Automotive Technology 6th Edition
Chapter 78 OXYGEN SENSORS
Opening Your Class

KEY ELEMENT	EXAMPLES
Introduce Content	This Automotive Technology 6th text provides complete coverage of automotive components, operation, design, and troubleshooting. 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, Animations, and ASEEducation (NATEF) Task Sheets.
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 on NEXT SLIDE. 1. Discuss how O2S sensors work. 2. List the methods that can be used to test oxygen sensors. 3. Describe the symptoms of a failed OS2 sensor. 4. Explain the operation of wide-band oxygen sensors. 5. Compare dual cell wide-band sensors to single cell wide-band sensors. 6. Describe wide-band oxygen pattern failures and interpret oxygen sensor-related diagnostic trouble codes.
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: Lesson plan is based on 6th Edition Chapter Images found on Jim's web site @ www.jameshalderman.com

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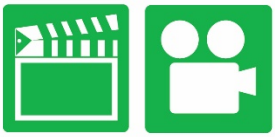
NOTE: You can use Chapter Images or possibly Power Point files:

ICONS	Chapter 78 OXYGEN SENSORS
	**1. SLIDE 1 Chapter 78 Oxygen Sensors**
	**Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/** **WEB SITE IS CONSTANTLY UPDATED** **http://www.jameshalderman.com/automotive_principles.html** **DOWNLOAD** **Crossword Puzzle (Microsoft Word) (PDF)** **Word Search Puzzle (Microsoft Word) (PDF**
	**Videos**
	
	**2. SLIDE 2 EXPLAIN Figure 78-1** Many oxygen sensors are located in exhaust manifold near its outlet so that the sensor can detect the presence or absence of oxygen in the exhaust stream for all cylinders that feed into the manifold.
	**DEMONSTRATION: Put an OBD-II vehicle on a LIFT and show students the oxygen sensors. Point out and explain upstream and downstream sensors to them.**
	**DISCUSSION: Have the students discuss oxygen sensors. How do O_2 sensors help achieve correct air-fuel ratio?**
	**DEMONSTRATION: Show conventional O_2 sensor that uses Zirconium Dioxide**
	**3. SLIDE 3 EXPLAIN Figure 78-2 (a)** exhaust is lean, the output of a Zirconia oxygen sensor is below 450 mV. **(b)** exhaust is rich, the output of a Zirconia oxygen sensor is above 450 mV. **4. SLIDE 4 EXPLAIN Figure 78-3** Most conventional Zirconia oxygen sensors and some wide-band oxygen sensors use the cup (finger) type of design. **5. SLIDE 5 EXPLAIN Figure 78-4** A typical heated Zirconia oxygen sensor, showing the sensor signal circuit that uses the outer (exhaust) electrode as the negative and the ambient air side electrode as the positive

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	**DISCUSSION:** Have students discuss cutaway views of oxygen sensors in **FIGURES 78–2, 78–3, & 76–4.** Call their attention to atmosphere tag in **FIGURES 78–3 & 76–4**. Oxygen sensors have to "breathe" in order to work.
	**DISCUSSION:** Have the students talk about 1-, 2-, 3-, & 4-wire oxygen sensors. What is same about these sensors, and what is different?
	6. **SLIDE 6 EXPLAIN Figure 78-5** The oxygen sensor provides a quick response at the stoichiometric air-fuel ratio of 14.7:1.s
	**DEMONSTRATION:** Use scan tool to show bias voltage. Have them watch data stream when Vehicle is started to see how long it takes for oxygen sensor to override bias voltage.
	Dual Cell O2 Sensor Voltage Check (View) (Download) O2 Sensor Volt Check (View) (Download) Test O2 Sensor (View) (Download) Wide Band O2 Sensor (View) (Download)
	**DISCUSSION:** Ask the students to discuss the **Titania Oxygen Sensor** and its operating characteristics. How is it different from Zirconia sensor?
	**DISCUSS FREQUENTLY ASKED QUESTION:** ***What Happens to the Bias Voltage?*** Some vehicle manufacturers, such as General Motors Corporation, have PCM apply 450 mV (0.45 V) to the O2S signal wire. This voltage is called the bias voltage and represents threshold voltage for the transition from rich to lean. Bias voltage is displayed on a scan tool when ignition switch is turned on with engine off. When engine is started, O2S becomes warm enough to produce a usable voltage, and bias voltage "disappears" as O2S responds to a rich and lean mixture. What happens to bias voltage that PCM applies to O2S? Voltage from

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	**O2S simply overcomes very weak voltage signal from PCM. This bias voltage is so weak that even a 20-megohm impedance DMM affects strength enough to cause voltage to drop to 426 mV. Other meters with only 10 megohms of impedance cause bias voltage to read less than 400 mV. Therefore, even though O2S voltage is relatively low powered, it is more than strong enough to override very weak bias voltage the PCM sends to the O2S.** **DISCUSS CASE STUDY: *Chevrolet Pickup Truck Story* The owner of a Chevrolet pickup truck complained that engine ran terribly. It would hesitate and surge, yet there were no diagnostic trouble codes (DTCs). After hours of troubleshooting, technician discovered, while talking to owner, that problem started after transmission had been repaired. However, the transmission shop said that problem was an engine problem and not related to transmission. A thorough visual inspection revealed that the front and rear oxygen sensor connectors had been switched. PCM was trying to compensate for an air-fuel mixture condition that did not exist. Reversing O2S connectors restored proper operation of the truck.** **Summary:** • **Complaint—Vehicle owner complained that pickup truck ran terribly.** • **Cause—During a previous repair, upstream and downstream oxygen sensor connectors were reversed.** • **Correction—connectors were moved to their correct locations, which restored proper engine operation.**

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 	**It may be necessary to access tune-up specs & diagrams to accurately identify bank 1 on different V6 & V8 engines.** **DISCUSS CASE STUDY: *Oxygen Sensor Is Lying to You* A technician was trying to solve a driveability problem with an older V-6 passenger car. Car idled roughly, hesitated, and accelerated poorly. A thorough visual inspection did not indicate problems and there were no diagnostic trouble codes stored. Technician checked oxygen sensor activity using a DMM. Voltage stayed above 600 mV most of time. *If technician removed a large vacuum hose, oxygen sensor voltage would temporarily drop to below 450 mV and then return to a reading of over*** **600 mV. Remember:** • **High O2S readings = rich exhaust (low O2 content in exhaust)** • **Low O2S readings = lean exhaust (high O2 content in the exhaust)** **As part of a thorough visual inspection, technician removed and inspected spark plugs. All the spark plugs were white, indicating a lean mixture, not rich mixture that oxygen sensor was indicating. High O2S reading signaled PCM to reduce amount of fuel, resulting in an excessively lean operation. After replacing oxygen sensor, engine ran great. But what killed the oxygen sensor? The technician finally learned from the owner that the head gasket had been replaced over a year ago. The silicate and phosphate additives in the antifreeze coolant had coated oxygen sensor. Because the oxygen sensor was coated, oxygen content of the exhaust could**

not be detected, resulting in a false rich signal from the oxygen sensor.

Summary:

- **Complaint—Vehicle owner complained that car equipped with a V-6 engine ran terribly.**
- **Cause—oxygen sensor was contaminated by additives in the coolant, caused by a previously repaired head gasket failure.**
- **• Correction—Replacing oxygen sensors restored proper engine operation.**

DEMONSTRATION: Show the typical locations of oxygen sensors on a vehicle. Show them number 1, number 2, upstream, and downstream sensors, if applicable. FIGURE 78-6

DISCUSS FREQUENTLY ASKED QUESTION: *Where is HO2S1?* Oxygen sensors are numbered according to their location in engine. On a V-type engine, heated oxygen sensor number 1 (HO2S1) is located in the exhaust system, upstream of catalytic converter, on side of engine where cylinder 1 is located. • SEE FIGURE 78–6.

7. **SLIDE 7 EXPLAIN FIGURE 78–6** Number and label designations for oxygen sensors. Bank 1 is the bank where cylinder 1 is located.
8. **SLIDE 8 EXPLAIN FIGURE 78–7** OBD-II catalytic converter monitor compares signals of upstream and downstream oxygen sensor to determine converter efficiency.

DISCUSS CASE STUDY: *The Missing Ford*

A Ford was being analyzed for poor engine operation. Engine ran perfectly during following conditions.

1. **Engine cold or operating in open loop**
2. **Engine at idle**
3. **Engine operating at or near wide-open throttle**

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	After hours of troubleshooting, technician determined cause to be a poor ground connection for oxygen sensor. The engine ran okay during times when PCM ignored oxygen sensor. Unfortunately, service technician did not have a definite plan during diagnostic process and as a result checked and replaced many unnecessary parts. An oxygen sensor test early in diagnostic procedure would have indicated that oxygen (O2S) signal was not correct. Poor ground caused oxygen sensor voltage level to be too high, indicating to PCM that mixture was too rich. PCM then subtracted fuel, which caused engine to miss and run roughly as result of the now too lean air fuel mixture. **Summary:** • **Complaint—Vehicle owner complained of poor engine operation except at idle and at wide open throttle conditions.** • **Cause—poor ground connection for the oxygen sensor cause the O2S to read incorrectly.** • **Correction—ground connection was cleaned and this restored proper engine operation under all operating conditions.**
	**DISCUSSION: Have the students discuss open-loop & closed-loop engine operation. Will an engine that runs well in open loop also run well in closed loop?**
	**DISCUSSION: Have students talk about how PCM uses the oxygen sensor to test other systems. What happens with other systems if a fault occurs with an oxygen sensor? FIGURE 78-7**
	**DISCUSSION: Have the students discuss the necessity of inspecting an old oxygen sensor. What can be determined by condition of sensor?**

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	**9. SLIDE 9 EXPLAIN Figure 78-8** Testing an oxygen sensor using a DMM set on DC volts. With the engine operating in closed loop, the oxygen voltage should read over 800 mV and lower than 200 mV and be constantly fluctuating.
	**EXPLAIN TECH TIP: *Do Not Solder Oxygen Sensor Wires.* Oxygen sensors must have outside oxygen to compare with oxygen content in exhaust. Most oxygen sensors breathe through signal wire and, if soldered, blocks flow of outside air to sensor. If a replacement oxygen sensor is used, always use factory replacement, using original connectors or a crimp and-seal connector that seals out any moisture and still allows air to flow through connector.**
	**DEMONSTRATION: Show examples of oxygen sensors that have failed due to other problems with the vehicle. Ask them to identify cause of failure. Work with students to test an oxygen sensor with DMM. FIGURE 78-8**
	**DISCUSSION: Have the students discuss the conditions that can cause a false rich indication by the oxygen sensor. Could anything else be cause of a false indication?**
	**DEMONSTRATION: Show examples of oxygen sensors that have failed. Try to show examples that demonstrate the specific failure causes**
	**DISCUSSION: Have the students discuss the conditions that can cause a false lean indication by the oxygen sensor. Could anything else be cause of a false indication?**
	**HANDS-ON TASK: Have students select and monitor oxygen sensor min-max voltage with a DMM. Have them chart minimum and maximum readings observed on sensors during a run cycle. Grade students on proper operation of DMM min and max functions as well as the voltage readings observed. FIGURE 78-8**

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	**DISCUSS FREQUENTLY ASKED QUESTION:** ***Why Does the Oxygen Sensor Voltage Read 5 Volts on Many Chrysler Vehicles?*** **Many Chrysler vehicles apply a 5-volt reference to the signal wire of oxygen sensor. Purpose of this voltage is to allow PCM to detect if oxygen sensor signal circuit is open or grounded.** • **If voltage on signal wire is 4.5 volts or more, PCM assumes that the sensor is open.** • **If voltage on signal wire is zero, PCM assumes that sensor is shorted-to-ground. If either condition exists, the PCM can set a diagnostic trouble code (DTC).**
	**EXPLAIN TECH TIP:** ***Key On, Engine Off Oxygen Sensor Test*** **This test works on GM vehicles and may work on others if PCM applies a bias voltage to oxygen sensors. Zirconia oxygen sensors become more electrically conductive as they get hot. To perform this test, be sure that vehicle has not run for several hours.** **STEP 1 Connect a scan tool and get the display ready to show oxygen sensor data.** **STEP 2 Key the engine on without starting the engine. The heater in the oxygen sensor starts heating sensor.** **STEP 3 Observe voltage of oxygen sensor. The applied bias voltage of 450 mV should slowly decrease for all oxygen sensors as they become more electrically conductive as the bias voltage flowing to ground.** **STEP 4 A good oxygen sensor should indicate a voltage of <100 mV after three minutes. Any sensor that displays a higher than usual voltage or seems to stay higher longer than the others could be defective or skewed high.**

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	**10. SLIDE 10 EXPLAIN Figure 78-9** Using a digital multimeter to test an oxygen sensor using the MIN/MAX record function of the meter.
	**DISCUSSION: DISCUSS min-max test results in Chart 78–1. Is it possible for a defective sensor to work well enough that it doesn't set a DTC?**
	**DEMONSTRATION: Show how to monitor oxygen sensor data with a scan tool. Ask them to identify the location of the sensors tested.**
	**DISCUSSION: Have students discuss frequency at which an oxygen sensor switches. What happens if the sensor switches too slowly?**
	**11. SLIDE 11 EXPLAIN Figure 78-10** Connecting a handheld digital storage oscilloscope to an oxygen sensor signal wire. Check the instructions for the scope as some require the use of a filter to be installed in the test lead to reduce electromagnetic interference that can affect the oxygen sensor waveform.
	**DEMONSTRATION: Show the students how to use a scope to test an oxygen sensor. Have them identify the high and low voltage readings on the scope. FIGURE 78-10**
	**12. SLIDE 12 EXPLAIN Figure 78-11** waveform of a good oxygen sensor as displayed on a digital storage oscilloscope (DSO). Note that the maximum reading is above 800 mV and minimum reading is < 200 mV.
	**DEMONSTRATION: Show data stream on a downstream oxygen sensor. Compare it to reading on an upstream sensor. Perform all demonstrations ahead of time to be sure the results are appropriate for the demonstration.**
	**DISCUSSION: discuss testing downstream oxygen sensor. What does this sensor really do?**
	**EXPLAIN TECH TIP: *Propane Oxygen Sensor Test*** **Adding propane to air inlet of a running engine is an**

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	excellent way to check if oxygen sensor is able to react to changes in air-fuel mixture. Follow these steps in performing the propane trick. **1. Connect a digital storage oscilloscope to the oxygen sensor signal wire.** **2. Start and operate the engine until it reaches operating temperature and is in closed-loop fuel control.** **3. While watching the scope display, add some propane to air inlet. The scope display should read full rich (over 800 mV).** **4. Shut off propane. The waveform should drop to <200 mV (0.2 V).** **5. Quickly add some propane while the oxygen sensor is reading low and watch for a rapid transition to rich. The transition should occur in less than 100 milliseconds (ms).**
	**13. SLIDE 13 EXPLAIN Figure 78-12** The post catalytic converter oxygen sensor should display very little activity if the catalytic converter is efficient
	**DISCUSSION: study Figure 78–12 compare normal (good converter) & abnormal (bad converter) after converter oxygen sensor readings. Could this test be used to diagnose other problems?**
	**14. SLIDE 14 EXPLAIN FIGURE 78–13** conventional zirconia oxygen sensor can only reset to exhaust mixtures that are richer or leaner than14.7:1 (lambda 1.00).
	**DISCUSSION: Explain operation of conventional oxygen sensors on 14.7:1 air-fuel ratio. Is this ratio accurate enough? FIGURE 78-13**
	**DISCUSSION: Have the students talk about wide-band oxygen sensors. What does "wide-band" mean?**
	**15. SLIDE 15 EXPLAIN FIGURE 78–14** planar design zirconia oxygen sensor places all of the elements together, which allows the sensor to reach operating temperature quickly.

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	**DISCUSSION:** Discuss planar design of wide-band oxygen sensor. What is main advantage of this design? **FIGURE 78-14**
	16. **SLIDE 16 EXPLAIN FIGURE 78-15** reference electrodes are shared by Nernst cell and the pump cell
	**DISCUSSION:** Have the students talk about **ULEV and SULEV** emissions systems. Why do these emissions ratings require more precise fuel management strategies?
	**DISCUSS FREQUENTLY ASKED QUESTION:** ***How Quickly Can a Wide-Band Oxygen Sensor Achieve Closed Loop?*** **In a Toyota Highlander hybrid-electric vehicle, the operation of gasoline engine is delayed for a short time when vehicle is first driven. During this time of electric operation, oxygen sensor heaters are turned on in readiness for gasoline engine starting. The gasoline engine often achieves closed-loop operation during cranking because oxygen sensors are fully warm and ready to go at the same time the engine is started. Having the gasoline engine achieve closed loop quickly, allows it to meet stringent SULEV standards.**
	**DISCUSSION:** Discuss dual cell, planar-type, wide-band oxygen sensor. In what major way does construction of this sensor differ from that of a conventional sensor?
	17. **SLIDE 17 EXPLAIN Figure 78-16** When exhaust is rich, PCM applies a negative current into the pump cell. 18. **SLIDE 18 EXPLAIN Figure 78-17** When exhaust is lean, the PCM applies a positive current into pump cell.
	**DISCUSSION:** Ask the students to discuss **stoichiometric** reading in the exhaust and fact that the oxygen sensor calculates this air-fuel ratio at 14.7:1. **FIGURE 78-16**

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	**DISCUSSION:** Ask the students to discuss the **number of wires needed** for an oxygen sensor to operate. They can use wiring diagrams of single-, three-, four-, five-, or six-wire sensors.
	**DISCUSSION:** Ask students to look at **Chart 78–2.** What is noticeable about factory and generic settings? Point out direct correlation between the voltage readings in factory & generic settings. **Chart 78-2.**
	**DISCUSSION:** Have the students discuss steps for **testing a wide-band oxygen sensor**. Why is it necessary to check service information first?
	**19. SLIDE 19 EXPLAIN Figure 76-18** Testing a dual cell wide-band oxygen sensor can be done using a voltmeter or a scope. 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 air-fuel ratio.
	**DEMONSTRATION:** If available, show students data stream readings using factory scan tool and generic scan tool. Have them observe difference in readings, if they are different. **FIGURE 78-18** Explain to the students what a breakout box is. Ask them to decide whether a breakout box would be beneficial in testing dual cell Wide-band oxygen sensor shown in Figure 78–18.
	**20. SLIDE 20 EXPLAIN Figure 78-19** single cell wide-band oxygen sensor has 4 wires with two for 4 heater and two for the sensor itself. The voltage applied to 4 sensor is 0.4 V (3.3 − 2.9 = 0.4) across the two leads of 4 sensor
	**DISCUSSION:** Have the students discuss **single cell** wideband oxygen sensors. How are they similar to other sensors? **FIGURE 78-19**
	**21. SLIDE 21 EXPLAIN FIGURE 78–20** A scan tool can display various voltages, but often shows 3.3 V because the PCM is controlling the sensor through applying a low current to the sensor to achieve balance.

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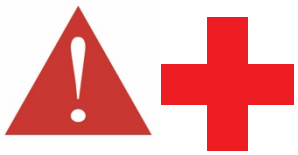	**SAFETY** Discuss importance of using proper terminals when testing any sensor, especially when back-probing connectors. Explain that piercing wires that will be exposed to elements is not an accepted testing procedure.
	**DISCUSSION:** Have the students discuss fact that a wide-band oxygen sensor can cause an engine to operate extremely lean, but still fail to trigger a DTC. Why might unplugging a sensor cause the engine to operate correctly?
 	**ON-VEHICLE ASEEDUCATION TASK:** Inspect and test **OXYGEN O_2 Sensor** using GMM)/(DSO); perform necessary action.
 	**ON-VEHICLE ASEEDUCATION TASK** Inspect and test **WIDE-BAND OXYGEN O_2 Sensor** using GMM)/(DSO); perform necessary action.