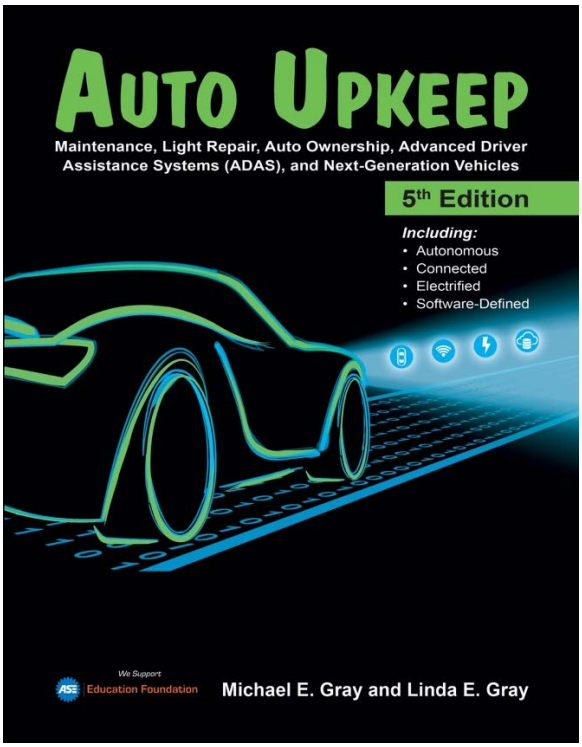
Auto Upkeep

5th Edition



Textbook

Sample Pages

Rolling Hills Publishing
www.rollinghillspublishing.com

Auto Upkeep: Maintenance, Light Repair, Auto Ownership, Advanced Driver Assistance Systems (ADAS), and Next-Generation Vehicles (Including: Autonomous, Connected, Electrified, and Software-Defined)

5th Edition

Michael E. Gray and Linda E. Gray

Executive Editor, Illustrator, Production Director: Linda E. Gray

Printed in the United States of America
30 29 28 27 26 25 10 9 8 7 6 5 4 3 2

Publisher's Cataloging-in-Publication Data

Names: Gray, Michael E., 1973- . | Gray, Linda E., 1972- .
Title: Auto upkeep : maintenance, light repair, auto ownership, advanced driver assistance systems (ADAS), and next-generation vehicles (including: autonomous, connected, electrified, and software-defined) / Michael E. Gray and Linda E. Gray.
Description: 5th ed. | Ozark, MO : Rolling Hills Publishing, 2025. | Includes over 1,100 full color illustrations including photos, line art, and tables. | Audience: Ages 15 to adult.
Identifiers: LCCN 2024934799 | ISBN 9781627020503 (hardcover) | ISBN 9781627020534 (ebook)
Subjects: LCSH: Automobiles – Maintenance and repair – Popular works. | Automobile driving. | BISAC: YOUNG ADULT NONFICTION / Transportation / Cars & Trucks. | TRANSPORTATION / Automotive / Repair & Maintenance. | TECHNOLOGY & ENGINEERING / Automotive.
Classification: LCC TL152.G739 2025 | DDC 629.28/72 G--dc23
LC record available at https://lccn.loc.gov/2024934799

For more information contact: Rolling Hills Publishing, LLC

Phone:	1-800-918-READ (1-800-918-7323)	Fax:	1-888-FAX-2RHP (1-888-329-2747)
Email:	info@autoupkeep.com	Website:	www.AutoUpkeep.com

Preface

Introduction

Auto Upkeep: Maintenance, Light Repair, Auto Ownership, Advanced Driver Assistance Systems (ADAS), and Next-Generation Vehicles (Including: Autonomous, Connected, Electrified, and Software-Defined) is an introductory book that is intended to provide individuals with the knowledge to make economical decisions and take preventative measures to enhance the overall satisfaction of being an automotive consumer. The textbook content and workbook activities provide the fundamental knowledge and experience in owning and maintaining an automobile. The *Auto Upkeep* curriculum is used in over 500 high schools, technology centers, community colleges, and universities to teach the first course in an automotive sequence, commonly titled *Automotive Maintenance and Light Repair*.

Updates to the 5th Edition

Auto Upkeep has undergone a complete revision with over 400 additional illustrations (1,100 total) and 112 new pages (400 total). This edition continues to focus on what every car owner should know and be able to do, while also introducing students to the rapidly advancing field of automotive technology. By learning how cars work, students develop a solid automotive foundation. They can continue to build upon this foundation, if they choose to become a technician, or use their knowledge throughout life as an educated consumer.

ASE Education Foundation Correlations

The *Auto Upkeep* curriculum correlates to the entry level tasks within the 2024 ASE Education Foundation Maintenance and Light Repair (MLR) task list. A correlation matrix can be accessed at **www.AutoUpkeep.com/standards**.

We Support
ASE Education Foundation

Reviewers

Thanks to all of the instructors, technicians, and readers who gave valuable input during the review process.

Technical Reviewers

Colin Dyvig
Automotive Technology Instructor
High Desert State Prison
Indian Springs, NV

Carl S. Fedele, Jr.
Lead Automotive Instructor
Proviso West High School
Hillside, IL

Robert Green
Automotive Technology Instructor
New Madrid Technical Skills Center
New Madrid, MO

Jed Alan Metzler
Automotive Instructor
South Branch Career & Technical Center
Petersburg, WV

Bryan D. Monaco
Automotive Instructor
Trenton High School
Trenton, MI

Larry Muhlstadt
Automotive Instructor
Glencliff High School
Nashville, TN

Rudolph Petrella
Automotive Instructor
West Orange High School
West Orange, NJ

Sean Reisdorf
Automotive Instructor
North Farmington High School
Farmington Hills, MI

Jack Stow, Jr.
Automotive Technology Instructor
North Kansas City Schools
Kansas City, MO
Adjunct Faculty, Automotive Technology
Johnson County Community College
Overland Park, KS

Student Reviewers

Aiden Gray
Ozark, MO

Landen Gray
Ozark, MO

Aaron Riley
Springfield, MO

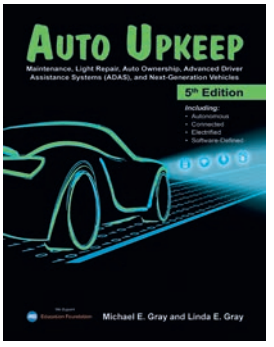
Michael Riley
Springfield, MO

Curriculum Resources

Textbook

Auto Upkeep is available in hardcover binding.

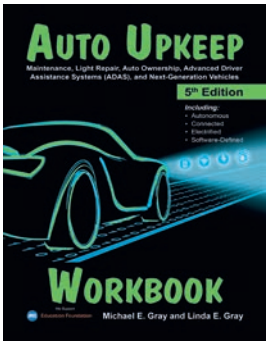
ISBN: 978-1-62702-050-3 (hardcover)



Workbook

Activities and study questions that correlate with the book's content can be accessed in the *Auto Upkeep Workbook*.

ISBN: 978-1-62702-051-0 (paperback)



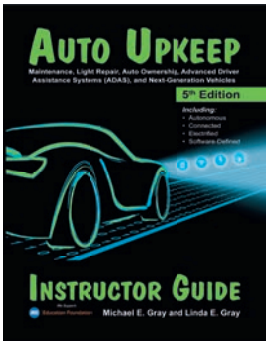
eBook

Auto Upkeep eTextbook and *eWorkbook* options are available at **www.AutoUpkeep.com/ebooks**.

Instructor Guide

The *Auto Upkeep Instructor Guide* is a comprehensive resource that assists in delivering the curriculum.

ISBN: 978-1-62702-059-6 (paperback)



Instructor Resources

The *Auto Upkeep Instructor Resources* include online files that assist instructors in curriculum implementation. Instructors at educational institutions that have adopted the curriculum may obtain access at **Academy.AutoUpkeep.com** through an instructor course. Email **info@autoupkeep.com** to request access. The resources on the Auto Upkeep Academy website include the following:

- Course Syllabus Outline
- Competency Profile
- ASE Education Foundation Correlation Matrix
- PowerPoint Slides
- Activities
- Lesson Plans
- Study Questions
- Chapter Tests and Final
- Answer Keys
- Self-Assessment Forms
- Readability Worksheets
- LMS Common Cartridge File
- Printable Certificates
- Learning Extensions

Additional Resources

Additional *Auto Upkeep* resources can be experienced online at **www.AutoUpkeep.com**.

Auto Upkeep Academy

The complete *Auto Upkeep* curriculum is also available online at **Academy.AutoUpkeep.com.**

Videos

Links to videos that support content learned can be accessed at **www.Video.AutoUpkeep.com.**

Features of the Text

QR (Quick Response) Codes - Scan to easily access additional chapter resources online.

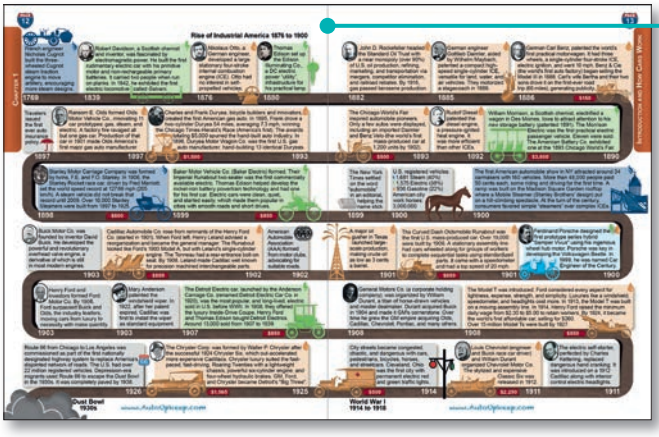
Introduction - Brief overview of the content that will be covered in the chapter.

Objectives - What you should know and be able to do upon completion of the chapter and activities.

Travel Trivia - Essential questions to stimulate thinking related to information in the chapter.

Road Trip - Your journey starts here! Scan the QR code to learn more about a National Park or a National Memorial destination. Road trip was inspired by the gamified design of the online **Academy.AutoUpkeep.com**.

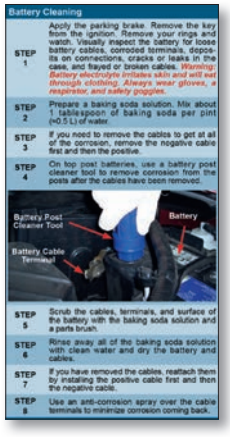
Illustrations - To clarify concepts and develop further understanding.



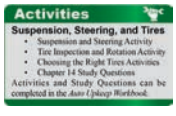
Automotive Timeline - Travel through history on the roadmap timeline to discover significant automotive innovations, people, events, and milestones. Vehicle energy sources are color coded.

Warnings - Potential hazard alerts that require safety precautions to avoid personal injury.

Procedures - Step-by-step hands-on learning experiences.

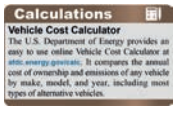


Activities and Study Questions - Located in the *Auto Upkeep Workbook* to extend learning.



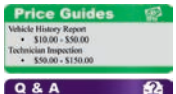
Apps - Helpful apps to extend learning can be accessed at **www.AutoUpkeep.com/apps**.

Calculations - Integrating practical math problems.



Career Paths - A brief introduction to automotive related fields to help you discover potential careers.

Price Guides - Tools, parts, and labor price estimates.



Q & A - Practical questions and answers from real problems.

Servicing - General guides to maintenance schedules.

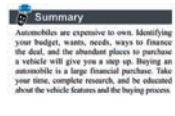
Tech Tip - Insightful, useful, and practical information, supplementing the content.

Trouble Guide - Quick reference for troubleshooting.

Videos - Links to videos that support content in the *Auto Upkeep* curriculum can be accessed at **www.Video.AutoUpkeep.com**.

Weblinks - Expand learning through online resources.

Summary - Reviews the chapter content, reinforcing the learning objectives.



Edge Index - Chapters are color coded and organized with an edge index to help you navigate the following:

- **Foundational (Top)** -These chapters will give you a solid automotive foundation to build upon.
- **Consumer and Advanced Technology (Middle)** - These chapters will help you become a more informed automotive consumer and expand awareness of advancing electric and next-generation technologies.
- **Automotive Systems (Bottom)** - These chapters will teach you how the systems of the automobile work together.

Authors

About Mike

Mike has roots in the automotive service industry. He began diagnosing and fixing cars at a young age in his family's service station. He has worked in automotive parts supply stores, towing companies, and service facilities. After graduating from St. Cloud State University (MN) with a Bachelor's degree, he implemented and taught a basic car care program at the high school level. During work on his Master's degree at Illinois State University (IL), he was a curriculum specialist on a National Science Foundation project where he co-authored ten integrated mathematics, science, and technology books designed for team teaching. Mike has also supervised teachers in Career and Technology Education as a school system administrator.

About Linda

Linda was motivated to learn about cars to be self-reliant and save money. During her studies at the University of Redlands (CA), she worked with classmates to design, build, and test an early hybrid electric vehicle. After graduating with a Bachelor's degree in Engineering, she worked as a Project Engineer for a bicycle component company. She has spent over 30 years studying, writing, and illustrating automotive concepts to simplify fundamental automotive knowledge for drivers and future technicians. She embraced the challenge of researching and presenting the latest electric and next-generation vehicle technologies for *Auto Upkeep*. She has many other interests, including alternative energies, home renovation, graphic design, and art, but her greatest joy comes from spending time with her family and friends.

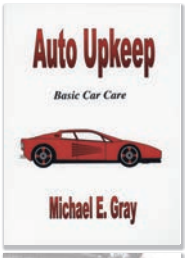
Acknowledgments

We would like to thank all of our family, friends, colleagues, and teachers for their guidance on life's journey. A special thanks to our two sons for helping us enjoy the simple things in life and for inspiring us to do our best.

Auto Upkeep History

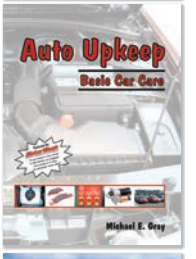
Over 25 Years of Auto Upkeep

1999



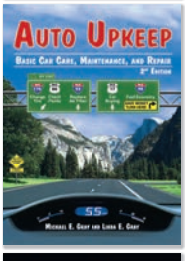
Manuscript
13 Chapters
154 Pages (Including Activities)

2003



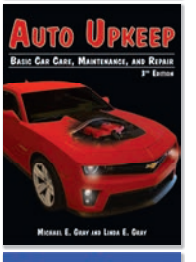
1st Edition
Paperback
2 New Chapters (15 Total)
Over 100 Illustrations
106 Pages
Activities on CD

2008



2nd Edition
Hardcover and Paperback
5 New Chapters (20 Total)
Over 400 Illustrations
192 Pages
Workbook Introduced

2013



3rd Edition
Hardcover and Paperback
eBook
Over 400 Illustrations
200 Pages
Full Color Introduced

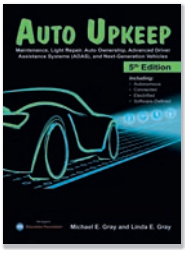
2018

4th Edition
Hardcover and Paperback
eBook
Over 700 Illustrations
288 Pages

2020

Academy
Online Learning
Interactive Lessons
Gamified Design
Connected Community
Detailed Reporting

2025



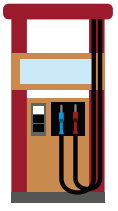
5th Edition
Hardcover
eBook
Academy
2 New Chapters (22 Total)
Over 1100 Illustrations
400 Pages

Table of Contents

CHAPTER 9
Electrical System

CHAPTER 10
Lubrication System

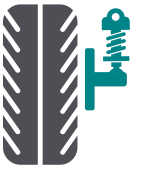
CHAPTER 11
Fuel System



CHAPTER 12
Cooling System and Climate Control

CHAPTER 13
Ignition System

CHAPTER 14
Suspension, Steering, and Tires



CHAPTER 15
Braking System

CHAPTER 16
Drivetrain

Introduction and How Cars Work

Photo: Library of Congress

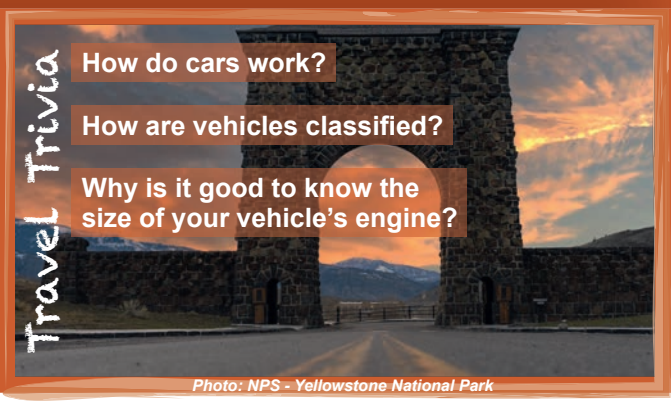


Photo: NPS - Yellowstone National Park

Introduction

For hundreds of years people have been compelled to find a better way to travel. It would be impossible to credit just one person for the development of the automobile. The word "automobile" literally means self-moving. People wanted a vehicle that could take them to new places. For many years people worked and lived within miles of where they were born and where they eventually died. Before the automobile, people traveled on land by foot, train, bicycle, or horse and carriage (***Figure 1.1***). Within a few years of the turn of the 20th century, the automobile would change society forever. Today, there are millions of vehicles on the roadways.

Figure 1.1 Pennsylvania Ave. Washington, DC 1880
Photo: Library of Congress

Weblinks

Automotive Museums

www.AutoUpkeep.com/resources
Click on Chapter 1

Objectives

Upon completion of this chapter and activities, you will be able to:

- Identify early automotive contributors.
- Differentiate between vehicle manufacturers, makes, models, and trim levels.
- Describe how cars work.
- Locate and use an online owner's manual.

Automotive Timeline

Numerous milestones and significant automotive events have made vehicles more efficient, comfortable, and reliable. This section focuses on:

- Early Years
- Henry Ford
- Over a Century of Growth

Early Years

One of the earliest recorded major milestones in the development of the automobile was the Cugnot steam traction engine in 1769 to 1770 (***Figure 1.2***). Even though this self-powered vehicle was rather impractical, it was a starting point for the automobile. The development of the internal combustion engine (ICE) in 1860 made road vehicles more promising. An 1886 patent credits Carl Benz with building the world's first practical motorcar.

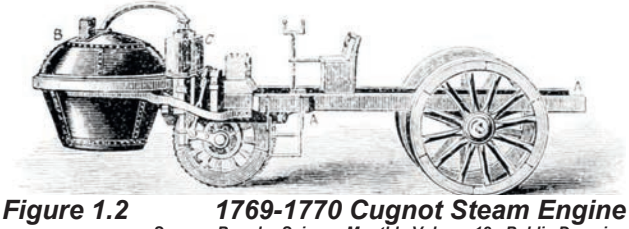


Figure 1.2 1769-1770 Cugnot Steam Engine
Source: Popular Science Monthly Volume 12 - Public Domain

Henry Ford

At the turn of the century, blacksmith shops around the country were hand-building gas, steam, and electric cars. Henry Ford, who introduced the Model T in 1908, put an end to many of the small hand-building automotive shops. By 1914, Ford was able to significantly decrease production time using a conveyor (moving) assembly line (***Figure 1.3***). Workers could put together a Model T in just 93 minutes. Originally introduced at $850 in 1908, the Model T eventually sold for as little as $260. By the 1920s, half the cars in the world were Model T Fords. In 1923 alone, Ford produced over 1.8 million Model Ts. The last Ford Model T rolled off of the assembly line in 1927. Ford produced over 15 million Model Ts.

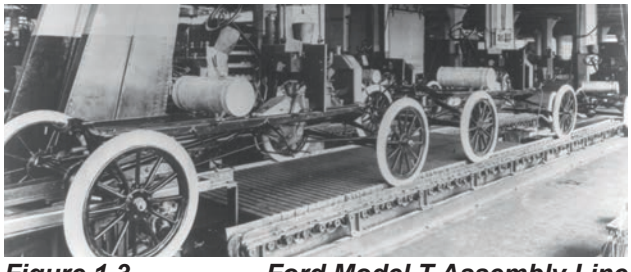


Figure 1.3 ***Ford Model T Assembly Line***
Photo: Library of Congress

Calculations

Consumer Price Index (CPI)

Inflation increases prices, requiring consumers to spend more to buy the same good or service. You can calculate what a vehicle from the ***Automotive Timeline (Pages 12-15)*** might have cost in today's dollars. Go to **www.bls.gov** and search *CPI Inflation Calculator* to find the inflation rate for any year after 1913.

Buying Power of a Dollar
$1 in 1913 had the buying power of $31.47 in 2024.
$1 in 1924 had the buying power of $17.83 in 2024.
$1 in 1933 had the buying power of $23.91 in 2024.

Initial Cost (Model T in 1924)		$260.00
x CPI Rate (1924 to 2024)		x 17.83
2024 Adjusted Price	=	**$4,635.80**

Over a Century of Growth

Over the last 100+ years, automobile production has grown substantially. In 1900, about 9,500 motor vehicles were produced in the world. In the early 1900s, electric and steam were favored over ICE vehicles. Cheap oil, the electric self-starter, and affordable mass-production vehicles drove the world to ICE vehicle dominance. Vehicle production peaked at 97 million vehicles in 2018, dipping to 85.4 million in 2022 from pandemic supply chain disruptions.

Electric Mobility. The United States projects up to 56% of new light-duty vehicles to be electric by 2032, asserting that electric mobility is transportation's future. Henry Ford and Thomas Edison even purchased EVs (***Figure 1.4***). See Chapter 21 to learn more about electric vehicles.

Figure 1.4 ***1914 Detroit Electric Ad***
Source: Library of Congress

Early Stages of Seismic Paradigm Shift. Electrification of vehicles is just one part of the paradigm shift. This shift unlocks a synergy of new capabilities: personalization, automation, connectivity, along with electrification, where software and data are center stage. To survive in this software-defined vehicle (SDV) world, the auto industry is transitioning from static hardware-defined vehicles to flexible software-defined vehicles. See Chapter 22 to learn more about autonomous vehicles.

Significant Automotive Events. Use the vehicle energy key while traveling through history on the ***Automotive Timeline (Pages 12-15)***.

Steam	Electric	Gasoline	Hybrid

Vehicle Energy Key for Automotive Timeline (Pages 12-15)

Travel Through History

Rise of Industrial America 1876 to 1900

French engineer Nicholas Cugnot built the three-wheeled Cugnot steam traction engine to move artillery, encouraging more steam designs.

1769

Robert Davidson, a Scottish chemist and inventor, was fascinated by electromagnetic power. He built the first rudimentary electric car with his primitive motor and non-rechargeable primary batteries. It carried two people when run on planks. In 1842, he exhibited the first electric locomotive called *Galvani*.

1839

Nikolaus Otto, a German engineer, developed a large stationary four-stroke internal combustion engine (ICE). Otto had no interest in self-propelled vehicles.

1876

Thomas Edison set up the Edison Illuminating Co., a DC electric power "utility", infrastructure for his practical lamp.

1880

Travelers issued the first ever auto insurance policy.

1897

Ransom E. Olds formed Olds Motor Vehicle Co., innovating 11 car prototypes: gas, steam, and electric. A factory fire ravaged all but one gas car. Production of that car in 1901 made Olds America's first major gas auto manufacturer.

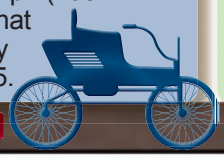
1897

Charles and Frank Duryea, bicycle builders and innovators, created the first American gas auto. In 1895, Frank drove a two-cylinder Duryea 54 miles, averaging 7.3 mph, winning the Chicago Times-Herald's Race (America's first). The awards totaling $5,000 spurred the hand-built auto industry. In 1896, Duryea Motor Wagon Co. was the first U.S. gas auto manufacturer, hand-building 13 identical Duryeas.

$1,500

1893

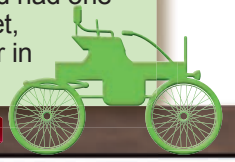
Stanley Motor Carriage Company was formed by twins, F.E. and F.O. Stanley. In 1906, the Stanley Rocket race car, driven by Fred Marriott, set the world speed record at 127.66 mph (205 km/h). A steam vehicle did not break that record until 2009. Over 10,000 Stanley Steamers were built from 1897 to 1925.



1898

$600

Baker Motor Vehicle Co. (Baker Electric) formed. Their Imperial Runabout two-seater was the first commercially available electric. Thomas Edison helped develop the nickel-iron battery powertrain technology and had one for his first car. Electric cars were clean, quiet, and started easily, which made them popular in cities with smooth roads and short drives.



1899

$850

Buick Motor Co. was founded by inventor David Buick. He developed the powerful and revolutionary overhead valve engine, a derivative of which is still in most modern engines.

1903

$850

Cadillac Automobile Co. rose from remnants of the Henry Ford Co. (started in 1901). When Ford left, Henry Leland advised a reorganization and became the general manager. The Runabout looked like Ford's 1903 Model A, but with Leland's single-cylinder engine. The Tonneau had a rear-entrance bolt-on seat. By 1908, Leland made Cadillac well known for precision machined interchangeable parts.

1902

American Automobile Association (AAA) formed from motor clubs, advocating for suitable roads.

1902

Henry Ford and investors formed Ford Motor Co. By 1908, Ford surpassed Buick and Olds, the industry leaders, moving cars from luxury to necessity with mass quantity.

1903

Mary Anderson patented the windshield wiper. In 1922, after her patent expired, Cadillac was first to install the wiper as standard equipment.

1903

The Detroit Electric car, launched by the Anderson Carriage Co. (renamed Detroit Electric Car Co. in 1920), was the most popular, and long-lived, electric sold in U.S. before WWII. In 1908, they offered the luxury Inside-Drive Coupe. Henry Ford and Thomas Edison bought Detroit Electrics. Around 13,000 sold from 1907 to 1939.

1907

$850

Route 66 from Chicago to Los Angeles was commissioned as part of the first nationally designated highway system to replace America's disjointed network of roads. The U.S. had over 22 million registered vehicles. Depression-era migrants used Route 66 to escape the Dust Bowl in the 1930s. It was completely paved by 1938.

The Chrysler Corp. was formed by Walter P. Chrysler after the successful 1924 Chrysler Six, which out-accelerated more expensive Cadillacs. Chrysler luxury suited the fast-paced, fast-driving, Roaring Twenties with a lightweight chassis, powerful six-cylinder engine, and four-wheel hydraulic brakes. GM, Ford, and Chrysler became Detroit's "Big Three".

1926

$1,565

1925

Dust Bowl 1930s

1882 — John D. Rockefeller headed the Standard Oil Trust with a near monopoly (over 90%) of U.S. oil production, refining, marketing, and transportation via mergers, competitor elimination, and railroad rebates. By 1916, gas passed kerosene production.

1885 — German engineer Gottlieb Daimler, aided by Wilhelm Maybach, patented a compact high-speed single-cylinder ICE, versatile for land, water, and air vehicles. They motorized a stagecoach in 1886.

1886 — German Carl Benz, patented the world's first practical motorwagen. It had three wheels, a single-cylinder four-stroke ICE, electric ignition, and went 10 mph. Benz & Cie. (the world's first auto factory) began selling the Model III in 1888. Carl's wife Bertha and their two sons drove it on the first-ever road trip (66 miles), generating publicity. $150

1890 — William Morrison, a Scottish chemist, electrified a wagon in Des Moines, Iowa to attract attention to his new storage battery (patented 1891). The Morrison Electric was the first practical electric passenger vehicle. Eleven were sold. The American Battery Co. exhibited one at the 1893 Chicago World's Fair. $3,600

1892 — Rudolf Diesel patented the diesel engine, a pressure-ignited heat engine. It was more efficient than other ICEs.

1893 — The Chicago World's Fair inspired automobile pioneers. Only a few autos were displayed, including an imported Daimler and Benz Velo (the world's first mass-produced car at 1,200 units by 1902). $500

1899 — The New York Times settled on the word "automobile" in an editorial, helping the name stick.

1900 — U.S. registered vehicles:
- 1,681 Steam (40%)
- 1,575 Electric (38%)
- 936 Gasoline (22%)

American city work horses: 3,000,000

1900 — The first American automobile show in NY attracted around 34 carmakers with 160 vehicles. More than 48,000 people paid 50 cents each, some riding and driving for the first time. A ramp was built on the Madison Square Garden rooftop where a Mobile Steamer (Stanley Brothers' design) put on a hill-climbing spectacle. At the turn of the century, consumers favored simple "steamers" over complex ICEs.

1900 — Ferdinand Porsche designed the first prototype series hybrid "Semper Vivus" using his ingenious wheel hub motor. Porsche was key in developing the Volkswagen Beetle. In 1999, he was named Car Engineer of the Century.

1901 — The Curved Dash Oldsmobile Runabout was the first U.S. mass-produced car. Over 19,000 were built by 1906. A stationary assembly line had cars wheeled along for groups of workers to complete sequential tasks using standardized parts. It came with a speedometer and had a top speed of 20 mph. $650

1901 — A major oil gusher in Texas launched large-scale production, making crude oil as low as 3 cents a barrel.

1908 — General Motors Co. (a corporate holding company), was organized by William Durant, a titan of horse-drawn vehicles and master dealmaker. Durant acquired Buick in 1904 and made it GM's cornerstone. Over time he grew the GM empire acquiring Olds, Cadillac, Chevrolet, Pontiac, and many others.

1908 — The Model T was introduced. Ford considered every aspect for lightness, expense, strength, and simplicity. Luxuries like a windshield, speedometer, and headlights cost more. In 1913, the Model T was built on a moving assembly line. In 1914, Henry Ford raised the minimum daily wage from $2.30 to $5.00 to retain workers. By 1924, it became the world's first affordable car, selling for $260. Over 15 million Model Ts were built by 1927. $850

1911 — The electric self-starter, perfected by Charles Kettering, replaced dangerous hand cranking. It was introduced on a 1912 Cadillac along with interior control electric headlights.

1911 — Louis Chevrolet (engineer and Buick race car driver) and William Durant organized Chevrolet Motor Co. The stylized and expensive Classic Six was released in 1912. $2,250

1914 — City streets became congested, chaotic, and dangerous with cars, pedestrians, bicycles, horses, and streetcars. Cleveland, Ohio was the first city with permanent electric red and green traffic lights. $500

World War I
1914 to 1918

Great Depression 1929 to 1939

UNITED WE STAND

Ford introduced the affordable mass-produced Roadster, igniting hot rod enthusiasm. Its powerful compact single-unit cast V8 engine (produced until 1953), opened the market for average consumers wanting speed.

1932 $500

GM, the world's top industrial corporation, sped up assembly lines to hold profits at the expense of worker safety. The Flint sit-down strike occupied the Fisher Body plant for 44 days and spread to over 136,000 United Auto Workers in 17 plants. By harnessing the power of unions, the strikers achieved one of America's most decisive labor victories.

1936

Golden Gate Bridge 1933 to 1937

World War II 1941 to 1945

U.S. auto manufacturers supported Allied Powers by producing military vehicles, tanks, airplanes, and more. When the war and wartime restrictions ended, America was anxious for new cars.

1942

First Willys-Overland 4x4 prototype Jeep, a light reconnaissance general-purpose (GP) vehicle, was delivered to the U.S. Army. A total of 647,925 versatile Willys MBs were built during WWII. Jeep became the 4x4 technology leader.

$738

1940

Hydra-Matic Drive was the world's first mass-produced fully automatic transmission. GM introduced it on Oldsmobiles as the simplest way to drive (no clutch to press).

GAS CLUTCH BRAKE

1939

NASCAR formed to sanction and promote stock car races. The first race cars were stock models found at dealership showrooms. Today, the cars have evolved into high-tech platforms with bodies resembling OEM brands.

NASCAR

1948

Hydraulic-assisted power steering, critical for heavy vehicles, was improved during WWII. It was first commercially on a Chrysler and quickly adopted by others.

1951

B.F. Goodrich Co. patented tubeless tires using butyl rubber, a synthetic produced to replace war shortages of natural rubber. The patent, filed in 1947, took years to test before approval. Tubeless tires proved safer and handled better. They became standard equipment by 1955.

1952

CitiCar, a tiny electric, was a street legal two-seat urban commuter based on a golf cart. The range was nearly 40 miles. By 1982, over 4,000 (including the Comuta-Car models) were built. It held the top selling EV spot in the U.S. until the Nissan Leaf in 2011.

$4,000

1974

OPEC (Organization of Petroleum Exporting Countries) imposed an oil embargo (ban on exports) against the U.S. The oil crisis caused the price of gas to soar while supply fell dramatically. Congress called for smaller fuel-efficient cars.

Sorry... NO GAS

1973

The National Highway Traffic Safety Administration (NHTSA) was formed to guide recommendations on road safety, risky driving, 5-star safety ratings, recalls, and automated technologies.

NHTSA

1970

The U.S. mandated lap and shoulder belts in new cars. New York state was the first to require drivers, front passengers, and kids under ten to wear seat belts.

1984

GM produced 1,117 units of the EV1, a modern era two-seat electric with a 55-mile range. It was popular, but could only be leased. GM killed the program in 2002, recalling and crushing all but about 40 EV1s to be used for education and museums.

1996 Lease

The Honda Insight, a two seater, was the first commercial hybrid electric car sold in the U.S. It was the most fuel-efficient (70 MPG) mass-produced car at the time. Honda Motor Co. Ltd. incorporated in Japan in 1948 with $3,300.

1999 $21,164

Up to 56% of new vehicles to be EVs, asserting that electric is the future of transportation. (Environmental Protection Agency's projection of performance-based emission limits set in 2024.)

2032

Rivian was the first to deliver an electric pickup (range 300 miles). The market for electric pickups heated up as range, towing, payload, and charge time improved.

$69,000

2021

The pandemic disrupted global semiconductor supply, which was compounded by tech advanced vehicles needing more chips.

2020

Waymo developed self-driving car technology. In 2019, limited areas started offering no-driver (Level 4) ride-hailing services. The ride is controlled by passengers through an app or buttons in the vehicle.

START RIDE

2016

1937 $4,500

Limited range and high prices slowed sales of electric cars. The Detroit Electric Model 99, one of the last produced, had a more-modern Dodge sourced body, but antiquated tiller steering and parlor style seating.

1937

Federal mandates made safety glass standard equipment. The first windshields (starting in 1904) were dangerous plate glass that could shatter into shards. Laminated safety glass was discovered by accident in 1903, but it was labor intensive to make, could delaminate, and would discolor in sunlight, so it was not widely adopted until advances were made.

1937

Toyota Motor Co., Ltd. was established. Toyota developed the Just-in-Time (JIT) manufacturing control system to increase efficiency and reduce inventory warehousing.

1939

Nash Motor Co. offered the Weather Eye Conditioned Air System, where fresh filtered outside air was warmed thermostatically by hot engine coolant. In 1954, they added cooling to their compact and affordable heating and ventilating system.

1939

Buick had the first factory flash turn signal. The Flash-Way was centered on the trunk (shown below with the right signal on). Turn signals did not catch on until the 1950s and were not required until 1968.

1938 $800

Volkswagen Beetle was introduced. It was practical, reliable, and affordable, with an innovative air-cooled rear engine. U.S. sales started in 1949. By 1972, it was the best-selling vehicle ever (over 23 million sold by 2019).

1954 $6,820

The Mercedes-Benz 300SL with exotic Gullwing doors was the first to have fuel injection. It was the fastest (160 mph) production car at the time. In 1999, it was voted sports car of the century.

1956

President Eisenhower signed Federal-Aid Highway Act to fund construction of the interstate highway system, the largest public works project in American history. Interstate locations dictated future suburban growth.

1957 $2,299

The Chevrolet Bel Air was an iconic 1950s American automobile. It had an optional 283 cubic inch small-block V8 engine. It was relatively inexpensive and easy to work on. Today, the 1957 Chevy is still popular with classic car collectors.

1970 $4,776

The 1970 Plymouth Superbird, created for NASCAR, rocketed over 200 mph. It won 18 times (8 wins by Richard Petty) before NASCAR limited engine displacement to 305 cubic inches. The Superbird, with an aerodynamic wing and nose cone, mimicked the 1969 Dodge Charger 500 that was aerodynamically engineered in a wind tunnel.

1965

Motor Vehicle Air Pollution Control Act authorized setting federal standards to regulate emissions.

1964 $2,368

The Ford Mustang was good looking and cheap, with a V8 option, making it very desirable. In 2019, the iconic brand joined the EV era with the Mustang Mach-E. It was the third most popular EV in 2022.

2000 $19,995

The Toyota Prius, a low-emission (48 MPG) family car, was offered for sale in the U.S. Its 1997 release in Japan made it the world's first mass-produced hybrid. By 2022, it was the world's top selling hybrid at 5 million sold.

2006 $98,950

The Tesla Roadster prototype, using a Lotus glider and lithium-ion cell battery pack (range over 200 miles), made people think more seriously about EVs and sustainable energy. In 2008, it was the first highway legal series production EV.

2006

Ford Motor Co. planned 25% North American workforce cut as part of restructuring.

2007

Tire pressure monitoring system (TPMS) required to warn driver of under-inflation.

2017 $35,000

The Tesla Model 3 (base range 220 miles) demonstrated that EVs are the future of sustainable mobility. Consumer interest was intense, with over 500,000 reservations. By early 2020 it was the world's best-selling EV. A million were sold globally by 2021.

2011 $33,600

The revolutionary Nissan LEAF, using a lithium-ion battery pack (base range 73 miles), was the first mass-produced EV by a major automaker. It became the world's all-time top selling EV through 2019, with total sales over 650,000 by 2024.

2009

General Motors and Chrysler filed for Chapter 11 bankruptcy protection allowing them to reorganize.

How Cars Work

Currently, the most common propulsion system in an automobile is the internal combustion engine (ICE). ICEs burn fuel in a combustion chamber inside the engine. This section focuses on:

- Conservation of Energy
- Force, Work, Power, and Energy
- Measuring Engine Output
- Engine Components
- Four-Stoke Engines
- Power Transfer

Conservation of Energy

Vehicles need energy to move. The energy used is commonly gasoline, diesel, or electricity. A key concept to understand is that energy cannot be created or destroyed, it is just converted from one form to another. This is called the law of conservation of energy in physics (specifically in a closed system). Gasoline vehicles are not very efficient at moving down the road. They do not destroy energy, but they lose energy. These losses occur in the engine, drivetrain, braking, overcoming the wind (aerodynamic drag), rolling resistance (tires contacting the road), and running accessories (parasitic losses). The energy into the system equals the energy out of the system, even if some of it is unwanted and not usable (***Figure 1.5***).

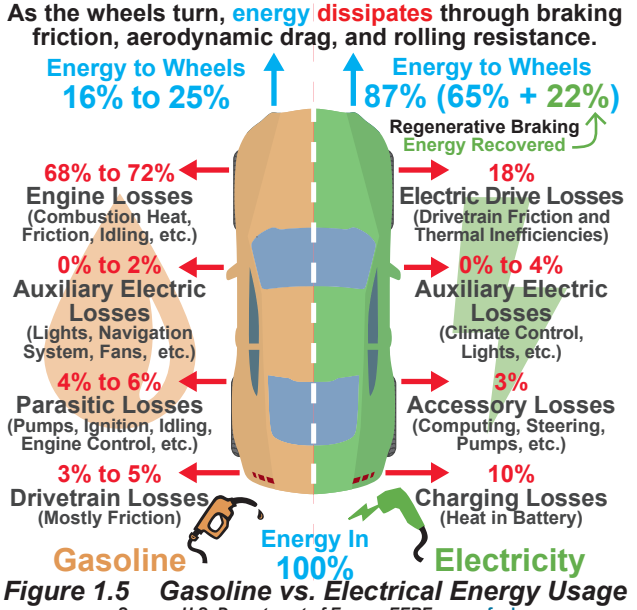


Figure 1.5 Gasoline vs. Electrical Energy Usage

Source: U.S. Department of Energy EERE - www.fueleconomy.gov

Force, Work, Power, and Energy

To learn how power is transferred in a vehicle, key terms (force, work, power, and energy) and the relationship between them need to be studied.

Force. Simply defined, force is a push or pull interaction between objects (***Figure 1.6***). This interaction can occur when objects are in physical contact with one another or when there is an action at a distance caused by magnetic forces, gravitational forces, and electric forces.

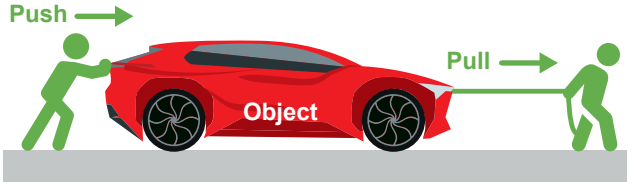


Figure 1.6 ***Force***

Work. When an object has moved from a force, the position of the object has changed and work has occurred. If no motion has occurred, no work has been done. Work is the transfer of energy from one object to another (***Figure 1.7***).

Work = Force x Distance

1 ft-lb = 1 pound x 1 foot

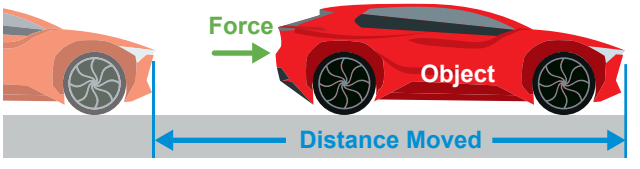


Figure 1.7 ***Work = Force x Distance***

Calculations

Calculating Work

If an object has moved 10 feet from a force of 25 pounds, how much work has occurred?

Force		10 lb
x Distance		x 25 ft
Work	=	**250 ft-lb**

Note: To use this formula, the force must be parallel to the movement.

Power. Power is the rate at which work is done (the amount of work done, energy delivered, in a given amount of time).

Power = Work / Time

Energy. Objects have the ability to do work when they have energy. Different forms of energy are classified into two categories: potential and kinetic. Potential energy is stored energy or energy of position. Kinetic energy is the energy of an object from its movement. Energy is required to do work. Gasoline, diesel, electricity, or some other source of energy is needed for a vehicle to do work. Energy and power are linked, but are not the same thing. This is helpful to know when looking at battery ratings on hybrid and electric vehicles. These batteries are usually rated in kilowatt hours (kWh).

Energy = Power x Time

1 kWh = 1 kilowatt x 1 hour

For example, an electric vehicle might have a battery capacity of 60 kWh. Think of energy as the amount of "fuel" stored or used to perform work.

Measuring Engine Output

Two numbers are commonly used in advertising a vehicle's output: torque and horsepower.

Torque. When force is in a twisting motion it is called torque. Tightening a bolt with a wrench is an example of torque (***Figure 1.8***). A special wrench, a torque wrench, is used to tighten bolts to an exact specification. A pound-foot (lb-ft) of torque is 1 pound of force at a lever length of 1 foot.

Torque = Force x Lever Length

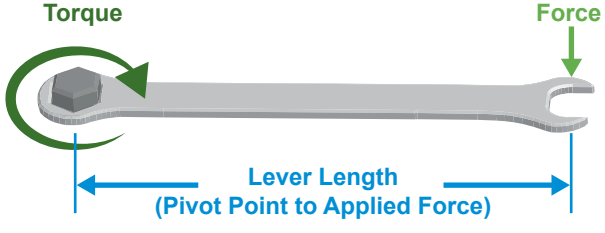


Figure 1.8 ***Torque = Force x Lever Length***

Crankshaft Torque. Torque is also used to describe the output rating of an engine, the crankshaft's turning force (***Figure 1.9***).

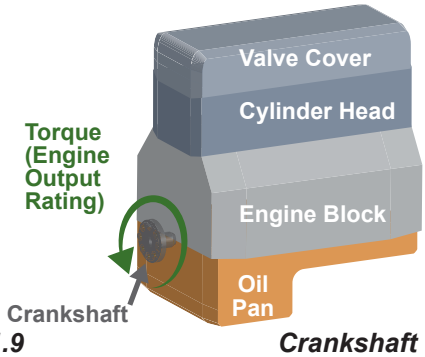
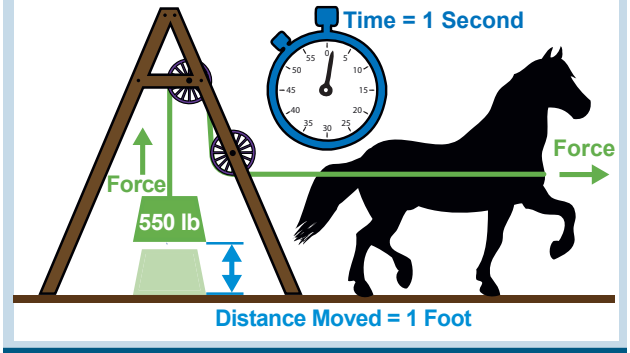


Figure 1.9 ***Crankshaft Torque***

Horsepower. A unit of power that is common in the automotive field is horsepower (hp). The work needed to lift 550 pounds a distance of 1 foot in 1 second is 1 horsepower (***Figure 1.10***).

Horsepower (U.S. Customary Units)

1 horsepower = 550 foot-pounds/second
1 horsepower = 33,000 foot-pounds/minute



Watt (International System of Units (SI))

1 horsepower = 746 watts = 0.746 kilowatts
1 kilowatt = 1,000 watts = 1.34 horsepower

Figure 1.10 ***Horsepower***

Revolutions Per Minute (RPM). Horsepower and torque change as engine speed (revolutions per minute or rpm) changes, so these ratings are given at a specific rpm (***Figure 1.11***).

	1920 Ford Model T	2024 Ford Super Duty
Engine	2.9 L Gasoline	6.7 L Turbo Diesel
HP	20 hp @ 1,600 rpm	475 hp @ 2,600 rpm
Torque	83 lb-ft @ 900 rpm	1,050 lb-ft @ 1,600 rpm

Figure 1.11 Horsepower and Torque Comparison

Engine Components

The basic parts in a four-stroke engine include intake valves, exhaust valves, pistons, connecting rods, an engine block, cylinder head(s), a crankshaft, camshaft(s), and an oil pan (***Figure 1.12***).

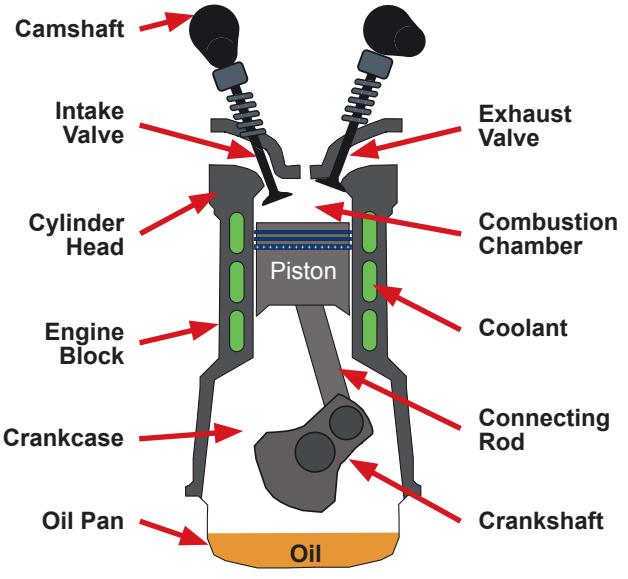
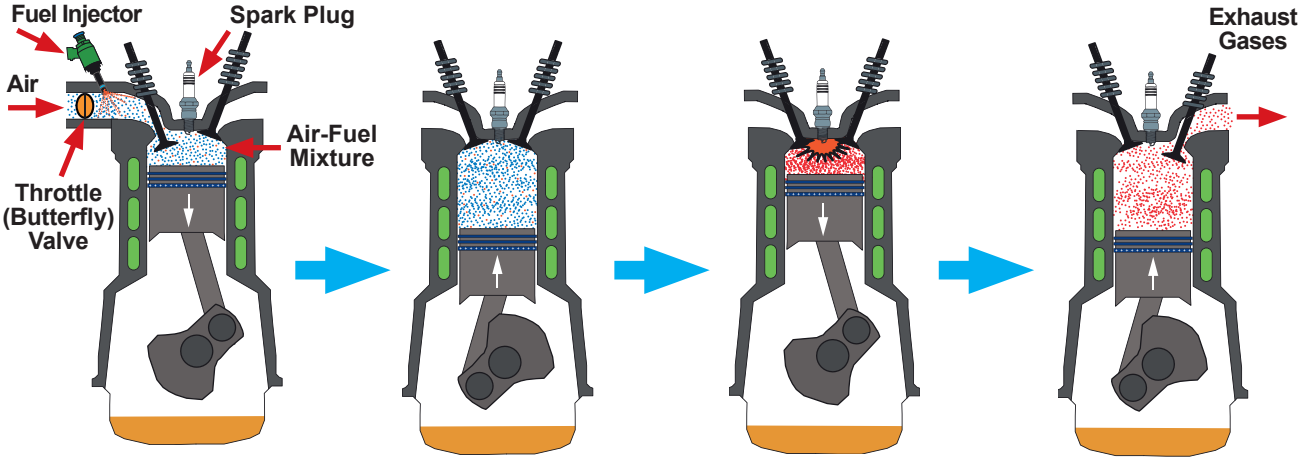


Figure 1.12 Dual Overhead Camshaft (DOHC) Engine

Four-Stroke Engines

The four-stroke internal combustion engine (also known as the Otto cycle, named after Nikolaus Otto) is the most common type used in automobiles. In a four-stroke engine the piston makes reciprocating (back and forth or up and down) movements inside a cylinder to convert the chemical energy of fuel into mechanical energy of motion (kinetic energy).

Spark Ignition. Spark ignition (SI) engines are fueled by gasoline, propane, natural gas, or a gasoline/alcohol blend. A spark plug ignites the air-fuel mixture. The four-strokes of the spark ignition engine (***Figure 1.13***) are intake, compression, power (combustion), and exhaust. To complete the four strokes, the crankshaft makes two revolutions. See Chapter 11 to learn more about gasoline direct injection (GDI) engines.



Intake Stroke
Intake valve is open. Exhaust valve is closed. Piston moves down. Air-fuel mixture enters the combustion chamber.

Compression Stroke
Intake and exhaust valves are closed. Piston moves up. Air-fuel mixture is compressed.

Power (Combustion) Stroke
Intake and exhaust valves are closed. A spark plug ignites the air-fuel mixture. Piston is forced down by combustion. This is the stroke that provides the power.

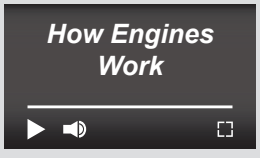
Exhaust Stroke
Exhaust valve opens. Intake valve is closed. Piston moves up, pushing exhaust gases out of the engine.

Four-Stroke Cycle Repeats

Figure 1.13 ***Four-Stroke Spark Ignition Engine (Port Fuel Injection) Compression Ratio Commonly 8:1 to 12:1***

Compression Ignition. Compression ignition (CI) engines are fueled by diesel. The four-strokes of the compression ignition engine (***Figure 1.14***) are similar to the spark ignition engine, except fuel is not mixed with air in the intake system. Instead diesel is injected directly into the combustion chamber or indirectly into a swirl (precombustion) chamber. Once in the combustion chamber, the diesel combusts spontaneously from the high pressure and heat. CI engines do not use spark plugs.

Videos



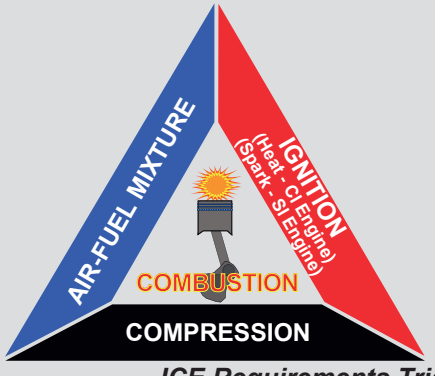
www.Video.AutoUpkeep.com

Click on Chapter 1

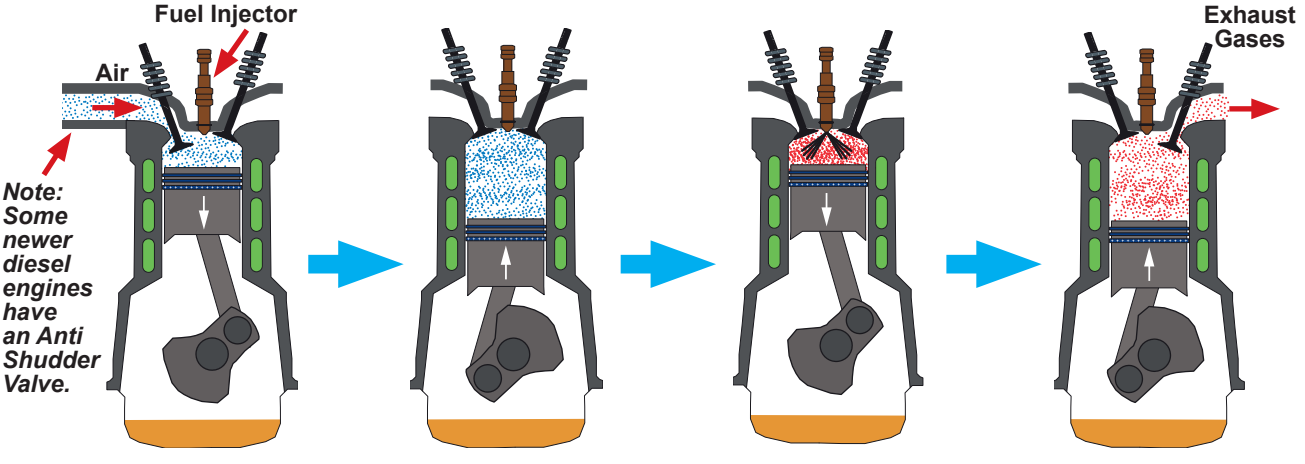
Tech Tip

ICE Requirements

For efficient combustion to occur in an internal combustion engine (ICE), there needs to be the correct air-fuel mixture, sufficient compression, and an ignition source (heat or spark). These three things must function properly to achieve engine efficiency and minimize emissions.



ICE Requirements Triangle



Intake Stroke
Intake valve is open. Exhaust valve is closed. Piston moves down. Air enters the combustion chamber.

Compression Stroke
Intake and exhaust valves are closed. Piston moves up. Air is compressed.

Power (Combustion) Stroke
Intake and exhaust valves are closed. Fuel is injected into the combustion chamber. The high pressure and heat ignite the fuel. Fuel combusts spontaneously. Piston is forced down by combustion. This is the stroke that provides the power.

Exhaust Stroke
Exhaust valve opens. Intake valve is closed. Piston moves up, pushing exhaust gases out of the engine.

Four-Stroke Cycle Repeats

Figure 1.14 ***Four-Stroke Compression Ignition Engine (Direct Injection Diesel)***
Compression Ratio Commonly 14:1 to 23:1

Power Transfer

Several processes have to occur in order for a vehicle to move. The following table explains how power is transferred in a common gasoline-powered (non-hybrid) automobile (***Figure 1.15***).

Power Transfer Process	
1	Fuel is stored as chemical energy in the gas tank.
2	Fuel is transported to the engine by a fuel pump.
3	Air-fuel mixture enters the engine.
4	Electrical energy is used to create a spark at the spark plug.
5	Combustion occurs, converting the chemical energy to kinetic energy. The piston moves linearly, reciprocating up and down or back and forth.
6	The reciprocating motion of the pistons is converted to rotary (circular) motion of the crankshaft.
7	The crankshaft's rotary motion turns the transmission.
8	On front-wheel drive (FWD) vehicles, rotary motion is transferred through a transaxle (transmission and differential combined). From the transaxle, rotary power is moved through constant velocity (CV) shafts. On rear-wheel drive (RWD) vehicles, rotary motion is transferred from the transmission through the drive shaft then to a differential and final drive assembly. In this situation, the differential changes the power flow 90° and allows the drive wheels to turn at different speeds when cornering. Power is transferred from the differential to axle shafts.
9	The axle shafts or CV shafts turn the wheels.
10	The rotary motion of the wheels converts to linear motion on the roadway.

Figure 1.15 ***How Power is Transferred***

Fuels and Designs

Most of the 278 million vehicles registered in the United States today burn either gasoline or diesel in an internal combustion engine. The simplest way to describe the difference between them is air is throttled in a gas engine and fuel is regulated in a diesel engine. This section focuses on:

- Gasoline-Powered Vehicles
- Diesel-Powered Vehicles
- Emerging Technologies

Gasoline-Powered Vehicles

Passenger cars and light trucks powered solely by burning gasoline in an internal combustion engine are the most popular. Gasoline engines use spark plugs to ignite the air-fuel mixture in the engine. There are several reasons for the popularity of gasoline-powered vehicles. They are currently affordable (this depends on the price of gas (***Figure 1.16***), easy to refuel (gas stations in just about every town), they meet performance expectations (range, acceleration, and speed), and we are most familiar with the technology.

Gasoline. One of the major disadvantages of gasoline is that once the fuel is burned, it is gone forever. In addition, gasoline engines emit hydrocarbons (HC), nitrogen oxides (NO_X), carbon monoxide (CO), and carbon dioxide (CO_2). See Chapter 17 to learn more about gasoline emissions.

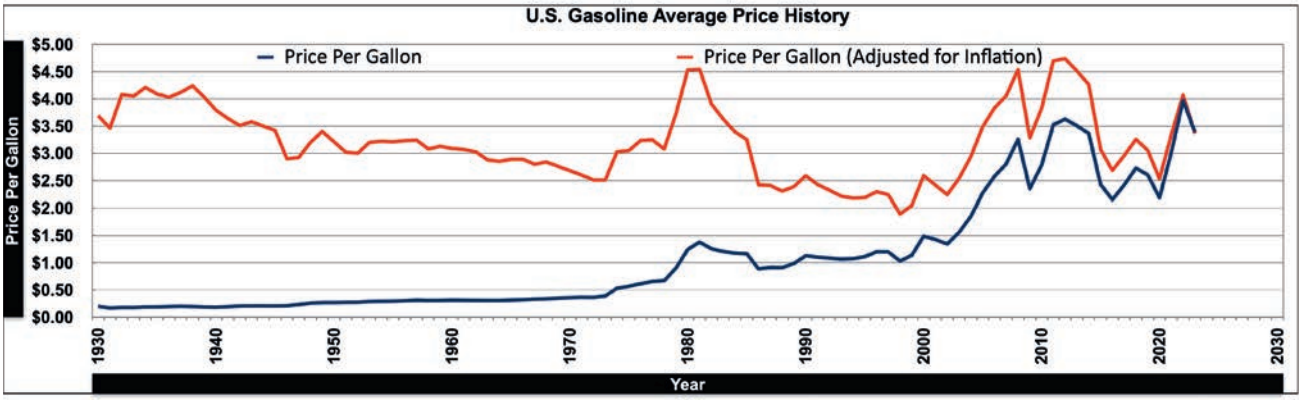


Figure 1.16 ***U.S. Gasoline Price History***

Diesel-Powered Vehicles

Diesel engines are compression ignition engines; they do not have spark plugs.

Diesel Fuel. Diesel fuel (***Figure 1.17***) has more energy per gallon as compared to gasoline, making it more efficient for every gallon of fuel burned. Diesels emit NO_X and particulate matter (PM), in addition to greenhouse gas pollutants. Ultra-low sulfur diesel and newer engine and emission systems have greatly decreased emissions. See Chapter 17 to learn more about diesel emissions.

Figure 1.17 ***Diesel Fuel Dispenser***

Medium-Duty/Heavy-Duty Vehicles. When thinking of diesel, a medium-duty (***Figure 1.18***) or heavy-duty truck might come to mind. Diesel-powered specialty vehicles (e.g., garbage trucks, school buses, and fire engines) and semi trucks pulling trailers are very common.

Figure 1.18 ***Ford F-650 Medium Duty***
Photo: Ford Motor Company

Light Trucks/Passenger Vehicles. Diesel engines are also popular in light trucks. Although more expensive, a diesel engine provides an increased towing capability over a gasoline engine.

Emerging Technologies

In 2024, the following electric vehicles (EVs) were among the highest rated MPGe by www.fueleconomy.gov (***Figure 1.19***). ***Note: Miles per gallon equivalent (MPGe) is a measure used to compare energy usage in advanced technology vehicles to the miles per gallon (MPG) rating in gasoline vehicles.***

2024 Electric Vehicles	MPGe
Hyundai IONIQ 6 RWD Long Range	140 MPGe
Lucid Air Pure RWD	137 MPGe
Hyundai IONIQ 6 RWD Standard Range	135 MPGe
Lucid Air Touring AWD	133 MPGe
Tesla Model 3 RWD	132 MPGe
Lexus RZ 300e	125 MPGe

Figure 1.19 ***2024 Electric Vehicles MPGe***

EV Charging. EVs use only electricity for propulsion. Their driving range is dependent on the traction battery, similar to a gasoline-powered vehicle dependent on a gas tank. Public and company-owned charging stations (***Figure 1.20***) are strategically placed to extend the range of electric vehicles if you cannot recharge at home.

Figure 1.20 ***Tesla Superchargers***
Photo: Tesla

Weblinks

EV Charging Stations

www.AutoUpkeep.com/resources
Click on Chapter 1

Engine Identification

A vehicle's engine is classified by its:

- Configuration
- Size/Displacement
- Compression Ratio (CR)

Configuration

Engine configurations describe the way cylinders are arranged in an engine block, commonly inline, opposed, or V (***Figure 1.21***). Engine design is also described by the number of cylinders. The most common engine configurations are inline 4s, V6s, and V8s.

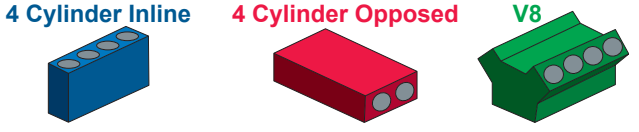


Figure 1.21 Common Engine Configurations

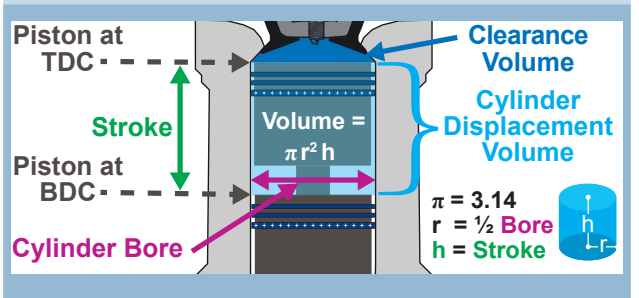
Size/Displacement

Engine size, listed in liters or cubic inches, can be found on the vehicle emission control information sticker under the hood. The size of an engine is calculated from the cylinder displacement volume during one piston stroke (bottom dead center (BDC) to top dead center (TDC)) multiplied by the number of cylinders in the engine. The bore is the diameter of a cylinder (***Figure 1.22***).

Common Engine Sizes/Displacements

1.8 L = 110 cu. in.	2.4 L = 147 cu. in.
4.6 L = 281 cu. in.	5.0 L = 305 cu. in.

Note: 1 L = 61.02 cu. in.



Cylinder Displacement Volume = π (½ Bore)² x Stroke

Engine Size = Cylinder Displacement Volume x $N_{Cylinders}$

Figure 1.22 Common Engine Sizes/Displacements

Compression Ratio (CR)

Compression ratio is the displacement volume (V_d) plus the clearance volume (V_c) divided by the clearance volume. Typical gas engines have a compression ratio between 8:1 and 12:1, while diesel engines are higher between 14:1 and 23:1. A higher compression ratio means more work from same amount of fuel, increasing efficiency.

CR = Compression Ratio
V_d = Displacement Volume
V_c = Clearance Volume

$$CR = \frac{V_d + V_c}{V_c}$$

Vehicle Identification

Vehicles can be identified by the:

- VIN
- Manufacturer
- Make
- Model
- Year
- Trim Level
- Type

VIN

The Vehicle Identification Number (VIN) is an important number on a vehicle. Keep the VIN handy to help find the correct replacement parts.

VIN Location. The 17-character VIN can be seen on the left side of the dash from outside the vehicle through the windshield. The VIN is also on the certification label inside the driver's doorjamb (***Figure 1.23***).

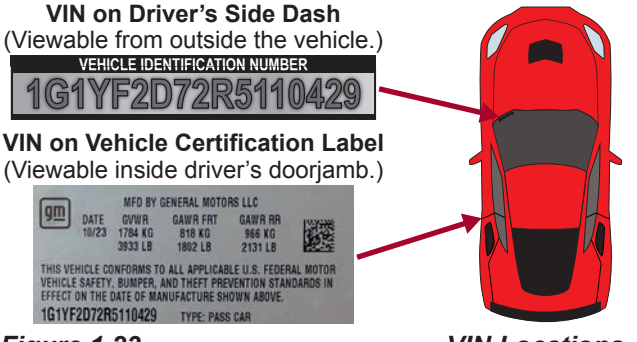


Figure 1.23 VIN Locations

VIN Information. The VIN contains coded vehicle information (***Figure 1.24***).

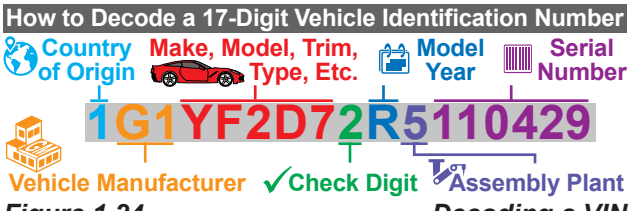


Figure 1.24 Decoding a VIN

Manufacturer

An automotive manufacturer is a company that produces vehicles.

Make

Automotive manufacturers (***Figure 1.25***) identify the various vehicles they produce by their "makes" (also known as brands or divisions).

Manufacturer	Make/Brand/Division
GM	Buick, Cadillac, Chevrolet, and GMC
Tesla	Tesla
Stellantis NV	Abarth, Alfa Romeo, Chrysler, Citroën, Dodge, DS, Fiat, Jeep, Lancia, Maserati, Opel, Peugeot, Ram, and Vauxall
Ford	Ford and Lincoln
Toyota	Lexus and Toyota
Volkswagen Group	Volkswagen, Audi, Bentley, Lamborghini, Porsche, SEAT, and Skoda
Honda	Acura and Honda
Hyundai	Hyundai and Kia
Nissan	Infiniti and Nissan

Figure 1.25 ***Examples of Makes***

Model

The model (***Figure 1.26***) of a vehicle refers to the specific name of each vehicle within a make. Model names often change over time.

Make	Model
Chevrolet	Bolt EV, Blazer, Blazer EV, Camaro, Colorado, Corvette E-Ray, Corvette Stingray, Corvette Z06, Equinox, Equinox EV, Silverado, Silverado EV, Suburban, Trax, Trailblazer, Traverse, and Tahoe

Figure 1.26 ***Examples of Models***

Year

The model year of a vehicle is not necessarily the year in which it was built. A vehicle built in October 2023 most likely would be considered a 2024 model year vehicle.

Model Year (MY). To find the actual model year of the vehicle look at the vehicle emission control information (VECI) sticker under the hood or on the opening face of the liftgate on some EVs. This sticker indicates the year of pollution standards conformance, which is also the model year.

Date of Manufacture. The date of manufacture is listed inside the driver's door on the vehicle certification label. This is the actual month and year that the vehicle rolled off the assembly line.

Trim Level

Trim levels (***Figure 1.27***) identify versions (different equipment and features) of the same vehicle model. Entry-level models, often called the base model, are the most affordable. A badge on the vehicle's back or side displays the trim level or a free online VIN decoder will identify it.

Model	Trim Level
Tahoe	LS, LT, Z71, RST, Premier, High Country

Figure 1.27 ***Examples of Trim Levels***

Type

Many different types (***Figure 1.28***) of vehicles are designed to meet consumer demands.

Type	Illustration	Make and Model*
Microcar		**Micro Microlino**, GEM e2, Renault Twizy, and XEV Yoyo
Subcompact Car		**MINI Cooper**, Hyundai Accent, Kia Rio, and Nissan Versa
Compact Car		**Honda Civic**, Toyota Corolla, Kia Forte, and Nissan Sentra
Mid-size Car		**Tesla Model 3**, Honda Accord, Nissan Altima, Toyota Camry, Kia K5, and Hyundai Sonata
Full-size Car		**Lucid Air**, Toyota Avalon, and Dodge Charger
Sports Car		**Lamborghini Revuelto** and Chevrolet Corvette
Compact SUV		**Volvo XC40**, Honda CR-V, Ford Escape, and Toyota RAV4
Mid-size SUV		**Kia Telluride**,Toyota Highlander, Honda Pilot, and Rivian R1S
Crossover SUV		**Ford Mustang Mach-E**, BMW X1, Hyundai IONIQ 5, Kia EV6, and Tesla Model Y
Full-size SUV		**Cadillac Escalade**, Ford Expedition, Jeep Wagoneer, and GMC Yukon
Compact Pickup		**Hyundai Santa Cruz** and Ford Maverick
Mid-size Pickup		**Rivian R1T**, GMC Canyon, Ford Ranger, Honda Ridgeline, and Toyota Tacoma
Full-size Pickup		**Ford F-Series**, Dodge Ram, GMC Sierra, Nissan Titan, and Toyota Tundra
Minivan		**Honda Odyssey**, Kia Carnival, and Chrysler Pacifica
Van		**Ford Transit**, GMC Savana, and Chevrolet Express

**** Illustration's make and model are highlighted in bold.***

Figure 1.28 ***Vehicle Types with Examples***

Parts and Systems

The automobile is made up of:

- Parts
- Systems

Parts

The car's frame and body (sometimes integrated together into one unit called a unibody) are large parts of the automobile.

Unibody Casting. Innovative and extensive unibody subframe casting greatly reduces the number of pieces needing assembly and welding (***Figure 1.29***).

Figure 1.29 Two Cast Body Pieces Highlighted
Photo: Tesla - Model Y Body Structure

Components. Smaller parts (also called components) and assemblies (e.g., engine, e-motor, and transmission) work together to make the vehicle move.

Tech Tip

Identifying Vehicle Parts

To purchase the correct maintenance items (e.g., filters) or replacement parts (e.g., a starter or an AC generator (alternator)), it is important to know a vehicle's VIN, make, model, engine size/configuration, production date, and model year. ***Note: The date of manufacture and the model year of a vehicle may differ. Manufacturers produce millions of vehicles each year by continuous manufacturing. Showroom floors often include vehicles from next year's model lineup 6 to 9 months before that calendar year.***

Systems

Parts that work together to perform a specific task make up a system.

Electrical System. The electrical system delivers power to various electrical components. Vehicles can have low and high-voltage systems.

Lubrication System. The lubrication system uses oil or e-fluids to reduce wear and heat.

Fuel System. Using fuel lines, injectors, and a fuel pump, the fuel system supplies the engine with the correct amount of fuel and air.

Cooling System and Climate Control. The general concept of a cooling system is similar in all vehicles, including EVs. Liquid coolant or e-fluid passes through or around components and carries away excess heat. Climate control is used to condition the air in the passenger's cabin.

Ignition System. The ignition system is designed to ignite the air-fuel mixture in a gasoline engine at the correct time.

Suspension, Steering, and Tires. The suspension system helps to control the vehicle's up and down movement. The steering system controls the vehicle's directional movements. The tires connect the vehicle to the road.

Braking System. The braking system slows and stops a vehicle.

Drivetrain. The drivetrain transfers power from the engine or e-motor to the wheels.

Exhaust and Emission System. The exhaust and emission system removes exhaust from the engine, quiets engine combustion, and lowers vehicle pollutants.

Weblinks

Automotive Manufacturers

www.AutoUpkeep.com/resources
Click on Chapter 1

Careers

Many careers exist in the automotive industry:

- Manufacturing Careers
- Service and Repair Careers
- Support Careers

Manufacturing Careers

Automotive manufacturers hire many different types of engineers that assist in pre-production, software and programming, automation, paint, and assembly. Designers, machinists, logistics personnel, production supervisors, and assembly line workers are all needed to build highly complex vehicles (***Figure 1.30***).

Figure 1.30 ***Automotive Manufacturing***
Photo: Tesla

Service and Repair Careers

Automotive technicians can work in a variety of repair facilities (***Figure 1.31***) in different capacities to diagnose, service, and repair a vehicle. Service managers oversee the shop operations. Service writers communicate with the customers and convey the concern or scheduled service to the technician through a work order.

Figure 1.31 ***Repair Facility***
Photo: Hyundai Motor Group

Support Careers

Careers that support the automotive industry include automotive teachers, salespeople, parts specialists, auto body technicians, insurance adjusters, auto loan specialists, car rental managers, and installers at specialty shops.

Workplace Skills

Workplace skills, including personal standards, work habits, and ethics, are integral to a professional work environment. See the Workplace Skills Activity in Chapter 1 of the workbook to learn more about workplace skills.

Summary

In well over 100 years, automobiles have become extremely popular. The automobile has made personal land transportation easy, allowing people to work great distances from where they live. Cugnot, Benz, and Ford, among others, changed the development of the automobile forever. Today, manufacturers are focused on mass-producing electric vehicles to increase efficiency, minimize pollution, and reduce our reliance on nonrenewable energy resources. See Chapter 21 to learn more about electric vehicles.

Activities

Introduction and How Cars Work

- Workplace Skills Activity
- Car Identification and Preparing for Vehicle Service Activity
- Owner's Manual Activity
- Chapter 1 Study Questions

Activities and Study Questions can be completed in the *Auto Upkeep Workbook*.

Career Paths

Automotive Teacher

Education: Bachelor's Degree and/or ASE Cert.
Median Income: $65,220
Abilities: Good communication with students in a technical hands-on environment.
Find your career at **www.bls.gov/ooh**.

Appendix A - Workbook Activities

Chapter 1

Workplace Skills Activity
Identify important workplace skills.

Car Identification and Preparing for Vehicle Service Activity
Identify an automobile by model year, make, model, and trim level. Prepare a vehicle for service.

Owner's Manual Activity
Locate and use an online owner's manual.

Chapter 2

Towing and Hauling Activity
Identify towing and hauling capabilities.

Advanced Driver Assistance System (ADAS) Activity
Research vehicles with ADAS to identify differences, limitations, and capabilities.

Buying a New Automobile Activity
Differentiate between MSRP, dealer invoice, and dealer cost.

Buying a Used Automobile Activity
Research prices, reliability ratings, and safety ratings on used automobiles.

Chapter 3

Automotive Expenses Activity
Calculate automotive expenses.

Chapter 4

Repair Facilities Activity
Choose a quality repair facility. Interpret a work order.

Chapter 5

Automotive Safety Activity
Identify the location of emergency and safety equipment.

Safety Data Sheet (SDS) Activity
Locate and interpret a safety data sheet.

Personal Protection Equipment (PPE) and Fire Safety Activity
Identify the importance of using PPE.

Chapter 6

Tools and Equipment Activity
Identify basic tools and equipment that are used in automotive shops.

Fasteners Activity
Identify fasteners that are used on automobiles.

Service Manual Activity
Navigate an online service manual.

Chapter 7

Interior Cleaning Activity
Clean the inside of a vehicle.

Exterior Cleaning Activity
Clean the outside of a vehicle.

Waxing Activity
Wax the finish on a vehicle

Chapter 8

Fluid Level Check Activity
Check the fluid level in various vehicle components.

Chapter 9

Ohm's Law Activity
Use ohm's law to calculate volts, amps, and ohms.

Circuit Construction Simulator Activity
Use a circuit construction simulator to build and analyze circuits.

Simple Circuits Activity
Build and test a simple circuit.

Voltage Drop Activity
Identify voltage drop and how to perform various voltage drop tests.

Wiring Diagram Activity
Locate and interpret a wiring diagram.

Battery Activity
Clean and test a 12-volt SLI battery.

Charging Activity
Test an alternator and replace a belt.

Starting Activity
Test a starter.

Chapter 10

Oil and Filter Change Activity
Change the oil and filter on an ICE vehicle.

Chapter 11

Fuel System Part Identification Activity
Use an online auto parts catalog to identify fuel system parts.

Fuel System Maintenance Activity
Identify the components of the fuel system. Change an air filter, PCV valve, and fuel filter.

Chapter 12

Air Conditioning Activity
Inspect and identify the components within the air conditioning system.

Cabin Air Filter Activity
Replace a cabin air filter.

Cooling System Activity
Test, inspect, and service the cooling system. Observe thermostat operation.

Chapter 13

Ignition System Activity
Install spark plugs. Inspect, test, and install spark plug wires. Inspect and install distributor cap and rotor on a distributor system.

Chapter 14

Suspension and Steering Activity
Inspect and perform basic service procedures on suspension and steering components.

Tire Inspection and Rotation Activity
Inspect and rotate tires.

Choosing the Right Tires Activity
Identify tires based on classification, tread, EV-specific, and new technologies.

Chapter 15

Brake Inspection Activity
Identify brake components and inspect disc brakes.

Chapter 16

Drivetrain Activity
Identify and inspect drivetrain components.

Chapter 17

Exhaust and Emission Activity
Identify and inspect exhaust and emission components.

Chapter 18

Payback Period Activity
Calculate payback period.

Future Vehicle Activity
Predict the role of the automobile in 2050.

Chapter 19

Automotive Accessories Activity
Estimate the cost of accessories for a vehicle.

Chapter 20

Changing a Flat Tire Activity
Change a flat tire.

Jump-Starting Activity
Jump-start a vehicle.

Lighting Activity
Replace various lights on a vehicle.

Replacing Wipers Activity
Replace wipers on a vehicle.

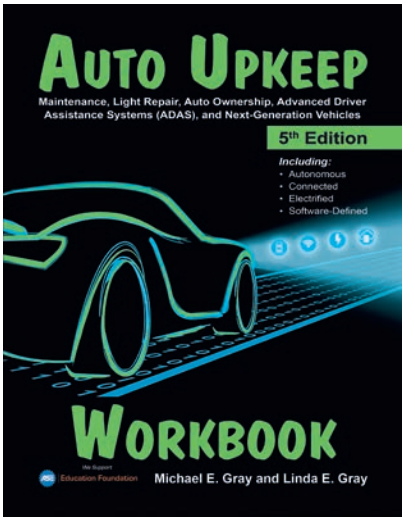
On-Board Diagnostics Activity
Retrieve diagnostic trouble codes (DTCs) from an OBD II system using a basic scan tool.

Chapter 21

Electric Vehicles Activity
Identify and compare current electric vehicles for sale.

Chapter 22

ADAS and Vehicle Automation Level Identification Activity
Identify a vehicle's ADAS systems, driving automation capabilities, and the responsibility of the dynamic driving task (DDT).



Appendix B - Acronyms/Abbreviations

Symbols

°	Degree
′	Foot
″	Inch
2WD	Two-Wheel Drive
3PMSF	Three-Peak Mountain Snowflake
4WD	Four-Wheel Drive
4x4	Four-Wheel Drive
4G	Forth Generation (Wireless)
5G	Fifth Generation (Wireless)
6G	Sixth Generation (Wireless)

A

A	Ampere
A/C	Air Conditioning
AAA	American Automobile Association
ABS	Antilock Brake System
AC	Alternating Current
ACC	Adaptive Cruise Control
ACEA	European Automobile Manufacturer's Association
ADAS	Advanced Driver Assistance Systems
ADB	Adaptive Driving Beam
AEB	Automatic Emergency Braking
AEB	Autonomous Emergency Braking
AEV	Autonomous Electric Vehicle
AGM	Absorbed Glass Mat
Ah	Ampere-hour
AI	Artificial Intelligence
ALCA	Active Lane Change Assist
ALI	Automotive Life Institute
AM	Amplitude Modulation
ANN	Artificial Neural Networks
ANSI	American National Standards Institute
APA	Active Parking Assist
API	American Petroleum Institute
API	Application Program Interface
APU	Auxiliary Power Unit
AQI	Air Quality Index
AR	Augmented Reality
AR-HUD	Augmented Reality Head-Up Display
ARB	Air Resources Board
ARB	Automatic Reverse Braking
ASE	Automotive Service Excellence
ASTM	American Society for Testing and Materials
ATF	Automatic Transmission Fluid
AV	Autonomous Vehicle
AWD	All-Wheel Drive

B

b	Bit (e.g., Internet Speed)
B	Byte (e.g., Data Storage)
B	Biodiesel
BAS	Belt-Alternator-Starter
BAS	Brake Assist System
BBB	Better Business Bureau
BbW	Brake-by-Wire
BC	Basecoat
BCI	Battery Council International
BCM	Body Control Module
BDC	Bottom Dead Center
BEV	Battery Electric Vehicle
BISG	Belt Integrated Starter Generator
BMS	Battery Management System
bps	Bits per Second
BSI	Blinds Spot Intervention
BSW	Blind Spot Warning
BTMS	Battery Thermal Management System
BTS	Bureau of Transportation Statistics
BTU	British Thermal Unit

C

c	Speed of Light in a Vacuum
C	Celsius
C-V2X	Cellular Vehicle-to-Everything
CA	Cranking Amps
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CAN	Controller Area Network
CAN-FD	CAN Flexible Data (Rate)
CARB	California Air Resources Board
CC	Clearcoat
CC	Cruise Control
CCA	Cold Cranking Amps
CCS	Combined Charging System
CCV	Crankcase Ventilation
CCW	Counterclockwise
Cd	Drag Coefficient
CD	Continuous Deployment
CFD	Computational Fluid Dynamics
CFPP	Cold Filter Plugging Point
CG	Center of Gravity
CI	Compression Ignition
CI	Continuous Integration
CPI	Contact Point Ignition
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Coil-On-Plug
CPS	Cyber-Physical System
CPU	Central Processing Unit
CR	Compression Ratio
CT	Continuous Testing
CTB	Cell-to-Body
CTC	Cell-to-Chassis
CTP	Cell-to-Pack
CV	Constant Velocity
CVT	Continuously Variable Transmission
CW	Clockwise

D

DAS	Driver Assistance Systems
dB	Decibels
DC	Direct Current
DDT	Dynamic Driving Task
DEF	Diesel Exhaust Fluid
DI	Distributor Ignition
DL	Deep Learning
DLC	Data Link Connector
DMM	Digital Multimeter
DMS	Driver Monitoring System
DOC	Diesel Oxidation Catalyst
DOE	Department of Energy
DOHC	Dual Overhead Cam
DOT	Department of Transportation
DPF	Diesel Particulate Filter
DRL	Daytime Running Lights
DSRC	Dedicated Short-Range Communications
DT	Digital Twin
DTC	Diagnostic Trouble Code
DTC	Direct-to-Consumer
DTV	Disc Thickness Variation

E

E	Ethanol
E/E	Electrical/Electronic
e.g.	For Example
e-Fluid	Advanced Fluid for EVs
e-Fuse	Electronic Fuse
e-Grease	Advanced Grease for EVs
e-Motor	Electric Motor
ECU	Engine Control Unit
EEC	Electronic Engine Control
ECM	Electronic Control Module
ECM	Engine Control Module
ECT	Engine Coolant Temperature
ECU	Electronic Control Unit
EGHR	Exhaust Gas Heat Recovery
EGR	Exhaust Gas Recirculation
EHB	Electro-Hydraulic Brake
EI	Electronic Ignition
ELC	Extended Life Coolant
EM	Electric Motor
EM	Electromagnetic
EMB	Electromechanical Brake
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMT	Emergency Medical Technicians
EOC	End of Charge
EPA	Environmental Protection Agency
EPB	Electric Parking Brake
EPDM	Ethylene Propylene Diene Monomer
EPS	Electric Power Steering
EREV	Extended Range Electric Vehicle
ERG	Emergency Response Guide
ESC	Electronic Stability Control
ETBE	Ethyl Tertiary Butyl Ether
ETC	Electronic Throttle Control
eV	Electron Volt
EV	Electric Vehicle
EVAP	Evaporative Emissions
EVSE	Electric Vehicle Supply Equipment

F

F	Fahrenheit
FC	Fuel Cell
FCEV	Fuel Cell Electric Vehicle
FCW	Forward Collision Warning
FGAW	Front Gross Axle Weight
FIR	Far-Infrared
FM	Frequency Modulation
FOTA	Firmware Over-the-Air
ft	Foot
FWD	Front-Wheel Drive

G

GAW	Gross Axle Weight
GAWR	Gross Axle Weight Rating
GB	Gigabyte
Gbit/sec	Gigabit per Second
GCW	Gross Combined Weight
GCWR	Gross Combined Weight Rating
GDI	Gasoline Direct Injection
GGE	Gasoline Gallon Equivalent
GF	Gasoline-Fueled
GHG	Greenhouse Gas
GHz	Gigahertz
GM	General Motors
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPU	Graphics Processing Unit
GTW	Gross Trailer Weight
GTWR	Gross Trailer Weight Rating
GVW	Gross Vehicle Weight
GVWR	Gross Vehicle Weight Rating

H

H	Hydrogen
H_2ICE	Hydrogen Internal Combustion Engine
H_2O	Water
HAV	Highly Automated Vehicle
HC	Hydrocarbon
HD	High Definition
HDA	Hill Descent Assist
HEPA	High-Efficiency Particulate Air (Filter)
HEV	Hybrid Electric Vehicle
HID	High-Intensity Discharge
HL	High Load (Tire Capacity)
HOAT	Hybrid Organic Acid Technology
HMI	Human-Machine Interface
hp	Horsepower
HPC	High Performance Computing
HSA	Hill Start Assist
HUD	Head-Up Display
HV	High Voltage
HVAC	Heating, Ventilation, and Air Conditioning
Hz	Hertz

I

I2V	Infrastructure-to-Vehicle
IAC	Idle Air Control
IAT	Inorganic Acid Technology
IBS	Intelligent Battery Sensor
ICCU	Integrated Charging Control Unit
ICE	Internal Combustion Engine
id	Inside Diameter
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
IIHS	Insurance Institute for Highway Safety
I/M	Inspection and Maintenance
ILSAC	International Lubricant Standardization and Approval Committee
IMA	Integrated Motor Assist
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IoT	Internet of Things
IR	Industrial Revolution
IR	Infrared
ISG	Integrated Starter/Generator
ISO	International Standards Organization
IT	Information Technology
IPEC	Integrated Power Electronics Controller
IVN	In-Vehicle Network

K

KBB	Kelley Blue Book
kg	Kilogram
kbit/s	Kilobit per Second
km	Kilometer
km/h	Kilometers per Hour
kPa	Kilopascal
KS	Knock Sensor
kW	Kilowatt
kWh	Kilowatt-hour

L

L	Liter
LAN	Local Area Network
Laser	Light Amplification by Stimulated Emission of Radiation
lb	Pound
lb-ft	Pound-foot
LCA	Lane Centering Assistance
LCD	Liquid Crystal Display
LCO	Lithium Cobalt Oxide
LDW	Lane Departure Warning
LED	Light-Emitting Diode
LEO	Low Earth Orbit
LFP	Lithium Ferrophosphate
Li+	Lithium Ion
Li	Lithium
Lidar	Light Detection and Ranging
Li-ion	Lithium-Ion
Li-poly	Lithium-Ion Polymer
LIN	Local Interconnect Network
LKA	Land Keeping Assist
LL	Light Load (Tire Capacity)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LRR	Long-Range Radar
LRR	Low Rolling Resistance (Tires)
LT	Light Truck (Tires)

M

m	Meter
M	Metric
M+S	Mud and Snow
mm	Millimeter
mmWave	Millimeter Wave
MAF	Mass Airflow
MAP	Manifold Absolute Pressure
Mbit/sec	Megabit per Second
Mbps	Megabit per Second
MG	Motor/Generator
MHEV	Mild Hybrid Electric Vehicle
MHz	Megahertz
MIL	Malfunction Indicator Light
MIMO	Multiple Input Multiple Output
MIR	Mid-Infrared
ML	Machine Learning
mm	Millimeter
MOST	Media-Oriented Systems Transport
MPG	Miles Per Gallon
MPGe	Miles Per Gallon equivalent
MRR	Mid-Range Radar
MSDS	Material Safety Data Sheet
MSRP	Manufacturer's Suggested Retail Price
MTBE	Methyl Tertiary Butyl Ether
MY	Model Year

N

N	Nitrogen
N•m	Newton-Meter
NAAQS	National Ambient Air Quality Standards
NACS	North American Charging Standard
NADA	National Automotive Dealers Association
NASCAR	National Association for Stock Car Auto Racing
NDS	Navigation Data Standard
NCA	Nickel Cobalt Aluminum
NEMA	National Electric Manufacturers Association
NFPA	National Fire Protection Association
NHTSA	National Highway Traffic Safety Administration
NIHL	Noise-Induced Hearing Loss
NiMH	Nickel Metal Hydride (Battery)
NIR	Near-Infrared
NIST	National Institute of Standards and Technology
NMC	Nickel Manganese Cobalt
NMVTIS	National Motor Vehicle Title Information System
NPT	Non-Pneumatic Tires
No.	Number
NOx	Nitrogen Oxides
NR	New Radio
NSC	National Safety Council
NV	Night Vision

O

O_2	Oxygen
OAT	Organic Acid Technology
OBD	On-Board Diagnostics
OBC	Onboard Charger
ODD	Operational Design Domain
OEDR	Object and Event Detection and Response
OEM	Original Equipment Manufacturer
OPEC	Organization of Petroleum Exporting Countries
OS	Operating System
OSHA	Occupational Safety and Health Administration
OSS	Open Source Software
OTA	Over-the-Air

P

P	Passenger
Pa	Pascal
PCM	Powertrain Control Module
PCU	Powertrain Control Unit
PCV	Positive Crankcase Ventilation
PDC	Power Data Center
PDR	Paintless Dent Repair
PEM	Proton Exchange Membrane
PFI	Port Fuel Injection
PH	Parallel Hybrid
PHEV	Plug-in Hybrid Electric Vehicle
PII	Personally Identifiable Information
PM	Particulate Matter
PM	Permanent Magnet
PM	Preventative Maintenance
PPE	Personal Protection Equipment
PPF	Paint Protection Film
PPM	Parts-Per-Million
psi	Pounds per Square Inch
PZEV	Partial Zero Emission Vehicle

R

R	Radial
R	Resistance
Radar	Radio Detection and Ranging
RCTW	Rear Cross Traffic Warning
RF	Reinforced (Tire)
RGAW	Rear Gross Axle Weight
RGAWR	Rear Gross Axle Weight Rating
RPM	Revolutions Per Minute
RSU	Roadside Unit
RTOS	Real-Time Operating System
RWD	Rear-Wheel Drive

S

SAE	Society of Automotive Engineers
SbW	Steer-by-Wire
SCR	Selective Catalytic Reduction
SDS	Safety Data Sheet
SDV	Software-Defined Vehicle
SI	International System of Units
SI	Spark Ignition
SL	Standard Load (Tire Capacity)
SLA	Short-Long Arm
SLI	Starter, Lighting, and Ignition (Battery)
SoC	State of Charge
SoC	System-on-Chip
SOTA	Software Over-the-Air
SRR	Short-Range Radar
SRS	Supplemental Restraint System
ST	Special Trailer
SUT	Sport Utility Truck
SUV	Sport Utility Vehicle
SVO	Straight Vegetable Oil

T

T	Temporary
TAME	Tertiary Amyl Methyl Ether
TBI	Throttle Body Injection
Tbit/sec	Terabit per Second
TCS	Traction Control System
TDC	Top Dead Center
THz	Terahertz
TM	Traction Motor
TMS	Thermal Management System
TPI	Threads per Inch
TPMS	Tire Pressure Monitoring System
TSB	Technical Service Bulletin
TW	Tongue Weight
TWC	Three-Way Converter

U

U-Joint	Universal Joint
UBI	Usage-Based Insurance
UC	Ultracapacitor
UL	Underwriter's Laboratories
ULSD	Ultra-Low Sulfur Diesel
UN	Unified National
UNC	Unified National Coarse
UNF	Unified National Fine
UTQG	Uniform Tire Quality Grading
US	Ultrasonic
USB	Universal Serial Bus
USFA	United States Fire Administration
USS	Ultrasonic Sensor
UV	Ultraviolet
UX	User Experience

V

V	Volt
V2C	Vehicle-to-Cloud
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
V2I	Vehicle-to-Infrastructure
V2L	Vehicle-to-Load
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VCMS	Vehicle Charging Management System
Vc	Clearance Volume (Engine)
Vd	Displacement Volume (Engine)
VECI	Vehicle Emission Control Information
VIN	Vehicle Identification Number
VOC	Volatile Organic Compound
VOM	Volt-Ohm-Meter
VTOL	Vertical Takeoff and Landing
VR	Virtual Reality
VRU	Vulnerable Road User

W

W	Watt
Wh	Watt-hour
Wi-Fi	Wireless Fidelity
WMA	Windows Media Audio
WSS	Wheel Speed Sensor
WVO	Waste Vegetable Oil

X

xEV	Electrified Propulsion Vehicle
XL	Extra Load (Tire Capacity)

Z

ZEV	Zero Emissions Vehicle

Appendix C - Text Features

Apps

Calculations

Career Paths

Procedures

Q & A

Servicing

Trouble Guides

Tech Tips

Videos

Weblinks

Appendix D - Symbols and Indicator Lights

Information
(On, Available, Standby, but Not Active)

Normal
(On, Ready, or Active)
Blue May Mean Cold

SERIOUS
(Attention Alert, Fix or Proceed with Caution)

WARNING
(Critical Immediate Risk, Stop as Soon as Safe)
Red May Mean Hot

Symbols may illuminate in different colors or flash to indicate the level of urgency.*

Active Safety

- Forward Collision Alert
- Rear Cross Traffic Alert
- Blind Spot Alert
- Cross Traffic Alert
- Lane Departure Alert
- Steering Required
- Driver Monitor
- Driver Break Time
- Master Alert
- Icy Road Alert
- System Message
- Safety Suport Alert
- Night Vision On
- Life Presence Alert
- Vehicle Alert
- Pedestrian Alert
- Cyclist Alert

Assistance

- Lane Keep Assist (LKA) Standby
- Lane Centering Assistance (LCA) On
- Cruise Control (CC) Set
- Adaptive Cruise Control (ACC) Active
- Parking Assist On
- Hill Descent Assist On
- Terrain/Trail (4WD) Assist On
- One Pedal Driving On
- Press Brake Pedal
- Hill Start Assist On

Body

- Fuel Cap Alert
- Door Ajar
- Hood Ajar
- Trunk Ajar

Brake System

- Parking Brake On
- Brake Fluid Low
- Brake Pad Fault
- BRAKE Brake Fault
- Electric Parking Brake Fault
- HOLD Brake Hold On
- RBS Regenerative Brake Fault
- ABS Antilock Brake System Fault

Charging System

- Charging System Fault

Drive Modes

- EV Drive Mode On
- Economy Mode On
- ECO Economy Mode On
- Snow/Ice Mode On
- Off-Road Mode on
- CrabWalk Mode On

Electric Vehicle

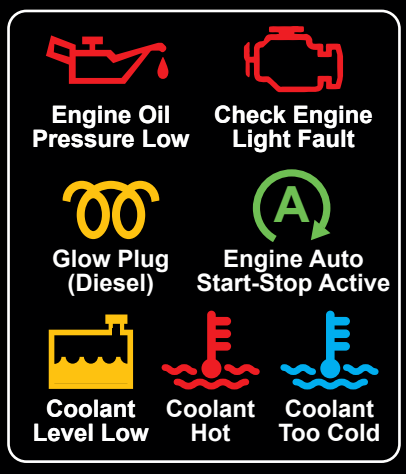
- Ready to Drive
- EV Electrical Fault
- EV Electrical Fault
- Battery Charge Level
- External Sound System Fault
- Power Limited
- Charge Cord Connected
- AGC Auto Glide Control On
- e-Motor Hot
- e-Motor Cold
- e-Motor Fault

Electronic Throttle

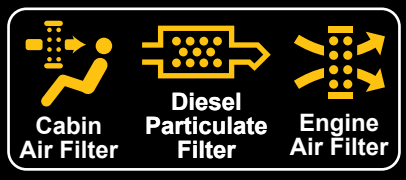
- Electronic Throttle Control Fault

** Symbols are not universal and may vary by manufacturer, make, and model. This appendix is not all inclusive.*

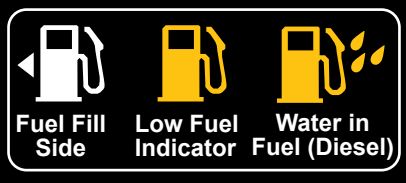
Engine



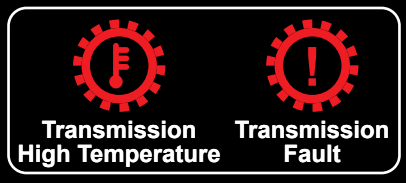
Filters



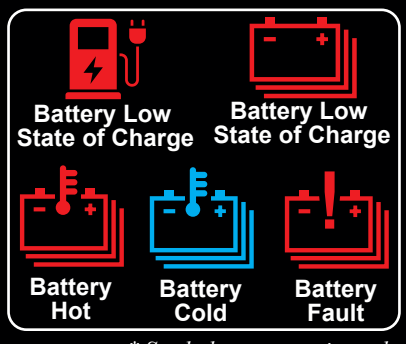
Fuel



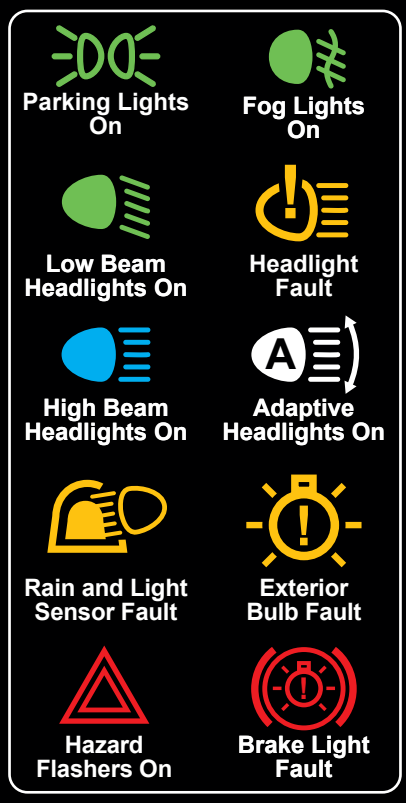
Gearbox



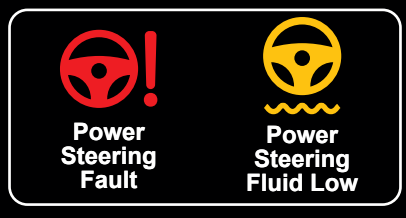
High-Voltage Battery



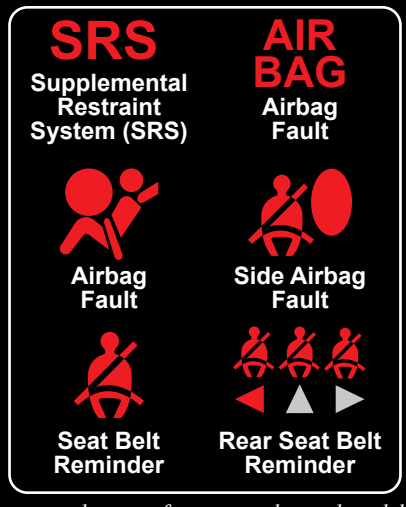
Lights



Power Steering

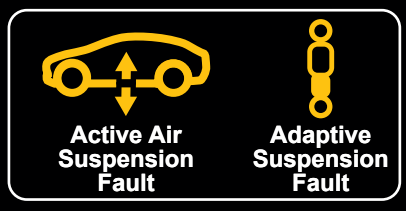


Restraint System

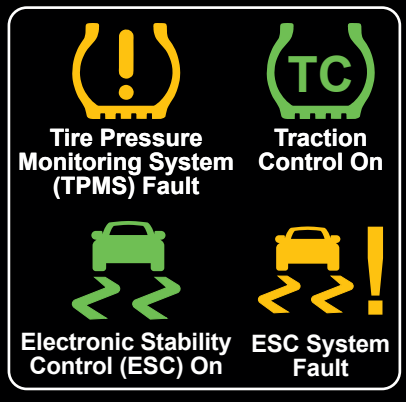


Security

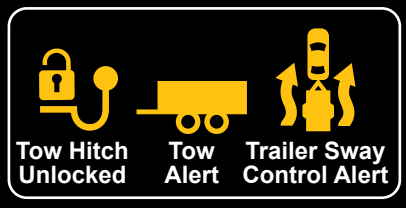
Suspension



Tires/Traction



Tow/Haul



Wipers

** Symbols are not universal and may vary by manufacturer, make, and model. This appendix is not all inclusive.*

Glossary

A

Advanced driver assistance systems (ADAS) – technologies that can assist human drivers with the dynamic driving task (DDT). ADAS features are the building blocks of an incremental evolution toward full automation.

Aftermarket part – a replacement part made by a company that did not originally make the part for the vehicle when the vehicle was assembled.

Alternating current (AC) – a type of electric current where electron (electricity) flow changes direction (alternates) back and forth.

Alternator – a device, also called an AC generator, that converts mechanical energy to electrical energy to recharge the battery.

American Petroleum Institute (API) – a trade organization that represents oil and natural gas stakeholders that, among other things, develops consensus standards within the oil and gas industry (e.g., engine oil service ratings).

Amperage – measured in amperes (or amps), is the strength (quantity of electrons) in the electrical circuit.

Antifreeze – also called coolant, is a substance with its main ingredient glycol, which has a high boiling point and a low freezing point when mixed with water.

Antilock brake system (ABS) – a system used to minimize wheel lockup when braking to maximize driver control.

Artificial intelligence (AI) – intelligence expressed by systems trained to mimic human cognition.

Asymmetrical – sides are not the same.

Automatic transmission – a transmission that shifts automatically from one gear ratio to another without the assistance of the driver.

Autonomous vehicles (AV) – vehicles that can drive without human input. They include advanced driver assistance systems (ADAS) as standard technology.

B

Battery – a device that stores chemical energy.

Battery management system (BMS) – regulates the energy in battery cells, to prevent unsafe conditions.

Big data – very large volumes of data, processed fast, with diverse information.

Blow-by – combustion gases that leak past piston rings and into the crankcase.

Brake-by-wire (BbW) – electrified braking system with smart electronic actuators, sensors, and control systems that generate the brake clamping force at each caliper.

Brake fluid – a hydraulic fluid used in automotive brake systems that withstands high temperatures and freezing.

British thermal unit (BTU) – a measurement of the amount of energy released burning one wooden match.

Bulkhead – see firewall.

C

Camber – a term used during wheel alignments to identify the tilt of the top of a wheel/tire assembly.

Caster – a term used during wheel alignments to identify the forward or backward tilt from absolute vertical as viewed from the side of the vehicle.

Catalytic converter – a device used to convert carbon monoxide, hydrocarbons, and nitrogen oxides into water vapor, carbon dioxide, and nitrogen.

Chamois – a leather towel, commonly made from sheepskin, used to dry a vehicle after washing.

Circuit – a path for electricity to flow that includes a power source, a conductor, and a load.

Conductor – a material that easily allows electron movement (electricity) from one point to another.

Connected vehicle – a vehicle with over-the-air connectivity, connected to everything (in the vehicle and the cloud).

Constant velocity (CV) shaft – a drive shaft commonly used on front-wheel and all-wheel drive vehicles that allows for power transfer to the wheels while also allowing for suspension movement and turning.

Contaminate – something impure.

Continuously variable transmission (CVT) – a type of automatic transmission commonly utilizing a chain or belt system that does not have a limited number of gear ratios like traditional automatic transmissions.

Corrosivity – able to corrode or dissolve.

Crude oil – a non-renewable resource, also known as petroleum, mainly containing carbon and hydrogen (hydrocarbons) found naturally in the earth. It is used to make gasoline, diesel, kerosene, and a wide range of products.

Current – the quantity of electrons moving through a conductor measured in amps.

D

Decibel (dB) – a measurement of the loudness of sound.

Deductible – the amount you must pay when you make an insurance claim.

Depreciation – a term used to describe how an asset has its value reduced over time.

Dielectric fluid – an insulating fluid with no loosely bound electrons to conduct electricity.

Diesel – a fuel (chemical energy) made from crude oil that has an energy content of approximately 129,500 BTUs per gallon.

Diesel, Rudolf – invented the diesel engine that eliminated a spark plug by instead using high compression to ignite the fuel.

Diodes – an electronic device that allows electricity to flow in only one direction.

Direct current (DC) – a type of electric current where electrons (electricity) flow in one direction.

Directional – one direction.

Disc thickness variation – subtle variation in thickness of the disc (rotor).

Distillation – the process of using heat to refine crude oil to make a variety of products.

Distributed architecture – a complex legacy E/E architecture with many dedicated electronic control units that are tightly coupled with software.

Domain architecture – consolidates multiple electronic control unit software functions logically to centralized domain controllers.

Driver monitoring system (DMS) – direct DMS (driver-facing cameras) and indirect DMS (steering input) are used to monitor the driver's attention to the road.

Dynamic driving task (DDT) – real-time operational and tactical driving functions, as well as object and event detection and response (OEDR).

E

e-Fluid – a lubricant engineered to meet EV parameters of minimizing friction, low viscosity, materials compatibility, dielectric properties, and heat transfer.

e-Fuse – semiconductors and electromechanical relays with solid-state switches to monitor and control current, protecting loads and wires from overheating.

e-Machine (electrical machines) – a term used for hybrid e-motors.

e-Motor (electric motor) – converts electrical energy into mechanical energy.

Electricity – the movement of electrons through a conductor.

Electrification – replacing parts that are powered by conventional energy sources (such as crude oil) with parts that run on electricity.

Electrolysis – the process of running an electric current through water to separate the hydrogen from the oxygen.

Electrolyte – a medium in a battery that transports ions.

Electromagnetic (EM) radiation – a stream of photons (particles with no mass) that move as waves. Their periodic oscillations can carry energy through air, solid materials, and space.

Electromechanical – a mechanical component or device that is activated and/or controlled with electrical energy.

Energy – the fuel stored or used to perform work.

Engine configuration – the design of the engine block, most commonly inline or V shaped.

Engine (internal combustion) – a machine where fuel (chemical energy) is burned inside a combustion chamber within the engine to produce motion (mechanical energy).

Engine oil – a substance, made from crude oil and/or synthetic compounds, that lubricates, cools, cleans, and seals moving parts inside an engine.

Engine size – the size of the engine calculated from the combined volume of all the cylinders.

F

Fail-operational – a system that must detect, assess, tolerate, isolate, and recover from all critical faults in fault-tolerant time.

Fiber optics – a flexible glass or plastic fiber that transmits huge amounts of data very quickly through pulses of visible light (laser or LED) utilizing total internal reflection.

Firewall (bulkhead) – the divider, commonly made of steel with insulating material, between the engine compartment and the passenger cabin.

First responder cut loop – loop cut to isolate (NOT de-energize) the high-voltage traction battery in an emergency.

Force – a push or pull, the interaction between objects.

Forced induction – the process of forcing and compressing air into the combustion chamber.

Ford, Henry – entrepreneur and founder of Ford Motor Company that successfully mass-produced cars on a moving assembly line in the early 1900s.

Fuse – an overcurrent protection device that safeguards electrical components.

G

Gasoline – a fuel (chemical energy) made from crude oil that has an energy content of approximately 114,100 BTUs per gallon.

Gasoline direct injection (GDI) – a type of fuel injection where high-pressure fuel injectors deliver a fine mist of fuel directly into the combustion chamber.

Gasoline gallon equivalent (GGE) – a measure used to compare the energy of an alternative fuel to gasoline.

Gear – engineered in sets, have teeth that mesh with one another to change speed, torque, and direction of travel.

Global navigational satellite system (GNSS) – is an international collaboration of constellations (groups of satellites).

Global positioning system (GPS) constellation – the U.S. navigational system of satellites that orbit the Earth, sending one-way signals to communicate their location and time.

H

Heater core – a small heat exchanger that provides heat from engine coolant to the passenger cabin.

High-performance computing (HPC) – high-level processing executed by a supercomputer with thousands of compute nodes to complete tasks faster.

High voltage – in the auto industry is any voltage above 60V DC. It requires contact protection. High-voltage cables are color coded in bright orange.

Horsepower (hp) – the work needed to lift 550 pounds a distance of 1 foot in 1 second.

Hybrid – a vehicle that uses more than one method for propulsion or power.

Hydroplane – sliding uncontrollably when a thin film of water causes the tire tread to lose traction with the road.

I

Ignitability – easily combustible.

Ignition coil – a step-up transformer used to convert a low voltage from the SLI battery into a high voltage at the spark plugs to ignite the air-fuel mixture.

Independent suspension – a type of suspension that allows the wheel/tire assembly to move up and down without relying on movements from another wheel/tire assembly.

Insulator – a material that resists the flow of electrons (electricity).

Insurance – a policy that provides protection against financial loss when accidents occur.

Interference engine – an engine where the valves and pistons could come in contact with one another if the timing belt or chain breaks, skips, or is stripped out.

Internet of things (IoT) – a network of billions of smart devices and machines with computer chips and sensors that communicate with each other.

K

Key fob – a remote transmitter for use in keyless entry and/or push button keyless ignition systems.

Kinetic energy – energy of motion.

L

Light detection and ranging (lidar) – an active system, using laser beams to detect objects and map their distance.

Load – in electricity, the resistance in a circuit.

Longitudinal engine – an engine that is mounted parallel with the length of the vehicle.

M

Machine learning (ML) – a branch of artificial intelligence using data and algorithms to classify objects.

MacPherson – a type of strut that integrates the shock and coil spring together into one unit.

Malfunction indicator light (MIL) – illuminates when a problem or potential problem exists within one of the vehicle's systems.

Manual transmission – a transmission that requires the driver to manually shift gear ratios with a gear stick shifter and a clutch.

Master cylinder – a component in the braking system that converts movement from the brake pedal to hydraulic pressure.

Miles per gallon equivalent (MPGe) – a measure used to compare energy usage in advanced technology vehicles to the MPG rating in gasoline vehicles.

Model Year (MY) – the year of a vehicle's pollution standards conformance, found on the VECI sticker under the hood.

N

New radio (NR) – a radio access technology for 5G mobile networks. It includes millimeter wave (mmWave) frequency infrastructure with base stations called massive MIMO (Multiple Input Multiple Output).

Next-generation vehicle – a vehicle incorporating four highly interconnected mega trends: electrification, autonomous, software-defined, and connected. A next-generation vehicle is essentially a supercomputer on wheels.

North American Charging Standard (NACS) – the new standard EV connector (formerly the Tesla charger design).

O

Occupational Safety and Health Administration (OSHA) – a governmental organization that was created to help prevent work related deaths, illnesses, and injuries.

Octane rating – a gasoline property a that resists premature combustion. The higher the number the more the fuel resists igniting (an antiknock quality).

Oil – see engine oil.

Open – in electricity, a break in the circuit.

Optical ethernet – transmits data signals over optical fiber cable at ultra-high bandwidth.

Original equipment manufacturer (OEM) – used to identify a replacement part that is made by the same company as the original part when the vehicle was assembled.

Otto cycle – named after Nikolaus Otto, the most common internal combustion engine design for automobiles which consists of four piston strokes (intake, compression, power, and exhaust).

P

Parallel – an electrical circuit with two or more paths.

Payload – the weight a vehicle is carrying.

Personal protection equipment (PPE) – clothing and equipment you wear to minimize exposure to hazards, protecting you from injuries and illnesses.

Personally identifiable information (PII) – data that identifies a person.

Photovoltaic cells – solar arrays that convert sunlight directly to electrical energy.

Polish – a product used to remove minor scratches and oxidation on surfaces.

Potential energy – stored energy, energy of position.

Power – the rate at which work is done.

Powertrain control module (PCM) – a computer that processes data from sensors and sends commands to the engine and transmission controls.

Preconditioning – preheating or precooling electric vehicle components using thermal management systems (TMS).

R

Radio detection and ranging (radar) – an active sensing device or system that provides its own electromagnetic wave pulses, relying on reflections back to determine distance, velocity, and angle of objects around a vehicle.

Reactivity – unstable under normal conditions.

Real-time operating system (RTOS) – an operating system that schedules many events concurrently, while making sure the system responds predictably on time.

Rebuilt part – a replacement part that has been fixed by removing and replacing the defective component(s), but has not necessarily been completely reworked.

Recall – a notice informing the owner that a service needs to be completed to remedy a defective or unsafe component or design.

Refrigerants – gaseous compounds with boiling points that are easy to manipulate. Refrigerants are used in heat pumps and A/C systems, changing states from a liquid to a gas, and a gas to a liquid, absorbing heat when evaporated into a gas and dissipating heat when condensed into a liquid.

Regenerative braking – a type of braking where a generator is used to recapture energy that would be normally lost when the driver is attempting to slow down the vehicle.

Remanufactured part – a replacement part that has been completely disassembled, inspected, and wearable parts replaced.

Resistance – measured in ohms (Ω), is used to identify the degree of an opposing electron flow (electricity).

Rotor (brake disc) – a rotating part connected to the wheel hub. When braking it creates friction with the brake pads.

Rotor (distributor) – a rotating part inside the distributor cap, distributing high voltage to each spark plug.

Rotor (electric motor) – a rotating part inside an electric motor.

Runout – the slight up and down or side to side movement in error when a part rotates.

S

Safety data sheet (SDS) – detailed information on the possible hazards of working with a chemical product.

Saturation – beyond its holding point.

Sensor fusion – uses artificial intelligence to merge the strengths of multiple synchronized sensor inputs and external data to create a more comprehensive map of a vehicle's environment.

Series – an electrical circuit with a single path.

Serpentine belt – a common type of drive belt (flat with grooves on one side and smooth on the other) used to turn the alternator, power steering, A/C compressor, and other components.

Short – in electricity, a shorter less resistant, unintended and unwanted path.

Society of Automotive Engineers (SAE) – a professional organization that establishes standards (e.g., oil classifications and vehicle automation levels).

Software-defined vehicle (SDV) – a vehicle when the amount and value of software managing operations, functionality, and features eclipses mechanical hardware.

Speed of light – light travels in a vacuum at a constant "c", about 300,000 kilometers (186,000 miles) per second. The upper speed limit of the universe.

Starter – a device that converts electrical energy to mechanical energy to turn over (crank) an engine.

Steer-by-wire (SbW) – uses an electrical connection to send steering input to the rack and pinion without a mechanical connection from the steering wheel.

Stoichiometric mixture – the mass ratio of 14.7 parts of air to 1 part of fuel, the ideal mixture for combustion.

Stranded energy – energy that remains trapped in a battery, even after methods have been used to deplete the energy.

Supercomputer – an extremely powerful computer for high-speed computations.

Symmetrical – the same on both sides.

Synthetic oil – oil made from chemically derived base stock (molecular engineered) with additives that create an oil with exceptional lubricating abilities.

System – parts that work together to perform a specific task.

T

Tactile alerts – alerts you feel, such as a vibration in the seat or a rumble in the steering wheel.

Technical service bulletin (TSB) – a written advisory statement by a vehicle manufacturer to assist dealerships in diagnosing reoccurring problems.

Tempered window – a durable safety glass that can be shattered to escape a vehicle in an emergency. A vehicle should have at least one window with tempered glass.

Thermal imaging – a passive imaging technology that observes wavelengths from infrared radiation emitted by warm objects.

Thermal runaway – an increase in current flow, triggered by a defect or abuse, resulting in a chain of exothermic reactions that lead to a domino effect or "runaway" of thermal energy.

Tire pressure monitoring system (TPMS) – a system used to alert a driver if any tire is significantly underinflated or overinflated.

Toe – a term used during wheel alignments to identify the outward (toe out) or inward (toe in) position of the front edge of a wheel/tire assembly.

Tongue weight (TW) – the downward force a trailer tongue applies to a hitch.

Torque – a rotational force used to turn an object around an axis, fulcrum, or pivot point.

Tow capacity – the trailer pulling capacity of a vehicle.

Traction motor – an electric motor that propels a vehicle using energy stored in a traction battery.

Transverse engine – an engine that is mounted perpendicular to the length of the vehicle.

U

Ultrasonic sensors (USS) – sensors that use sonar (sound navigation and ranging) to help detect near proximity objects.

Unibody – a design that combines the body and frame into one unit.

Uniform tire quality grading (UTQG) – ratings used to compare treadwear, traction, and temperature capabilities between different tires.

V

Viscosity – the measure of resistance of a fluid to flow (e.g., low viscosity oils flow easier than high viscosity oils).

Visible light – the smallest region of the electromagnetic spectrum and the only part a human eye is "tuned" to see without the use of technology.

Voltage – the electrical potential measured in volts.

W

Wax – a product used to protect an automobile's exterior finish.

Wheel chock – a device used to block a wheel to help keep a vehicle from rolling.

Window sticker – a sticker that includes a vehicle's technical specifications and safety, environmental, and fuel economy ratings.

Windshield washer fluid – specially formulated fluid which resists freezing that is added to the windshield washer reservoir, assisting in cleaning the windshield.

Work – the transfer of energy from one object to another.

X

X-by-wire – also called drive-by-wire, provides critical components (powertrain, steering, braking, and suspension) with virtually infinite electronic control to improve a vehicle's physical handling and stability through electrical signals.

Z

Zerk fitting – a fitting that can be greased using a grease gun commonly found on a steering or drivetrain component.

Zone architecture – a structure of the electrical/electronic (E/E) architecture that uses strategically placed zone controllers to carry out actions as local hubs, aggregating data onto a high-speed Ethernet bridge to one or more supercomputers for high-level processing.

Zone controller – intelligent power data centers (PDC) with semiconductor smart-fuses that act as local hubs.

Index

Symbols

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

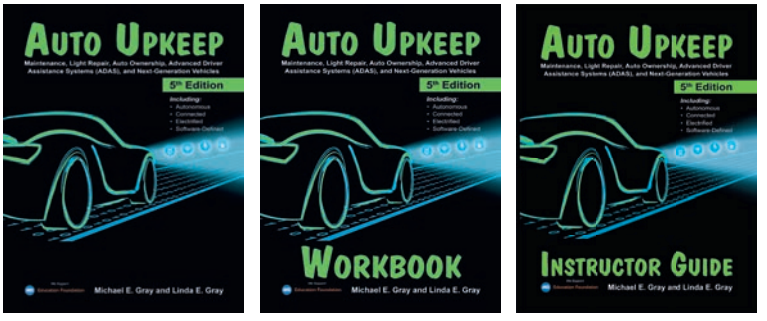
Y

Z

PAGE 400

Auto Upkeep

Maintenance, Light Repair, Auto Ownership, Advanced Driver Assistance Systems (ADAS), and Next-Generation Vehicles



Michael E. Gray and Linda E. Gray

Edition 5th

Including:
- Autonomous
- Connected
- Electrified
- Software-Defined

Order Info
(800) 918-READ
www.AutoUpkeep.com

Print Books*

** Similar Content - Delivered in Three Ways*

Textbook ISBN: 978-1-62702-050-3
Hardcover (400 Pages)

Workbook ISBN: 978-1-62702-051-0
Paperback (224 Pages)

Set ISBN: 978-1-62702-052-7
Textbook and Workbook

Easy-to-Read | Durable Binding | Life Skill Building | Over 1,100 Illustrations | Related Videos | Workbook Activities | Related Apps | Related Weblinks | Glossary/ Index

eBooks*

ISBN: 978-1-62702-053-4
eTextbook (400 Pages)

ISBN: 978-1-62702-054-1
eWorkbook (224 Pages)

eSet ISBN: 978-1-62702-055-8
eTextbook and eWorkbook

Read Anywhere | Skim, Jump, and Search | Bookmark Navigation | Related Videos | Printable Activities | Text-to-Speech | Digital Notes | Highlight Text | Build Study Guides

Online Academy*

Academy.AutoUpkeep.com

Interactive Lessons | Gamified Design | Private Groups | Embedded Videos | Fillable PDF Activities | Human Voice Read Aloud | Graded Online Tests | Printable Certificates | Online Gradebook

Instructor Resources

ISBN: 978-1-62702-057-2 Includes Textbook, Workbook, Instructor Guide, and Online Access to Instructor Resources

Course Syllabus Outline | Competency Profile | Lesson Plans | Chapter Tests and Final | Answer Keys | LMS Common Cartridge File | ASE Correlation Matrix | Readability Worksheets | PowerPoint Slides | Learning Extensions

www.AutoUpkeep.com