









Hybrids & Alternative Fuel Vehicles

Chapter 18 Fuel Cells and Advanced Technologies

Opening Your Class

KEY ELEMENT	EXAMPLES
Introduce Content	This course or class covers operation and service of Hybrid and Alternative Fueled Vehicles . It correlates material to task lists specified by ASE and NATEF.
Motivate Learners	Explain how the knowledge of how something works translates into the ability to use that knowledge to figure why the engine does not work correctly and how this saves diagnosis time, which translates into more money.
State the learning objectives for the chapter or course you are about to cover and explain this is what they should be able to do as a result of attending this session or class.	Explain the chapter learning objectives to the students. 1. Explain how a fuel cell generates electricity. 2. Discuss the advantages and disadvantages of fuel cells. 3. List the types of fuel cells. 4. Explain how ultracapacitors work. 5. Discuss alternative energy sources.
Establish the Mood or Climate	Provide a <i>WELCOME</i> , Avoid put downs and bad jokes.
Complete Essentials	Restrooms, breaks, registration, tests, etc.
Clarify and Establish Knowledge Base	Do a round robin of the class by going around the room and having each student give their backgrounds, years of experience, family, hobbies, career goals, or anything they want to share.

NOTE: This lesson plan is based on Hybrids 4th Edition
Chapter Images found on Jim's web site @
www.jameshalderman.com
LINK CHP 18: [Chapter Images](#)

ICONS	Ch18 Fuel Cells and Advanced Technologies
	<p>1. SLIDE 1 CH18 FUEL CELLS AND ADVANCED TECHNOLOGIES</p>
	<p>Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/ WEB SITE IS CONSTANTLY UPDATED</p>
	<p>At the beginning of this class, you can download the crossword puzzle & Word Search from the links below to familiarize your class with the terms in this chapter & then discuss them</p>
	<p>SHOW ANIMATION: <u>FUEL CELL ENGINE ID</u> <u>WWW.MYAUTOMOTIVELAB.COM</u> HTTP://MEDIA.PEARSONCMG.COM/PH/CHET/CHET_MYAUTOMOTIVELAB_2/ANIMATIONS/AX_ANIMATIONS/CHAPTER66_FIG_66_27/INDEX.HTM</p>
	<p>2. SLIDE 2 EXPLAIN Figure 18-1 Ford Motor Company has produced a number of demonstration fuel-cell vehicles based on the Ford Focus.</p> <p>3. SLIDE 3 EXPLAIN Figure 18-2 Hydrogen does not exist by itself in nature. Energy must be expended to separate it from other, more complex materials.</p>
 <p>QUESTION</p>	<p><u>DISCUSSION: HAVE THE STUDENTS COMPARE AND CONTRAST OPERATION OF INTERNAL COMBUSTION ENGINE VEHICLES, FUEL-CELL VEHICLES, FUEL-CELL HYBRID VEHICLES, AND HYBRID ELECTRIC VEHICLES. WHAT ARE ADVANTAGES OF POWERING VEHICLES WITH A FUEL CELL? FIGURES 18-1 & 3</u></p>
 <p>QUESTION</p>	<p><u>DISCUSSION: DISCUSS FUEL CELL TECHNOLOGY. AS A FUEL, HOW DOES HYDROGEN COMPARE TO FOSSIL FUEL? FIGURE 18-2</u></p>
	<p>5. SLIDE 5 EXPLAIN Figure 18-3 The Mercedes-Benz B-Class fuel-cell car was introduced in 2005.</p> <p>6. SLIDE 6 EXPLAIN Figure 18-4 The Toyota FCHV is based on the Highlander platform and uses much of Toyota's Hybrid Synergy Drive (HSD) technology in its design</p>

ICONS**Ch18 Fuel Cells and Advanced Technologies****QUESTION****QUESTION****QUESTION**

DISCUSSION: HAVE THE STUDENTS DISCUSS TYPES OF FUEL CELLS. WHICH TYPE OF FUEL CELL IS BEST SUITED TO AUTOMOTIVE APPLICATIONS? CHART 18-1

DISCUSSION: HAVE THE STUDENTS TALK ABOUT THE CURRENT GENERATED BY A FUEL CELL. WHY DOES A FUEL CELL GENERATE DIRECT CURRENT ELECTRICITY?

9. **SLIDE 9 EXPLAIN** Figure 18-5 **polymer electrolyte membrane** only allows H^+ ions (protons) to pass through it. This means that electrons must follow the external circuit and pass through the load to perform work

HANDS-ON TASK: HAVE STUDENTS EXPLAIN PEM FUEL-CELL PROCESS. HAVE THEM USE FIGURE 16-5 IN THEIR EXPLANATION.

10. **SLIDE 10 EXPLAIN** Figure 18-6 A fuel-cell stack is made up of hundreds of individual cells connected in series

DISCUSSION: HAVE STUDENTS DISCUSS FUEL-CELL STACKS. HOW IS TOTAL VOLTAGE OF A FUEL-CELL STACK DETERMINED? FIGURE 18-6

EXPLAIN TECH-TIP

11. **SLIDE 11 EXPLAIN** Figure 18-7A hydrogen fueling station located at a Shell gasoline station in Los Angeles
12. **SLIDE 12 EXPLAIN** Figure 18-7B door on the side is opened to show the fill nozzle with shut-off valve.
13. **SLIDE 13 EXPLAIN** Figure 18-8 direct methanol fuel cell uses a methanol/water solution for fuel instead of hydrogen gas.
14. **SLIDE 14 EXPLAIN** Figure 18-9 A direct methanol fuel cell can be refueled similar to a gasoline-powered vehicle

DISCUSS FREQUENTLY ASKED QUESTION

ICONS**Ch18 Fuel Cells and Advanced Technologies**

DISCUSSION: HAVE STUDENTS TALK ABOUT WAY **HYDROGEN** IS STORED ONBOARD A VEHICLE. WHAT ARE PROS & CONS OF **METHANOL** FOR FUEL CELLS?

ARE METHANOL FUEL CELLS LIKELY TO BE USED IN AUTOMOTIVE? **FIGURES 18-7 & 8**

DISCUSSION: HAVE THE STUDENTS DISCUSS FUEL PURITY IN **PEM FUEL CELLS**. WHAT HAPPENS IF THE HYDROGEN STREAM BEING FED TO PEM ANODE IS NOT PURE? WHY IS THIS A CONCERN FOR USAGE IN VEHICLES?

15. SLIDE 15 **EXPLAIN** Figure 18-10 Powertrain layout in a Honda FCX fuel-cell vehicle. Note the use of a humidifier behind the fuel-cell stack to maintain moisture levels in the membrane electrode assemblies

DISCUSS FREQUENTLY ASKED QUESTION

DISCUSSION: REVIEW WITH STUDENTS PURPOSE OF HAVING MOISTURE IN CONTACT WITH **ELECTROLYTE MEMBRANE IN A PEM FUEL CELL**. USE **FIGURE 18-9** TO HIGHLIGHT **HUMIDIFIER** USED IN HONDA FCX FUEL-CELL VEHICLE. WHAT IS PURPOSE OF HUMIDIFIER?

16. SLIDE 16 **EXPLAIN** Figure 18-11 Honda FCX uses one large radiator for cooling the fuel cell, and two smaller ones on either side for cooling drive train components.

DISCUSSION: HAVE STUDENTS DISCUSS WASTE HEAT AND LOW-GRADE HEAT. HOW DO THE CONDITIONS OF LOW-GRADE HEAT AFFECT HEAT TRANSFER? HOW IS HEAT GENERATED BY FUEL CELLS DEALT WITH IN AN FCHV? **FIGURE 18-10**

HANDS-ON TASK: HAVE STUDENTS EXPLAIN WHY IT IS IMPORTANT TO **KEEP ELECTROLYTE MEMBRANE COOL IN PEM FUEL CELL**. WHAT CAN BE DONE TO CONTROL ITS TEMPERATURE? GRADE STUDENTS ON THEIR UNDERSTANDING OF HEAT ISSUES IN PEM FUEL CELLS.

ICONS**Ch18 Fuel Cells and Advanced Technologies****QUESTION****QUESTION****QUESTION****QUESTION**

17. **SLIDE 17 EXPLAIN** Figure 18-12 Space is limited at the front of the Toyota FCHV engine compartment, so an auxiliary heat exchanger is located under the vehicle to help cool the fuel-cell stack

DISCUSSION: HAVE STUDENTS DISCUSS HYBRIDIZATION OF FUEL-CELL VEHICLES. WHAT IS PURPOSE OF AN ELECTRICAL STORAGE DEVICE IN A HYBRID VEHICLE? FIGURE 18-11

18. **SLIDE 18 EXPLAIN** Figure 18-13 secondary battery in a fuel-cell hybrid vehicle is made up of many individual cells connected in series, much like a fuel-cell stack

19. **SLIDE 19 EXPLAIN** Figure 18-14 Honda ultracapacitor module & construction of individual cells.

DISCUSSION: HAVE THE STUDENTS TALK ABOUT SECONDARY BATTERIES AND ULTRACAPACITORS. WHY ARE ULTRACAPACITORS SUITED TO ELECTRIC ASSIST APPLICATIONS IN FUEL-CELL HYBRID VEHICLES? FIGURES 18-12 & 13

20. **SLIDE 20 EXPLAIN** Figure 18-15 ultracapacitor can be used in place of a high voltage battery in a hybrid electric vehicle. Example is from Honda FCX

DISCUSSION: DISCUSS ADVANTAGES & DISADVANTAGES OF ULTRACAPACITORS IN CURRENT USE. WHAT IS MAJOR DOWNSIDE OF ULTRACAPACITORS? FIGURE 18-14

21. **SLIDE 21 EXPLAIN** FIGURE 18-16 GM “Skateboard” concept uses a fuel-cell propulsion system with wheel motors at all four corners

22. **SLIDE 22 EXPLAIN** FIGURE 18-17 electric drive motor and transaxle assembly from a Toyota FCHV. Note the three orange cables

23. **SLIDE 23 EXPLAIN** Figure 18-18 Drive motors in fuel-cell hybrid vehicles often use stator assemblies similar to ones found in Toyota hybrid electric vehicles. Rotor turns inside stator and has permanent magnets on its outer circumference

DISCUSSION: HAVE THE STUDENTS TALK ABOUT ELECTRIC TRACTION MOTORS. WHY IS THE TYPICAL DRIVE MOTOR USED IN FCHVS AND HEVS

ICONS**Ch18 Fuel Cells and Advanced Technologies****SO RELIABLE? FIGURE 18–15**

DISCUSSION: HAVE THE STUDENTS DISCUSS TRANSAXLES USED IN FUEL-CELL HYBRID VEHICLES. HOW DO THESE TRANSAXLES COMPARE TO TRANSMISSIONS REQUIRED FOR VEHICLES POWERED BY INTERNAL COMBUSTION ENGINES? FIGURE 18–17



24. **SLIDE 24 EXPLAIN Figure 18-19** power control unit (PCU) on a Honda FCX fuel-cell hybrid vehicle is located under the hood.

25. **SLIDE 25 EXPLAIN Figure 18-20** Toyota's FCHV uses a power control unit that directs electrical energy flow between the fuel cell, battery, and drive motor.



DISCUSSION: HAVE THE STUDENTS TALK ABOUT POWER CONTROL UNITS (PCU) IN FUEL-CELL HYBRID VEHICLES. WHY DOES AN FCHV NEED AN INVERTER? WHAT ARE THE OTHER FUNCTIONS OF THE PCU? FIGURES 18–18 & 19



HANDS-ON TASK: HAVE STUDENTS COMPARE BENEFITS OF ELECTRIC MOTORS WITH THOSE OF IC ENGINES. GRADE STUDENTS ON THEIR UNDERSTANDING OF OPERATION OF BOTH ELECTRIC MOTORS AND INTERNAL COMBUSTION ENGINES AS WELL AS THE COMPARISON.



26. **SLIDE 26 EXPLAIN Figure 18-21** This GM fuel-cell vehicle uses compressed hydrogen in 3 high-pressure storage tanks



27. **SLIDE 27 EXPLAIN Figure 18-22** Toyota FCHV uses high-pressure storage tanks that are rated at 350 bar. This is the equivalent of 5,000 pounds per square inch.



DISCUSSION: HAVE THE STUDENTS REVIEW AND DISCUSS REGENERATIVE BRAKING SYSTEMS. HOW DOES THE ELECTRIC DRIVE MOTOR FUNCTION DURING REGENERATIVE BRAKING?



DISCUSSION: HAVE THE STUDENTS DISCUSS THE ISSUE OF HYDROGEN STORAGE IN FUEL-CELL HYBRID VEHICLES. REVIEW PHYSICAL DENSITY WITH STUDENTS. HOW DOES PHYSICAL DENSITY

ICONS**Ch18 Fuel Cells and Advanced Technologies****QUESTION****QUESTION****QUESTION****QUESTION****AFFECT HYDROGEN STORAGE CAPACITY? FIGURES 18-20 & 21**

28. **SLIDE 28 EXPLAIN** Figure 18-23 The high-pressure fitting used to refuel a fuel-cell hybrid vehicle.

29. **SLIDE 29 EXPLAIN** Figure 18-24 Note that high-pressure hydrogen storage tanks must be replaced in 2020

DISCUSSION: HAVE STUDENTS DISCUSS HOW COMPRESSED HYDROGEN GAS IS STORED & HOW TANKS ARE RATED. HOW DOES USE OF MULTIPLE SMALL STORAGE TANKS FURTHER REDUCE HYDROGEN STORAGE CAPACITY ON FUEL-CELL HEVS? FIGURE 18-22 & 23

30. **SLIDE 30 EXPLAIN** Figure 18-25 GM's Hydrogen3 has a range of 249 miles when using liquid hydrogen.







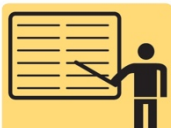

31. **SLIDE 31 EXPLAIN** Figure 18-26 Refueling a vehicle with liquid hydrogen

EXPLAIN TECH-TIP**DISCUSSION: HAVE THE STUDENTS DISCUSS LIQUID HYDROGEN AND ITS PROPERTIES AND REQUIREMENTS. HOW DOES ENERGY CONTENT OF LIQUID HYDROGEN COMPARE TO THAT OF GASOLINE? FIGURE 18-24 & 25****DISCUSSION: HAVE STUDENTS REVIEW HYDROGEN GAS, LIQUID HYDROGEN, & SOLID STORAGE OF HYDROGEN. WHAT ADVANTAGES AS A FUEL DOES HYDROGEN HAVE OVER HYDROCARBONS? FIGURE 18-24 & 25**

32. **SLIDE 32 EXPLAIN** Figure 18-27 Carbon deposits, such as these, are created by incomplete combustion of a hydrocarbon fuel.

33. **SLIDE 33 EXPLAIN** Figure 18-28 Both diesel and conventional gasoline engines create exhaust emissions due to high peak temperatures created in the combustion chamber. The lower combustion temperatures during HCCI operation result in high efficiency with reduced emissions

DISCUSSION: HAVE THE STUDENTS TALK ABOUT THE HOMOGENEOUS CHARGE COMPRESSION IGNITION PROCESS. HAVE THEM USE FIGURE 18-27 TO COMPARE HCCI SYSTEM TO DIESEL AND

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	<p>GASOLINE ENGINES. WHAT ARE THE CURRENT DOWNSIDES TO THE HCCI SYSTEM?</p> <p><u>DISCUSSION:</u> HAVE THE STUDENTS DISCUSS <u>PLUG-IN HYBRID ELECTRIC VEHICLES</u>. WHAT IS THE MAIN ADVANTAGE OF <u>PHEVS</u>? HOW CAN THESE PLUG-IN HYBRIDS ACHIEVE <u>ZERO EMISSIONS</u>? <u>FIGURE 18-28</u></p>
	<p><u>DISCUSSION:</u> TALK ABOUT FACTORS AFFECTING FUTURE OF ELECTRIC VEHICLES. HOW IS RISING COST OF FOSSIL FUELS AFFECTING CONSUMERS' ABILITY TO CONTINUE WITH ICE VEHICLES? HOW MIGHT THIS FACTOR SPUR DEVELOPMENT OF EVS?</p>
	<p><u>DISCUSSION:</u> HAVE STUDENTS DISCUSS <u>WEATHER CONCERNS FOR ELECTRIC VEHICLES</u>. HOW DO BOTH COLD AND HOT WEATHER AFFECT ELECTRICAL POWER NEEDS FOR ELECTRIC VEHICLES?</p>
	<p><u>ON-VEHICLE NATEF TASK ELECTRIC/FUEL CELL VEHICLE IDENTIFICATION: IDENTIFY HIGH-VOLTAGE CIRCUITS OF ELECTRIC VEHICLES AND RELATED SAFETY PRECAUTIONS. PAGE 283</u></p>
	<p>34. SLIDE 34 <u>EXPLAIN</u> Figure 18-29 typical wind generator that is used to generate electricity</p>
	<p><u>DISCUSSION:</u> HAVE THE STUDENTS DISCUSS WIND POWER. HOW IS ELECTRICITY GENERATED FROM <u>WIND POWER</u>? WHAT ARE ITS ADVANTAGES? WHY CAN'T WIND FARMS BE PLACED IN MORE LOCATIONS?</p>
	<p>35. SLIDE 34 <u>EXPLAIN</u> Figure 18-30 The Hoover Dam in Nevada/Arizona is used to create electricity for use in the southwest United States</p>
	<p><u>DISCUSSION:</u> TALK ABOUT HYDROELECTRIC POWER. HOW IS <u>HYDROELECTRIC</u> POWER GENERATED? WHAT IS THE ADVANTAGE OF HYDROELECTRIC POWER OVER WIND POWER?</p>