AUTO FUNDAMENTALS

13th EDITION

Chris Johanson

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Preface

Auto Fundamentals provides students with a thorough understanding of the design, construction, and operation of automotive systems. It contains information on the latest developments in the field of automotive technology and introduces students to various career pathways available to them in the vast automotive industry. The automotive theory presented in this textbook is applicable to all automobiles and light trucks.

Auto Fundamentals was written to fill the need for a textbook that presents the how and why of vehicle construction and operation in a concise, easy-to-understand manner. The textbook is also meant to establish in students a foundational knowledge of the overall automotive industry and the different career opportunities it offers. To accomplish this, the textbook begins by providing insight into how to get an automotive-centered education or training in preparation for a career as a service technician or in another automotive-related occupation. Deciding on a career path in the automotive industry and the steps necessary to secure a position in your chosen path are discussed. The textbook progresses into automotive theory and technology and covers every major automotive system, starting with a discussion of basic system functions and progressing to more detailed explanations of the design and operation of individual system components. By following this model, the purpose of each system is fully explained and its relationship to the complete vehicle is made clear.

A build-it-yourself approach is used in a number of the automotive theory and technology areas. Students will "build" on paper many of the systems being described. This provides a thorough understanding of the basic principles that are necessary to learning automotive technology. Fundamental math, physics, chemistry, electricity, magnetism, and hydraulics are covered in the textbook where they apply.

Many of the illustrations used in *Auto Fundamentals* were created specifically for this textbook. Important details are featured in these illustrations, and many are exaggerated to place emphasis on the parts being discussed.

Like all Goodheart-Willcox products, the *Auto Fundamentals* instructional package is accurate and thorough, providing both instructors and students with the tools they need to succeed in the classroom.

Chris Johanson

About the Author

Chris Johanson has been involved in the automotive service business for more than 35 years, as a technician, instructor, and author. He has a bachelor's degree in Industrial Arts Education and has written several books on the subject of automotive technology. Mr. Johanson is an ASE-certified Master Technician and also has ASE certifications in Advanced Engine Performance, Light Vehicle Diesel Engines, Light-Duty Hybrid Electric Systems, Refrigerant Recovery and Recycling, Auto Maintenance and Light Repair, and Undercar Specialist Exhaust Systems.

Reviewers

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ZF Transmissions

New to This Edition

This edition of *Auto Fundamentals* contains numerous enhancements to help students succeed.

- Content has been updated throughout the book. Dated automotive concepts, systems, and materials have been removed, and information on the latest automotive technologies has been added. Specific content updates include information on the following:
  - Active engine mounts and magnetorheological fluid
  - Electric vehicles
  - Three-phase current in hybrid and electric vehicles
  - Lambda measures
  - Radiator shutters
  - SiOAT and Glysantin® antifreezes
  - Variable displacement vane oil pumps
  - PCV systems on supercharged and turbocharged engines
  - Advanced driver assistance system (ADAS)
  - Autonomous and semi-autonomous vehicles
  - Dual mass flywheels
  - Anti-lock brake systems
  - Magnetorheological shock absorbers
- "Workplace Skills" features have been added throughout the textbook to emphasize the soft skills needed to succeed in the automotive field.
- New images have been added to show the latest tools, equipment, and vehicles.

ASE Connections

Auto Fundamentals prepares you for further study in automotive technology, leading to a mastery of the standards established by the National Institute for Automotive Service Excellence (ASE). These standards were developed with input from industry experts to ensure they reflect the skills students and technicians must master to succeed in the automobile service and repair industry.

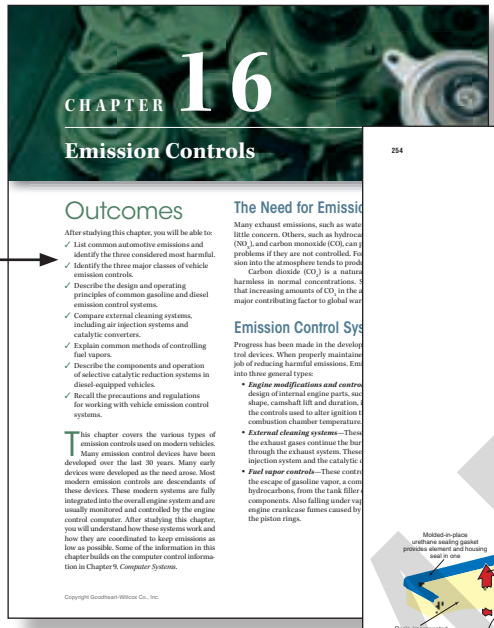
ASE certification is becoming the benchmark for automobile repair technicians. It is recommended that you seek ASE certification once you have sufficient knowledge and meet the work experience requirements. Visit the ASE website for more information on ASE certification.

The ASE Education Foundation has established a training program accreditation process designed to improve the quality of training offered at both secondary and post-secondary levels. This foundation grants accreditation to programs that comply with its evaluation procedure, meet established standards, and adhere to the policies set forth by the organization. To learn more about the accreditation process, visit the ASE Education Foundation website.

Guided Tour

The instructional design includes student-focused learning tools to help students succeed. This visual guide highlights the features designed for the textbook.

Outcomes clearly identify the knowledge and skills to be obtained when the chapter is completed.



CHAPTER 16

Emission Controls

Outcomes

After studying this chapter, you will be able to:

- ✓ List common automotive emissions and identify the three considered most harmful.
- ✓ Identify the three major classes of vehicle emission controls.
- ✓ Describe the design and operating principles of common gasoline and diesel emission control systems.
- ✓ Compare external cleaning systems, including air injection systems and catalytic converters.
- ✓ Explain common methods of controlling fuel vapors.
- ✓ Describe the components and operation of selective catalytic reduction systems in diesel-equipped vehicles.
- ✓ Recall the precautions and regulations for working with vehicle emission control systems.

This chapter covers the various types of emission controls used on modern vehicles. Many emission control devices have been developed over the last 30 years. Many early devices were developed as the need arose. Most modern emission controls are descendants of these devices. These modern systems are fully integrated into the overall engine system and are usually monitored and controlled by the engine control computer. After studying this chapter, you will understand how these systems work and how they are coordinated to keep emissions as low as possible. Some of the information in this chapter builds on the computer control information in Chapter 9, *Computer Systems*.

The Need for Emissi

Many exhaust emissions, such as wate little concern. Others, such as hydroca (NO_x), and carbon monoxide (CO), can p problems if they are not controlled. Fo sion into the atmosphere tends to prod

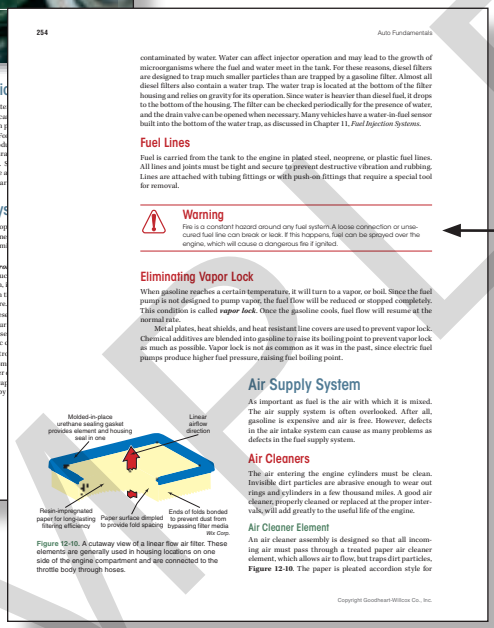
Carbon dioxide (CO_2) is a natura harmless in normal concentrations. S that increasing amounts of CO_2 in the a major contributing factor to global war

Emission Control Sys

Progress has been made in the develop trol devices. When properly maintaine job of reducing harmful emissions. Em into three general types:

- ***Engine modifications and contro*** design of internal engine parts, suc shape, camshaft lift and duration, t the controls used to alter ignition t combustion chamber temperatures
- ***External cleaning systems***—These the exhaust gases continue the bur through the exhaust system. These injection system and the catalytic c
- ***Fuel vapor controls***—These contro the escape of gasoline vapor, a com hydrocarbons, from the tank filler components. Also falling under vap engine crankcase fumes caused by the piston rings.

Warnings alert you to potentially dangerous materials and practices.



254 Auto Fundamentals

contaminated by water. Water can affect injector operation and may lead to the growth of microorganisms where the fuel and water meet in the tank. For these reasons, diesel filters are designed to trap much smaller particles than are trapped by a gasoline filter. Almost all diesel filters also contain a water trap. The water trap is located at the bottom of the filter housing and relies on gravity for its operation. Since water is heavier than diesel fuel, it drops to the bottom of the housing. The filter can be checked periodically for the presence of water, and the drain valve can be opened when necessary. Many vehicles have a water-in-fuel sensor built into the bottom of the water trap, as discussed in Chapter 11, *Fuel Injection Systems*.

Fuel Lines

Fuel is carried from the tank to the engine in plated steel, neoprene, or plastic fuel lines. All lines and joints must be tight and secure to prevent destructive vibration and rubbing. Lines are attached with tubing fittings or with push-on fittings that require a special tool for removal.

Warning
Fire is a constant hazard around any fuel system. A loose connection or unsecured fuel line can break or leak. If this happens, fuel can be sprayed over the engine, which will cause a dangerous fire if ignited.

Eliminating Vapor Lock

When gasoline reaches a certain temperature, it will turn to a vapor, or boil. Since the fuel pump is not designed to pump vapor, the fuel flow will be reduced or stopped completely. This condition is called ***vapor lock***. Once the gasoline cools, fuel flow will resume at the normal rate.

Metal plates, heat shields, and heat resistant line covers are used to prevent vapor lock. Chemical additives are blended into gasoline to raise its boiling point to prevent vapor lock as much as possible. Vapor lock is not as common as it was in the past, since electric fuel pumps produce higher fuel pressure, raising fuel boiling point.

Air Supply System

As important as fuel is the air with which it is mixed. The air supply system is often overlooked. After all, gasoline is expensive and air is free. However, defects in the air intake system can cause as many problems as defects in the fuel supply system.

Air Cleaners

The air entering the engine cylinders must be clean. Invisible dirt particles are abrasive enough to wear out rings and cylinders in a few thousand miles. A good air cleaner, properly cleaned or replaced at the proper intervals, will add greatly to the useful life of the engine.

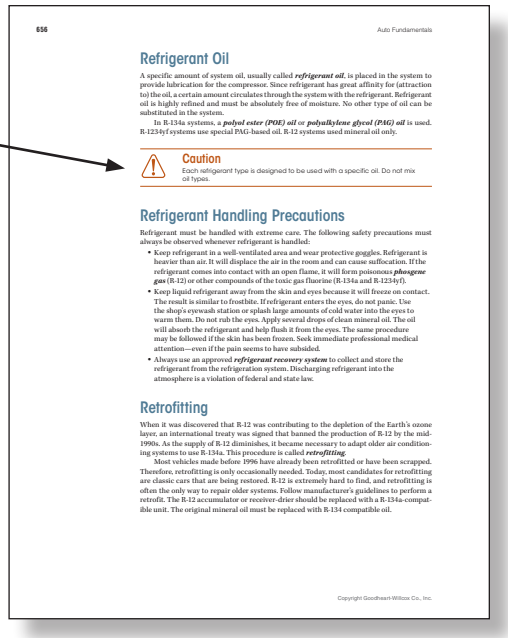
Air Cleaner Element

An air cleaner assembly is designed so that all incoming air must pass through a treated paper air cleaner element, which allows air to flow, but traps dirt particles, **Figure 12-10**. The paper is pleated accordion style for

Molded-in-place urethane sealing gasket provides element and housing seal in one
Linear airflow direction
Resin-impregnated paper for long-lasting filtering efficiency
Pulser surface dimpled to provide fold spacing
Ends of folds bonded to prevent dust from bypassing filter media
Wix Corp.

Figure 12-10. A cutaway view of a linear flow air filter. These elements are generally used in housing locations on one side of the engine compartment and are connected to the throttle body through hoses.

Cautions alert you to practices that could potentially damage equipment or instruments.



656 Auto Fundamentals

Refrigerant Oil

A specific amount of system oil, usually called ***refrigerant oil***, is placed in the system to provide lubrication for the compressor. Since refrigerant has great affinity for (attraction to) the oil, a certain amount circulates through the system with the refrigerant. Refrigerant oil is highly refined and must be absolutely free of moisture. No other type of oil can be substituted in the system.

In R-134a systems, a ***polyol ester (POE) oil*** or ***polyalkylene glycol (PAG) oil*** is used. R-1234yf systems use special PAG-based oil. R-12 systems used mineral oil only.

Caution
Each refrigerant type is designed to be used with a specific oil. Do not mix oil types.

Refrigerant Handling Precautions

Refrigerant must be handled with extreme care. The following safety precautions must always be observed whenever refrigerant is handled:

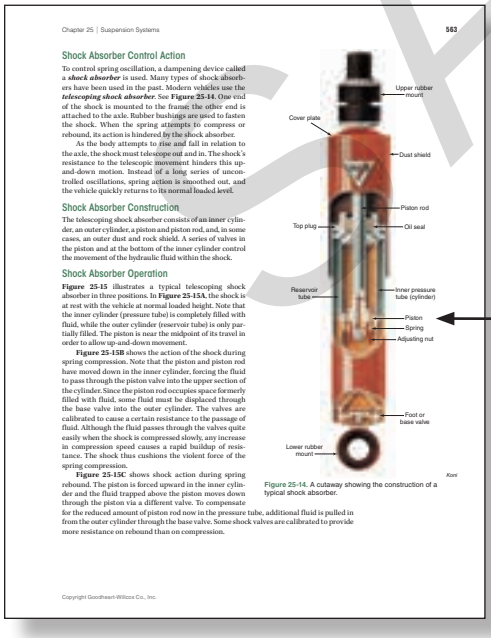
- Keep refrigerant in a well-ventilated area and wear protective goggles. Refrigerant is heavier than air. It will displace the air in the room and can cause suffocation. If the refrigerant comes into contact with an open flame, it will form poisonous ***phosgene gas*** (R-12) or other compounds of the toxic gas fluorine (R-134a and R-1234yf).
- Keep liquid refrigerant away from the skin and eyes because it will freeze on contact. The result is similar to frostbite. If refrigerant enters the eyes, do not panic. Use the shop's eyewash station or splash large amounts of cold water into the eyes to warm them. Do not rub the eyes. Apply several drops of clean mineral oil. The oil will absorb the refrigerant and help flush it from the eyes. The same procedure may be followed if the skin has been frozen. Seek immediate professional medical attention—even if the pain seems to have subsided.
- Always use an approved ***refrigerant recovery system*** to collect and store the refrigerant from the refrigeration system. Discharging refrigerant into the atmosphere is a violation of federal and state law.

Retrofitting

When it was discovered that R-12 was contributing to the depletion of the Earth's ozone layer, an international treaty was signed that banned the production of R-12 by the mid-1990s. As the supply of R-12 diminishes, it became necessary to adapt older air conditioning systems to use R-134a. This procedure is called ***retrofitting***.

Most vehicles made before 1996 have already been retrofitted or have been scrapped. Therefore, retrofitting is only occasionally needed. Today, most candidates for retrofitting are classic cars that are being restored. R-12 is extremely hard to find, and retrofitting is often the only way to repair older systems. Follow manufacturer's guidelines to perform a retrofit. The R-12 accumulator or receiver-drier should be replaced with a R-134a-compatible unit. The original mineral oil must be replaced with R-134 compatible oil.

Illustrations have been designed to clearly and simply communicate the specific topic.



Chapter 25 | Suspension Systems 563

Shock Absorber Control Action

To control spring oscillation, a dampening device called a ***shock absorber*** is used. Many types of shock absorbers have been used in the past. Modern vehicles use the ***telescoping shock absorber***. See **Figure 25-14**. One end of the shock is mounted to the frame; the other end is attached to the axle. Rubber bushings are used to fasten the shock. When the spring attempts to compress or rebound, its action is hindered by the shock absorber.

As the body attempts to rise and fall in relation to the axle, the shock must telescope out and in. The shock's resistance to the telescopic movement hinders this up-and-down motion. Instead of a long series of uncontrolled oscillations, spring action is smoothed out, and the vehicle quickly returns to its normal loaded level.

Shock Absorber Construction

The telescoping shock absorber consists of an inner cylinder, an outer cylinder, a piston and piston rod, and, in some cases, an outer dust and rock shield. A series of valves in the piston and at the bottom of the inner cylinder control the movement of the hydraulic fluid within the shock.

Shock Absorber Operation

Figure 25-15 illustrates a typical telescoping shock absorber in three positions. In **Figure 25-15A**, the shock is at rest with the vehicle at normal loaded height. Note that the inner cylinder (pressure tube) is completely filled with fluid, while the outer cylinder (reservoir tube) is only partially filled. The piston is near the midpoint of its travel in order to allow up-and-down movement.

Figure 25-15B shows the action of the shock during spring compression. Note that the piston and piston rod have moved down in the inner cylinder, forcing the fluid to pass through the piston valve into the upper section of the cylinder. Since the piston rod occupies space formerly filled with fluid, some fluid must be displaced through the base valve into the outer cylinder. The valves are calibrated to cause a certain resistance to the passage of fluid. Although the fluid passes through the valves quite easily when the shock is compressed slowly, any increase in compression speed causes a rapid buildup of resistance. The shock thus cushions the violent force of the spring compression.

Figure 25-15C shows shock action during spring rebound. The piston is forced upward in the inner cylinder and the fluid trapped above the piston moves down through the piston via a different valve. To compensate for the reduced amount of piston rod now in the pressure tube, additional fluid is pulled in from the outer cylinder through the base valve. Some shock valves are calibrated to provide more resistance on rebound than on compression.

Upper rubber mount
Cover plate
Dust shield
Piston rod
Top plug
Oil seal
Reservoir tube
Inner pressure tube (cylinder)
Piston
Spring
Adjusting nut
Foot or base valve
Lower rubber mount
Koni

Figure 25-14. A cutaway showing the construction of a typical shock absorber.

Notes features provide supplemental technical information related to the automotive system being explained.

Workplace Skills help you understand what you can anticipate and expect in the workplace.

Summary feature provides an additional review tool for you and reinforces key learning objectives.

Critical Thinking Questions develop higher-order thinking and problem-solving, personal, and workplace skills.

Technical Terms list the key terms to be learned in the chapter.

Review Questions allow you to demonstrate knowledge, identification, and comprehension of chapter material.

TOOLS FOR STUDENT AND INSTRUCTOR SUCCESS

Student Tools

Student Text

Auto Fundamentals leads students through the design, construction, and operation of all major automotive systems. Each system is explained in detail, starting with its basic function and progressing to the construction and operation of its individual components.

Workbook

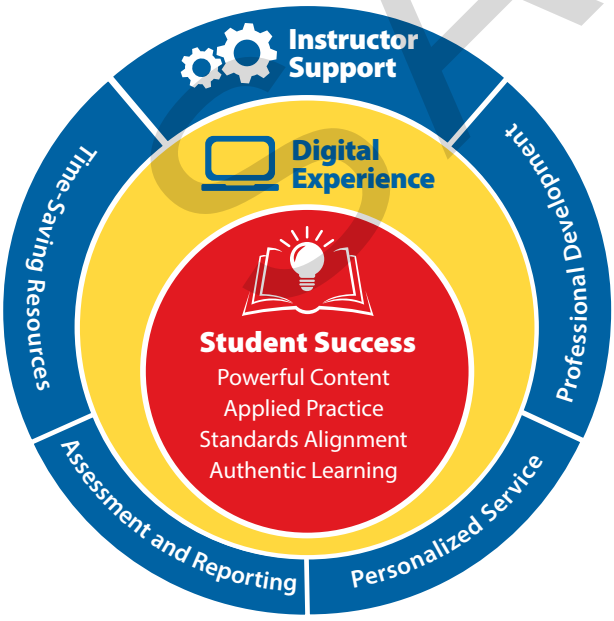
- Provides questions that reinforce and review textbook content.
- Organized to follow the textbook chapters to help students achieve key learning outcomes.

G-W Digital Companion

- E-flash cards and vocabulary exercises allow interaction with content to create opportunities to increase achievement.

Online Learning Suite

- Online student text and lab workbook, along with rich supplemental content, brings digital learning to the classroom.
- All instructional materials are accessible at home, at school, or on the go.
- Videos provide overviews of basic service and repair procedures to complement the theory presented in the textbook.



Instructor Tools

LMS Integration

Integrate Goodheart-Willcox content within your Learning Management System for a seamless user experience for both you and your students. LMS–ready content in Common Cartridge® format facilitates single sign-on integration and gives you control of student enrollment and data. With a Common Cartridge integration, you can access the LMS features and tools you are accustomed to using and G-W course resources in one convenient location—your LMS.

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Online Instructor Resources

- The **Instructor Resources** provide instructors with time-saving preparation tools such as answer keys, editable lesson plans, and other teaching aids.
- **Instructor's Presentations for PowerPoint®** are fully customizable, richly illustrated slides that help you teach and visually reinforce the key concepts from each chapter.
- Administer and manage assessments to meet your classroom needs using **Assessment Software with Question Banks**, which include hundreds of matching, completion, multiple choice, and short answer questions to assess student knowledge of the content in each chapter.

See **www.g-w.com/auto-fundamentals-2024** for a list of all available resources.

Professional Development

- Expert content specialists
- Research-based pedagogy and instructional practices
- Options for virtual and in-person Professional Development

Brief Contents

Contents