GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)

VI – Semester

Course Title: Electric and Hybrid Vehicle

(Course Code: 4366403)

Diploma programmer in which this course is offered	Semester in which offered
Renewable Energy	Sixth

1. RATIONALE

The shift from traditional combustion-engine vehicles to electric and hybrid technologies marks a crucial step toward a sustainable, eco-friendly future. This syllabus is crafted to establish a foundational understanding of electric and hybrid vehicles (EVs and HEVs), blending essential theoretical concepts with practical, hands-on learning. Designed as an introductory course, it focuses on key aspects of EV and HEV systems, technologies, and applications.

1. Foundations of Sustainable Vehicle Technology: Foundation introduces the evolution, types, and configurations of EVs and HEVs, building a foundation in sustainable vehicle technology.

2. Core Powertrain Elements: Covering battery technology and management systems, this unit highlights energy storage, efficiency, and safety, which are vital for the operation of electric vehicles.

3. Battery Dynamics and Management: Solar PV reduces dependence on fossil fuels, which are often imported. This enhances energy security and reduces exposure to volatile fuel prices.

4. Configurations and Energy Recovery Systems: This explains series and parallel hybrid configurations and regenerative braking, showcasing how hybrids optimize energy use and improve efficiency.

5. EV Charging Systems and Emerging Innovations: Focusing on charging infrastructure and emerging technologies like V2G, this unit provides insights into the practical and innovative aspects of EV infrastructure.

6. Environmental Impact and Economic Value: examines the ecological and economic benefits of electric vehicles, emphasizing lifecycle emissions, cost efficiency, and policy-driven adoption trends.

In summary, the rationale for Electric and Hybrid Vehicle covers essential aspects of electric and hybrid vehicles, from their fundamental components and configurations to advanced topics

like battery management, charging infrastructure, and environmental impact. Each unit is designed to provide a comprehensive understanding of the technologies shaping the future of transportation, with a focus on sustainability, energy efficiency, and practical applications.

2. COMPETENCY

This course equips learners with the essential knowledge and skills needed to understand, analyze, and contribute to the rapidly advancing field of electric and hybrid vehicles, focusing on key technologies, systems, and their environmental and economic impacts:

- **Understand EV/HEV Types & Configurations**
- **Evaluate Powertrain Components**
- **Apply Battery Technology & Management**
- **Optimize Hybrid Systems**
- **Design & Analyze Charging Systems**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

CO 1: Understand the various types of EVs and HEVs, and their environmental and economic impacts on sustainable transportation.

CO 2: Identify and evaluate the components of EV powertrains, including motors, inverters, and drivetrains, for performance and selection.

CO 3: Comprehend battery types, BMS functionality, and thermal management for efficient energy storage and safe EV operation.

CO 4: Analyze various hybrid vehicle configurations and energy management systems to optimize performance and efficiency.

CO 5: Understand EV charging infrastructure, standards, and emerging technologies like V2G and wireless charging for future advancements.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	4	5	30	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of Cos and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain Uos required for the attainment of the Cos.
***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** – Practical; **C** – Credit, **CA** – Continuous Assessment; **ESE** – End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the Course Outcomes (Cos). Some of the **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Compare EVs, HEVs, and conventional vehicles in terms of emissions, energy efficiency, and environmental impact.	I	4
2	Research and present on Indian policies and the FAME scheme for EV adoption.	I	4
3	Study series, parallel, and series-parallel hybrid configurations.	I	2
4	Demonstrate the construction and working principles of BLDC, PMSM, and induction motors	II	2
5	Simulate the performance characteristics of BLDC motors using tools like MATLAB.	II	4
6	Simulate the performance characteristics of PMSM motors using tools like MATLAB.	II	4
7	Simulate inverters and converters used in EV systems.	II	4
8	Study the importance and working of direct-drive systems in EV transmissions.	II	2
9	Identify and describe properties of different batteries used in EVs, including lithium-ion and solid-state batteries.	III	2
10	Simulate and get value of SOC for a small battery pack using MATLAB simulation.	III	2
11	Simulate and get value of SOH for a small battery pack using MATLAB simulation.	III	2
12	Compare AC Level 1, AC Level 2, and DC fast charging systems and explore wireless charging advancements.	III	4

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
13	Study and compare different cooling strategies for battery packs (air, liquid, PCM).	III	4
14	Simulate energy flow in series, parallel, and series-parallel hybrid configurations.	IV	4
15	Demonstrate regenerative braking principles using a simulation or small prototype.	IV	4
16	Study and document standards like CHAdeMO, CCS, and Tesla Supercharger protocols.	V	2
17	Simulate energy transfer between an EV and the grid to showcase V2G concepts.	V	4
18	Study how solar panels or wind energy can be integrated into an EV charging station.	V	2
	Minimum 10 Practical Exercises		56

Note:

*i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the Cos. The above table is only a suggestive list.*

*ii. The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the Cos and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Understanding of concepts	20
2	Explanation of conclusion	20
3	Student attitude towards learning	20
4	Quality of term work	20
5	Timely completion of term work	20
Total		**100**

5. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practicals in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Battery Packs (Lithium-Ion and Lead-Acid)	1,3,8,10,11
2	BLDC and PMSM Motors	4,5,6
3	Invertor and Convertor Module	7
4	Hybrid Vehicle Powertrain Demonstration Kit	1,3,8,14
5	Current, Voltage Sensors and Temperature Sensor	9,10,11,,12
6	Regenerative Braking Prototype Kit	15
7	Solar PV characteristic Kit	18

6. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned Cos and PrOs. More could be added to fulfill the development of this course competency.

a) Work as a leader/a team member (while doing a micro-project)
b) Follow safety practices while using Electrical supply and electrical equipment.
c) Follow ethical practices.
d) Adhere to safety protocols to ensure the safe installation and maintenance of system.
e) Practice environmental friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level Uos of *Revised Bloom's taxonomy* that are formulated for development of the Cos and competency. If required,

more such Uos could be included by the course teacher to focus on attainment of Cos and competency.

Unit	Unit Outcomes (Uos) (4 to 6 Uos at different levels)	Topics and Sub-topics
Unit –I Introduction to Electric and Hybrid Vehicles	**1a**. Evolution, significance, and market trends of EVs and HEVs **1b**. Overview of FAME Scheme and its impact on EV adoption. **1c**. Comparison of EVs, HEVs, and conventional vehicles in energy efficiency and emissions. **1d**. Distinguish between the different types of hybrid powertrains. **1e.** Illustrate the environmental lifecycle of EVs, focusing on emissions and battery recycling.	**1.1** Evolution and significance of EVs in sustainable transportation. **1.2** Indian Policies and subsidies, on adoption of Electric Vehicle. **1.3** Benefits of EVs in terms of emissions, energy efficiency, and renewable integration. **1.4** Types of HEVs; Mild HEV, Full HEV, Plug in HEV, Series HEV, Parallel HEV, Series – Parallel HEV **1.5** Comparative analysis: EVs vs. HEVs vs. conventional vehicles. **1.6** Classification of hybrid powertrains into series, parallel configurations **1.7** Analyze the lifecycle emissions of EVs
Unit-II Electric Vehicle Powertrain Components	**2a**. Identify different types of motors used in EV applications **2b**. Explain the role, Functions, and working of electric motors in EV and HEV. **2c**. Compare and Analyze the performance characteristics and selection criteria of various motor types for EV applications. **2d**. Role and functions of inverters, converters, and direct-drive systems in EV powertrains.	**2.1** Electric Motors in EV and HEVs; Construction and working of Brushless DC Motor (BLDC), Permanent Magnet Synchronous Motors (PMSM) and Induction Motors. **2.2** Motors Performance characteristics and selection criteria for electric vehicle applications. **2.3** Importance of inverters in EV systems. **2.4** Role of converters in EV systems. **2.5** Overview of motor control strategies and importance of efficiency in drives. **2.6** Simplified transmission systems in EVs and HEVs. **2.7** Role and importance of direct-drive systems.
Unit-III Battery Technology and Battery Management Systems (BMS)	**3a**. Identify Types of EV batteries, their properties, and sustainability aspects. **3b**. Functions of Battery Management Systems (BMS), including SOC and SOH estimation. **3c**. Importance of thermal management and comparison of charging technologies.	**3.1** Types of Battery and its comparative analysis. **3.2** Battery Management System (BMS); Functions **3.3** State of Charge and State of Health and enlist their estimation methods **3.4** Importance of temperature control in battery life and safety. **3.5** Cooling strategies: Air, liquid, and phase-change material (PCM) cooling. **3.6** Charging levels (AC Level 1, AC Level 2, DC fast charging). **3.7** Wireless charging technology and recent advancements.

Unit-IV Hybrid Electric Vehicle Configurations	**4a**. Describe the characteristics and components of series, parallel, and series-parallel hybrid configurations **4b.** Understand Energy flow and role of components in hybrid energy management. **4c**. Explain the role of Regenerative braking, ultracapacitors, and fuel cells for efficiency improvement.	**4.1** Detailed study of series, parallel, and series-parallel configurations. **4.2** Power flow management in different HEV configurations. **4.3** Overview of auxiliary systems: Ultracapacitors, fuel cells, and regenerative braking systems. **4.4** Role of regenerative braking and energy recovery in hybrids.
Unit-V Charging Infrastructure and Emerging Technologies	**5a.** Learn Standards, protocols, and charging infrastructure requirements for EVs. **5b.** Describe Vehicle-to-Grid (V2G) technology and its role in renewable energy integration. **5c**. Overview of emerging technologies, including solid-state batteries.	**5.1** Charging station requirements, standards, and protocols. **5.2** Grid integration and smart charging solutions.. **5.3** Vehicle-to-Grid (V2G) and Vehicle-to-Home (V2H) concepts. **5.4** Solid-state batteries and their potential benefits.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to Electric and Hybrid Vehicles	07	6	4	2	12
II	Electric Vehicle Powertrain Components	12	6	6	6	18
III	Battery Technology and Battery Management Systems (BMS)	11	4	6	6	16
IV	Hybrid Electric Vehicle Configurations	06	4	6	2	12
V	Charging Infrastructure and Emerging Technologies	06	4	4	4	12
Total		42	24	26	22	70

Legends: *R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions*

to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.

10. SUGGESTED STUDENT ACTIVITIES

To enhance learning outcomes and practical understanding, students can undertake the following co-curricular activities individually or in groups. They should prepare concise reports (around 5 pages) and collect physical evidence for their portfolios to showcase during placement interviews:

a) Seminar Presentations
b) Comparative Analysis
c) Field Visits and Industry Interaction
d) Practical Simulations and Experiments
e) Case Studies Study policies like the FAME scheme and analyze their impact on EV adoption
f) Research Projects
g) Numerical Problem Solving
h) Design and Installation Practices
i) Interactive Learning
j) Community Awareness

The student should be encouraged to get their work assessed by the concerned teacher progressively during the term and at the end of the term the whole work should be submitted to the concerned teacher.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Leverage Online Learning Platforms like NPTEL, COURSERA etc.
b) Guide student(s) in undertaking micro-projects.
c) ***Diverse Teaching Methods***.
d) Use multimedia tools.
e) Arrange visits to EV charging stations, automotive service centers, or renewable energy integration facilities to observe real-world applications
f) Link with Other Disciplines
g) Discuss Policies and Trends.
h) Creative Outreach Activities
i) Promote Environmental Responsibility.

12. SUGGESTED MICRO-PROJECTS

Each student or group (max three members) is encouraged to undertake one micro-project assigned at the start of the semester. These projects should integrate two or more Course Outcomes (COs) and provide hands-on, industry-relevant experience. Projects should be completed in 14-16 engagement hours, with students documenting progress in a work diary and delivering a seminar presentation upon completion.

a) Design a Simple EV Charging Station Model
b) Build a Basic Battery Cooling System
c) Investigate EV Battery Efficiency
d) Compare Charging Techniques
e) Regenerative Braking System Prototype
f) Analyze Motor Performance
g) Create a Direct-Drive EV Prototype
h) Battery Management System (BMS) Simulation
i) Study Hybrid Powertrains
j) Analyze Energy Flow in a Hybrid System
k) Wireless Charging Prototype
l) Environmental Impact Analysis of EV Batteries
m) Vehicle-to-Grid (V2G) Demonstration Model
n) Develop an EV Maintenance Manual
o) Renewable Integration with EV Charging

13. SUGGESTED LEARNING RESOURCE

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Introduction to Electric Vehicles (1st Edition)	James Billings	Published by Billings Energy Research (2020) ISBN: 978-0977659944
2	The Guide to Electric, Hybrid & Fuel-Efficient Cars (1st Edition)	John L. Sullivan and James P. Sullivan	Haynes Publishing (2010) ISBN: 978-1844256788
3	Electric Vehicle Technology Explained (2nd Edition)	James Larminie and John Lowry	Wiley (2012) ISBN: 978-1118361127
4	Electric and Hybrid Vehicles: Design Fundamentals (2nd Edition)	Iqbal Husain	CRC Press (2011) ISBN: 978-1439802861

13. SOFTWARE/LEARNING WEBSITES

Software Tools

MATLAB/Simulink – For simulating motor performance, energy flow in hybrid systems, SOC/SOH estimation, and inverter/converter operations.

1. **PSIM** – For power electronics simulations (inverters, converters).
2. **Ansys Fluent** – For studying cooling strategies in battery packs.
3. **LabVIEW** – For data logging and control systems.
4. **ETAP** – For grid integration studies and V2G simulations.
5. **Fusion 360** – For designing and simulating mechanical components like direct-drive systems.
6. **PSpice** – For electronic circuit simulations related to EV systems.
7. **TinkerCAD** – For basic circuit design and visualization.

Learning Websites

1. **National Programme on Technology Enhanced Learning (NPTEL)** – Offers free EV and power electronics-related courses.
2. **Coursera** – Hosts EV-related courses from universities (e.g., EV Design and Policy).
3. **edX** – Offers advanced EV and hybrid vehicle systems courses.
4. [**YouTube Channels**]
    - **GreatScott!** – For hands-on electronic projects.
    - **MathWorks** – For MATLAB/Simulink tutorials.
5. **OpenStax** – Provides free textbooks on engineering fundamentals.
6. **Khan Academy** – Basics of electricity and electronics.
7. **IEEE Xplore** – Access to technical papers and standards on EVs.
8. **EV Obsession** – EV market trends and news.
9. **Battery University** – For detailed insights into battery technology.
10. **Skill-Lync** – Specialized courses in hybrid vehicles and EV technology.

15. PO-COMPETENCY-CO MAPPING:

Semester IV	Solar Photovoltaic (Course Code: 1346401)						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solution	PO4 Engineering Tools, Experimentation Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency	To help individual to understand their role and responsibilities						

	for depth Understanding of Solar Photo Voltaic system						
CO 1: Understand the various types of EVs and HEVs, and their environmental and economic impacts on sustainable transportation.	3	1	-	-	3	-	-
CO 2: Identify and evaluate the components of EV powertrains, including motors, inverters, and drivetrains, for performance and selection.	2	3	3	3	-	-	-
CO 3: Comprehend battery types, BMS functionality, and thermal management for efficient energy storage and safe EV operation.	2	2	2	3	2	-	-
CO 4: Analyze various hybrid vehicle configurations and energy management systems to optimize performance and efficiency.	2	3	3	3	-	-	-
CO 5: Understand EV charging infrastructure, standards, and emerging technologies like V2G and wireless charging for future advancements.	2	1	2	3	3	-	-

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
1.	Mitul M. Modi Lecturer Electrical Engg.	AVPTI, Rajkot	9638074390	Mitulmodi.gp@gmail.com