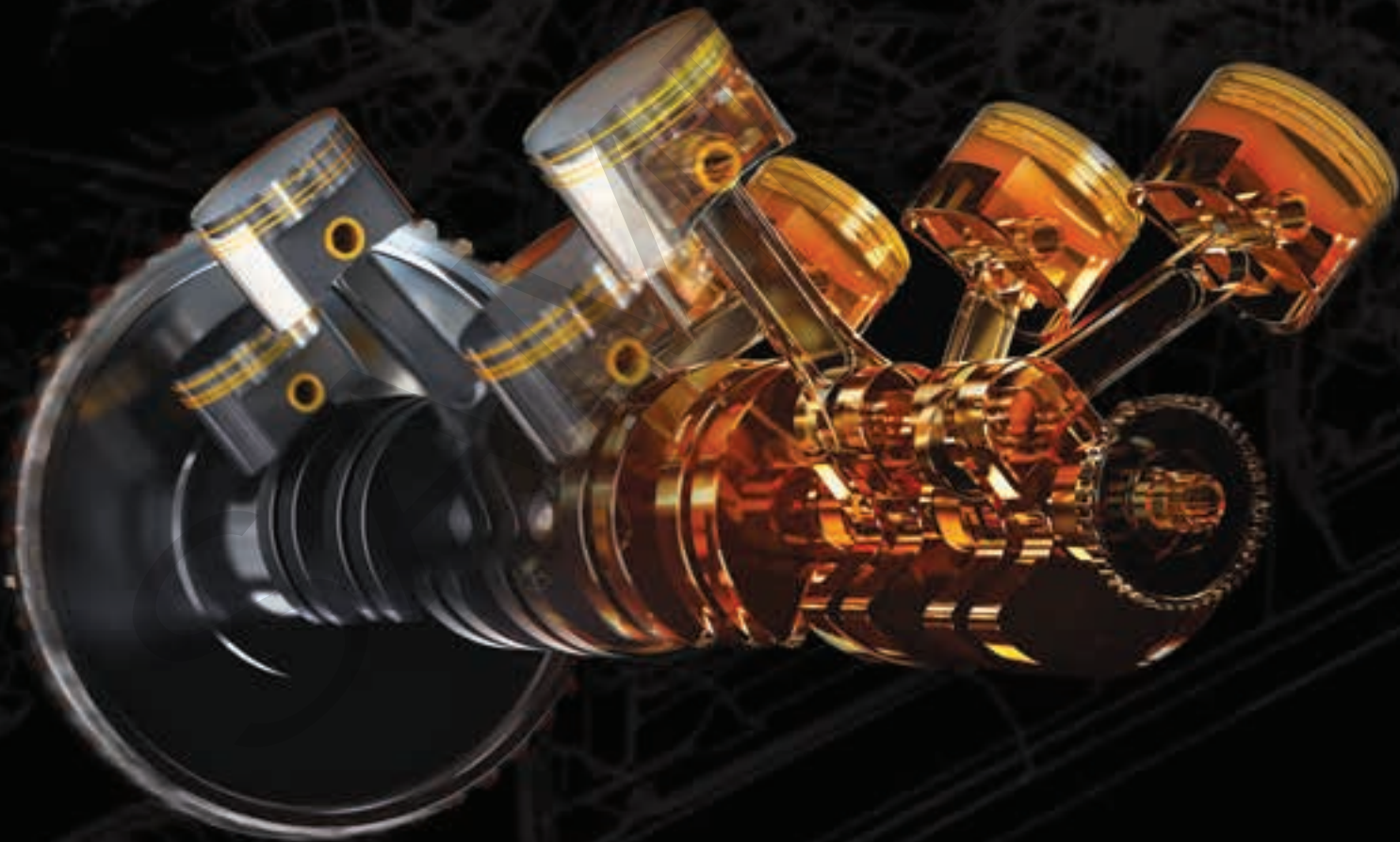


AUTO

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

The author and publisher wish to thank the following industry and teaching professionals for their valuable input into the development of *Auto Fundamentals*.

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Detroit Diesel Corp.	Moog	Wix Corp.
Dodge	Motorcraft	ZF Transmissions
EIS	Nissan	

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.



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Education Foundation

SAMPLE

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.



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.

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The Need for Emission Controls

Many exhaust emissions, such as water vapor, carbon monoxide (CO), and carbon dioxide (CO₂), can be considered harmless if they are not controlled. Pollution into the atmosphere tends to produce global warming. Carbon dioxide (CO₂) is a natural greenhouse gas. In normal concentrations, it is harmless to humans. However, increasing concentrations of CO₂ in the atmosphere are contributing to global warming.

Emission Control Systems

Progress has been made in the development of emission control systems. When properly maintained, modern vehicles can reduce harmful emissions. Emission control systems are divided into three general types:

- **Engine modifications and controls.** These include timing, valve timing, and camshaft lift and duration. The controls used to alter ignition timing include the distributor and the ignition control module.
- **External cleaning systems.** These include the air filter, air cleaner, and catalytic converter. These systems clean the air entering the engine and the exhaust gases leaving the engine.
- **Fuel vapor controls.** These include the evaporative emission control system (EVAP) and the purge control valve. These systems prevent fuel vapors from escaping the fuel tank and the carburetor.

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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 of with push-on fittings that require a special tool for removal.

Warning

Fuel is a constant hazard around any fuel system. A loose connection or unsecured fuel line can break or leak. If the propane fuel can be sprayed over the engine, which will cause an 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. Check the gasoline coils, fuel flow will resume at the normal rate.

Metal plates, heat shields, and heat-resistant hose 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. Inevitable 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 interval, 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

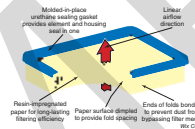
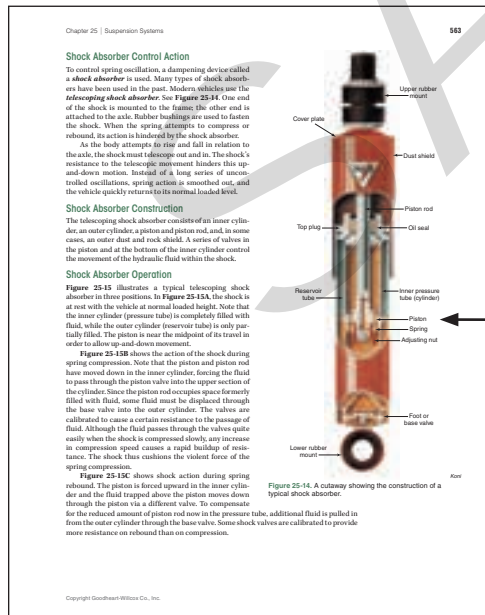


Figure 12-10. A cutaway view of a linear flow air filter. These elements are generally used in housing locations on one side of the engine compartment and are connected to the throttle body through hoses.

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



Chapter 25 | Suspension Systems

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Shock Absorber Control Action

To control spring oscillations, 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 attach 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 state.

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 absorbers are calibrated to provide more resistance on rebound than on compression.

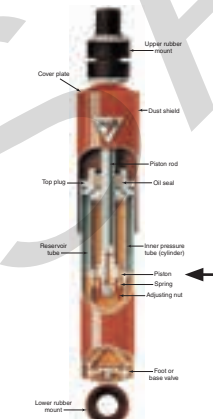


Figure 25-14. A cutaway showing the construction of a typical shock absorber.

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

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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 **polyester (POE) oil** or **polyalkylene glycol (PAG) oil** is used. R-12/R136 systems use special PVE base oil. R-12 systems used mineral oil only.

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-123)).
- 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 safety 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-134a compatible oil.

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Note
In solid axle vehicles, a differential housing is combined with housings that enclose the axle shafts. The resulting assembly is commonly called an axle housing. On vehicles with independent axles, the housing does not enclose the axle shafts, so it is often referred to as simply a differential housing rather than an axle housing.

Solid Axles
On solid rear axle vehicles, two steel axles are located inside the axle housing. Their inner ends almost touch. The outer ends protrude out of the housing and form the hubs to which the wheels and hubs are attached. The inner ends are splined by the differential assembly. The outer ends are supported in a straight roller, or ball bearings. The axles are held in the housing by retainers on the outside of the axle, under the brake components, or by C-clocks in the assembly. **Figure 22-26.**

Attaching Wheel Hubs
The wheel hub is welded to the axle. The axle end is formed into a flange which is bolted. The wheel hubs are pressed into drilled holes in the hub have a hole to reach the backing plate nuts. **Figure 22-27.**

Full-Floating and Semi-Floating Axles
The two basic types of solid axles include the **full-floating axle** and the **semi-floating axle**. The full-floating axle transmits engine power, but does not carry any of it. All weight is supported through the outer bearing assembly.

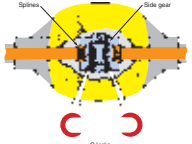
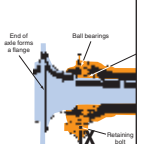



Figure 22-26. Axle shafts are cranks in some differentials. The C-locks are retained in position by a groove cut in the side gear. The C-locks cannot be removed until it is free of the side gear groove.

Figure 22-27. This flanged axle end is used and hubs. The wheel is bolted directly to the side gear.

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

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Other systems also provide programmed ride control. The degree of stiffness and handling can be programmed into the system by the driver. Modern systems are usually computer controlled, with a control pad or switch in the passenger compartment.

Roll Control During Turns
To reduce body leaning, or roll, in turns, some computerized ride control systems vary the shock absorber stiffness. When the driver steers the vehicle into a sharp turn, a steering sensor sends an appropriate signal to the control module. The module signals the actuators to increase shock pressure on the outside of the turn. This reduces vehicle roll during the turn.

Another roll control device is attached to the front stabilizer bar. **Figure 25-47.** It consists of a hydraulically operated rotary actuator that divides the stabilizer bar into left and right side sections. The actuator contains an internal pump that supplies pressure. When the driver makes a sharp turn, the ECM directs the actuator to push the stabilizer bar section on the outside of the turn upward. This upward push keeps the outside suspension from drooping. The force of pushing the outside stabilizer up pushes the inside stabilizer down. This keeps the inside suspension from rising, protecting against a rollover. This system can be used on both front and rear suspension systems.

Workplace Skills
In most jobs, teamwork is essential. When a car pulls into the pits, the pit crew must work as a team to get the car back on the track in the shortest possible time. Each team member has a specific job to do and relies on his or her teammates to do their jobs to the highest possible performance level. The best driver in the world could not win a race without an effective and efficient pit crew.

Working as part of a team will increase your job satisfaction and productivity. You will also learn how to negotiate and build trust in others. You will spend a large portion of your life working. Why not enjoy it? Consider the following questions:

1. What are the three most important things needed for effective teamwork in the workplace?
2. How do you show teamwork at work? How do you show it in school?
3. What are the qualities of good teamwork?

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

Critical Thinking Questions

1. What are the features and the advantages and disadvantages of body-over-frame and unibody vehicle construction? What processes and materials are used in the manufacturing of each? Does either design have a stronger safety rating based on accident tests?

2. Choose a sports car, a compact to full-size car, and a large pickup truck or sport-utility vehicle. Determine the type of suspension system used on each vehicle. What are the reasons for the vehicle manufacturer's choice of suspension system on each vehicle? What are the benefits and disadvantages of each suspension system design based on how each vehicle is likely to be driven?

19. An active suspension system can be controlled manually by the driver through a control pad or switch or automatically through _____.
A. a computer control module
B. the tire pressure monitoring system
C. MacPherson strut assembly
D. MagnetoRide® shock absorbers

20. To control vehicle body roll during cornering, a computerized ride control system may use a _____ with hydraulically operated rotary actuators.
A. coil spring
B. stabilizer bar
C. strut rod
D. steering knuckle




Figure 25-47. This stabilizer bar is divided into two sections by the central actuator. The actuator operates to vary pressure on the stabilizer bar sections when the vehicle enters a turn.

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

Summary

- Vehicle bodies must be suspended on some type of spring device to isolate them from the irregularities of the road.
- Spring weight refers to the weight of all vehicle parts that are supported by the suspension system. Unsprung weight refers to all parts of the vehicle that are not supported by the suspension system.
- A vehicle body or frame must be rigid and strong to provide secure anchorage for the suspension system and to provide alignment and the securing of all parts.
- A vehicle built with body-over-frame construction has a separate steel frame constructed of channel or square tubing and welded together.
- A vehicle built with unibody construction has the metal body and frame manufactured together as a singular structural unit.
- There are four types of springs used to suspend a vehicle: leaf springs, coil springs, torsion bars, and air springs.
- Shock absorbers are used to control spring oscillation on vehicle suspension systems. Hydraulic telescoping shock absorbers are common in many vehicles.
- A vehicle suspension system depends on springs and shock absorbers, as well as control arms, struts, ball joints, and steering knuckles, and other parts to control suspension operation.
- All modern vehicles use ball joints to provide for movement between the spindle and the control arm on each wheel.
- Stabilizer bars help prevent vehicle body tipping or rolling during cornering.
- On the front axle, most vehicles have independent wheel suspensions that use either the conventional front suspension or MacPherson strut front suspension designs.
- Most late-model front-wheel-drive vehicles use the MacPherson strut suspension design on the front axle. Many rear axle suspensions also make use of MacPherson strut assemblies.
- A MacPherson strut assembly contains a coil spring, damper, and shock absorber unit and is a structural part of the vehicle's suspension system. The entire strut assembly turns during cornering.
- Rear axle suspensions can be independent or solid axles.
- Common springs used in a vehicle's rear axle suspension are the coil spring, leaf spring, or torsion bar. Various combinations of control arms or stabilizer bars are used, depending on the type of drive.
- Most new vehicles have no provision for suspension part lubrication. If an original equipment suspension part becomes loose or worn, it is replaced.
- An automatic level control suspension system maintains a nearly constant rear curb height (distance from the frame to the ground)—regardless of load changes over the rear axle—by increasing or decreasing air or hydraulic pressure in the shock absorbers.
- A basic level control system typically includes an air compressor, air tank, pressure regulator, taking control valve, special shock absorbers, connecting wire, taking hose, and an air dryer.
- A height control sensor in an automatic level control system senses a distance change between the vehicle's frame and suspension through an overtravel lever attached to the rear axle housing. As the distance changes, air or fluid is admitted or exhausted from the shock absorbers to maintain the set curb height.

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Technical Terms

active suspension	computerized ride control system	MacPherson strut front suspension	stabilizer bar
air shock absorbers	control arms	plugs	strut rod
air springs	conventional front suspension	preloaded	struts
automatic level control system	damper	semi-elliptical leaf spring	suspension system
ball joints	follower ball joint	shock absorber	telescoping shock absorber
body-over-frame construction	grasping fitting	spring	tension loading
coil springs	height control sensor	spring oscillation	torsion bar
compression loading	leaf springs	spring shackles	unibody construction
	load-carrying ball joint	spring weight	unsprung weight

Review Questions

Answer the following questions using the information provided in this chapter.

1. All of the following vehicle parts are categorized as unsprung weight, except _____.
A. wheel bearings and hubs
B. wheels
C. engine
D. tires
2. In _____ vehicle construction, the body sections of the vehicle serve as structural support members.
A. prototype
B. unibody
C. body-over-frame
D. abbreviated
3. What type of automotive spring has its ends curled back around on themselves to form "spring eyes"?
A. Leaf spring
B. Coil spring
C. Torsion bar
D. Air spring
4. True or False? The hinge shackle used with a leaf spring allows the spring to change length as it moves up and down.

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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

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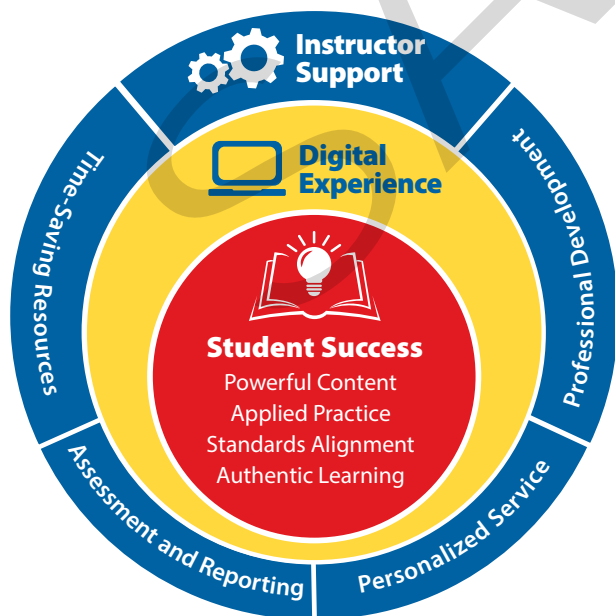
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See www.g-w.com/auto-fundamentals-2024 for a list of all available resources.

Professional Development

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





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