

Automotive Electrical & Engine Performance 8/E

Chapter 46 Fuel Cells & Advanced Technologies

Opening Your Class

KEY ELEMENT	EXAMPLES
Introduce Content	This Automotive Electrical & Engine Performance 8th edition provides complete coverage of automotive areas pertaining vehicle electrical systems and engine performance. It correlates material to task lists specified by ASE and ASEEducation (NATEF) and emphasizes a problem-solving approach. Chapter features include Tech Tips, Frequently Asked Questions, Case Studies, Videos, and Animations that are listed in this Lesson Plan. This Lesson Plan also references ASEEducation (NATEF) Task Sheets available from Jim's web site.
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 learning objectives to students as listed below: <ol style="list-style-type: none"> 1. Understand the technology of fuel cells. 2. Explain fuel-cell vehicle systems. 3. Discuss hydraulic hybrid storage systems. 4. Explain homogeneous charge compression ignition (HCCI). 5. Discuss plug-in hybrid electric vehicles (PHEVs).
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 **Automotive Electrical & Engine Performance 8th Edition** Chapter Images found on Jim's web site @ www.jameshalderman.com

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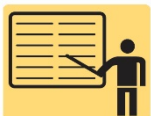
ICONS



QUESTION



QUESTION



Ch46 Fuel Cells & Advanced Technologies

1. SLIDE 1 CH46 FUEL CELLS & ADVANCED TECHNOLOGIES

Check for **ADDITIONAL VIDEOS & ANIMATIONS**
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Videos

At the beginning of this class, you can download the crossword puzzle & Word Search from Jim's web site to familiarize your class with terms in this chapter & then discuss them, see below:

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WORD SEARCH PUZZLE (MICROSOFT WORD) (PDF)







2. **SLIDE 2 EXPLAIN** Figure 46-1 Ford Motor Company has produced a number of demonstration fuel-cell vehicles based on the Ford Focus.

3. **SLIDE 3 EXPLAIN** Figure 46-2 Hydrogen does not exist by itself in nature. Energy must be expended to separate it from other, more complex materials.

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 46-1 & 3

DISCUSSION: HAVE THE STUDENTS TALK ABOUT FUEL CELL TECHNOLOGY. AS A FUEL, HOW DOES HYDROGEN COMPARE TO FOSSIL FUEL? FIGURE 46-2

4. **SLIDE 4 EXPLAIN** Figure 46-3 Mercedes-Benz B-Class fuel-cell car was introduced in 2005.

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     	<p>5. SLIDE 5 EXPLAIN Figure 46-4 The Toyota FCHV is based on the Highlander platform and uses much of Toyota's Hybrid Synergy Drive (HSD) technology in its design.</p> <p><u>DISCUSSION:</u> HAVE THE STUDENTS DISCUSS TYPES OF FUEL CELLS. WHICH TYPE OF FUEL CELL IS BEST SUITED TO AUTOMOTIVE APPLICATIONS? CHART 95-1</p> <p><u>DISCUSSION:</u> HAVE THE STUDENTS TALK ABOUT THE CURRENT GENERATED BY A FUEL CELL. WHY DOES A FUEL CELL GENERATE DIRECT CURRENT ELECTRICITY?</p> <p>6. SLIDE 6 EXPLAIN Figure 46-5 polymer electrolyte membrane only allows H^+ ions (protons) to pass through it. This means that electrons must follow the external circuit and pass through load to perform work</p> <p><u>HANDS-ON TASK:</u> HAVE THE STUDENTS EXPLAIN THE PEM FUEL-CELL PROCESS. HAVE THEM USE FIGURE 46-5 IN THEIR EXPLANATION. GRADE STUDENTS ON THEIR UNDERSTANDING OF THE PROCESS.</p> <p><u>EXPLAIN TECH TIP:</u> <i>CO Poisons the PEM Fuel-Cell Catalyst:</i> Purity of the fuel gas is critical with PEM fuel cells. If more than 10 parts per million (PPM) of carbon monoxide is present in hydrogen stream being fed to PEM anode, catalyst is gradually poisoned and fuel cell is eventually disabled. This means that purity must be "five nines" (99.999% pure). This is a major concern in vehicles where hydrogen is generated by reforming hydrocarbons, such as gasoline, because it is difficult to remove all CO from the hydrogen during the reforming process. In these applications, some means of hydrogen purification must be used to prevent CO poisoning of the catalyst.</p> <p>7. SLIDE 7 EXPLAIN Figure 46-6 fuel-cell stack is made up of hundreds of individual cells connected in series</p>

ICONS**Ch46 Fuel Cells & Advanced Technologies****QUESTION****QUESTION****QUESTION****DISCUSSION: DISCUSS FUEL-CELL STACKS. HOW IS THE TOTAL VOLTAGE OF A FUEL-CELL STACK DETERMINED? FIGURE 46-6**






8. SLIDE 8 **EXPLAIN** FIGURE 46-7 (a) A hydrogen fueling station located at a Shell gasoline station in Los Angeles, CA. (b) The door on the side is opened to show fill nozzle with shut-off valve. The hydrogen at this station is made on the roof of the dispenser using water and electricity. An electrical current separates the hydrogen from the oxygen in water, then compresses hydrogen, which is then sent to a storage tank, also on the roof.













9. SLIDE 9 **EXPLAIN** Figure 46-8 Direct methanol fuel cell can be refueled similar to a gasoline-powered vehicle











DISCUSSION: HAVE THE STUDENTS TALK ABOUT THE WAY HYDROGEN IS STORED ONBOARD A VEHICLE. WHAT ARE THE PROS AND CONS OF METHANOL FOR FUEL CELLS?**ARE METHANOL FUEL CELLS LIKELY TO BE USED IN AUTOMOTIVE APPLICATIONS? FIGURES 46-8****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?**









10. SLIDE 10 **EXPLAIN** FIGURE 46-9 Powertrain layout in a Honda FCX fuel-cell vehicle. Note use of a humidifier behind the fuel-cell stack to maintain moisture levels in membrane electrode assemblies.

DISCUSS FREQUENTLY ASKED QUESTION: WHAT IS THE ROLE OF THE HUMIDIFIER IN A PEM FUEL CELL? THE POLYMER ELECTROLYTE MEMBRANE ASSEMBLY IN A PEM FUEL CELL ACTS AS A CONDUCTOR OF POSITIVE IONS AND AS A GAS SEPARATOR. HOWEVER, IT CAN PERFORM THESE FUNCTIONS EFFECTIVELY ONLY IF IT IS KEPT MOIST. A FUEL-CELL VEHICLE USES AN AIR COMPRESSOR TO SUPPLY AIR TO THE POSITIVE ELECTRODES OF EACH CELL, AND

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    	<p>THIS AIR IS SOMETIMES SENT THROUGH A HUMIDIFIER FIRST TO INCREASE ITS MOISTURE CONTENT. THE HUMID AIR THEN COMES IN CONTACT WITH THE MEMBRANE ASSEMBLY AND KEEPS THE ELECTROLYTE DAMP AND FUNCTIONING CORRECTLY.</p> <p><u>DISCUSSION:</u> REVIEW PURPOSE OF HAVING MOISTURE IN CONTACT WITH <u>ELECTROLYTE MEMBRANE IN A PEM FUEL CELL.</u></p> <p><u>DISCUSSION:</u> 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? <u>FIGURE 46–11</u></p> <p>11. SLIDE 11 <u>EXPLAIN</u> FIGURE 46–10 Honda FCX uses one large radiator for cooling fuel cell and two smaller ones on either side for cooling drivetrain components..</p> <p>12. SLIDE 12 <u>EXPLAIN</u> FIGURE 46–11 Space is limited at front of Toyota FCHV engine compartment, so an auxiliary heat exchanger is located under vehicle to help cool fuel-cell stack.</p> <p><u>HANDS-ON TASK:</u> HAVE STUDENTS EXPLAIN WHY IT IS IMPORTANT TO <u>KEEP ELECTROLYTE MEMBRANE COOL IN A PEM FUEL CELL.</u> WHAT CAN BE DONE TO CONTROL ITS TEMPERATURE? GRADE STUDENTS ON THEIR UNDERSTANDING OF HEAT ISSUES IN PEM FUEL CELLS.</p> <p>13. SLIDE 13 <u>EXPLAIN</u> FIGURE 46–12 secondary battery in fuel-cell hybrid vehicle is made up of many individual cells connected in series, much like a fuel-cell stack..</p> <p>DISCUSS FREQUENTLY ASKED QUESTION: WHEN IS METHANOL CONSIDERED TO BE A “CARBON-NEUTRAL” FUEL? MOST OF THE METHANOL IN THE WORLD IS PRODUCED BY REFORMING NATURAL GAS. NATURAL GAS IS A HYDROCARBON, BUT DOES NOT INCREASE THE CARBON CONTENT OF OUR ATMOSPHERE</p>

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	<p>AS LONG AS IT REMAINS IN RESERVOIRS BELOW THE SURFACE. HOWEVER, NATURAL GAS THAT IS USED AS A FUEL CAUSES EXTRA CARBON TO BE RELEASED INTO THE ATMOSPHERE, WHICH IS SAID TO CONTRIBUTE TO GLOBAL WARMING. NATURAL GAS IS NOT A CARBON-NEUTRAL FUEL, AND NEITHER IS METHANOL THAT IS MADE FROM NATURAL GAS.</p>
  <p>QUESTION</p>	<p><u>DISCUSSION:</u> HAVE THE STUDENTS DISCUSS <u>HYBRIDIZATION OF FUEL-CELL VEHICLES.</u> WHAT IS PURPOSE OF ELECTRICAL STORAGE DEVICE IN A HYBRID VEHICLE?</p>
	<p>14. SLIDE 14 EXPLAIN FIGURE 46–13 Honda ultracapacitor module & construction of individual cells..</p>
  <p>QUESTION</p>	<p>15. SLIDE 15 EXPLAIN FIGURE 46–14 ultracapacitor can be used in place of a high-voltage battery in a hybrid electric vehicle. This example is from the Honda FCX fuel-cell hybrid vehicle.</p>
	<p><u>DISCUSSION:</u> HAVE STUDENTS TALK ABOUT <u>SECONDARY BATTERIES AND ULTRACAPACITORS.</u> WHY ARE ULTRACAPACITORS SUITED TO ELECTRIC ASSIST APPLICATIONS IN FUEL-CELL HYBRID VEHICLES?</p>
	<p>16. SLIDE 16 EXPLAIN FIGURE 46–15 Drive motors in fuel-cell hybrid vehicles often use stator assemblies similar to ones found in Toyota hybrid electric vehicles. The rotor turns inside the stator and has permanent magnets on its outer circumference.</p>
  <p>QUESTION</p>	<p><u>DISCUSSION:</u> HAVE THE STUDENTS DISCUSS <u>ADVANTAGES & DISADVANTAGES OF ULTRACAPACITORS</u> IN CURRENT USE. WHAT IS MAJOR DOWNSIDE OF ULTRACAPACITORS?</p>
	<p>17. SLIDE 17 EXPLAIN FIGURE 46–16 General Motors “Skateboard” concept uses a fuel-cell propulsion system with wheel motors at all four corners.</p>
  <p>QUESTION</p>	<p><u>DISCUSSION:</u> DISCUSS <u>ELECTRIC TRACTION MOTORS.</u> WHY IS THE TYPICAL DRIVE MOTOR USED IN FCHVS AND HEVS SO RELIABLE?</p>

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	<p>18. SLIDE 18 EXPLAIN FIGURE 46–17 electric drive motor and transaxle assembly from a Toyota FCHV. Note the three orange cables, indicating that this motor is powered by high-voltage three-phase alternating current.</p>
	<p>19. SLIDE 19 EXPLAIN FIGURE 46–18 power control unit (PCU) on a Honda FCX fuel-cell hybrid vehicle is located under the hood.</p>
	<p><u>DISCUSSION:</u> DISCUSS TRANSAXLES USED IN FUEL-CELL HYBRID VEHICLES. HOW DO THESE TRANSAXLES COMPARE TO TRANSMISSIONS REQUIRED FOR VEHICLES POWERED BY INTERNAL COMBUSTION ENGINES?</p>
	<p>20. SLIDE 20 EXPLAIN FIGURE 46–19 Toyota’s FCHV uses a power control unit that directs electrical energy flow between the fuel cell, battery, and drive motor.</p>
	<p>21. SLIDE 21 EXPLAIN FIGURE 46–20 GM fuel-cell vehicle uses compressed hydrogen in three high-pressure storage tanks.</p>
	<p><u>DISCUSSION:</u> DISCUSS POWER CONTROL UNITS (PCU) IN FUEL-CELL HYBRID VEHICLES. WHY DOES AN FCHV NEED AN <u>INVERTER</u>? WHAT ARE OTHER FUNCTIONS OF PCU?</p>
	<p><u>HANDS-ON TASK:</u> HAVE STUDENTS COMPARE THE <u>BENEFITS OF ELECTRIC MOTORS</u> WITH THOSE OF INTERNAL COMBUSTION ENGINES. GRADE STUDENTS ON THEIR UNDERSTANDING OF THE OPERATION OF BOTH ELECTRIC MOTORS AND INTERNAL COMBUSTION ENGINES AS WELL AS THE COMPARISON.</p>
	<p>22. SLIDE 22 EXPLAIN FIGURE 46–21 Toyota FCHV uses high-pressure storage tanks that are rated at 350 bar. This is the equivalent of 5,000 pounds per square inch.</p>
	<p>23. SLIDE 23 EXPLAIN FIGURE 46–22 high-pressure fitting used to refuel a fuel-cell hybrid vehicle.</p>
	<p><u>DISCUSSION:</u> HAVE THE STUDENTS REVIEW AND DISCUSS <u>REGENERATIVE BRAKING SYSTEMS</u>. HOW DOES THE ELECTRIC DRIVE MOTOR FUNCTION DURING REGENERATIVE BRAKING?</p>

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	<p>DISCUSSION: HAVE THE STUDENTS DISCUSS THE ISSUE OF <u>HYDROGEN STORAGE</u> IN FUEL-CELL HYBRID VEHICLES. REVIEW PHYSICAL DENSITY WITH STUDENTS. HOW DOES PHYSICAL DENSITY AFFECT HYDROGEN STORAGE CAPACITY?</p>
	<p>24. SLIDE 24 EXPLAIN FIGURE 46–23 Note that high-pressure hydrogen storage tanks must be replaced in 2031</p>
	<p>25. SLIDE 25 EXPLAIN FIGURE 46–24 GM’s Hydrogen3 has a range of 249 miles when using liquid hydrogen.</p>
	<p>DISCUSSION: HAVE STUDENTS DISCUSS HOW COMPRESSED HYDROGEN GAS IS STORED & <u>HOW TANKS ARE RATED</u>. HOW DOES USE OF <u>MULTIPLE</u> SMALL STORAGE TANKS FURTHER REDUCE HYDROGEN STORAGE CAPACITY ON FUEL-CELL HEVS?</p>
	<p>26. SLIDE 26 EXPLAIN FIGURE 46–25 Refueling a vehicle with liquid hydrogen</p>
	<p>DISCUSSION: HAVE THE STUDENTS DISCUSS LIQUID HYDROGEN AND ITS PROPERTIES AND REQUIREMENTS. HOW DOES ENERGY CONTENT OF LIQUID HYDROGEN COMPARE TO THAT OF GASOLINE?</p>
	<p>DISCUSSION: HAVE STUDENTS REVIEW HYDROGEN GAS, LIQUID HYDROGEN, & SOLID STORAGE OF HYDROGEN. WHAT ADVANTAGES AS A FUEL DOES HYDROGEN HAVE OVER HYDROCARBONS?</p>
	<p>EXPLAIN TECH TIP: <i>Hydrogen Fuel = No Carbon</i> Most fuels contain hydrocarbons or molecules that contain both hydrogen and carbon. During combustion, first element that is burned is the hydrogen. If combustion is complete, then all of the carbon is converted to carbon dioxide gas and exits the engine in the exhaust. However, if combustion is not complete, carbon monoxide is formed, leaving some unburned carbon to accumulate in the combustion chamber. • SEE FIGURE 46–26.</p>

ICONS

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27. **SLIDE 27 EXPLAIN FIGURE 46–26** Carbon deposits, such as these, are created by incomplete combustion of a hydrocarbon fuel.

28. **SLIDE 28 EXPLAIN FIGURE 46–27** 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 95–27 TO COMPARE HCCI SYSTEM TO DIESEL AND GASOLINE ENGINES. WHAT ARE THE CURRENT DOWNSIDES TO THE HCCI SYSTEM?



29. **SLIDE 29 EXPLAIN FIGURE 46–28** After Chevrolet Volt has been charged, it uses the electrical power stored in the high-voltage battery to propel vehicle and provide heating and cooling for 25 to 50 miles (40 to 80 km). Then the gasoline engine starts and maintains SOC between 25% and 35%. The gasoline engine cannot fully charge the high-voltage batteries but rather the vehicle has to be plugged in to provide a higher SOC level.






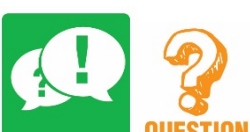

30. **SLIDE 30 EXPLAIN FIGURE 46–29** (a) Chevrolet Volt is charged using a standard SAE 1772 connector using either 110 or 220 volts. (b) After connecting the charging plug, a light on the top of the dash turns green and the dash display shows the estimated time when high-voltage battery will be fully charged and the estimated current range using battery power alone.









31. **SLIDE 31 EXPLAIN FIGURE 46–30** SAE J 1772 plug is used on most Electric and plug-in hybrid electric vehicles and is designed to work with Level 1 (110 to 120 V) and Level 2 (220 to 240 V) charging.



EXPLAIN TECH TIP: Batteries Like the Same Temperature Range as Humans. Batteries work best when they are kept within a temperature range that is also the most comfortable for humans. Most people are comfortable when temperature is between 68°F and 78°F (20°C and 26°C).

- **Below 68°F (20°C), most people want heat.**
- **Above 78°F (26°C), most people want cooling.**

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	<p>Batteries perform best when they too are exposed to same temperature range. Therefore, a proper heating and cooling system must be used to keep batteries within this fairly narrow temperature range for best performance.</p> <p>DISCUSS FREQUENTLY ASKED QUESTION: WHAT IS A “CHADEMO” CONNECTOR?</p> <p>CHADEMO is a Japanese trade name of a quick charging method for level 3 charging using dc electricity at a high rate. “CHADEMO” is an abbreviation of “charge de move,” which can be translated to mean “CHARGE FOR MOVING.”</p> <ul style="list-style-type: none"> • SEE FIGURE 46–31.
	<ol style="list-style-type: none"> 32. SLIDE 32 EXPLAIN FIGURE 46–31 A Nissan Leaf electric vehicle charging ports located at the front of the vehicle under a hinged door for easy access. 33. SLIDE 33 EXPLAIN FIGURE 46–32 A typical wind generator that is used to generate electricity. 34. SLIDE 34 EXPLAIN FIGURE 46–33 Hoover Dam in Nevada/Arizona is used to create electricity for use in the southwestern United States.
	<p><u>DISCUSSION:</u> HAVE THE STUDENTS DISCUSS <u>PLUG-IN HYBRID ELECTRIC VEHICLES.</u></p> <p>WHAT IS THE MAIN ADVANTAGE OF <u>PHEVS</u>? HOW CAN THESE PLUG-IN HYBRIDS ACHIEVE <u>ZERO EMISSIONS</u>?</p>
	<p><u>DISCUSSION:</u> HAVE THE STUDENTS TALK ABOUT THE FACTORS AFFECTING THE FUTURE OF ELECTRIC VEHICLES. HOW IS THE RISING COST OF FOSSIL FUELS AFFECTING CONSUMERS’ ABILITY TO CONTINUE WITH ICE VEHICLES? HOW MIGHT THIS FACTOR SPUR THE DEVELOPMENT OF EVS?</p>
	<p><u>DISCUSSION:</u> HAVE THE STUDENTS DISCUSS <u>WEATHER CONCERNS FOR ELECTRIC VEHICLES.</u> HOW DO BOTH COLD AND HOT WEATHER AFFECT ELECTRICAL POWER NEEDS FOR ELECTRIC VEHICLES?</p>

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	 QUESTION	DISCUSSION: HAVE THE STUDENTS TALK ABOUT ELECTRIC VEHICLE RANGE, CHARGING, & RECHARGING. WHAT ARE FACTORS THAT <u>AFFECT EVS' RANGE</u> ? HOW HAS CALIFORNIA ADDRESSED RANGE OF EVS?
	 QUESTION	DISCUSSION: 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?
	 QUESTION	DISCUSSION: HAVE THE STUDENTS TALK ABOUT HYDROELECTRIC POWER. HOW IS <u>HYDROELECTRIC</u> POWER GENERATED? WHAT IS THE ADVANTAGE OF HYDROELECTRIC POWER OVER WIND POWER?
	 QUESTION	DISCUSSION: HAVE THE STUDENTS DISCUSS <u>DRAG RACING FOR ELECTRIC-POWERED VEHICLES</u> . HOW IS POWER OF THE ELECTRIC POWERED VEHICLES INCREASED? WHAT ARE NEDRA'S REASONS FOR PROMOTING ELECTRIC DRAG RACING?