

Tim Gilles

# AUTOMOTIVE SERVICE

INSPECTION  
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# AUTOMOTIVE SERVICE

INSPECTION,  
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SIXTH EDITION



**Tim Gilles**

Professor Emeritus  
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**Tim Gilles**  
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**NOTE TO STUDENT:** *Learn to use the index. It has been constantly updated and will help you find what you need in the book.*

# Preface

*Automotive Service: Inspection, Maintenance, Repair, 6th edition* evolved in part from my participation in a successful articulation program between local high schools and the community college where I was a teacher for 38 years. The text and art manuscripts of this best-selling book have once again been updated and improved in this sixth edition revision. This is not a training manual. It is a textbook. Its primary purpose is to help you to think critically and learn to make decisions.

An array of excellent technical reviews by a dedicated group of professional teachers and technicians ensures that this is the most technically accurate and up-to-date comprehensive automotive textbook available in the marketplace. The text has been written from a carefully detailed outline to allow each chapter to follow a logical, easy-to-understand path. Many new original color photographs and sketches have been added to update and supplement earlier material.

The transportation industry in North America is vast, with one in every six people contributing to it in some way. These include people of many levels of understanding and ability. With that in mind, the introductory fundamentals chapters are written at a lower level for all the students, whereas the service chapters are for those who have mastered the introductory material.

As a teacher, my philosophy is to challenge the best students in anticipation that the rest will be brought to a higher level: “A rising tide raises all boats.” In writing this textbook, my target was to provide everything within one cover that would provide a student with all of the knowledge needed to make a job-entry level apprentice. The text can be used for a variety of educational purposes, including:

- As an accompanying text to any automotive repair class
- To educate entry-level or apprentice technicians
- To prepare more experienced technicians for ASE certification

*Automotive Service: Inspection, Maintenance, Repair, 6th edition* is divided into 82 chapters that cover both the ASE Education Foundation Automotive Maintenance and Light Repair (MLR) Program tasks and A1–A9 (the nine ASE automotive specialty areas). Advanced engine performance and emission controls are also covered in detail. In addition to coverage of the usual repairs performed in almost any automotive repair facility, the reader is introduced to the most frequently performed inspection and service procedures—from safety inspections to tire and wheel service. Hybrid and electric vehicles are also covered in detail.

The automotive repair industry of today continues to evolve into more of a maintenance industry as vehicles last longer and require fewer repairs. Long-term customer relationships, ethics, and professionalism have become even more important to the success of a business. There are also environmental concerns today that were not a part of the industry of the past. The text includes chapters on safety, hand tools, and vehicle maintenance and lubrication that are more comprehensive than those found in most comparable texts. An accompanying lab manual emphasizes the ASE Education Foundation Automotive Maintenance and Light Repair (MLR) Program tasks, those jobs done in service stations, fast-lube outlets, and mass merchandisers (such as Sears, Goodyear, Firestone, or Walmart).

Automobiles have become so complex in the last 30 years that to remain competent, many of today’s technicians specialize in one or more systems of the car. Basic theory of all automotive and light truck systems is covered so that service personnel will understand the function of the parts being serviced. When working in the industry, there is often no time for basic theory. Therefore, automotive class work could be the one and only chance students have to learn how systems operate so they can become better diagnosticians in the future.

This book is comprehensive in that it deals with the entire car and aims to teach theory of vehicle systems at an introductory student level, followed by service, diagnosis, and repairs at a more advanced student level. The book focuses on the basic skills and understanding required to fix a vehicle. Students will learn the principles that govern the different systems, rather than technical details of a particular vehicle. The latter details will be learned from technical service information or in manufacturer or after-market training programs.

Most of the systems used in automobiles today are strikingly similar. Repair techniques universal to all automobiles are discussed, and procedures or conditions unique to one specific manufacturer of automobiles are purposely avoided. The reader is encouraged to refer to service and repair information for the specific vehicle in question.

A major challenge for me as an automotive author is to keep the scope of the book from growing out of control by expanding into areas of in-service training best covered by manufacturers and aftermarket educators. My objective is to take an abundance of sometimes complicated information and to condense and simplify that information so it can be understood by a student preparing for the *job-entry level*. Following the completion of this text, better students will be at a high job-entry level, at a skill level suitable for entry as an apprentice in one or more of the specialty areas

of automotive repair in a new car dealership or an independent repair facility.

A primary objective of this book is to help the reader develop confidence in both thinking skills and problem-solving ability. One unique aspect of automotive education is that many automotive graduates venture into other professions and skilled trades, such as engineering or construction. They will find much of the material learned in automotive classes to be very valuable and useful in their chosen fields. This aspect of the student's education is especially valuable when one considers how middle school and high school industrial arts programs have been scaled back in recent years. Dealing with such things as tools, soldering, basic electrical repairs, and repairing broken fasteners helps to provide some measure of practical education.

The tremendous decline in the number of corner gasoline service stations has resulted in a loss of those jobs formerly available in abundance to students. Successful service personnel who possess necessary basic automotive skills must continually learn new things in order to progress into other (higher-paying) specialty areas. The *Lab Manual for Automotive Service* lists service jobs that students should be able to perform before enrolling in an advanced automotive specialty area class.

**Note to Teachers**—Log on to [timgilles.com](http://timgilles.com) and [www.cengage.com/sso](http://www.cengage.com/sso) to access photos and ancillary materials to use in preparation for your classes.

## UPDATES AND ENHANCEMENTS TO THE SIXTH EDITION

Producing a new edition of a successful book is a lot of work! It is rewarding for the author to be able to update and improve on an earlier project. The world of Automotive Technology is in a state of constant flux. This book has been developed with the student in mind, by an author with many years of teaching experience. It would not be the most accurate and up-to-date book on the market without the many competent reviewers who have provided so much valuable input over the years and in this new edition. New information and updates to *Automotive Service: Inspection, Maintenance, Repair, 6th edition* follow closely on the heels of the substantial updates and new chapters in the previous edition.

Up-to-date and technically accurate coverage throughout ensures that you have access to the latest “need to know” automotive information.

The following are examples of some of the new and updated information to *Automotive Service, 6th edition*.

- New material has been added for self-parking vehicles, autonomous (self-driving) vehicles, future trends, telematics, and advanced body electronics.
- The ABS chapter has been entirely updated and revamped, including active wheel speed sensors and the latest technologies in adaptive braking including active brake assist, rain-drying brakes, knock back mitigation, electronic brake force distribution, and electronic stability control. Updates to ABS service include testing digital wheel speed sensors with a graphing meter or scan tool.
- The latest tire pressure monitoring information has been incorporated into the tire chapters.
- The cooling system chapters have been revised and updated to include the most recent coolant recommendations and service information. Ed Eaton has been an important contributor to this revision. Mr. Eaton is an engineer who is a member of the ASTM International Committee D15 on engine coolants. He is an expert in engine coolants, and his input was invaluable in updating the cooling system chapters.
- R1234yf refrigerants are now supplied in most new vehicles. The air conditioning chapters have been revised and updated to include this and new refrigerant laws and technology.
- Other chapters in the book have been revised and updated to remain current.
- Up-to-date ASE Education Foundation coverage includes the latest information on ASE Education Foundation Automotive Maintenance and Light Repair, as well as the eight ASE Master Technician areas.
- The updated Instructor Resources, now available online and on DVD, are designed to improve the organization and quality of time spent in the classroom and shop. An updated Lab Manual and all-new MindTap for Automotive Services are also available (see the Supplements page for more detail).
- All automotive terms, abbreviations, and acronyms used in this text comply with the SAE Technical Standards Board Publication *SAE J1930*.

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- Alan Nagel worked for many years at GM Canada and SAIT. He is one of many friends I have made at NACAT conferences. Alan is extremely knowledgeable about hybrid and electric vehicles. He has helped with reviews on several editions of this textbook. Alan is now with Sun Country Highway, Canada, continuing to stay at the top of his field.
- Sean Bennett is a colleague and fellow Cengage author. He is always helpful with valuable input on diesels and diesel fuels.
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- Bob Stockero has been a wonderful reviewer during several editions of this book, and this edition has been no exception. Bob offered very concise and helpful edits to the chassis and antilock brake chapters. He is a true subject matter expert, and his input is invaluable.

## REVIEWERS' CONTRIBUTIONS ARE IMPORTANT!

Reviewers are such an important asset when writing a book of 82 chapters and more than 1600 pages. I try my best to keep up with industry trends and new technology. However, I cannot do this on my own. Cengage has always been very generous in providing resources to hire reviewers. Reviewers put a great deal of effort into improving my projects. It is very rewarding to me to have fellow teachers and industry experts who care so much about improving our industry and teaching practices. I learn much from them, and I would like to thank each of them for caring.

During my 38-year career as an automotive teacher, I always felt that all of my students (clients) should have a chance to provide anonymous feedback about their experiences in my class. This gave me opportunities to make adjustments and fine-tune my course offerings. As a writer, I've found the same thing to be true. I have always asked my publisher to provide more than the normal

amount of reviewer feedback. I need to know about any problems so I can correct them, but more importantly, I need to know what teachers (clients) think.

If you would like to provide feedback on my book, or if you would like to be a future reviewer, please send me an e-mail at [Timgilles@timgilles.com](mailto:Timgilles@timgilles.com).

The following reviewers are gratefully acknowledged for their invaluable input during the development of this sixth edition revision. In addition, the author and publisher would like to thank the reviewers who offered feedback for previous editions:

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## DEDICATION

The completion of this book was made possible with help from a great many individuals. *Automotive Service: Inspection, Maintenance, Repair, 6th edition* is dedicated to them and to my wife, Joy. Her organizational skills and able assistance have been invaluable. Writing a comprehensive textbook with many thousands of photos and sketches is a daunting task. I would not be able to concentrate as much of my time on the important upgrading and editorial work if I did not have Joy organizing the art package and submitting final manuscript changes to the publisher. She retired from her full-time job to help with this project and has been especially helpful.

## ABOUT THE AUTHOR

Tim Gilles has authored and coauthored several textbooks, including *Automotive Engines, 8th edition* and *Automotive Chassis: Brakes, Suspension, and Steering*. He is professor emeritus in the Automotive Technology Department at Santa Barbara City College from which he recently retired after teaching automotive for 38 years. Tim earned a Bachelor of Arts degree in Industrial Arts from Long Beach State University and a Master of Arts degree in Occupational Education from Chicago State University. He has held the industry certifications of ASE Master Automotive Technician and ASE Master Engine Machinist.

Tim has been active in professional associations for many years, as president and board member of the California Automotive Teachers (CAT) and as a board member and election committee chair of the North American Council of Automotive Teachers (NACAT). He has been a frequent seminar presenter at association conferences. Tim was a longtime member of the California Community College Chancellor's Trade and Industry Advisory Committee. He is active in industry associations, including AERA, ARC, ASCCA, and IATN, and served several terms as education representative on the board of the Santa Barbara Chapter of the Independent Automotive Professionals Association (IAPA).



## CASE HISTORIES

Case histories are presented throughout the text. These true stories recount actual automotive situations encountered by the author in over 40 years in automotive service. Case histories present the reader with examples of the pattern of critical thinking skills required to diagnose automotive problems.

## SCIENCE, HISTORY, COMPUTER, AND MATH NOTES

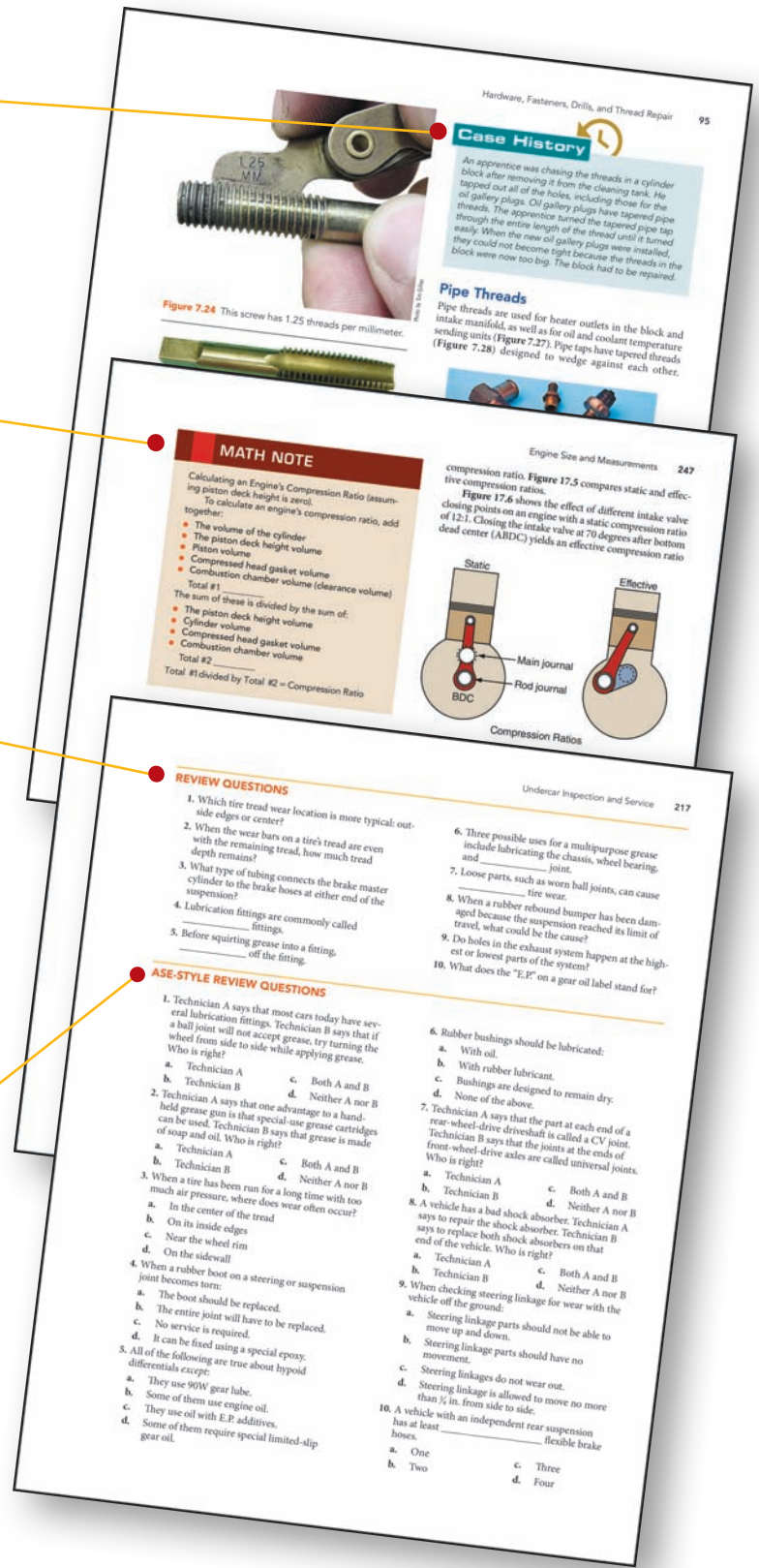
These notes are included when interesting topics relating to them are covered in the text. The objective of these features is to pique the student's interest and show a correlation between his or her automotive studies and these areas of learning.

## REVIEW QUESTIONS

These questions guide the student to the most important points in the chapter and act as a check for understanding of the material. Each chapter's review questions are presented in the same order in which the information appears in the chapter. This provides an instructor with the flexibility to assign portions of the chapter to read and then follow up with a few of the study questions.

## ASE-STYLE REVIEW QUESTIONS

These questions are designed to provide preparation for the certification examinations administered by the *National Institute for Automotive Service Excellence (ASE)*. The ASE test is a task-oriented test (the test taker is supposed to be able to relate to shop-oriented questions), so the practice tests should help the student to become familiar with accepted trade procedures.





## SUPPLEMENTS

### MindTap for Automotive Service: Inspection, Maintenance, Repair, 6th edition

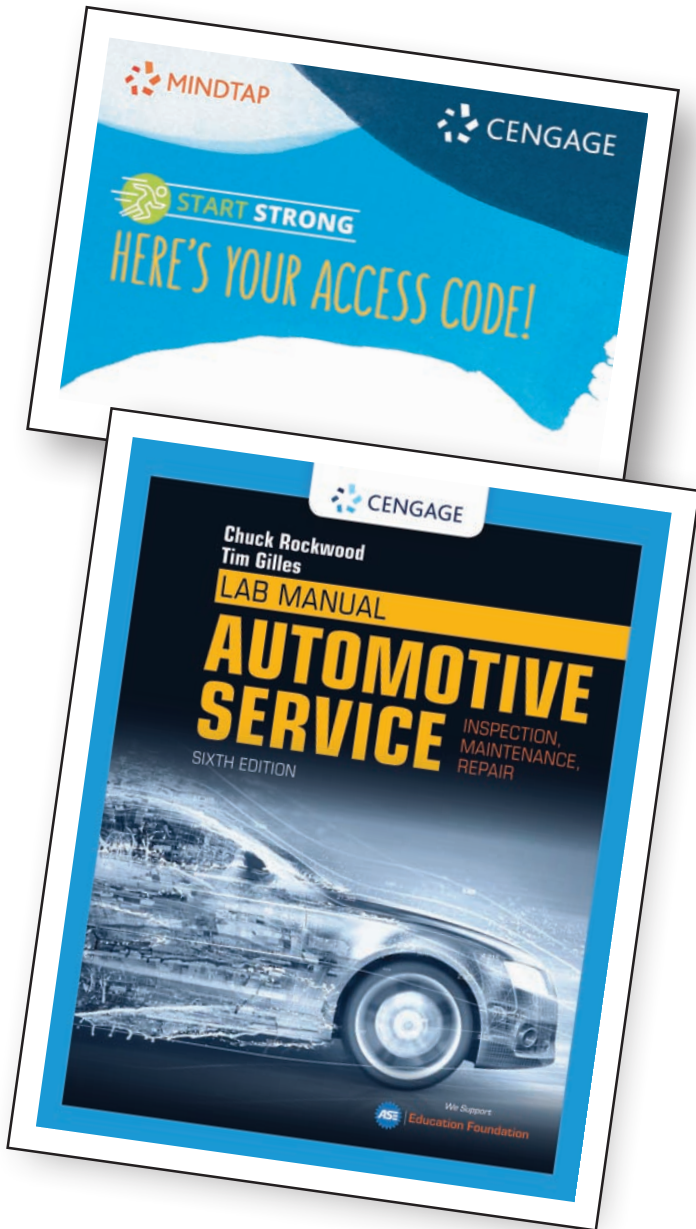
MindTap for *Automotive Service* provides a customized learning experience with relevant assignments that will help students learn and apply concepts while it allows instructors to measure skills and outcomes with ease.

MindTap for *Automotive Service* meets the needs of today's automotive classroom, shop, and student. Within the MindTap, faculty and students will find Cengage's full suite of Theory Simulations, SP/2 Safety Training and Soft Skills modules, and online ASE Lab Preparation Worksheets updated to 2017 ASE Education Foundation task lists. MindTap also offers students the opportunity to practice diagnostic techniques in a safe environment while strengthening their critical thinking and troubleshooting skills with the inclusion of diagnostic scenarios from Delmar Automotive Training Online (DATO). Additional engaging activities include videos, animations, matching exercises, and gradable assessments.

- **Instructor Resources**—The sixth edition offers Instructor Resources online and on DVD. This robust collection of instructor resources includes an Instructor's Guide in Microsoft Word, Cengage Testing powered by Cognero (with hundreds of modifiable questions: true/false, fill-in-the-blank, and ASE-style multiple choice), chapter presentations in PowerPoint with full-color images, video clips and animations, an Image Gallery with hundreds of full-color photos and line art from the core text, and Correlation Grids to the ASE Education Foundation Automobile Program tasks.
- **Automotive Service Lab Manual**—The *Lab Manual for Automotive Service, Inspection, Maintenance, Repair, Sixth Edition*, is designed to help students

build automotive skills. It contains two parts: Part I is made up of Activity Sheets to reinforce the theory learned in the core text. Activity Sheet exercises include parts identification, matching exercises, and fill-in sheets designed to help reinforce students' understanding of the operation of the automobile and its systems.

Part II of the Lab Manual includes Worksheets that define each lab procedure, presented in increasing levels of difficulty. Each project or lab assignment is built upon the next in a logical sequence in much the same manner as science instructional programs are constructed, and the reader completes one task before progressing to the next one. In addition, a variety of illustrations support the Worksheets and help visual learners better understand the jobs. The Worksheets are keyed to the ASE Education Foundation Automotive Maintenance and Light Repair (MLR) Program tasks where applicable.





# THE AUTOMOBILE INDUSTRY

## Then and Now: The Automobile Industry

On January 29, 1886, Karl Benz of Mannheim, Germany, patented the world's first automobile, the three-wheeled *Benz Motorwagen*. Later that same year, Gottlieb Daimler of Cannstatt, Germany, built a four-wheeled car. Its 1.5 HP engine had 50 percent more power than the Benz; the horsepower race had begun. In 1900, Benz's company became the biggest auto maker in the world, building 603 cars.

Long before Benz's patent, there were ingenious automotive inventors and tinkerers in the United States. But the 1896 *Duryea* of Massachusetts was the first car to be produced for sale in the United States, followed shortly by the *Haynes and Winton*. In 1900, Ransom E. Olds of Detroit became the first to mass-produce automobiles in America, the curved-dash "merry Oldsmobile" of the song "Come Away with Me, Lucille."

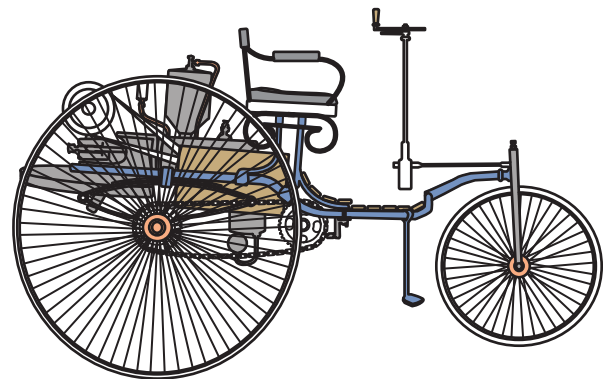
Henry Ford was the first to produce the automobile in mass quantities. His grand idea was to build a car that everyone could afford. In 1903, the current Ford Motor Company was founded. The first Model T was sold in 1908. In its 19-year run, 15 million copies of that rugged, simple automobile were produced. This record was not surpassed until the Volkswagen Beetle did so in the early 1970s.

Another early automotive giant was General Motors, which in 1908 bought Buick, Oldsmobile, Cadillac, and Oakland (which would become Pontiac). Within 2 years, 30 firms had been brought under the GM umbrella, including 11 auto makers.

Walter P. Chrysler merged Willys and Maxwell-Chalmers in 1920. The first car to bear the Chrysler name went on sale in 1924 and was a huge success.

Today, foreign car makers have assembly plants in the United States. This idea is far from new. In 1888, Steinway & Sons, the New York piano maker, obtained the rights to all Daimler patents in the United States. It produced engines and cars in this country between 1905 and 1907.

Today, one out of every nine working Americans builds, sells, or fixes and maintains motor vehicles. Automobile dealerships account for 29 percent of the retail business conducted in the United States. Automotive-related business represents about a third of a trillion dollars worth of our nation's economy in an average year. It is estimated that \$150 billion of that total is spent on parts, repairs, and maintenance.



The 1886 Benz Patent Motorwagen had three wheels and a steering tiller.



A delivery to a modern dealership.

Photo by Tim Gillies

## Introduction to the Automobile

### OBJECTIVES

Upon completion of this chapter, you should be able to:

- Describe the differences between the unibody design and frame-and-body design.
- Tell how the four-stroke cycle engine operates.
- Understand the purposes of the major engine support systems.
- Describe the parts of front- and rear-wheel drive powertrains.
- Explain major events in the history of the automobile.

### KEY TERMS

- |                                       |                        |
|---------------------------------------|------------------------|
| actuators                             | ignition timing        |
| all-wheel drive (AWD)                 | Otto-cycle             |
| atomization                           | piston ring            |
| butterfly valve                       | rear-wheel drive (RWD) |
| chassis                               | reciprocating engine   |
| clutch                                | Selden patent          |
| Corporate Average Fuel Economy (CAFE) | sensor                 |
| four-stroke cycle                     | stroke                 |
| front-wheel drive (FWD)               | torque                 |
| horseless carriage                    | transaxle              |
|                                       | unibody design         |

## INTRODUCTION

Automobiles have been around for over 100 years. Early vehicles were built on the principle of the horse and wagon and were called **horseless carriages** (Figure 1.1). Continuing developments in vehicle design since those early years have resulted in the high-tech automobile of today (Figure 1.2). Some of those developments are outlined later in this chapter.

Today, there are over 130 million passenger cars in the United States alone (1.5 per household). This is just



Courtesy of Ford Motor Company

Figure 1.2 Today's automobile.



Photo by Tim Gilles

Figure 1.1 Henry Ford's horseless carriage.

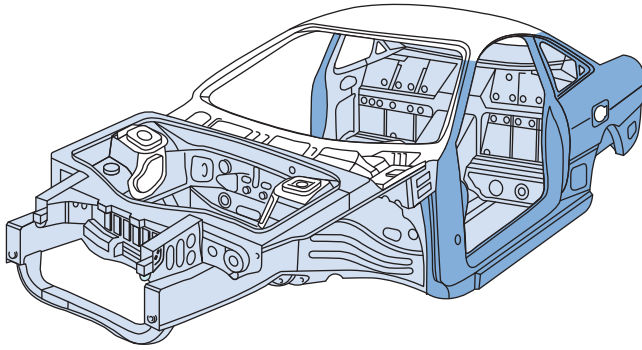
over one-third of the cars in the world. The automobile is a direct or indirect source of employment for one of every nine workers in the country. Americans drive an average of 7,767 miles per year.

The automobile includes several systems. These systems include the body and suspension, the engine, the electrical system, the powertrain, the emission controls, and the accessory systems.

## BODY AND CHASSIS

The **chassis** (pronounced "chassy") includes the suspension. It supports the engine and the car body. The chassis also includes the *frame*, the *brakes*, and the *steering* components. Older cars had heavy frames, but most cars are built today with what is known as a **unibody design**





**Figure 1.3** Unibody construction.

(**Figure 1.3**). This design has a floorpan and a small sub-frame section in the front and rear. The *body* includes the interior of the car, windows, door latches, the body electrical system, and the body accessories.

## Body Types

Different body types include the coupe, sedan, hatchback, wagon, sport utility vehicle (SUV), and crossover utility vehicle (CUV). A coupe has two doors and a sedan has four doors. Hatchbacks and wagons are based on the coupe or sedan but have a different door on the back instead of the traditional trunk lid, or deck lid. The door is known as a *hatch*. The difference between the two is that the wagon has more rear storage, its roof line extends nearly to the back of the vehicle, and it has a more vertical hatch line.

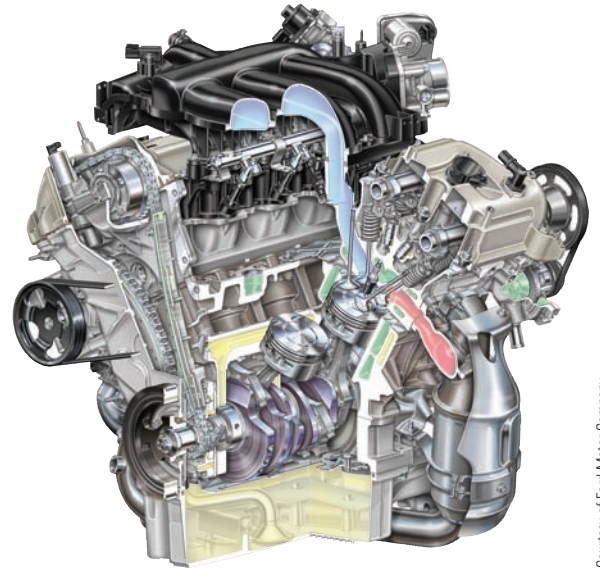
An SUV is similar to a wagon and is built on a light truck chassis. This design is sometimes called *body-on-frame*. A crossover is a smaller SUV, built on a car chassis, called a *unibody*.

## ENGINE PARTS AND OPERATION

Most of today's automobiles use spark-ignited *four-stroke reciprocating* gasoline engines. A limited number of cars use diesel engines. **Figure 1.4** shows a cutaway of a modern gasoline engine. In-depth coverage of engine operation is found in Chapter 15. A quick overview is given here.

A reciprocating gasoline engine has a round piston in a cylinder, a connecting rod, and a crankshaft. The principle of its operation is simple. The piston moves up in the cylinder, compressing a mixture of air and fuel in front of it. Compressing the air and fuel makes it very flammable. When the piston reaches the top of its travel, the *air-fuel mixture* is ignited. As the piston is pushed down in the cylinder by the expanding gases, it pushes on the rod, forcing the crankshaft to rotate.

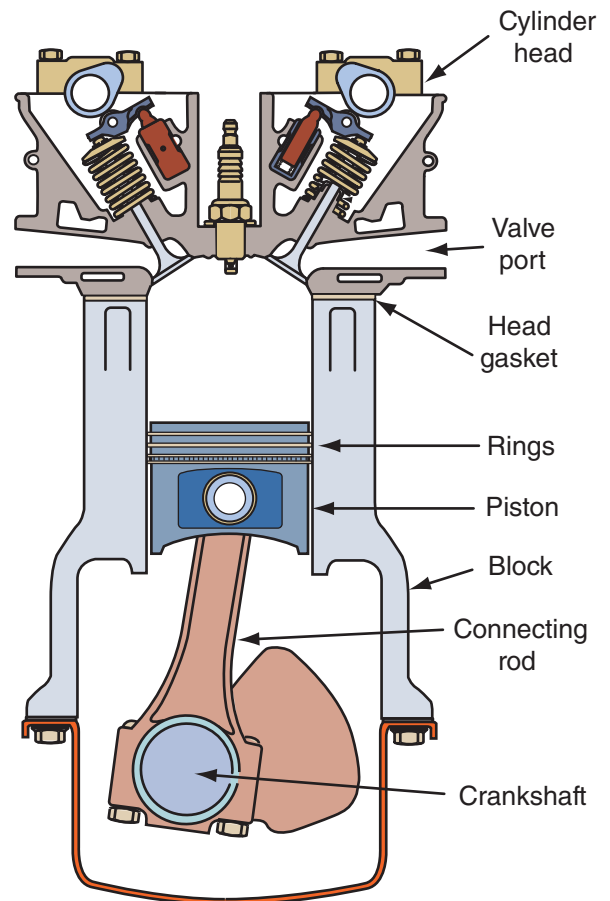
Power from the rotation of the crankshaft turns the wheels. As the crankshaft turns, the piston is returned to the top of the cylinder to repeat the cycle. The continuing up-and-down motion of the piston is why the engine is called a **reciprocating engine**.



Courtesy of Ford Motor Company

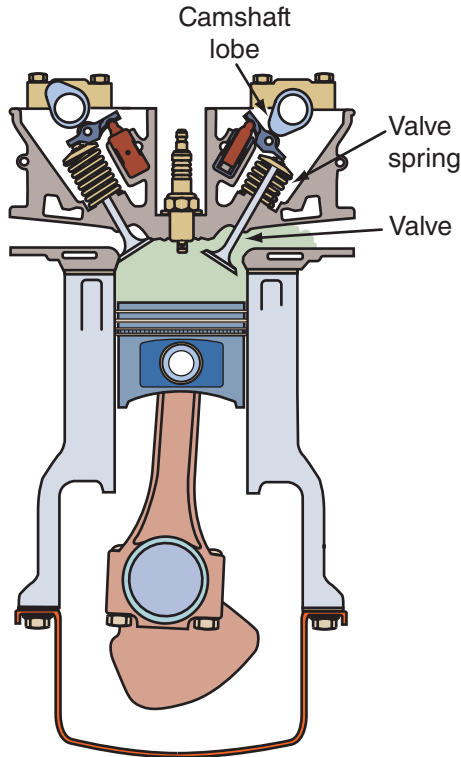
**Figure 1.4** A modern gasoline-powered engine.

The burning mixture is sealed into the cylinder on the top end by a *cylinder head* and a *head gasket* (**Figure 1.5**). The cylinder head has intake and exhaust ports. The intake port allows the flow of the air-fuel mixture into



**Figure 1.5** Engine parts.

the cylinder. The exhaust port allows the escape of the exhaust gases after the mixture has been burned. Each port is sealed by a valve that is opened by a lobe on the camshaft and closed by a spring (Figure 1.6). The piston is sealed to the cylinder with **piston rings** that slide against the cylinder wall as the piston moves up and down.



**Figure 1.6** The valve is opened by a lobe on the camshaft and closed by a spring.

## Four-Stroke Cycle

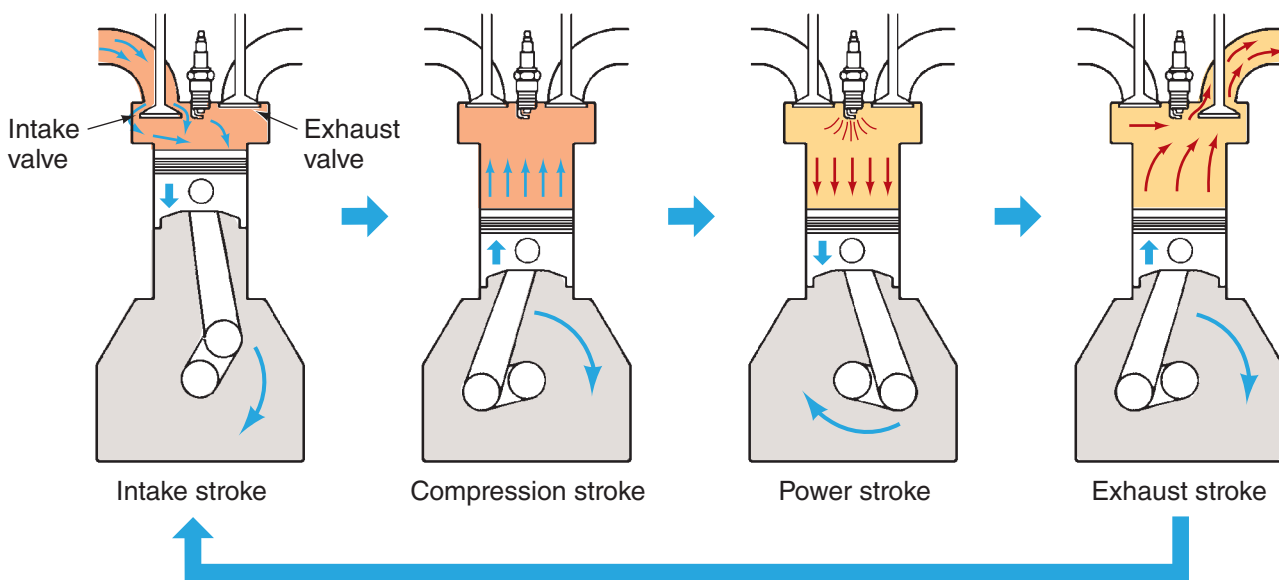
The **four-stroke cycle** is described here using a single-cylinder engine (Figure 1.7). Automobile engines actually have multiple cylinders. The movement of the piston from the top of its travel to the bottom of its travel is called a **stroke**. Each cycle required to burn the air–fuel mixture has four strokes; hence the name *four-stroke cycle*.

During the *intake stroke*, the piston is pulled down by the turning crankshaft, creating a vacuum above it. Because the intake valve is open while the piston is moving down, the air–fuel mixture is drawn into the cylinder through the intake valve port. The mixture is supplied to the cylinder by the fuel system. In a spark-ignition engine, gasoline is especially combustible when one part of it is atomized with about 15 parts of air. **Atomization** makes the mixture like fog.

With both valves closed, the piston moves back up in the cylinder on the *compression stroke*, compressing the air–fuel mixture and making it far more combustible. As the piston approaches the top of its travel, a spark plug ignites the mixture.

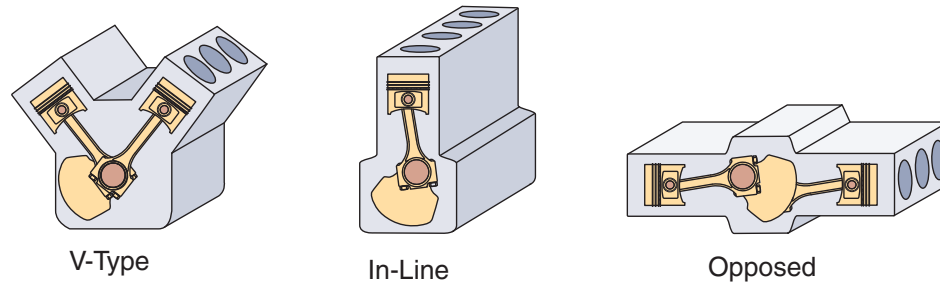
During the *power stroke*, the burning fuel expands rapidly, forcing the piston to move back down in the cylinder. The exhaust valve opens as the piston approaches the bottom of its travel. This is so that burning gases can escape before the piston begins to move upward in the cylinder once again.

During the *exhaust stroke*, the piston moves back up, forcing any remaining exhaust gas from the cylinder through the open exhaust valve. As the crankshaft continues to rotate, the piston goes back down in the cylinder as the four-stroke cycle repeats itself.



**Figure 1.7** The four-stroke cycle.





**Figure 1.8** Common cylinder block arrangements.

## Cylinder Arrangement

Car engines have multiple cylinders, commonly 4, 6, or 8 (**Figure 1.8**). Cylinder blocks have rows of cylinders that are arranged either *in-line*, or in a “V” or “W,” or are *opposed* to each other.

## ENGINE SUPPORT SYSTEMS

Several subsystems support engine operation. They are the *cooling system*; the *fuel system*; the *lubrication system*; the *electrical system*, including the *charging*, *starting*, *ignition*, and *computer systems*; and the *exhaust system*. These systems are covered in detail in later chapters. To provide improvements in fuel economy and exhaust emissions, new cars also have sophisticated computerized systems that operate fuel and emission control systems.

## The Cooling System

As an engine operates, it creates a great deal of heat that is wasted and must be carried away by the cooling system

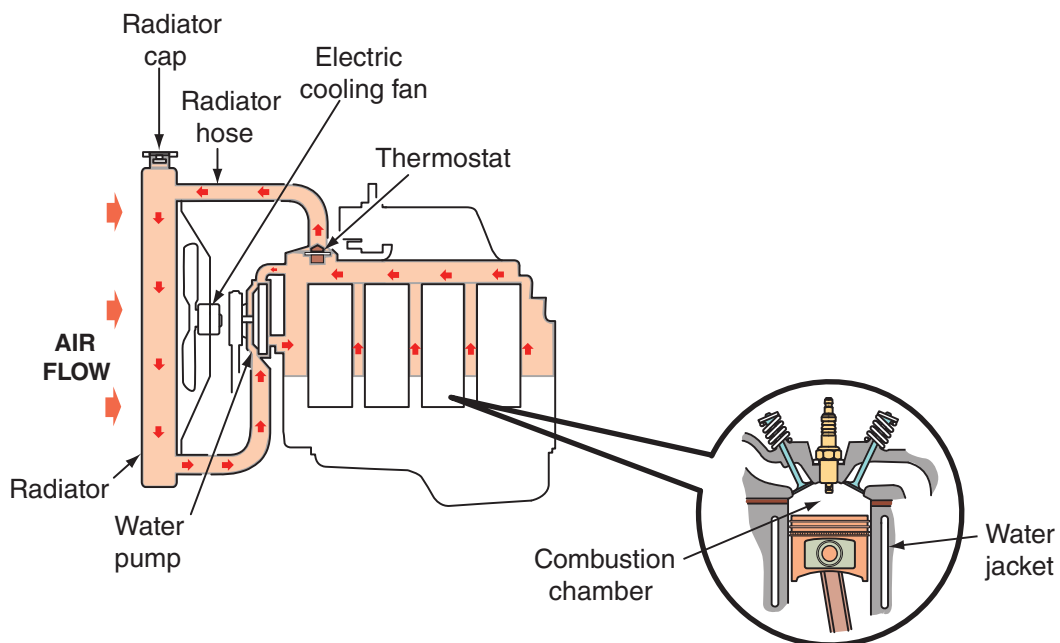
(**Figure 1.9**) so the engine does not get too hot. *Coolant*, also known as *antifreeze*, is circulated by the *coolant pump* through *coolant jackets* in the engine’s cylinder block. It carries heat to the radiator, where it can be carried away by the outside air.

The cooling system’s thermostat maintains the coolant at a constant temperature. It also speeds the warmup of the engine so emission controls and the heater can operate. The engine experiences less wear once it is at operating temperature.

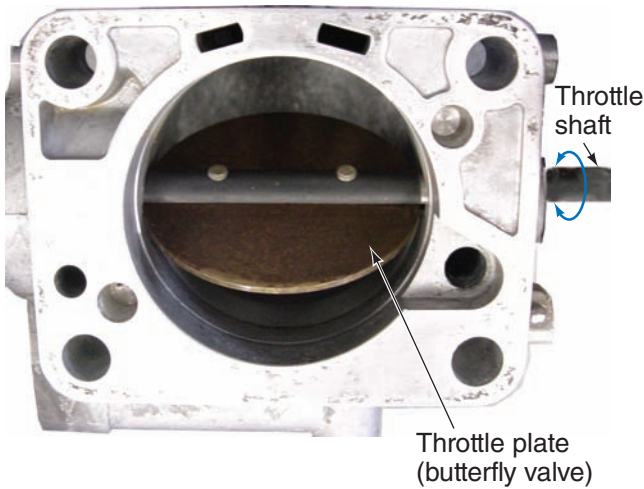
## Fuel System

The fuel system is responsible for supplying the correct air–fuel mixture to the cylinder. Liquid gasoline does not burn. It must first be mixed with air in the correct proportion to form a vapor. The *air–fuel ratio* on gasoline engines ranges from about 12:1 (12 parts of air to 1 part of fuel) to 15:1.

Three types of fuel delivery systems have been used on automobile four-stroke cycle engines: *carburetor*, *gasoline fuel injection*, and *diesel fuel injection*. Carburetors were



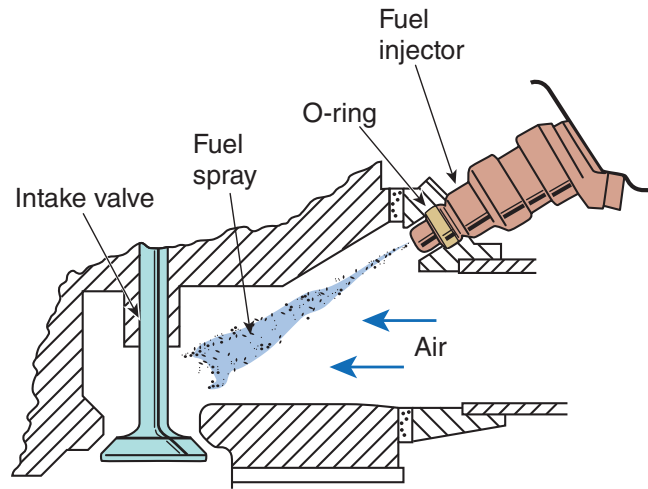
**Figure 1.9** Parts of the cooling system.



**Figure 1.10** A butterfly valve controls airflow into the engine.

used on many cars built through about the 1985 model year. More exact control of the fuel system was needed to control exhaust emissions, so fuel injection systems eventually replaced carburetors.

A running engine draws in a great deal of air. Air rushing through the intake system is mixed with fuel on its way to the cylinders. This results in lower pressure in the intake manifold, which is known as *vacuum*. When the driver steps on the accelerator pedal the throttle, a **butterfly valve**, opens to let in more air and fuel (**Figure 1.10**). When more air moves past the throttle valve, engine speed increases.

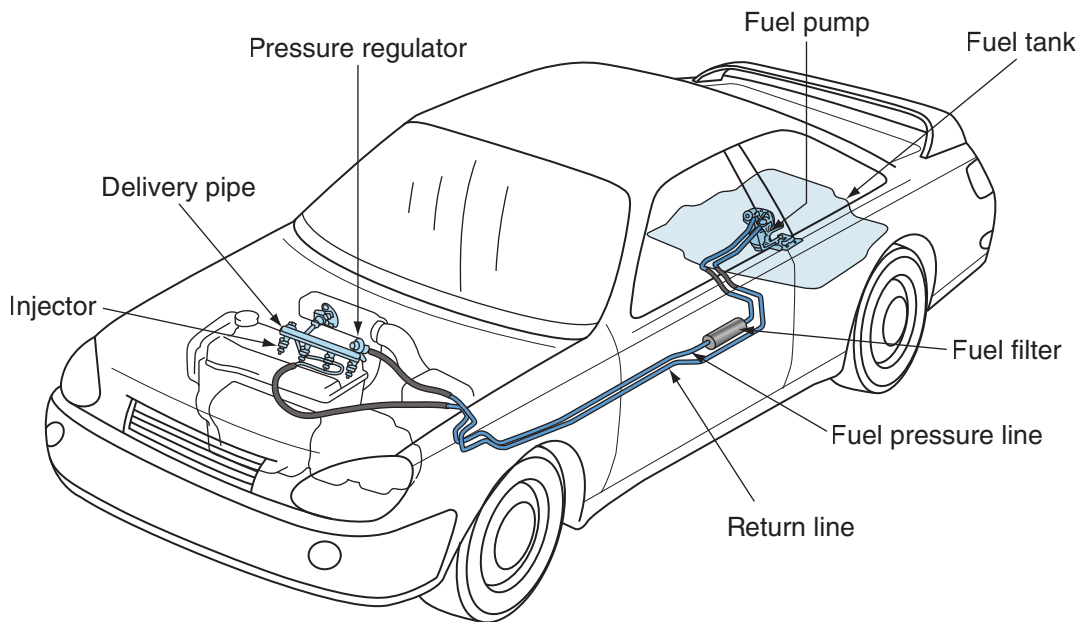


**Figure 1.11** Fuel injection.

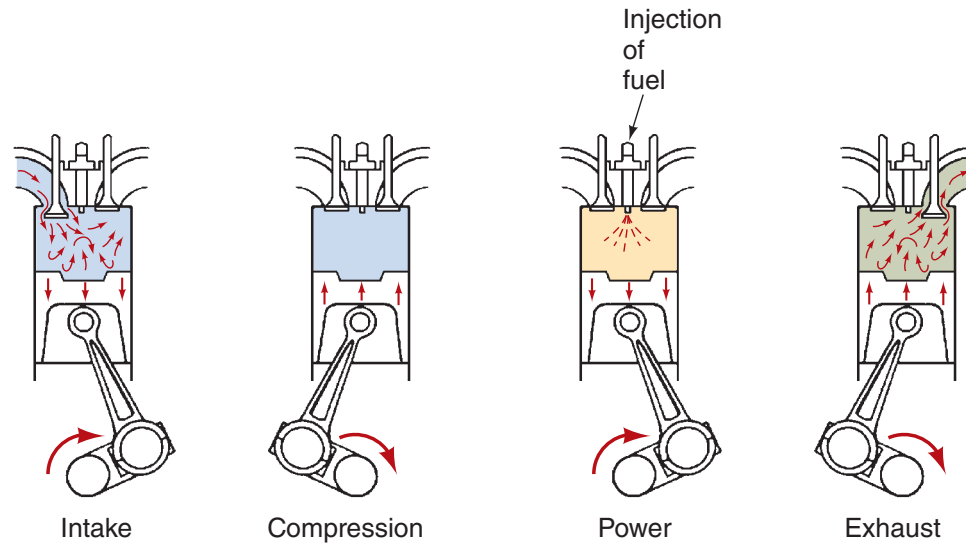
**Carburetor.** Vintage engines have a carburetor that mixes fuel and air in response to the amount of air that flows through it. A mechanical fuel pump supplies the carburetor reservoir with fuel.

**Gasoline Fuel Injection.** Since 1985, most engines have used fuel systems with computer-controlled fuel injection. Fuel injectors spray fuel into the airstream flowing into the engine (**Figure 1.11**).

Fuel at a constant pressure is supplied to electronic fuel injectors by an electric fuel pump (**Figure 1.12**). The injectors remain open for a specified amount of time.



**Figure 1.12** The fuel system.



**Figure 1.13** Diesel four-stroke cycle.

Fuel sprays out of them in the exact amount called for by the operating condition at the moment. An open throttle allows the injectors to remain open longer, while a closed throttle leaves them open for only a short time.

**Diesel Fuel Injection.** A diesel engine draws only air into the cylinder through the air intake system, without fuel. The air that enters the cylinder is compressed to about one-half of the size it would be compressed to in a gasoline engine. A great deal of heat results. If fuel was already included with the incoming air, heat would ignite the fuel during compression. Unlike gasoline engines, diesel engines do not have spark plugs or an ignition system because spark timing is controlled by the fuel injection system. When diesel fuel is injected by high-pressure injectors into the hot air in the cylinder, it ignites instantly (**Figure 1.13**). To overcome the high pressure in the cylinder, the fuel system on a diesel must be under very high pressure.

## The Lubrication System

The engine has a lubrication system that moves pressurized oil to all areas of the engine (**Figure 1.14**). A pump pulls oil out of the oil pan and forces it through a filter before it is distributed to the engine's parts. The oil prevents moving parts from touching each other.

**NOTE:** *In theory, during a 1,000-mile trip a properly operating lubrication system will allow about as much wear between parts as occurs during the first 15 seconds of engine operation in the morning before oil has reached all of the engine's parts.*

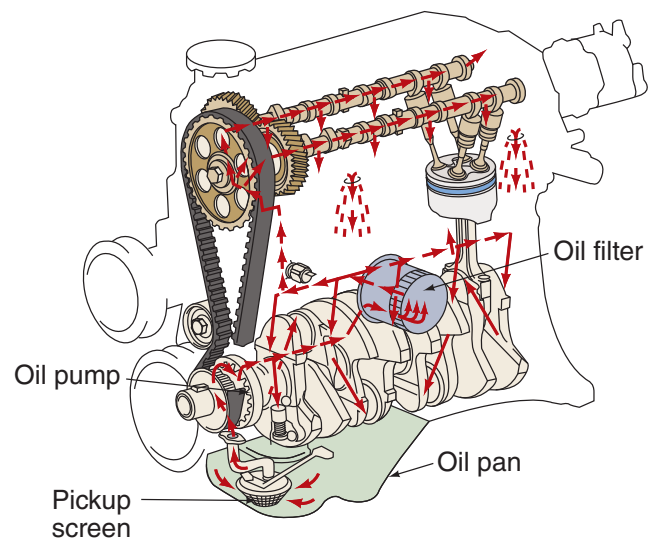
## The Electrical System

The engine electrical system includes the *ignition system*, *starting system*, *charging system*, and fuel and emission

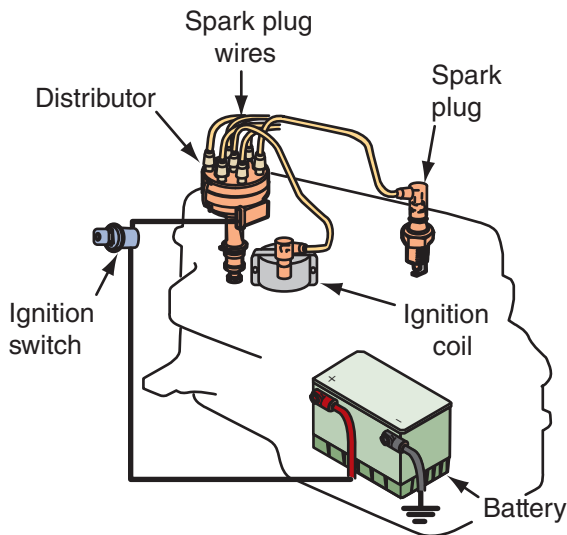
systems controlled by computer. The body electrical system includes lighting and wiring systems.

**The Ignition System.** The ignition system has the job of creating and distributing a timed spark to the engine's cylinders (**Figure 1.15**). Through a process called electromagnetic induction (see Chapter 25), a voltage that can range from 5,000 to about 100,000 volts (on some of the newer systems) is created. The voltage causes a spark to jump a gap at the spark plugs to ignite the air-fuel mixture. The spark is timed to occur just before the top of the compression stroke. This is called **ignition timing**.

**The Starting System.** The starting system has an electric motor usually mounted low on the rear of the engine. It has a small *pinion gear* on it that meshes with a large

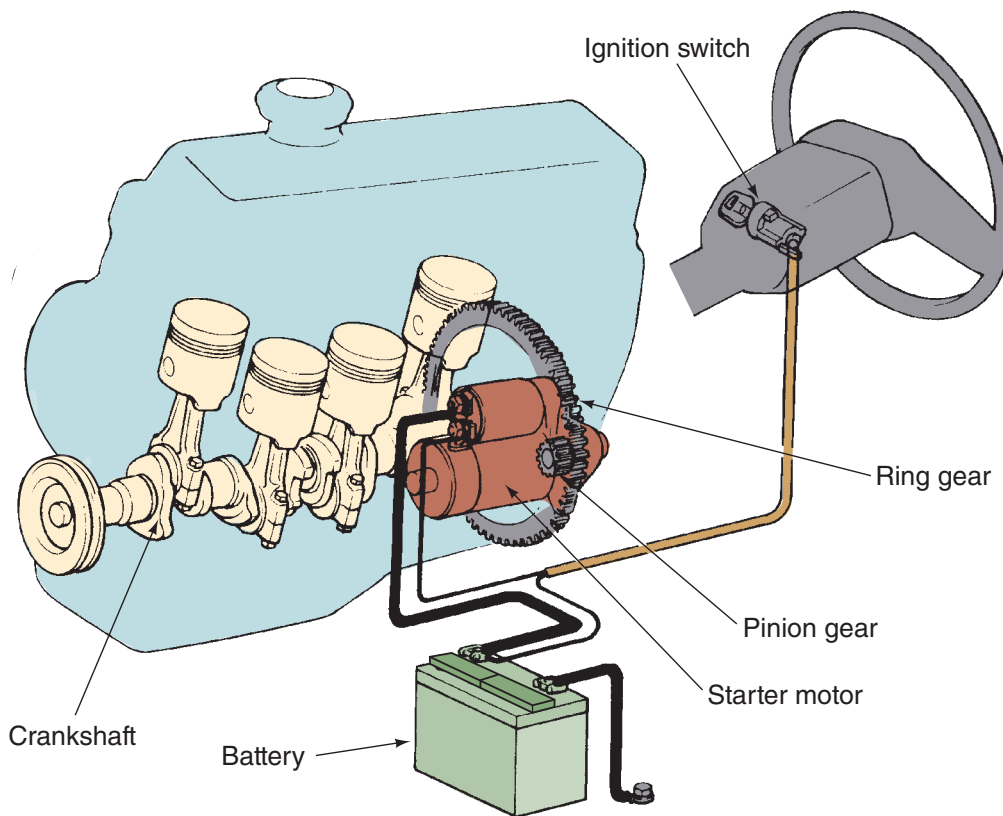


**Figure 1.14** Engine lubrication system.



**Figure 1.15** The ignition system provides a timed spark to each cylinder.

*ring gear* on the engine's flywheel (**Figure 1.16**). The flywheel is bolted to the rear of the engine's crankshaft. The motor draws electrical current through a large cable from the car's battery. When the starter operates, the pinion gear turns the flywheel. This causes the crankshaft to rotate, drawing in air and fuel to start the engine.



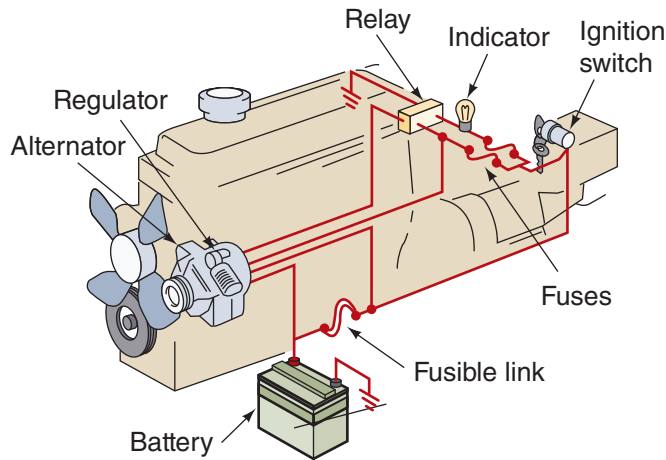
**Figure 1.16** The starter motor turns the engine's crankshaft.

**The Charging System.** With the engine running, electricity is drawn from the charging system to operate the ignition system, body electrical accessories, or lighting. The charging system (**Figure 1.17**) includes an *alternator*, which is driven by a belt on the engine's crankshaft pulley. The alternator produces electrical current and forces it into the battery to recharge it. Battery voltage is monitored, and the alternator is switched on or off depending on charging requirements.

**The Computer System.** Modern automobiles have a substantial amount of on-board electronics. Vehicle electronics is a specialty repair area with high earning potential. Qualified automotive electronics technicians command excellent pay. The computer system manages the operation of fuel injection, ignition, emission system components, automatic transmission shifting, antilock brakes, and body electrical accessories. Many of today's cars have several computers that manage these systems.

A main *computer*, called a *powertrain control module (PCM)* on late-model cars, controls the operation of all of the system components. **Sensors** react to temperature, airflow, engine load, road speed, and oxygen content in the exhaust stream. The various sensors send voltage signals to the computer. The computer processes the data and makes compensating adjustments using **actuators**. Operation of the computer system is covered in Chapter 45.





**Figure 1.17** The charging system recharges the battery during engine operation.

## The Exhaust System

The exhaust system carries exhaust from the engine to the rear of the car. It also quiets sound. The exhaust manifold, pipes, muffler, catalytic converter, and sometimes a resonator make up the exhaust system components (**Figure 1.18**).

## The Emission Control System

Since the mid-1960s, various emission devices have been installed on cars. Pollutants are produced during the combustion of air and fuel. The computer system controls the operation of the fuel system to provide the most complete combustion during all driving conditions. The emission system's purpose is to reduce or eliminate any remaining pollutants in the engine's exhaust. In addition to the

control of exhaust pollutants, fuel vapors are controlled. Operation of these systems is covered in Chapter 43.

## THE POWERTRAIN

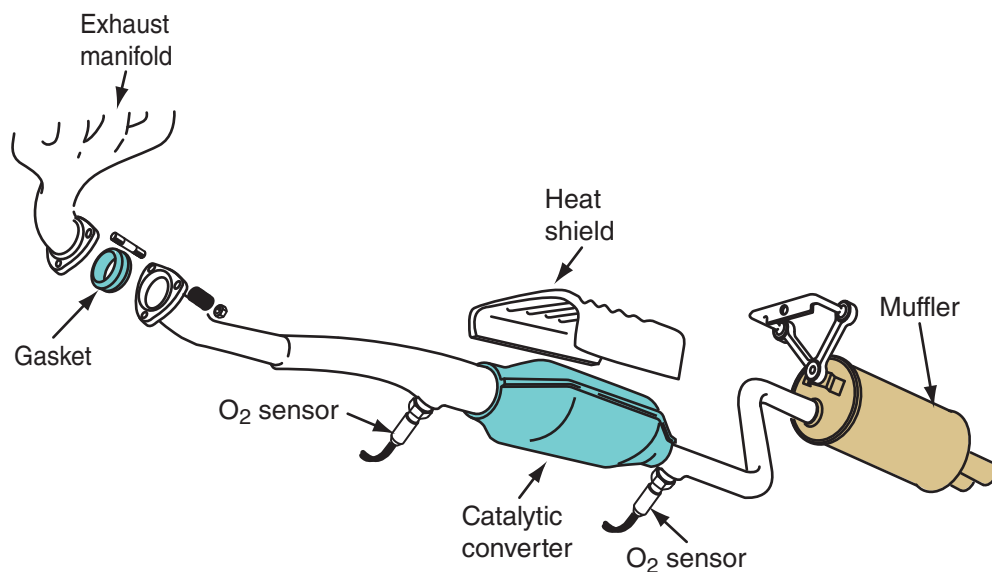
Engine power is transmitted to the wheels through the *powertrain*, which includes the *transmission* or *transaxle*, the *clutch* (used with manual transmissions) or *torque converter* (on automatic transmissions), and the *differential* and axles or half-shafts.

Vehicles have **front-wheel drive (FWD)**, **rear-wheel drive (RWD)**, or **all-wheel drive (AWD)**. Front-wheel-drive cars (**Figure 1.19**) use a transaxle and axle shafts, while rear-wheel-drive cars use a transmission and drive-shaft coupled to a differential and rear axles (**Figure 1.20**). Transmissions can either be manually shifted using a clutch or they can shift automatically.

## Manual Transmission

A manual transmission (see **Figure 1.20**) provides for shifting of the gears by the driver. Changing gears results in a change in leverage or **torque**. The car's engine develops more pushing power when its crankshaft rotates at a certain number of revolutions per minute (rpm). Shifting the transmission into different gears allows the engine to be operated at the best rpm so that it can propel the car more efficiently. This can be compared to shifting the gears on a ten-speed bicycle to make it possible to climb a steep hill slowly or go fast downhill.

**Clutch** A **clutch** (see **Figure 1.20**) is used on cars with standard (manual shift) transmissions. Depressing the clutch pedal in the driver's compartment uncouples the powertrain from the engine.



**Figure 1.18** Parts of the exhaust system.