

SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution)

SRM Nagar, Kattankulathur– 603203.

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTION BANK



VI SEMESTER

PME203 CLEAN OFF–HIGHWAY VEHICLE TECHNOLOGY

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DEPARTMENT OF MECHANICAL ENGINEERING

PME203 CLEAN OFF-HIGHWAY VEHICLE TECHNOLOGY

UNIT I – LOW & ZERO-CARBON FUELS FOR OFF-HIGHWAY VEHICLES

Ethanol, Methanol, Butanol, Biodiesel, HVO–Hydrotreated Vegetable Oil, CNG, LNG, LPG, Dimethyl Ether (DME), Polyoxymethylene Dimethyl Ether (PODE), Ammonia, Hydrogen fuel properties, handling and safety, fuel injection system compatibility, fuel sensors, ECU calibration basics, and role of vehicle software in alternate fuel utilization.

PART - A (2 Marks)

Q.No.	Questions	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Define ethanol as an alternative automotive fuel.	CO1	BTL-1	Remember
2.	List any two properties of methanol used as a fuel.	CO1	BTL-1	Remember
3.	Identify any two advantages of butanol over ethanol as a fuel.	CO1	BTL-2	Understand
4.	Define biodiesel.	CO1	BTL-1	Remember
5.	Why is biodiesel considered eco-friendly?	CO1	BTL-2	Understand
6.	What is HVO (Hydrotreated Vegetable Oil)?	CO1	BTL-1	Remember
7.	List two advantages of HVO fuel.	CO1	BTL-1	Remember
8.	Define Compressed Natural Gas (CNG).	CO1	BTL-1	Remember
9.	Differentiate between CNG and LNG.	CO1	BTL-2	Understand
10.	What is Liquefied Petroleum Gas (LPG)?	CO1	BTL-1	Remember
11.	Define Dimethyl Ether (DME).	CO1	BTL-1	Remember
12.	State any two benefits of using Dimethyl Ether (DME) as a fuel.	CO1	BTL-1	Remember

13.	What is Polyoxymethylene Dimethyl Ether (PODE)?	CO1	BTL-1	Remember
14.	Represent how Polyoxymethylene Dimethyl Ether (PODE) improves combustion.	CO1	BTL-2	Understand
15.	Define ammonia as an alternative fuel.	CO1	BTL-1	Remember
16.	Mention one challenge in using ammonia as fuel.	CO1	BTL-1	Remember
17.	List two properties of hydrogen fuel.	CO1	BTL-1	Remember
18.	Why is hydrogen safety important in vehicles?	CO1	BTL-2	Understand
19.	What is meant by fuel injection system compatibility?	CO1	BTL-1	Remember
20.	Report on why fuel system compatibility is needed for alcohol fuels.	CO1	BTL-2	Understand
21.	Name any two fuel sensors used in alternate fuel vehicles.	CO1	BTL-1	Remember
22.	Express the role of oxygen sensor in alternate fuel engines.	CO1	BTL-2	Understand
23.	Define ECU calibration.	CO1	BTL-1	Remember
24.	Why is ECU calibration required for alternate fuels?	CO1	BTL-2	Understand
25.	Express the role of vehicle software in alternate fuel utilization.	CO1	BTL-2	Understand

PART - B (16 Marks)

Q.No.	Questions	Marks	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Explain the production methods, properties, and engine performance characteristics of ethanol, methanol, and butanol as alternative fuels.	16	CO1	BTL-3	Apply

2.	Analyze the suitability of alcohol fuels for SI engines in terms of efficiency, emissions, and material compatibility.	16	CO1	BTL-4	Analyze
3.	Explain the process of biodiesel production and discuss its combustion and emission characteristics in CI engines.	16	CO1	BTL-3	Apply
4.	Analyze the advantages and limitations of biodiesel compared to conventional diesel fuel.	16	CO1	BTL-4	Analyze
5.	Describe the production process and fuel properties of Hydrotreated Vegetable Oil (HVO) and explain its advantages over biodiesel.	16	CO1	BTL-3	Apply
6.	Analyze the potential of HVO as a drop-in fuel for existing diesel engines and fuel infrastructure.	16	CO1	BTL-4	Analyze
7.	Explain the storage, handling, and safety aspects of CNG, LNG, and LPG used in automotive applications.	16	CO1	BTL-3	Apply
8.	Compare CNG, LNG, and LPG in terms of energy density, storage requirements, and vehicle applications.	16	CO1	BTL-4	Analyze
9.	Explain the combustion characteristics and engine requirements of Dimethyl Ether (DME) as an alternative fuel.	16	CO1	BTL-3	Apply
10.	Analyze the role of Polyoxymethylene Dimethyl Ether (PODE) in reducing soot and	16	CO1	BTL-4	Analyze

	particulate emissions in diesel engines.				
11.	Explain the properties, production, and safety considerations of ammonia as a carbon-free fuel.	16	CO1	BTL-3	Apply
12.	Analyze the challenges associated with using ammonia as a fuel in IC engines and fuel cells.	16	CO1	BTL-4	Analyze
13.	Explain the properties of hydrogen fuel and discuss the safety measures required for its handling and storage in vehicles.	16	CO1	BTL-3	Apply
14.	Analyze the technical challenges and risks associated with hydrogen fuel utilization in automotive systems.	16	CO1	BTL-4	Analyze
15.	Explain the concept of fuel injection system compatibility and discuss its importance for alternate fuels.	16	CO1	BTL-3	Apply
16.	Analyze the role of fuel sensors and ECU calibration in enabling multi-fuel or flex-fuel engine operation.	16	CO1	BTL-4	Analyze
17.	Explain the basics of ECU calibration for alternate fuel engines and discuss key parameters that must be optimized.	16	CO1	BTL-3	Apply
18.	Analyze the role of vehicle software and electronic control systems in efficient utilization of alternate fuels.	16	CO1	BTL-4	Analyze

UNIT II – GREEN ENERGY INTEGRATION FOR OFF-HIGHWAY VEHICLES

Solar energy harvesting systems, hybrid solar–battery architecture, green electricity-based hydrogen production, electrolyzers (PEM/Alkaline), hydrogen smart grids, hydrogen storage methods, hydrogen safety, hydrogen-ICE conversion concepts, and green hydrogen applications in agricultural and mining equipment.

PART - A (2 Marks)

Q.No.	Questions	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Define solar energy harvesting systems.	CO2	BTL-1	Remember
2.	List any two components of a hybrid solar–battery architecture.	CO2	BTL-1	Remember
3.	Interpret the purpose of hybrid solar–battery systems.	CO2	BTL-2	Understand
4.	What is meant by green electricity-based hydrogen production?	CO2	BTL-1	Remember
5.	Why is green hydrogen considered clean energy?	CO2	BTL-2	Understand
6.	Define an electrolyzer used in hydrogen production.	CO2	BTL-1	Remember
7.	Differentiate between PEM and alkaline electrolyzers.	CO2	BTL-2	Understand
8.	State one advantage of PEM electrolyzers.	CO2	BTL-1	Remember
9.	Mention one advantage of alkaline electrolyzers.	CO2	BTL-1	Remember
10.	What is a hydrogen smart grid?	CO2	BTL-1	Remember
11.	Represent the role of hydrogen smart grids.	CO2	BTL-2	Understand
12.	Define hydrogen storage.	CO2	BTL-1	Remember
13.	List any two hydrogen storage methods.	CO2	BTL-1	Remember
14.	Show why hydrogen storage is challenging.	CO2	BTL-2	Understand

15.	What is meant by hydrogen safety?	CO2	BTL-1	Remember
16.	State any two safety issues related to hydrogen handling.	CO2	BTL-1	Remember
17.	Define hydrogen-ICE conversion.	CO2	BTL-1	Remember
18.	Why are engine modifications required for hydrogen-ICE?	CO2	BTL-2	Understand
19.	List one benefit of using hydrogen in ICE engines.	CO2	BTL-1	Remember
20.	What is green hydrogen?	CO2	BTL-1	Remember
21.	List two applications of green hydrogen.	CO2	BTL-1	Remember
22.	Represent the use of green hydrogen in agricultural equipment.	CO2	BTL-2	Understand
23.	State one advantage of green hydrogen in agriculture.	CO2	BTL-1	Remember
24.	Review the application of green hydrogen in mining equipment.	CO2	BTL-2	Understand
25.	Why is green hydrogen suitable for mining operations?	CO2	BTL-2	Understand

PART - B (16 Marks)

Q.No.	Questions	Marks	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Explain the working principle of solar energy harvesting systems and discuss their role in sustainable energy production.	16	CO2	BTL-3	Apply
2.	Analyze the advantages and limitations of solar energy harvesting systems when used for large-scale applications.	16	CO2	BTL-4	Analyze

3.	Describe the architecture of a hybrid solar–battery system and explain how energy is managed between solar panels and batteries.	16	CO2	BTL-3	Apply
4.	Analyze the performance benefits of hybrid solar–battery systems compared to standalone solar systems.	16	CO2	BTL-4	Analyze
5.	Explain the concept of green electricity-based hydrogen production and discuss its environmental significance.	16	CO2	BTL-3	Apply
6.	Analyze the challenges involved in producing green hydrogen using renewable electricity sources.	16	CO2	BTL-4	Analyze
7.	Describe the working principle of PEM and alkaline electrolyzers with suitable diagrams.	16	CO2	BTL-3	Apply
8.	Compare PEM and alkaline electrolyzers in terms of efficiency, operating conditions, and applications.	16	CO2	BTL-4	Analyze
9.	Explain the concept of hydrogen smart grids and discuss their role in future energy systems.	16	CO2	BTL-3	Apply
10.	Analyze how hydrogen smart grids help in balancing renewable energy generation and demand.	16	CO2	BTL-4	Analyze
11.	Describe various hydrogen storage methods and explain their suitability for different applications.	16	CO2	BTL-3	Apply

12.	Analyze the safety challenges associated with hydrogen storage and handling and suggest mitigation measures.	16	CO2	BTL-4	Analyze
13.	Explain hydrogen safety requirements in production, storage, and transportation systems.	16	CO2	BTL-3	Apply
14.	Analyze the technical challenges involved in converting conventional IC engines to hydrogen-ICE operation.	16	CO2	BTL-4	Analyze
15.	Explain the concept of hydrogen-ICE conversion and discuss necessary engine modifications.	16	CO2	BTL-3	Apply
16.	Describe the application of green hydrogen in agricultural equipment with suitable examples.	16	CO2	BTL-3	Apply
17.	Analyze the feasibility of using green hydrogen-powered agricultural machinery in rural areas.	16	CO2	BTL-4	Apply
18.	Evaluate the application of green hydrogen in mining equipment and discuss its impact on emissions and sustainability.	16	CO2	BTL-4	Analyze

UNIT III – FUEL CELL POWERED OFF-HIGHWAY VEHICLES

Fuel cell fundamentals, PEMFC, SOFC, DMFC technologies, system components (stack, humidifier, compressor, DC-DC converter), sizing and energy management, off-highway case studies (construction equipment, mining trucks), limitations, durability issues, and recent research advancements.

PART - A (2 Marks)

Q.No.	Questions	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Define a fuel cell.	CO3	BTL-1	Remember
2.	State the basic working principle of a fuel cell.	CO3	BTL-1	Remember
3.	What is a Proton Exchange Membrane Fuel Cell (PEMFC)?	CO3	BTL-1	Remember
4.	List any two applications of PEMFC.	CO3	BTL-1	Remember
5.	Define Solid Oxide Fuel Cell (SOFC).	CO3	BTL-1	Remember
6.	Predict any two advantages of Solid Oxide Fuel Cell (SOFC).	CO3	BTL-2	Understand
7.	What is a Direct Methanol Fuel Cell (DMFC)?	CO3	BTL-1	Remember
8.	Mention one limitation of DMFC.	CO3	BTL-1	Remember
9.	List the main components of a fuel cell system.	CO3	BTL-1	Remember
10.	What is the function of a fuel cell stack?	CO3	BTL-1	Remember
11.	Represent the role of a humidifier in PEMFC systems.	CO3	BTL-2	Understand
12.	State the purpose of a compressor in fuel cell systems.	CO3	BTL-1	Remember
13.	Define a DC–DC converter in fuel cell applications.	CO3	BTL-1	Remember
14.	Why is sizing important in fuel cell systems?	CO3	BTL-2	Understand

15.	What is meant by energy management in fuel cell systems?	CO3	BTL-1	Remember
16.	Indicate the need for energy management strategies.	CO3	BTL-2	Understand
17.	State any two applications of fuel cells in construction equipment.	CO3	BTL-1	Remember
18.	How are fuel cells used in mining trucks?	CO3	BTL-2	Understand
19.	List any two advantages of fuel cells in off-highway vehicles.	CO3	BTL-1	Remember
20.	Mention any two limitations of fuel cell technology.	CO3	BTL-1	Remember
21.	What are durability issues in fuel cells?	CO3	BTL-1	Remember
22.	Show how operating conditions affect fuel cell durability.	CO3	BTL-2	Understand
23.	State one challenge in commercializing fuel cells.	CO3	BTL-1	Remember
24.	What are the recent research advancements in fuel cell technology?	CO3	BTL-1	Remember
25.	Represent why fuel cell research is important for the future of transport.	CO3	BTL-2	Understand

PART - B (16 Marks)

Q.No.	Questions	Marks	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Explain the fundamental working principle of a fuel cell and discuss how it differs from conventional combustion-based power systems.	16	CO3	BTL-3	Apply
2.	Analyze the advantages and limitations of fuel cell technology in comparison with internal combustion engines.	16	CO3	BTL-4	Analyze

3.	Describe the construction and working of a Proton Exchange Membrane Fuel Cell (PEMFC) with a neat diagram.	16	CO3	BTL-3	Apply
4.	Analyze the suitability of PEMFCs for automotive and off-highway applications.	16	CO3	BTL-4	Analyze
5.	Explain the operating principle of Solid Oxide Fuel Cells (SOFC) and discuss the significance of high operating temperature.	16	CO3	BTL-3	Apply
6.	Analyze the advantages and challenges associated with SOFC technology in heavy-duty applications.	16	CO3	BTL-4	Analyze
7.	Describe the working principle of Direct Methanol Fuel Cells (DMFC) and explain their key applications.	16	CO3	BTL-3	Apply
8.	Compare PEMFC, SOFC, and DMFC technologies in terms of efficiency, operating temperature, and applications.	16	CO3	BTL-4	Analyze
9.	Explain the role and construction of major fuel cell system components such as stack, humidifier, compressor, and DC-DC converter.	16	CO3	BTL-3	Apply
10.	Analyze how proper sizing of fuel cell systems affects performance, efficiency, and durability.	16	CO3	BTL-4	Analyze
11.	Explain the concept of energy management in fuel cell hybrid	16	CO3	BTL-3	Apply

	systems and discuss common control strategies.				
12.	Analyze the importance of energy management strategies in off-highway fuel cell vehicles.	16	CO3	BTL-4	Analyze
13.	Describe the application of fuel cell systems in construction equipment with suitable case examples.	16	CO3	BTL-3	Apply
14.	Analyze the use of fuel cell-powered mining trucks and discuss their operational benefits and challenges.	16	CO3	BTL-4	Analyze
15.	Explain the major limitations of fuel cell technology related to cost, infrastructure, and materials.	16	CO3	BTL-3	Apply
16.	Analyze durability issues in fuel cells and discuss the factors affecting fuel cell lifetime.	16	CO3	BTL-4	Analyze
17.	Describe recent research advancements aimed at improving fuel cell efficiency and durability.	16	CO3	BTL-3	Apply
18.	Evaluate the future prospects of fuel cell technology in off-highway and heavy-duty vehicle sectors.	16	CO3	BTL-4	Analyze

UNIT IV – ADVANCED IN-CYLINDER COMBUSTION TECHNOLOGIES

Low-temperature combustion (LTC), Homogeneous Charge Compression Ignition (HCCI), Premixed Charge Compression Ignition (PCCI), Reactivity Controlled Compression Ignition (RCCI), Gasoline Direct Injection Compression Ignition (GDCI) concepts, dual-fuel strategies, water injection systems, EGR technologies, variable valve actuation for emission control, combustion phasing and knock mitigation.

PART - A (2 Marks)

Q.No.	Questions	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Define low-temperature combustion (LTC).	CO4	BTL-1	Remember
2.	State the main objectives of LTC techniques.	CO4	BTL-1	Remember
3.	What is Homogeneous Charge Compression Ignition (HCCI)?	CO4	BTL-1	Remember
4.	Mention any two advantages of HCCI combustion.	CO4	BTL-1	Remember
5.	Represent any two limitations of HCCI engines.	CO4	BTL-2	Understand
6.	Define Premixed Charge Compression Ignition (PCCI).	CO4	BTL-2	Understand
7.	How does PCCI differ from HCCI?	CO4	BTL-2	Understand
8.	What is Reactivity Controlled Compression Ignition (RCCI)?	CO4	BTL-1	Remember
9.	State any two benefits of RCCI combustion.	CO4	BTL-1	Remember
10.	Summarize the concept of Gasoline Direct Injection Compression Ignition (GDCI).	CO4	BTL-2	Understand
11.	What is meant by dual-fuel strategy in engines?	CO4	BTL-1	Remember
12.	List out the applications of dual-fuel combustion.	CO4	BTL-1	Remember
13.	Define water injection system in IC engines.	CO4	BTL-1	Remember

14.	Why is water injection used in engines?	CO4	BTL-2	Understand
15.	What is Exhaust Gas Recirculation (EGR)?	CO4	BTL-1	Remember
16.	State any two advantages of EGR technology.	CO4	BTL-1	Remember
17.	Represent the role of variable valve actuation (VVA).	CO4	BTL-2	Understand
18.	What is meant by combustion phasing?	CO4	BTL-1	Remember
19.	Why is combustion phasing important?	CO4	BTL-2	Understand
20.	Define engine knock.	CO4	BTL-1	Remember
21.	List the methods used for knock mitigation.	CO4	BTL-1	Remember
22.	Show how EGR helps in knock mitigation.	CO4	BTL-2	Understand
23.	State one challenge in implementing LTC engines.	CO4	BTL-1	Remember
24.	What are the emission benefits of advanced combustion concepts?	CO4	BTL-1	Remember
25.	Summarize why advanced combustion concepts are important for future engines.	CO4	BTL-2	Understand

PART - B (16 Marks)

Q.No.	Questions	Marks	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Explain the concept of Low-Temperature Combustion (LTC) and discuss its role in reducing NO _x and particulate emissions in IC engines.	16	CO4	BTL-3	Apply
2.	Analyze the advantages and limitations of Low-Temperature Combustion techniques when applied to modern engines.	16	CO4	BTL-4	Analyze

3.	Describe the working principle of Homogeneous Charge Compression Ignition (HCCI) engines and explain the challenges in controlling combustion timing.	16	CO4	BTL-3	Apply
4.	Analyze the operating range limitations of HCCI combustion and suggest possible control strategies.	16	CO4	BTL-4	Analyze
5.	Explain the concept of Premixed Charge Compression Ignition (PCCI) and discuss how it improves emission control compared to conventional diesel combustion.	16	CO4	BTL-3	Apply
6.	Compare HCCI and PCCI combustion modes in terms of combustion control, emissions, and engine performance.	16	CO4	BTL-4	Analyze
7.	Describe the working principle of Reactivity Controlled Compression Ignition (RCCI) and explain the role of dual fuels in combustion control.	16	CO4	BTL-3	Apply
8.	Analyze the benefits of RCCI combustion in terms of efficiency and emissions compared to single-fuel combustion systems.	16	CO4	BTL-4	Analyze
9.	Explain the concept of Gasoline Direct Injection Compression Ignition (GDICI) and discuss its potential advantages over traditional diesel combustion.	16	CO4	BTL-3	Apply

10.	Analyze the challenges involved in implementing GDCI engines for real-world automotive applications.	16	CO4	BTL-4	Analyze
11.	Explain dual-fuel combustion strategies used in advanced IC engines and discuss their role in emission reduction.	16	CO4	BTL-3	Apply
12.	Analyze the effectiveness of dual-fuel strategies in achieving controlled combustion and improved fuel efficiency.	16	CO4	BTL-4	Analyze
13.	Explain the working principle of water injection systems and discuss their impact on combustion temperature and knock suppression.	16	CO4	BTL-3	Apply
14.	Analyze the role of Exhaust Gas Recirculation (EGR) technologies in emission control and combustion stability.	16	CO4	BTL-4	Analyze
15.	Explain how variable valve actuation (VVA) systems are used for emission control and combustion phasing optimization.	16	CO4	BTL-3	Apply
16.	Analyze the importance of combustion phasing control and discuss various knock mitigation techniques used in advanced engines.	16	CO4	BTL-4	Analyze
17.	Explain the interaction between EGR, water injection, and valve	16	CO4	BTL-3	Apply

	actuation in achieving low-emission combustion.				
18.	Evaluate the future prospects of advanced combustion concepts in meeting stringent emission norms and fuel efficiency targets.	16	CO4	BTL-4	Analyze



UNIT V – AFTER-TREATMENT & WASTE HEAT RECOVERY TECHNOLOGIES

Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), Selective Catalytic Reduction (SCR), Lean NO_x Trap (LNT), Ammonia Slip Catalyst (ASC) technologies, ammonia slip reduction, active and passive regeneration, CO₂ capture concepts for mobile machinery, waste heat recovery cycles, Organic Rankine Cycle (ORC) applications in off-highway vehicles.

PART - A (2 Marks)

Q.No.	Questions	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Define Diesel Oxidation Catalyst (DOC).	CO5	BTL-1	Remember
2.	State any two functions of DOC in diesel vehicles.	CO5	BTL-1	Remember
3.	What is a Diesel Particulate Filter (DPF)?	CO5	BTL-1	Remember
4.	Summarize the importance of DPF in emission control.	CO5	BTL-2	Understand
5.	Define Selective Catalytic Reduction (SCR).	CO5	BTL-1	Remember
6.	Why is urea used in SCR systems?	CO5	BTL-2	Understand
7.	What is Lean NO _x Trap (LNT)?	CO5	BTL-1	Remember
8.	State the limitations of LNT systems.	CO5	BTL-1	Remember
9.	Define Ammonia Slip Catalyst (ASC).	CO5	BTL-1	Remember
10.	Represent the need for ammonia slip reduction.	CO5	BTL-2	Understand
11.	What is meant by active regeneration in DPF?	CO5	BTL-1	Remember
12.	What is passive regeneration in DPF?	CO5	BTL-1	Remember
13.	Differentiate between active and passive regeneration.	CO5	BTL-2	Understand
14.	Define CO ₂ capture in mobile machinery.	CO5	BTL-1	Remember

15.	Why is CO ₂ capture challenging in mobile machinery?	CO5	BTL-2	Understand
16.	What is waste heat recovery?	CO5	BTL-1	Remember
17.	State one benefit of waste heat recovery systems.	CO5	BTL-1	Remember
18.	Define Organic Rankine Cycle (ORC).	CO5	BTL-1	Remember
19.	Why are organic fluids used in ORC?	CO5	BTL-2	Understand
20.	List out the applications of ORC in off-highway vehicles.	CO5	BTL-1	Remember
21.	Show how ORC improves vehicle efficiency.	CO5	BTL-2	Understand
22.	State the advantages of SCR over LNT systems.	CO5	BTL-1	Remember
23.	What is ammonia slip?	CO5	BTL-1	Remember
24.	Report the role of ASC in SCR systems.	CO5	BTL-2	Understand
25.	Why are after-treatment systems important for off-highway vehicles?	CO5	BTL-2	Understand

PART - B (16 Marks)

Q.No.	Questions	Marks	Course Outcomes	Bloom's Taxonomy Level	Competence
1.	Explain the construction, working principle, and emission control role of a Diesel Oxidation Catalyst (DOC) in modern diesel engines.	16	CO5	BTL-3	Apply
2.	Analyze the role of Diesel Particulate Filters (DPF) in controlling particulate emissions and discuss the challenges	16	CO5	BTL-4	Analyze

	associated with their operation in off-highway vehicles.				
3.	Describe the working principle of Selective Catalytic Reduction (SCR) systems and explain how urea injection helps in NOx reduction.	16	CO5	BTL-3	Apply
4.	Compare SCR and Lean NOx Trap (LNT) technologies in terms of efficiency, operating conditions, and suitability for mobile machinery.	16	CO5	BTL-4	Analyze
5.	Explain the construction and working of Lean NOx Trap (LNT) systems and discuss their limitations under real operating conditions.	16	CO5	BTL-3	Apply
6.	Describe the role of Ammonia Slip Catalyst (ASC) in SCR systems and analyze its importance in reducing ammonia slip emissions.	16	CO5	BTL- 4	Analyze
7.	Explain the phenomenon of ammonia slip in SCR systems and discuss various methods used to minimize it.	16	CO5	BTL-3	Apply
8.	Differentiate between active and passive regeneration in Diesel Particulate Filters with neat sketches and suitable examples.	16	CO5	BTL- 4	Analyze
9.	Explain the need for regeneration in DPF systems and describe the	16	CO5	BTL-3	Apply

	factors influencing regeneration efficiency.				
10.	Discuss the concept of CO ₂ capture in mobile machinery and analyze the technical challenges involved in its implementation.	16	CO5	BTL- 4	Analyze
11.	Explain various waste heat recovery cycles used in internal combustion engines and evaluate their benefits in heavy-duty vehicles.	16	CO5	BTL- 4	Analyze
12.	Describe the working principle of waste heat recovery systems in off-highway vehicles and explain how they improve overall engine efficiency.	16	CO5	BTL-3	Apply
13.	Explain the Organic Rankine Cycle (ORC) with a neat layout and discuss the selection of working fluids for automotive applications.	16	CO5	BTL-3	Apply
14.	Analyze the advantages and limitations of Organic Rankine Cycle systems when applied to off-highway vehicles.	16	CO5	BTL-4	Analyze
15.	Discuss the integration of ORC systems with diesel engines and analyze their impact on fuel economy and emissions.	16	CO5	BTL-4	Analyze
16.	Explain how after-treatment systems such as DOC, DPF, and	16	CO5	BTL-3	Apply

	SCR work together as an integrated emission control system.				
17.	Analyze the emission challenges faced by off-highway vehicles and discuss how advanced after-treatment technologies address these issues.	16	CO5	BTL-4	Analyze
18.	Evaluate the future prospects of waste heat recovery and CO ₂ capture technologies in achieving emission reduction targets for mobile machinery.	16	CO5	BTL-4	Analyze

