# Hybrids & Alternative Fuel Vehicles 4/E

## Chapter 3 Internal Combustion Engine Systems

## Opening Your Class

| KEY ELEMENT | EXAMPLES |
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| **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.<br>1. Explain how a four-stroke cycle gasoline engine operates.<br>2. Explain the Atkinson cycle and how it affects engine efficiency.<br>3. List the various methods by which vehicle engines are classified and measured.<br>4. Describe the importance of using the specified oil in the engine of a hybrid electric vehicle.<br>5. Describe how the fuel injection and ignition systems work on hybrid gasoline engines.<br>6. Explain how active control engine mounts function.<br>7. Describe how wide-band oxygen sensors work.<br>8. Explain how variable valve timing is able to improve engine power and reduce exhaust emissions |
| **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 3: Chapter Images**

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| | **1. SLIDE 1 CH3 Internal Combustion Engine Systems**<br><br>**Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/**<br>**WEB SITE IS CONSTANTLY UPDATED**<br><br>**Videos**<br><br>**4-Stroke Cycle**<br><br>**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**<br>**Crossword Puzzle (Microsoft Word) (PDF)**<br>**Word Search Puzzle (Microsoft Word) (PDF)**<br><br>2. **SLIDE 2 EXPLAIN FIGURE 3-1** downward movement of piston draws air-fuel mixture into cylinder through the intake valve on intake stroke. On compression stroke, mixture is compressed by upward movement of piston with both valves closed. Ignition occurs at beginning of power stroke, and combustion drives piston downward to produce power. On exhaust stroke, upward-moving piston forces burned gases out open exhaust valve. Downward movement of piston draws air-fuel mixture into cylinder through the intake valve on intake stroke. On compression stroke, mixture is compressed by upward movement of piston with both valves closed. Ignition occurs at beginning of power stroke, and combustion drives piston downward to produce power. On exhaust stroke, upward-moving piston forces burned gases out open exhaust valve. |

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| | 3. **SLIDE 3 EXPLAIN FIGURE 3-2** Cutaway of an engine showing cylinder, piston, connecting rod, and crankshaft |
| QUESTION | **<u>DISCUSSION 4-STROKE CYCLE:</u> ASK STUDENTS TO EXPLAIN THE FOUR-STROKE CYCLE OPERATION** |
| | **MANY NEWER ENGINES ARE USING DIRECT INJECTION DUE TO ITS APPROXIMATELY 10% EFFICIENCY INCREASE** |
| **INTAKE STROKE** | **<u>INTAKE STROKE:</u> starts with piston at TDC. Lobe on camshaft opens intake valve piston moves down in bore due to crankshaft rotation. As piston moves down, it pulls outside air through air cleaner and into the intake manifold past open intake valve and into cylinder. Downward movement of piston creates a low-pressure area above piston (volume increases, pressure decreases). Air rushes in to fill space left by piston downward movement, because atmospheric pressure is greater than pressure in cylinder. Piston tries to inhale a volume equal to its own displacement. Fuel-air mixture is homogeneous. During intake stroke, an air-fuel ratio is inducted. Throttle controls air mass that enters cylinder. Energy needed to move piston from TDC downward comes from either flywheel or overlapping power strokes. As piston nears BDC: slows down nearly to a stop. When piston reaches BDC, intake valve closes sealing cylinder & compression stroke begins.** |
| **COMPRESSION STROKE: Internal energy of gas is increased as heat added to gas. Near end of compression** | **<u>COMPRESSION STROKE:</u> turning crankshaft now forces piston upward. Both valves are closed; there is no way (except past rings) for air to get out. Volume is decreasing as piston rises, so air-fuel gas mixture is compressed. Pressure is inversely proportional to volume according to Boyle's law. In compression of a gas, volume decreases & pressure and temperature rise as external work is done on gas. Compression ratio is ratio of volume at BDC to volume at TDC (clearance** |

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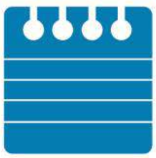
| stroke, a spark plug will ignite mixture | volume). Higher compression ratio means higher thermal efficiency or that portion of heat supplied to engine that is turned into work. As compression ratio increases, expansion ratio also increases; thus, thermal efficiency increases. |
| VOLUME BDC<br>VOLUME TDC | COMPRESSION RATIO |
| <br>POWER STROKE | **COMBUSTION (POWER STROKE):**<br>The power stroke begins shortly after fuel-air gas mixture is ignited by spark plug. High pressures in cylinder push down on piston. This pressure forces the piston down in the bore, which causes crankshaft to rotate (translation to rotation). Pressure falls as volume increases. Temperature falls, as gas does external work. Arc ignites air-fuel mixture in combustion chamber & fuel (reactant) burns supported by oxygen. Nitrogen expands and pushes piston down during power stroke. As piston continues downward, these gases in cylinder expand and cool as they give up their energy. Power stroke is only stroke in which energy is used from fuel & cylinder pressure is highest. |
| <br>EXHAUST STROKE | **EXHAUST STROKE:** As piston nears bottom of its travel, exhaust valve begins to open. Piston begins to rise in cylinder, beginning exhaust stroke. Upward movement of piston forces spent gases past exhaust valve & out of cylinder. As piston nears top of its movement, camshaft lobe again opens intake valve & cycle repeats itself. Exhaust valve is allowed to close, by spring pressure, shortly after piston begins-its downward movement. This is a stroke that produces no work but expends a quantity of energy to push exhaust gases from cylinder. In a spark-ignited gasoline-fueled engine, we have *flame speed*, which is nearly proportional or increases when engine speed increases. Therefore, number of crank angles occupied by combustion process is nearly independent of RPM. |

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| | 4. **SLIDE 4 EXPLAIN FIGURE 3-3** pressure volume diagram showing where additional work generated by delayed closing of intake valve. Point "S" is where spark occurs. |
| | **DISCUSSION: DISCUSS DIFFERENCE BETWEEN A NATURALLY ASPIRATED (NA) ENGINE AND A SUPERCHARGED OR TURBOCHARGED ENGINE.** |
| | **MOST INTERNAL COMBUSTION ENGINES ACHIEVE ONLY ABOUT 20% EFFICIENCY.** |
| | **MOST MANUFACTURERS DO NOT ALLOW FUELS WITH METHANOL TO BE USED IN THEIR VEHICLES. SOME OEMS ALLOW A SMALL PERCENTAGE (NO MORE THAN 5%).** |
| | **DISCUSS FREQUENTLY ASKED QUESTION** |
| | 5. **SLIDE 5 EXPLAIN FIGURE 3-4** The bore and stroke of pistons are used to calculate an engine's displacement |
| | **Displacement & Compression Ratio**<br>**Math Formula, Engine Displacement**<br>**Math Formula, Volume of Cylinder** |
| | 6. **SLIDE 6 EXPLAIN COMPRESSION RATIO & FIGURE 3-5** Compression ratio is the ratio of the total cylinder volume (when the piston is at the bottom of its stroke) to the clearance volume (when the piston is at the top of its stroke).<br>7. **SLIDE 7 EXPLAIN HOW TO CALCULATE COMPRESSION RATIO & FIGURE 3–6** Combustion chamber volume is the volume above the piston with the piston is at top dead center |
| | **DEMONSTRATION: SHOW THE STUDENTS HOW TO DETERMINE BORE & STROKE OF AN ENGINE USING SERVICE INFORMATION.** |

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**HANDS-ON TASK:** HAVE STUDENTS LOOK UP ENGINE DISPLACEMENT USING SERVICE INFORMATION FOR SEVERAL LAB VEHICLES. SINCE ALL SPECS ARE NOW METRIC, HAVE STUDENTS CALCULATE EQUIVALENT SIZE IN CUBIC INCHES.

Math Formula, Metric-Eng Conversion - Area

Math Formula, Eng-Metric Conv - Ci to Cc

Math Formula, Metric-Eng Conv - Cc to Ci

Math Formula, Metric-Eng Conversion - Volume

**DEMONSTRATION CID:** SHOW HOW TO CALCULATE THE CUBIC INCH DISPLACEMENT OF AN ENGINE GIVEN BORE & STROKE.

**DISCUSSION:** ASK THE STUDENTS HOW A BUILD-UP OF CARBON ON TOP OF THE PISTONS WOULD AFFECT COMPRESSION RATIO. (ANSWER: IT WOULD INCREASE COMPRESSION RATIO.)

**While most modern gasoline engines have a compression ratio of 8 to 10:1, diesel engines have compression ratio of 20 to 22:1.**

8. **SLIDE 8 EXPLAIN FIGURE 3-7** Torque is a twisting force equal to the distance from the pivot point times the force applied expressed in units called pound-feet (lb-ft) or Newton-meters (N-m)

**DISCUSS FREQUENTLY ASKED QUESTION**

9. **SLIDE 9 EXPLAIN FIGURE 3-8** Work is calculated by multiplying force times distance. If you push 100 pounds 10 feet, you have done 1,000 foot-pounds of work

**DEMONSTRATION:** SHOW THE STUDENTS EXAMPLES OF VARIOUS TORQUE WRENCHES AND DEMONSTRATE THEIR PROPER USE.

**HANDS-ON TASK:** HAVE THE STUDENTS LOOK UP THE TORQUE SPECS FOR VARIOUS ENGINE FASTENERS.

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**ON-VEHICLE NATEF TASK A1A4: LOCATE AND INTERPRET VEHICLE AND MAJOR COMPONENT IDENTIFICATION NUMBERS (P-1)**

**HANDS-ON TASK: SEARCH INTERNET TO FIND OUT DIFFERENCE BETWEEN A FOUR-STROKE ENGINE AND TWO-STROKE ENGINE.**

10. **SLIDE 10 EXPLAIN FIGURE 3-9** One horsepower is equal to 33,000 foot-pounds (200 lbs ×165 ft) of work per minute.
11. **SLIDE 11 EXPLAIN FIGURE 3-10** Piston pin offset toward the major thrust surface.
12. **SLIDE 12 EXPLAIN FIGURE 3-11** Engine rotation and rod angle during the power stroke causes piston to press harder against one side of cylinder, called major thrust surface.
13. **SLIDE 13 EXPLAIN FIGURE 3-12** crank throw is halfway down on the power stroke. The piston on the left without an offset crankshaft has a sharper angle than the engine on the right with an offset crankshaft.

**HANDS-ON TASK: HAVE THE STUDENTS LOOK UP VAIABLE VALVE TIMING FOR SEVERAL ENGINES.**

**ON-VEHICLE NATEF TASK: LOCATE AND INTERPRET VEHICLE AND MAJOR COMPONENT IDENTIFICATION NUMBERS**

**HANDS-ON TASK: SEARCH INTERNET TO FIND OUT DIFFERENCE BETWEEN A FOUR-STROKE ENGINE AND TWO-STROKE ENGINE.**

14. **SLIDE 14 EXPLAIN FIGURE 3-13** Camshaft rotation during advance and retard
15. **SLIDE 15 EXPLAIN FIGURE 3–14** spline phaser assembly.
16. **SLIDE 16 EXPLAIN FIGURE 3–15** vane phaser is used to move the camshaft, using changes in oil pressure from the oil control valve

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**DISCUSSION: DISCUSS WHY SOME DUAL OVERHEAD CAM ENGINES MAY HAVE A DIFFERENT CAMSHAFT PROFILE FOR EACH OF INTAKE VALVES AND EXHAUST VALVES. (ANSWER: THIS CREATES AN ENGINE THAT IS ABLE TO PRODUCE A HIGH TORQUE OVER A BROADER ENGINE SPEED RANGE.)**

Rotary Engine

17. **SLIDE 17 EXPLAIN FIGURE 3-16** screen (s) protect the solenoid valve from dirt and debris that can cause the valve to stick. This fault can set a P0017 diagnostic trouble code (crankshaft position/ camshaft position correlation error).

**DISCUSS TECH TIP**

**HANDS-ON TASK: HAVE STUDENTS SEARCH SERVICE INFORMATION TO DETERMINE WHAT CONTROLS CAMSHAFT POSITION ACTUATOR OIL CONTROL VALVE.**

**DISCUSSION: DISCUSS ADVANTAGES OF INTAKE AND EXHAUST CAMSHAFT PHASING.**

**The control solenoid screen can become plugged if the oil is not changed regularly. This can cause changes in performance and emissions.**

18. **SLIDE 18 EXPLAIN FIGURE 3-17** magnetically controlled vane phaser.

19. **SLIDE 19 EXPLAIN FIGURE 3-18** camshaft position actuator used in a cam-in-block engine.
20. **SLIDE 20 EXPLAIN FIGURE 3-19** A plastic mockup of a Honda VTEC system that uses two different camshaft profiles—one for low-speed engine operation and the other for high speed.
21. **SLIDE 21 EXPLAIN FIGURE 3-20** Engine oil pressure is used to switch cam lobes on VTEC system.

**DISCUSS TECH TIP**

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**DEMONSTRATION: USING A SCAN TOOL AND VEHICLE EQUIPPED WITH VARIABLE VALVE TIMING, SHOW THE STUDENTS WHAT VARIABLE VALVE TIMING DATA CAN BE OBSERVED USING THE SCAN TOOL.**

**HANDS-ON TASK: FOR A VEHICLE THAT USES VARIABLE VALVE TIMING, HAVE THE STUDENTS USE SERVICE INFORMATION TO READ A DESCRIPTION OF THE VARIABLE VALVE TIMING AND HOW IT IS CONTROLLED ON THAT VEHICLE.**

22. **SLIDE 22 EXPLAIN FIGURE 3-21** Oil pressure applied to the locking pin causes the inside of the lifter to freely move inside the outer shell of the lifter, thereby keeping the valve closed.
23. **SLIDE 23 EXPLAIN FIGURE 3-22** active fuel MGMT includes many different components and changes to oiling system, which makes routine oil changes even more important

**DISCUSS FREQUENTLY ASKED QUESTION**

24. **SLIDE 24 EXPLAIN FIGURE 3-23** (a) Ford Escape hybrid engine mount in rigid position. (b) At idle speed, engine mount passages are opened, allowing more movement of engine to reduce vibration.
25. **SLIDE 25 EXPLAIN FIGURE 3-24** typical coil-on-plug ignition system showing the triggering and the switching being performed by the PCM via input from the crankshaft position sensor.
26. **SLIDE 26 EXPLAIN FIGURE 3-25** letter printed on the top of the center electrode indicates that this spark plug is designed to fit into a spark plug opening that is stamped with a "B," so the open side of the side electrode is pointing toward the intake valve for best combustion of the air–fuel mixture in the cylinder.
27. **SLIDE 27 EXPLAIN FIGURE 3-26** throttle pedal is connected to the accelerator pedal position (APP) sensor. The electronic throttle body includes a throttle position sensor to provide throttle angle feedback to the vehicle computer. Some systems use a Throttle Actuator Control (TAC) module to operate the throttle blade (plate).

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| | 28. **SLIDE 29 EXPLAIN FIGURE 3-27** default position for the throttle plate is in slightly open position. The servomotor then is used to close it for idle and open it during acceleration.<br>29. **SLIDE 29 EXPLAIN FIGURE 3-28** conventional Zirconia oxygen sensor can only reset to exhaust mixtures that are richer or leaner than 14.7:1 (lambda 1.00).<br>30. **SLIDE 30 EXPLAIN FIGURE 3-29** planar design Zirconia oxygen sensor places all of the elements together, which allows the sensor to reach operating temperature quickly. |
| | **DISCUSS FREQUENTLY ASKED QUESTION** |
| | 31. **SLIDE 31 EXPLAIN FIGURE 3-30** reference electrodes are shared by Nernst cell and pump cell.<br><br>32. **SLIDE 32 EXPLAIN FIGURE 3-31** Testing a dual cell wide-band oxygen sensor can be done using a voltmeter or a scope. The meter reading is attached to Nernst cell and should read stoichiometric (450 mV) at all times. The scope is showing activity to pump cell with commands from PCM to keep Nernst cell at 14.7:1 **SLIDE 33 EXPLAIN FIGURE 3-32** single cell wide-band oxygen sensor has 4 wires with 2 for 2 heater and two for sensor itself. Voltage applied to sensor is 0.4 V (3.3 – 2.9 = 0.4) across 2 leads of sensor. |
| | **DISCUSS TECH TIP** |
| | 34. **SLIDE 34 EXPLAIN FIGURE 3-33** typical port fuel-injected system showing a vacuum-controlled fuel-pressure regulator.<br>35. **SLIDE 35 EXPLAIN FIGURE 3-34** mechanical returnless fuel system. The bypass regulator in the fuel filter controls fuel line pressure.<br>36. **SLIDE 36 EXPLAIN FIGURE 3-35** fuel-pressure sensor and fuel-temperature sensor are often constructed together in one assembly to help give the PCM the needed data to control the fuel-pump speed. |

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|  | 37. **SLIDE 37 EXPLAIN FIGURE 3-36** demand delivery system uses a fuel pressure regulator attached to the fuel pump assembly.<br><br>38. **SLIDE 38 EXPLAIN FIGURE 3-37** A typical direct injection system uses two pumps—one low-pressure electric pump in the fuel tank and the other a high-pressure pump driven by the camshaft. The high pressure fuel system operates at a pressure as low as 500 PSI during light load conditions and as high as 2,900 PSI under heavy loads |