Syllabus of 4 + 1 Year Integrated UG and PG Programme

w. e. f 2024-25 Academic Year

GRADUATE SCHOOL

Mahatma Gandhi University

P. D. Hills P O

Kottayam, Kerala

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Schools offering Majors

SL.No	School/Centre
1	School of Bio Sciences
2	School of Chemical Sciences
3	School of Computer Sciences
4	School of Environmental Sciences
5	School of Gandhian Thought and Development Studies
6	School of International Relations and Politics
7	School of Pure and Applied Physics
8	School of Social Sciences

Sl. No.	Major	Intake
SCIENCE		
1	Bio Sciences	6**
2	Chemistry	6
3	Computer Science	6
4	Environmental Science	6
5	Physics	6
SOCIAL SCIENCES		
1	Development Studies	5
2	Gandhian Studies	5
3	History	10
4	International Relations and Politics	10

Majors offered and Intake *1 seat shall be sanctioned over and above the intake in each major in the 3rd semester for students who opt for a change of major after two semesters.

**Progression to PG Shall be based on the specialization selected by students as Biochemistry (2 seats) Biotechnology (2 seats) and Microbiology (2 seats) based on merit.

Schools offering Minors/MDCs/AECs/VACs/SECs

SL.No	School/Centre
1	School of Artificial Intelligence And Robotics
2	School of Behavioural Sciences
3	School of Biosciences
4	School of Chemical Sciences
5	School of Computer Sciences
6	School of Data Analytics
7	School of Energy Materials
8	School of Environmental Sciences
9	School of Food Science And Technology
10	School of Gandhian Thought And Development Studies
11	School of Gender Studies
12	School of Indian Legal Thought
13	School of International Relations And Politics
14	School of Letters
15	School of Mathematics And Statistics
16	School of Nanoscience And Nano Technology
17	School of Pedagogical Sciences
18	School of Polymer Science And Technology
19	School of Pure And Applied Physics
20	School of Social Sciences
21	School of Tourism Studies
22	International and Inter University Centre for Nanoscience and Nanotechnology
23	K N Raj School of Economics

Scheme for 4 + 1 Integrated UG and PG Programme
Graduate School
Mahatma Gandhi University

Course Code	Title	Credits	Hours per Week		Level	Type
			Theory	Practical's		
SEMESTER I						
	Major	4			Foundation (100-199)	
MG1DSCUEM121	**Fundamentals of Material Science**	4	2	2	"	Minor
MG1DSCUEM141	**Basics of Energy Science**	4	2	2	"	Minor
MG1MDCUEM101	**Energy crisis and Sustainable solutions**	3	3	-	"	MDC
	AEC (Eng)	3			"	
	AEC (Mal)	3			"	
SEMESTER II						
	Major	4			"	
MG2DSCUEM121	**Physics of Materials**	4	2	2	"	Minor
MG2DSCUEM141	**Materials Chemistry**	4	2	2	"	Minor
MG2MDCUEM101	**Fundamentals of Electrochemical Devices**	3	3	-	"	MDC
MG2MDCUEM102	**Bio Energy**	3	3	-		
	AEC (Eng)	3			"	
	AEC (Mal)	3			"	
SEMESTER III						
	Major	4			Intermediate (200-299)	
	Major	4			"	
	Major	4			"	
MG3DSCUEM221	**Energy Conversion, Storage and Transportation**	4	2	2	"	Minor
MG3DSCUEM222	**Introduction to Numerical Methods**	4	2	2		
MG3MDCUEM201	**Energy Management, Economics and Policies**	3	3	-	"	MDC
MG3MDCUEM202	**Solar Photovoltaics**	3	3	-		
MG3VACUEM201	**Renewable Energy Systems**	3	3	-	"	VAC
MG3VACUEM202	**Quantitative Aptitude and Reasoning**	3	3	-		
SEMESTER IV						
	Major	4			"	
	Major	4			"	
	Major	4			"	
MG4DSCUEM241	**Hydrogen and Fuel cells**	4	2	2	"	Minor
MG4DSCUEM242	**Heat and Thermodynamics**	4	2	2		
MG4SECUEM201	**Software Tools for Energy Analysis**	3	3	-	"	SEC
MG4SECUEM202	**Innovative Techniques in Academic Writing**	3	3	-		

MG4VACUEM201	**Waste to Energy Conversion**	3	3	-	"	VAC
MG4VACUEM202	**Smart materials and structures**	3	3	-		
	Internship/Fieldwork	2				
SEMESTER V						
	Major	4			Higher (300-399)	
	Major	4			"	
	Major	4			"	
	Major	4			"	
MG5SECUEM301	**Design and Installation of Solar panels**	3	2	2	"	SEC
MG5SECUEM302	**Thin film Fabrication Techniques**	3	2	2		
MG5VACUEM301	**Batteries and Supercapacitors**	3	3	-	"	VAC
MG5VACUEM302	**Innovation and Entrepreneurship**	3	3	-		
SEMESTER VI						
	Major	4			"	
	Major	4			"	
	Major	4			"	
	Major (E)	4			"	
	Major (E)	4			"	
MG6SECUEM301	**Flexible Electronics**	3	2	2	"	SEC
MG6SECUEM302	**Advanced Electrochemical Devices**	3	2	2		
Total Credits		**133**				

SEMESTER VII						
	Major	4			Advanced (400-499)	
	Major (E)	4			"	
	Major (E)	4			"	
MG7DSCUEM421	**Electric Vehicle Design**	4	2	2	"	Minor
MG7DSCUEM422	**MEMS & Nanofabrication**	4	2	2		
MG7DSCUEM423	**Spectroscopic Techniques for Material Science**	4	2	2		
MG7DSEUEM424	**Nanomaterials for Energy Harvesting and Storage Applications**	4	2	2	"	Minor
MG7DSEUEM441	**Structural & Morphological Characterization Techniques**	4	2	2	"	Minor
SEMESTER VIII						
	Major	4			"	
	Major (E)	4			"	
	Research Project	12			"	
	Major*	4			"	
	Major*	4			"	

	Major*	4			“	
Total Credits		**44**				
SEMESTER IX						
	Major	4			PG Level (500-599)	
	Major	4			“	
	Major	4			“	
	Major	4			“	
	Major	4			“	
SEMESTER X						
	Research Project	20			“	
	Major**	4			“	
	Major**	4			“	
	Major**	4			“	
	Major**	4			“	
	Major**	4			“	
Total Credits		**40**				

*Only for 4-Years Honours Students

**Only for students who opt for theory courses instead of Research Project

Note: General foundations courses shall be offered by different schools. Students can flexibly choose the courses across disciplines.

Level	Foundation (100-199	Intermediate (200-299)	Higher (300-399)	Advanced (400-499)	PG Level (500-599)

Type	Major	Minor	MDC	SEC	VAC	AEC

SEMESTER I

	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Fundamentals of Material Science**		
Course Type	**Minor**		
Course Level	**100-199**		
Course Code	**MG1DSCUEM121**		
Course Overview	This foundational course introduces students to the essential principles of materials science. Beginning with an examination of atomic structure and chemical bonding, including ionic, covalent, metallic, and intermolecular bonds, students gain a comprehensive understanding of the fundamental building blocks of matter. They then move to crystal structure and properties, learning about lattice points, unit cells, crystal systems, and advanced topics such as X-ray diffraction techniques. Students will explore imperfections in solids, including point defects, dislocations, and interfacial defects, and understand their impact on material properties. The course also covers diffusion mechanisms, emphasizing Fick's laws and factors influencing diffusion. Through classroom lectures, discussion and assignments, students will gain a solid foundation in materials science, preparing them for advanced studies and engineering applications.		
Semester	**1**	**Credit**	**4**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hour	**30 Hour Practicum**	
Pre-requisite	A solid understanding of calculus, physics, and chemistry is required.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	To know the evolution of materials science and understanding materials around us.	U	
2	Explain and Analyse various atomic bonds (ionic, covalent, metallic, van der Waals, dipole) and their energies.	U, An	

3	Analyse atomic structure, Crystal structure, Crystal axes and planes, X-ray diffraction data.	U, A, An	
4	Identify and classify defects (point defects, impurities, dislocations, interfacial, bulk) and understand atomic vibrations' impact on materials.	U	
5	Explain diffusion mechanisms, apply Fick's laws of diffusion, and analyse factors influencing diffusion in materials.	U, A, An	

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

COURSE CONTENT

Module 1	CO No.	Hours
Introduction to engineering materials, Description of materials science, Classification of Materials, Atomic structure, Bohr atom model, Quantum numbers, Basic ideas of bonding, bonding forces and energies, ionic bonding, covalent bonding (hybridization), metallic bonding, van der Waals bonding, dipole bonds	**1,2**	**13 Hours**
Module 2	**3**	**13 Hours**
Lattice points and space lattice, basis and crystal structure, unit cell and primitive cell, seven crystal systems and fourteen Bravais space lattice, coordination number, nearest neighbour distance, atomic radius, atomic packing factor in crystal structure, calculation of lattice constant, lattice planes and Miller indices, separation between lattice planes, single crystals and polycrystalline materials, amorphous materials, X-ray diffraction, Bragg's law of X-ray diffraction.		
Module 3	**4**	**9 Hours**
Imperfections in Solids: Point Defects, Vacancies and Self-Interstitials, Impurities in Solids, Dislocations-Linear Defects, Interfacial Defects, Bulk or Volume Defects, Atomic Vibrations		
Module 4	**5**	**10 Hours**
Diffusion phenomenon: Diffusion Mechanisms; Vacancy Diffusion and Interstitial Diffusion, Steady-State Diffusion; Fick's first law, Nonsteady-State Diffusion; Fick's second law, Factors that influence Diffusion		

Mode of Transaction	Classroom activities Authentic learning, case-based learning, collaborative learning, seminar, group activities.

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**

Learning Resources

1. Callister, William D., and David G. Rethwisch. *Fundamentals of materials science and engineering*. Vol. 471660817. London: Wiley, 2000.
2. William F. Smith, and Javad Hashemi. *Foundations of materials science and engineering*. Mcgraw- Hill Publishing, 2006.
3. Wahab, Mohammad Abdul. *Solid state physics: structure and properties of materials*. Alpha Science Int'l Ltd., 2005.
4. C. Kittel, Introduction to solid state physics

Relevance of Learning the course/ Employability of the course
Understanding engineering materials is essential for a wide range of industries and fields, making this course highly relevant for students pursuing careers in materials science, and related disciplines. It covers the atomic and molecular principles that governs material properties, essential for selecting and developing materials with tailored characteristics for specific applications. By exploring crystal structures, imperfections and diffusion phenomena in solids, the course enables students to advance in fields such as structural engineering, and nanotechnology.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**
	4 + 1 Integrated UG and PG Programme

School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Basics of Energy Science**		
Course Type	**Minor**		
Course Level	**100-199**		
Course Code	**MG1DSCUEM141**		
Course Overview	The course provides a comprehensive introduction to the fundamental principles and contemporary issues in energy production, utilization, and sustainability. This course covers a wide range of topics, including current energy scenarios, renewable energy sources, environmental impacts, and advanced energy storage technologies. It aims to equip students with the foundational knowledge necessary to understand and engage with the evolving landscape of energy science.		
Semester	**1**	**Credit**	**4**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**30 Hour Practicum**	
Pre-requisite	No prior knowledge of energy science is required. A basic understanding of high school-level physics and chemistry will be beneficial.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome	Learning Domains	PSO No.
1	To investigate the correlations between energy production/utilization and environmental impact, emphasizing global warming and environmental degradation.	U, An	
2	To Explain Various Non-Conventional Energy Resources and their Usage.	E	

3	To compare biological energy sources with fossil fuels, analysing their environmental impacts and sustainability.	E, A	

4	To study the principles of photovoltaic energy conversion and the functioning of various types of photovoltaic cells.	R, A, S	
5	To understand the nanostructured materials, primary and secondary batteries, lithium-ion batteries, and the principles and trends of capacitors and supercapacitors.	C, An	
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	Hours	CO No.
Fundamentals of Energy: Current energy scenario; Outline of alternative energy schemes, clean low cost, sustainable energy production based on renewable energy sources, Energy and environment correlations, Environmental degradation due to energy production and utilization, global warming; Environmental impact assessment of materials used in energy and applications and their properties, Overview of biomass as energy source, Biofuels.	**10**	**1**
Module 2	**10**	**2,3**
Conventional & Non-Conventional Energy Source: Biological energy sources and fossil fuels, Fluid dynamics and power in the wind, available resources, fluids, viscosity, types of fluid flow, lift, Wind turbine dynamics and design, wind farms, Geothermal power and ocean thermal energy conversion, Tidal/wave/hydro power		
Module 3	**13**	**4**
Solar Energy: Fundamentals of solar radiation and its measurement aspects, Basic physics of semiconductors, Carrier transport, generation and recombination in semiconductors, Semiconductor junctions: metal-semiconductor junction & p-n junction, Solar thermal conversion, principles of photovoltaic energy conversion, Types of photovoltaic cells, first, second and third generation solar cells, PV system design and economics.		
Module 4	**12**	**5**

Materials & devices for energy storage: Issues and challenges of functional nanostructured materials for electrochemical energy storage systems, Primary and Secondary batteries, Lithium-ion batteries, Current status and future trends. Capacitor, Electrochemical supercapacitors, Current status and future trends.		

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.

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**

Learning Resources

1. Energy and the Challenge of Sustainability, World Energy Assessment, UNDP, New York, (2000).
2. Physics of Solar Cells: From Basic Principles to Advanced Concepts by Peter Wurfel, John Wiley & Sons, 2016
3. Advanced Nanomaterials and their applications in Renewable energy, Jingbio louise Liu, Sajid Bashir, Elsevier, 2015
4. Nanostructured Materials for Solar Energy Conversion, Tetsuo Soga, Elsevier, 2006
5. Lithium Batteries: Science and Technology, G.A. Nazri and G. Pistoia, Kluwer Academic Publishers, Dordrecht, Netherlands, 2004.

Relevance of Learning the course/ Employability of the course
As the world shifts towards sustainable and renewable energy sources, understanding the fundamental principles of energy science becomes crucial. This course equips students with essential knowledge about various energy forms, conversion processes, and storage technologies, making them well-prepared to tackle contemporary energy challenges. With a strong foundation in energy science, graduates are highly employable in diverse sectors such as renewable energy, energy management, environmental consultancy, and research and development. This expertise is invaluable for roles in government agencies, private industry, and non-profit organizations dedicated to advancing sustainable energy solutions and improving energy efficiency.

	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Energy Crisis and Sustainable solutions**		
Course Type	**Multi - Disciplinary Course (MDC)**		
Course Level	**100-199**		
Course Code	**MG1MDCUEM101**		
Course Overview	This course provides a comprehensive examination of the global energy crisis, exploring the causes, impacts, and potential solutions to the world's growing energy demands and challenges. The course covers a wide range of topics including fossil fuels, renewable energy sources, energy efficiency, and solutions to prevent energy crisis. This course will discuss the sources, generation, transportation/distribution, and use of energy as well as the efficiency, side-effects, and dangers that are involved. Students will gain an understanding of the technical, economic, environmental, and geopolitical dimensions of energy production and consumption. Modern sustainable technologies for transportation to lighting, from industry to individual homes, are covered in this course.		
Semester	**1**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
Pre-requisite	This course has no prerequisites and can be taken by anyone.		

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 various forms of energy and its importance	U	
2	To get an insight of energy crisis and energy conservation practices. Critically analyze the factors contributing to the global energy crisis.	U, An	

3	Understand the key factors influencing energy demand and consumption.	U	
4	Identify and evaluate various solutions to prevent the energy crisis.	U, An, E	
5	Develop strategic plans for integrating multiple solutions to address the energy crisis.	U, A, E	
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	**Hours**	**CO No.**
Energy Scenario: Commercial and Non-Commercial Energy, Primary Energy Resources, Commercial Energy Production, Final Energy Consumption, Energy Needs of Growing Economy, Long Term Energy Scenario, Energy Pricing, Energy Sector Reforms. Fossil fuels and Renewable sources including Bio-fuels in India - Their utilization pattern in the past, present and future.	**10**	**1**
Module 2	**9**	**2**
Energy crisis –History of Energy Crisis - Types of Energy Crisis - Major cause of energy crisis - Over consumption, over population - Impact of Energy Crisis - Energy Crisis in India-Unexplored Renewable Energy Options – Commissioning of Power Plants.		
Module 3	**13**	**3,4**
Energy Demand and Sustainable Solutions; Energy consumption – energy consumption (per capita) and economic growth - Global energy consumption – Energy demand – primary energy demand and cumulative energy demand. Solutions to Prevent Energy Crisis - Embracing Renewable Energy - Enhancing Energy Efficiency - Innovating Energy Storage and Transmission - Advancing Nuclear Energy- Implementing Sustainable Energy Policies.		
Module 4	**13**	**5**
Sustainable Technologies: Introduction of Energy storage systems- Mechanical energy storage technologies - Conventional thermal energy conversion - Solar energy technologies - Wind energy technology- Batteries -Supercapacitors - Fuel cells - Tidal Energy - Thermal and vibrational energy harvesting - Water treatment and remediation.		

Mode of Transaction	**Classroom** **activities Field** **activities** **Lab based activities**
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**

Learning Resources

1. Albert Thumann, D. Paul Mehta, *Handbook of Energy Engineering* , The Fairmont Press Inc - 6th edition, 2008.
2. D. Yogi Goswami, Frank Kreith, *Energy Management and Conservation Handbook*, CRC Press, 2007
3. Thipse. S.S. *Non- Conventional and Renewable energy sources*, Narosa Publishing House, 2014.
4. Robert A. Huggins, *Energy storage*, Springer Science & Business Media, 2010
5. Jenny A. Nelson, *The Physics of Solar Cells*, World Scientific Publishing Company, 2003.
6. Robert Huggins, *Advanced Batteries: Materials Science Aspects*, Springer; 2009.

Relevance of Learning the course/ Employability of the course
This course will give an overview to prevent an energy crisis is learning how to conserve energy, improving, and modernizing energy infrastructure with the help of sustainable technologies. By the end of this course students will be able to appreciate the physics of metals, semiconductors and insulators. The implementation of this course will help the students to understand specific techniques to resolve the energy problem. After completing the course, you will attain the ability to evaluate, appraise and provide solutions to the current energy crisis in the world.

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SEMESTER II

	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Physics of Materials**		
Course Type	**Minor**		
Course Level	**100-199**		
Course Code	**MG2DSCUEM121**		
Course Overview	This course provides an in-depth understanding of the physics of materials, focusing on the fundamental properties of various materials. Students will explore semiconductor physics, dielectric properties such as polarization and dielectric constants, and light-matter interactions including reflection and refraction. The course also covers magnetic properties, the classification of magnetic materials, and the phenomenon of superconductivity. Through these topics, students will gain comprehensive knowledge of material behaviours and their applications in modern technology**.**		
Semester	**2**	**Credit**	**4**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**30 Hours Practicum**	
Pre-requisite	A solid grounding in introductory physics and basic materials science principles are required		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Differentiate crystalline and amorphous solids, understand lattice structures, unit cells, and Bravais lattices in seven crystal systems	R, U	

2	Gain knowledge of intrinsic and extrinsic semiconductors, band gaps, carrier concentrations, and the influence of doping on Fermi level.	R, U, An	
3	Describe the dielectric properties of materials, including polarization, capacitance, and ferroelectricity, and relate them to the underlying molecular structure.	U, An	
4	Explain the interaction of light with matter, including reflection, refraction, absorption, and emission processes.	U, An	
5	Classify magnetic materials based on their atomic structure and magnetic properties, and explain phenomena like diamagnetism, superconductivity, and hysteresis.	U, A, An	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	**Hours**	**CO No.**
Crystallography: Crystalline and amorphous solids, Lattice and Unit cell, Seven crystal system and Bravais lattice, Symmetry operation, Miller Indices, Atomic Radius, Coordination number, Atomic packing fraction.	7	1
Module 2	10	2
Semiconductor Physics: Introduction, Intrinsic and extrinsic semiconductors, Direct and Indirect band gap semiconductors, compound semiconductors. Carrier concentration in intrinsic semiconductor, carrier concentration in n-type and p-type semiconductor, Fermi level, Law of Mass action, Charge neutrality, Hall effect.		
Module 3	14	3,4
Dielectric properties: Polar and non-polar molecules, polarization, capacitance and dielectric constant, displacement vector, local electric field, Clausius– Mossotti relation, dielectric materials and ferroelectricity. Optical properties: Electromagnetic radiation, light-matter interaction: reflection, refraction, absorption and transmission, photoluminescence and photoconductivity.		

Module 4		
Magnetic properties: Atomic structure and quantum numbers, orbital and spin angular momentum, magnetic moment in uniform and non-uniform magnetic fields: energy, force and torque, Larmor precession, Classification of magnetic material; diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic and ferrimagnetic materials, magnetic domains and hysteresis Superconductors: Definition, Meissner effect, Type I & II superconductors, London equations, Cooper pair.	**14**	**5**

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
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**

Learning Resources

1. Wahab, Mohammad Abdul. *Solid state physics: structure and properties of materials*. Alpha Science Int'l Ltd., 2005.
2. Omar, M. Ali. *Elementary solid-state physics: principles and applications*. Pearson Education India, 1999.
3. Callister, William D., and David G. Rethwisch. *Fundamentals of materials science and engineering*. Vol. 471660817. London: Wiley, 2000.
4. Krishnan, Kannan M. *Fundamentals and applications of magnetic materials*. Oxford University Press, 2016.

Relevance of Learning the course/ Employability of the course
Learning the physics of materials is crucial for understanding the fundamental properties and behaviour of different materials. This knowledge enables students to understand the development of advanced materials with specific electrical, optical, dielectric, and magnetic properties, which are essential for various technological applications. This course also equips students with a good theoretical foundation and insights needed to innovate and solve real-world engineering and scientific challenges. It bridges the gap between fundamental physics and material science, driving progress in multiple cutting-edge fields.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Materials Chemistry**		
Course Type	**Minor**		
Course Level	**100-199**		
Course Code	**MG2DSCUEM141**		
Course Overview	In this course on chemistry of materials, we intend to introduce basic understanding of materials that has been used in today's technology. In the introductory module, students delve into the periodic table to understand the physical and chemical properties of elements, alongside exploring the structural intricacies of solids, crystalline imperfections, and the crucial structure-property relationship. The curriculum progresses to encompass systems of technological significance, including naturally occurring materials, optical and magnetic systems, and semiconductors, fostering an understanding of their synthesis, properties, and applications. Additionally, students explore diverse material synthesis methods, from solution-based approaches to solid-state and hybrid techniques, preparing them to engineer novel materials tailored to specific needs.		
Semester	**2**	**Credit**	**4**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**30 Hours Practicum**	
Pre-requisite	The basic chemistry, familiarity with the periodic table, and introductory knowledge of solid-state chemistry concepts are required**.**		

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 physical and chemical properties of elements, the structural intricacies of solids, and analyze the significance of the structure-property relationship in materials chemistry	U, R	
2	To explore the synthesis, properties, and applications of naturally occurring materials, optical and magnetic systems, and semiconductors, fostering a comprehensive understanding of materials under technological significance	A	

3	To gain proficiency in diverse material synthesis methods, ranging from solution-based approaches to solid-state and hybrid techniques, enabling the engineering of novel materials tailored to specific applications.	An, E, S	
4	To investigate advanced materials such as biodegradable polymers, conducting polymers, composite materials, liquid crystal polymers, and nanomaterials, and evaluate their properties and diverse applications across various fields, including medicine, environmental science, and electronics.	I, An	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	**Hours**	**CO No.**
Introduction to Materials: Periodic table – physical and chemical properties of Elements; Structure of solids- description of unit cell and space lattices, Coordination number, APF for cubic and hexagonal close-packed structures, Miller indices, non-Crystalline structures properties of crystalline and amorphous structures, Crystal imperfections; Significance of structure-property relationship.	**10**	**1**
Module 2	**12**	**2**
Systems under Technological Importance: Naturally occurring materials; Optical and magnetic systems based on Metals; Inorganic semiconductors- Optical and magnetic materials; Organic semiconductors - Optoelectronic materials; Superconductivity - Application of High-Temperature Superconductivity.		
Module 3	**12**	**3**
Chemical and Non-Chemical approach to Material Synthesis Solution-based material synthesis-Precipitation methods, hydrothermal, etc., Solution based materials synthesis: Micro-emulsion, Sol-gel, Phase transfer reactions; Material synthesis using microwave radiation and ultra-sonic waves.		
Module 4	**11**	**4**
Advanced Materials Properties and applications-Biodegradable polymers-polylactic acid (PLA) and Polycaprolactone (PCL). Conducting polymers-polycetylene, polyaniline. Polypyrrole, Composite materials-introduction, general classification. Nanomaterials-Definition, nano scale. Carbon nano tubes (CNT) types and difference between Single wall NT, Multi wall NT; applications of nanomaterials in medicine, environment and electronics.		

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Mode of Assessment	**2. 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**

Learning Resources

1. A.R. West, Solid-State Chemistry and its applications
2. D.M. Adams, Inorganic Solids
3. P.A. Cox, The electronic structure and chemistry of solids
4. R.C. Evans, An Introduction to crystal chemistry
5. N.N. Greenwood, Ionic crystal, lattice defect and non-stoichiometry
6. C. Kittel, Introduction to solid state physics
7. C.N.R. Rao and J. Gopalakrishnan, New directions in solid state chemistry

Relevance of Learning the course/ Employability of the course
The course is designed to introduce the various aspects of Materials Chemistry - Candidates desires to learn chemistry related aspects of materials would benefit from the course. The course also introduces many aspects from a fundamental understanding, which would be beneficial to the students who is pursuing studies on materials

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Fundamentals of Electrochemical Devices**		
Course Type	**MDC**		
Course Level	**100-199**		
Course Code	**MG2MDCUEM101**		
Course Overview	Energy is a fundamental issue facing society world-wide. Electrochemical devices play an important role in energy storage and conversion, especially at certain power-levels. Evolving renewable energy sources may have a critical dependence on electrochemical devices. The course is appropriate for students interested in the general topic of energy and more specifically electrochemical devices used to store or convert energy from one for to another.		
Semester	**2**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**15 Hours Tutorial**	
Pre-requisite	This course has no prerequisites and can be taken by anyone.		

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 be introduced to the principles and functioning of Electrode processes	U, R	
2	Gain knowledge of Electrochemical thermodynamics, kinetics, and transport phenomena.	U, An	

3	To be proficient in utilizing a variety of electrochemical techniques to analyze and interpret the behavior of electrochemical systems, enabling them to conduct advanced research and practical applications in the field.	A, E	
4	Understand the fundamental physicochemical mechanisms and interactions that underlie in electrodes in an energy storage and conversion system	C,S	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	Hours	CO No.
Introduction and Overview of Electrode processes: Electrochemical Cells and Reactions, Nature of Electrode-Solution Interface, Faradaic Reactions, Mass Transfer Controlled Reactions, Coupled Chemical Reactions	**8**	**1**
Module 2	**10**	**2**
Electrochemical Thermodynamics: Basics of Electrochemical Thermodynamics, Liquid Junction Potentials. Kinetics of Electrochemical Reactions: Arrhenius Equation, Transition state theory, Butler Volmer model, Marcus Theory.		
Module 3	**15**	**3**
Electrochemical Methods: Linear Sweep Voltammetry, Cyclic Voltammetry, Square wave Voltammetry, Chronoamperometry, Chronopotentiometry, Rotating Disk Electrode, Rotating Ring-disk Electrode, AC impedance, Spectro electrochemistry.		
Module 4	**12**	**4**
Applications of Electrochemistry: Electron Transfer, Characterization of Inorganic Complexes, Catalysis, Supercapacitors and Batteries.		

Mode of Transaction	**Classroom activities** ● **Class room lecture** ● **Visual presentation** ● **Discussion/ Brainstorming** **Field activities** **Lab based activities**
Mode of Assessment	**Continuous Internal Assessment (CIA)** **1. Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class **3. Semester End Examination**

Learning Resources

1. Electrochemical Methods: Fundamentals and Applications, Allen J Bard and Larry R. Faulkner, 2nd Edition, John Wiley and Sons
2. Modern Electrochemistry Ionics: Volume 1, John O'M. Bockris and Amulya K. N. Reddy, 2nd Edition, Plenum Press.

Relevance of Learning the course/ Employability of the course
A thorough understanding of electrochemical principles and techniques equips students with the skills necessary to innovate and improve devices like batteries, fuel cells, and biosensors. This expertise is highly sought after in industries focused on renewable energy, medical diagnostics, and electronic manufacturing. Additionally, the course enhances employability by preparing students for roles in research and development, quality control, and technical consulting, making them valuable assets in both industrial and academia. The knowledge gained from this course also provides a strong foundation for advanced studies and specialized careers in electrochemistry and related fields.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Bio Energy**		
Course Type	**MDC**		
Course Level	**100-199**		
Course Code	**MG2MDCUEM102**		
Course Overview	Bioenergy is one of many diverse resources available to help meet our demand for energy. It is a form of renewable energy that is derived from recently living organic materials known as biomass, which can be used to produce transportation fuels, heat, electricity, and products. This course aims to develop fundamental inputs required to meet the challenges of a sustainable energy future. The bioenergy industry is undergoing rapid growth due to the policy drivers underpinning the current interest in bioenergy, such as energy security and climate change. This course adopts a whole systems approach and enables students to critically appraise the sustainability of various biomass energy production routes.		
Semester	**2**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**15 Hours Tutorial**	
Pre-requisite	This course has no prerequisites and can be taken by anyone.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Learn how Energy is obtained from biomass sources and their conversion technologies.	U, R	
2	Classify gasifiers and understand their application.	U	

3	Explain the basic concepts of biomass technologies and generation of biofuels.	An, S	
4	Understand on anaerobic digestion and biomass combined heat and power.	U, A	
5	Design a bio-energy production system.	C, S	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	**Hours**	**CO No.**
Introduction: Biomass- types- Energy from Biomass-Sources-Conversion Technologies - Biogas Plants-Classification-Advantages and Disadvantages- Carbon neutrality.	**8**	**1**
Module 2	**10**	**2,3**
Methods for Energy From biomass -Thermal gasification- Classification of gasifiers- Application of gasifiers-Problems-Pyrolysis -Alternative liquid fuels. Combustion: Perfect, complete and incomplete, equivalence ratio, fixed Bed, fluid Bed, fuel and ash handling, steam cost comparison with conventional fuels.		
Module 3	**15**	**4**
Biomass technologies- Carbon cycle- Biofuels-Ethanol-bio diesel and green fuels-bio fuel from algae-Anaerobic digestion- Bio mass combined heat and power.		
Module 4	**12**	**5**
Bio-methanation: Microbial systems, phases in biogas production, possible feed stocks. Biogas plants, types, design, constructional details and comparison, biogas appliances, Burner, illumination and power generation, effect on engine performance		

Mode of Transaction	**Classroom** **activities Field** **activities** **Lab based activities**

Mode of Assessment	**Continuous Internal Assessment (CIA)** **1. Internal Test** **2. Assignment – Every student needs to write an assignment on a given topic based on the available published literature** **3. Seminar Presentation – A topic needs to be presented and discussed with the class** **3. Semester End Examination**

Learning Resources

1. Non-conventional energy sources; G. D. Rai, 2011, Fifth Edition, Khanna Publishers
2. Renewable energy systems, David M Buchla, Thomas E kissell, Thomas L Flyod
3. Bio Energy Technology Thermodynamics and costs. David Boyles, (1984), Ellis Hoknood Chichester
4. Biomass Gasification – Principles and Technology. Tom B Reed, (1981)
5. Biogas Technology – A Practical Handbook, Khandelwal, K.C, Mahdi, S.S. (1986) Tata McGraw Hill

Relevance of Learning the course/ Employability of the course
This course adopts a whole systems approach and enables students to critically appraise the sustainability of various biomass energy production routes. The module teaching and learning will comprise lectures and a site visit. The coursework requires students to either design a biofuel/bioenergy production system, or critically review a biofuel/bioenergy production process. The bioenergy industry is currently undergoing rapid growth.

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SEMESTER III

	MAHATMA GANDHI UNIVERSITY **Graduate School**
	4 + 1 Integrated UG and PG Programme
School Name	**School of Energy Materials**
Programme	**4 + 1 Integrated UG and PG Programme**
Course Title	**Energy Conversion, Storage and Transportation**
Course Type	**Minor**
Course Level	**200-299**
Course Code	**MG3DSCUEM221**
Course Overview	This foundational course introduces students to the essential principles of energy conversion, storage and transportation. Energy storage solutions are receiving high marks in the energy sector. This course covers a variety of topics in Energy Storage such as batteries and supercapacitors, application of energy storage in electrical engineering, hydrogen production and various storage methods and also different transportation methods of hydrogen fuel.
Semester	**3** **Credit** **4**
Total Student Learning Time	**Instructional hours for theory** **Instructional hours for practical/lab work/field work**
	45 Hours Teaching Hour **30 Hour Practicum**
Pre-requisite	General Chemistry and Physics, Introductory Materials Science, Elementary Semiconductor Theory.

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 have the ideas in energy conversion methods.	U	
2	Understand the basic concept of energy storage devices	U, An	
3	Understand the background, synthesis, properties and applications of energy storage devices and perform the selection based on techno economic view point.	U, A, An	
4	Familiarize the concept of hydrogen production techniques.	U, A, An	
5	To familiarize various hydrogen transportation methods.	U, A, An	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

Module 1 - Principles of Energy Conversion	CO No.	Hours
Trends in energy consumption - world energy scenario vs Indian energy scenario, energy resources and their availability, conventional and renewable sources like solar, geothermal, wind, biomass, ocean and tidal. Conversion of Chemical Energy of Fuel to Heat, Thermal Efficiency of Energy Conversions, Ideal Fluid-Flow Energy Conversions, Efficiency of Mechanical Conversions, Conversion of Thermal Energy by Heat Engines, Improving Efficiency of Heat Engines, Energy Conversions in Biological Systems.	**1**	10 Hours
Module 2 - Energy Storage Methods and Devices	**2,3**	13 Hours
Introduction Importance and need of energy storage, modes of energy storage, Importance of energy density and power density. Primary and secondary batteries, battery potential, charge figure of merit, energy and power in battery. Secondary batteries: Lead–acid battery, Nickel–cadmium battery (NiCd), Nickel–metal hydride battery (NiMH), Lithium-ion battery, Lithium-ion polymer battery. Super Capacitors: Electrochemical Double Layer Capacitor (EDLC), principle of working, structure, performance and application, role of activated carbon and carbon nanotube (CNT).		
Module 3 - Hydrogen and its Production Techniques	**4**	10 Hours
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 thermal or catalytic splitting of water.		
Module 4 - Hydrogen Storage and Transportation	**5**	12 Hours
Hydrogen storage: Physical and chemical properties, general storage methods, compressed storage-composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, Carbon based materials for hydrogen storage. Long distance hydrogen transport via pipelines, ships and in form of LOHC; hydrogen transport via road; hydrogen refueling stations; Use of hydrogen in internal combustion engines,hydrogen sensing, Properties of hydrogen associated with hazards, classification of hydrogen hazards, compressed and liquid hydrogen related hazards.		

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Mode of Assessment	**Continuous Internal Assessment (CIA)** 1. **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class 4. **Semester End Examination**

Learning Resources

1. Electrochemical Supercapacitors - Scientific Fundamentals and Technological Applications, Conway, B. E., Springer, 2014.
2. Lindon David, "Handbook of Batteries", McGraw Hill, 2002.
3. Yasar Demirel, "Energy Production, Conversion, Storage, Conservation, and Coupling",Springer,2012.
4. Detlef Stolten,"Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications", Wiley, 2010.
5. Rebecca L. and Busby, "Hydrogen and Fuel Cells: A Comprehensive Guide", Penn Well Corporation, Oklahoma, (2005).
6. Bent Sorensen (Sorensen), "Hydrogen and Fuel Cells: Emerging Technologies and Applications", Elsevier, UK, (2005).
7. Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, Ru-Shi Liu, "Electrochemical Technologies for Energy Storage and Conversion", John Wiley and Sons, 2012.
8. Francois Beguin and Elzbieta Frackowiak ,"Super capacitors", Wiley, 2013.
9. Doughty Liaw, Narayan and Srinivasan, "Batteries for Renewable Energy Storage", The Electrochemical Society, New Jersy,2010.

Relevance of Learning the course/ Employability of the course
Understanding the course on Energy Conversion, Storage, and Transportation is highly relevant in today's world for several reasons, especially given the global focus on sustainability and the ongoing transition to cleaner energy systems. This course provides the technical know-how to design and optimize these systems, ensuring that renewable energy can be efficiently captured, converted, and integrated into the grid. Understanding the principles of energy storage technologies allows individuals to contribute to advancements in energy storage solutions. Learning about the transportation of energy through grids, pipelines, and fuel systems equips you to contribute to reducing emissions in the transportation sector, such as optimizing energy delivery or developing alternative fuels. With the rise of new energy technologies, there is a growing demand for professionals skilled in energy conversion, storage, and transportation. This opens up career opportunities in fields like renewable energy engineering, energy storage systems, electric vehicle development, and smart grids.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Introduction to Numerical Methods**		
Course Type	**Minor**		
Course Level	**200-299**		
Course Code	**MG3DSCUEM222**		
Course Overview	This course offers an introduction to numerical analysis, with a focus on accuracy and efficiency of numerical algorithms. Topics include an introduction to the computational methods and approximations in the first module. Next three modules include, linear systems, algorithms in numerical linear algebra for linear systems and eigenproblems, algebraic Equations and Numerical Differentiation. Other advanced numerical techniques like Regression, Interpolation and Curve Fitting, Initial Value Problems also included.		
Semester	**3**	**Credit**	**4**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hour	**30 Hours Tutorial**	
Pre-requisite	General mathematics and computation		

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 understand the history and basics of numerical analysis basic mathematical methods.	U	
2	To understand and formulate the basic numerical representation and methods.	U, An	
3	Analysis and application of basic algebraic equations and numerical Differentiation	A, An	
4	Understand the advanced computational methods, analysis and evaluation	U,A,An	

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

COURSE CONTENT

Module 1 - Introduction and approximations	CO No.	Hours
Old Numerical Methodes, Accuracy and precision; Truncation and round-off errors; Binary Number System; Error propagation	**1**	**8 Hours**
Module 2 – Linear systems and Equations	**2**	10 Hours
Matrix representation; Cramer's rule, Gauss Elimination, Matrix Inversion, LU Decomposition Iterative Methods, Relaxation Methods, Eigen Values.		
Module 3 - Algebraic Equations and Numerical Differentiation	**3**	13 Hours
Introduction to Algebraic Equations Bracketing methods: Bisection, Reguli-Falsi. **Open Methods:** Secant, Fixed point iteration, Newton-Raphson, Multivariate Newton's method. **Numerical differentiation:** error analysis, higher order formulae.		
Module 4 – Advanced computation	**5**	15 Hours
Integration and Integral Equations: Trapezoidal rules, Simpson's rules, Quadrature. **Regression:** Linear regression; Least squares; Total Least Squares. **Interpolation and Curve Fitting:** Interpolation; Newton's Difference Formulae; Cubic Splines. **Initial Value Problems:** Euler's methods; Runge-Kutta methods; Predictor-corrector methods;		

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Mode of Assessment	1. **Continuous Internal Assessment (CIA)** **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class 4. **Semester End Examination**

Learning Resources

1. Niyogi, Pradip, "Numerical Analysis and Algorithms", Tata McGraw –Hill 2.
2. Balagurusamy,E., "Numerical Methods", Tata McGraw –Hill
3. Sastry, S.S., "Introduction Methods of Numerical Analysis", PHI 4. Chapra, S.C. and Canale, R.P., "Numerical Methods for Engineers", Tata McGraw –Hil
4. W. Cheney and D. Kinciad, "Ntth'erical Mathematics. and Computing", 2nd edition, Brooks/Cole Publishing Co., 1985 W.H. Press,
5. B.P. Flannery et. al., "Numerical Recipes in C", l Edition, Cambridge Press, 1998.

Relevance of Learning the course/ Employability of the course
This course “Introduction to Numerical Methods" is highly relevant and potential due to its practical applications across various fields. Many real-world problems in science, engineering, finance, and other disciplines involve complex mathematical equations that lack analytical solutions. Numerical methods provide the tools to approximate solutions to these problems efficiently. With the rise of powerful computers, numerical methods have become indispensable for tackling large-scale simulations and data analysis. The principles of numerical methods are applicable across various domains, making it a valuable skill for individuals seeking careers in diverse fields.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Energy Management, Economics and Policies**		
Course Type	**Multi - Disciplinary Course (MDC)**		
Course Level	**200-299**		
Course Code	**MG3MDCUEM201**		
Course Overview	The course provides a comprehensive understanding of the principles, methodologies, and strategies required to optimize energy use, evaluate economic aspects of energy systems, and develop effective energy policies for sustainable development. It equips students with theoretical knowledge and practical skills to address the energy challenges of today and the future. This course familiarizes students with advanced tools, techniques, and computer-aided systems used in energy management and policy-making. It prepares students for careers in energy management, renewable energy consultancy, policy development, and sustainability planning.		
Semester	**3**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hour	**15 Hours Tutorial**	
Pre-requisite	Students have the foundational knowledge and skills to grasp the technical, economic, and policy aspects of energy management.		

COURSE OUTCOMES (CO)

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

1	Develop a thorough understanding of energy management principles, and knowledge of India's energy scenario and conservation initiatives.	U, An	
2	Prepares students to become competent energy auditors who can address energy inefficiencies in diverse sectors while promoting sustainability.	U, A, An	
3	Understand the principles and importance of energy audits for optimizing energy use.	U, A, An	
4	Understand and apply various economic analysis methods to evaluate energy projects and policies.	U, A	
5	To engage with the complex and dynamic field of energy policy-making, equipping them with the tools to contribute to sustainable energy transitions at local, national, and global levels.	U, A, An	

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

COURSE CONTENT

Module 1	Hours	CO No.
Energy Management- Definition, significance, objectives, Energy Crisis, Environmental Aspects, Alternative Sources of Energy, Energy Efficiency, Energy Scenario in India and its Conservation Program, General principles of energy management, Energy Management program, Energy strategies and energy planning, Applications of Computer in Energy Management.	**13**	**1,2**
Module 2		
Energy Audit - Definition, Concept, Type of Audit, Need of EnergPy Audit, Energy Audit Team, Energy Audit Methodology, Process Flow Diagram, Energy Audit Reporting Format, Energy Audit Instruments, Energy Audit for Buildings, Energy Audit form for Commercial Buildings, Checklist for Energy Saving Measures in Hotels.	**10**	**3**
Module 3		
Energy Economics- Economic analysis methods, cash flow model, time value of money, evaluation of proposals, pay-back period, average rate of return method, internal rate of return method, present value method, life cycle costing approach. Computer-aided Energy Management Systems (EMS).	**9**	**4**
Module 4		
Energy Policies – Purpose, Perspective, Contents and Formulation, Tools and methods to address complex Energy policy problems in the context of sustainable development. Assessment of the desirability of a policy option. Different kinds of analysis such as GIS, cost-benefit, social cost-benefit, tradeoffs, technology evaluation etc. Energy policies from past and present.	**13**	**5**

For example : Bio Fuel Policy, UMPP, current Bidding and Auctions in Wind and Solar projects.		

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.

Mode of Assessment	**Continuous Internal Assessment (CIA)** 1. **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature. 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class 4. **Semester End Examination**

Learning Resources

1. Energy Management by W.R.Murphy, G.Mckay. Butterworths.
2. Energy Management Principles by C.B.Smith, Pergamon Press.
3. Turner, W. C., Doty, S. and Truner, W. C., (2009), Energy Management Handbook, (7thedition), Fairmont Press.
4. Albert Thumann, William J. Younger, Handbook of Energy Audits, CRC Press, 2003.
5. Capehart B.L., Turner W.C., Kennedy W.J. (2011). Guide to Energy Management (7th Edition). Fairmont Press. ISBN: 1439883483.
6. Patrick D.R., Fardo S.W., Richardson R.E., Fardo B.W. (2014). Energy Conservation Guidebook (3rd Edition). Fairmont Press. ISBN: 1482255693.

Relevance of Learning the course/ Employability of the course
This course is highly relevant for addressing global energy challenges, ensuring economic and environmental sustainability, and advancing careers in energy-related fields. It empowers individuals to make informed decisions, influence policy, and contribute to the energy transition needed for a sustainable future. The course combines technical, economic, and policy perspectives, making it highly interdisciplinary. Its concepts are globally applicable, allowing students to work in diverse settings and address regional or international energy challenges. Understanding this course empowers individuals to address complex energy challenges and contribute meaningfully to sustainable development.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Solar Photovoltaics**		
Course Type	**MDC**		
Course Level	**200-299**		
Course Code	**MG3MDCUEM202**		
Course Overview	This course is designed at providing students with concepts of photovoltaic (PV) systems, overview of PV usage in the world, basic structure and characteristics of solar cells and Working and Types of Solar Power plant. The course also provide knowledge about solar power management This course offers an advanced knowledge within the field of photovoltaic system technology. By completing this course students can get a knowledge about the solar resource and how photovoltaic energy conversion is used to produce electric power. This course also provides fundamental starting point for the design and fabrication of different solar cell and module technologies, the various photovoltaic system components, how to design a photovoltaic cell etc.		
Semester	**3**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**15 Hours Tutorial**	
Pre-requisite	This course has no prerequisites and can be taken by anyone.		

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 solar cell theory to improve and optimize its performance of solar cell device.	U, An	
2	Identify the potential of energy harvesting systems.	U, I	
3	To learn about fabrication of different types of solar cells.	U, C	
4	Gain knowledge about photovoltaic technical parameters and emerging technologies.	A, S	

5	Understand the components of solar powerplant and its working.	U, R	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1 - Photovoltaic (PV) systems	Hours	CO No.
Historical development of PV systems, Overview of PV usage in the world, Solar energy potential for PV, irradiance, solar radiation and spectrum of sun, geometric and atmospheric effects on sunlight, Photovoltaic effect, conversion of solar energy into electrical energy, behavior of solar cells.	**15**	**1, 2**
Module 2 - Photovoltaic devices, modules and technical parameters	**15**	**1, 3**
Solar cells, basic structure and characteristics: Single-crystalline, multicrystalline, thin film silicon solar cells, emerging new technologies, Electrical characteristics of the solar cell, equivalent circuit, modeling of solar cells. Solar cell arrays, PV modules, PV generators. Terrestrial PV module modelling.		
Module 3 - Solar Power Plant	**15**	**4,5**
Components and Working: Types of Solar Power Plant: Off grid, Grid Connected, Hybrid, Interfacing PV modules to loads, direct connection of loads to PV modules, connection of PV modules to a battery and load together, DC-DC Converters, Inverters.		
Module 4 - Solar Power Management	**15**	**5**
Power conditioning and maximum power point tracking (MPPT) algorithms based on buck- and boost-converter topologies, Maximum power point tracking (MPPT) algorithms, Inverter topologies for stand-alone and grid-connected operation.		

Mode of Transaction	**Classroom activities** **Field activities** **Lab based activities**

Mode of Assessment	**Continuous Internal Assessment (CIA)** 1. **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class 4. **Semester End Examination**

Learning Resources

1. Photovoltaics: Designs, Systems and Applications, Michael Stock, Larsen and Keller Education
2. Photovoltaics: Engineering and Technology for Solar Power, Catherine Waltz, Syrawood Publishing House
3. Principles of Solar Engineering, D. Goswami, CRC Press
4. Solanki S. Chetan. Solar Photovoltaics: Fundamentals, Technologies and Applications, New Delhi, PHI, 2012.

Relevance of Learning the course/ Employability of the course
This course implements the solar cell theory to improve and optimize its performance of solar cell device and enables students to critically appraise the sustainability of various renewable energy production routes. The module teaching and laboratory practice will comprise lectures and industry visits. The coursework requires students to learn about fabrication of different types of solar cells. The photovoltaic industry is currently undergoing rapid growth.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**
	4 + 1 Integrated UG and PG Programme
School Name	**School of Energy Materials**
Programme	**4 + 1 Integrated UG and PG Programme**
Course Title	**Renewable Energy Systems**
Course Type	**VAC**
Course Level	**200-299**
Course Code	**MG3VACUEM201**
Course Overview	This course is designed at providing students with concepts of renewable energy systems such as photovoltaic (PV) and wind energy systems. Overview of PV usage in the world, basic structure and characteristics of solar cells, study about Solar Power Plant, its Components and Working and Types of Solar Power plant. The course also provide knowledge about solar and wind energy management. This course offers an advanced knowledge within the field of green energy technology. By completing this course students can get a knowledge about the solar, wind and hydrogen resource and how photovoltaic energy conversion is

	used to produce electric power. This course also provides fundamental starting point for the design and fabrication of different solar cell and module technologies, the various photovoltaic system components, how to design a hydrogen fuel cell etc.		
Semester	**3**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**15 Hours Tutorial**	
Pre-requisite	This course has no prerequisites and can be taken by anyone.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Understanding of different renewable energy source and its potentials.	U, R	
2	Identify the potential of solar energy harvesting systems.	U, I	
3	To learn about fabrication of different types of solar cells.	U, C	
4	Gain knowledge about photovoltaic technical parameters and emerging technologies.	A, S	
5	Learn and evaluate the potential and applications of Hydrogen energy and Fuel cells.	E, Ap	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1 - Renewable Energy	Hours	CO No.
Introduction to Energy Sources-Energy sources and their availability-Conventional energy sources. Renewable energy sources. Need of renewable energy sources. Solar energy, Wind energy, Hydrogen energy.	**15**	**1, 2**
Module 2- Solar Photovoltaic (PV) systems	**15**	**1, 3**
Historical development of PV systems, Overview of PV usage in the world, Solar energy potential for PV, irradiance, solar radiation and spectrum of sun. Photovoltaic effect, conversion of solar energy into electrical energy, behaviour of solar cells.		
Module 3 - Photovoltaic devices and technical parameters		

Solar cells, basic structure and characteristics: Single-crystalline, multi-crystalline, thin film silicon solar cells, emerging new technologies, Electrical characteristics of the solar cell, equivalent circuit. Solar cell arrays, PV modules, PV generators. Components and Working: Types of Solar Power Plant: Off grid, Grid Connected, Hybrid, Interfacing PV modules to loads, direct connection of loads to PV modules.	**15**	**4**
Module 4 - Hydrogen and Fuel Cells		
Basics of Hydrogen Energy - Production methods - Storage and transportation – Applications Fuel Cell: Principle of working -Basic thermodynamic and electrochemical principles - Classifications-Applications for power generations. Types of fuel cells.	**15**	**5**

Mode of Transaction	**Classroom activities** **Field activities** **Lab based activities**

Mode of Assessment	**Continuous Internal Assessment (CIA)** **1. Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature **3. Seminar Presentation –** A topic needs to be presented and discussed with the class **4. Semester End Examination**

Learning Resources

1. Non-conventional energy sources; G. D. Rai; 2011; Fifth Edition, Khanna Publishers
2. Photovoltaics: Engineering and Technology for Solar Power, Catherine Waltz, Syrawood Publishing House
3. Principles of Solar Engineering, D. Goswami, CRC Press
4. Solar Photovoltaics: Fundamentals, Technologies and Applications, Solanki S. Chetan. New Delhi, PHI, 2012
5. Renewable energy systems, David M Buchla, Thomas E kissell, Thomas L Flyod
6. Wind Energy: Fundamentals, Resource Analysis and Economics; Mathew Sathyajith; 2006, Springer
7. Hydrogen and Fuel Cells: A Comprehensive Guide, Rebecca L. and Busby, Penn Well Corporation, Oklahoma, (2005).

8. Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorensen (Sorensen), Elsevier, UK, (2005).

Relevance of Learning the course/ Employability of the course
This course adopts a whole systems approach and enables students to critically appraise the sustainability of various renewable energy production routes. The module teaching and learning will comprise lectures and a site visit. The coursework requires students to either design a renewable/solar energy production system, or critically review an energy production process. The renewable energy industry is currently undergoing rapid growth.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Quantitative Aptitude and Reasoning**		
Course Type	**Value Added Course (VAC)**		
Course Level	**200-299**		
Course Code	**MG3VACUEM202**		
Course Overview	The course is designed for all in view of assessing cognitive abilities of students in various competitive examinations. It is desired that a graduate must possess skill attributes to pursue further avenues in higher education and other sectors. This Value-added course is expected to enhance employability of students pursuing FYUGP.		
Semester	**3**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**Nil**	
Pre-requisite	This course has no prerequisites and can be taken by anyone, making it accessible to learners from all backgrounds who wish to build or enhance their quantitative aptitude and reasoning skills.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Enhance employability skills by mastering aptitude and reasoning topics commonly tested in campus placement exams, government exams, and other competitive assessments.	U,A,E	
2	Efforts will be made to accommodate fundamental and mathematical aspects to develop confidence among students	U, An,S	
3	Students will enrich their knowledge and develop their logical reasoning ability	U, A, An	
4	Students will understand the methods to solve quantitative and reasoning problems with accuracy and in a time bound manner.	U, A, An	
5	Enhance logical reasoning and critical thinking skills to solve problems	U, A, An,I	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1 – Mental Ability	CO No.	Hours
Number system; Concepts of whole numbers, integers, rational and irrational numbers, Prime numbers, factors, multiples, and divisibility rules. Applications of HCF and LCM in problem-solving, Ages, Averages, Time and Calendar, Speed and Distance.	1,3,5	10 Hours
Module 2 – Numerical Aptitude	2,3	13 Hours
Ratios and proportions; ratio problems in mixtures, partnerships, and shares. Profit and Loss; Concepts of cost price, selling price, marked price, and discounts, Simple and Compound interest.		
Module 3 – Logical Reasoning	4,5	10 Hours
Alphanumeric series; Identification of patterns and sequences in alphanumeric combinations, Blood relations, Directions, Seating arrangement, Deductive-Inductive Reasoning, Coding- Decoding; Filling blanks and decoding sequences.		
Module 4 – Data Handling	2, 5	12 Hours
Data: meaning, types, sources; Data representation using Diagrams and Charts; bar graphs, pie charts, histograms, and line graphs. Data interpretation, Data Sufficiency.		

Mode of Transaction	Classroom activities
	Authentic learning, case-based learning, collaborative learning, seminar, group activities.

Mode of Assessment	Continuous Internal Assessment (CIA) 1. **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class 4. **Practical worksheet** will be provided to ensures hands-on learning and provides a robust platform for assessment, reinforcing the theoretical concepts taught in the course. 5. **Semester End Examination**

Learning Resources

- R.S. Aggarwal, Quantitative Aptitude for Competitive Examinations, S. Chand.
- A. Guha, Quantitative Aptitude for Competitive Examinations, (7th edition), Mc Graw Hill.
- R. Verma, Fast Track Objective Mathematics, Arihant.
- Rajesh Verma, Fast Track Objective Arithmetic, Arihant.

Relevance of Learning the course/ Employability of the course
The **Quantitative Aptitude and Reasoning** course is highly relevant in today's competitive academic and professional landscapes. Proficiency in these skills is essential for excelling in placement tests, competitive exams, and entrance assessments for higher education. Logical reasoning and quantitative aptitude are universally recognized as core competencies that enhance problem-solving, analytical thinking, and decision-making abilities, which are critical for success in fields like engineering, management, finance, data analysis, and technology. Employers increasingly seek candidates with strong aptitude and reasoning skills as they demonstrate the ability to think critically, adapt to complex challenges, and deliver results efficiently. By equipping students with practical, hands-on problem-solving techniques and strategies, this course bridges the gap between theoretical knowledge and its real-world application, thereby improving employability and preparing students for diverse career opportunities.

SEMESTER IV

	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Hydrogen and Fuel cells**		
Course Type	**Minor**		
Course Level	**200-299**		
Course Code	**MG4DSCUEM241**		
Course Overview	In this course, we will cover various concepts, reactions and applications of Hydrogen and 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 economic motivations. Fuel Cell Chemistry - Fundamental processes in a Fuel Cell and their efficiency.		
Semester	**4**	**Credit**	**4**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**15 Hours practical**	
Pre-requisite	This course has no prerequisites and can be taken by anyone.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Understand the 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
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	Hours	CO No.
HYDROGEN ENERGY Hydrogen – Physical and chemical properties - Salient characteristics - Hydrogen Energy Economy – Conception - Applications of Hydrogen - Transport application - cars, light trucks, buses -Stationary and Portable - Electronic gadgets.	**10**	**1, 2**
Module 2	**15**	**3,4**
HYDROGEN PRODUCTION TECHNIQUES Production of hydrogen – Steam reforming – Water electrolysis – Gasification and woody biomass conversion – Biological hydrogen production – Photo dissociation –splitting of water.		
Module 3	**10**	**5**
HYDROGEN STORAGE & TRANSPORT Hydrogen storage options – Compressed gas – Liquid hydrogen – Hydride – Chemical Storage – Comparisons - Transport of Hydrogen - Pipelines, Gaseous, Liquid and Compound materials.		
Module 4	**10**	**5,6**
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.		

Mode of Transaction	**Classroom activities** **Field activities** **Lab based activities**

Mode of Assessment	Continuous Internal Assessment (CIA) 1. **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class 4. **Semester End Examination**

Learning Resources

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).

Relevance of Learning the course/ Employability of the course
This course equips students with essential knowledge about various conversion processes, and storage technologies to tackle contemporary energy challenges. The module teaching and learning will comprise lectures and hands on practical. The coursework requires students to either design a hydrogen production system, or critically review the production process. The green hydrogen and fuel cell industry is currently undergoing rapid growth. After completing the course, students will attain the ability to evaluate, appraise and provide solutions to the energy crisis in the world.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Heat and thermodynamics**		
Course Type	**Minor**		
Course Level	**200-299**		
Course Code	**MG4DSCUEM242**		
Course Overview	The students are expected to know the fundamental concepts of heat and thermodynamics. This course deals with the relationship between the macroscopic and microscopic properties of physical systems in equilibrium. It reviews the concepts of thermodynamics learned at school from a more advanced perspective and how to develop them further to build new concepts. The course gives an understanding of the fundamental laws of thermodynamics and their applications to various systems and processes. The course begins with the basic concepts of thermodynamics, and the first and the second law of thermodynamics. It helps to understand the concepts of reversibility, irreversibility, and entropy. The students will be able to apply these concepts to several problems on heat, which includes the Carnot theorem for heat engines. It also includes a basic idea about the third law of thermodynamics and its application. Finally, the course helps to understand various thermodynamic potentials and their physical significance with respect to different thermodynamic systems and processes. Also, it enables students to deduce Maxwell's thermodynamical relations and use them for solving various problems in Thermodynamics.		
Semester	**4**	**Credit**	**4**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching	**15 hours tutorial**	
Pre-requisite	An introductory background in physics and chemistry will be helpful.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Gain knowledge on the basic concepts of thermodynamics, zeroth and the first law of thermodynamics.	U	
2	To derive expressions and find experimental verifications for the laws studied.	U, An	

3	Understanding the concepts of a Carnot theorem for heat engines and entropy of a system.	U, A, An	
4	To understand the third law of thermodynamics and its applications.	U,A	
5	Develop a critical understanding of thermodynamic potentials and Maxwell's equations.	U, A, An	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	**CO No.**	**Hours**
Introduction, definitions of system and surroundings; type of systems. Extensive and intensive properties. Concept of thermal equilibrium and the zeroth-law of thermodynamics. State functions and path functions. Reversible and irreversible process, First law of thermodynamics, Internal energy, Mathematical formulation of first law of thermodynamics, Enthalpy, Calculation of Cp-Cv Thermodynamically, Joule's law, Joule Thomson Effect, Joule-Thomson coefficient in ideal gas, Joule-Thomson coefficient for a real gas	**1,2**	15 Hours
Module 2	**3**	15 Hours
Second law of thermodynamics. Concept of heat reservoirs and heat engines, Carnot cycle, Efficiency of heat engine, enthalpy and heat capacities-concept of entropy. Entropy change of systems and surroundings for various processes and transformations. Entropy change during the isothermal mixing of ideal gases. Auxiliary state functions (G and A) and their variation with T, P and V. Criteria for spontaneity and equilibrium.		
Module 3	**4**	15 Hours
Third law of thermodynamics-residual entropy. Fugacity, Physical Significance of Fugacity, Free Energy Change (G) in Chemical Reactions, Activity Concept, Activity Coefficients of Electrolytes.		
Module 4	**5**	15 Hours
Thermodynamic relations: Maxwell's relations, Partial Molar Quantities/Chemical Potential, Gibbs Duhem Equations, Variation of Chemical Potential, Variation with Temperature, Variation of Chemical Potential with Pressure, Clapeyron Equation, Clasius Clapeyron Equation, Changes in Gibbs free energy (G) in Chemical Reactions, Standard Value of		

Gibbs Potential, van't Hoffs Equation, Feasibility of a Reaction.		

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Mode of Assessment	**Continuous Internal Assessment (CIA)** 1. **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class 4. **Semester End Examination**

Learning Resources

1) P. W. Atkins, Physical Chemistry, 9th Edtion Oxford University Press, 2010.
2) Heat and Thermodynamics- MS Yadav, Anmol Publications Pvt. Ltd, 2000.
3) Thermodynamics, R.C.Srivastava, S.K.Saha&AbhayK.Jain, Eastern Economy Edition.
4) Heat and Thermodynamics -N BrijLal, P Subrahmanyam, S.Chand& Co.,2012.
5) Heat and Thermodynamics: M. W. Zemansky and R. Dittman, 1981, Tata McGraw-Hill.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**
	4 + 1 Integrated UG and PG Programme
School Name	**School of Energy Materials**
Programme	**4 + 1 Integrated UG and PG Programme**
Course Title	**Software Tools for Energy Analysis**
Course Type	**SEC**
Course Level	**200 --299**
Course Code	**MG4SECUEM201**

Course Overview	This course is designed to equip students with the essential skills to utilize advanced software tools for analyzing, modeling, and optimizing energy systems. With the growing emphasis on renewable energy integration and sustainable solutions, proficiency in software-driven energy analysis has become crucial for tackling real-world energy challenges. Students will explore a range of software platforms commonly used in energy system design, simulation, and performance evaluation. The course emphasizes hands-on learning through case studies and practical exercises, enabling participants to model energy systems, assess their efficiency, and analyze environmental and economic impacts.		
Semester	**3**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**15 Hours Tutorial**	
Pre-requisite	No prior experience is required; however, a basic understanding of energy systems and proficiency in using computers will be beneficial.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Develop proficiency in using advanced software tools for modeling and analyzing energy systems.	U,A,E	
2	Design and simulate renewable energy systems, including solar, hybrid configurations, to assess their performance and feasibility.	U, An,S	
3	Evaluate the energy efficiency of systems and propose optimization strategies for sustainable energy solutions.	U, A, An	
4	Perform life cycle assessments and environmental impact analyses of energy projects using relevant software tools.	U, A, An	
5	Conduct economic feasibility studies for energy projects, enabling data-driven decision-making in real-world scenarios.	U, A, An,I	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1 – Introduction to Energy Systems and Software Tools	CO No.	Hours
Overview of energy systems: Renewable and non-renewable energy sources, Importance of energy analysis in sustainability. Introduction to energy analysis software's. Basic concepts of energy auditing and management. Case studies on successful energy audits using software tools	1,3,5	10 Hours
Module 2 – Energy Simulation and Modeling		

Fundamentals of energy modeling and simulation. Building energy performance simulation using EnergyPlus, Case studies: Solar PV systems, wind energy systems, Sensitivity analysis and optimization techniques.	2,3	13 Hours
Module 3 – Data Analysis and Visualization for Energy Systems	4,5	10 Hours
Introduction to data collection methods in energy systems, Data processing and analysis techniques, Visualization of energy data using Python and MATLAB.		
Module 4 – Future Trends in Energy Analysis	2, 5	11 Hours
Integration of energy systems with smart grids, AI and machine learning in energy optimization, Energy storage systems and their simulation. Emerging tools and technologies for energy analysis.		

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.
Mode of Assessment	**Continuous Internal Assessment (CIA)** 1. **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class 4. **Practical worksheet** will be provided to ensures hands-on learning and provides a robust platform for assessment, reinforcing the theoretical concepts taught in the course. 5. **Semester End Examination**

Learning Resources

1. *EnergyPlus Documentation* by U.S. Department of Energy.
2. Eastop, T.D., & Croft, D.R. (2014). Energy Efficiency and Management for Engineers.

Relevance of Learning the course/ Employability of the course
The course **Software Tools for Energy Analysis** holds significant relevance in today's energy sector, where the transition to sustainable and renewable energy solutions is a global priority. By equipping students with practical knowledge of industry-standard tools, the course bridges the gap between theoretical energy concepts and their real-world applications. Students gain essential skills in energy modeling, simulation, and performance optimization, preparing them for roles such as energy analysts, renewable energy consultants, and building energy modelers. The course enhances employability by meeting the growing demand for professionals capable of optimizing energy systems, managing renewable energy projects, conducting energy audits, and supporting energy policy development. With expertise in these tools, graduates are well-positioned to address challenges in energy efficiency, sustainability, and grid management, making them valuable assets in both the private and public sectors.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Innovative Techniques in Academic Writing**		
Course Type	**SEC**		
Course Level	**200-299**		
Course Code	**MG4SECUEM202**		
Course Overview	This course is designed for providing students with concepts of academic writing methods. The course also provide knowledge to identify the potential of innovative techniques in academic content creation. This course offers an advanced knowledge of different types of creative academic writing process. By completing this course students can get knowledge about the journal publication process. The module teaching and practice will comprise lectures and tutorials. This helps to understand the process of examining and avoiding plagiarism and successful publication of letters, reviews, articles, and communications with the peer review process.		
Semester	**4**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hours	**15 Hours Tutorial**	
Pre-requisite	This course has no prerequisites and can be taken by anyone.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Understand the academic writing methods with the differentiation of formal and informal language in writing.	U, An	1,2
2	Identify the potential of innovative techniques in academic content creation.	I, C	2,4
3	To learn about architecture of different types of creative academic writing methodology.	U, C	2,3

4	Gain knowledge about framework for thesis-driven writing skill and the use of software tools to improve readability and style of writing.	A, S	3,6
5	Understand the process of examining and avoiding plagiarism and publications of letters, reviews, articles, and communications with peer review process.	U, R	4,7
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1	Hours	CO No.
Introduction to academic writing Thinking in words, Social context of writing, Public and private writing, Genres. Writing for the academic discourse community, Formal and informal language in writing, Academic vocabulary.	**15**	**1, 2**
Module 2	**15**	**1, 3**
Architecture of academic writing Title, Introduction, Materials and Methods, Results, Discussion, References, Summary or Abstract. Graphical abstract, Tables and Graphs, Posters, Writing Process- Brainstorming, Outlining, Rough Draft, Editing.		
Module 3	**15**	**4,5**
Writing the research paper Thesis statement, Thesis outline, Framework for thesis-driven writing, conducting research for an academic paper, Developing a new working thesis. Description and narrative in thesis writing, Introductions and conclusions, Editing for readability and style. Software tools for innovative writing.		
Module 4	**15**	**5**
Plagiarism and Publication Examining and avoiding plagiarism, Ethics, Originality, Scientific Quality. Examining quotations, Examining paraphrase. Publications-Letters, Reviews, Articles, Communications. Peer Review Process. Journal impact factor, H index, i10-index.		

Mode of Transaction	**Classroom activities** **Field activities** **Workshops**

Mode of Assessment	**Continuous Internal Assessment (CIA)** **1. Internal Test** **2. Assignment –** Every student needs to write an assignment on a given topic based on the available published literature **3. Seminar Presentation –** A topic needs to be presented and discussed with the class **4. Semester End Examination**

Learning Resources

1. Lindsay D (2020) Scientific Writing, Thinking in Words. 2nd edn. CSIRO Publishing, Melbourne.
2. Patricia Prinz, The Art and Architecture of Academic Writing, City University of New York, DOI 10.1075/z.231
3. Academic writing: an introduction, Janet Giltrow, Richard Gooding. Daniel Burgoyne, Marlene Sawatsky. Third edition. ISBN 9784-55481-187-8

Relevance of Learning the course/ Employability of the course
This course implements the innovative methods in academic writing to enhance performance and skills of students for scientific writing. The software tools for academic writing enables students to critically appraise the writing methods. The modules focus teaching, which comprise lectures and tutorials. This helps to understand the process of examining and avoiding plagiarism and successful publication of letters, reviews, articles, and communications with peer review process.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Waste to Energy Conversion**		
Course Type	**Value Added Course (VAC)**		
Course Level	**200-299**		
Course Code	**MG4VACUEM201**		
Course Overview	This course explores the various technologies and processes that convert waste materials into energy. It covers conventional and emerging techniques for transforming different types of waste (such as municipal solid waste, agricultural residues, industrial waste, and biomass) into usable forms of energy, including electricity, heat, and biofuels. The course emphasizes the principles, applications, and environmental implications of these technologies, and their role in sustainable energy production and waste management. Students will gain practical insights into the latest advancements in Waste-to-Energy technologies and their contribution to the transition toward a more sustainable energy future.		
Semester	**4**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 hours Teaching	**15 Hours Tutorial**	
Pre-requisite	Students have the foundational knowledge needed to identify wastes and waste-to-energy conversion processes.		

COURSE OUTCOMES (CO)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning Domains	PSO No.
1	Identify and explain the sources and types of waste produced in various sectors, including domestic, industrial, agricultural, and post-consumer waste.	U, An	
2	Understand the principles, advantages, and disadvantages of waste-to-energy technologies such as incineration, gasification, pyrolysis, and syngas utilization.	U, A, An	
3	Develop critical insights into the role of waste-to-energy technologies in promoting sustainable energy production and waste management systems.	U, A, An	

4	Evaluate the technological, environmental, and economic aspects of energy production from algae, solid wastes, and waste plastics.	U, A	
5	Promote a sustainable and environmentally compliant approach to Waste-to-Energy systems while emphasizing resource optimization and climate change mitigation.	U, A, An	
*Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)			

COURSE CONTENT

Module 1- Waste Sources and Characterization	CO No.	Hours
Waste production in different sectors such as domestic, industrial, agriculture, postconsumer, waste etc. Classification of waste – agro based, forest residues, domestic waste, industrial waste (hazardous and non-hazardous). Characterization of waste for energy utilization. Waste Selection criteria.	1	9
Module 2	2, 3	13
Technologies for Waste to Energy – Incineration, gasification, pyrolysis, syngas utilization, and other newer technologies. Principle, advantages, and disadvantages of each method. Energy production through anaerobic digestion, fermentation, transesterification, and introduction to microbial fuel cells, Principle, advantages, and disadvantages of each method.		
Module 3	4	13
Options for Waste to Energy- Energy Production from Algae: Cultivation of algal biomass from wastewater and energy production from algae. Energy Production from Solid Wastes: Densification of solids, efficiency improvement of power plant, energy production from waste plastics. Applications of waste plastics in energy generation.		
Module 4	5	10
Environmental Implications and Waste To Energy Environmental standards for Waste to Energy Plant operations and gas clean-up. Savings on non-renewable fuel resources. Carbon Credits: Carbon foot calculations and carbon credits transfer mechanisms.		

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.

Mode of Assessment	**1. Continuous Internal Assessment (CIA)** **2. Internal Test** **3. Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 4. **Seminar Presentation –** A topic needs to be presented and discussed with the class 5. **Semester End Examination**

Learning Resources

1. Harker, J. H. and Backhusrt, J. R., "Fuel and Energy", Academic Press Inc, 1981.
2. Mondal, P. and Dalai, A. K. eds., 2017. Sustainable Utilization of Natural Resources. CRC Press.
3. Naomi B Klinghoffer, Marco J Castaldi, 2013. Waste to Energy Conversion Technology, Woodhead Publishing Series.
4. Hall, D.O. and Overeed, R.P.," Biomass – Renewable Energy", John Willy and Sons.
5. Rogoff, M. J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store, 2011.

Relevance of Learning the course/ Employability of the course
The course is highly relevant in the context of modern environmental challenges, energy sustainability, and the growing global need for efficient waste management solutions. As the world grapples with increasing waste generation and the depletion of non-renewable energy resources, learning about the technologies and processes that convert waste into usable energy provides critical insights into addressing these problems. This course prepares students for a wide range of careers at the intersection of environmental science, energy, and technology, positioning them as leaders in addressing global sustainability challenges and contributing to a circular economy.

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	MAHATMA GANDHI UNIVERSITY **Graduate School**		
	4 + 1 Integrated UG and PG Programme		
School Name	**School of Energy Materials**		
Programme	**4 + 1 Integrated UG and PG Programme**		
Course Title	**Smart materials and structures**		
Course Type	**VAC**		
Course Level	**200-299**		
Course Code	**MG4VACUEM202**		
Course Overview	Smart materials can sense and respond to the environment in optimal manner and hence gains much significance in new materials technologies for achieving energy security, effective healthcare and food security to support sustainable cities in the near future. The course is intended to provide an overview of different classes and categories of smart materials and their synchronous roles in building smart systems. The effective application of any material being dependent on the ability to tailor its properties, various mechanisms governing the smart behavior in smart alloys, smart polymers, piezoelectric materials and chromogenic materials are discussed. The wide range of applications of smart materials with emphasis on space applications is also included.		
Semester	**4**	**Credit**	**3**
Total Student Learning Time	**Instructional hours for theory**	**Instructional hours for practical/lab work/field work**	
	45 Hours Teaching Hour	**15 Hour Tutorial**	
Pre-requisite	Fundamental solid-state physics, Basic concepts on chemistry and physics		

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 have the ideas in basic material science and engineering. Understand the background of smart materials.	U	
2	Understand the basic concept of sensors and activators, a fundamental part of metamaterial	U, A, An	

3	Understanding the general way of processing smart materials	U, A, An	
4	Familiarize the application and feture persepectives of smart materials.	U,A,An	

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

COURSE CONTENT

Module 1 - Introduction to Smart Materials	**CO No.**	**Hours**
Classification and characteristics of materials: metals, polymers and ceramics. **Introduction to smart materials:** Components of a smart system, Properties and classification of smart materials, Applications of smart material	**1**	10 Hours
Module 2 – Sensors and Actuators	**2**	13 Hours
Sensors: Conductometric sensors, Capacitive sensors, Piezoelectric sensors, Magnetostrictive sensors, Piezoresistive sensors, Optical sensors, Resonant sensors, semiconductor-based sensors, Acoustic sensors, polymerize sensors, Carbon nanotube sensors **Actuators:** Electrostatic transducers, Electromagnetic transducers, Electrodynamic transducers, Piezoelectric transducers, Electro-strictive transducers, Magneto-strictive transducers, Electro thermal actuators, Comparison of actuation, Applications		
Module 3 – Processing of smart materials	**3**	10 Hours
Semiconductors and their processing, Metals and metallization techniques, Ceramics and their processing, Polymers and their synthesis, UV radiation curing of polymers		
Module 4 – Advanced materials and Future perspectives		
Shape memory materials: Shape memory alloys (SMAs), Shape memory effect, Martensitic transformation, One way and two-way SME, training of SMAs, binary and ternary alloy systems, Functional properties of SMAs **Chromogenic materials**: Thermochromism, Photochromism, Electrochromism, Halochromism, Solvatochromism- principle and design strategies, **Smart materials for robotics:** Future impact and challenges	**4**	15 Hours

Mode of Transaction	**Classroom activities** Authentic learning, case-based learning, collaborative learning, seminar, group activities.

Mode of Assessment	Continuous Internal Assessment (CIA) 1. **Internal Test** 2. **Assignment –** Every student needs to write an assignment on a given topic based on the available published literature 3. **Seminar Presentation –** A topic needs to be presented and discussed with the class **1. Semester End Examination**

Learning Resources

1. D.J. Leo, *Engineering Analysis of Smart Material Systems,* Wiley 2007.
2. M. Addington, D.L. Schodek, *Smart Materials and New Technologies in Architecture,* Elsevier 2005.
3. K. Otsuka, C.M. Wayman (Eds.), *Shape Memory Materials,* Cambridge University Press, 1998.
4. M.V. Gandhi, B. S. Thompson, *Smart Materials and Structures,* Chapman & Hall, 1992.
5. M. Schwartz, *New Materials, Processes, and Methods Technology*, CRC Press, 2006.
6. Gandhi, M.V. and Thompson, B.S. Smart Materials and structures (2nd Edition), Chapman & Hall, 1992.
7. Haim Abramovich, Intelligent materials and structures, De Gruyter Publications, 2016.
8. Gabbert, U. and Tzou, H.S. Smart Structures and Structuronic System, Kluwer Academic Publishers, 2001.
9. Banks, H.T., Smith, R.C. and Qang, Y.W. Smart Material structures: Modeling, Estimation and Control (6th Edition), John Wiley & Sons, 1997.
10. Otsuka, Wayman, Shape memory materials, Cambridge University Press, 2002.
11. Mel Schwartz, Encyclopedia of Smart Materials, 2 Volume set, CRC Press, 2007.
12. Cecilia Laschi, Robert J. Wood, Smarter materials for smarter robots.Sci. Robot.**6**,eabh4443(2021).DOI:10.1126/scirobotics.abh4443

Relevance of Learning the course/ Employability of the course
Understanding engineering materials is essential for a wide range of industries and fields, making this course highly relevant for students pursuing careers in materials science, and related disciplines. It covers the atomic and molecular principles that governs material properties, essential for selecting and developing materials with tailored characteristics for specific applications. Advanced level robotics and AI assisted automation also a developing area.