles behind and the type of information that different characterisation techniques provide	U, A	2
3	Evaluate the strengths and limitations of various synthesis and characterisation methods	U, A	2,7
4	Propose technical applications for materials produced by different synthesis methods	An, E	2,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

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

Module – 5	Photoluminescence Spectroscopy, Raman Spectroscopy, X-Ray Photoelectron Spectroscopy (XPS), Thermal analysis – Differential Scanning Calorimetry (DSC) – Thermogravimetric Analysis (TGA) – Differential Thermal Analysis (DTA) – Dynamic Mechanical Analysis (DMA), Mechanical Testing- Nano Indentation -Vibrating Sample Magnetometer, Zeta Potential and Particle size measurement.	15	2,3

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

REFERENCE BOOKS:

1. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
2. B. D. Cullity, "Elements of X-ray Diffraction", 4th Edition, Addison Wiley, 1978.
3. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate (Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.
4. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
5. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties &Applications, Imperial College Press, 2004.
6. J. George, Preparation of Thin Films, Marcel Dekker, Inc., New York.2005.
7. D.A. Skoog, F.J. Holler, S. R. Crouch, Instrumental Analysis, Cengage Learning, 2007.
8. K. J. Klabunde and R.M. Richards (Eds.), Nanoscale Materials in Chemistry, 2nd Edn.,John Wiley & Sons, 2009.

	MAHATMA GANDHI UNIVERSITY

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

Course Summary & Justification	To impart the modern ideas of thin film technologies used in various solid state physics and day today applications.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	30	0	30	90
Pre-requisite	Basic knowledge in vacuum science and electrical properties.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	To familiarise with the vacuum science and different thin film deposition methods.	U,R	1,2
2	To understand the nuclear theories of thin film formation.	U	2
3	To familiarise with the measurements techniques of the properties of thin films.	An,E	2,9
4	Awareness and knowledge of various applications of thin films in semiconductor devices and in day today life.	U,An	2,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

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

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

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

Reference Books:

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

	MAHATMA GANDHI UNIVERSITY
	Bio Energy Technology
School Name	**School of Energy Materials (SEM)**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Bioenergy Technology**
Course Credit	**2**
Type of Course	**ELECTIVE**
Course Code	**EMM23E24**
Course Summary & Justification	This course aims to develop researchers who can provide fundamental inputs required to meet the challenges of a sustainable energy future.
Semester	**I**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	30	0	30	90
Pre-requisite	Basics of Energy: Energy and development, Units and measurements, Solar spectrum, Electromagnetic spectrum.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Acquiring the knowledge of biomass energy	U, An	1,2
2	To design bio-energy systems	U, I	2,4
3	Understanding Biomass as a renewable energy and its importance	U, C	2,3,5
4	Develop knowledge on historical background and scope of geothermal systems.	A, S	3,6
5	Understand the concepts on Bio Gas these subjects for further learning.	U, R	4,7
6	Understand the concepts on Bio Gas these subjects for further learning.	E, Ap.	7
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
1	**Introduction**: Biomass- types, advantages and drawbacks, Indian scenario, characteristics, carbon neutrality, conversion mechanisms, fuel assessment studies	**8**	**1,2**
2	**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,	**8**	**1,3**

	illumination and power generation, effect on engine performance.		
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.	**8**	**4,5**
4	**Gasification**: Types, comparison, application, performance evaluation, economics, dual fuel engines, 100 % Gas Engines, engine characteristics on gas mode, gas cooling and cleaning train.	**8**	**6**
5	**Pyrolysis and Carbonization**: Types, process governing parameters, thermo gravimetric analysis, differential thermal analysis, differential scanning calorimetry, Typical yield rates.	**8**	**5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** **1. 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 **2. Semester End examination**

REFERENCE BOOKS:

1. David Boyles, (1984) Bio Energy Technology Thermodynamics and costs, Ellis Hoknood Chichester

2. Khandelwal, K.C, Mahdi, S.S. (1986) Biogas Technology – A Practical Handbook, Tata McGraw Hill

3. Mahaeswari, R.C. (1997) Bio Energy for Rural Energisation, Concepts Publication.

4. Tom B Reed, (1981) Biomass Gasification – Principles and Technology, Noyce Data Corporation, Best Practises Manual for Biomass Briquetting, I R E D A, 1997.

5. Eriksson S. and M. Prior, (1990) The briquetting of Agricultural wastes for fuel, FAO Energy and Environment paper.

6. Iyer PVR et al, Thermochemical Characterization of Biomass, M N E S.

MAHATMA GANDHI UNIVERSITY

	Laser and Nonlinear Optics
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Laser and Non-linear Optics**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**EMM23E51**

Course Summary & Justification	The course aims at developing creative skills among students by understanding the principles of high power lasers and applications. Topics include revising the basic principles of lasers, laser cavities, properties of Gaussian beams and imaging. The latter part of the course focuses on high power pulsed lasers from Q-switched nanosecond lasers to femto-second lasers and amplifiers.					
Semester	**I**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	30	0	30	90
Pre-requisite	Basic knowledge in laser optics and linear optics.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Analyse the propagation of Gaussian beams.	U,An	1,2
2	Apply the principles of phase contrast imaging.	A	2
3	Illustrate pulse shortening mechanisms and chirped pulse amplification.	An,E	2,9
4	Elaborate high power laser interaction with material.	U,An	2,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	Review of Radiation Laws (Stefan Boltzmann, Wien Displacement, Planks) and basics of lasers (Population Inversion - Stimulated emission - Einstein Coefficients) - Laser, Ruby Laser.	**15 Hrs.**	**1**
Module 2	Optical Resonant Cavities, Longitudinal and Transverse modes, Properties of Gaussian laser beams, Spatial frequencies, Abbels theory of image formation, Spatial Filtering phase contrast Imaging.	**15 Hrs.**	**2**
Module 3	Pulsed high power lasers, Q switching, Methods of producing Q switching, Mode locking, Methods of producing mode locking, Pulse shortening by self phase modulation, Group velocity dispersion, gratings or prisms, femto-second lasers, basic ideas of chirped pulse amplification and regenerative amplifiers	**15 Hrs.**	**3**
Module 4	Nonlinear Optics, Nonlinear Wave equation, Optical rectification, Harmonic Generation, Phase matching, Third Harmonic generation, Parametric oscillator, B integral - self focusing, Two photon absorption.	**15 Hrs.**	**4**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

Reference Books:

1. Hecht, E and A R Ganesan, Optics 4th Ed., Pearson (2019).
2. Silfvast, W T, Laser Fundamentals 2nd Ed., Cambridge University Press (2008)
3. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press (2003).
4. Ajoy Ghatak, Optics, 5th Ed., McGraw Hill.
5. Bahaa E. A. Saleh and Malvin Carl Teich, Fundamentals of Photonics 2nd Ed., Wiley (1991)
6. Laud, B.B. - Lasers and Nonlinear Optics, New Age International (P) Limited (1991).

SEMESTER II

MAHATMA GANDHI UNIVERSITY

Statistical Mechanics

School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Statistical Mechanics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C57**
Course Summary & Justification	Statistical mechanics provides a theoretical bridge that takes you from the micro world to the macro world. This makes an attempt to derive the macroscopic properties of an object from the properties of its microscopic constituents and the interactions amongst them. It tries to provide a theoretical basis for the empirical thermodynamics. This course introduces students to the fundamental principles of equilibrium statistical physics. Thefocus is on developing a formalism to derive macroscopic or emergent quantities of various physicalsystems. The course is a very relevant one for students at a Master's level, as the formalism introducedunderpins all of material science and other branches where one is interested in the collective behaviour of a system.
Semester	**II**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120

	Basics of Thermodynamics, Quantum dynamics and Probability theory. This is based on statistical methods, probability theory and the microscopic physical laws. It can be used to explain the

Pre-requisite	thermodynamic behaviour of large systems
Others- Library, seminar and assignment preparations, test, journal, discussion etc.	

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Knowledge of Thermodynamics and probability theory,Demonstrate an understanding of the terminology, concepts and principles of describing equilibrium properties of physical systems.(Module 1)	U, A	2, 9
2	Understand the inadequacy of Quantum dynamics and Probability theory.For a given ideal system, derive various macroscopic quantities - either using a classical or a quantum setting - using the principles learned.(Module 2)	U, A	2, 6
3	Derive the macroscopic properties of ideal quantum gases. (Module 3)	An, E	2, 6
4	Derive the macroscopic properties of ideal quantum gases and develop a basic understanding of various aspects of the statistical physics of systems with interactionbetween its constituent components. (Module 4)	E	2, 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No.	**Module Content**	**Hrs.**	**CO No.**
1	Features of macroscopic systems: Concept of equilibrium, Irreversibility and approach to equilibrium, Basic probability concepts: Statistical ensembles, Mean values and fluctuations, Statistical description of a system of particles, Micro and macro states, The microcanonical ensemble, Boltzmann's formula for entropy.	**15 Hrs.**	**1**

2	Thermal Interaction, Distribution of energy between macroscopic systems, Systems in contact with a heat reservoir, Canonical ensemble and the Boltzmann distribution, Partition function and Free energy, Paramagnetism, Langevin and Brillouin functions, Curie's law, Ideal gas in canonical ensemble - mean energy and mean pressure, harmonic oscillator, Grand Canonical ensemble.	**15 Hrs.**	**2**
3	Canonical distribution in the classical approximation: Phase space of classical systems, Ideal gas, entropy of mixing and Gibbs paradox, Maxwell velocity distribution, harmonic oscillator, The equipartition theorem and its applications, Liouville's theorem.	**15 Hrs.**	**3**
4	Statistical physics of ideal quantum gases: Ideal Fermi gas at zero and non-zero temperatures, FermiDirac and Bose-Einstein integrals, Ideal Bose gas - Bose-Einstein condensation, Density operator. Interacting systems: 1D Ising model, Mean field approach, Phase transitions, Critical point and critical exponents, Universality, Renormalization group approach (Qualitative ideas).	**15 Hrs.**	**4**

Teaching and Learning Approach	Classroom Procedure (Mode of transaction) Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	Mode of Assessment 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4.Semester End examination

Reference Books:

1. Statistical Physics, Berkeley Physics Course, Volume 3, F. Reif, Tata- McGraw-Hill (2008).
2. Principles of equilibrium statistical mechanics, D. Chowdhury and D. Stauffer, Wiley (2000).
3. An introduction to thermal physics, Daniel V Schroeder, Pearson Education (2007).
4. Statistical Mechanics, K. Huang, Wiley India (2008). 3. Statistical Physics, Landau and Lifshitz, Elsevier (2005).
5. Statistical Mechanics, K. Huang, Wiley India (2008).
6. Statistical Physics, Landau and Lifshitz, Elsevier (2005).
7. D. Chandler, Introduction to Modern Statistical Mechanics, Oxford University press, 1987
8. C. J. Thompson, Equilibrium Statistical Mechanics, Clarendon Press, 1988
9. R. K. Pathria, Statistical Mechanics, Elsevier, 1972.
10. F. Reif, Fundamentals of Statistical and Thermal Physics, International Student Edition, McGraw-Hill, 1988.

11. K. Huang, Statistical Mechanics, Wiley Eastern, 1988.
12. F. Reif, Statistical Physics (Berkeley Physics Course, Vol. 5), McGraw Hill, 1967.
13. F. Mandl, Statistical Physics, 2nd edition, ELBS & Wiley, 1988.
14. E. S. R. Gopal, Statistical Mechanics and Properties of Matter MacMillan India, 1988.
15. R. Kubo. Statistical Physics -Problems and Solutions, North Holland, 1965.
16. Y. K. Lim, Problems and Solutions in Thermodynamics and Statistical Mechanics, World Scientific, 1990.

	MAHATMA GANDHI UNIVERSITY **Quantum Mechanics II**					
School Name	**School of Energy Materials**					
Programme	**MSc. Physics (Specialization in Energy Science)**					
Course Name	**Quantum Mechanics II**					
Type of Course	**Core**					
Credit Value	**3**					
Course Code	**EMM23C58**					
Course Summary & Justification	The course aims to provide an introduction to advanced level topics in quantum mechanics. These include quantum theory of angular momentum, quantum concept of identical particles and an introduction to relativistic and multi-particle quantum mechanics. This includes the formulation of quantum theorem of spin and orbital angular momentum. This course also formulates the non-relativistic scattering theory and relativistic quantum mechanics.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	-	40	120
Pre-requisite						
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**

1	Get a complete understanding of total angular momenta and spin angular momenta of particles. They will be able to understand the quantum mechanical techniques to find the total angular momenta of combined system. This is very important to understand further studies of spectroscopic methods and techniques (Module I)	U, A	4, 6
2	Understand the quantum mechanical problems by approximation techniques. They will be able to study the time independent perturbation theory for understanding the quantum mechanical problems. (Module 2)	U, A	4,6
3	The student will be able to understand the quantum mechanical theories of time dependent perturbation theory. They can solve the quantum mechanical problems more accurately using this perturbation method (Module 3).	An, E	6, 9
4	Students will be able to understand the concept of identical particles. They will study the symmetric and antisymmetricwavefunctions and can understand the profound physics of bosons and fermions. Students will be able to understand the elements of relativistic quantum mechanics (Module 4).	E	6, 8, 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Module No.	**Module Content**	**Hrs.**	**CO No.**
1	Review of Orbital angular momentum; Total angular momentum: Commutation relations, eigenvalues, Matrix representation of angular momentum; Spin angular momentum: Pauli spin matrices and their properties, Two component wave function, Pauli's equation; Addition of Angular momentum and Clebsch-Gordan coefficients.	**15 Hrs.**	**1**
2	Time-independent perturbation theory: Non degenerate perturbation theory, The Stark effect, Degenerate perturbation theory: Spin Orbit Coupling, Fine structure; Variational method; WKB method, Bound states for potential wells with no rigid walls, Tunnelling through a potential barrier	**15 Hrs.**	**2**

3	Schrodinger and Heisenberg Pictures of Quantum Mechanics; The interaction Picture and Time- dependent perturbation theory: Transition probability; Constant perturbation; Harmonic perturbation; Adiabatic and sudden approximations; Interaction of atoms with radiation: Transition rates for absorption and stimulated emission of radiation, Dipole approximation, Electric dipole selection rules	**15 Hrs.**	**3**
4	Klein-Gordon equation: Free particle solutions, Probability density; Dirac equation: Dirac matrices, Probability density, Solution of free Dirac equation and positrons; Many-particle systems: Interchange symmetry; Systems of distinguishable non-interacting particle; Systems of identical particles: Exchange degeneracy, Symmetrization postulate; Constructing symmetric and anti-symmetric wave functions, Pauli's exclusion principle.	**15 Hrs.**	**4**

Teaching and Learning Approach	Classroom Procedure (Mode of transaction) Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	Mode of Assessment 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments. 4. Semester End examination

Reference Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009.
2. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley, 1994.
3. Walter Greiner, Relativistic Quantum Mechanics Wave Equations, 3rd Edition, Springer, 2000.
4. G. Aruldhas, Quantum Mechanics, PHI learning Pvt Ltd, second edition, 2009.
5. E. Merzbacher, Quantum Mechanics, 2nd Edition, Wiley International Edition, 1970.
6. P. A. M. Dirac, The Principles of Quantum Mechanics, Oxford University Press, 1991.
7. L. D. Landau and E. M. Lifshitz, Quantum Mechanics -Nonrelativistic Theory, 3rd Edition, Pergamon, 1981.
8. J. Bjorken and S. Drell, Relativistic Quantum Mechanics, McGraw-Hill, 1965.
9. A. Messiah, Quantum Mechanics, Vols. 1 and 2, North Holland, 1961.
10. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994.
11. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004.
12. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill, 2010.

13. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985.
14. John S. Townsend, A Modern Approach to Quantum Mechanics, University Science Books, 2000.

	MAHATMA GANDHI UNIVERSITY
	Electrodynamics
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Electrodynamics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C59**

Course Summary & Justification	The course aims to develop the fundamental concepts in classical electrodynamics. For students who are already familiar with the basics of electromagnetism, Maxwell's equations will be introduced and they will be equipped with advanced mathematical methods to tackle various boundary value problems in electrodynamics. By introducing the time dependent fields, the connection between magnetic and electric fields and the role of special theory of relativity in understanding the electromagnetic phenomena is also explained.					
Semester	**II**					
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 in classical electrodynamics.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	To understand the concepts of boundary value problems to be able to use various techniques for solving the boundary value problems.	U,A	2,6

2	Apply Maxwell’s Equations in Various situations	U,A	2,8
3	Will learn some of the other important consequences of Maxwell's equations by studying: i. Electromagnetic wave propagation in wave guides and conducting media. ii. The electromagnetic radiation phenomena.	An,E	2,9
4	Will understand the important concepts involved in special theory of relativity and its intimate connection to the electrodynamics phenomena	U,An	2,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	Review of vector calculus, Multipole expansion-electrostatic multipole moments - energy of a charge distribution in an external field. Boundary value problems, Introduction to Green's function, formal solution with Green's functions, electrostatic potential energy. Method of images- point charge near a grounded conducting sphere-point charge near a charged insulated conducting sphere – conducting sphere in an uniform electric field. Laplace equation in spherical polar coordinates - boundary value problem with azimuthal symmetry.	**15 Hrs.**	**1**
Module 2	Maxwell's equations. Vector and scalar potentials - gauge transformations - Lorentz gauge, Coulomb gauge. Poynting's theorem and conservation of energy and momentum, complex Poynting vector. Boundary conditions for the electric and magnetic fields at an interface - Plane electromagnetic wave in a non-conducting medium, linear and circular polarization, reflection and refraction at a dielectric interface, polarization by reflection and total internal reflection.	**15 Hrs.**	**2**

Module 3	Waves in conducting or dissipative medium-skin depth. Cylindrical cavities and wave guides, metallic wave guides, modes in a rectangular wave guide, resonant cavities. Green's function for wave equation. Simple radiating systems - fields and radiation of a localized oscillating source - electric dipole field and radiation, magnetic dipole and electric quadrupole fields.	**15 Hrs.**	**3**
Module 4	Special theory of relativity - Postulates of relativity, Lorentz transformations, four vectors, addition of velocities, four velocity, relativistic momentum and energy, mathematical properties of space-time, matrix representation of Lorentz transformation. Dynamics of relativistic particles. Lagrangian and Hamiltonian of relativistic charged particle, motion in a uniform static electric and magnetic fields, magnetism as a relativistic phenomenon, transformation of the electromagnetic field, electromagnetic field tensor.	**15 Hrs.**	**4**

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

Reference Books:

1. J. D. Jackson, Electrodynamics, 3rd Edition, Wiley (2009).
2. Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).
3. The Classical theory of fields - L D Landau and E M Lifshitz, Pergamom Press Ltd. (1971)
4. Electrodynamics - M. Chaichian, I. Merches, D Radu and A. Tureanu, Springer Verlag, (2016).
5. Classical Electrodynamics - W Greiner, Springer Verlag , New York (1998).
6. Cheng, D. K.(2015). Field and wave Electromagnetics, Pearson Education, 2nd ed.
7. Sadiku, M. N. O. & Kulkarni, S. V. (2015). Principles of Electromagnetics, Oxford University Press, 6th ed.

	MAHATMA GANDHI UNIVERSITY
	POWER ELECTONICS AND APPLICATIONS
SchoolName	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**POWER ELECTONICS AND APPLICATIONS**
Course Credit	**3**
Type of Course	**CORE**
Course Code	**EMM23C60**
Course Summary & Justification	This course is primarily concerned with the wide range of power electronic converter circuits for AC-DC, DC-DC and DC-AC power conversion. The operating principles, design, characteristics, protection and application of these electronic power converter circuits are treated in detail, with the goal of equipping the students with capability to design, select and maintain such power supplies This course also aims to equip the student with a basic understanding of modern power semiconductor devices, their strengths, and their switching and protection techniques. These include power diodes, bipolar and MOSFET power transistors, other gate controlled devices such as thyristors, insulated-gate bipolar transistors (IGBT) and gate turn-off thyristors (GTO). Various important topologies of power converter circuits for specific types of applications are covered and analyzed. These include controlled and uncontrolled rectifiers, DC-DC converters and inverters.
Semester	**II**

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 knowledge in semiconductor devices.

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Compare the characteristics of power electronic devices	U, R	1,2
2	Describe the role of Power Electronics as an enabling technology in various applications such as flexible production systems and energy conservation.	U, A, C	2,4,6
3	Learn the basic concepts of operation of dc-ac converters.	U, An	3,4
4	Understand, simulate and design single-phase and three-phase thyristor converters	A, S	3,6
5	Recognize the role power electronics play in the improvement of energy usage efficiency and the applications of power electronics in emerging areas.	U, R	3,5
6	Design and Analyze power converter circuits and learn to select suitable power electronic devices by assessing the requirements of application fields.	I, R	4,5
7	Learn the role of Power Electronics in utility-related applications which are becoming extremely important.	A, S	5,6
8	Design various application of power electronics for motor speed control in electric vehicles.	E, Ap.	3,7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
1	**Power Semiconductor Devices**: Introduction, Scope and Application- Construction and characteristics of Thyristors SCR, TRIAC, DIAC, SBS, UJT, MOSFET, IGBT, MCT and GTO, Comparison of Controllable switches.	**10**	**1,2**

2	**Phase Controlled Converters:** Principle of phase control, Full-wave controlled Converters. Single phase full wave converters, Single phase two pulse converters with discontinuous load and its performance, three phase thyristor converters: half wave, full and semi converters. Dual Converters. Effect of source impedance on performance of converter.	**15**	**2,3**
3	**DC to AC Converters:** Introduction, Classification, single phase half and full bridge VSI, three phase VSI 120 and 180-degree conduction mode. Performance Parameters of Inverter, Voltage control of single phase and three phase Inverter, Series inverter, Parallel inverter, Current source inverter.	**12**	**3,4,6**
4	**AC Voltage Controllers:** Introduction, Principal of On-Off control and Phase Control, Single phase Bidirectional Controllers with R and R-L Loads, Three phase full wave controllers Cycloconverters-Single Phase and Three phase cycloconverters.	**15**	**5,7,8**
5	**Application of Power Electronics:**UPS, Battery Charging, HVDC, DC, BLDC and PMS Motor Speed control, A.C. Drives-variable frequency drives. DC and AC Power supplies, Electric Vehicle.	**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** **1. 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 **2. Semester End examination**

REF

ERENCE BOOKS:

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

10. Recent Trends in Nanomaterials: Synthesis and Properties (Advanced Structured Materials), Zishan Husain Khan, Springer

	MAHATMA GANDHI UNIVERSITY
	LAB II- ADVANCED EXPERIMENTS - PHYSICS
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**LAB II - ADVANCED EXPERIMENTS - PHYSICS**
Type of Course	**Practical - Core**
Credit Value	**3**
Course Code	**EMM23C61**

Course Summary & Justification	At the end of this course students should acquire skills in doing experiments in physics as well as advanced physics.					
Semester	**II**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	0	0	25	0	25
Pre-requisite	Basic synthesis lab skills					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	To recognize various magnetic properties of materials and to get ability to determine the various magnetic parameters of ferromagnetic substances	A, An, S	1,4
2	To determination of both the sign of the charge carriers, e.g. electron or holes, and their density in a given sample.	A, An, S	1,4

3	To determine reverse saturation current, temperature coefficient of junction voltage and energy gap	A, An, S	1,4
4	To find the wavelength and velocity measurement of ultrasonic waves in a liquid sensing ultrasonic diffractometer	A, An, S	1,4
5	To determine the wavelength of He-Ne laser or diode laser beam.	A, An, S	1,4
6	To ascertain the molecular structure of a crystalline material by diffracting x-rays through the sample. It helps to calculate crystalline size of the particles and lattice parameters of the crystalline samples	A, An, S	1,4
7	To measure how much a chemical substance absorbs light. To calculate the wavelength of measurement, absorbance (A) or Transmittance (%T) or Reflectance (%R), and its change with time	A, An, S	1,4
8	to measure the inductance (L), Capacitance (C), and resistance (R) of a material. From the capacitance values students can calculate the dielectric permittivity of the material.	A, An, S	1,4
9	To use a particle beam of electrons to visualize specimens and generate a highly-magnified image. TEMs can magnify objects up to 2 million times.	A, An, S	1,4
10	To confidently measure the size distribution profiles of particles in the sub-micron range.	A, An, S	1,4
11	Understand how the four-probe measurement set up can be used for measuring the current and voltage.	A, An, S	1,4
12	Understand and learn the theory of photoelectric effect. Learn the working of a photocell and the light source. Work function and Planck constant can be estimated from the data.	A, An, S	1,4
13	Understand the theory of heat capacity and measure the heat capacity of the calorimeter using the data collected from thermometers. Estimate the Lorentz number from the electrical and thermal conductivity data	A, An, S	1,4
14	Learn and understand the working of a Fabry-Perot Interferometer, electromagnet set up, polarizer-lens assembly, and a pen type mercury lamp.	A, An, S	1,4
15	Learn and understand the theory of the Faraday effect and analyse the relationship between the degree of polarization rotation and magnetic field	A, An, S	1,4
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 – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

Sl.No.	**Experiments**	**Course Outcome**
Advanced Physics Practical		
1	Magnetic Hysteresis loop tracer	1
2	Hall effect experiment	2
3	Study of P-N junction	3
4	Ultrasonic Diffractometer	4
5	Michelson Interferometer	5
6	X-Ray Diffractometer	6
7	UV-Visible spectrometer	7
8	Impedance Analyser	8
9	Transmission Electron Microscopy (TEM)	9
10	Dynamic Light Scattering (DLS) analysis	10
11	Resistivity of semiconductor specimen–Four Probe Method.	11
12	Photoelectric effect – determination of Plank’s constant using excel or origin.	12
13	Electrical and thermal conductivity of copper and determination of Lorentz number	13
14	Zeeman effect setup – measurement of Bohr magnetron	14
15	Faraday effect- rotation of plane of polarization as a function of magnetic flux density	15

[Few more experiments of equal standard can be added.]

MAHATMA GANDHI UNIVERSITY

Internship/ Miniproject

School Name	**School of Energy Materials**					
Programme	**M. Sc. Physics (Specialization in Energy Science)**					
Course Name	**Internship/ Miniproject**					
Type of Course	**Core**					
Course Code	EMM23C62					
Course Summary & Justification	The candidate shall do 20 days internship in any of the industries or do a miniproject. The report will be evaluated by internal panel of experts authorized by director of the department.					
Semester	**II**		**Credit**		**3**	
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	-	40	40	40	120
Pre-requisites	Aptitude for research work in one of the interdisciplinary areas in the realm of interface between physical science and nanotechnology. Literature survey.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

ELECTIVE COURSES

	MAHATMA GANDHI UNIVERSITY
	ENERGY CONVERSION, STORAGE AND TRANSPORTATION
SchoolName	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**ENERGY CONVERSION, STORAGE AND TRANSPORTATION**
Course Credit	**3**
Type of Course	**ELECTIVE**
Course Code	**EMM23E26**
Course Summary & Justification	Energy storage solutions are receiving high marks in the energy sector. Energy storage is a useful tool to support grid electrical supply, transmission and distribution systems. This course covers a variety of topics in Energy Storage such as: Basics of energy storage systems, application of energy storage in electrical engineering, application of energy storage in transportation, energy storage in photovoltaic (PV) systems, energy storage applications in mobile applications, micro-power application of energy storage, hydrogen and thermal storage, lead acid batteries, fuel cell principles, electrochemical storage, and super capacitors.
Semester	**II**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Othes	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	0	40	120
Pre-requisite	General Chemistry and Physics, Introductory Materials Science, Elementary Semiconductor Theory, Thermodynamics of Materials.					

COURSE OUTCOMES (CO)

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

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
1	**PRINCIPLES OF ENERGY CONVERSION** Introduction to power system and technologies. Demand variation and forecasting. Grid features. Siting and costing. Renewable energy: solar, geothermal, wind, biomass, ocean, fuel cells, unique features of decentralized systems. Co-generation systems. Environmental issues, sustainability and future scenarios.	**10**	**1,2**
2	**HOME HEATING COOLING AND TRANSPORTATION** Furnace efficiency-heat pumps- air conditioning-integrated HVAC systems minimizing heat loss-insulation, windows, and air leaks-	**15**	**2,3**

	residential lighting transportation-FUEL Economy-hybrid vehicles.		
3	**ENERGY STORAGE** Introduction-pumped hydroelectric power-bath country pumped hydroelectric facility-compressed air energy storage-implementation of compressed air energy storage-fly wheels-superconducting magnetic energy storage (SMES).	**10**	**3,4,6**
4	**BATTERY ELECTRIC VEHICLES** BEVs- Introduction-battery types-the cost of electricity-BEV requirements and design-flow batteries-history of BEVs-rechargeable sodium batteries-Super capacitors.	**15**	**5,7**
5	**HYDROGEN FUELS** Introduction-properties of hydrogen-hydrogen production methods – electrolysis-Thermal Decomposition of Water-Chemical Reactions-Storage and Transportation of Hydrogen-Hydrogen Internal Combustion Vehicles Fuel Cells-Fuel Vehicles-Hydrogen Present and Future-Efficiency of Different Transportation Technologies.	**10**	**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** **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 **11. Semester End examination**

REFERENCE BOOKS:

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

<table>
<tr><td rowspan="2"></td><td colspan="6">MAHATMA GANDHI UNIVERSITY</td></tr>
<tr><td colspan="6">MEMS AND NANOFABRICATION</td></tr>
<tr><td>SchoolName</td><td colspan="6">School of Energy Materials</td></tr>
<tr><td>Programme</td><td colspan="6">MSc. Physics (Specialization in Energy Science)</td></tr>
<tr><td>Course Name</td><td colspan="6">MEMS AND NANOFABRICATION</td></tr>
<tr><td>Course Credit</td><td colspan="6">3</td></tr>
<tr><td>Type of Course</td><td colspan="6">Elective</td></tr>
<tr><td>Course Code</td><td colspan="6">EMM23E52</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">This course is based on the manufacturing and characterization fundamentals of nano-scale materials for nano- and micro-electro-mechanical systems (N/MEMS). The students-who want to specialize on N/MEMS and CMOS devices and smart hybrid materials systems for nano and micro-electronics and nano-composites based structures-are targeted. There is a big demand from high-tech precision industry (medical and electronic) for the engineers having knowledge of fabrication and characterization of nano- and micro-systems.</td></tr>
<tr><td>Semester</td><td colspan="6">II</td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Othes</td><td>Total Learning Hours</td></tr>
</table>

	Authentic learning Collaborative learning Case based learning	40	40	0	40	120
Pre-requisite	Basics concepts in Microsystems and Microelectronics.					

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
1	Understand the basic concept of nanoscience and nanotechnology.	U, R	1,2
2	Have a concept on the scope and recent development of the science and technology of micro- and nano-systems	U, A, C	2,4,6
3	Gain the physical knowledge underlying the operation principles and design of microand nano- systems.	U, An	3,4
4	to understand the operation of micro devices, micro systems and their applications	A, S	3,6
5	Gain a knowledge of basic approaches for various sensor design	U, R	3,5
6	Gain the technical knowledge required for computer-aided design, fabrication, analysis and characterization of nano-structured materials, micro- and nano-scale devices.	I, R	4,5
7	Select one or more suitable MEMS/NEMS integration and packaging approaches for a given application.	A, S	5,6
8	Exploring the fundamental working principle of bio-molecule sensing/sensors, and applying this knowledge to design solutions to probe biomedical and biology systems.	E, Ap.	3,7
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
1	**Overview and working principles of MEMS** MEMS and Microsystems – Typical MEMS and Microsystems	**10**	**1,2**

	products – Microsystems and Microelectronics –Miniaturization – Applications of Microsystems –Microsensors, Micro actuators, Microgrippers, Micromotors, Microvalves, Micropumps and Micro accelerometers.		
2	**Fabrication & microsystem design** Ions and Ionization – Doping – Scaling Laws for Electrical design – Substrate and wafers – Silicon as a substrate – Silicon compounds – Piezoresistors – Piezocrystals – Gallium Arsenide, Quartz -Polymers in MEMS –PMMA. Micro System Fabrication Processes – Photolithography, Ion Implantation, Diffusion, Oxidation, Chemical Vapour Deposition, Physical Vapour Deposition – Sputtering, Deposition by Epitaxy, Etching.	**15**	**2,3**
3	**Overview of Micromanufacturing** Bulk Micromanufacturing, Surface Micromachining and LIGA Process. Microsystem Design- Design Considerations – Use of CAD tool in Microsystem Design.	**10**	**3,4,6**
4	**Microsystem Packaging** General considerations in Packaging Design- Levels of Microsystem Packaging. Bonding Techniques for MEMS: Surface Bonding, Anodic bonding Wire Bonding. Overview of MEMS areas: RF MEMS, Bio- MEMS, MOEMS, NEMS.	**10**	**5,7,8**
5	**Introduction to Nanofabrication** Introduction to methods of fabrication of nano layers, different approaches, Fabrication of nano particle, Precipitation of quantum dots. Electron beam evaporation Sputtering, Cathodic Arc Deposition, Atomic Layer Deposition, Pulsed Laser Deposition, Molecular Beam Epitaxy, Lithography and their types, mechanical milling, Chemical Methods; Sol-Gel technique, self-assembly, colloidal method, hydro-thermal method, coprecipitation method, solid state synthesis, microwave method, micro-emulsion method.	**15**	**6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student.
Assessment Types	**Mode of Assessment** **12. 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 **13. Semester End examination**

REFERENCE BOOKS:

1. "MEMS & Micro Systems Design and Manufacture" – Tai-Ran-Hsu, TMH, 2002 Edition.
2. Julian W Gardner, Microsensors: Principles and Applications- John Wiley & Sons, 1994
3. 2. Mark Madou, Fundamentals of Micro Fabrication, CRC Press, New York, 1997
4. 3. Stephen D Senturia, Microsystem design, Springer (India) ,2006
5. 4. Thomas B Jones, Electromechanics and MEMS, Cambridge University Press 2001
6. Chattopadhyay, Banerjee, Introduction to Nanoscience & Technology, PHI, 2012
7. George W. Hanson, Fundamentals of Nanoelectronics, Pearson Education, 2009.

	MAHATMA GANDHI UNIVERSITY **Advanced Magnetism and Magnetic Materials**
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Advanced Magnetism and Magnetic Materials**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**EMM23E53**
Course Summary & Justification	This course in Advanced Magnetism and Magnetic Materials will help in student having a thorough understanding of magnetism in condensed matter. Further, this course will equip the student with required prerequisites to proceed with a Ph.D. program in condensed matter physics or with a scientific position in magnetic materials industry. Starting from an electron in a magnetic field, the magnetic responses of a collection of atoms in a solid are worked out. Magnetization and susceptibility in para and diamagnetic cases, their applications and excitations are discussed. Superconductivity: zero resistance, Meissner effect, perfect diamagnetism; BCS theory, energy gap, isotope effect and tunneling experiments worked out. Josephson junctions and their applications, qubits and quantum chips discussed. Novel high-TC superconductor introduced. The emphasis is on working things out from very simple physical concepts.
Semester	**II**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	30	0	30	90
Pre-requisite	Basics of solid-state physics, quantum mechanics, statistical mechanics and atomic physics. Need a mathematical skill to understand the differential equations and algebra.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To understand theparamagnetism based on both classical and quantum mechanical theory.	U	1,3
2	The calculations of diamagnetic susceptibility of a solid using different models based on classical and quantum mechanics.	U, A	1,2,3
3	To understand and demonstrate a working understanding of permanent magnets, magnetic data storage, and magnetic refrigeration.	U, R	1,2,4
4	To explain different types of interactions in a magnetic solid and ordered magnetic structures.	U,R	1,2,3,6
5	To understand the origins of magnetic anisotropy and correlate the technical magnetic properties with the underlying microstructure of the material.	U,S,Ap	1,2
6	To articulate knowledge of ferromagnetism in 3d transition metals and the formation of domains.	U, A,I	1,2,4
7	To understand the mechanism behind the antiferromagnetic materials including theoretical models and the identification using neutron diffraction technique.	U, An	1,3
8	To gain an understanding of the different types of anisotropies in a magnetic material and to learn the advanced topics of AMR, GMR and CMR	U, A, An	1,2,3
9	To gain a deep understanding in the energy conversion techniques using magnetic materials that include magnetic thermoelectric, and magnetocaloric materials.	U, A	1,3,4
10	To learn the advanced applications of magnetic materials to be used in spintronics and quantum computing field.	U, A,C	1,2,6,8

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

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	Review on basic magnetism: Magnetic poles - Magnetic flux - Circulating currents - Ampere's circuital law - Biot - Savart law- Field from a straight wire - Magnetic dipole - Magnet induction and magnetization - Flux density - Susceptibility and permeability - Hysteresis loops - Solution of the Schrodinger equation for a free atom- Extension to many-electron atoms - Normal Zeeman effect - Pauli exclusion principle - R-S coupling -Hund's rules - jj coupling - Anomalous Zeeman effect	**10 Hrs.**	**1,2**
Module 2	Diamagnetism and Paramagnetism: Diamagnetism: Diamagnetic susceptibility - Diamagnetic substances & applications - Superconductivity-Paramagnetism: Langevin theory of paramagnetism -Curie - Weiss law - Quenching of orbital angular momentum - Pauli Paramagnetism – Paramagnetic oxygen - Applications of paramagnets	**10 Hrs.**	**1,3,4**
Module 3	Ferromagnetism, Antiferromagnetism, and Ferrimagnetism: Interactions in ferromagnetic materials: Weiss molecular field theory - Origin of the Weiss molecular field - Collective-electron theory of ferromagnetism - Ferromagnetic domains - Observing domains - The occurrence of domains – Domain walls - Magnetization and hysteresis Antiferromagnetism: Neutron diffraction - Weiss theory of Antiferromagnetism - Cause of negative molecular field – Use of antiferromagnets - Applications Ferrimagnetism: Weiss theory of ferrimagnetism - Ferrites	**10 Hrs.**	**5,6,7**
Module 4	Magnetic anisotropy and Applications: Magnetocrystalline anisotropy - Shape anisotropy – Induced magnetic anisotropy, Magnetoresistance: Anisotropic magnetoresistance - Giant magnetoresistance - Colossal magnetoresistance, Multiferroics: The magnetoelectric effect, Magneto-optics: Kerr effect - Faraday effect, Magnetic semiconductors and insulators, Applications of Magnetic Materials-Future of magnetic data storage-	**10 Hrs.**	**8,9,10**

	Permanent Magnets-Magnetocaloric effect (Elementary)		

Reference Books:

1. Solid State Physics by N W Ashcroft and N D Mermin
2. Magnetism in Condensed Matter by S. Blundell
3. Magnetic Materials, Fundamentals and Applications by Nicola A. Spaldin
4. Introduction to Magnetic Materials by B. D. Cullity
5. Introduction to Magnetism and Magnetic Materials by David Jiles
6. Magnetism from Fundamentals to Nanoscale Dynamics by J. Stohr and H. C. Siegmann

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

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

Pre-requisite	Basic knowledge on atomic and nuclear forces.
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.	

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Understanding the different types of nuclear energy.	U	2
2	Understand the impact of radiation damages.	U,An	2,6
3	understand basic theoretical concepts of nuclear physics, reactor physics, and energy removal	U	1,2
4	describe radiation damage mechanisms in materials and biological tissue, estimate radiation dose, understand radiation shielding	U,An	2,6
5	understand the concepts of chain reaction, neutron balance, criticality, reactivity, and reactivity control	U	2
6	understand the fundamental aspects of used fuel reprocessing and disposal	U	2,3
7	Illustrate different nuclear fuels.	A,An	2,6
8	General ideas about future nuclear reactors.	U	2,6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	**Types of Nuclear Energy**: Nuclear Fission Energy, Nuclear Fusion Energy, Radioisotopic Energy; Neutron Classification, Neutron Sources, Interactions of Neutrons with Matter: Fission Chain Reaction, Neutron Flux and Fluence, Neutron Cross Section: Reactor Flux Spectrum, Nuclear heat energy, Types of Reactors: A Simple Reactor Design, Generation-I,II,III and IV Reactors, Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), CANDU Reactor, RMBK Reactor, Fast Breeder Test Reactor, Fusion Reactor, Materials Selection Criteria, Reactor Components: Structural/Fuel Cladding Materials, Moderators and Reflectors, Control Materials, Coolants, Shielding Materials, Fusion Reactors.	**10 Hrs.**	**1,2,3**

Module 2	Radiation Damage, Radiation Effects on non-fuel reactor Materials: Microstructural Changes: Cluster Formation, Extended Defects, Nucleation and Growth of Dislocation Loops, Void/Bubble Formation and Consequent Effects, Radiation-Induced Segregation, Radiation-Induced Precipitation or Dissolution; Mechanical Properties: Radiation Hardening, Saturation Radiation Hardening, Radiation Anneal Hardening (RAH), Channeling: Plastic Instability, Radiation Embrittlement, Effect of Composition and Fluence, Effect of Irradiation Temperature, Effect of Thermal Annealing, Helium Embrittlement, Irradiation Creep, Radiation Effect on Fatigue Properties; Radiation Effects on Physical Properties: Density, Elastic Constants, Thermal Conductivity, Thermal Expansion Coefficient; Radiation Effects on Corrosion Properties: Metal/Alloy, Protective Layer, Corrodent, Irradiation-Assisted Stress Corrosion Cracking (IASCC)	**10 Hrs.**	**2,4,5**
Module 3	Nuclear Fuels: Metallic Fuels: Uranium, Plutonium and Thorium, and their fabrication structure, physical, mechanical and corrosion properties, Ceramic Fuels: Ceramic Uranium Fuels, Uranium Dioxide, Uranium Carbide, Uranium Nitride, Plutonium-Bearing Ceramic Fuels, Thorium-Bearing Ceramic Fuels.	**10 Hrs.**	**3,6**
Module 4	**Future Nuclear Reactors:** General Considerations for Future Reactors (The End of the First Era of Nuclear Power, Important Attributes of Future Reactors, Reactor Size, U.S. Licensing Procedures); Survey of Future Reactors (Classification of Reactors by Generation, U.S. DOE Near-Term Deployment Roadmap, Illustrative Compilations of Reactor Designs); Individual Light Water Reactors (Evolutionary Reactors Licensed by the U.S. NRC, Innovative Light Water Reactors); High-Temperature, Gas-Cooled Reactors (HTGR Options, Historical Background of Graphite-ModeratedReactors, General Features of Present HTGR Designs, HTGR Configurations); Liquid-Metal Reactors (Recent United States Programs, Safety Features of LMRs); The Generation IV Program (Overview of the Program, Systems Emphasized in the United States); Radical Nuclear Alternatives to Present Reactors (Fusion, Accelerator-Driven Fission).	**10 Hrs.**	**4,5,8**

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

Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

Reference books:

1. Lamarsh, J.R. and Baratta, A.J., 2001. Introduction to nuclear engineering (Vol. 3). Upper Saddle River, NJ: Prentice hall.
2. Murty, K.L. and Charit, I., 2013. An introduction to nuclear materials: fundamentals and applications. John Wiley & Sons.
3. Murray, R.L. and Holbert, K.E., 2008. An Introduction to the Concepts, Systems, and Applications of Nuclear Processes. Nuclear Energy, 6.
4. Nuclear Energy: Principles, Practices, and Prospects, David Bodansky, Springer 2004.

<table>
<tr><td rowspan="2"></td><td colspan="6">MAHATMA GANDHI UNIVERSITY</td></tr>
<tr><td colspan="6">Energy from Wind, Geothermal and Water</td></tr>
<tr><td>School Name</td><td colspan="6">School of Energy Materials (SEM)</td></tr>
<tr><td>Programme</td><td colspan="6">MSc. Physics (Specialization in Energy Science)</td></tr>
<tr><td>Course Name</td><td colspan="6">Energy from Wind, Geothermal and Water</td></tr>
<tr><td>Course Credit</td><td colspan="6">2</td></tr>
<tr><td>Type of Course</td><td colspan="6">ELECTIVE</td></tr>
<tr><td>Course Code</td><td colspan="6">EMM23E30</td></tr>
<tr><td>Course Summary & Justification</td><td colspan="6">This course aims to develop researchers who can provide fundamental inputs required to meet the challenges of a sustainable energy future.</td></tr>
<tr><td>Semester</td><td colspan="6">II</td></tr>
<tr><td>Total Student Learning Time (SLT)</td><td>Learning Approach</td><td>Lecture</td><td>Tutorial</td><td>Practical</td><td>Others</td><td>Total Learning Hours</td></tr>
</table>

		30	30		30	90
Pre-requisite	Basics of Energy: Energy and development, Units and measurements, Solar spectrum, Electromagnetic spectrum.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Able to understand the renewable energy sources available at present.	U, An	1,2
2	Identify the potential of energy harvesting systems.	U, I	2,4
3	To educate the wind energy operation and its types	U, C	2,3,5
4	To educate the tidal and geothermal energy principles and its operation	A, S	3,6
5	To understand the biomass energy generation and its technologies	U, R	4,7
6	Deep understand in hydroelectric Energy Production	E, Ap.	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	**Basics of Wind Energy Conversion**: Power available in the wind spectra, Wind turbine power and torque, Classification of wind turbines, Horizontal axis wind turbines, Vertical axis wind turbines, Darrieus rotor, Savonius rotor, Musgrove rotor, Characteristics of wind rotors, Aerodynamics of wind turbines-Airfoil, Aerodynamic theories, Axial momentum theory, Blade element theory, Strip theory, Rotor design, Rotor performance. Analysis of wind regimes: The wind -Local effects, Wind shear, Turbulence, Acceleration effect, Time variation, Measurement of wind-Ecological indicators, Anemometers, Cup anemometer, Propeller anemometer, Pressure plate anemometer, Pressure tube anemometers, Sonic anemometer, Wind direction, Analysis of wind data	**8**	**1,2**
2	**Wind energy conversion systems**: Wind electric generators -	**8**	**1,3**

	Tower, Rotor, Gear box, Power regulation, Safety brakes, Generator; Induction generator, Synchronous generator. Fixed and variable speed operations, Grid integration, Wind farms, Offshore wind farms, Wind pumps.		
3	**Wind energy and Environment**: Environmental benefits of wind energy, Life cycle analysis, Net energy analysis, Life cycle emission, Environmental problems of wind energy - Avian issues, Noise emission, Visual impact, Economics of wind energy: Factors influencing the wind energy economics - Site specific factors, Machine parameters, Energy market, Incentives and exemptions, The 'present worth' approach, Cost of wind energy; Initial investment, Operation and maintenance costs.	**8**	**4,5**
4	**Geothermal Energy**: Introduction to Geothermal Resources, Geothermal Power Plants-Dry Steam Units, Single-Flashing Units, Dual Flashing Units, Several Flashing Processes: A Useful Theoretical, Binary Units, Hybrid Geothermal-Fossil Power Units, Effects of Impurities in the Geothermal Fluid, Cooling Systems, Geothermal District Heating: An Example of Exergy Savings and Environmental Benefit, Environmental Effects.	**8**	**6**
5	**Power from the Water**: Hydroelectric Power -Global Hydroelectric Energy Production, Planned Hydroelectric Installations and Future Expansion, Environmental Impacts and Safety Concerns, Tidal Power -Systems for Tidal Power Utilization, Environmental Effects of Tidal Systems, Ocean Currents, Wave Power -Wave Mechanics and Wave Power, Systems for Wave Power Utilization, Environmental Effects of Wave Power and Other Considerations, Ocean Thermal Energy Conversion -Two Systems for OTEC, Environmental Effects of OTEC and Other Considerations, Types of Water Power Turbines, Concluding Remarks on Water Power.	**8**	**5,6**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contact classes, Tutorials, Seminar, Assignments, Authentic learning, Library work, independent studies, Presentation by individual student
Assessment Types	**Mode of Assessment** 1. **Continuous Internal Assessment (CIA)** ○ Surprise test ○ Internal Test – Objective and descriptive answer type ○ Submitting assignments

	o Seminar Presentation – select a topic of choice in the concerned area and present in the seminar 2. **Semester End examination**

Reference Books:

3. Wind Energy: Fundamentals, Resource Analysis and Economics, Sathyajith Mathew, Springer, 2006.
4. Renewable Energy Sources, Efstathios E. (Stathis) Michaelides, Springer, 2012.
5. Wind Energy Explained: Theory, Design and Applicationbooks.google.co.in › books
6. James F. Manwell, Jon G. McGowan, Anthony L. Rogers · 2010
7. Geothermal Energy from Theoretical Models to Exploration and Development
8. By Ingrid Stober, Kurt Bucher · 2013
9. Geothermal Energy: An Alternative Resource for the 21st Centurybooks.google.com › books
10. Harsh K. Gupta, Sukanta Roy · 2006
11. Energy: Renewable Energy and the Environmentbooks.google.co.in › books
12. Bikash Pandey, Ajoy Karki · 2016
13. Introduction to Hydro Energy Systems Basics, Technology and Operation By Hermann-Josef
14. Wagner, Jyotirmay Mathur, 2011.

SEMESTER III

	MAHATMA GANDHI UNIVERSITY
	Nuclear and Particle Physics
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Nuclear and Particle Physics**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C63**

Course Summary & Justification	The first part of the course will discuss nuclear physics. Properties of nuclei and details of popular nuclear models, properties of nuclear decays and nuclear reactions will be discussed in brief, but in a self-consistent manner. The second part will discuss the basics of particle physics. In this part, the fundamental forces and the dynamics of elementary particles under these forces will be considered. The course aims to develop an understanding of advanced nuclear physics with the underlying quantum mechanical principles. Also, the students can get the idea of different types of nuclear radiation detectors and their properties. The course provides the details of different elementary particles and its properties. In short, the course provides a good platform to carry forward the studies to higher levels. Course Outcomes. After completing this course, the students should be able to describe the basic properties of the nuclear force and explain the nucleon-nucleon scattering and its underlying principles. These ideas will be clear to the students after completing the first module. Students will be able to review the different nuclear models and nuclear reactions and discuss nuclear fission and its applications once they complete the second module. After learning the third and fourth modules, the students will be able to classify different nuclear radiations and radiation detectors and explain the properties of the nucleus.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	0	40	120
Pre-requisite	Fundamental concepts in nuclear force.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the basic concepts of nuclear physics and some of the major events in nuclear physics.	U	1,2
2	Understand and learn the basics of different radioactive decays, half-life and decay constant.	U, A	1,2
3	Understand a comprehensive and rigorous treatment of alpha, beta, and gamma decay.	U, R	1,3

4	Review the different nuclear models and nuclear reactions and discuss nuclear fission and its applications.	U,R	1,2,4,6
5	Understand and learn the elementary particle and its properties and classify different nuclear radiations and radiation detectors.	U,S,Ap	1,2
6	Study of nuclear forces and characteristics assists to develop inclusive knowledge of the students in the nuclear structure.	U, A,I	1,2,3
7	Study of liquid drop model provides skill of preparing empirical models.	U, An	1,3
8	Analytical understanding is developed by studying the shell model. Concept of experimental results and its representation in theory is developed by studying Fermi theory of beta decay, Kurie plot. Students get equipped with understanding of experimental plots.	U, A, An	1,2,3
9	A comprehensive knowledge is gathered after going through the basic particle physics. Particles and their properties are well understood by this topic.	U, A	1,4,6
10	Students get skilled by understanding of different symmetry. Thinking ability is nurtured by studying the CP violation. A clear concept of Standard Model of Physics is grown within students after studying this topic.	U, A,C	4,6,8
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	Classification of fundamental forces, Nuclear properties: Review of basic concepts, nuclear radius, shape, spin, parity, Magnetic and electric moments, Nuclear binding energy. Nuclear two body problem, The deuteron, simple theory, spin dependence, tensor force, nucleon-nucleon scattering, partial wave analysis of n-p scattering, determination of phase shift, singlet and triplet potential, effective range theory, low energy p-p scattering.	**15 Hrs.**	**1,2**
Module 2	Nuclear models, semi empirical mass formula, stability of nucleus, shell model, liquid drop model, spin orbit potential, valance nucleons, Collective Model, Rotational and Vibration States. Nuclear reactions, conservation laws, energetic, compound nuclear reactions, direct reaction, resonant reaction, nuclear fission, energy in fission, controlled fission reactions, fission reactors.	**15 Hrs.**	**3,4,5**
Module 3	Nuclear decays: barrier penetration and alpha decay, beta decay, simple theory of beta decay, Kurie plot, parity	**15**	**6,7,8**

	violation in beta decay, gamma decay, multipole moments and selection rules. Detection of nuclear radiation: Interaction of radiation with matters, gas-filled counters scintillation detectors, semiconductor detectors, energy and timing measurement.	**Hrs.**	
<u>Module 4</u>	Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.), Gellmann-Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematics.	**15 Hrs.**	**9,10**

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

Reference Books:

1. Introduction to Nuclear Physics (1st Edition), Harald A. Enge, Addison Wesley (1996).
2. Concepts of Nuclear Physics, B. L. Cohen, McGraw-Hill Inc., US (1971).
3. Nuclear Physics: Theory and Experiment, R. R. Roy and B.P. Nigam, Newage publishers (1996).
4. Theoretical Nuclear Physics, J. M. Blatt and V. F. Weisskopf, Springer-Verlag New York (1979).
5. An Introduction to Nuclear Physics (2nd Edition), S. B. Patel, New Age International (2011)
6. Introduction to Elementary Particles (2nd Revised Edition), David Griffiths, Wiley VCH (2008).

	MAHATMA GANDHI UNIVERSITY
	Condensed Matter Physics

School Name	**Condensed Matter Physics**					
Programme	**MSc. Physics (Specialization in Energy Science)**					
Course Name	**Condensed Matter Physics**					
Type of Course	**Core**					
Credit Value	**3**					
Course Code	**EMM23C64**					
Course Summary & Justification	This course aims to establish the fundamental concepts of condensed matter physics to students and also provides the knowledge to apply other concepts of physics which have been previously learned by the students particularly in quantum mechanics, classical mechanics, electromagnetism and statistical mechanics. Research in condensed matter physics has given rise to enormous technological applications which we witness in our daily life. The fundamental knowledge of condensed matter physics is very much essential and plays a major role in other research areas like material science, nanomaterial science, functional materials, spintronics, quantum computing, bio physics, cryogenics, low dimensional semiconductors, etc. This course helps the students to gain essential knowledge required to enhance their basic understanding in these research areas. By the end of this course, students will be able to analyse different types of matter depending on nature of chemical bonds and their electronic properties. They will be able to analyse the crystal structures by applying crystallographic parameters and also to determine the crystal structure by analysis of XRD data. This course enables the students to analyse electron transport and energy related problems by applying quantum mechanical principles. Solving theoretical problems of condensed matter physics in tutorials helps to improve the analytical skills of students. Participating in seminars and interactions, completing the assignments helps the students further to develop their communication skills and understanding of subject respectively. Some of the experiments related to condensed matter physics have been included in the laboratory component. The experimenting activity helps student to analyze and compare the theoretical predictions and measured data, to arrive at conclusions and present the results in a comprehensible manner.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	40	40	0	40	120
Pre-requisite	Basics of solid-state physics (Undergraduate level). Basic mathematical skill in Differential Equations and Linear Algebra.					

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	Understand the significance and value of condensed matter physics, both scientifically and in the wider community.	U	1,3
2	Understand the historic development of solid-state physics and how they explain specific heat of solids.	U, A	1,2,3
3	To understand the details about the vibrations in the atomic chain and the applications of scattering experiments in solids.	U, R	1,2,3
4	To understand and study the behaviour of electrons in solids, and analyze it using various theoretical models that include Kronig-Penny model and Tight Binding model.	U,R	1,2,4,6
5	To perform band structure calculations for simple systems in the weak potential- and in the Linear Combination of Atomic Orbitals approximations and to describe the relation between electron band-structure and crystal symmetry.	U,S,Ap	1,2
6	To explain the effective electron mass and apply it to describe electron dynamics in semiconductors and to describe the effect of doping on the electronic properties of semiconductor.	U, A,I	1,2,3
7	To analyse the crystal structures by applying crystallographic parameters and also to determine the crystal structure by analysis of XRD data.	U, An	1,3
8	To gain an understanding of the interplay between classical - and quantum mechanical phenomena, and how microscopic/atomic processes acting between many atoms/molecules produces the typical properties of different solid-state matter.	U, A, An	1,2,3
9	To gain and apply discipline-specific knowledge, including self-directed research into the scientific literature and to apply key analysis techniques to typical problems encountered in the field.	U, A	1,3,6
10	To summarize the details of band theory and the developments of semiconductor physics and bandgap engineering, to learn the magnetic properties of solids, its microscopic details, and mean-field theories are covered.	U, A,C	1,4,6,8
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module	Module Content	Hrs	CO.

No:			No.
Module 1	Solids Without Considering Microscopic Structure: The Early Days of Solid State, Specific Heat of Solids-Einstein's Calculation-Debye's Calculation-Periodic (Born-von Karman) Boundary Conditions - Debye's Calculation Following Planck - Debye's "Interpolation" - Shortcomings of the Debye Theory - Electrons in Metals: Drude Theory - Electrons in an Electric Field - Electrons in Electric and Magnetic Fields - Thermal Transport - Sommerfeld (Free Electron) Theory - Basic Fermi-Dirac Statistics - Electronic Heat Capacity - Magnetic Spin Susceptibility (Pauli Paramagnetism) - Shortcomings of the Free Electron Model.	**15 Hrs.**	**1,2,3**
Module 2	Vibrations of a One-Dimensional Mono-atomic Chain - Phonons-Crystal Momentum , Vibrations of a One-Dimensional Diatomic Chain - The Reciprocal Lattice in Three Dimensions - General Brillouin Zone Construction - Electronic and Vibrational Waves in Crystals in Three Dimensions - Wave Scattering by Crystals - Equivalence of Laue and Bragg conditions - Scattering Amplitudes – Systematic Absences - Geometric Interpretation of Selection Rules - Methods of Scattering Experiments – Powder Diffraction - Scattering in Liquids and Amorphous Solids.	**15 Hrs.**	**4,5**
Module 3	Electrons in Solids - Electrons in a Periodic Potential - Kronig-Penny Model- Bloch's Theorem- Nearly Free Electron Model - Tight Binding Model - Energy Bands in One Dimension - Energy Bands in Two and Three Dimensions - Introduction to Electrons Filling Bands - Multiple Bands - Band-Structure Picture of Metals and Insulators - Optical Properties of Insulators and Semiconductors - Direct and Indirect Transitions - Optical Properties of Metals - Optical Effects of Impurities - Electrons and Holes - Doping - Impurity States - Statistical Mechanics of Semiconductors -Band Structure Engineering -Designing Band Gaps - Non-Homogeneous Band Gaps.	**15 Hrs.**	**6,7**
Module 4	Magnetism and Mean Field Theories - Hund's Rules - Coupling of Electrons in Atoms to an External Field - Free Spin (Curie or Langevin) Paramagnetism - Larmor Diamagnetism - (Spontaneous) Magnetic Order - Ferromagnets - Antiferromagnets – Ferrimagnets, Superconductors - Type-I and Type-II superconductors -	**15 Hrs.**	**8,9,10**

	Meissner effect - BCS theory (qualitative) -High temperature superconductors - applications - Josephson effect. Superfluidity. Defects and dislocations. Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order. Quasi crystals. Hall effect and thermoelectric power.		

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

Reference Books:

1. Solid state physics, Ashcroft, Neil W. and Mermin, N., Brooks/Cole (1976).

2. The Oxford solid state basics, Simon, Steven, Oxford University Press (2004).

3. Introduction to Solid State Physics (8th Edition), Charles Kittel, Wiley (2004).

4. Solid State Physics, Dekker, A. J., Macmillan (2000).

5. Elementary Solid State Physics: Principles and Applications, Ali Omar, Pearson (1993).

6. Elements of x-ray diffraction (3rd edition), Cullity, B. D. and Stock, Stuart H., Prentice Hall (2001).

	MAHATMA GANDHI UNIVERSITY **Advanced Computation in Materials Science**
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Advanced Computation in Materials Science**
Type of Course	**Core**
Credit Value	**3**

Course Code	EMM23C35

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

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	To introduce students to the fundamental aspects of computational science and its increasing role in the development and optimization of materials.	U, A	6,8
2	Provide a combination of theory and laboratory activities for establishing the potential of computational tools in novel materials' design.	U, A	2
3	To help students become aware of the various tools available for materials discovery andoptimization.	U, A,I	2,7

4	Students will get introduced to the new interdisciplinary field of computational materials science and engineering	An, E	2,7
5	Students gain an understanding of the theory behind computations and various tools relevant to the design of future materials.	U, I	1,3,4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT:

Module No:	**Module Content**	**Hrs**	**CO.No.**
1	Introduction to computational modeling and simulation for Materials Science, First principle methods: the beginnings of Quantum mechanics, Schrodinger wave equation, time-independent wave equation, Molecular mechanics- Force Field Methods, Postulates of quantum mechanics, Energy Hamiltonian, early first principles calculation, Born-Oppenheimer approximation, Hartree method (one electron), HartreeFock molecular orbital theory, Self-consistent-field (SCF) procedure;	15	1
2	Density functional theory (DFT): electron density in DFT, Hohenberg-Kohn theorems, Kohn-Sham approach, exchange correlation functionals, solving Kohn-Sham equations, DFT extensions and limitations. DFT exercises using software (VASP/Gaussian).	12	2
3	Molecular dynamics (MD): Atomic model in MD, Molecular mechanics, potentials, solutions for newton's equation of motion, running MD: initialization, pre-set ups, periodic boundary condition, positions and velocity, time steps, ensembles, integration equilibration, minimisation in static MD run – steepest descent method, conjugate gradients method, run analysis. MD analysis exercises using software (LAMMPS/ XMD)	10	3

4	Monte Carlo (MC) methods: Basis of MC methods, stochastic processes, Markov's process, ergodicity; Algorithms for MC simulations, random numbers, sampling techniques. Applications of MC methods: System of classical particles, percolation, polymer systems, nucleation, crystal growth, fractal systems. Limitations of MC methods, introduction to quantum MC methods.	15	4
5	Materials genomics: High through-put combinatorial algorithms for materials design.	8	2,4,5

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

Reference Books:

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

	MAHATMA GANDHI UNIVERSITY
	Atomic and Molecular Physics
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Atomic and Molecular Physics**

Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C65**

Course Summary & Justification	Atomic and molecular spectroscopy has played an integral role in providing the necessary information leading to the development of quantum mechanics and to the understanding of the building blocks of matter. The objective of this course is to understand the origin of the quantized nature of atomic and molecular energy levels in a system and its application in molecular structure determination and medicine. This course also aims to give the detailed working principle of different laser systems, which has numerous applications in industry, material science, medicine, and telecommunications.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	40	40	0	40	120
Pre-requisite	Basics of Atomic stucture and Quantujm mechanics (Undergraduate)					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Describe the electronic state of atoms in terms of quantum numbers, the complexity of atomic spectra due to spin-orbit coupling, and the interpretation of term symbols.	U,R	4,6,7
2	Explain how atoms absorb and emit light and how this process can be affected by magnetic and electric fields.	U,A	2,6,7
3	Explain the contributions of transitions between rotational, vibrational and electronic states to the spectra of diatomic molecules.	An	2,6
4	Describe how IR and Raman spectroscopic techniques are used in molecular structure determination.	A,An	2,6
5	Distinguish different spectroscopic techniques (absorption, fluorescence, Raman, NMR, and EPR)	An	2,6

6	Write the rate equations of three-level and four-level laser systems, and to describe the working principle of specific laser systems.	A	2
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	Quantum states of electrons in atoms - Pauli's exclusion principle, calculation of spin-orbit interaction energy in one electron systems, fine structure of spectral lines in hydrogen and alkali atoms. Equivalent and non-equivalent electrons, two electron systems, interaction energy in LS and j j couplings, spectra of helium and alkaline earth elements. Normal and anomalous Zeeman effects, Stark effect, Paschen- Back effect (all in one electron system only). Hyperfine structure of spectral lines - calculation in one electron systems. Line broadening mechanisms - line shape functions for Doppler and natural broadening	**15 Hrs.**	**1,2**
Module 2	Types of molecules, rotational spectra of diatomic molecules as rigid rotor, intensity of rotational lines, The effect of isotopic substitution, energy levels and spectrum of non-rigid rotor, techniques and instrumentation for microwave spectroscopy. The vibrating diatomic molecule - simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator - CO molecule. Interaction of rotation and vibrations, the vibrations of polyatomic molecules and their symmetry, the influence of rotation on the spectra of linear molecules - Electronic spectra of diatomic molecules - Born-Oppenheimer approximation, vibrational coarse structure - progressions. Intensity of vibrational transitions – the Franck-Condon principle. Dissociation energy and dissociation products. Rotational fine structure of electronic-vibrational transitions - the Fortrat diagram. Predissociation.	**15 Hrs.**	**3**

Module 3	Raman effect - classical theory, elementary quantum theory, pure rotational Raman spectra – linear molecules, vibrational Raman spectra polarization of light and Raman effect, techniques and instrumentation of Raman and IR spectroscopy, structure determination by IR and Raman spectroscopy simple examples, fundamentals of SERS. Nuclear and electron spin - interaction with applied magnetic field, population of energy levels Larmor procession, NMR: NMR of hydrogen nuclei – chemical shift, techniques and instrumentation for NMR spectroscopy, medical applications of NMR – ESR spectroscopy - g factor - fine and hyperfine structure, double resonance, Basic idea of Mossbauer Spectroscopy- Recoilless emission and absorption.	**20 Hrs.**	**4,5**
Module 4	Einstein's coefficients, Laser fundamentals and fabrication- active medium, pumping source, and the optical resonator, Phenomenon of population inversion, Characteristics of laser light, Three level laser - Four level laser - rate equations - pumping threshold, Specific laser systems - He-Ne laser -Argon ion laser - CO_2 laser - excimer laser - ruby laser - dye laser - Nd:YAG laser - semiconductor diode lasers.	**10 Hrs.**	**6**

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

Reference Books:

1. Introduction to Atomic Spectra, H. E. White, McGraw-Hill Inc., US (1934).
2. Fundamentals for Molecular Spectroscopy, 4th Ed., C. N. Banwell and E. M. McCash, McGraw Hill Education (2017).
3. Laser fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
4. Lasers Theory and Applications, 2nd Ed., K. Thayagarajan and A.K Ghatak, Springer (2011).
5. Molecular structure and Spectroscopy (2nd Edition), G. Aruldhas, Prentice Hall of India (2007).
6. Spectroscopy Vol. I, II and III, B.P. Straughan and S.Walker, Chapman and Hall (1976).

7. Introduction to Molecular Spectroscopy, G. M. Barrow, McGraw-Hill Inc.,US (1962).
8. The Physics of Atoms and Quanta (4th ed.), H. Haken and Hans C.Wolf, Springer-Verlag (1994).
9. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley-Blackwell (2010).
10. Optical Electronics, A.K.Gahtak and K. Thayagarajan, Cambridge University press (1989).

	MAHATMA GANDHI UNIVERSITY
	LAB III- Energy devices and Fabrication
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**LAB III-** **Energy devices and Fabrication**
Type of Course	**Core**
Credit Value	**3**
Course Code	**EMM23C36**

Course Summary & Justification	The lab course will include detail on Fabrication of Energy devices					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	0	40	40	40	120
Pre-requisite	Basic synthesis lab skills					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Synthesise a material by a variety of different synthesis routes, having assessed their suitability	U, A	6,8

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

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

ELECTIVE COURSES:

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

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

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
	Upon completion of this course, students will be able to;		
1	To understanding the concepts of device fabrication technologies.	U,R	1
2	To analyze the material design and relate to photovoltaic device and analyze their quantum efficiency. .	U,An	4
3	To develop an attitude of innovation/creativity towards material design for various energy harvesting devices.	An, Ap	2,9
4	Understanding of principles of operation of modern devices for electrochemical energy conversion and storage. Super Capacitor, Electrochemical supercapacitors. Nanostructured Carbon-based materials.	U, An	2,6

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

COURSE CONTENT

Module No:	**Module Content**	**Hrs**	**CO. No.**
Module 1	Device fabrication technologies: diffusion, oxidation, photolithography, sputtering, physical vapor deposition, chemical vapor deposition (CVD), plasma enhanced CVD (PECVD), hot wire CVD (HWCVD)	**15 Hrs.**	**1**
Module 2	High efficiency solar cells, PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, solar PV concentrator cells and systems, III - V, II - VI thin film solar cells; Amorphous silicon thin film (and/or flexible) technologies, multi-junction (tandem) solar cells, organic/flexible solar cells, polymer composites for solar cells, Spectral response of solar cells, quantum efficiency analysis, dark conductivity, I-V characterization	**15 Hrs.**	**2**
Module 3	Materials and devices for energy storage; Batteries, Carbon Nano Tubes (CNT), fabrication of CNTs, CNTs for hydrogen storage, CNT polymer composites, ultra capacitor; Polymer membranes for fuel cells, PEM fuel cell, Acid/alkaline fuel cells	**15 Hrs.**	**3**
Module 4	Super Capacitor, Electrochemical supercapacitors , Basic components of supercapacitors, types of electrodes like high surface area, activated carbons, metal oxide and conducting polymers, aqueous and organic electrolytes, Nanostructured Carbon-based materials Electrical double layer model - Principles and materials design Redox capacitor Nano Oxides , Conducting polymers-based materials	**15 Hrs.**	**4**

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

Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

Reference Books:

1. Robert F.P.(2002).*Advanced Semiconductor Fundamentals*,2nd Edition, Pearson
2. Duncan W.B., Dermot O., and Richard I.W.(2011).*Energy Materials*,1st Edition, Wiley
3. Linden D. and Reddy Thomas B., "Handbook of Batteries", 2001, McGraw Hill Publications. Larminie and A. Dicks, Fuel Cell Systems Explained, 2nd Edition, Wiley (2003).
4. Fahren bruch A.L. and Bube R.H.(1983);*Fundamentals of Solar Cells: PV Solar Energy Conversion*, Academic Press.
5. Tom M. and Luis C. (2005). *Solar Cells: Materials, Manufacture and Operation*,1st Edition, Elsevier Science.
6. Christoph B., Ullrich S. and VladimirD.(2014).*Organic Photovoltaics: Materials, Device Physics, and Manufacturing Technologies*, 2nd Edition, Wiley-VCH.
7. San P.J. and Pei K.S. (2013). *Nanostructured and Advanced Materials for Fuel Cells*,1st Edition, CRC Press.
8. Daniel C. And Besen hard J.O.(2011).*Handbook of Battery Materials*,1st Edition Wiley-VCH.
9. Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, Ru-Shi Liu, “Electrochemical Technologies for Energy Storage and Conversion”, John Wiley and Sons, 2012.
10. Francois Beguin and ElzbietaFrackowiak ,“Super capacitors”, Wiley, 2013
11. Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).

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

Credit Value	**3**
Course Code	**EMM23E32**

Course Summary & Justification	This course is designed at providing students with concepts of atomic defects, electrical properties. In depth knowledge on dielectrics, magnetic properties. Concept on sintering, densification, thermal and mechanical properties. Knowledge on composite interface, metal, ceramic composites. This course aims to impart basic knowledge on atomic structure, diffusion mechanism, electrical properties. To introduce the basic concepts on magnetic properties, dielectrics, magnetism, solid state sintering, densification and coarsening processes. To familiarize thermal expansion, creep and thermal stress. To give the concept of analysing the thermal and mechanical properties. Understanding the concept of composites, bonding interfacial properties and also metal matrix, ceramic matrix composites for energy applications.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Learning Approach Authentic learning Collaborative learning Case based learning	40	40	0	40	120
Pre-requisite	Basic knowledge in atomic structure and dielectrics.					

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** **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**

REFERENCE BOOKS:

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

2.K. Vijayamohanan Pillai and Meera Parthasarathi Functional Materials: A Chemist's Perspective by, Orient Blackswan (21 November 2013).

3.Physical Metallurgy Principles Reed-Hill - R. E., and R. Abbaschian, 3rd ed. Boston: PWS-Kent, 1992.

4.Structure and Properties of Engineering Alloys - Smith, W. F., Mc GrawHill, 1981.

5.Introduction to Ceramics W. D. Kingery, H.K. Bowen, D.R. Ulhmann.

6.Treatise on Inorganic Chemistry, Vol. II: Subgroups of the periodic table and general topics, Preparation of Metals - H. Remy, Elsevier, 1956.

7.Synthesis of Advanced Ceramic Materials David Segal.

8.Fundamentals of Polymer Science: An Introductory Text - P. Painter and M. Coleman, Technomic, 1997.

9.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
	Astrophysics
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Astrophysics**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**EMM23E54**

Course Summary & Justification	To study in detail the elements of Astrophysics, with an aim to develop the taste of research in the field.					
Semester	**III**					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	30	0	30	90
Pre-requisite	Basic knowledge in astrophysics and energy transport mechanism.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**

1	Acquire a thorough understanding of the basic concepts like magnitudes, colour, H-R diagram etc.	U,R	1
2	Understand the theory of hydrostatic equilibrium in stars.	U	4
3	Get a clear idea about the energy production in stars.	An,E	2,9
4	Get a clear knowledge about the evolution of the main sequence stars.	U,An	2,6
***Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)**			

COURSE CONTENT

Module No:	Module Content	Hrs	CO. No.
Module 1	Magnitudes: Apparent and Absolute stellar magnitudes, distance modulus, Bolometric and radiometric magnitudes, Colour - index, Colour temperature, effective temperature, Brightness temperature, luminosities of stars. Equatorial, ecliptic and galactic system of coordinates. Apparent and Mean solar time and their relations. Classification of stars, H-D classification, Hertzsprung-Russel (H-R) diagram.	**10 Hrs.**	**1**
Module 2	Fundamental Equations: Equation of mass distribution. Equation of hydrostatic equilibrium. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar opacity. Stellar energy sources.	**10 Hrs.**	**2**
Module 3	Stellar Models: The overall problem and boundary conditions. Russell Voigt theorem. Dimensional discussions of mass luminosity law. Polytropic configurations. Homology transformations.	**10 Hrs.**	**3**
Module 4	Stellar Evolution: Jean's criterion for gravitational contraction and its difficulties. Pre-main sequence contraction under radiative and convective equilibrium. Evolution in the main sequence. Growth of isothermal core and subsequent development. Ages of galactic and globular clusters.	**10 Hrs.**	**4**

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

Assessment Types	Mode of Assessment 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

Reference Books:

1. Textbook of astronomy and astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2. Astrophysics - Stars and Galaxies, K. D. Abhyankar, University Press, 2001.
3. Introduction to Cosmology- J. V. Narlikar (1993), Cambridge University Press.
4. M.Schwarzschild: Stellar Evolution.
5. S.Chandrasekhar: Stellar Structure
6. Theoritical Astrophysics (Vols.I,II,III) - T. Padmanabhan (CUP)
7. Menzel,Bhatnagar and Sen:Stellar Interiors.
8. Black Holes, White Dwarfs and Neutron Stars - S.L.Shapiro and S.A.Teukolsky, John Wiley, (1983).
9. Cox and Guili:Principles of Stellar Interiors - Vol.I and II.
10. R.Bowers and T. Deeming:Astrophysics (John and Barlett.Boston)

	MAHATMA GANDHI UNIVERSITY **RESEARCH METHODOLOGY**
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**RESEARCH METHODOLOGY**
Type of Course	**Elective**
Credit Value	**2**
Course Code	**EMM23E34**

Course Summary & Justification	This course aims to impart systematic knowledge on research methodology and scientific methods. To familiarize the types of research, qualities of good researcher, and how to write good quality thesis and papers. The subject forms the basis upon which the right attitude towards scientific thinking is built. This course is designed at providing students with concepts of research, data analysis, data interpretation and so on. This course help to design thesis projects by addressing the fundamentals of research designs and methods. The course covers a variety of issues—the selection of research topic, the articulation of research questions, the development of theory, the derivation of empirically testable hypotheses, and the analysis of quantitative and qualitative data.
Semester	**III**

Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	30	30	0	30	90
Pre-requisite	Basics knowledge in research and sampling theory.					
Others- Library, field work, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning Domains**	**PSO No.**
1	Identify theories, hypotheses, and methods used in research	U	1
2	Conduct scientific research, which is reproducible by other researchers	U	1
3	Analyze data and communicate the results in an appropriate fashion	R	1
4	Choose a method and apply it to your own research in order to answer your research questions	E	1
***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>	Research Methodology: An Introduction, Meaning of Research, Objectives of Research, Motivation in Research,	**10 Hrs.**	**1**

	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		
Module 2	Sampling Technique: Sampling theory, Types of sampling, Steps in sampling-Sampling and Non-sampling error, Sample size, Advantages and limitations of sampling.	**8 Hrs.**	**2**
Module 3	Computer Applications: Spreadsheet Tool: Introduction to spreadsheet application, features and functions, using formulas and functions, Data storing, Features for Statistical data analysis, Generating charts/ graph and other features. (Microsoft Excel or similar tool) 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	**12 Hrs.**	**3**
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	**10 Hrs.**	**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)** 1. Surprise test 2. Internal Test – Objective and descriptive answer type 3. Submitting assignments 4. Seminar Presentation – select a topic of choice in the concerned area and present in the seminar **B. Semester End examination**

REFERENCE BOOKS:

1. Montgomery, Douglas C. (2007), 5/e, Design and Analysis of Experiments, (Wiley India).
2. Montgomery, Douglas C. &Runger, George C. (2007), 3/e, Applied Statistics &Probability for Engineers (Wiley India).
3. Kothari C.K. (2004), 2/e, Research Methodology- Methods and Techniques (New Age International, New Delhi).
4. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
5. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International. 418p.
6. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology, Ess Publications. V2.
7. Trochim, W.M.K., 2005. Research Methods: the concise knowledge base, Atomic Dog Publishing. 270p.
8. Wadehra, B.L. 2000. Law relating to patents, trademarks, copyright designs and geographical indications. Universal Law Publishing.
9. How to write a Technical report – AlamSmithee, Fictitious Institute of Technology, 1999.
10. How to write technical reports-Understandabble structure, Good Design, Convincing presentation – Hering Lutz, Hering Heike, Springer, 2010.

	MAHATMA GANDHI UNIVERSITY **NANOSENSORS AND NANODEVICES**
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**NANOSENSORS AND NANODEVICES**
Type of Course	**Elective**
Credit Value	**2**

Course Code	EMM23E35					
Course Summary & Justification	In the broadest sense, nanosensors and nanodevices are the critical enablers that will allow mankind to exploit the ultimate technological capabilities of electronic, magnetic, mechanical, and biological systems. While the best examples of nanodevices at present are clearly associated with the information technology industry, the potential for such devices is much broader. Nanosensors and Nanodevices will ultimately have an enormous impact on our ability to enhance energy conversion, control pollution, produce food, and improve human health and longevity. This course summarizes the different types of nanosensors and nanodevices which have application in wide variety of fields.					
Semester	**III**					
Total Student Learning Time(SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Independent learning	30	30	0	30	90
Pre-requisite	Basics of sensors and microelectronics.					

COURSE OUTCOMES (CO)

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

COURSECONTENT

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

Module 3	**Mechanical Sensors and Actuators:** Accelerometers (capacitive, piezoelectric, piezoresistive, thermal), Force sensors (strain gauges, tactile sensors), Pressure sensors (semiconductor, piezoresistive, capacitive, VRP), Gyroscopes (mechanical, optical, fiber-optics). Night Vision, System, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry, For other civil applications: metrology, bridges etc., gas sensors.	**8 Hrs.**	**3**
Module 4	**Metal Insulators Quantum Structures and Devices:** Metal Insulator Semiconductor devices, molecular electronics, information storage, molecular switching, Schottky devices.	**8 Hrs.**	**4**
Module 5	**Quantum Structures and Devices:** Quantum layers, wells, dots and wires, Mesoscopic Devices, Nanoscale Transistors, Single Electron Transistors, MOSFET and Nano FET, Resonant Tunneling Devices, Carbon Nanotube based logic gates, optical devices. .Connection with quantum dots.	**8 Hrs.**	**5**

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Contactclasses,Tutorials,Seminar,Assignments,Authenticlearning,Librarywork,independentstudies,Presentationby individual student
Assessment Types	**Mode of Assessment** **A.Continuous Internal Assessment (CIA)** 1. Surprise test 2. Internal Test–Objective and descriptive answer type 3. Submitting assignments 4. SeminarPresentation–selectatopicofchoiceintheconcernedareaandpresentintheseminar **B. Semester End examination**

REFERENCE BOOKS:

1. Nanosensors: Physical, Chemical, and Biological, Vinod Kumar Khanna, CRC Press,2011.
2. Chemical Sensors: An Introduction for Scientists and Engineers, Peter Grundler, Springer.
3. Smart Sensors for industrial Applications, KrzysztofIniewski, CRCPress.
4. Introduction to Nanoelectronics, Science, Nanotechnology, Engineering, and Applications, Vladimir V.Mitin, Viatcheslav A.Kochelap, Michael A.Stroscio, Cambridge University Press, 2007.
5. Nanotechnology and Nanoelectronics, Fahrner, Wolfgang (Ed.), 2005, Springer.
6. Introduction to the Physics of Nanoelectronics, Tan & Jalil 2012. Woodhead publishing.
7. Fundamentals of Nanoelectronics, George W.H, Pearson education india 2009.
8. Current at the Nanoscale, Colm Durkan, University of Cambridge, 2008.
9. Nanotechnology and Nanoelectronics,- Prof.Dr.W.R.Fahrner,Springer,2005.
10. Nanoelectronics and information Technology, Rainer Weiser, 2012, Wiley.
11. Chemical Sensors and Biosensors; Brian, R Eggins; Wiley;NewYork, Chichester, 2002.
12. Biosensors: A Practical Approach, J.Cooper&C.Tass, Oxford UniversityPress,2004.
13. Nanomaterials for Biosensors,C S.Kumar,Wiley–VCH,2007.
14. Smart Biosensor Technology, G.K.Knoff, A.S.Bassi, CRCPress, 2006.

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

Course Summary & Justification	This main objective of this course is to give a theoretical and practical overview of nanotechnology with applications in energy production, conversion and storage. The specific objectives of this course are to familiarize with nanomaterials, manufacturing processes, characterization and also reliability characteristics. Upon completion of the course on Nanotechnology in Energy, students will understand the fundamental laws governing energy conversion and storage efficiency, the importance of favourable nanomaterials in the energy conversion, and storage application and reliability of materials. This paper encompasses a detailed exposure to the alternative energy technologies with a special focus on solar-photovoltaic, batteries and hydrogen-fuel cell technologies. The proposed course will be one of the elective courses to introduce students to applications of nanotechnology through five different modules. The modules are selected in order to have hierarchy in student learning in three different areas (renewable energy technologies, batteries, fuel cells, hydrogen storage and solar photovoltaics) of alternative energy technologies.					
Semester	III					
Total Student Learning Time (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total Learning Hours
	Authentic learning Collaborative learning Case based learning	30	30	-	30	90
Pre-requisite	Basics of Energy production, conversion and storage systems. (Graduate Level)					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

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

COURSE CONTENT

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

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

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Assessment Types	**Mode of Assessment** 1. Continuous Internal Assessment (CIA) 2. Seminar Presentation – a theme is to be discussed and identified to prepare a paper and present in the seminar 3. Assignments 4. Semester End examination

REFERENCE BOOKS:

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

	MAHATMA GANDHI UNIVERSITY
	Open Course

School Name	**School of Energy Materials**					
Programme	**M.Sc. Physics (Specialization in Energy Science)**					
Course Name	**Open Course**					
Course Credit	**4**					
Type of Course	**Core**					
Course Code						
Course Summary & Justification	The students can opt. a general course offered by any of the department as open course. It aims to provides the interdisciplinary knowledge on various topics.					
Semester	**III**					
Total StudentLearningTime (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total LearningHours

	Visiting other department and interact with expertises	40	40	-	40	120
Pre-requisite	Basic knowledge in Science and Arts topics.					

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

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

SEMESTER IV

	MAHATMA GANDHI UNIVERSITY **DISSERTATION/VIVA-VOCE**
	DISSERTATION/VIVA-VOCE
School Name	**School of Energy Materials**
Programme	**MSc. Physics (Specialization in Energy Science)**
Course Name	**Dissertation/Viva-voce**
Type of Course	**Core**
Course Code	**EMM23C66**

Course Summary & Justification	The candidate shall do a research project in any of the research institute. This follows discussion with the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.					
Semester	**IV**		**Credit**		**13**	
Total Student Learning Time (SLT)	**Learning Approach**	**Lecture**	**Tutorial**	**Practical**	**Others**	**Total Learning Hours**
	Authentic learning **Collaborative learning** **Case based learning**					
Pre-requisites	Aptitude for research work in one of the interdisciplinary areas in the realm of interface between physical science and nanotechnology. Literature survey.					
Others- Library, seminar and assignment preparations, test, journal, discussion etc.						

COURSE OUTCOMES (CO)

CO No.	**Expected Course Outcome**	**Learning Domains**	**PSO No.**
	At the end of the course the students are expected to		
1	Clearly present and discuss the research objectives, Methodology, analysis, results and conclusions effectively.	**A**	**1, 2, 3, 4, 5**
2	Acquire a comprehensive knowledge of the area subject of study	**Ap**	**1, 7**
3	Gain deeper knowledge of methods in the topic of study.	**A**	**6**
4	Able to contribute to research and development work.	**U**	**3**
5	Undertake independent, original and critical research on a relevant topic.	**U**	**5**

6	Able to plan and use adequate methods to conduct specific tasks in given frameworks and to evaluate this work.	**U**	**6**
7	Create, analyse and critically evaluate different problems and their solutions.	**C**	**7,8**
8	Gain consciousness about the ethical aspects of research.	**E**	**6,9**
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

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

	MAHATMA GANDHI UNIVERSITY
	Industrial visit

School Name	**School of Energy Materials**					
Programme	**M.Sc. Physics (Specialization in Energy Science)**					
Course Name	**Industrial Visit**					
Course Credit	**3**					
Type of Course	**Core**					
Course Code	**EMM23C67**					
Course Summary & Justification	The Industrial visit shall be conducted by the School of Energy Materials. The students have to visit an industry in the presence of a faculty member of the School during the programme and submit a report on the same at the end of the fourth semester.					
Semester	**IV**					
Total StudentLearningTi me (SLT)	Learning Approach	Lecture	Tutorial	Practical	Others	Total LearningHours
	Visiting the industry and interacting with the personnel	-	-	-	-	-
Pre-requisite	Basic knowledge in Physics practicals and industrial physics					

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

Teaching and Learning Approach	**Classroom Procedure (Mode of transaction)** Main aim of industrial visit is to provide an exposure to students about practical working environment. They also provide students

	a good opportunity to gain full awareness about industrial practices. Through industrial visit students get awareness about new technologies.
Assessment Types	**Mode of Assessment** The report shall be evaluated by the Examination Board consisting of the Chairman, the Internal Examiner and the External Examiner.

MODEL QUESTION PAPER

SCHOOL OF ENERGY MATERIALS

MAHATMA GANDHI UNIVERSITY

SEMESTER

PROGRAMME

EXTERNAL EXAMINATION (YEAR/ MONTH)

COURSE CODE: COURSE NAME

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

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

1. ……………………………………………………………………………………
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Part B. Answer any 4 Questions (Each question carries 5 marks)

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

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