Hybrids & Alternative Fuel Vehicles

Chapter 9 Electric Motors, Generators, and Controls

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. Describe the operation of DC and AC electric motors. 2. Explain how a brushless DC motor works. 3. Discuss the advantages and disadvantages of using electric motors in hybrid electric vehicles. 4. Explain how electric power steering works. 5. Describe how a DC-to-DC converter works. 6. Discuss how a DC-to-AC inverter works
Establish the Mood or Climate	Provide a *WELCOME,* 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 9: Chapter Images

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1. **SLIDE 1 CH9 ELECTRIC MOTORS, GEN, & CONTROLS**

Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/

WEB SITE IS CONSTANTLY UPDATED

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

Crossword Puzzle (Microsoft Word) (PDF)

Word Search Puzzle (Microsoft Word) (PDF)

2. **SLIDE 2 EXPLAIN FIGURE 9.1freely suspended natural magnet will point toward magnetic north pole.**

EXPLAIN TECH TIP

3. **SLIDE 3 EXPLAIN FIGURE 9.2** If a magnet breaks or is cracked, it becomes two weaker magnets.
4. **SLIDE 4 EXPLAIN FIGURE 9.3** Magnetic lines of force leave the north pole and return to the south pole of a bar magnet.
5. **SLIDE 5 EXPLAIN FIGURE 9.4** Iron filings or a compass can be used to observe the magnetic lines of force.
6. **SLIDE 6 EXPLAIN FIGURE 9.5** Magnetic poles behave like electrically charged particles—unlike poles attract and like poles repel.

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 	**DISCUSSION: HAVE THE STUDENTS DISCUSS THE PRINCIPLES OF MAGNETISM. WHAT CAUSES A STRONGER MAGNETIC FIELD?**
	**DEMONSTRATION: USE TWO BAR MAGNETS TO SHOW THE STUDENTS HOW LIKE MAGNETIC CHARGES REPEL WHILE OPPOSITE CHARGES ATTRACT.**
	**EXPLAIN TECH TIP**
	7. **SLIDE 7 EXPLAIN FIGURE 9.6** magnetic field surrounds a current-carrying conductor.
	**EXPLAIN TECH TIP**
	8. **SLIDE 8 EXPLAIN FIGURE 9.7** right-hand rule for magnetic field direction is used with conventional theory of electron flow.
	9. **SLIDE 9 EXPLAIN FIGURE 9.8** Conductors with opposing magnetic fields will move apart into weaker fields 10. **SLIDE 10 EXPLAIN FIGURE 9.9** Electric motors use interaction of magnetic fields to produce mechanical energy. 11. **SLIDE 11 EXPLAIN FIGURE 9.10** magnetic lines of flux surrounding a coil look similar to those surrounding a bar magnet. 12. **SLIDE 12 EXPLAIN FIGURE 9.11**iron core concentrates magnetic lines of force surrounding coil.
	13. **SLIDE 13 EXPLAIN FIGURE 9.12** Voltage can be induced by the relative motion between a conductor and magnetic lines of force. 14. **SLIDE 14 EXPLAIN FIGURE 9.13** No voltage is induced if the conductor is moved in the same direction as the magnetic lines of force (flux lines). 15. **SLIDE 15 EXPLAIN FIGURE 9.14** Maximum voltage is induced when conductors cut across the magnetic lines of force (flux lines) at 90-degree angle

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16. **SLIDE 26 EXPLAIN FIGURE 9.15** armature loops rotate due to difference in the strength of the magnetic field. Loops move from a strong magnetic field strength toward a weaker magnetic field strength.
17. **SLIDE 17 EXPLAIN FIGURE 9.16** typical DC brush-type motor cutaway showing armature, commutator, and brushes on the left side.

DISCUSS FREQUENTLY ASKED QUESTION

DISCUSSION: **HAVE STUDENTS DISCUSS PRINCIPLE OF CEMF (COUNTERELECTROMOTIVE FORCE). HOW IS TORQUE OF A SHUNT MOTOR AFFECTED BY CEMF?**

DISCUSSION: **HAVE STUDENTS DISCUSS CHARACTERISTICS OF A SERIES MOTOR. WHAT IS RELATIONSHIP BETWEEN THE STRENGTH OF MAGNETIC FIELDS AND STARTER TORQUE?**

18. **SLIDE 18 EXPLAIN FIGURE 9.17** squirrel-cage type rotor used in an AC induction motor.
19. **SLIDE 19 EXPLAIN FIGURE 9.18** Typical AC induction motor design
20. **SLIDE 20 EXPLAIN FIGURE 9.19** rotor for the integrated motor assist (IMA) used on the Honda Insight and Civic is a surface permanent magnet (SPM) design. The magnets are made from neodymium.
21. **SLIDE 21 EXPLAIN FIGURE 9.20** rotor in most electric motors used to propel hybrid electric vehicles uses a permanent magnet design. The coils surrounding the rotor in the stator are pulsed on and off to control the speed and torque of the motor.
22. **SLIDE 22 EXPLAIN FIGURE 9.21** The rotor is forced to rotate by changing the polarity and the frequency of the coils surrounding rotor

DISCUSS FREQUENTLY ASKED QUESTION

EXPLAIN TECH TIP

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23. **SLIDE 23 EXPLAIN FIGURE 9.22** Notice on graph that at lower motor speeds torque produced by motor is constant and at higher motor speeds power is constant. Power is equal to torque times RPM; therefore, as torque decreases the speed increases, keeping power constant.

24. **SLIDE 24 EXPLAIN FIGURE 9.23** power cables for a motor-generator in a Toyota hybrid transaxle.
25. **SLIDE 25 EXPLAIN FIGURE 9.24** drive control unit on a Honda hybrid electric vehicle controls the current and voltage through the stator windings of the motor.
26. **SLIDE 26 EXPLAIN FIGURE 9.25** three legs of brushless motor run through 3 Hall-effect-type current sensors. The conductors used in the Honda unit are flat aluminum and attach to the motor controller terminals

27. **SLIDE 27 EXPLAIN FIGURE 9.26** A schematic showing the motor controls for a Lexus RX 400h. Note the use of the rear motor to provide 4WD capability.
28. **SLIDE 28 EXPLAIN FIGURE 9.27** Toyota motor speed sensor called a resolver.
29. **SLIDE 29 EXPLAIN FIGURE 9.28** Each coil in the speed sensor (resolver) generates a unique waveform, allowing the motor controller to determine the position of the rotor in the motor. The top waveform is coil A, the middle waveform is coil B, and the bottom waveform is coil C. The controller uses the three waveforms to determine the position of the rotor.
30. **SLIDE 30 EXPLAIN FIGURE 9.29** The underside of the Toyota Prius controller showing the coolant passages used to cool the electronic control unit

31. **SLIDE 31 EXPLAIN FIGURE 9.30** This simple capacitor, made of two plates separated by an insulating material, is called a dielectric.
32. **SLIDE 32 EXPLAIN FIGURE 9.31** As the capacitor is charging, the battery forces electrons through the circuit.
33. **SLIDE 33 EXPLAIN FIGURE 9.32** When the capacitor is charged, there is equal voltage across the capacitor and the battery. An electrostatic field exists between the capacitor plates. No current flows in circuit.

HANDS-ON TASK: RESEARCH INDEPENDENT REPAIR SHOPS THAT WORK ON HYBRID ELECTRIC VEHICLES. WHAT TYPES OF REPAIRS ARE THEY DOING, AND WHAT SAFETY

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PRECAUTIONS ARE BEING OBSERVED?

34. **SLIDE 34 EXPLAIN FIGURE 9.33** three large capacitors in this Honda hybrid absorb voltage spikes that occur when voltage level is changed in DC-DC converters.
35. **SLIDE 35 EXPLAIN FIGURE 9.34** dark cylinders are capacitors that are part of the electronic control unit of this Toyota hybrid.

EXPLAIN CAUTION

36. **SLIDE 36 EXPLAIN FIGURE 9.35** Using CAT III-rated digital meter and wearing rubber lineman's gloves, this technician is checking for voltage at the inverter to verify that the capacitors have discharged.
37. **SLIDE 37 EXPLAIN FIGURE 9.36 T**ypical snubber circuit showing a capacitor and a resistor in series and connected to ground.
38. **SLIDE 38 EXPLAIN FIGURE 9.37** snubber circuit from a Honda hybrid showing the six capacitors used to control voltage spikes in switching circuits
39. **SLIDE 39 EXPLAIN FIGURE 9.38** DC-to-DC converter is built into most powertrain control modules (PCM) and is used to supply 5-volt reference, called V-ref, to many sensors used to control the internal combustion engine.
40. **SLIDE 40 EXPLAIN FIGURE 9.39** DC-DC converter is designed to convert 42 volts to 14 volts to provide 14 V power to accessories on a hybrid electric vehicle operating with a 42-volt electrical system
41. **SLIDE 41 EXPLAIN FIGURE 9.40** A typical circuit for an inverter designed to change DC current from a battery to AC current for use by the electric motors used in a hybrid electric vehicle.
42. **SLIDE 42 EXPLAIN FIGURE 9.41** switching (pulsing) MOSFETs create a waveform called modified sine wave (solid lines) compared to a true sine wave (dotted lines)

EXPLAIN WARNINGS

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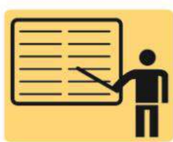
	43. **SLIDE 43 EXPLAIN FIGURE 9.42** Toyota Highlander hybrid EPS assembly. 44. **SLIDE 44 EXPLAIN FIGURE 9.43** torque sensor converts the torque the driver is exerting to the steering wheel into a voltage signal 45. **SLIDE 45 EXPLAIN FIGURE 9.44** electric power steering used in Toyota/Lexus SUVs use brushless DC (labeled BLDC) motor around rack of unit and operates on 42 volts
	**<u>HANDS-ON TASK:</u> HAVE HALF THE STUDENTS LOCATE AND LABEL SYSTEM EPS COMPONENTS WITH NUMBERS. HAVE OTHER HALF IDENTIFY THE COMPONENTS BY NUMBER.**
	46. **SLIDE 46 EXPLAIN FIGURE 9.45** Photo of electric power steering gear on a Lexus 400h taken from underneath the vehicle. 47. **SLIDE 47 EXPLAIN FIGURE 9.46** cross-sectional view of a Honda electric power steering (EPS) steering gear showing the torque sensor and other components. 48. **SLIDE 48 EXPLAIN FIGURE 9.47** Honda electric power steering unit cutaway 49. **SLIDES 49-66 SLIDE SHOW FOR INVERTER/CONVERTER REPLACEMENT**