GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester -VI
Course Title: **Electric & Hybrid Vehicle**
(Course Code: 4360204)

Diploma programme in which this course is offered	Semester in which offered
Automobile Engineering	6th

1. RATIONALE

Electric and hybrid vehicles have gained significant attention and popularity in recent years due to their potential to address various environmental and energy-related challenges. Introducing the electric and hybrid vehicles in the syllabus for a diploma program's 6th semester can provide students with a solid foundation and understanding of this rapidly evolving field. Electric and hybrid vehicles offer a more environmentally friendly alternative, more energy-efficient than conventional internal combustion engine vehicles. Understanding the fundamental principles and components of these vehicles can provide students with insights into the latest technological advancements, including electric & hybrid drivetrains, energy storage systems (such as batteries). Students can gain knowledge and skills that align with the growing demand for professionals in the field of electric and hybrid vehicle design, development, maintenance, and infrastructure deployment. By incorporating the study of electric and hybrid vehicles into the diploma program's 6th semester, students can gain a comprehensive understanding of the technical, environmental, and societal aspects of these vehicles.

2. COMPETENCY

The course content should be taught and curriculum should be implemented with the aim to develop different types of skills leading to the achievement of the following competency.

- **Apply principles of electric and hybrid vehicle technology for sustainable solutions**.

3. COURSE OUTCOMES (COs)

The underpinning knowledge and the relevant skills associated with this competency are to be developed in the student to display the following COs:

a) Understand the history, evolution, and future prospects of electric and hybrid vehicles.
b) Identify the components of electric vehicles including electric motors, controllers, and battery technologies.
c) Analyze different types of hybrid powertrain configurations (series, parallel, series-parallel) and understand their integration with combustion engines.
d) Demonstrate knowledge of safety precautions and procedures related to electric and hybrid vehicles.
e) Comprehend the charging technologies, standards, and infrastructure for electric vehicles, including fast charging and smart grid integration.

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	
2	0	2	3	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) that are the sub-components of the COs. These PrOs need to be attained to achieve the COs.

Sr. No	Practical Outcomes (PrOs)		Unit No.	Approx. Hrs. required
1	Compare and contrast the environmental, economic, and performance advantages and disadvantages of electric and hybrid vehicles.	Any one	1	2
2	Evaluate the constraints of current battery technology, such as energy density, cost, and lifetime.		1	2
3	Study the future prospects and impacts of electric and hybrid vehicles.		1	2
4	Identify and develop Battery Pack Components, monitor And check performance of high voltage rechargeable energy storage system.	Any two	2	4
5	Describe Battery Management System in electric Vehicles.		2	4
6	Describe different types of Battery Cooling System or Technologies.		2	4
7	Identify different components of EV and Hybrid Vehicle Motors.		2	4
8	Check controlling system of different EV motors.		2	4
9	Identify various parts/ components of Battery Electric Vehicles (BEVs), Fuel Cell Electric Vehicles (FCEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Range Extender Electric Vehicles (REEVs).	Any two	3	4
10	Identify various parts/ components in between Series hybrids, Parallel hybrids and Series-parallel hybrids		3	4
11	Draw power flow line diagram in Parallel hybrid transmissions & Power-split hybrid transmissions		3	4

12	Study and understand working of control systems used in Electric vehicle and Hybrid electric vehicles.		3	4
13	Study and understand about Safety tools and their applications.	Any two	4	4
14	Observe and study of regularly maintenance on EV and Hybrid vehicles.		4	4
15	Examine, Remove and Replace Procedure of Electric Vehicle Components.		4	4
16	Identify different diagnostic and maintenance tools of EV and Hybrid Vehicles.		4	4
17	Compare and understand the operation of different Charging stations.	Any one	5	2
18	Understand Safety measures and standards in charging infrastructure.		5	2
	Total Hrs.			**28**

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. Care must be taken in assigning and assessing study report as it is a study report. Study report, data collection and analysis report must be assigned in a group. Teacher has to discuss about type of data (which and why) before group start their market survey.

*iii. 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.*

S. No.	Sample Performance Indicators for the Practical's	Weightage in %
1	Basic knowledge and understanding of experiments	40%
2	Identification of components of experiments	20%
3	Answer to questions	20%
4	Timely submission	20%
Total		**100%**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Cutaway Models/ Demonstrative models of each vehicle type to showcase internal components. This is made out using original Components of electric and hybrid vehicles showcasing arrangements and operation in their	For all

	respective types of vehicles. The entire model is mounted on a sturdy iron frame.	
2	Power Electronics Lab: Equipped with converters and inverters for practical experiments on power electronics.	For All
3	Safety Equipment's for EV vehicle. • Face Shield with head band • Under gloves • Over Gloves • Insulating Gloves • Insulating Mat • Voltage Detector • Flat Blade Screw Driver • Cable Cutter	For All
4	Multimeters, Oscilloscopes, and Power Supplies: Basic electronic testing equipment for troubleshooting and experimentation.	For all
5	Cut Section of Lithium ion Battery (or Any EV vehicle Battery). • Individual or Battery Pack. Passenger Vehicle Battery.	4,6
6	Cut Section of Any EV Motor. • Realization of miniaturization and weight reduction with high output density • Maximizing cooling effect with optimal water cooling design • Use of high-grade electrical steel sheet with low loss • Use in high speed area by securing structural strength safety • Spline or Round Shaft • Use of high-temperature insulation and designed for inverter surge NTC temperature sensor, speed sensor(Resolver or hall effect sensor)	7,8
7	EV Scanners Tools. • Ultra EV integrates programming • coding, • intelligent diagnostics, • VCMI, • 40+ reset services Split/Flat screen	5, 12
8	Hands-on model kits to help students assemble and understand series, parallel, and series-parallel hybrid powertrains. may contain these components: DC Motors, Rechargeable Batteries, Power Electronics: Inverters and converters for controlling power flow, Transmission Components: Gears and shafts to represent the transmission system,	9, 10, 11

	Controller/ECU: Microcontroller for system control, Wiring and Connectors: Facilitating assembly and connection of components. Chassis/Frame: Structure to hold and arrange components realistically.	
9	Models or setups illustrating the components and operation of electric vehicle brake systems and regenerative braking. list of components for a model illustrating the operation of an electric vehicle brake system: Brake Caliper and Pads: Demonstrating the friction components responsible for slowing down the vehicle. Regenerative Braking Module: Showing how energy is captured during braking. ABS Module: Illustrating anti-lock braking system components for wheel control. Brake Pedal and Sensor: Simulating the driver's input and sensor feedback.	12
10	Models or setups illustrating the components and operation of electric power steering. Model may include a sturdy frame consisting of main components like Electric Motor, Steering Column, Steering Angle Sensor, Torque Sensor, Control Unit (ECU) & Drive Mechanism	12

7. AFFECTIVE DOMAIN OUTCOMES

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

a) Work as a leader/a team member.
b) Follow ethical practices.
c) Practice environmentally friendly methods and processes. (Environment related)

The ADOs are best developed through the field based exercises/project work. 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 higher level 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 Electric and Hybrid Electric Vehicle Technology	1.a The students should be able to comprehend the historical development of electric vehicles, evaluate the impact of carbon-based fuel vehicles on the environment, and assess the influence of government policies and regulations on the evolution of electric vehicles. 1.b The students should be able to identify and compare the benefits and challenges of electric and hybrid vehicles, as well as analyze future prospects and innovations in this field.	1.1 History and evolution of electric vehicles • Evolution of electric vehicle technology • Effects of carbon-based fuels vehicles on the environment 1.2 Benefits and challenges of electric and hybrid electric vehicles • Environmental Benefits (Reduced Emissions) • Economic Benefits (Lower Operating Costs) • Performance Advantages • Range Limitations • Charging Infrastructure Challenges • Battery Technology Constraints 1.3 Future prospects of electric and hybrid vehicles • Advancements in Battery Technology • Autonomous Features in Electric Vehicles • Vehicle-to-Grid Technology • Market Projections and Growth Potential • Potential Impacts on Energy Grids
Unit II Batteries, motors, and control system of an electric vehicle	2.a The students should be able to understand the fundamental principles and advancements in battery technologies, types of electric vehicle motors, and the operation of control systems in electric vehicles. 2.b The students should be able to analyze and apply advanced control systems used in electric vehicles for efficient operations and performance.	2.1 Battery Technologies: 2.1.1 Introduction to Battery Basics: Range, Life, Recycling Charging state & Health 2.1.2 Types of Batteries: • Lead-Acid • Alkaline • Sodium-Nickel Chloride • Sodium-Sulfur • Lithium-ion 2.1.3 Battery Developments: • Temperature management • Fast Charging Batteries • Solid State Batteries

		2.2 Electric vehicle motors: 2.2.1 Types, construction and functions of electric vehicle motors • Brushless DC motor • Permanent magnet synchronous motor (PMSM) • Three phase AC induction motor 2.3 Control Systems: 2.3.1 Importance of motor controller in electric and hybrid electric vehicles 2.3.2 Basic operation of control systems 2.3.3 Types of motor controllers • Variable resistor type controller • Pulse width modulation 2.3.4 Sensors in control systems 2.3.5 Battery and cell balancing in control systems 2.3.6 Component cooling in control systems 2.3.7 Battery Management system (BMS)
Unit III Powertrain - Systems of Battery Electric Vehicles (BEVs) and Hybrid Electric Vehicle (HEVs)	3.a The students should be able to Identify and compare electric vehicle types and hybrid powertrain configurations, understanding their advantages. 3.b The students should be explain the role of transmissions, integration of combustion engines and electric motors, and other systems in electric and hybrid vehicles.	3.1 Components (configurations) of electric and hybrid vehicles. 3.1.1 Electric Vehicle types and its configurations • Battery electric vehicles (BEVs) • Fuel cell electric vehicles (FCEVs) • Plug-in hybrid electric vehicles (PHEVs) • Range extender electric vehicles (REEVs) 3.1.2 Hybrid powertrain configurations • Series hybrids • Parallel hybrids • Series-parallel hybrids 3.2 Electric Vehicle Transmissions and Transaxle 3.3 Hybrid Vehicle Transmissions and Transaxles • Parallel hybrid transmissions • Power-split hybrid transmissions 3.4 Combustion engines and electric motors integration. • Engine-motor coupling mechanisms • Starter-generators • Integrated motor-generators 3.5 Other systems: • Brake systems • Electric power steering (EPS) • Converters & inverters

		• Supercapacitors & Flywheels 3.6 Energy management system.
Unit IV Diagnostics and Maintenance of Electric and Hybrid Electric Vehicles	4.a The students will be well-versed in safety guidelines and procedures associated with the maintenance and operation of electric and hybrid vehicles. 4.b The students will be capable of conducting maintenance and diagnostics for electric powertrain components while adhering to appropriate safety protocols. They will also understand safe procedures for battery maintenance and disposal.	4.1 Safety precautions and procedures of Electric and Hybrid Vehicles. 4.1.1 General safety guideline for before, during and after maintenance of EV's. 4.1.2 High voltage safety precautions • Personal Protective Equipment (PPE) • High-energy cables and components • AC electric shocks • DC electric shocks 4.2 Maintenance and diagnostics of electric powertrain components. • Inspect, remove and replace procedure of high voltage & low voltage components 4.3 Various tools required for EV/Hybrid Vehicle components testing. 4.4 Battery maintenance and disposal procedure and techniques.
Unit V Electric Vehicle Charging Infrastructure and Energy Management	5.a The students will acquire comprehensive knowledge about various EV charging technologies, standards, and infrastructure deployment. 5.b The students will be able to understand and analyze smart grid integration and the concept of swap-able battery charging stations.	5.1 EV's Charging technologies and standards (AC, DC, fast charging). 5.2 EV's Charging station infrastructure and deployment. • Overview of electric vehicle charging • Types of charging stations: Level 1, Level 2, DC Fast Charging • Public charging networks and stations • Components of a charging station: Chargers, Connectors, Communication Protocols • Charging station operation and protocols • Safety measures and standards in charging infrastructure 5.3 Smart grid integration and Swap-able battery charging station.

***Note**: The UOs need to be formulated at the 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Electric and Hybrid Electric Vehicle Technology	4	04	06	02	12
II	Batteries, motors, and control system of an electric vehicle	6	03	04	07	14
III	Powertrain - Systems of Battery Electric Vehicles (BEVs) and Hybrid Electric Vehicle (HEVs)	8	04	07	07	18
IV	Diagnostics and Maintenance of Electric and Hybrid Electric Vehicles	6	03	04	07	14
V	Electric Vehicle Charging Infrastructure and Energy Management	4	02	06	04	12
	Total	28	16	27	27	70

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

Note*: This specification table provides general guidelines to assist student 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

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of each activity. They should also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Charts can be prepared.
b) Small report on any topic given by concern faculty.
c) Small groups of students can be formed for assigned work. Assigned work should be such that it covers market survey, team work, presentation, time management, quality development.

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) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4*** means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably being ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that she/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should be about **14 - *16 (fourteen to sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

1) Prepare a report on history and evolution of electric and hybrid electric vehicles in Indian automobile sector.
2) Prepare a report on evolution of electric and electric hybrid electric vehicles of global scenario.
3) Prepare presentation on Impact of government policies and regulations on the development of electric vehicles.
4) Electronically commutated motor and switched reluctance motor.
5) Heating, ventilation, and air conditioning (HVAC) systems
6) To check, identify and interpret different types of Electric and Hybrid vehicles and their specifications.
7) To prepare report or poster on different types of EV battery.
8) To arrange Group Discussion on different electric vehicles and their challenges.
9) To Visit any EV workshop and prepare report on it.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Electric & Hybrid Vehicles	A.K. Babu	Khanna Publishing House ISBN-10: 9386173719, ISBN-13: 9789386173713
2	Electric and Hybrid Electric Vehicles	James Halderman	Pearson Publication ISBN-10: 9356066280 ISBN-13: 978-9356066281
3	Electric and Hybrid Vehicles	Tom Denton	Published by Routledge ISBN 9780367273231
4	Electric Vehicle Engineering (ELECTRONICS)	Per Enge (Author), Nick Enge (Author), Stephen Zoepf (Author)	McGraw Hill ISBN-10: 1260464075 ISBN-13: 978-1260464078
5	Electric and Hybrid Vehicles	Dr. C. Balakrishna Moorthy (Author), Dr. U. Muthuraman (Author), Inder Singh Bisht (Author), Dr. M. Rajeshwaran (Author), Dr. P. Gomathi and Dr. S. Devi (Author)	AkiNik Publications ISBN-10: 9355703562 ISBN-13: 978-9355703569

14. SOFTWARE/LEARNING WEBSITES

a) https://www.howacarworks.com
b) https://swayam.gov.in
c) https://auto.howstuffworks.com
d) https://nptel.ac.in
e) https://tinyurl.com/3zd97hhe for video link
f) https://tinyurl.com/dy8z6b9p for web link

15. PO-COMPETENCY-CO MAPPING

Semester VI	Electric & Hybrid Vehicle (4360204)						
	POs						
Competency & Course Outcomes	**PO 1 Basic & Discipline specific knowledge**	**PO 2 Problem Analysis**	**PO 3 Design/ development of solutions**	**PO 4 Engineering Tools, Experimentation &Testing**	**PO 5 Engineering practices for society, sustainability & environment**	**PO 6 Project Management**	**PO 7 Life-long learning**
• Apply principles of electric and hybrid vehicle technology for sustainable solutions.	3	2	2	2	3	2	3
a) Understand the history, evolution, and Future prospects of electric and hybrid vehicles.	3	2	2		2		3
b) Identify the components of electric vehicles including electric motors, controllers, and battery technologies.	3	2		2	2	2	3
c) Analyze different types of hybrid powertrain configurations (series, parallel, series-parallel) and understand their integration with combustion engines.	3	2	2	2	2	2	3
d) Demonstrate knowledge of safety precautions and procedures related to electric and hybrid vehicles.	3	2		2	2		3
e) Comprehend the charging technologies, standards, and infrastructure for electric vehicles, including fast charging and smart grid integration.	3	2			2		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

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1	Mr. D. A. Dave (Retd. HOD Automobile)	Sir B.P.T.I, Bhavnagar	9427182407	deven_a_dave@yahoo.co.in
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