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Automotive Technology

Principles and Practice

THIRD EDITION

Kirk VanGelder

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How to Use This Text

The third edition of *Fundamentals of Automotive Technology, Principles and Practice* is a comprehensive resource that covers the foundational theory and skills necessary to prepare entry-level technicians to maintain, diagnose, and repair today's light-duty vehicles.

Several of the original 64 chapters have been split, creating 75 chapters in the *Third Edition*. The smaller chunks of content fit nicely into the schedule of most two-year programs. Additionally, the reading level has been lowered to eighth/ninth-grade level, making it easier for more students to comprehend. Several features are included in the text to facilitate student learning. Instructors are encouraged to incorporate these features and activities into their lessons.

Learning Objectives

Learning Objectives are skills, knowledge, and behaviors that translate to on-the-job requirements. Instructors should align the Learning Objectives to the outcomes defined by accreditors and advisory boards. This will help instructors ensure that they have provided the training necessary for safety and competence on the job. Learning Objectives are listed at the beginning of each chapter and emphasized when supporting material appears in the chapter content. Organizing each chapter by the Learning Objectives makes the content more manageable for students and focuses their attention on the relevant information.

You Are the Automotive Technician

Each chapter includes a You Are the Automotive Technician scenario and open-ended questions intended to provide relevance to the chapter content. Instructors can use this feature to stimulate classroom discussion, capture students' attention, and provide an overview of key topics in the chapter.

Skill Drills

Skill Drills offer a step-by-step portrayal, in words and images, of necessary skills. These are particularly helpful as students prepare to perform the tasks themselves for the first time or if they need reference information in the lab. Instructors can use Skill Drills when discussing difficult steps or preparing students for the nuances of a procedure. Breaking down these processes into individual steps helps students internalize the importance of each step. The visual component further assists students in determining what needs to be done, and how it needs to be done, at each step.

Applied Academics

The Applied Academics feature provides a practical scenario for specific communication, math, or science skills in the shop. Instructors who are required to address STEM (science, technology, engineering, and mathematics) content and similar grade-level outcomes (GLOs) will find this feature especially helpful as both a skill review and a reference tool. After the scenario is presented, students are guided through application of the concept. This feature pulls students' existing academic skills into the automotive context and helps them apply these skills to real-world automotive situations.

Technician Tips

Technician Tips add extra background information, details, and suggestions that students will find helpful in both their studies and their work in the shop. These details provide insight into the topic from technicians with years of experience.

How to Use This Text

Safety Tips

Safety Tips draw attention to specific safety concerns and address how to avoid injury in the shop. Instructors know that reinforcement is key for many of these very important practices. Safety Tips alert students to potential hazards and remind instructors to address the dangers in class, ahead of exposure in the shop.

Wrap-Up

The Wrap-Up at the end of each chapter pulls together the information learned in the chapter. In addition to highlighting key topics and terms, the Wrap-Up gives students an opportunity to test their knowledge of the material they learned. Instructors can use the questions in this section as a homework assignment, an in-class (individual or group) activity, or the basis of a class discussion. Students can develop their critical-thinking and problem-solving skills in the context of automotive service and repair—skills essential for success in the field.

Note to Students

This course was created to help you on your path to a successful career in the transportation industry. Employability basics covered early in the text will help you get and keep a job in the field. Essential technical skills, which are the core building blocks of an automotive technician's skill set, are presented from cover to cover. This course also introduces *strategy-based diagnostics*, a method used to solve technical problems correctly on the first attempt. The text explores virtually every task the various industry standards recommend for technicians and will help you prepare for a successful career.

As you navigate this text, do what successful technicians do—they continuously ask themselves questions. Ask yourself, "Do I understand this concept or task? Can I explain it in my own words? Does this make sense to me?" If not, go back and reread the text and study the pictures.

This course is designed to help you answer the comprehension questions above. Each chapter starts with a list of Learning Objectives. Each chapter ends with a review of the chapter's highlights. The content of each chapter is written to explain each objective. As you read, continue to ask yourself those questions. Study the concepts and wrestle with them in your mind. Every part of the vehicle is governed by the same laws of physics that govern the world around us, so the concepts can be understood. You are on a mission to seek the answers and gain this understanding. Gauge your progress by imagining yourself as the technician. Do you have the knowledge of the concepts presented, and can you perform the tasks explained within each chapter? Know that combining your knowledge with hands-on experience is essential to becoming a Master Technician.

Stay curious. Ask questions. Practice your skills, and always remember that one of the best resources you have for learning is right there in your classroom . . . your instructor. But before you go to them, make sure that you have done your own research. Use your instructor to verify that your answers are correct or for those difficult concepts or techniques that you just can't work out on your own. Once you graduate from the program, your instructor will no longer be there to help answer your questions. You will need to be able to answer them yourself. Now is the best time to begin practicing that skill. Equipped with the knowledge in this course and your drive to learn more about automotive technology, you will go far in your career.

Best wishes and enjoy!
The CDX Learning Automotive Team

SECTION 1

Safety and Foundation

CHAPTER 1

Careers in Automotive Technology

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- **1-1** Outline the history of the automobile.
- **1-2** Describe the careers in the automotive service sector.
- **1-3** Describe each type of repair facility.
- **1-4** Explain the importance of automotive industry certification and ongoing training.

YOU ARE THE AUTOMOTIVE TECHNICIAN

A customer brings her 2016 V6 Dodge minivan to the dealership for its 15,000-mile oil change. You pull the vehicle into the bay and set the vehicle safely on the hydraulic lift. Next, you reference the computer to check the service history and any technical service bulletins (TSBs) or recalls for the vehicle. You can see that all previous services were done on time, and there are no TSBs or recalls for the vehicle. You then verify the manufacturer's scheduled maintenance recommendations for the mileage on the vehicle. You find that the tires need to be rotated and that the air filter needs to be inspected.

After you complete the tire rotation, you use the hydraulic lift to raise the vehicle and proceed to change the oil and filter. First, you drain and dispose of the old oil and remove and replace the filter. Then you add 4.5 quarts (4.3 L) of new oil. When finished, you inspect all the fluids, belts, and hoses as well as the air filter. You find them to be in good condition. You reset the oil life monitor on the vehicle, clean your area, and return all tools to their correct locations.

You process the customer's invoice with notes from your inspection, tire rotation, and oil change. The service advisor reviews the work and invoice with the customer. She thanks the customer for her business and provides her with a reminder card to return for the next scheduled maintenance appointment.

1. If you had noticed a worn belt or hose during the oil change, which type of technician would you have asked to look at the vehicle?
2. In the shop, who is responsible for initially filling out a new repair order?
3. What are the job duties of a lot attendant?
4. Of the types of shops listed in this chapter, which would you prefer to work in, and why?
5. What are the benefits of Automotive Service Excellence (ASE) certification for a technician and shop?

Introduction

The automotive industry offers many opportunities for people to pursue rewarding careers of their choice. These include everything from technician positions, to sales, to management, to engineering, to racing. There is something of interest to just about everybody. And don't worry—if you get tired of one job, you can transition to one of the others.

In this chapter, we will begin by outlining the history of the automobile. This will give you some background on how the industry progressed. We will then describe some of the main jobs at a typical shop. Next, we will discuss the five primary types of shops and their pros and cons. Last, we will cover the industry certification requirements and the importance of ongoing training. Now sit back and explore the world of automotive technology!

A Brief History of the Automobile

LO 1-1

Outline the history of the automobile.

Early vehicles were basic machines. Drivers started the vehicles' engines by manually operating a crank handle. These vehicles also needed almost continual tinkering and maintenance. As vehicle technology developed, the maintenance requirements evolved as well (**FIGURE 1-1**). Early vehicles had many of the same basic systems as today's vehicles. These include the engine, ignition, cooling, lubrication, suspension, and drivetrain. However, the systems on modern vehicles are much more sophisticated and reliable. This means that modern vehicles travel much farther between maintenance visits than earlier models. As opposed to visits every 1000 miles, today's vehicles are serviced every 7500 to 10,000 miles. In a few years, it could be up to 25,000 miles between scheduled services.

FIGURE 1-1 Typical dealership shop.

Maintenance requirements and the need for major repairs have decreased over time. Forty years ago, engines used to last 100,000 miles on average. Now they routinely last well over 200,000 miles. Better metals, machining processes, and lubricants all extend the life of the vehicle's parts. Parts still wear out or need to be replaced—just not as often as in years past.

Vehicles also have many more safety, convenience, and entertainment systems and features than they used to. This makes them much more complex. At the same time, the amount of service information has grown to cover the new systems. This requires that technicians have more knowledge to perform repairs on these vehicles. Strong reading skills are needed to keep up with the demands of technology. A solid understanding of electrical and electronic theory and diagnosis is also required.

That's a fairly concise overview; let's dig in a bit deeper. In the late 1800s, several engineers were working on the concept and design of the automobile. Karl Benz is generally acknowledged to have invented the modern automobile around 1885 (**FIGURE 1-2**). The concept of the automobile continued to develop in those early days. Many inventors produced various models. The early versions of the automobile were like hand-built horse carriages but with engines. Being hand-built, these early automobiles tended to lack uniformity. This made them unreliable as well as expensive to buy and maintain. Therefore, they were considered a novelty that only the wealthy could afford.

TECHNICIAN TIP

Service or maintenance intervals are also influenced by the severity of operating conditions. The more severe the conditions, the more frequent the required maintenance. Most service information gives both a normal-duty and a severe-duty maintenance schedule.

In the early 1900s, the advent of mass production made automobiles available to more people. Henry Ford applied two concepts that helped make the Model T affordable for the masses. The first was the concept of interchangeability. This meant that each part was made to the same specifications so that it would fit properly with its related parts. Parts could now be stockpiled, ready for later use. Henry Ford's second concept was the assembly line, which brought the car to the worker (**FIGURE 1-3**). This approach made assembly much more efficient.

FIGURE 1-2 Karl Benz is generally acknowledged to have invented the modern automobile around 1885.

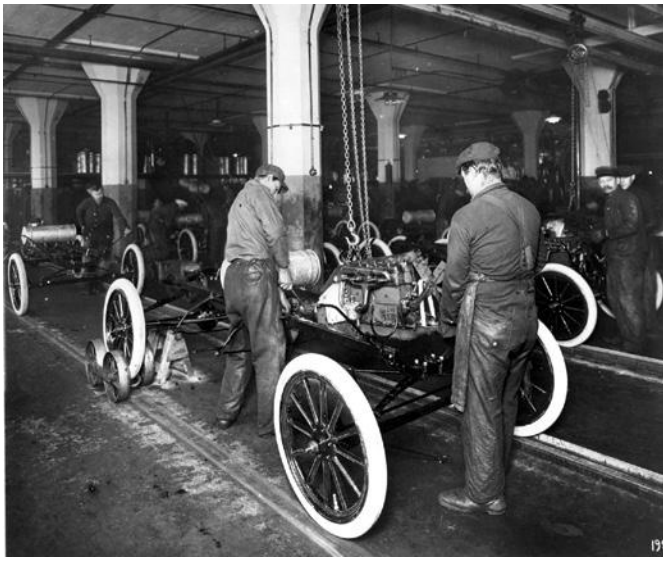


FIGURE 1-3 The assembly line was essential in the mass production of vehicles.

It increased the number of vehicles that could be built in a shift and lowered production costs. As prices dropped, more powerful and reliable automobiles were produced. Lower cost and greater availability allowed the automobile to become the preferred mode of personal transportation.

Vehicle Manufacturing

Vehicles were manufactured by small independent companies in the late 1800s. They relied on large amounts of labor and limited automation. Now manufacturers have large-scale production lines that use extensive automation. The globalization of the automotive industry has seen manufacturers sharing models. This allows them to make vehicles that are sold across the world.

Modern assembly lines require large-scale investments. Because of this, manufacturers must be confident that consumers will buy the new vehicle model. Otherwise, the billions of investment dollars would be wasted. This is due to the need for expensive retooling of the production line to produce a new model (**FIGURE 1-4**).

Assembly lines use robots for many of the assembly processes, including welding seams. Assemblers continue to work up and down the assembly line, doing tasks that are still too complicated for robots.

Vehicle manufacturing is a high-volume business. Everything needs to work in the correct timing and sequence, from the supply of the required parts, down to the speed at which the production line runs. Sophisticated technology allows for the mass production of high-quality, affordable vehicles.

Mass production uses **just-in-time manufacturing**. With this system, vehicle manufacturers schedule (days or weeks in advance) the order in which vehicles will be produced. Large-scale parts manufacturers then preassemble various parts into unit assemblies. Those units are delivered in the correct order to the vehicle manufacturer shortly before assembly. They go into the assembly lines to meet with their specified vehicle at just the right time. This means that the manufacturer doesn't have to store large quantities of parts on-site.

FIGURE 1-4 Modern assembly lines require large-scale investments in high-tech equipment.

Technology in Vehicles

Vehicle technology continues to adapt and change. Consumers expect increased comfort and entertainment as well as a reduced impact on the environment. This adds more complex electrical, electronic, and mechanical systems. Future consumer demands and environmental pressures will continue to increase this trend. A few of the recent technological trends include the following:

- Hybrid electric vehicles (HEVs)
- Gas direct injection (GDI) engines
- Electric vehicles (EVs) (**FIGURE 1-5**)
- Lane departure and blind spot warning
- Adaptive cruise control
- Accident avoidance
- Autonomous vehicles (AVs) (self-driving) (**FIGURE 1-6**)

FIGURE 1-5 Fully electric vehicle.

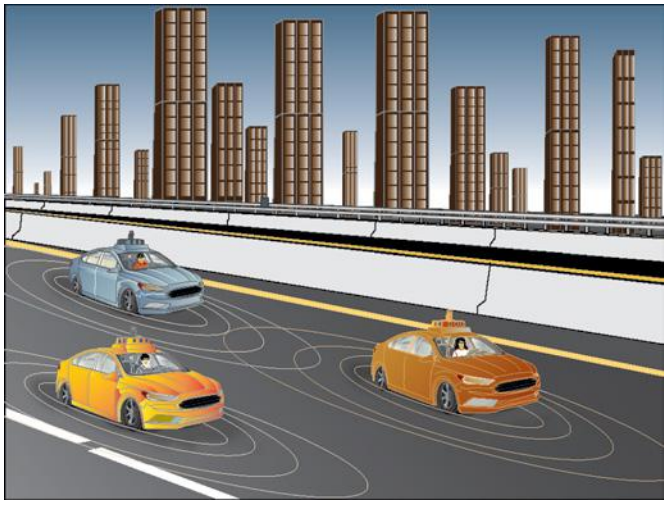


FIGURE 1-6 Autonomous vehicles are likely to radically change the way we travel between places and even the way we own vehicles.

The next 5 to 10 years are going to be exciting times as technology moves forward!

Careers in the Automotive Sector

LO 1-2

Describe the careers in the automotive service sector.

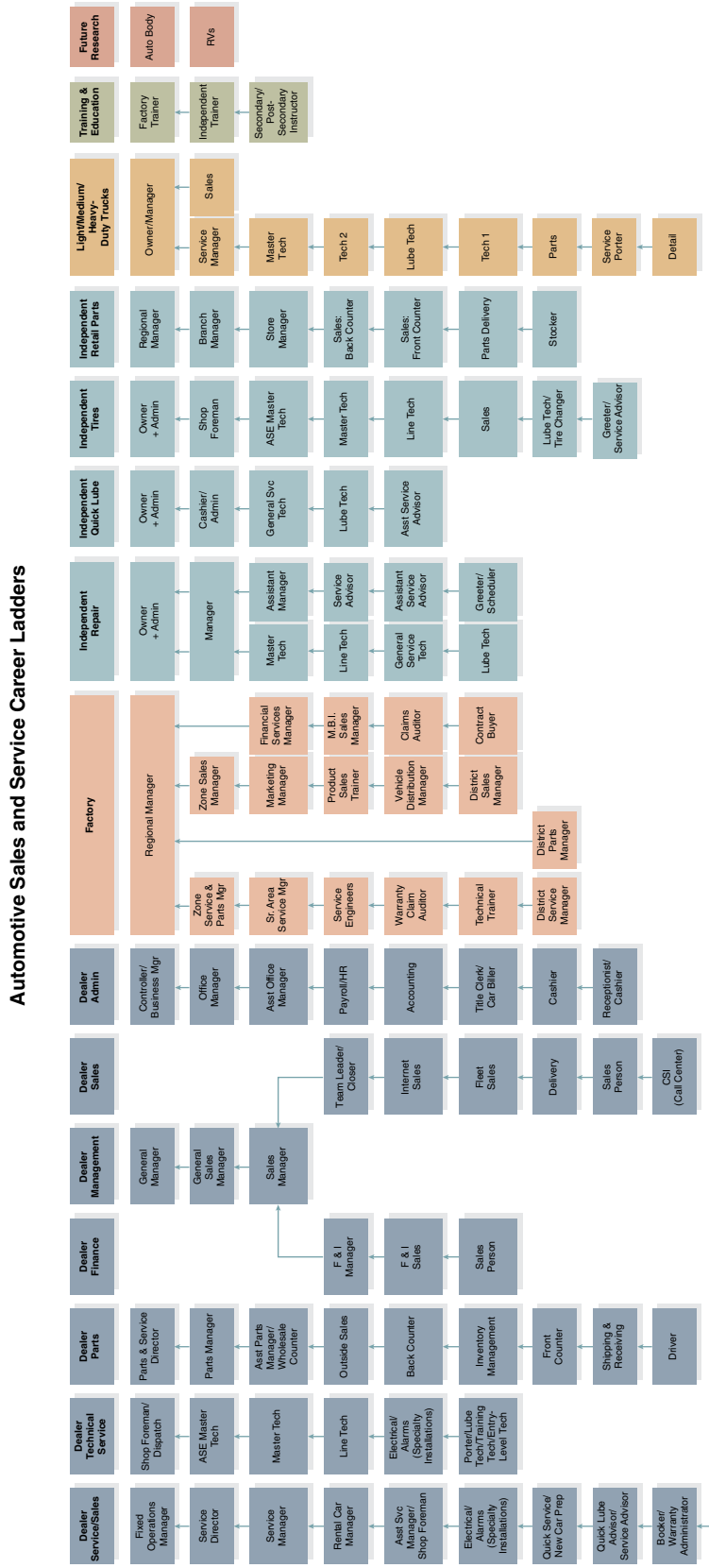
The automotive sector provides for many career choices within the manufacturing, service, and retail sectors. The manufacturing sector offers options from factory workers and assemblers to design engineers and senior administrators (**FIGURE 1-7**). In the service sector, jobs range from maintenance/service technicians, light vehicle technicians, and heavy vehicle technicians, to service advisors and service managers. In the retail sector, jobs range from positions in new and used vehicle sales, leases, and rentals, to parts counter person. As technical complexity has grown in modern vehicles, so has the need for more specialized job roles. For example, there is now a need for hybrid technicians. They are trained to service systems specific to hybrid vehicles.

This section will describe only some of the most common jobs in the automotive sector. Refer to Figure 1-7 to identify any other jobs that you may have an interest in. Then use the internet to research their duties, requirements, and pay.

Lot Attendant

One common entry-level position is the **lot attendant**. Lot attendants work with both the sales and the service side of a new or used car dealership. They are primarily responsible for keeping the vehicles in the lot organized, clean, and prepared for sale (**FIGURE 1-8**). This means that they constantly move vehicles around the lot as vehicles are test-driven and sold. They are also responsible for keeping the vehicles clean, fueled up, and charged. This ensures that vehicles are ready for a test drive or sale. When new vehicles are delivered to the dealership, lot attendants may be responsible for checking the vehicles in. This involves inspecting them for damage and missing accessories. Each vehicle's vehicle identification number (VIN) is compared with the invoice.

Lot attendants must have a valid driver's license and a clean driving record. It is also important that they be cautious drivers who don't take risks that could result in an accident. Vehicles are packed into tight spaces at



This career ladder shows a series of jobs progressing from simpler to more complex duties and responsibilities in automotive sales and service. These pathways represent a sequence of defined job levels where the nature of work is similar throughout the pathway.

FIGURE 1-7 The opportunities for challenging and rewarding careers in the automotive field are endless.
Courtesy of Shoreline Community College, Seattle, Washington.

FIGURE 1-8 Lot attendants are responsible for keeping the vehicles organized, clean, and prepared for sale.

FIGURE 1-9 New car lots are notoriously packed tight, so caution when moving vehicles is important.

most car lots, meaning that there is not much room for error (**FIGURE 1-9**). Good driving skills and situational awareness are important. The vehicles typically cost between $20,000 and $80,000 each, so an accident would be costly to the dealership.

Lot attendants must also be able to take directions from many different people. They must be able to prioritize these requests to achieve the goals of the dealership. This means that they need to think on their feet, juggle several tasks, have a good memory, and be able to create and modify plans quickly.

Finally, being a lot attendant provides valuable experience in learning how a dealership runs. Many lot attendants move up to other jobs at the dealership. Becoming a lot attendant is a great way to get your foot in the door, even if you have your eye on another job at the dealership.

FIGURE 1-10 Lube technicians are responsible for carrying out all aspects of the vehicle's scheduled maintenance.

TECHNICIAN TIP

Do not think poorly of the lot attendant job. There are people who started as lot attendants who now own the dealership. Starting at the bottom and working your way up gives you great experience and helps you manage others in that role as you promote to higher-level positions.

Lube Technician

A **lube technician** carries out all aspects of manufacturer-scheduled maintenance activities. These technicians work on a range of vehicle systems, performing the following duties (**FIGURE 1-10**):

- Change oil and filters
- Perform fluid inspection and fluid service
- Inspect the vehicle for any issues or concerns
- Reset the maintenance reminder systems
- Rotate tires

While performing these duties, lube technicians also perform a visual inspection of the entire vehicle. They look for any other service needs, such as worn belts, hoses, tires, and suspension system parts. When servicing vehicles, lube technicians are required to raise and support vehicles safely using hydraulic lifts or jacks. They also routinely use hand and air tools.

In addition, lube technicians typically enter time, materials, and the maintenance tasks they performed into the shop's computerized repair order system. They may also be required to assist other types of technicians with their work. Finally, lube technicians are responsible for keeping their workspace and tools clean and organized.

Light Line Technician

A **light line technician** diagnoses and replaces the mechanical and electrical components of motor

FIGURE 1-11 Light line technicians diagnose and replace the mechanical and electrical components of vehicles.

FIGURE 1-12 A heavy line technician removing an engine.

FIGURE 1-13 A chassis and brake technician performing suspension repairs.

vehicles (**FIGURE 1-11**). Common examples of these components include the following:

- Gaskets
- Belts
- Hoses
- Timing belts
- Water pumps
- Radiators
- Alternators
- Starters

In doing their job, light line technicians may be required to perform a variety of tasks:

- Discussing problems with vehicle owners
- Operating special test equipment
- Test-driving vehicles to identify faults

They also need to be able to research service information and interpret wiring diagrams. This information is used to diagnose and make repairs.

In addition, light line technicians reassemble, test, clean, and adjust repaired or replaced parts or assemblies. They use various instruments to make sure that the parts are working properly. They also test and repair electrical systems such as lighting, instrumentation, vehicle sensors, and engine management systems. Finally, light line technicians inspect vehicles. They may issue state safety certificates or list the work required before a certificate can be issued.

Heavy Line Technician

A **heavy line technician** undertakes major engine, transmission, and differential overhaul and repair. These technicians may diagnose, overhaul, repair, or replace parts and assemblies (**FIGURE 1-12**). They must be able to research service information and use that information to help determine the cause of the problem. They also reassemble, test, clean, and adjust repaired or replaced parts or assemblies. This involves using various test and measuring instruments to make sure that the parts are working properly.

Some heavy line technicians are more generalized and work on a broad range of vehicles. Others specialize in particular areas by working on specific makes and models. Heavy line technicians may also specialize in particular vehicle systems, such as engines, transmissions, or final drives.

Chassis and Brake Technician

A **chassis and brake technician** specializes in and works primarily on both the chassis and the brakes of vehicles. This includes steering and suspension system repairs (**FIGURE 1-13**). These technicians inspect, diagnose, and service these systems. In many cases, this also includes performing wheel alignments once any repairs have been completed.

Chassis and brake technicians generally perform this work on all types of vehicles. Diagnosing faults in steering and suspension systems begins with understanding

FIGURE 1-14 Chassis and brake technicians diagnose and repair faults; replace or overhaul brake systems; and test the components of disc, drum, or power brake systems.

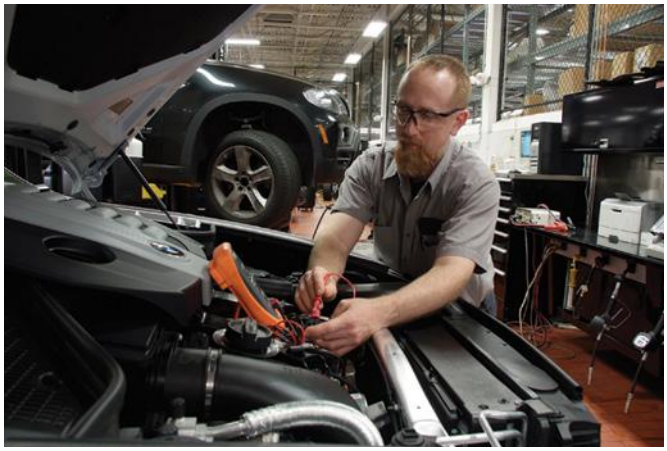


FIGURE 1-15 Electrical technicians install, maintain, identify faults with, and repair electrical wiring and computer-based equipment in vehicles.

the vehicle owner's concern and test-driving the vehicle. They can then note the vehicle's performance and compare that with their knowledge of how the components and systems function. After diagnosis, they replace faulty components. This work could include replacing bushings and servicing wheel bearings. It could involve checking and replacing shock absorbers or steering joints and knuckles, or performing wheel alignments. Chassis and brake technicians also diagnose and repair faults and replace or overhaul brake systems. This involves testing the components of disc, drum, and power brake systems (**FIGURE 1-14**). The information from both the customer and the test drive is used with the service information to diagnose and service the vehicle.

Chassis and brake technicians also visually inspect brake units for wear, damage, or possible failure. They then repair or replace the components as required. Brake technicians can measure brake drums and rotors to the nearest 0.0001" (0.00254 mm). This measurement is used to determine whether the wear or finished size meets specifications. Often, these technicians replace leaky brake cylinders, machine rotors, and drums, when necessary. They also ensure that brake systems are filled with the correct brake fluid, are bled or flushed, and are functioning properly.

Electrical and Drivability Technician

The roles of the electrical and drivability technician may be performed by a single person. Or they may be performed by technicians who specialize in only one of the two areas. For example, in larger shops, roles could be assigned to separate electrical and drivability technicians. In smaller shops, one technician could perform both roles. Often, roles overlap. An electrical technician needs to understand drivability. A drivability technician needs to understand electrical systems.

Electrical Technician

An **electrical technician** diagnoses, replaces, maintains, and repairs electrical wiring and electronic components (**FIGURE 1-15**). These technicians diagnose charging and starting system faults and work with body electric systems. This includes the electrical portions of accessories such as the following:

- Power windows and door locks
- Radios
- Air-conditioning systems
- Lighting systems
- Entertainment systems
- Antitheft systems

They may also perform drivability diagnosis and repair on computer-controlled engine management system faults. This includes faults in the fuel, ignition, and emissions systems.

Often, electrical technicians use meters, oscilloscopes, and test instruments to diagnose electrical faults. They refer to service information and wiring diagrams to understand how circuits operate and are controlled. Once they have a good understanding, they perform tests to locate the cause of the fault. This requires a strong understanding of electrical and electronic theory as well as problem-solving skills. It is said that in electrical repair, the diagnosis is by far the largest part of the job while the actual repair is usually much smaller. Electrical technicians often use solder equipment and special terminal tools when repairing electrical faults.

Drivability Technician

A **drivability technician** diagnoses mechanical and electrical faults that affect the performance and emissions of vehicles. These technicians carry out maintenance activities, replace parts, and repair computer-based systems

FIGURE 1-16 A drivability technician using a scan tool to diagnose a vehicle.

FIGURE 1-17 A transmission specialist rebuilding an automatic transmission.

in vehicles. They work with computer-controlled engine management systems to diagnose and repair faults on mechanical and electronically controlled vehicle systems, including the engine, fuel injection, ignition, and emissions control systems (**FIGURE 1-16**).

Often, drivability technicians use electronic test equipment and circuit wiring diagrams to locate electrical, fuel, and emissions systems faults. Common test equipment includes the following:

- Scan tools
- Pressure transducers
- Exhaust gas analyzers
- Lab scopes
- Meters

They may be required to reprogram (reflash) powertrain control modules (PCMs) using computerized equipment on a wide variety of vehicles. In doing so, they use updates supplied by the manufacturer to ensure that the vehicle runs properly and within acceptable emissions limits.

Transmission Specialist

With the increasing complexity of modern transmissions comes the need for transmission specialists. A **transmission specialist** diagnoses, overhauls, and repairs transmission units using specialized service equipment (**FIGURE 1-17**). These specialists work on various types of manual and automatic transmissions. They usually specialize in either light vehicle or heavy truck transmissions.

Transmission specialists may also work on the other components of the drivetrain, including driveshafts and differentials. They test drive vehicles and listen to customer concerns. They use many of the hand tools that heavy line technicians use, but they also use specialized tools to measure tolerances, check electrical circuits, and measure hydraulic pressures.

FIGURE 1-18 A shop foreman training a new technician on how to perform a procedure.

Shop Foreman

A **shop foreman** is the supervisor in a shop. Shop foremen oversee the work of all types of technicians and staff. They also communicate with customers and external suppliers and handle the various administrative duties involved in running a shop. Some shop foremen are responsible for hiring and training new workers. They may also provide regular performance reviews (**FIGURE 1-18**). They oversee technicians' work to ensure that customers receive quality repair work. The shop foreman is also responsible for enforcing safety procedures at all times. This is to avoid accidental injuries to technicians or damage to vehicles.

Service Consultant

A **service consultant** (also called a *service advisor*) works with both customers and technicians (**FIGURE 1-19**).

FIGURE 1-19 Service consultants work with both customers and technicians.

FIGURE 1-20 The service manager is accountable for the overall performance of the shop.

Service consultants are the first point of contact for the customer and provide advice and assistance to customers concerning their vehicles. They book customer work into the shop, fill out repair orders, price repairs, invoice, and keep track of work being performed. Service consultants also build customer relationships to provide a high level of customer satisfaction. They are the interface between the technician and the customer. Good communication and organizational skills are essential. A service consultant can advance to become a service manager.

Service Manager

The role of a **service manager** is demanding and challenging. Service managers are responsible for the functioning of the entire service department. This career requires great communication skills and the ability to motivate people (**FIGURE 1-20**). Service managers are critical in creating a positive work environment. They often hire and supervise employees in the service department. They deal with any customer complaints. They are also accountable for the overall performance of the shop.

This job requires the following qualities:

- Personal commitment and focus
- Exceptional people skills
- Excellent leadership ability
- High level of business knowledge

Service managers may have worked their way up through the various roles within a shop. For example, the service manager may have once been a technician or a service consultant. Others may enter the position with backgrounds and college degrees in business management. In smaller shops, the service manager typically reports directly to the business owner. In larger shops, the service manager reports to the service director, who in turn reports to the business owner.

Technician Pay

Technicians can be paid in one of three common ways: flat rate, hourly, or hourly plus a bonus. Flat rate is currently the most common basis for pay. In this system, technicians are paid a flat rate for each job they do no matter how long or short it takes. For example, if changing the water pump on a certain car is specified to take two hours, the technician is paid two hours to change it. If the technician changes it in one hour, they are still paid for two hours of work. If it takes four hours, they are paid for only two hours. If you learn the job well and have the right tools, you can make more than your hourly wage on the flat rate basis. The flip side is that if you are a slow worker or encounter difficulties in the process, you will make less than your hourly wage. Another potential downside of flat rate pay is that the technician doesn't get paid to fix the job if it comes back with a problem.

Hourly technicians are paid for each hour they work, no matter how much work they get done. If they work eight hours, they are paid for eight hours. Technicians who are paid hourly plus a bonus get paid for the time they work, and they also get a bonus. The bonus could be based on the number of billable hours. It could also be based on the amount of additional work that they find a vehicle needs that the customer approves. Or it could be based on the shop's productivity over a certain time frame, such as a month.

TECHNICIAN TIP

Automotive shops slow down from December (holidays) until March (tax season) in many parts of the country. Technicians on the flat rate system need to plan for smaller paychecks during this time of year.

Types of Shops

LO 1-3

Describe each type of repair facility.

Shops can be broken down into the following types of repair facilities:

- Dealerships
- Independent shops
- Specialty shops
- Franchises
- Fleet shops

Each type of shop caters to a particular segment of the industry and to specific customer needs. Knowing the focus of the different types of shops will help you determine your interest in pursuing a career there.

Dealerships

Dealerships are affiliated with specific vehicle manufacturers. The dealership sells new and used vehicles and technicians perform maintenance, service, and warranty repairs on that manufacturer's vehicles (**FIGURE 1-21**).

Customers with newer vehicles often return to the dealership for services covered under warranty. This means that dealership technicians have the chance to work on the latest vehicles, which are at the cutting edge of vehicle technology. This can make diagnosis and repair more difficult. Because of this, manufacturers provide their technicians with additional resources. The first is factory training for their technicians. Technicians attend these training classes to learn how to maintain, diagnose, and repair these vehicles. Also, dealership technicians have instant access to the manufacturer's service information. This information is much more complete than generic service information. Finally, when dealership technicians run into a difficult diagnostic situation, they have direct access to the manufacturer's service representatives. These representatives have additional training and experience and are great resources to dealership technicians.

Independent Shops

Independent shops are not affiliated with vehicle manufacturers. Thus, they have limited access to new vehicle technology training (**FIGURE 1-22**). They typically service a broad range of vehicles. However, it is common for independent shops to limit their clientele. They usually specialize in European, Asian, or domestic vehicles. Some shops specialize in a particular system of the vehicle, such as brakes and alignment. Independent technicians often work on vehicles that are out of warranty. Although technicians need to be familiar with diagnosing vehicles from several manufacturers, the technology has been around for a while. This helps offset the challenge of needing to know a variety of vehicles.

TECHNICIAN TIP

A good way to help decide which type of shop you would like to work in is through either a job shadow or internship. Being able to observe the employees and customers will give you a good feel for what you prefer. The more shops you can observe, the better.

Specialty Shops

Specialty shops are usually independent shops that focus on one type of service. Common examples are transmission service, electrical system repair, or tires and wheel alignment (**FIGURE 1-23**). They usually become experienced with the system they work on, allowing them to provide excellent service. They typically work on a variety of vehicles from a variety of manufacturers. A shop that specializes in one area, such as air-conditioning, may

FIGURE 1-21 Dealership technicians perform maintenance, service, and warranty repairs on vehicles sold by a particular manufacturer.

FIGURE 1-22 Independent shops are not affiliated with vehicle manufacturers.

FIGURE 1-23 Specialty shops focus on one type of service.

FIGURE 1-24 Typical quick lube franchise business.

experience a slow period during certain times of the year. This is appealing to some owners who enjoy vacation time.

Franchises

Franchises are similar to specialty shops, but they are connected to a larger parent organization. This can help with marketing. It also provides a mechanism for warranty claims that are honored at related franchise shops across the country. Some examples include Goodyear Tire Company, AAMCO Transmissions, and Jiffy Lube (**FIGURE 1-24**).

Fleet Shops

A fleet shop maintains and repairs a specific fleet of vehicles. It could be a private business that services its own vehicles in-house (**FIGURE 1-25**). It could also be a government agency, such as a city or county, that services its own vehicles and equipment.

It is important that all vehicles are serviced on a regular basis to prevent downtime. This is especially true for commercial vehicles that are depended on for work. This means that most of the fleet shop work is at the maintenance and light repair level. If larger repairs are needed, some fleet shops send the vehicle to either a dealership or a specialty shop. Fleet shops are typically a bit slower paced than other types of shops. This is because fleet technicians are generally paid on an hourly basis. They do not have the same time constraints as most dealership and independent technicians, who are paid on a flat rate basis.

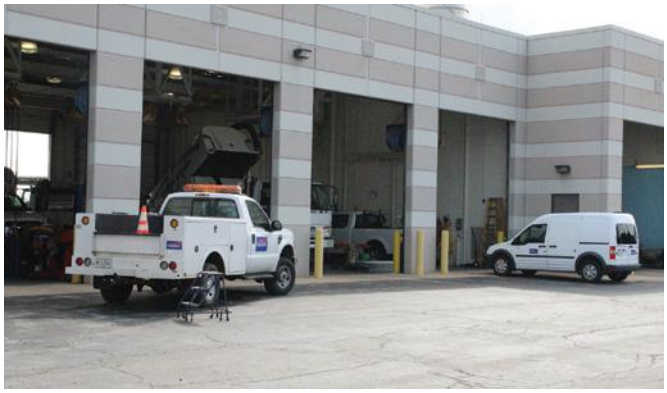


FIGURE 1-25 Fleet shop.

Automotive Industry Certification

LO 1-4

Explain the importance of automotive industry certification and ongoing training.

The automotive service industry in the United States usually does not require technicians to be licensed, although some localities and shops do. This means that a technician generally does not have to pass a licensure test to work in the industry. Still, many technicians become **Automotive Service Excellence (ASE)** certified (**FIGURE 1-26**). This certification helps technicians show their skill to potential employers. It also helps create a professional workplace, which helps shops promote their businesses to customers. The ASE is an independent, nonprofit organization. It is dedicated to improving vehicle repair by testing and certifying automotive professionals.

Recently, the ASE updated their levels of certification (**FIGURE 1-27**):

- ASE student certification
  - Students must pass a student-level written test.
  - No work experience is required.
  - It is valid for two years.
- ASE maintenance and light repair (MLR) certification
  - Technicians must pass the MLR written test.
  - One year of qualifying work experience is required.
  - It is valid for five years.

FIGURE 1-26 The ASE certifies automotive technicians.
Courtesy of National Institute for Automotive Service Excellence (ASE).

	ASE Entry-Level Certification	Maintenance & Light Repair (G1)	All Other ASE Certifications	L1, L2, L3
Required Work Experience	None	1 Year	2 Years	3 Years
Duration of Certification	2 Years	5 Years	5 Years	5 Years

FIGURE 1-27 ASE certification levels.
Courtesy of ASE Education Foundation.

- ASE journeyman-level certification
  - Technicians must pass one or more ASE certification tests.
  - Two years of qualifying work experience as a technician is required.
  - It is valid for five years.
- ASE advanced-level certification
  - Technicians must have passed certain prerequisite regular tests.
  - Technicians must pass one or more advanced-level tests.
  - Three years of qualifying work experience is required.
  - It is valid for five years.

FIGURE 1-28 The ASE Education Foundation accredits automotive training programs.
Courtesy of ASE Education Foundation

All but the student-level ASE certification needs to be renewed every five years. Renewal is done by taking and passing recertification tests. Renewal tests can be taken on-site or through the ASE Renewal app. If you use the ASE Renewal app, questions are delivered electronically every month. After answering enough correctly, your ASE certification will be extended another year. There are currently about 300,000 certified ASE technicians in the United States.

The **ASE Education Foundation** is an accrediting body. It certifies secondary and postsecondary automotive, diesel, and collision repair programs (**FIGURE 1-28**). The ASE Education Foundation is an independent, nonprofit organization under the umbrella of the ASE. For programs to be accredited by the ASE Education Foundation, they have to demonstrate their compliance to a rigorous set of standards. The standards are developed by the automotive industry.

Program instructors must also maintain ASE certification in the areas they teach. Instructors must complete at least 20 hours of technical update training each year. ASE Education Foundation accreditation is valid for five years, at which point the program must go through a re-accreditation process.

The ASE Education Foundation has recently brought another organization under its umbrella: Automotive Youth Educational Systems (AYES). The goals of AYES have now been integrated into the mission of the ASE Education Foundation. According to the ASE Education Foundation website, their mission is "to educate, prepare and inspire a new kind of automotive service workforce. One that embraces innovation, today's workforce demands and critical thinking." They do this by establishing business and education partnerships among the following:

- Qualified high school automotive programs
- Qualified automotive dealers and aftermarket service employers

- Qualified high school automotive technology students

These programs may receive access to new vehicle technology and manufacturer service information. This can help prepare students for working on today's vehicles. It is also a great way for students to enter the automotive workforce.

One part of this model is a 320-hour internship opportunity. Internships usually take place during the summer between the student's junior and senior years. During this internship, students work alongside a trained and qualified mentor. This is usually an ASE-certified Master Technician. By working this way, students receive firsthand experience working in a real shop. This helps prepare them for entry-level career positions. It also allows them to pursue advanced studies in automotive technology. It is a great way for students to practice what they are learning in the training program. Shops and manufacturers also benefit from working with highly motivated students who are preparing to work for them.

Special Certification

The automotive industry has two special certification requirements. These apply only to certain automotive technician specialists. To diagnose and repair vehicle emissions failures in some localities, technicians must be certified by the appropriate agency. In many cases, the technician must have ASE advanced engine performance certification. In other cases, the technician must have passed an approved emissions specialist's course.

Technicians who handle refrigerants or work on air-conditioning systems need special Environmental Protection Agency (EPA) section 609 certification. This is obtained by taking a training course and passing the 609 exam. Once certified, technicians are legally able to handle refrigerants and repair air-conditioning systems. All students should obtain their 609 certification during their training program. They can then show it to potential employers when they graduate (**FIGURE 1-29**).

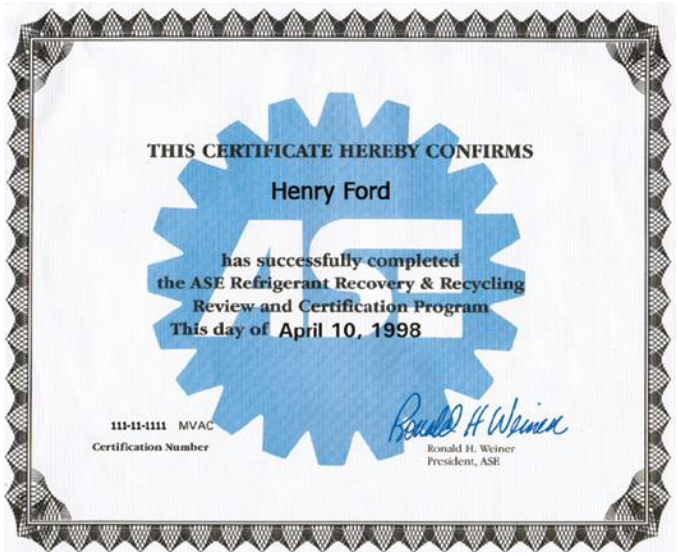


FIGURE 1-29 EPA 609 certificate.
Courtesy of ASE Education Foundation

FIGURE 1-30 Dealership technicians at a regional training class.

TECHNICIAN TIP

After you graduate, be sure to continue to seek out new industry information. A lifelong commitment to learning will help keep you on the cutting edge of new technology and will bring you far in your career.

Ongoing Training

Even after technicians graduate from automotive technology programs, they are never finished learning. Being an automotive technician means that you will always be learning new things. Vehicle technology changes rapidly. In fact, it is easy to fall behind. Training classes help technicians stay up to date.

Dealership technicians typically have access to the manufacturer's online training classes. They also have the chance to attend regional training classes (**FIGURE 1-30**). Independent technicians usually have a more difficult time accessing training. However, there are both online and face-to-face classes that technicians can attend.

Also, organizations like the Automotive Service Association (ASA) hold yearly regional training conferences. These conference sessions are popular and attract some of the best minds in the industry. No matter what, successful automotive technicians are always learning. By doing the same, you are preparing for an exciting and rewarding journey.

WRAP-UP

Ready for Review

- Karl Benz is generally acknowledged to have invented the modern automobile around 1885.
- The advent of mass production made automobiles available to more people in the early 1900s. Lower cost and greater availability allowed the automobile to become the preferred mode of personal transportation.
- The automotive sector provides many career choices within the manufacturing, service, and retail industries. Positions include, but are not limited to, lot attendant, lube technician, light line technician, heavy line technician, chassis and brake technician, electrical and drivability technician, transmission specialist, shop foreman, service consultant, and service manager.
- Technicians are typically paid on one of the following systems: flat rate, hourly, or hourly plus bonus.
- Shops that cater to specific customer needs can be categorized as dealerships, independent shops, specialty shops, franchises, and fleet shops.
- Automotive Service Excellence (ASE) certification helps technicians prove their skills to employers and helps shops market themselves to customers.
- The ASE Education Foundation accredits automotive training programs to ensure that they are preparing students for the workplace.
- The ASE Education Foundation also facilitates partnerships among local shops, training programs, and students. Each of these three groups benefits greatly from this partnership.
- As vehicle technology continues to change at a rapid rate, training classes help technicians stay up to date and prepared for an exciting and rewarding journey.

Key Terms

ASE Education Foundation The portion of Automotive Service Excellence (ASE) that evaluates and accredits automotive technology programs. It also brings together secondary training programs, shops, and students.

Automotive Service Excellence (ASE) An independent, nonprofit organization dedicated to the improvement of vehicle repair through the testing and certification of automotive professionals.

chassis and brake technician A technician who services the chassis and brake systems.

drivability technician A technician who diagnoses and identifies mechanical and electrical faults that affect vehicle performance and emissions.

electrical technician A technician who diagnoses, replaces, maintains, identifies faults with, and repairs electrical and electronic equipment in vehicles.

heavy line technician A technician who undertakes major engine, transmission, and differential overhaul and repair.

just-in-time manufacturing A process in which large-scale parts manufacturers preassemble various parts into unit assemblies, which are then delivered in the correct order to the vehicle manufacturer shortly before assembly, meeting with the specified vehicle at just the right time.

light line technician A technician who diagnoses and replaces the mechanical and electrical components of motor vehicles.

lot attendant A person who is responsible for keeping vehicles in salable condition on a car lot.

lube technician A technician who carries out scheduled maintenance activities on a range of mechanical and related vehicle components.

service consultant A customer service worker who works with both customers and technicians. This person is the first point of contact for customers seeking vehicle repairs; also called a *service advisor*.

service manager The person who is responsible for the management of the service department.

shop foreman The supervisor in a shop who oversees the work of technicians and staff and who communicates with customers and external suppliers.

transmission specialist A technician who diagnoses, overhauls, and repairs transmissions.

Review Questions

1. When compared to early vehicles, modern vehicles do NOT have:
   a. as much sophistication and reliability.
   b. as much speed.
   c. as many maintenance requirements.
   d. as many convenience systems.
2. Which of the following statements is true?
   a. Interchangeability means that parts do not have to be custom built to match a particular car.
   b. Assembly line manufacturing involved workers moving to the car as it was being assembled rather than bringing the car to the worker.
   c. The advent of mass production made automobiles available only to the wealthy.
   d. Efficiency in mass production is increased when parts are produced where the vehicle is being assembled.
3. In just-in-time manufacturing:
   a. there is no need for scheduling.
   b. the manufacturer doesn't have to store large quantities of parts.
   c. parts are delivered a few months before assembly and in the order the supplier prefers.
   d. technology use is reduced in response to environmental pressures.
4. Which of the following would be the most likely to program or reprogram (reflash) powertrain control modules (PCMs) using computerized equipment?
   a. Transmission specialists
   b. Brake technicians
   c. Drivability technicians
   d. Heavy line technicians
5. All of the following statements are true EXCEPT:
   a. service consultants work only with customers.
   b. a shop foreman is the supervisor of the shop.
   c. service managers are responsible for the functioning of the entire service department.
   d. a shop foreman may be responsible for hiring and training new workers.
6. A technician wants to be at the cutting edge of technology. Which type of repair facility would be the best fit for them?
   a. Franchise
   b. Fleet shop
   c. Independent shop
   d. Dealership
7. Jiffy Lube outlets are examples of:
   a. dealerships.
   b. franchises.
   c. fleet shops.
   d. independent shops.
8. Which of the following type of shop is a bit slower paced?
   a. Dealerships
   b. Franchises
   c. Fleet shops
   d. Independent shops
9. Special certification is required for technicians who handle which of the following systems?
   a. Refrigerants and air-conditioning systems
   b. Computer-controlled systems
   c. Automatic transmission systems
   d. Engine management systems
10. Which of the following organizations certifies technicians in all areas of vehicle repair?
    a. EPA
    b. ASE
    c. ASA
    d. AYES

ASE Technician A/Technician B-Style Questions

1. Technician A says that newer vehicles require less maintenance compared to older vehicles. Technician B says that major repairs are needed more frequently on newer engines. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B
2. Technician A says that Henry Ford is known for the invention of the gasoline engine. Technician B says that Karl Benz is credited with the invention of the automobile. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B

3. Technician A says that vehicle production today requires a mix of robotic and human assembly. Technician B says that most of the parts on a vehicle are preassembled into unit assemblies before they reach the assembly line. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B
4. Technician A says that the jobs in the automotive industry are limited to technicians and service advisors. Technician B says that the automotive industry offers numerous career choices. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B
5. Technician A says that a technician can specialize in different areas based on their interest and ability. Technician B says that most specialty shops, such as transmission shops, primarily work on only one manufacturer's vehicles. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B
6. Technician A says that the shop foreman is the first point of contact for customers. Technician B says that the service consultant typically reports directly to the business owner. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B
7. Technician A says that dealership technicians generally have access to manufacturers' training courses. Technician B says that an independent shop works on a wide variety of vehicles, requiring technicians to have a broad skill level. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B
8. Technician A says that EPA section 609 certification is required for all technicians. Technician B says that having ASE certifications can make it easier to get a job. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B
9. Technician A says that franchises are connected to a larger parent organization. Technician B says that independent shops usually work on vehicles that are still in warranty. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B
10. Technician A says that a technician can progress to different jobs within the industry. Technician B says that careers in the automotive industry include lot attendants. Who is correct?
    a. Technician A
    b. Technician B
    c. Both Technician A and Technician B
    d. Neither Technician A nor Technician B

CHAPTER 2

Introduction to Automotive Technology

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

2-1 Identify vehicle body types and their characteristics.

2-2 List the functions of common vehicle systems and describe general vehicle operation.

2-3 Describe drivetrain layouts and their major components.

2-4 Describe torque and identify engine configurations.

YOU ARE THE AUTOMOTIVE TECHNICIAN

The sales manager asks you to provide training for the new vehicle sales associates in your recently expanded dealership. The first training lesson takes place in the dealership showroom, where several styles of vehicles are on display. You explain the concept of the unibody design and compare it to the full-frame design. You also show examples of various drivetrain layouts and discuss their pros and cons. The second training lesson is in the shop area designated for engine repair. You show the trainees the various engine classifications and configurations.

What are the common vehicle body types and their characteristics?

1. How does the unibody design differ from the full-frame vehicle?
2. What are the benefits of the unibody design?
3. What are the various engine configurations, and how do they differ?
4. How is a transaxle different from a transmission?

Introduction

As you prepare to work in the automotive repair industry, you will need to learn a whole new vocabulary. Some examples of these terms are *hygroscopic*, *asymmetrical*, *reciprocating motion*, and *volumetric efficiency* (**FIGURE 2-1**). It's similar to healthcare professionals. They need to know how each of the body's systems functions, the organs that make up the system, and how to diagnose an issue. Automotive technicians need to have the same level of understanding about vehicles. The good news is that automotive names are not in Latin, as they are in health care, although sometimes it may seem like they are.

Knowing automotive terminology and concepts will help you fit into your new work environment. It will also help you communicate accurately with customers, suppliers, and fellow employees. You will be able to complete repair orders, parts requisitions, and warranty paperwork as you maintain, diagnose, and repair vehicles. This chapter will help you start the process of learning automotive terminology related to vehicle types, drivetrain layouts, engine configurations, and axle arrangements.

Overview of Vehicle Design

LO 2-1

Identify vehicle body types and their characteristics.

Vehicle bodies come in a variety of designs depending on the intended function of the vehicle. They are also designed to incorporate style, aesthetics, and, most importantly, safety. Vehicle body design has changed over time to accommodate the owners' lifestyles and personal tastes (**FIGURE 2-2**). Look, for example, at the Scion XB or the Tesla Model X. Each of these vehicles has a unique body design to fit the needs and taste of its owner. Manufacturers also use vehicle body design in advertising to tempt buyers to purchase their vehicles.

Common types of body design cater to both passenger and light commercial use. Terms to describe various body designs have become part of common automotive language. However, names describing the same body design type can vary from country to country. For example, a sedan in the United States is a saloon in the United Kingdom. This text will use U.S. terms. Types of body designs include the following:

- Sedan
- Coupe
- Hatchback
- Convertible
- Station wagon
- Pickup
- Minivan and van
- Sport utility vehicle

Glossary Excerpt	
AMP	Ampere
AMP/hour	Amperes per hour. A standard measure for a rate of current flow.
Amperage	An amount of current, expressed as amperes
Ampere	Usually called an *amp*, the unit for measuring electrical current
Ampere turns	The unit of measurement for electrical magnetic field strength
Analog instrument	An instrument that displays measurements with a needle on a dial
Analog signal	An electrical signal that varies in amplitude within a given parameter
Anchor	A mounting point on a vehicle for a stressed, nonstructural component such as a seat or seat belt
Anchor end	The end of a brake shoe that is attached to a fixed point on the backing plate
Anchor pin	The steel pin attached to the backing plate of drum brakes. Return springs are attached to the anchor pin and to the brake shoes to hold the shoes against the anchor pin in a non-applied position. In an applied position, it prevents the shoes from rotating with the drums.
Anion	A negative ion. Alkali, molten carbonate, and solid oxide fuel cells are anion-mobile cells.
Anode	The positively charged electrode in an electrolytic cell toward which current flows
Anodize	An electrochemical process that coats and hardens the surface of aluminum
ANSI	American National Standards Institute. A privately funded organization that promotes uniform standards in areas such as measurements.
Antenna	A conductive metallic structure used for radiating or receiving electromagnetic signals, such as those for radio transmissions and television signals
Antifoam agent	An additive that reduces foaming caused by the churning action of the crankshaft in the engine oil
Antifreeze	A liquid that easily mixes with water and is used to cool the engine. It also lowers the coolant's freezing point and increases its boiling point. Coolant is typically mixed at a ratio of 50% antifreeze and 50% water.

FIGURE 2-1 A sample list of automotive vocabulary terms.

A

B

FIGURE 2-2 Vehicle body design continues to evolve to accommodate the owners' lifestyles and personal tastes. **A.** Car from the 1950s. **B.** Car from the 2020s.

FIGURE 2-3 A sedan has an enclosed body, with a maximum of four doors.

FIGURE 2-4 Traditionally, the coupe has two standard-size seats in front, with two smaller seats behind.

Sedan

A **sedan** has an enclosed body, with a maximum of four doors to allow access to the passenger compartment (**FIGURE 2-3**). The sedan design also allows for storage of luggage or other items in a trunk. The trunk is located in the rear of the vehicle and is accessible from a trunk lid. A sedan traditionally has a fixed roof. However, there are soft-top versions of sedans, which have only two doors.

Coupe

A **coupe** has only two doors. Reducing the number of passenger compartment doors makes the vehicle structurally more rigid. Traditionally, a coupe has two standard-size seats in front and possibly two smaller seats behind (**FIGURE 2-4**). Coupes are available in both a fixed-roof and a convertible style. They also are equipped with a trunk for storage purposes. In most cases, the trunk is on the small side.

Hatchback

A **hatchback** is available in three-door and five-door designs. The odd-numbered door is a hatch that lifts up at the rear of the vehicle. This gives access to the luggage area. The rear seats usually fold down to increase the luggage area (**FIGURE 2-5**). Often, the rear seat is split. This allows one side to be folded down if the other seat is required for a passenger. Hatchbacks are versatile vehicles, combining some of the benefits of both sedans and station wagons.

Convertible

A **convertible** is an automobile with a roof that can be removed, retracted, or folded away (**FIGURE 2-6**). The roof is most often a flexible fabric such as canvas or vinyl. Most convertibles use electric motors that retract and raise the top. In some vehicles, known as *hardtop convertibles*, the roof is made of folding or fixed steel or fiberglass panels. When in place, the hard roof makes these vehicles look more like conventional fixed-roof coupe

FIGURE 2-5 Rear seats in hatchbacks usually fold down to increase the luggage area.

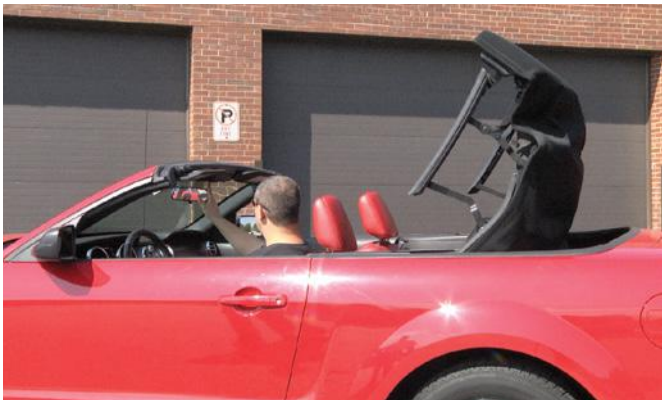


FIGURE 2-6 A convertible is an automobile that can convert from having an enclosed top to having an open top by means of a roof that can be removed, retracted, or folded away.

vehicles (**FIGURE 2-7**). In other vehicles, such as a T-top, only a smaller section of the roof area is convertible. The term *roadster* was applied to a vehicle with no permanent roof covering or side windows. Nowadays, the term is most often used to describe any convertible sports car.

TECHNICIAN TIP

A convertible is commonly known as a *cabriolet* in Europe.

Station Wagon

A **station wagon** has an extended roof that goes all the way to the rear of the vehicle. It is similar to a van but not as tall. The extra length in the roof increases the luggage capacity. In some cases, the passenger capacity is increased with extra seats in the very rear of the vehicle. Station wagons have a large rear door for easy access. The

FIGURE 2-7 Hardtop convertibles have a hard roof that makes the vehicle look more like a conventional fixed-roof vehicle.

FIGURE 2-8 A station wagon has increased luggage capacity and a large rear door for access.

rear seats can usually be folded to increase the storage capacity even further (**FIGURE 2-8**). Station wagons usually have fixed roofs.

Pickup

The **pickup**, or **truck**, carries and tows cargo. Usually, it has heavier-duty chassis and suspension components than a passenger car. This is used to support greater loads. Traditionally, pickups had only a single cab with two doors. This limited the number of passengers they could carry. Today's pickups have options for extended cabs or four-door versions to carry more passengers (**FIGURE 2-9**). In some cases, the four-door pickup has a reduced cargo-carrying space. This is to accommodate the extra seating in the cab.

Minivan and Van

A **minivan** is usually a lighter-duty vehicle. Minivans have suspension systems similar to those in passenger

FIGURE 2-9 More recent versions of pickups have options for extended cabs or four-door versions to carry more passengers.

FIGURE 2-10 Minivans can be configured for maximum cargo space or maximum passengers.

cars. Alternatively, full-size vans use heavy-duty pickup truck–type suspension systems. Minivans can be configured in two different ways. The first way maximizes the number of seats for passengers. The second way maximizes the cargo space (**FIGURE 2-10**). Also, because they are light duty, the fuel economy of minivans is substantially better than that of full-size vans.

Sport Utility Vehicle

The **sport utility vehicle (SUV)** is popular in the United States. SUVs can easily be used to carry out functions that would otherwise require several different vehicles (**FIGURE 2-11**). They act like both a full-size van and a pickup. They typically have a heavy-duty chassis so that they can carry heavier loads. This load can be in the form of passengers, luggage, or cargo. They can also tow moderately heavy loads. This makes them a great vehicle for family outings, as they can pull a trailer while still carrying a several passengers and luggage.

FIGURE 2-11 Sport utility vehicles (SUVs) are designed for flexible use while being heavier duty than minivans.

Vehicle Chassis

A **chassis** is an underlying supporting structure where some vehicle components are mounted. It is similar to the skeleton of a human. In a vehicle, a traditional chassis gives the vehicle structural strength. It also has a platform to mount the engine, wheels, transmission, and all the other mechanical components. The vehicle body is also bolted onto this frame. Originally made of wood, vehicle chassis were soon changed to an open steel ladder-frame structure. This is easier to manufacture and is longer lasting (**FIGURE 2-12**).

Body-on-frame is the term used when a vehicle body is mounted on a rigid frame or chassis. It was the preferred way of building passenger vehicles. Manufacturers did not need to retool the structural components to release new models of vehicles with different body styles. However, by the 1960s, most manufacturers switched to vehicle designs that integrated the bodywork into a single unit with the chassis. The vehicle body became part of the vehicle structure rather than just an external skin. This is the **unibody design**, or single-shell design (**FIGURE 2-13**). The unibody design is constructed of many steel sheet metal panels. They are precisely formed in presses and spot-welded together into a structural unit.

The unibody design was first used in aircraft and then spread to automobiles. This is because with less of a chassis component, it was quicker to manufacture and lighter in weight. The lighter weight meant less cost in both material and labor. Another benefit of being lighter was that the vehicles became more fuel-efficient.

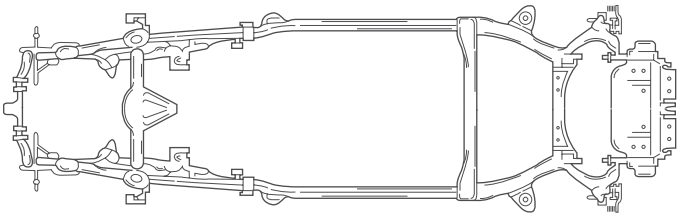


FIGURE 2-12 Steel ladder-frame chassis.

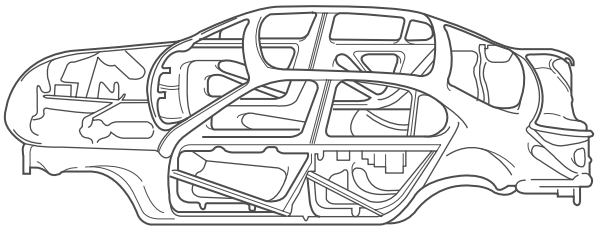


FIGURE 2-13 The unibody design.

Vehicle Closure Designs

Apart from the vehicle doors, a vehicle body contains many openings that allow access to various parts of the vehicle. These include the following:

- Engine compartment hood
- Hatch and tailgate openings
- Fuel door
- Battery access cover (in some cases) or charging port door

All these openings have to be secured and may require a remote switch or lever to be activated. In some cases, the access door is opened mechanically by the driver pulling a lever. This moves a cable and releases a latch. Other doors may use electric- or vacuum-operated solenoids to release the latch. In this case, the driver pushes a switch that sends an electric or vacuum signal to the release mechanism, which releases the door. Some fuel doors and charging port doors unlock automatically when certain parameters are met. This could be when the key fob is removed from the vehicle without locking the vehicle doors. It could also be when the key fob is brought near the fuel door. Some rear hatch doors have a hinged window incorporated. This window offers easy access to the storage space without opening the entire back door.

Engine compartment hoods on modern-day vehicles usually have a remote release lever. This lever prevents unauthorized access to the engine compartment. This is mainly for security reasons. The release lever is usually located inside the passenger compartment. It may be found under the dash, in the glove compartment, or on a doorjamb (**FIGURE 2-14**). Once the hood is open, it stays open by one of the following three methods: large springs on the hinges, pressurized gas strut assemblies, or a prop rod (**FIGURE 2-15**).

FIGURE 2-14 The engine compartment release may be located inside the passenger compartment under the dash, in the glove compartment, or on a doorjamb.

Vehicle Systems and Operation

Every vehicle is made of many different systems. Each system is critical to the operation, passenger safety, and environmental impact of the vehicle. Together, the systems work to drive the vehicle and provide safety, comfort, and entertainment for the occupants. It is important for technicians to understand what the systems do and how they operate. Let's get started.

Overview of Vehicle Systems

LO 2-2

List the functions of common vehicle systems and describe general vehicle operation.

A vehicle's components are arranged in systems that are designed to perform specific functions (**FIGURE 2-16**). Knowing all the systems and their purposes will aid you when we explore them further. Here is a list of the major vehicle systems:

- Powertrain system: One of the largest systems on the vehicle. It has several smaller subsystems to get its job done. It powers the vehicle down the road and provides all on-vehicle power.
- Engine system: The power plant of the vehicle. This system converts gasoline energy or electrical energy into mechanical energy.
- Lubrication system: Lubricates the internal components of the engine for long life and quiet operation.

A B C

FIGURE 2-15 Mechanisms for holding hoods open. **A.** Springs. **B.** Gas strut. **C.** Prop rod.

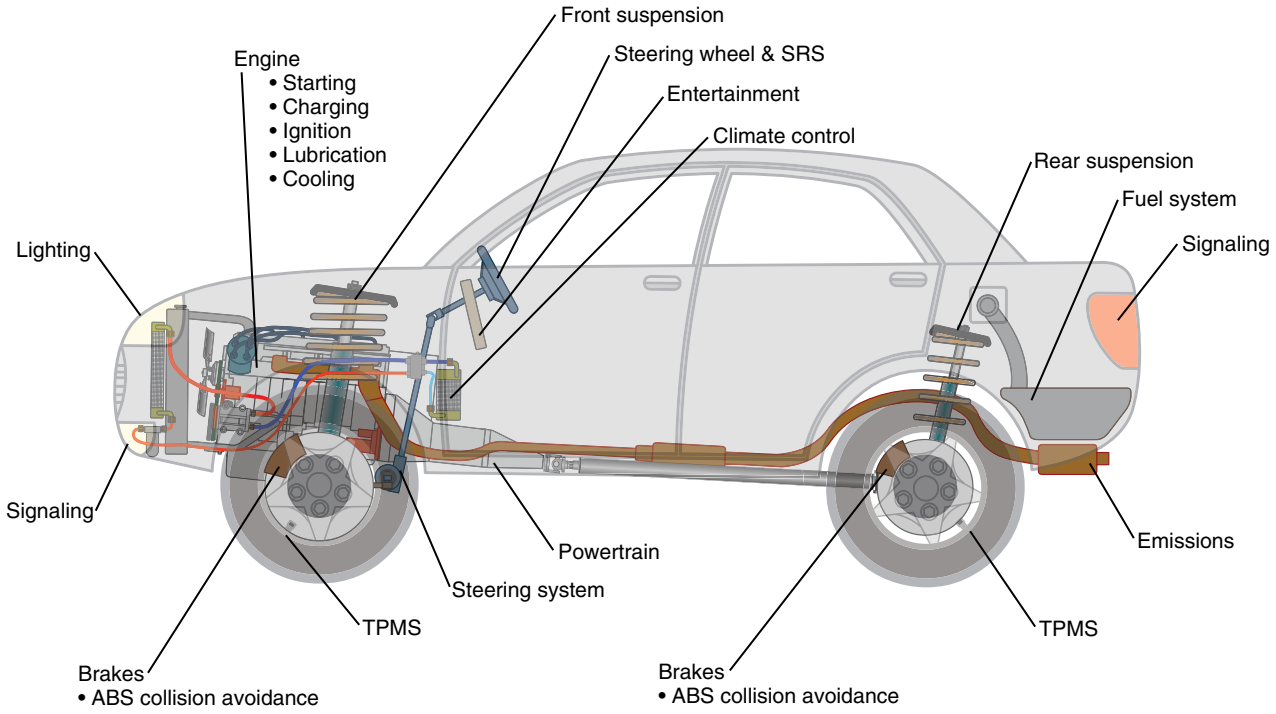


FIGURE 2-16 Vehicles are made from a variety of systems.

- Cooling system: Regulates the temperature of the engine so that it operates at the ideal temperature for efficiency and long life.
- Fuel system: Stores and delivers the correct amount of fuel to the engine's combustion chambers.
- Ignition system: Creates and delivers high-voltage sparks at the right time. This ignites the air-fuel mixture in the combustion chamber.
- Emissions control system: Controls and reduces the amount of harmful emissions that the powertrain creates.

- Transmission system: Extends the vehicle's operating range by multiplying either the engine's torque or the engine's speed.
- Electrical system: The nerve center of the vehicle. Electricity is used in all the vehicle's systems. It can be used to control, and possibly power, circuits.
- Starting system: Used to crank the engine over so that it will start and run. Cranking is usually performed by an electric starter motor.
- Charging system: Used to charge the vehicle's battery as well as run the entire vehicle's electrical system when the engine is running.
- Lighting system: Supplies lighting both outside and inside the vehicle, including warning lights.
- Entertainment system: Provides entertainment such as audio, video, and internet to vehicle occupants.
- Safety system: An important system on the vehicle that is designed to protect the vehicle's occupants. In some vehicles, it also provides a level of accident avoidance.
- Supplemental restraint system (SRS): Designed to restrain and cushion vehicle occupants in an accident.
- Tire pressure monitoring system (TPMS): Monitors tire pressure and warns the driver of tires with low pressure.
- Crash avoidance system: Monitors the area around the vehicle and predicts potential accidents. It then either alerts the driver or takes evasive actions to avoid the accident.
- Climate control system: Maintains a comfortable temperature and humidity inside the vehicle. Also clears the windshield of fog and frost.
- Braking system: Used to slow or stop the vehicle. Must be capable of working quickly and on all types of surfaces.
- Steering system: Allows the vehicle to track straight while making it easy for the wheels to be steered by the driver, without losing control.
- Suspension system: Keeps the tires in contact with the road surface while absorbing road harshness. It also reduces vehicle body sway and dive during vehicle maneuvers.

We cover each of these systems and more in the following chapters. This is so that you will be prepared to maintain, diagnose, and repair them. For now, sit back and see how some of these systems work together as the vehicle drives down the road.

Vehicle Operation Overview

For a vehicle to operate, a lot of almost magical things need to happen. First, vehicle operation requires a means of converting stored energy into a form of energy that can turn the wheels. In most vehicles, the stored energy is in the chemical form of gasoline or diesel fuel. Nowadays, natural gas, alcohol, biodiesel, hydrogen, and battery acid are also used in vehicles as their stored chemical energy source.

Chemical energy can be converted into mechanical energy in two primary ways. The first is through the operation of an internal combustion engine. The second is through the operation of a battery and electric motor (**FIGURE 2-17**). Both of these methods take energy in a chemical form and convert it into mechanical energy by causing a shaft to rotate. In an internal combustion engine, it is the crankshaft that rotates. In an electric motor, it is the armature. The shaft then provides mechanical energy to move the vehicle. It also powers all the other accessories on the vehicle.

The vehicle's internal combustion engine is an engineering marvel. It combines fuel with air to create a combustible mixture. This mixture is compressed by the

A

B

FIGURE 2-17 Stored chemical energy is converted to mechanical energy to propel the vehicle down the road. **A.** Internal combustion engine. **B.** Hybrid engine with internal combustion engine and electric motor.

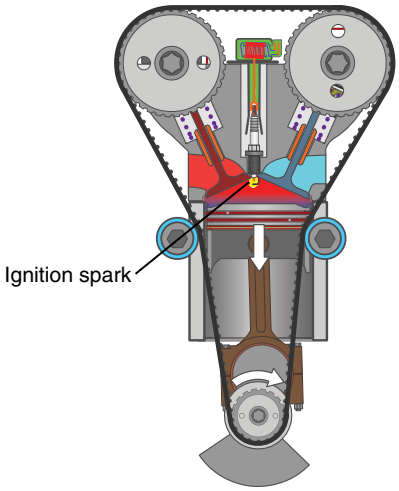


FIGURE 2-18 Internal combustion engine.

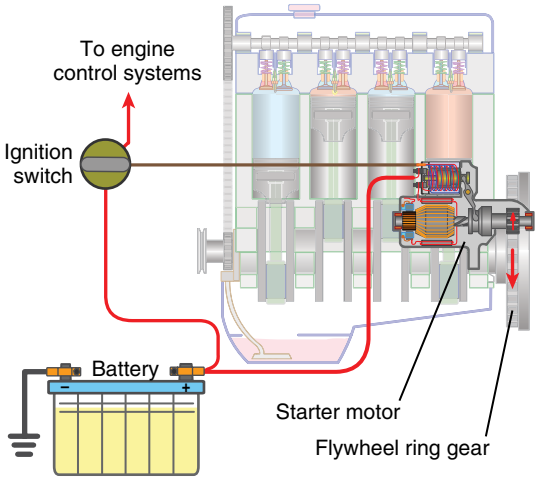


FIGURE 2-19 The starter cranks the engine over.

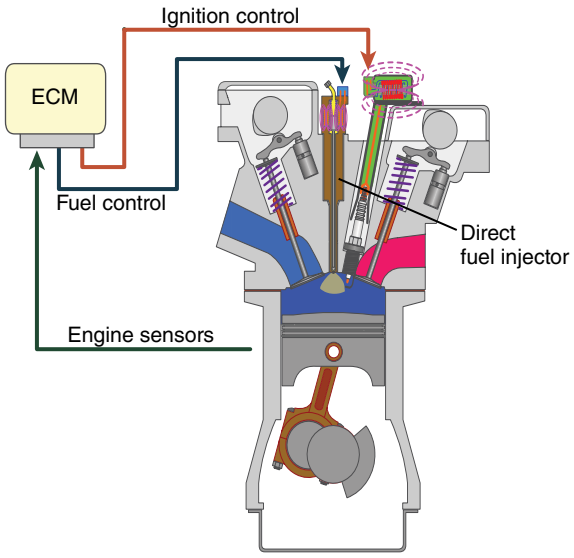


FIGURE 2-20 The engine management system controls the amount of fuel injected.

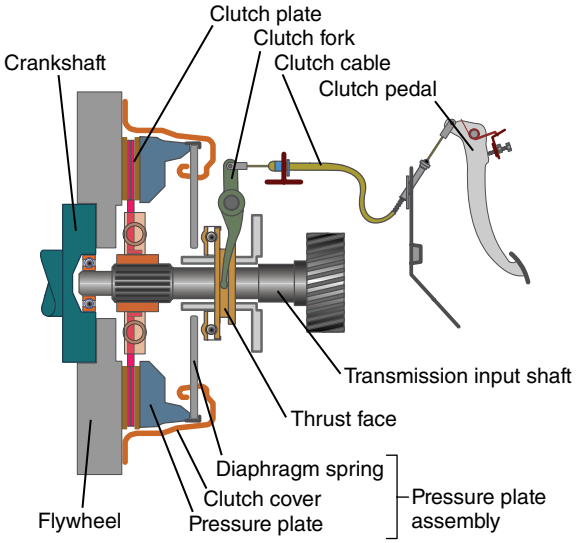


FIGURE 2-21 The crankshaft rotates the flywheel or flexplate, which sends power to the transmission.

pistons and ignited by a spark plug in the engine cylinders (**FIGURE 2-18**). The burning, expanding gases create high pressure. This rapidly pushes the pistons down the cylinders and spins the crankshaft.

The driver initiates the starting process by turning the ignition key to run (or using a smart key). Power is sent from the battery to a variety of vehicle circuits, including energizing the fuel pump. This pressurizes the fuel system in preparation for the engine to start. When the key is moved just a bit further to the crank position (or the start button is activated), the starter motor is energized. It cranks over the engine by turning the crankshaft (**FIGURE 2-19**).

The rotation of the crankshaft moves the pistons up and down. This draws air and fuel into the cylinders, which is ignited when each piston reaches the top of the cylinder. Once the cylinders start to fire, the engine runs by itself and the starter motor is disengaged. The engine continues to run while the ignition key is in the run position. Depressing the accelerator pedal allows more air and fuel to enter the engine. This greatly increases the engine speed and power.

As the engine cranks, the engine management system monitors the many engine sensors. It makes critical decisions such as the correct timing to fire the spark plugs, when to inject fuel, and how much fuel to inject (**FIGURE 2-20**). The fuel mixture is ignited by a high-voltage spark (up to 100,000 volts) that is created by the ignition system. This causes the burning gases to expand rapidly. In fact, the gases almost explode. This expansion forces each piston down its cylinder, which in turn causes the crankshaft to rotate.

As the pistons move up and down, they rotate the crankshaft. This turns the **flywheel** or flexplate, which is bolted to the engine crankshaft (**FIGURE 2-21**). In a manual transmission, the flywheel transmits the engine

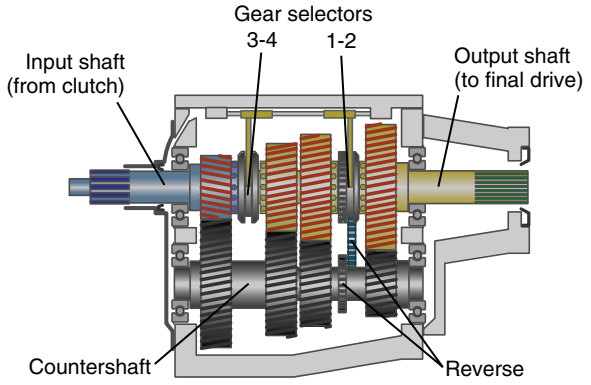


FIGURE 2-22 Transmissions transmit the engine's power through various gears.

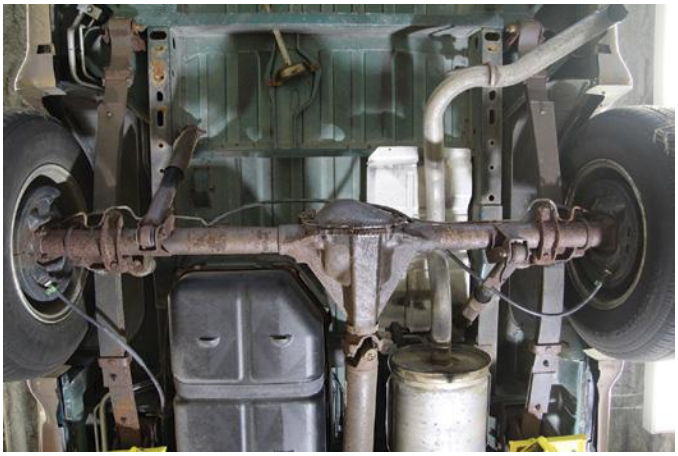


FIGURE 2-23 Rear axle assembly sending torque from the driveshaft to the rear wheels.

output through a clutch. In an automatic transmission, the flexplate transmits the engine output through a torque converter.

The vehicle's transmission takes the torque from the engine and multiplies it. This happens by running the torque through several different gear ratios. They modify the torque to allow the vehicle to pull away quickly from a stop or to cruise effortlessly down the highway (**FIGURE 2-22**). The transmission connects to a final drive assembly. It divides the power and sends it through axles to the drive wheels (**FIGURE 2-23**).

Now that the vehicle is moving at a fast speed, we need to be able to stop it. Brake assemblies are attached to the wheels. They provide a means of slowing or stopping the vehicle. The driver operates the brakes by stepping on a brake pedal. The power booster amplifies the force from the brake pedal to the master cylinder. The master cylinder creates hydraulic pressure to apply the wheel brake units. The brake units force brake friction pads against metal discs or drums connected to the wheels. This creates friction, which transforms the vehicle's kinetic energy into heat energy, slowing the wheel's rotation. The harder the driver presses on the brake pedal, the firmer

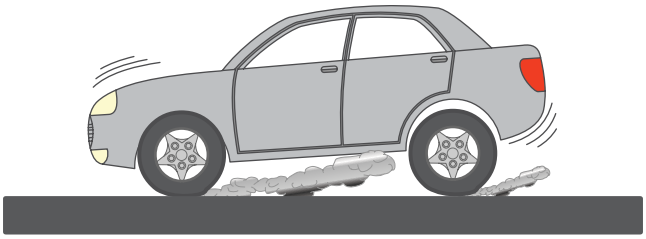


FIGURE 2-24 Brakes stopping a vehicle.

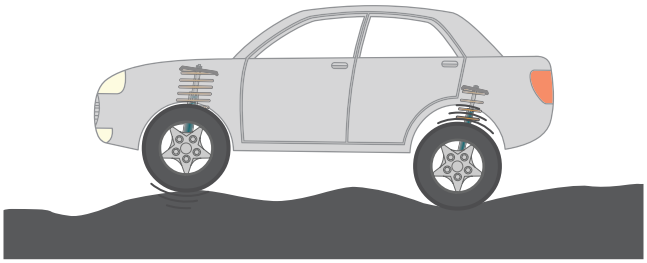


FIGURE 2-25 The suspension system absorbs road shock.

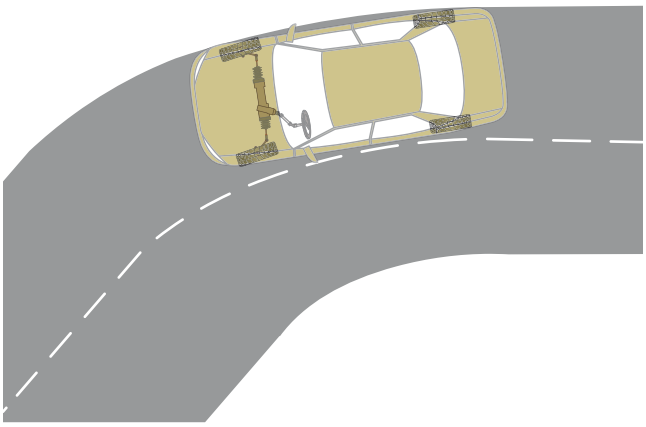


FIGURE 2-26 The steering system allows the driver to control the intended direction of travel.

the brakes are applied and the quicker the vehicle slows down (**FIGURE 2-24**).

The vehicle suspension system suspends the body above the wheels through flexible springs and pivoting links. This allows the wheels to follow uneven roads while isolating the passengers from the bumps and dips. It also maintains the orientation of the wheels so that the vehicle drives in a stable and predictable manner (**FIGURE 2-25**).

The steering system connects the steering wheel to the road wheels. This occurs so that the driver can point the wheels in the intended direction of travel (**FIGURE 2-26**). Power steering systems assist the driver in steering the vehicle's wheels. They use either an engine-driven pump or electric motor to power this system.

The electrical system is the nerve system of the vehicle. It is interconnected to virtually all the other systems. It includes the battery, which stores a supply of electricity. This is for starting the vehicle and operating the electrical

accessories (**FIGURE 2-27**). A charging system, driven by the engine, creates electrical energy to charge the battery. It also runs all the other parts of the electrical system. The electrical system is part of virtually every other system on the vehicle, including the following:

- Powertrain control system
- Lighting system
- Accessory systems
- Safety systems
- Passenger comfort systems
- Entertainment systems

All these systems work together to provide a safe, efficient, and enjoyable form of transportation. However, because customers have different needs and desires, not all vehicles are designed to look and perform the same way. We will explore those differences as we cover other topics.

Drivetrain Layouts

LO 2-3

Describe drivetrain layouts and their major components.

The **drivetrain** includes the major assemblies that power the vehicle down the road. This includes the engine, transmission/transaxle, differential, axles, and wheels (**FIGURE 2-28**). Drivetrains are designed in different layouts based on the vehicle use and manufacturer's preferences. For example, the drivetrain layout used in pickups facilitates driving up muddy mountain roads. The layout is different in a high-performance sports car, which runs around a smooth asphalt track. Differences in configuration between each of the drivetrains' major assemblies define the drivetrain layout.

The drivetrain layout includes three main engine-mounting positions: front, mid, and rear (**FIGURE 2-29**). The front-engine design is the most common in everyday vehicles. It has the engine mounted between the front wheels. In mid-engine vehicles, the engine is mounted in front of the rear wheels. It provides a more equal weight distribution between the front and the rear wheels. However, this occupies some of the passenger or cargo space.

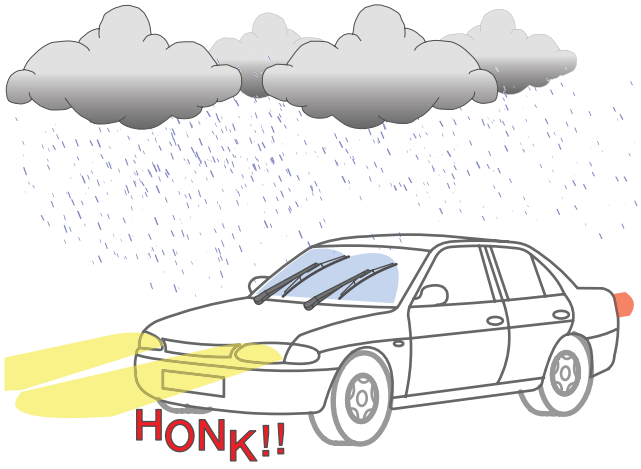


FIGURE 2-27 The electrical system operates all the systems on the vehicle.

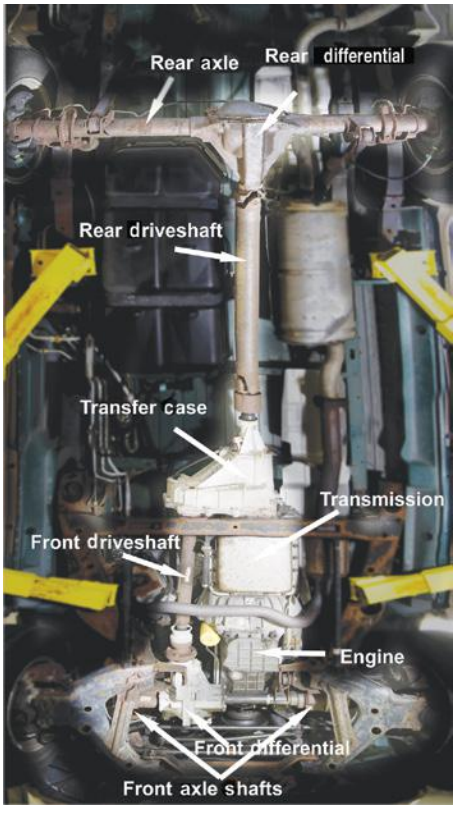


FIGURE 2-28 The drivetrain encompasses the engine, transmission, differential, axles, and wheels.

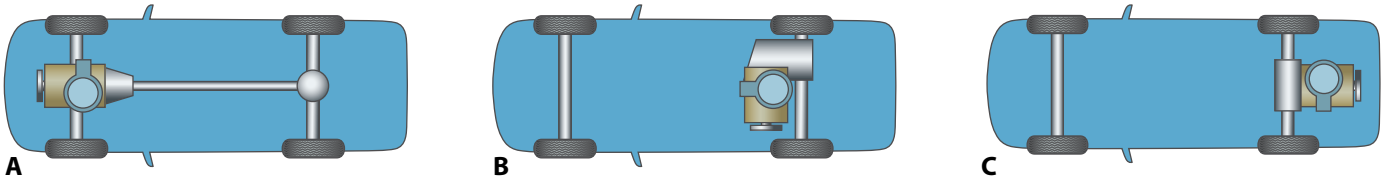


FIGURE 2-29 The three engine-mounting positions. **A.** Front. **B.** Mid. **C.** Rear.

A

B

FIGURE 2-30 **A.** Longitudinal engine orientation. **B.** Transverse engine orientation.

In rear-engine vehicles, the engine is mounted between or behind the rear wheels.

Mid- and rear-engine designs are usually reserved for performance-type vehicles. There have been some exceptions, however, such as the Volkswagen Beetle. Manufacturers also mount engines in one of two orientations: **longitudinal** (front to back) and **transverse** (side to side). The orientation depends on which design best fits the vehicle and the rest of the drivetrain (**FIGURE 2-30**).

The engine does not necessarily drive all four wheels. Drivetrain layouts accommodate four common drive wheel arrangements. **Front-wheel drive (FWD)** is common in modern vehicles. In this arrangement, only the front wheels are driven by the engine. **Rear-wheel drive (RWD)** is when the engine drives only the rear wheels. Both of these arrangements are called **two-wheel drive (2WD)** vehicles. Becoming increasingly popular is **all-wheel drive (AWD)**, with all four wheels driven by the engine all the time. The final arrangement is **four-wheel drive (4WD)**, which is slightly different from AWD. In a 4WD vehicle, the driver can select between 2WD and 4WD.

The drivetrain layout can be defined by a combination of the following:

- Engine position
- Engine orientation
- Type of drive

For example, using different variations can give the following drivetrain layouts:

- Front-engine, front-wheel drive
- Front-engine, rear-wheel drive
- Front-engine, all-wheel drive/4WD
- Rear-engine, rear-wheel drive
- Rear-engine, all-wheel drive
- Mid-engine, rear-wheel drive
- Mid-engine, all-wheel drive

TECHNICIAN TIP

Knowing the drivetrain layout of the vehicle you are working on is important when positioning the vehicle on a lift. The vehicle's weight needs to be centered on the lift. That varies greatly based on the drivetrain. This will be covered more in a later chapter.

Transmission and Axle Configurations

In most vehicles, the engine is bolted firmly to either a transmission or a transaxle (**FIGURE 2-31**). A transmission transmits engine power to the driveshaft, final drive and differential gears, and driving axles. Transmissions are typically used in front-engine, RWD vehicles. Alternatively, a transaxle is a self-contained unit. It has the transmission, final drive gears, and differential located in one casing. It is usually used on front-engine, FWD vehicles or rear-engine, RWD vehicles. Some sports cars with front-engine, RWD have them. These vehicles have the transaxle connected to the engine by a driveshaft (**FIGURE 2-32**).

Live and Dead Axles

Vehicles can be described by the number of axles and driven wheels. Each axle typically has one wheel on each end of the axle. An **axle** comes in one of two configurations: live axles and dead axles. A **live axle** uses the engine's torque to turn the wheels (drive the vehicle) and at the same time supports the weight of the vehicle. The wheels and axles on a live axle are also called *drive wheels* and *drive axles* because they propel the vehicle. A **dead axle** supports the weight of the vehicle only while allowing the wheels to rotate freely on the axle. The wheels on dead axles are not considered drive wheels because they support only the vehicle's weight.

Most light vehicles have only two axles: one live axle and one dead axle (**FIGURE 2-33**). On commercial vehicles, the