CHAPTER 9
Automotive Engine Designs and Diagnosis

CHAPTER OVERVIEW

This chapter introduces the student to the internal combustion engine. A variety of popular designs are described and a general discussion of engine diagnosis and testing is introduced.

LEARNING OUTCOMES

- Describe the various ways in which engines can be classified.
- Explain what takes place during each stroke of the four-stroke cycle.
- Outline the advantages and disadvantages of the in-line and V-type engine designs.
- Define important engine measurements and performance characteristics, including bore and stroke, displacement, compression ratio, engine efficiency, torque, and horsepower.
- Outline the basics of diesel, stratified, and Miller cycle engine operation.
- Explain how to evaluate the condition of an engine.
- List and describe abnormal engine noises.

INSTRUCTIONAL OUTLINE WITH TEACHING HINTS

I. Introduction to Engines
  A. Engine Construction
II. Engine Classifications
  1. Operational Cycles
  2. Number of Cylinders
  3. Cylinder Arrangement
  4. Valve Train Type
  5. Ignition Type
  6. Cooling Systems
  7. Fuel Type
  Hint: Give examples of various engine classifications.
  A. Four-Stroke Gasoline Engine
    1. Four-Stroke Cycle
    2. Intake Stroke
    4. Compression Stroke
    5. Power Stroke
    6. Exhaust Stroke

7. Four–Stroke Operating Dynamics

B. Two-Stroke Gasoline Engine
   1. Engine Rotation

C. Combustion

D. Engine Configurations
   1. In-Line Engine
   2. V-Type Engine
   3. Slant Cylinder Engine
   4. Opposed Cylinder Engine

E. Camshaft and Valve Location
   1. Overhead Valve (OHV)
   2. Overhead Cam (OHC)

F. Valve and Camshaft Operation

G. Engine Location
   1. Front Engine Longitudinal
   2. Front Engine Transverse
   3. Mid-Engine Transverse

   Hint: Describe changes in engine designs and discuss how engines will change in the future.

H. Gasoline Engine Systems
   1. Air/Fuel System
   2. Ignition System
   3. Lubrication System
   4. Cooling System
   5. Exhaust System
   6. Emission Control System

III. Engine Measurement and Performance

A. Bore and Stroke

B. Displacement

C. Compression Ratio

D. Engine Efficiency
   1. Volumetric Efficiency
   2. Thermal Efficiency
   3. Mechanical Efficiency

E. Torque versus Horsepower

   Hint: Discuss how displacement, compression, torque, and horsepower affect engine performance.

F. Atkinson Cycle Engines
   1. Hybrid Engines
   2. Miller Cycle Engines

IV. Other Automotive Power Plants

A. Hybrids
   1. Battery-Operated Electric Vehicles
   2. Fuel Cell Electric Vehicles

B. Rotary Engines

V. Diesel Engines

A. Construction
   1. Starting
   2. Sound
   3. Emissions

B. Homogeneous Charge Compression Ignition Engines

1. Dual Mode
2. Benefits

C. Variable Compression Ratio Engines

VI. Engine Identification

A. Using Service information
   1. Engine ID Tags
   2. Casting Numbers
   3. Underhood Label

   Hint: Have the students use the VIN and the underhood label to identify the model years and engine sizes of an assortment of vehicles.

VII. Engine Diagnostics

A. Compression Test
   1. Wet Compression test

B. Running Compression Test

C. Cylinder Leakage Test

D. Cylinder Power Balance Test

E. Vacuum Tests
   1. Vacuum Transducers

F. Oil Pressure Testing

   Hint: Discuss when each of these tests would be the most useful. Describe the difference between a compression test, a cylinder leakage test, and a cylinder power balance test.

VIII. Evaluating the Engine's Condition

A. Fluid Leaks

B. Exhaust Smoke Diagnosis

IX. Noise Diagnosis

A. Using a Stethoscope

B. Common Noises
   1. Ring Noise
   2. Piston Slap
   3. Piston Pin Knock
   4. Ridge Noise
   5. Rod-Bearing Noise
   6. Main or Thrust Bearing Noise
   7. Tappet Noise
   8. Abnormal Combustion Noises
   9. Cleaning Carbon Deposits

   Hint: Describe the various noises and whether they happen at crankshaft or camshaft speed. If possible, record some normal and abnormal engine noises for playback to the students.

ADDITIONAL TEACHING HINTS

- Demonstrate power balance testing, then evaluate the engine's condition. Have the students identify their family vehicles as to engine type, valve train, camshaft location, and cylinder arrangement.

WHAT ARE COMMON STUDENT MISCONCEPTIONS AND STUMBLING BLOCKS?

- One of the biggest stumbling blocks for beginning technicians is understanding how an engine operates by creating the change of energy from chemical to mechanical.
- To aid in their understanding use the chapter information starting on page 221 of Chapter 9 and a cutaway of an engine if available. Operate the engine by hand through the four strokes. Use some simple chemistry examples of burning a fuel if available.
- If possible obtain a few single cylinder lawnmower engines for the students to disassemble. Show the similarities in these engines to an automobiles engine.

SHOP ACTIVITIES AND CASE STUDIES

Here are some activities you can review in-class as a group, or ask students to complete individually or in pairs:

1. Describe the four strokes of an internal combustion engine. Make sure your description includes the direction of the movement of the piston, the position of the intake and exhaust valves, and the amount of pressure inside the cylinder.

2. Calculate the compression ratio of a four-cylinder engine that has a bore of 92 mm (3.62 in.), a stroke of 78 mm (3.07 in.), and a clearance volume of 72.26 cm^3 (4.41 cu. in.).

3. Use available shop resources to create a list of vehicles using the engine technology listed above. Find at least one example of a vehicle using an Atkinson cycle engine, a Miller cycle engine, and a rotary engine.

4. Select a vehicle and write down its VIN. Using a service manual and the textbook, explain all of the information that is given in the VIN by deciphering the codes.

ANSWERS TO TEXTBOOK REVIEW QUESTIONS

1. The combustion chamber is the space between the top of the piston and the cylinder head. It is an enclosed area in which the gasoline and air mixture is burned.
2. The four strokes are intake, compression, power, and exhaust.
3. As an engine's compression ratio increases, there should also be an increase in the octane rating of the fuel in order to avoid abnormal combustion. Gasoline with too low an octane rating may ignite before spark occurs due to the additional heat produced by a higher compression ratio, or it may burn in an explosive and destructive manner.
4. A cylinder balance test can be used to compare the efficiency of each cylinder. Ideally, all of the cylinders should produce an equal amount of power.

5. Tappet noise is a term used to describe a noisy valve train. It is characterized as a light regular clicking noise, which is more noticeable at idle speed. Because the camshaft rotates at one-half crankshaft speed, valve train noises may be identified by a lower frequency.
6. a. The statement “The engine provides the rotating power to drive the wheels through the transmission and driving axle” is true.
7. a. The ignition of the fuel/air mixture begins the power stroke.
8. c. The compression ratio describes the amount that the air/fuel mixture will be compressed.
9. b. The camshaft is responsible for opening and closing the intake and exhaust valves.
10. a. A diesel engine may have a compression ratio of up to 25:1.
11. a. A cylinder leakage test is performed to pinpoint the cause of a low cylinder compression test reading.
12. c. Piston slap is a noise that is produced when the piston slaps against the cylinder wall due to excessive clearances.
13. a. The exhaust system removes burned gases and limits the noise produced by the engine.
14. b. Piston slap is generally a hollow, bell-like noise that is produced when the piston slaps against the cylinder wall due to excessive clearances. It is commonly heard when the engine is cold, and gets louder when the engine is accelerated. Shorting out the spark plug of the affected cylinder may quiet the noise.
15. c. The stroke of an engine is equal to two times the crankshaft throw.
16. c. During a cylinder leakage test of a cylinder with worn piston rings, air should be found at the oil fill port. The air from the tester will enter the crankcase past the worn piston rings and vent to the atmosphere through the oil fill port or the dipstick tube.
17. a. An oil pressure regulator valve that is defective (sticking) can cause abnormally high oil pressure.
18. b. A sharp metallic rapping sound originating from the upper portion of an engine would most likely be a piston pin knock.
19. b. A collapsed lifter would most likely not show up on either a compression or a cylinder leakage test, but would cause the cylinder to produce less power than other cylinders.
20. d. Thermal efficiency describes how well the engine converts the heat produced during combustion into usable power.

CHAPTER 10
Engine Disassembly

CHAPTER OVERVIEW

This chapter instructs the student in engine removal and disassembly of the cylinder head and cylinder block. Identification and cleaning of engine parts and crack detection and repair are explained in depth.

LEARNING OUTCOMES

- Prepare an engine for removal.
- Remove an engine from a FWD and a RWD vehicle.
- Describe how to disassemble and inspect an engine.
- Name the three basic cleaning processes.
- Identify the types of cleaning equipment.
- Describe the common ways to repair cylinder head cracks.

INSTRUCTIONAL OUTLINE WITH TEACHING HINTS

I. Removing an Engine
A. General Procedures
1. Battery
2. Hood
3. Fluids
4. Underbody Connections
5. Air-Fuel System
6. Accessories
7. Electrical Connections
8. Cooling System
B. FWD Vehicles
1. Drive Axles
2. Transaxle Connections
3. Starter
4. Removing the Engine through the Hood Opening
5. Removing the Engine from Under the Vehicle
C. RWD Vehicles
1. Transmission
2. Removing the Engine
Hint: Divide the students into several groups. Have them find the procedure

for removing an engine from several types of vehicles such as a FWD van and RWD light truck in the service manuals. Compare and discuss the differences as a class.

II. Engine Disassembly and Inspection
- A. Cylinder Head Removal

III. Cleaning Engine Parts
- A. Types of Soil Contaminants
  1. Water-Soluble Soils
  2. Organic Soils
  3. Rust
  4. Scale
- B. Cleaning with Chemicals
  1. Chemical Cleaning Machines
- C. Thermal Cleaning
- D. Abrasive Cleaners
  1. Abrasive Cleaning Methods
  2. Alternative Cleaning Methods

  Hint: Show the labels and MSDS for the chemicals used in the lab and discuss how to safely store and use them.

IV. Crack Detection and Repair
  1. Dye Penetrant
- A. Furnace Welding Crack Repairs
- B. Repairing Aluminum Heads

ADDITIONAL TEACHING HINTS

- Disassemble a cylinder block in the shop.
- Display samples of soil contaminants for students to view.
- Demonstrate chemical, abrasive, or some other cleaning method.
- Use and review all MSDSs for the shop chemical cleaning agents.
- Show how disassembled engine parts should be organized.

WHAT ARE COMMON STUDENT MISCONCEPTIONS AND STUMBLING BLOCKS?

- Student misconceptions in this area will include the lack of organizing required while disassembling a vehicle and its engine.
- Stress the importance of organization and the need to label and bag most components during removal and disassembly.
- It is possible for there to be a couple of weeks or longer before reassembling the engine and reinstalling in the vehicle. Refer to page 258 of Chapter 10 for information.

SHOP ACTIVITIES AND CASE STUDIES

Here are some activities you can review in-class as a group, or ask students to complete individually or in pairs:

1. Choose two vehicles, one FWD and one RWD, each made by a different manufacturer, and compare the engine disassembly procedures given in their service information. Describe the similarities and the differences and explain why there are differences.

2. List all of the engine-cleaning equipment and solvents that are available in your shop. When listing the solvents, include the health-related precautions listed on the solvent container's label or on its MSDS. Also determine how the waste-cleaning agents are to be disposed of when they need to be replaced.

CASE STUDY

3. A technician is preparing to rebuild a 2.4-litre engine from a 2011 Buick Regal. After removing the heads, what procedure should be performed before removing the pistons from the block, and why?

ANSWERS TO TEXTBOOK REVIEW QUESTIONS

1. All electronic and fuel injection parts should be covered with plastic bags during steam or other cleaning procedures to avoid direct contact with steam, water, or other cleaning agents. Environmental regulations should always be followed.
2. Wear protective gloves and goggles when using chemical cleaners.
3. The best method for repairing cracked cast-iron heads is furnace welding by a specialist.
4. The typical steps for removing an engine from a rear-wheel-drive vehicle involves performing all the usual steps involved in engine removal such as electrical, fuel, exhaust, and hose removal. A typical RWD vehicle has the engine removed through the hood opening. If the engine is to be removed separately from the transmission, the transmission must be supported and disconnected from the engine. If the transmission and engine are to be removed together, the transmission must be drained and all linkage, cables and electrical connections must be removed and a floor jack placed under the transmission. The engine hoist should now be put in place and the engine (and transmission) mounts should be disconnected. At this point the engine or engine/transmission assembly can be carefully lifted from the vehicle.
5. a. The most common method of removing an engine from a front-wheel-drive vehicle is to lower the engine and transaxle as an assembly with the cradle.
6. a. Removing the intake and exhaust manifolds is usually the first step in engine disassembly.
7. d. For front wheel drive vehicles, a frame contact hoist bay is usually recommended. This hoist allows the engine to be lowered to the floor and the vehicle lifted to allow the engine to be removed from underneath the vehicle.
8. b. The next step would be to relieve the pressure in the fuel system.
9. d. When removing a cylinder head, a breaker bar should be used to loosen each head bolt one or two turns starting from the outside of the cylinder head working inward.
10. b. The buildup of minerals and deposits is called scale.
11. a. Hydrocarbon based solvents are toxic as well as flammable.
12. b. Grit media blasting is used to etch the surface of a material.
13. d. Tungsten inert gas (TIG) welding is the only crack repair method used on aluminum engine components.
14. a. Ultrasonic cleaning uses high-frequency sound waves to loosen dirt particles.

15. c. Spray washers are often used to pre-clean engine components prior to disassembly.
16. d. There is no particular order to loosening connecting rod cap bolts.
17. c. Use at least four bolts to mount an engine block to an engine stand.
18. d. After the fuel system is depressurized the negative battery cable should be disconnected.
19. c. Removal of the engine mount bolts should only be done once the supports or crane is in place.
20. a. You should vee out the damaged area and weld with an aluminum filler rod on an aluminum head with a crack in the coolant passage.

CHAPTER 11
Lower End Theory and Service

CHAPTER OVERVIEW

This chapter discusses the cylinder block, crankshaft, crankshaft bearings, connecting rods, pistons and rings, oil galley, core plugs, flywheel, and harmonic balancer, focusing attention on the design and function of these essential parts.

LEARNING OUTCOMES

- Disassemble and inspect an engine's cylinder block.
- List the parts that make up a short block and briefly describe their operation.
- Describe the major service and rebuilding procedures performed on cylinder blocks.
- Describe the purpose, operation, and location of the camshaft.
- Describe the four types of camshaft drives.
- Inspect the camshaft and timing components.
- Describe how to install a camshaft and its bearings.
- Explain crankshaft construction, inspection, and rebuilding procedures.
- Explain the function of engine bearings, flywheels, and harmonic balancers.
- Explain the common service and assembly techniques used in connecting rod and piston servicing.
- Explain the purpose and design of the different types of piston rings.
- Describe the procedure for installing pistons in their cylinder bores.
- Inspect, service, and install an oil pump.

INSTRUCTIONAL OUTLINE WITH TEACHING HINTS

I. Short Block Disassembly
    A. Cylinder Block Disassembly
II. Cylinder Block
    A. Lubrication and Cooling
III. Cylinder Block Reconditioning
    A. Deck Flatness
    B. Cylinder Walls
    C. Cylinder Bore Inspection
    D. Cylinder Bore Surface Finish

1. Cylinder Deglazing
2. Cylinder Boring
3. Cylinder Honing

E. Lifter Bores
F. Checking Crankshaft Saddle Alignment
G. Installing Core Plugs
1. Disc- or Dished-Type
2. Cup-Type
3. Expansion-Type

Hint: Show examples of each type of plug and describe their proper uses.

IV. Camshaft

A. Valve Timing Terminology
1. Lobe Terminology

B. Timing Mechanisms
1. Gear Drive
2. Chain Drive
3. Belt Drive
4. Tensioners
5. Variable Valve Timing

C. Valve Lifters
1. Operation of Hydraulic Valve Lifters

D. Camshaft Bearings
E. Balance Shafts

V. Inspection of Camshaft and Related Parts

A. Timing Components
B. Lifters
C. Camshaft

VI. Installing the Camshaft and Related Parts

A. Camshaft Bearings
B. Camshaft

VII. Crankshaft

A. Crankshaft Torsional Dampers
1. Harmonic Balancer
2. Fluid Damper

B. Flywheel
1. Flywheel Inspection

Hint: Show students different crankshaft configurations. Show both forged and cast crankshafts.

VIII. Crankshaft Inspection and Rebuilding

A. Crankshaft Reconditioning
B. Checking Crankshaft Straightness
C. Crankshaft Bearings
D. Bearing Materials
E. Bearing Spread
F. Bearing Crush
G. Bearing Locating Devices
H. Oil Grooves
I. Oil Holes
J. Oil Clearance
K. Bearing Failure and Inspection

Hint: Show students a variety of damaged and worn bearings. Discuss the causes of the failures. Have students look up crankshaft specifications in service manuals or information systems.

IX. Installing Main Bearings and Crankshaft
- A. Crankshaft End Play
- B. Connecting Rod
  1. Inspection

  Hint: Demonstrate the use of Plastigage and crankshaft end play measurements.

X. Piston and Piston Rings
- A. Piston Terminology
  1. Inspection
- B. Piston Pins
- C. Piston Rings
  1. Compression Rings
  2. Oil-Control Rings

XI. Installing Pistons and Connecting Rods

XII. Crankshaft and Camshaft Timing
- A. Camshaft End Play
- B. Lifters
- C. Oil Pump

ADDITIONAL TEACHING HINTS

- Measure deck warpage.
- Demonstrate deglazing and honing.
- Demonstrate a crankshaft inspection.
- Demonstrate how to use Plastigage on the main and rod bearings.

WHAT ARE COMMON STUDENT MISCONCEPTIONS AND STUMBLING BLOCKS?

- It will be difficult for students to understand the machining processes required to rebuild an engine. Attempt to arrange a field trip to a local machine shop; this will give the students a different perspective on what it takes. Use information throughout the chapter to reinforce this knowledge.
- Have the students create a list of parts they believe is needed to rebuild an engine, possibly one that is apart in your shop. Do this individually and then as a group to compare.

SHOP ACTIVITIES AND CASE STUDIES

Here are some activities you can review in-class as a group, or ask students to complete individually or in pairs:

1. Following the service information procedures, perform the task of cylinder deglazing.

2. Identify the various parts of a crankshaft: main bearing journals, connecting rod bearing journals, flywheel end, drive belt end, offset crankpin, and counterweights.

3. Identify the following parts of a piston: dome, grooves, ring lands, piston pin bore, mark (to ensure correct piston installation), piston skirt, piston thrust surface, compression ring, and oil control ring.

4. Remove the piston rings from a piston with a piston ring expanding tool.
CAUTION: *Do not attempt to remove a piston ring without a piston ring expanding tool. The ends of the piston ring could scratch and damage the piston.*

5. Following the service information procedures, clean the ring grooves on a piston using a ring groove cleaner tool.

6. Following the service information procedures, measure piston ring gap and ring side clearance.

7. Following the service information procedures, time the camshaft to the crankshaft for an engine using sprocket and chain system.

CASE STUDY
8. A technician is installing a crankshaft into a block. After checking the main bearing oil clearance, he finds the clearance to be excessive. List three factors that could be the cause and give your recommendations.

ANSWERS TO TEXTBOOK REVIEW QUESTIONS

1. Camshaft lobe wear may be measured with an outside micrometer or with a dial indicator.
2. The deck is the top surface of the block to which the cylinder head mounts.
3. Maximum cylinder bore wear occurs at the top of the ring travel area.
4. Compression rings form a seal between the piston and the cylinder walls using combustion pressure to force the ring against the bottom edge of the ring groove. Compression rings not only prevent combustion pressure from entering the crankcase but they also help prevent oil from entering the combustion chamber.
5. a. Hydraulic lifters automatically compensate for changes in engine temperature.
6. b. Aluminum pistons are most commonly used in automotive engines.
7. b. The initial purpose of core plugs is to allow the release of sand from the inside of the engine block during the moulding process.
8. c. A straightedge and feeler gauge is generally used to measure cylinder block deck warpage.
9. b. A micrometer is generally used to measure crankshaft bearing journals.
10. c. Roller lifters produce the least amount of camshaft wear.
11. a. Excessive piston clearance can cause piston slap.
12. b. Cylinders are deglazed to ensure proper ring sealing.
13. b. Bearing crush refers to each half of a split bearing being slightly greater than an exact half. Bearing spread means that the distance across the parting edges of the insert should be slightly greater than the diameter of the bearing bore.
14. d. The connecting rod journal is also called the crank pin.
15. d. Main bearing bore misalignment can be corrected by line boring the bearing saddles.
16. d. The correct procedure for boring cylinders is to bore the cylinder to the new piston size and hone to the proper clearance specification.
17. c. A rigid hone should be used during the boring process to maintain straight cylinder walls.

18. b. The correct replacement bearing for this connecting rod journal would be U/S—0.254 mm (0.010 in.) undersize. The bearing is identified as undersize because they are named after the shaft size that they fit.

19. c. To calculate cylinder bore taper a reading must be taken at the top and bottom of ring travel at 90° to the block centreline (c/l). Greater cylinder wear occurs at 90° to the block c/l.

20. b. The cam changes rotary motion of the camshaft into the reciprocating motion of the valves.

CHAPTER 12
Upper End Theory and Service

CHAPTER OVERVIEW

This chapter draws attention to the different types of combustion chamber designs and intake and exhaust valves. Additional information is given about reconditioning aluminum cylinder heads, resurfacing cylinder heads, grinding valves, valve guide reconditioning, and reconditioning of valve seats.

LEARNING OUTCOMES

- Describe the purpose of an engine's cylinder head, valves, and related valve parts.
- Describe the types of combustion chamber shapes found on modern engines.
- Know why there are special service procedures for aluminum and OHC heads.
- Describe the different ways that manufacturers vary valve timing.
- Perform a complete inspection on valve train components.
- Explain the procedures involved in reconditioning cylinder heads, valve guides, valve seats, and valve faces.
- Explain the steps in cylinder head reassembly.

INSTRUCTIONAL OUTLINE WITH TEACHING HINTS

I. Cylinder Head
  A. Ports
II. Combustion Chamber
  A. Wedge Chamber
  B. Hemispherical Chamber
  C. Pentroof Chamber
    Hint: Show examples of different combustion chamber designs.
III. Intake and Exhaust Valves
  A. Valve Construction
    1. Stainless Steel Valves
    2. Inconel Valves
    3. Stellite Valves
    4. Sodium Filled
    5. Titanium Valves
    6. Ceramic Valves
    7. Valve Terminology
  B. Valve Stems

C. Valve Seats
D. Important Valve Components of Four-Stroke Engines
1. Valve Guides
2. Valve Springs, Retainers, and Seals
3. Valve Rotators
4. Camshaft Bearings
5. Pushrods
Hint: Show some failed pushrods. Explain what to look for when examining pushrods.
6. Pushrod Guide Plates
7. Rocker Arms
E. Multivalve Engines

IV. Variable Valve Timing
A. Staged Valve Timing
B. Continuously Variable Timing
1. Toyota's VVT-i System
2. Fiat's Multiair System
3. Valvetronic System
C. Other VVT Systems
D. Cylinder Deactivation
1. Honda
2. Other Cylinder Deactivation Systems

V. Cylinder Head Disassembly

VI. Inspection of Cylinder Head and Valve Train
A. Timing Components
B. Timing Chains
C. Belt Idler Pulley
D. Tensioners
E. Gears and Sprockets
F. Cam Phasers
G. Cam Followers and Lash Adjusters
H. Rocker Arms
1. Honda's Variable Cylinder Management Rocker Arms
I. Pushrods
J. Retainers and Keepers
K. Valve Rotators
L. Valve Springs
M. Cylinder Heads
N. Crack Repair
1. Furnace Welding Crack Repairs
2. Flame Spray Welding
3. Repairing Aluminum Heads
4. Pinning Cracks
O. Camshaft and Bearings
P. Valves
Hint: Show examples of each of the cylinder head and valve train components listed. Show where to look for wear patterns.

VII. Aluminum Cylinder Heads
A. Reconditioning Aluminum Cylinder Heads

VIII. Resurfacing Cylinder Heads
A. Surface Finish

1. Resurfacing Machines
2. Stock Removal Guidelines

IX. Grinding Valves

X. Valve Guide Reconditioning

A. Knurling
B. Reaming and Oversized Valves
C. Thin-Wall Guide Liners
D. Valve Guide Replacement
   1. Integral Guides
   2. Insert Guides

   Hint: Compare reaming and oversized valves with thin-walled and cast-iron inserts.

XI. Reconditioning Valve Seats

A. Installing Valve Seat Inserts
   1. Reconditioning Integral Seats
   2. Grinding Valve Seats
   3. Cutting Valve Seats
   4. Machining Valve Seats

   Hint: Show a valve seat insert and describe the method used to install it.

XII. Valve Stem Seals

A. Installing Positive Valve Seals
B. Installing Umbrella-Type Valve Seals
C. Installing O-Rings

   Hint: Discuss the merits of positive seals over other types.

D. Valve Springs
   1. Freestanding Height Test
   2. Spring Squareness Test
   3. Open/Close Spring Tension Test

   Hint: Discuss why valve springs need to be tested and the consequences of omitting this service. Show examples of failed valve springs.

XIII. Assembling the Cylinder Head

A. OHC Engines

ADDITIONAL TEACHING HINTS

- Demonstrate carbon removal and cleaning techniques.
- Check the head surface for warpage with a straightedge and feeler gauge.
- Pass around a valve with a too-narrow margin.
- Demonstrate how to check for valve spring tensions.
- Check for cam bore warpage on an OHC head.
- Demonstrate cylinder head disassembly and reassembly.
- Demonstrate how disassembled cylinder head parts should be organized.

WHAT ARE COMMON STUDENT MISCONCEPTIONS AND STUMBLING BLOCKS?

- Students will typically have a difficult time understanding the machining processes required to recondition a cylinder head to the point where it is able to be reused. There are a large number of measurements required to perform these tasks. Using information from throughout the chapter and a used cylinder head, take the students through all of the processes required from disassembly right through to reassembly of just one cylinder's valve train.

SHOP ACTIVITIES AND CASE STUDIES

Here are some activities you can review in-class as a group, or ask students to complete individually or in pairs:

1. Using a service information system, describe the components of the valve assembly for five different engines. Identify the differences—for example, some have more than one valve spring per valve—and explain why these differences exist. To benefit from this activity, you should have a variety of the type of engines and the engine manufacturers that you will use in this study.

2. Identify the following parts in a cylinder head: valves, valve seats, valve guides, valve springs, rocker arm supports, the recessed area that makes up the top position of the combustion chamber, and (on an overhead cam engine only) the supports for the camshaft and camshaft bearings.

3. Identify two different types of variable valve timing or cylinder deactivation systems and list all of the components involved in their operation.

CASE STUDIES

4. A customer brings her 2010 Ford Focus into the shop and complains that the engine is using too much oil. She presents a log of when oil was added. The log certainly verifies her complaint. The technician carefully inspects the engine for leaks and finds none. What should she do next?

5. A customer brings in a 2011 Chevrolet HHR with valve noise. List, in proper sequence, the first three checks the technician should make.

ANSWERS TO TEXTBOOK REVIEW QUESTIONS

1. If valve spring tension is too low, the valves will not be closed promptly enough and there will be valve float at higher engine speeds.
2. Valve margin is the area between the valve face and the head of the valve that allows for some machining of the valve face, which is sometimes necessary to restore its finish, and allows the valve an extra capacity to hold heat.
3. Warpage in an aluminum cylinder head is usually the result of overheating or uneven cooling within the cylinder head.
4. Pushrods may be checked for straightness while installed in the engine by rotating them when the valve is closed and visually checking for indications of wobble. When the pushrods are out of the engine, they can be checked by rolling them on a flat surface; a pushrod that is not straight will appear to hop. The most accurate method is by using a dial indicator. If more than 0.003 (0.076 mm) TIR is found, the pushrod should be replaced.

5. Because knurling only restores a portion of the valve guides ID to original dimensions. The raised edges produced by knurling soon wear down, and clearances rapidly become excessive.
6. **b**. The margin is the distance between the valve face and the valve head.
7. d. Oil can leak into the intake charge and the exhaust gases when the valve guide is worn. The air flow into the cylinder during the intake stroke can pull oil down the intake valve guide and into the combustion chamber. The exhaust gas flow past the guide can also draw oil into the exhaust gases.
8. c. Bronze valve guides tend to last 2 to 5 times longer than cast iron guides due to its ability to retain oil and their anti-wear and anti-seize characteristics.
9. c. A wider than specified valve seat can be narrowed by using a three angle valve grind. A topping stone will remove material from the outer edge of the seat and a throating stone will remove material from the inner edge.
10. d. Positive valve stem seals fit tightly over the guide and removes excess oil off the valve as it moves up and down through the seal.
11. b. A valve seat insert should be staked after installation to secure it in the counterbore.
12. a. Rocker arm ratio is used to open the valve further than the cam lobe lift.
13. a. The interference angle is the one degree angle difference between the valve face and the valve seat.
14. a. Shims are placed under the valve springs to restore the correct valve spring installed height. When the valve and seat is machined material is removed from both resulting in the valve stem extending further through the head. A shim is used to counter this extra stem height.
15. a. In general, maximum cylinder head deck surface deformation is 0.1 mm (0.004 in.).
16. c. Installing new valve guide inserts would be the first procedure performed. The valve seats can only be cut or ground after the guide is repaired because the seat must be concentric to the guide centreline.
17. **c**. Broaching machines use an underside rotary cutter.
18. b. The ideal intake valve seat width 1.6 mm (1/16 in.).
19. d. Quenching is the cooling of gases by pressing them into a thin area.
20. d. The exhaust valve margin should be greater than 1.14 mm (0.045 in.). An exhaust valve with a thinner margin could burn during operation.

CHAPTER 13
Engine Sealing and Reassembly

CHAPTER OVERVIEW

This chapter describes the gaskets, sealants, adhesives, and fasteners needed to correctly seal an engine. Improvement in sealing technologies is introduced in this chapter. Proper engine reassembly procedures are also covered in detail.

LEARNING OUTCOMES

- Explain the purpose of the various gaskets used to seal an engine.
- Identify the major gasket types and their uses.
- Explain general gasket installation procedures.
- Describe the methods used to seal the timing cover and rear main bearing.
- Reassemble an engine including core plugs, bearings, crankshaft, camshaft, pistons, connecting rods, timing components, cylinder head, valve train components, oil pump, oil pan, and timing covers.
- Explain the ways to prelubricate a rebuilt engine.
- Reinstall an engine and observe the correct starting and break-in procedures.

INSTRUCTIONAL OUTLINE WITH TEACHING HINTS

I. Torque Principles
- A. Thread Repair
- B. Torque-to-Yield (TTY) Bolts

II. Gaskets
- A. Cut Gaskets
  1. Paper/Fiber Gaskets
  2. Cork Gaskets
- B. Molded Rubber Gaskets
- C. Hard Gaskets
- D. Replacement Gaskets
- E. General Gasket Installation Procedures

III. Specific Engine Gaskets
- A. Cylinder Head Gaskets
  1. Bimetal Engine Requirements
  2. Multilayer Steel (MLS)
- B. Head Gasket Failures
  1. Head Bolts

   C. Manifold Gaskets
   D. Valve Cover Gaskets
   E. Oil Pan Gaskets
   F. EGR Valve

IV. Adhesives, Sealants, and Other Chemical Sealing Materials
   A. Adhesives
   B. Sealants
      1. General-Purpose Sealants
      2. Thread Sealants
      3. Silicone Sealants
      4. Anaerobic Formed-in-Place Sealants
   C. Antiseize Compounds
      Hint: Discuss the importance of using oxygen-sensor safe RTV and anti-seize compounds.

V. Oil Seals
   A. Timing Cover Oil Seals
   B. Rear Main Bearing Seals
   Hint: Discuss oil seal burning and emphasize the importance of lubricating the oil seal lip.

VI. Engine Reassembly
   A. Installing the Cylinder Head and Valve Train
      1. Torque Angle Gauge
   B. Timing Belts and Chains
   C. Final Reassembly Steps
      1. Coolant Drains and Plugs
      2. Timing Sensors
      3. Install the Timing Cover
      4. Install the Vibration Damper
      5. Install the Valve Cover
      6. Install Oil Pan
      7. Install Intake Manifold
      8. Install the Thermostat and Water Outlet Housing
      9. Install Exhaust Manifold
      10. Install Flywheel or Flex Plate
      11. Install Clutch Parts
      12. Install Torque Converter
      13. Install Engine Mounts
      14. Other Parts

VII. Installing the Engine
   A. Installing an Engine into a FWD Vehicle
   B. Installing an Engine in an RWD Vehicle
   C. Prelubrication
      1. Distributor-Driven Oil Pumps
   D. Starting Procedure
   E. Break-In Procedure
   F. Relearn Procedures

ADDITIONAL TEACHING HINTS

- Examine various metric and UNS bolts. Identify the size of the bolt head, and the diameter, length, and thread pitch of each bolt.
- Demonstrate impression testing.
- Demonstrate RTV, antiseize, Loctite, and other gasket sealers.
- Demonstrate engine prelubrication processes.
- Demonstrate torque-to-yield bolt tightening.
- Demonstrate valve lash adjustment.

WHAT ARE COMMON STUDENT MISCONCEPTIONS AND STUMBLING BLOCKS?

- Students entering the automotive trade will typically not have a feeling for a certain torque value. Using the torque value chart on page 371 of Chapter 13, place various fasteners into a threaded metal plate and have the students practise applying the proper torque values on these fasteners without a torque wrench and checking their accuracy. This will get them used to having a "feel" for torque values.
- Students will typically struggle with understanding which one of the many sealers or adhesives to use in each situation. Using information starting from page 380 of Chapter 13, have the students make a list of each sealer and adhesive used in an engine of their choice and why they would use each.

SHOP ACTIVITIES AND CASE STUDIES

Here are some activities you can review in-class as a group, or ask students to complete individually or in pairs:

1. Refer to the service information for the engine of your choice. Find the torque specifications for the following parts: cylinder head, intake manifold, oil pan, valve (cam) covers, and water pump bolts.

2. Describe what each of the following gaskets must do or seal: cylinder head gasket, intake manifold gasket, oil pan gasket, valve cover gasket, and water pump gasket. Include in your description everything that is sealed by the gasket.

ANSWERS TO TEXTBOOK REVIEW QUESTIONS

1. A bolt that has been stretched to its yield point will not return to its original length.
2. Cylinder head, exhaust manifold, and some intake manifold gaskets.
3. On the threads of bolts exposed to fluids.
4. Whether they cure in the presence of air (aerobic) or with the absence of air (anaerobic). Aerobic can be used where flexibility or gap filling ability is needed while anaerobic is used to seal machined surfaces of rigid components.
5. b. Bolt torque values are calculated to 25 percent below the bolts yield point.
6. d. When torquing cylinder head bolts, always follow the manufacturer's recommendations.

7. a. Tightening torque-to-yield fasteners requires torquing the bolt to a specified torque followed by turning it an additional number of degrees.
8. d. Engine block bolt holes that have been pulled up should be filed flat, chamfered and the threads cleaned before it is reused.
9. a. Unless otherwise noted, coat the threads and the underside of the bolt head with engine oil.
10. b. Anaerobic sealants are used to seal machined surfaces of rigid castings.
11. c. The torque converter must be inserted over the transmission input shaft and rotated until it engages the transmission oil pump. Failure to engage the oil pump can cause damage to both the torque converter and transmission.
12. a. When starting a rebuilt engine the throttle should be set at approximately 1500 rpm until operating temperature is reached.
13. c. During the initial test run of a rebuilt engine, repeated full throttle accelerations from 50 to 80 km/h (30 to 50 mph) should be performed. This will result in accelerated ring seating.
14. a. Graphite is a lubricant that will allow the head to slide across the gasket as it expands and contracts.
15. c. Mechanical flat base lifters require valve train adjustment.
16. a. RTV sealants can be used to replace oil pan gaskets and other flexible stampings.
17. b. Synthetic rubber lip type seals are commonly used as rear main seals on current engines.
18. c. Aluminum heads can expand two to three times more than the cast iron engine block which will produce movement between the two components.
19. d. A prelubricator should be used to prime or circulate engine oil throughout a rebuilt engine before the initial startup.
20. a. Not all timing belt tensioners require adjustment.

CHAPTER 14
Lubricating and Cooling Systems

CHAPTER OVERVIEW

This chapter describes the functions of the components of a typical lubricating and cooling system. Also explained are service requirements such as oil types, oil pump inspection and installation, and cooling system inspection and service.

LEARNING OUTCOMES

- Name and describe the components of a typical lubricating system.
- Inspect, service, and install an oil pump.
- Describe the purpose of a crankcase ventilation system.
- List and describe the major components of the cooling system.
- Describe the operation of the cooling system.
- Describe the function of the water pump, radiator, radiator cap, and thermostat in the cooling system.
- Test and service the cooling system.

INSTRUCTIONAL OUTLINE WITH TEACHING HINTS

I. Lubrication System
- A. Engine Oil
  1. Oil Pump
  2. Types of Oil Pumps
  3. Pressure Regulation
  4. Oil Pan or Sump
  5. Pan Baffles
  6. Dry Sump
  7. Oil Filter
- B. Oil Coolers
- C. Engine Oil Passages or Galleries
- D. Dipstick
- E. Oil Pressure Indicator

II. Oil Pump Service
- A. Inspection
  1. Pickup Unit

III. Installing the Oil Pump

- A. Crankshaft-Driven Pump
- B. Cam-Driven Pumps
  - 1. Distributor-Driven Pump

IV. Basic Lubrication System Diagnosis and Service
- A. Oil Passages, Galleries, and Lines
- B. Oil Consumption
  - 1. Oil Usage
  - 2. Sludge
- C. Flushing the System
- D. Oil Cooler

V. Cooling Systems
- A. Coolant
- B. Thermostat
- C. Water Pump
  - 1. Electric Water Pumps
- D. Radiator
  - 1. Transmission Cooler
- E. Radiator Pressure Cap
  - 1. Expansion Tank
- F. Hoses
  - 1. Water Outlet
  - 2. Water Jackets
- G. Hose Clamps
- H. Belt Drives
- I. Heater System
- J. Cooling Fans
  - 1. Electric Cooling Fans
- K. Hydraulic Cooling Fans
  - 1. Temperature Sensors
- L. Temperature Indicators
- M. Engine Block Heaters

VI. Cooling System Diagnosis
- A. Testing for Electrolysis in Cooling Systems
- B. Overheating
- C. Effects of Overheating
- D. Temperature Test
- E. Radiator Checks
- F. Checking and Replacing Hoses
- G. Belt Drives
- H. Checking Fans and Fan Clutches
  - 1. Electric Cooling Fans
- I. Testing the Thermostat
- J. Water Pump Checks
- K. Testing for Leaks
- L. Pressure Testing
  - 1. Leak Detection with Dye
  - 2. Combustion Leak Check
- M. Testing the Radiator Pressure Cap
- N. Water Outlet

VII. Cooling System Service
- A. Hoses

1. Hose Clamps

B. Thermostat

C. Repairing Radiators

1. Replacing the Water Pump

D. Draining the Coolant

E. Coolant Recovery and Recycle System

F. Flushing Cooling Systems

1. Flushing Chemicals

G. Refilling and Bleeding

H. Special Precautions for Hybrid Vehicles

I. Coolant Exchangers

Hint: Show examples of various hose and belt failures. Cut an upper radiator hose lengthwise so that students can see how hoses begin to deteriorate from the inside first. Show a hose with ECD. Demonstrate testing a thermostat for opening temperature and for sticking.

ADDITIONAL TEACHING HINTS

- Examine and discuss an oil pump pressure valve.
- Examine an oil pressure system, pointing out the location of sending units, oil lines, and gauges.
- Completely inspect several types of oil pumps according to manufacturer's recommendations.
- Examine the various types of radiator core constructions.
- Pressure test the cooling system for leaks.

WHAT ARE COMMON STUDENT MISCONCEPTIONS AND STUMBLING BLOCKS?

- Students may have a hard time understanding the importance of both the lubrication and cooling systems. Within reason both systems can survive a long time with no maintenance. Assemble a number of failed components from an engine that has had little or no maintenance to either the lubrication or cooling system.
- Using the information on page 422 of Chapter 14, have the students drain the cooling system and remove a number of cooling hoses to examine the degradation of the hoses on their inner liner. Discuss the causes of this electrochemical degradation.

SHOP ACTIVITIES AND CASE STUDIES

Here are some activities you can review in-class as a group, or ask students to complete individually or in pairs:

1. On a vehicle, locate and identify as many of the following parts of the lubrication system as you can: oil pump, oil pan, oil filter, oil cooler, oil pressure switch or sending unit, dipstick, oil filler cap, and PCV valve.

2. As more of today's higher performance vehicles are using dry sump oil systems, use a vehicle in your shop and locate the components used in a dry sump oil system. If a vehicle isn't available, use service information to list the components.

3. On a vehicle, locate and identify as many of the following parts of the cooling system as you can: water pump, radiator, heater core, lower radiator hose, upper radiator hose, heater hoses, radiator pressure cap, coolant expansion tank, and engine coolant temperature sensor or sending unit.
4. Using a hybrid vehicle, locate as many of the cooling system components as possible. Focus on the system components that would be particular to a hybrid: electric in-line water pump, special coolant reservoir, special air bleeder on inverter. **NOTE:** *Be cautious working around high-voltage components. Review the section in the text referring to working around hybrid vehicles.*

CASE STUDY
5. A technician is testing the cooling system on a 2012 Dodge Ram 1500. While testing for internal leakage, the gauge jumped suddenly and showed an excessively high pressure. What three faults could cause this to happen?

ANSWERS TO TEXTBOOK REVIEW QUESTIONS

1. The basic design, area, the radiator core thickness, coolant flow through the radiator and the temperature of the outside air flowing through it will all influence the radiator's efficiency.
2. The closed system type radiator cap is the one that is most commonly used.
3. To determine whether the water pump is creating good circulation, warm up the engine and run it at idle speed. Squeeze the upper radiator hose with one hand and accelerate the engine with the other. If a surge of coolant is felt at the hose, the pump is circulating coolant.
4. The oil pump is typically driven by the crankshaft or camshaft.
5. The pressure regulator valve.
6. a. The full flow oil filter bypass valve should open when the filter element becomes clogged.
7. b. Increased bearing clearances reduce resistance to oil flow and increase the volume of oil circulating through the engine.
8. c. One of the main purposes of the cooling systems thermostat is to bring the engine to operating temperature quickly. It also tries to control the engines minimum operating temperature.
9. b. The vacuum valve in the radiator cap allows coolant to return to the radiator from the overflow tank. This occurs when the coolant in the cooling system cools and contracts.
10. a. The temperature of the engine controls the cycling of the electric cooling fan. The coolant temperature sensor monitors coolant temperature and cycles the fan on and off.
11. c. The fan shroud concentrates the airflow through the radiator.
12. b.
13. d. The conventional pellet type thermostat is installed with the pellet positioned toward the engine. This allows the pellet to better sense internal engine coolant temperature.
14. b. Every 6.89 kPa (1 pound) of pressure on engine coolant raises the boiling point approximately 1.66°C (3°F).
15. **b**. Automotive water pumps are usually belt driven from the crankshaft.
16. d. The inner rotor to housing dimension is not measured, but the clearance between the outer rotor and housing is checked with feeler gauges.
17. d. Premature bearing and bushing failure in water pumps, generators, and power steering pumps results from excessive belt tension, not insufficient tension as stated.

18. c. A thermostat must be fully open when it is 11.1°C (20°F) above its opening temperature.

19. a. The recommended antifreeze/water mixture for freeze-up and corrosion protection in moderate climates is 50 percent antifreeze and 50 percent water. Stronger mixtures are recommended for colder climates.

20. c. A defective oil pressure regulator valve could cause abnormally high engine oil pressure. Higher viscosity oil could cause slightly higher oil pressure readings but the regulator valve should limit the maximum pressure.