Automotive Technology 6th Edition
Chapter 21 Cooling System Operation & Diagnosis
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 the chapter learning objectives to the students as listed: 1. Explain the purpose and function of the cooling system, and cooling system operation. 2. Explain the purpose and function of thermostats, radiators, and pressure caps. 3. Explain coolant flow in the engine, water pumps, and coolant recovery systems. 4. Explain the purpose and function of cooling fans and heater cores. 5. Describe cooling system testing and explain the purpose of coolant temperature warning light. 6. Explain cooling system inspection and cooling system service.
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 the 6th Edition Chapter Images found on Jim's web site @ www.jameshalderman.com

DOWNLOAD Chapter 21 Chapter Images: From http://www.jameshalderman.com/automotive_principles.html NOTE: You can use Chapter Images or possibly Power Point files:

ICONS	CH21 Cooling System Operation & Diagnosis
	**1. SLIDE 1 CH21 COOLING SYSTEM OPERATION**
	**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**
	**Cooling System Videos**
	**2. SLIDE 2 EXPLAIN Figure 21-1** Typical combustion and exhaust temperatures.
	**Coolant Replacement (View) (Download)** **Cooling System Heat Store (View) (Download)**
	**EXPLAIN TECH TIP: Overheating Can Be Expensive** **A faulty cooling system seems to be a major cause of engine failure. Engine rebuilders often have nightmares about seeing their rebuilt engine placed back in service in a vehicle with a clogged radiator. Most engine technicians routinely replace the water pump and all hoses after an engine overhaul or repair. The radiator should also be checked for leaks and proper flow whenever the engine is repaired or replaced. Overheating is one of the most common causes of engine failure.**

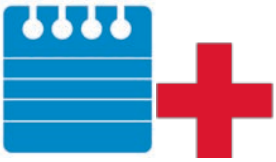
ICONS	CH21 Cooling System Operation & Diagnosis
	**DISCUSSION:** Have students discuss heat generated in an engine. Ask: "If one-third of the heat is removed through the cooling system, and one-third is removed through the exhaust system, what is the other one-third used for?" (Answer: Pushing pistons down.)
	**Engines that do not reach proper operating temperature may leave water in oil, which cause engine bearing failure.**
	**DISCUSSION:** Discuss with students how improper coolant temperature can harm fuel economy. Why does temperature affect fuel economy? (ANS: Changes fuel vaporization rate)
	3. **SLIDE 3 EXPLAIN Figure 21-2** Coolant circulates through water jackets in engine block and cylinder head. 4. **SLIDE 4 EXPLAIN Figure 21-3** Coolant flow through a typical engine cooling system
	**DISCUSSION: Discuss reasons that older engines were less likely to have engine failure from overheating. (Steel blocks and heads displaced heat better & able to take higher temperatures without damage due to amount of metal.)**
	Coolant Flow-World Engine (View) (Download) Coolant Replacement (View) (Download)
	**DEMONSTRATION: Show students a bypass hose and where it is located on different engines.**
	**DISCUSSION: Discuss with students why the bypass hose is so important. Why is it important? (ANS: Allows for rapid engine warm up)**

ICONS	CH21 Cooling System Operation & Diagnosis
 	**ON-VEHICLE ASEEDUCATION Task: Research applicable vehicle and service information, vehicle service history, service precautions, and technical service bulletins (P-1)**
	**DISCUSS CHART 21-1**
	5. **SLIDE 5 EXPLAIN Figure 21-4** A cross section of a typical wax-actuated thermostat showing the position of the wax pellet and spring. 6. **SLIDE 6 EXPLAIN Figure 21-5 (a)** When the engine is cold, the coolant flows through the bypass. **(b)** When the thermostat opens, the coolant can flow to the radiator. 7. **SLIDE 7 EXPLAIN Figure 21-6** A thermostat stuck in open position caused engine to operate too cold. If a thermostat is stuck closed, this can cause engine to overheat. 8. **SLIDE 8 EXPLAIN FIGURE 21–7** cutaway of a small block Chevrolet V-8 showing the passage from the cylinder head through the front of the intake manifold to the thermostat.
	**DISCUSS FREQUENTLY ASKED QUESTION: Why Is an Electronic Thermostat Used in Some Engines? An electronic thermostat allows the engine temperature to be more closely controlled during cruise, city driving, or heavy load conditions to optimize fuel economy, and reduce exhaust emissions. • SEE FIGURE 21–8.**

ICONS	CH21 Cooling System Operation & Diagnosis
	9. **SLIDE 9 EXPLAIN FIGURE 21–8** electronic thermostat uses a wax pellet to open and a spring to close it, but it also uses an electric heater controlled by the powertrain control module (PCM) to accurately control engine coolant temperature. 10. **SLIDE 10 EXPLAIN FIGURE 21–9** A scan tool can be used to monitor the engine coolant temperature (ECT).
	**EXPLAIN TECH TIP: Do Not Take Out the Thermostat! Some vehicle owners and technicians remove the thermostat in the cooling system to "cure" an overheating problem. In some cases, removing the thermostat can cause overheating rather than stop it. This is true for three reasons.** 1. **Without a thermostat, the coolant can flow more quickly through the radiator. The thermostat adds some restriction to the coolant flow, and therefore keeps the coolant in the radiator longer. This also allows additional time for the heat transfer between the hot engine parts and the coolant.** 2. **Heat transfer is greater with a greater difference between the coolant temperature and air temperature.** 1. **Therefore, when coolant flow rate is increased (no thermostat), the temperature difference is reduced. 3. Without the restriction of the thermostat, much of the coolant flow often bypasses the radiator entirely and returns directly to the engine.**
	**Removing a thermostat may cause overheating issues because coolant flows so quickly that it cannot absorb the heat.**

ICONS	CH21 Cooling System Operation & Diagnosis
	**11. SLIDE 11 EXPLAIN Figure 21-10** Some thermostats are an integral part of housing. This thermostat and radiator hose housing is serviced as assembly. Some thermostats snap into engine radiator fill tube underneath pressure cap.
	**When checking a thermostat for an overheating condition, be sure the thermostat is installed correctly.**
	**Thermostat Electric Assist (View) (Download)** **Thermostat Operation (View) (Download)**
	**DISCUSSION: Discuss with students the 3 methods of testing thermostats & positive and negatives of each.**
	**DEMONSTRATION: Using the hot water method, show how a thermostat opens and closes.**
	HANDS-ON TASK: Have students perform thermostat testing using at least one of 3 methods listed in the text on page 185 of Chapter 21.
	**When replacing thermostat, be sure sensing pellet is facing engine block.**
	**ON-VEHICLE ASEEDUCATION TASK: Inspect, test, remove and replace thermostat and gasket/ seal. (P-1)**
Education Foundation	

ICONS	CH21 Cooling System Operation & Diagnosis
	12. **SLIDE 12 EXPLAIN Figure 21-11** tubes and fins of radiator core. 13. **SLIDE 13 EXPLAIN Figure 21-12** radiator may be either a down-flow or a crossflow type. 14. **SLIDE 14 EXPLAIN Figure 21-13** Many vehicles equipped with automatic transmission use a transmission fluid cooler installed in one of radiator tanks.
	**Older steel radiators could often be repaired. Most newer radiators cannot be repaired, due to cost, & must be replaced**
	**DEMONSTRATION: Show students different styles of radiators.**
	**DISCUSSION: Discuss importance of heat transfer. What are the 3 forms of heat transfer from Physics Class? (ANS: Conductance, Convection, & Radiation. Radiators despite their name, generally transfer the bulk of their heat via convection, not by thermal radiation. Convection is transfer of heat from one place to another by movement of fluids. Convection is usually dominant form of heat transfer in liquids and gases)**
 	**ON-VEHICLE ASEEDUCATION TASK: Remove and replace radiator (P-2)**
	15. **SLIDE 15 EXPLAIN Figure 21-14** pressure valve maintains system pressure and allows excess pressure to vent. The vacuum valve allows coolant to return to the system from the recovery tank.

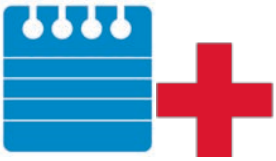
ICONS	CH21 Cooling System Operation & Diagnosis
	**DISCUSS CASE STUDY: The Collapsed Radiator Hose Story: A student asked automotive instructor what brand of radiator hose is best. Not knowing exactly what to say, instructor asked if there was a problem with brand hose used. The student had tried 3 brands and all of them collapsed when the engine cooled. The instructor then explained that the vehicle needed a new pressure cap and not a new upper radiator hose. Student thought that because the lower hose did not collapse that the problem had to be a fault with the hose. The instructor then explained that the lower radiator hose has a spring inside to keep the lower hose from collapsing due to the lower pressure created at the inlet to the water pump. The radiator cap was replaced and the upper radiator hose did not collapse when the engine cooled. Summary:** **Complaint—An automotive student stated the upper radiator hose would collapse when the engine cools.** **Cause—The upper radiator collapsed due to a fault with the radiator pressure cap.** **Correction—A new radiator cap solved problem**
	**SAFETY TIP: Always remove a pressure cap slowly using rags or heavy gloves for protection. A hot cooling system can spray coolant or steam under pressure. Even a cold system may have pressure that can spray coolant into eyes or damage paint.**

ICONS	CH21 Cooling System Operation & Diagnosis
	**EXPLAIN TECH TIP: Working Better under Pressure** **A problem that sometimes occurs with a high pressure cooling system involves the water pump. For the pump to function, the inlet side of the pump must have a lower pressure than its outlet side. If inlet pressure is lowered too much, the coolant at the pump inlet can boil, producing vapor. The pump will then spin the coolant vapors and not pump coolant. This condition is called pump cavitation. Therefore, a radiator cap could be the cause of an overheating problem. A pump will not pump enough coolant if not kept under the proper pressure for preventing vaporization of the coolant.**
	**Overheating transmissions can cause engine overheating issues.**
	**DISCUSS CHART 21-2**
	**DEMONSTRATION: Demonstrate how a pressure cap vents at the pressure listed.**
	16. **SLIDE 16 EXPLAIN Figure 21-15** level in the coolant recovery system raises and lowers with engine temperature. 17. **SLIDE 17 EXPLAIN Figure 21-16** Some vehicles use a surge tank, which is located at the highest level of the cooling system, with a radiator cap.
	**Pressure Cap Operation (View) (Download)** **Water Pump Operation (View) (Download)**

ICONS	CH21 Cooling System Operation & Diagnosis
	**DEMONSTRATION:** Show students different types of coolant recovery bottles
	**DISCUSSION:** Discuss with students why the recovery bottle is important to longevity of the cooling system's effectiveness.
	Collapsed hoses may be caused by pressure cap not venting correctly.
 	**ON-VEHICLE ASEEDUCATION Task:** Inspect and replace engine cooling and heater system hoses (P-1)
	**DISCUSS FREQUENTLY ASKED QUESTION:** **How Much Coolant Can a Water Pump Move?** A typical water pump can move a maximum of about 7,500 gallons (28,000 liters) of coolant per hour, or recirculate the coolant in the engine over 20 times per minute. This means that a water pump could be used to empty a typical private swimming pool in an hour! The slower the engine speed, the less power is consumed by the water pump. However, even at 35 mph (56 km/h), the typical water pump still moves about 2,000 gallons (7,500 liters) per hour or 0.5 gallon (2 liters) per second! • **SEE FIGURE 21–18.**

ICONS	CH21 Cooling System Operation & Diagnosis
	18. **SLIDE 18 EXPLAIN Figure 21-17** Coolant flow through impeller & scroll of coolant pump for a V-type 19. **SLIDE 18 EXPLAIN FIGURE 21-18** DEMO engine running on a stand, showing the amount of coolant flow that actually occurs through cooling system**.** 20. **SLIDE 20 EXPLAIN Figure 21-19** This severely corroded water pump could not circulate enough coolant to keep the engine cool. As a result, the engine overheated and blew a head gasket. 21. **SLIDE 21 EXPLAIN Figure 21-20** bleed weep hole in the water pump allows coolant to leak out of the pump and not be forced into the bearing. If the bearing failed, more serious damage could result. 22. **SLIDE 22 EXPLAIN Figure 21-21** cutaway of a typical water pump showing the long bearing assembly and the seal. The weep hole is located between the seal and the bearing. If the seal fails, then coolant flows out of weep hole to prevent the coolant from damaging the bearing.
	**EXPLAIN TECH TIP: Release the Belt Tension before Checking a Water Pump: The technician should release water pump belt tension before checking for water pump bearing looseness. To test a water pump bearing, it is normal to check the fan for movement; however, if the drive belt is tight, any looseness in the bearing will not be felt.**
	**On vehicles that use a timing belt to run water pump, it is strongly recommended that the water pump be replaced when the timing belt is replaced.**
	**DISCUSSION: Discuss water pump operation with students**

ICONS	CH21 Cooling System Operation & Diagnosis
DEMO	**DEMONSTRATION: Show students different variations of a water pump.**
	Pressure Cap Operation (View) (Download) **Water Pump Operation (View) (Download)**
DEMO	**DEMONSTRATION: Show students water pump weep hole.**
	Be sure to install the serpentine belt correctly when replacing water pump; otherwise, pump may turn backwards.
Education Foundation	**ON-VEHICLE ASEEDUCATION Task: Inspect, test, remove, and replace water pump. (P-1)**
	23. SLIDE 23 EXPLAIN Figure 21-22 Chevrolet V-8 block that shows the large coolant holes and the smaller gas vent or bleed holes that must match the head gasket when the engine is assembled.
	DISCUSSION: Discuss with students differences in coolant flow systems.
DEMO	**DEMONSTRATION: Show students different head gasket designs and the coolant passages through them.**

ICONS	CH21 Cooling System Operation & Diagnosis
	**24. SLIDE 24 EXPLAIN Figure 21-23** typical electric cooling fan assembly showing the radiator and related components. **25. SLIDE 25 EXPLAIN Figure 21-24** A typical engine-driven thermostatic spring cooling fan.
	**WARNING: SOME ELECTRIC COOLING FANS CAN COME ON, AFTER THE ENGINE IS OFF, WITHOUT WARNING. ALWAYS KEEP HANDS AND FINGERS AWAY FROM THE COOLING FAN BLADES UNLESS THE ELECTRICAL CONNECTOR HAS BEEN DISCONNECTED TO PREVENT FAN FROM COMING ON. ALWAYS FOLLOW ALL WARNINGS AND CAUTIONS.**
	**SAFETY: Electrical cooling fans can come on unexpectedly. Always keep hands and objects clear of them. Spring-type fans should spin freely on a cold engine.**
	**DEMONSTATION: Show students how to remove and replace a cooling fan assembly.**
	**EXPLAIN TECH TIP: Be Sure to Always Use a Fan Shroud A fan shroud forces the fan to draw air through the radiator. If a fan shroud is not used, then air is drawn from around the fan and will reduce the airflow through the radiator. Many overheating problems are a result of not replacing the factory shroud after engine work or body repair work to the front of the vehicle.**

ICONS	CH21 Cooling System Operation & Diagnosis
 	**ON-VEHICLE ASEEDUCATION TASK:** Inspect and text fans(s) (electrical or mechanical), fan clutch, fan shroud, and air dams. (P-1)
	**DEMONSTRATION:** Show students how fan shroud helps direct airflow through radiator.
	**26. SLIDE 26 EXPLAIN Figure 21-25** A typical heater core installed in a heating, ventilation, and air-conditioning (HVAC) housing assembly
	**DEMONSTRATION:** Show students examples of heater cores and their locations.
	**Coolant on the passenger floor or a mist out of the vents may be caused by a leaking heater core.**
	**Some vehicles, especially hybrids, use a form of electrical heater core**
	**27. SLIDE 27 EXPLAIN Figure 21-26** heavily corroded radiator from a vehicle that was overheating. A visual inspection discovered that the corrosion had eaten away many of the cooling fins, yet did not leak. This radiator was replaced and it solved the overheating problem.

ICONS	CH21 Cooling System Operation & Diagnosis
	If using a dye to leak test, it may be necessary to remove the blower resistor to access the heater core for inspection.
	28. SLIDE 28 EXPLAIN Figure 21-27 Pressure testing cooling system. Hand operated pressure tester applies pressure equal to radiator cap pressure. The pressure should hold; if it drops, this indicates a leak somewhere in cooling system. An adapter is used to attach pump to cap to determine if radiator can hold pressure, & release it when pressure rises above max rated pressure setting. **29. SLIDE 29 EXPLAIN Figure 21-28** pressure cap should be checked for proper operation using a pressure tester as part of the cooling system diagnosis.
Education Foundation	**ON-VEHICLE ASEEDUCATION TASK Perform cooling system pressure tests; determine necessary action (P-1)** **ON-VEHICLE ASEEDUCATION TASK Identify and interpret engine concern; determine necessary action (P-1),**
	DISCUSSION: Discuss with students how incorrect ignition timing can cause overheating issues (i.e., cause a lean condition, which leads to the engine running at hotter temperatures.)
Education Foundation	**ON-VEHICLE ASEEDUCATION TASK Identify causes of engine overheating (P-1)**
	30. SLIDE 30 EXPLAIN Figure 21-29 Use dye specifically made for coolant when checking for leaks using a black light.

ICONS	CH21 Cooling System Operation & Diagnosis
DEMO	**DEMONSTRATION: Show students how dye illuminates with a black light.**
	**31. SLIDE 31 EXPLAIN Figure 21-30** When an engine overheats, often the coolant overflow container boils.
	**32. SLIDE 32 EXPLAIN Figure 21-31** Typical marks on an accessory drive belt tensioner.
DEMO	**DEMONSTRATION: Show students proper procedure for using a belt tension gauge.**
	**DISCUSS CHART 21-3**
  Education Foundation	**ON-VEHICLE ASEEDUCATION TASK (A1-D-4) Inspect, replace, and adjust drive belts, tensioners and pulleys; check pulley and belt alignment (P-1)**

ICONS	CH21 Cooling System Operation & Diagnosis
	**DISCUSS CASE STUDY: Highway Overheating** **A vehicle owner complained of an overheating vehicle, but problem occurred only while driving at highway speeds. The vehicle, equipped with a 4-cylinder engine, would run in a perfectly normal manner in city driving situations. The technician flushed the cooling system and replaced radiator cap and water pump, thinking that restricted coolant flow was the cause of the problem. Further testing revealed coolant spray out of one cylinder when the engine was turned over by the starter with the spark plugs removed. A new head gasket solved the problem. Head gasket leak was not great enough to cause any problems until the engine speed and load created enough flow and heat to cause the coolant temperature to soar. Technician also replaced the oxygen (O2) sensor.** **Summary:** **Complaint—Customer stated that the engine would overheat, but only if driven at highway speed.** **Cause—The root cause was determined to be a defective head gasket.** **Correction—The head gasket was replaced and the oxygen sensor was also replaced because coolant can cause the sensor to read incorrectly. Replacing the oxygen sensor was done to be insured that the engine ran correctly.**

ICONS	CH21 Cooling System Operation & Diagnosis
	33. **SLIDE 33 EXPLAIN Figure 21-33 (a)** Many vehicle manufacturers recommend that the bleeder valve be opened whenever refilling the cooling system.**(b)** Chrysler recommends that a clear plastic hose (1/4 in. ID) be attached to the bleeder valve and directed into a suitable container to keep from spilling coolant onto the ground and on the engine and to allow the technician to observe the flow of coolant for any remaining oil bubbles. 34. **SLIDE 34 EXPLAIN Figure 21-34** Using a coolant exchange machine helps eliminate the problem of air getting into the system which can cause overheating or lack of heat due to air pockets getting trapped in the system.
	**WARNING: Coolant level should only be checked when engine is cool. Removing the pressure cap from a hot engine will release the cooling system pressure while the coolant temperature is above its atmospheric boiling temperature. When the cap is removed, the pressure will instantly drop to atmospheric pressure level, causing coolant to boil immediately. Vapors from the boiling liquid will blow coolant from the system. Coolant will be lost, and someone may be injured or burned by the high temperature coolant that is blown out of the filler opening.**
	**DISCUSSION: Discuss proper coolant disposal procedures.**
	**DEMONSTRATION: Show students proper procedure for using a coolant exchange machine.**

ICONS	CH21 Cooling System Operation & Diagnosis
	Air pockets around thermostat can cause thermostat to malfunction, causing an overheating condition.
	35. SLIDE 35 EXPLAIN FIGURE 21–35 Hose clamps come in a variety of shapes and designs.
DEMO	**DEMONSTRATION: Show students where radiator petcock is located and how to properly open and close it without breaking it.**
DEMO	**DEMONSTRATION: Show students different types of heater hoses.**
	When checking radiator hoses, remember that the bottom hose may have a spring inside to keep it from collapsing.
Education Foundation	**HANDS-ON ASEEDUCATION TASK: Have students remove and replace a radiator hose.**
	HOMEWORK: Have students research the Internet and find our how hybrid vehicles keep the engine coolant warm even though the engine is not always running. Have them report their findings to the class.

ICONS	CH21 Cooling System Operation & Diagnosis
	**EXPLAIN TECH TIP: The Water Spray Trick** Lower-than-normal alternator output could be the result of a loose or slipping drive belt. All belts (V and serpentine multigroove) use an interference angle between the angle of the Vs of the belt and the angle of the Vs on the pulley. A belt wears this interference angle off the edges of the V of the belt. As a result, the belt may start to slip and make a squealing sound even if tensioned properly. A common trick to determine if the noise is from the belt is to spray water from a squirt bottle at the belt with the engine running. If the noise stops, the belt is the cause of the noise. The water quickly evaporates and therefore, water just finds the problem—it does not provide a short-term fix. If belt noise stops, but returns when the belt dries out, cause is often called chirp and is due to pulley misalignment. If the belt noise gets louder when sprayed with water, the cause is often called squeal and is caused by low belt tension.
	**EXPLAIN TECH TIP: Always Replace the Pressure Cap:** Replace old radiator cap with new cap with same pressure rating. Cap can be located on: 1. Radiator 2. Coolant recovery reservoir/expansion tank 3. Upper radiator hose **WARNING: Never remove a pressure cap from a hot engine. When the pressure is removed from the system, the coolant will immediately boil and will expand upward, throwing scalding coolant in all directions. Hot coolant can cause serious burns.**
	**EXPLAIN TECH TIP: Always Use Heater Hoses Designed for Coolant** Many heater hoses are sizes that can also be used for other purposes, such as oil lines. Always check and use hose that states it is designed for heater or cooling system use. • SEE FIGURE 21–36.

ICONS	CH21 Cooling System Operation & Diagnosis
 	**36. SLIDE 36 EXPLAIN FIGURE 21–36** The top 3/8 inch hose is designed for oil and similar liquids, whereas the 3/8 inch hose below is labeled “heater hose” and is designed for coolant. **EXPLAIN TECH TIP: Quick and Easy Cooling System Problem Diagnosis** **1. If overheating occurs in slow stop-and-go traffic, the usual cause is low airflow through the radiator. Check for airflow blockages or cooling fan malfunction.** **2. If overheating occurs at highway speeds, the cause is usually a radiator or coolant circulation problem. Check for a restricted or clogged radiator.**