GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Diploma Engineering

Level: Diploma

Branch: Plastics Engineering

Subject Code: DI04023091

Subject Name: Green Hydrogen Production Technology

w. e. f. Academic Year:	2025-26
Semester	4th
Category of the Course:	MOPEC

Prerequisite:	
Rationale:	The course is designed to provide the fundamental concept of hydrogen and fuel cell and relevant engineering and technologies. Green Hydrogen Production Technology will prepare students for the global transition toward clean and sustainable energy systems. As a developing nation India need to work to reduce carbon emissions. Green hydrogen emerges as a key solution for decarbonizing transport, industry and power sectors. This course equips learners with foundational knowledge of hydrogen properties, advanced production technologies, safe storage - transportation methods and critical safety practices. Students also explore real-world applications and future trends shaping the hydrogen economy. The course will lead to develops skilled professionals capable of contributing to India's National Green Hydrogen Mission and global Clean- Entergy goals.

Course Outcome:

The course content should be taught and implemented with the aim of developing different types of skills so that students are able to acquire following competency, after the Completion of the Course:

No	Course Outcomes	RBT Level
1	Explain the fundamental properties, behavior, and energy relevance of hydrogen, including its types and lifecycle impacts.	R,U
2	Analyze and compare major green hydrogen production technologies based on principles, efficiency, and operational parameters.	R, U, A
3	Evaluate hydrogen storage and transportation methods considering technical, material, and logistical challenges.	R, U, A
4	Understand risk assessment and safety requirements for hydrogen handling and emergency response systems.	R, U
5	Explain the techno-economic feasibility and sector-wise applications of green hydrogen in transport, industry, power systems and its future.	R,U

**Revised Bloom's Taxonomy (RBT)*

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Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA(M)	PA(I)	ESE(V)	
3	0	0	3	70	30	0	0	100

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Unit-1: Fundamentals of Green Hydrogen** 1. **Introduction to Hydrogen** ○ Hydrogen as an element ○ Natural occurrence and isotopes 2. **Physical and Chemical Properties of Hydrogen** ○ Flammability, energy content ○ Storage and safety characteristics 3. **Types of Hydrogen** ○ Green, Blue, Grey: Production methods & emissions ○ Lifecycle carbon analysis 4. **Green Hydrogen as an Energy Carrier** ○ Efficiency, conversion, and advantages ○ Integration into energy systems 5. **Applications and Value Chain of Green Hydrogen** ○ End-use sectors: transport, industry, grid storage ○ Overview of production to utilization stages	9	20%

2.	**Unit-2: Green Hydrogen Production Technologies** 1. **Principles of Water Electrolysis** o Electrochemical reaction o Thermodynamics and energy requirements 2. **Alkaline Electrolyzer (AE) Technology** o Components, working, electrolyte systems o Merits and limitations 3. **PEM and Solid Oxide Electrolyzers (SOEC)** o PEM: Catalyst, membrane o SOEC: High-temperature operation 4. **Emerging Technologies in Hydrogen Production** o Photoelectrochemical (PEC) water splitting o Thermochemical and biological methods 5. **Operational Parameters and Optimization** o Current density, pressure, temperature impact o System efficiency and energy consumption	9	20%
3.	**Unit-3: Storage and Transportation of Green Hydrogen** 1. **Overview of Hydrogen Storage & Transport Needs** o Role in hydrogen economy o Safety and technical challenges 2. **Compressed Gas & Liquid Hydrogen Storage** o High-pressure storage systems (350-700 bar) o Cryogenic storage and boil-off management 3. **Hydrogen Transportation Methods** o Pipeline systems and material selection o Compression and distribution stations 4. **Mobile and Maritime Hydrogen Transport** o Tube trailers, tankers, and shipping options o Logistics and cost considerations 5. **Fuel Cell Technologies for Transport** o PEMFC working principle and applications o Efficiency, types, and comparison with combustion engines	9	20%

4.	**Unit-4: Safety and Hazards Management in of Green Hydrogen** 2. **Hydrogen Safety Fundamentals** ○ Physical and chemical properties affecting safety ○ Flammability, diffusivity, ignition energy, and explosive limits ○ Behavior of hydrogen leaks and dispersion characteristics ○ Real-world examples of hydrogen-related incidents 3. **Risk Assessment and Hazard Analysis** ○ Techniques: HAZOP, FMEA, What-If analysis ○ Failure mode identification and mitigation planning ○ Safety integration into hydrogen storage and transport systems ○ Case studies on risk and safety failures 4. **Leak Detection and Safety Systems** ○ Leak detection methods: electrochemical, ultrasonic, infrared ○ Ventilation, accumulation control, and flame behavior ○ Safety systems: fire suppression, alarms, isolation systems 5. **Safety Standards and Regulatory Compliance** ○ International codes: ISO, IEC, NFPA ○ Indian standards: BIS, PESO, OSHE regulations ○ Safety certification, inspection, and compliance requirements 6. **Emergency Response and Best Practices** ○ Emergency planning and incident response protocols ○ Safety training, PPE, signage, and regular audits ○ Drills, safety audits and organizational safety culture	9	20%
5.	**Unit-5: Utilization and Applications of Green Hydrogen** 1. **Applications in Transport Sector** ○ Fuel Cell Electric Vehicles (FCEVs) ○ Heavy-duty transport, buses, trains 2. **Industrial Applications** ○ Ammonia production, refineries, steel manufacturing ○ Hydrogen as a reducing agent 3. **Power Sector Integration** ○ Power-to-Gas and Power-to-X applications ○ Hydrogen turbines and hybrid systems 4. **Residential and Commercial Uses** ○ Hydrogen for heating and fuel blending ○ Hydrogen microgrids and back-up power 5. **Future Technologies and Global Trends** ○ Hydrogen blending in natural gas pipelines ○ Role in decarbonization pathways and international trade	9	20%
	Total	**45**	**100**

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks (in %)					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
35%	35%	30%	--	--	--

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

No.	Authors	Title	Publisher	ISBN
1.	Viswanathan, B.; M. Aulice Scibioh	Fuel Cells – Principles and Applications	Universities Press	9788173715570
2.	Rebecca L. Busby	Hydrogen and Fuel Cells: A Comprehensive Guide	PennWell Corporation, Oklahoma	9781593700430
3.	Bent Sorensen	Hydrogen and Fuel Cells: Emerging Technologies and Applications	Elsevier Academic Press, UK	9780123877093
4.	Kordesch, K.; G. Simader	Fuel Cells and Their Applications	Wiley-VCH, Germany	9783527285792
5.	Hart, A.B.; G.J. Womack	Fuel Cells: Theory and Application	Chapman & Hall	9780412078606
6.	Jeremy Rifkin	The Hydrogen Economy	Penguin Group, USA	9781585422548
7.	Paramvir Singh; Avinash Kumar Agarwal; Anupma Thakur; R.K. Sinha (Eds.)	Challenges and Opportunities in Green Hydrogen Production	Springer (Energy, Environment & Sustainability Series)	9819713412
8.	Junbo Hou; Min Yang (Eds.)	Green Hydrogen Production by Water Electrolysis	CRC Press / Routledge	9781032438108
9.	Ashwani Kumar; Sivasakthivel Thangavel; Gaurav Dwivedi	Green Hydrogen Production: Storage, Transportation and Applications	Apple Academic Press	(ISBN not listed in snippet)
10.	Agata Godula-Jopek	Hydrogen Production: By Electrolysis	Wiley-VCH	9783527333428

11.	Keith Scott (Ed.)	Electrochemical Methods for Hydrogen Production (Chapter: Introduction to Electrolysis, Electrolysers and Hydrogen Production)	Royal Society of Chemistry	9781788016032
12.	Agata Godula-Jopek	Hydrogen Production – By Electrolysis (Google Books Edition)	John Wiley & Sons	
13.	Jianxin Zou	Hydrogen Storage and Transportation	Springer	9789819628759
14.	Mohammad Reza Rahimpour; Mohammad Amin Makarem; Parvin Kiani (Eds.)	Hydrogen Transportation and Storage	CRC Press	9781003382553
15.	Raj Kumar Arya; Anurag Kumar Tiwari; George Verros; Prashant Malik; J. Paulo Davim	Sustainable Hydrogen Energy: Production, Storage & Transportation	Walter de Gruyter GmbH	9783110793018
16.	**Fotis Rigas**	Hydrogen Safety	CRC Press / Green Chemistry & Chemical Engineering Series	1138071749
17.	**Yiliu Liu; Nicola Paltrinieri (Eds.)**	Safety Measures for Hydrogen Fueling Stations: A Multi-disciplinary Risk Management Approach	CRC Press	9780367251548 (from listing)
18.	**Solomon Asante-Okyere et al.**	Risk and Safety Assessment of Hydrogen Pipelines and Storage Tanks (Frontiers Research Article)	Frontiers in Chemical Engineering	— (journal article)
19.	Bent Sørensen	Hydrogen and Fuel Cells: Emerging Technologies and Applications	Academic Press	9780123877093
20.	Rebecca L. Busby	Hydrogen and Fuel Cells: A Comprehensive Guide	PennWell	9781593700430
21.	Agata Godula-Jopek	Hydrogen Production & Applications	Wiley-VCH	9783527333428
22.	Michael Ball; Martin Wietschel (Eds.)	The Hydrogen Economy: Opportunities and Challenges	Cambridge University Press	9780521882163

23.	International Energy Agency (IEA)	The Future of Hydrogen	IEA	

(b) Open-source software and website:

Open-source software

A. **H2Tools (Pacific Northwest National Laboratory)** Hydrogen properties calculator, safety data, leak behavior models. https://h2tools.org/
B. **NIST Chemistry WebBook** Thermodynamic properties of hydrogen and isotopes. https://webbook.nist.gov/
C. **OpenModelica** Models electrolysis systems, thermodynamics, and energy flows. https://openmodelica.org/
D. **PyBaMM (Python Battery & Electrochemical Modeling)** Can be adapted for PEM electrolysis modeling. https://www.pybamm.org/
E. **Cantera** Open-source chemical kinetics & electrochemistry simulation. https://cantera.org/
F. **HyRAM (Hydrogen Risk Assessment Model)** Open-source tool for hydrogen safety, leaks, dispersion, and risk. https://hyram.github.io/
G. **OpenFOAM** CFD simulation of hydrogen leaks, dispersion, and explosions. https://openfoam.org/
H. **SAM (System Advisor Model)** For hydrogen-integrated renewable systems. https://sam.nrel.gov/
I. **OpenFTA** Fault-tree analysis for hydrogen safety. https://openfta.sourceforge.net/
J. **HOMER Energy (Free Academic Version)** Hydrogen microgrids, hybrid systems, backup power. https://www.homerenergy.com/
K. **EnergyPlus** Hydrogen heating & building integration. https://energyplus.net/
L. **PyPSA (Python for Power System Analysis)** Power-to-X, hydrogen turbines, grid integration. https://pypsa.org/
M. **OpenHPL (Hydrogen Pathway Library)** Models hydrogen value chains. https://github.com/OpenEnergyPlatform/ontology
N. MATPOWER (for grid-integrated electrolysis) https://matpower.org/

Website

1. https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office
2. https://www.iea.org/reports/the-future-of-hydrogen
3. https://hydrogeneurope.org/
4. https://www.energy.gov/eere/fuelcells/electrolyzer-technologies
5. https://www.fraunhofer.de/
6. https://hysafe.info/
7. https://ehb.eu/
8. https://www.dnv.com/hydrogen/
9. https://h2tools.org/
10. https://www.nfpa.org/
11. https://www.iso.org/
12. https://peso.gov.in/

13. https://bis.gov.in/
14. https://www.iea.org/topics/hydrogen
15. https://www.fchea.org/
16. https://www.ballard.com/

(c) Suggested Project List:

1. Build a Small-Scale Electrolyzer (Low-Voltage Demonstration)
2. Design a Green Hydrogen Production Plant (Mini-Scale) that includes: Solar sizing, Electrolyzer selection, Storage design, Safety systems, Cost analysis
3. Hydrogen-Based Rural Energy System A complete solution for a village that includes: (a) Solar + electrolyzer (b) Hydrogen storage Fuel cell for night power (c) Cost & feasibility study.

(d) Suggested Activities for Students:

1. Calculate hydrogen's thermodynamic properties
2. Compare hydrogen vs methane vs gasoline
3. Compare Grey vs Blue vs Green hydrogen
4. Identify India's hydrogen potential
5. Identify renewable hotspots in India
6. Propose a green hydrogen corridor in India
7. Prepare Emergency Response Plan for Evacuation and Fire suppression strategy in plant
8. Prepare PPE requirements and Safety signage for Green Hydrogen Production Plant

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