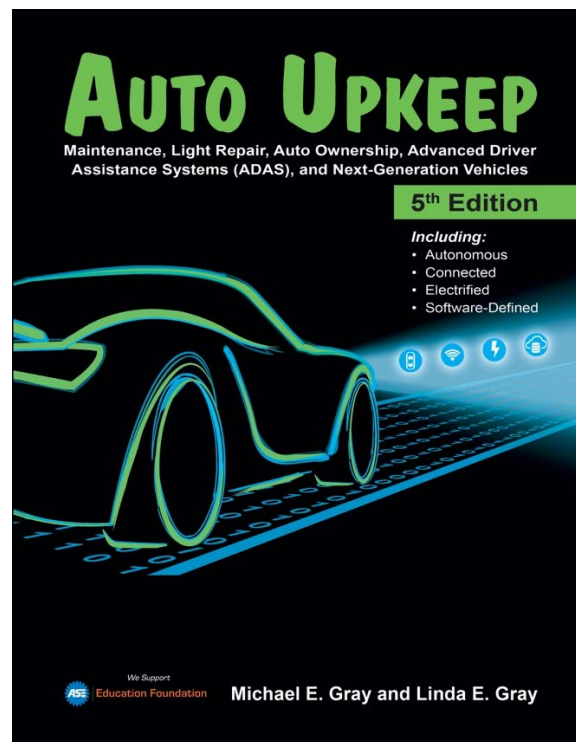


# Auto Upkeep

5<sup>th</sup> Edition



Textbook

Sample Pages



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

5<sup>th</sup> Edition

Michael E. Gray and Linda E. Gray

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

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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)

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[www.AutoUpkeep.com](http://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 5<sup>TH</sup> 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](http://www.AutoUpkeep.com/standards).



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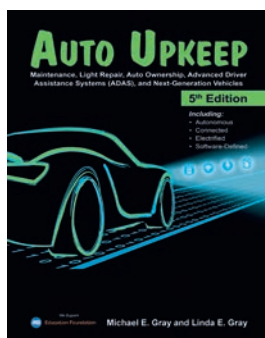
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# Curriculum Resources

## TEXTBOOK

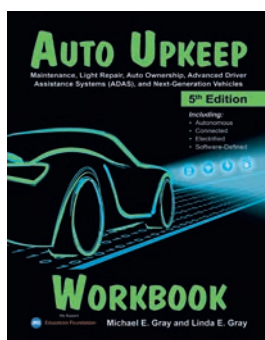
*Auto Upkeep* is available in hardcover binding.  
ISBN: 978-1-62702-050-3 (hardcover)



## 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)



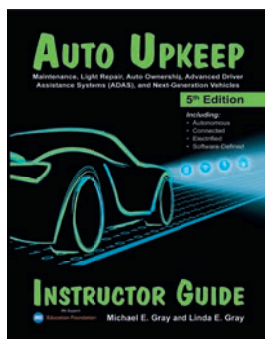
## eBOOK

*Auto Upkeep eTextbook* and *eWorkbook* options are available at [www.AutoUpkeep.com/ebooks](http://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](http://Academy.AutoUpkeep.com) through an instructor course. Email [info@autoupkeep.com](mailto:info@autoupkeep.com) to request access. The resources on the Auto Upkeep Academy website include the following:

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

## ADDITIONAL RESOURCES

Additional *Auto Upkeep* resources can be experienced online at [www.AutoUpkeep.com](http://www.AutoUpkeep.com).



## AUTO UPKEEP ACADEMY

The complete *Auto Upkeep* curriculum is also available online at [Academy.AutoUpkeep.com](http://Academy.AutoUpkeep.com).



## VIDEOS

Links to videos that support content learned can be accessed at [www.Video.AutoUpkeep.com](http://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.

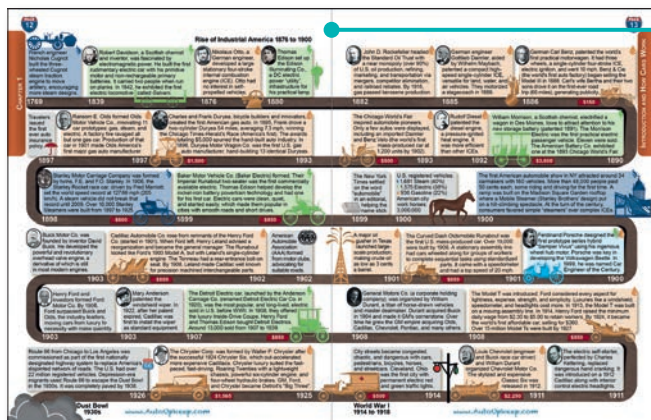
**Objectives** - What you should know and be able to do upon completion of the chapter and activities.



**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](http://Academy.AutoUpkeep.com).

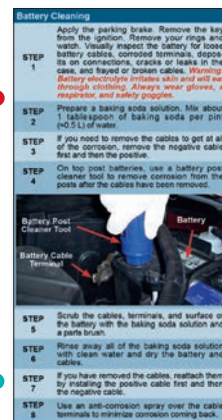
**Illustrations** - To clarify concepts and develop further understanding.



**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.

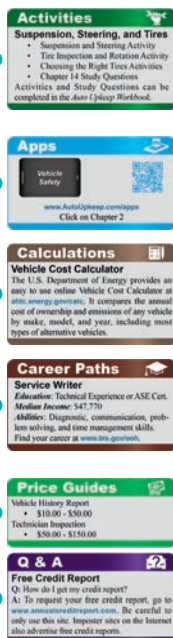
**Apps** - Helpful apps to extend learning can be accessed at [www.AutoUpkeep.com/apps](http://www.AutoUpkeep.com/apps).

**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.

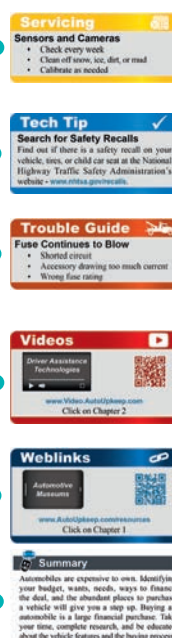
**Tech Tip** - Insightful, useful, and practical information, supplementing the content.

**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](http://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.

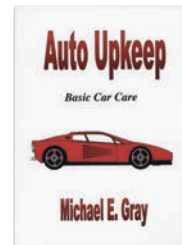
## Acknowledgments

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  
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200 Pages  
Full Color Introduced

2018



**4th Edition**  
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Academy  
2 New Chapters (22 Total)  
Over 1100 Illustrations  
400 Pages

# Table of Contents

## CHAPTER 1

### Introduction and How Cars Work



Introduction .....	10
Objectives .....	10
Automotive Timeline.....	10
How Cars Work.....	16
Fuels and Designs .....	20
Engine Identification.....	22
Vehicle Identification .....	22
Parts and Systems.....	24
Careers .....	25
Workplace Skills.....	25
Summary.....	25

## CHAPTER 2

### Buying an Automobile



Introduction .....	26
Objectives .....	26
Purpose of Buying.....	26
Budgeting for a Vehicle .....	26
Vehicle Architecture .....	28
Towing and Hauling.....	29
Driver Assistance Systems (DAS) .....	34
Advanced Driver Assistance Systems (ADAS).....	36
Buying or Leasing .....	42
Buying a New Automobile .....	42
Researching Vehicles .....	46
Final Buying Steps .....	47
Buying a Used Automobile.....	48
Selling, Trading In, or Donating.....	51
Summary.....	51

## CHAPTER 3

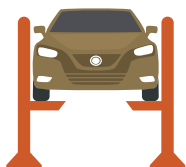
### Automotive Expenses



Introduction .....	52
Objectives .....	52
Auto Loan Payments.....	52
Insurance .....	53
Fuel Expenses .....	56
License and Registration .....	56
Maintenance and Repairs.....	57
Depreciation.....	58
Annual Cost to Own a Car .....	59
Summary.....	59

## CHAPTER 4

### Repair Facilities



Introduction .....	60
Objectives .....	60
Key Characteristics of a Quality Repair Facility .....	60
Facility Types .....	62
Estimate and Work Order/Repair Invoice.....	64
Warranties and Recalls.....	66
Summary.....	67

## CHAPTER 5

### Safety Around the Automobile



Introduction .....	68
Objectives .....	68
Laboratory Safety.....	68
EPA .....	70
OSHA.....	71
Safety Data Sheets (SDSs) .....	72
First Aid .....	73
Lifting and Carrying Safety.....	73
Personal Protection Equipment (PPE) .....	74
Fire Safety.....	78
Lifting a Vehicle Safely.....	80
Using Jacks and Jack Stands .....	82
Safety Around Airbags .....	82
Summary.....	83

## CHAPTER 6

### Tools, Fasteners, and Equipment



Introduction .....	84
Objectives .....	84
Common Hand Tools .....	84
Lifting Tools .....	88
Tire Tools.....	89
Measuring Tools.....	90
Electric Related Tools .....	92
Oil Change and Lube Tools.....	94
Metalworking Tools .....	95
Fasteners .....	96
Power Tools .....	100
Inspection Tools .....	101
General Shop Equipment.....	101
Automotive Lifts .....	102
Specialty Tools and Equipment.....	103
Vehicle Service Manuals.....	104
Cleaning Supplies .....	105
Summary.....	105

## CHAPTER 7

### Auto Care and Cleaning



Introduction .....	106
Objectives .....	106
Automotive Finishes.....	106
Exterior Care and Cleaning.....	107
Engine Compartment Cleaning.....	111
Weatherstripping .....	111
Interior Care and Cleaning .....	112
Forgotten Part Lubrication .....	113
Finish Repair.....	114
Summary.....	115

## CHAPTER 8

### Fluid Level Check



Introduction .....	116
Objectives .....	116
Opening the Hood .....	116
Fluid Specifications .....	116
Types of Fluids.....	116
Storage and Disposal.....	125
Summary.....	125

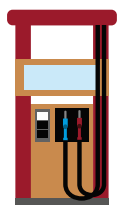


**CHAPTER 9****Electrical System**

Introduction .....	126
Objectives .....	126
Electrical Principles .....	126
Electrical Circuits .....	128
Circuit Problems .....	132
Digital Multimeter (DMM) .....	132
Fuse Box .....	134
Circuit Protection Devices .....	134
Circuit Control Devices .....	135
Starting, Lighting, and Ignition (SLI) .....	
Battery .....	136
Starting System .....	138
Charging System .....	140
Computers .....	141
Drive Belt .....	142
Lights .....	144
Accessory Power Points .....	145
Summary .....	145

**CHAPTER 10****Lubrication System**

Introduction .....	146
Objectives .....	146
Engine or Motor .....	146
Types of Lubricants .....	147
EV Lubricant Parameters .....	148
Types of e-Fluid Lubricants .....	149
Purpose of Engine Oil .....	150
Additive Packages .....	151
Oil Filters .....	151
Engine Oil Ratings .....	152
Oil Change .....	154
Summary .....	155

**CHAPTER 11****Fuel System**

Introduction .....	156
Objectives .....	156
Fuel System Purpose .....	156
Air-Fuel Mixtures .....	156
Fuel System Components .....	157
Technological Advancements .....	161
Petroleum Refining Process .....	162
Gasoline Properties .....	162
Diesel Properties .....	164
Refueling .....	166
Fuel Prices .....	166
Fuel Saving Tips .....	167
Summary .....	167

**CHAPTER 12****Cooling System and Climate Control**

Introduction .....	168
Objectives .....	168
Forms of Heat Transfer .....	168
Cooling System Purpose .....	169
Cooling System Components .....	169
Coolant Flow in an ICE .....	174
Special Cooling Systems .....	175
EV Thermal Management .....	176
Coolant .....	178
Technological Advancements .....	180
Cabin Air Filter .....	181
Air Conditioning .....	182
Summary .....	183

**CHAPTER 13****Ignition System**

Introduction .....	184
Objectives .....	184
Ignition System Purpose .....	185
Ignition System Components .....	185
Ignition System Generations .....	190
Summary .....	191

**CHAPTER 14****Suspension, Steering, and Tires**

Introduction .....	192
Objectives .....	192
Suspension System .....	192
Suspension Components .....	194
Steering System .....	198
Steering Components .....	199
Tires .....	200
Tire Care and Maintenance .....	207
Summary .....	211

**CHAPTER 15****Braking System**

Introduction .....	212
Objectives .....	212
Braking System Purpose .....	212
Types of Brakes .....	212
Brake Fluid .....	214
Braking System Components .....	215
Control and Safety Systems .....	218
Parking Brakes .....	221
Summary .....	221

**CHAPTER 16****Drivetrain**

Introduction .....	222
Objectives .....	222
Purpose of the Drivetrain .....	222
Gears .....	223
Engine Orientation .....	223
Transmissions .....	224
Driveline Components .....	228
Drivetrain Configurations .....	230
Summary .....	231

## CHAPTER 17

### Exhaust and Emission System



Introduction .....	232
Objectives .....	232
Exhaust and Emission System Purpose .....	232
Exhaust Components .....	233
Automotive Emissions .....	235
Controlling Emissions .....	237
Emission Components .....	238
Diesel Emissions Technology .....	241
Emissions Testing .....	243
Summary .....	243

## CHAPTER 18

### Alternative Fuels and Designs



Introduction .....	244
Objectives .....	244
Tailpipe and Upstream Emissions .....	244
Purpose of Alternatives .....	245
Gasoline Gallon Equivalent .....	245
Biodiesel Vehicles .....	246
Flex-Fuel E85 Vehicles .....	246
Natural Gas Vehicles .....	247
Propane Vehicles .....	248
Bi-Fuel Vehicles .....	249
Mixed-Fuel Vehicles .....	249
Hydrogen-Powered Vehicles .....	250
Hybrid and Electric Vehicles .....	253
Solar Vehicles .....	260
Compressed-Air Vehicles .....	260
Autonomous Vehicles .....	261
FlyDrive Vehicles .....	262
Technological Issues .....	262
Summary .....	263

## CHAPTER 19

### Automotive Accessories



Introduction .....	264
Objectives .....	264
Interior Accessories .....	264
Electronic Accessories .....	266
Exterior Accessories .....	271
Hauling and Towing Accessories .....	276
Summary .....	279

## CHAPTER 20

### Common Problems and Roadside Emergencies



Introduction .....	280
Objectives .....	280
Diagnosing Problems .....	281
Common Problems .....	286
Roadside Emergencies .....	292
Summary .....	299

## CHAPTER 21

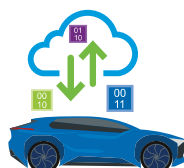
### Electric Vehicles



Introduction .....	300
Objectives .....	300
Electric Vehicle Development .....	300
How EVs Work .....	306
Exterior Design Efficiency .....	307
EV Powertrain Components .....	308
Power and Energy .....	312
Charging an EV .....	314
Rechargeable Batteries .....	318
High-Voltage Safety .....	326
EV Emergencies .....	330
Buying an EV .....	332
Driving an EV .....	336
Maintaining an EV .....	338
EV Conversion Kits .....	339
Next-Generation Vehicles .....	339
Summary .....	339

## CHAPTER 22

### Next-Generation Vehicles



Introduction .....	340
Objectives .....	340
Internet of Things (IoT) .....	340
Next-Generation Trends .....	341
Electromagnetic Spectrum .....	342
EM Technology in Vehicles .....	344
Electrification .....	350
Autonomous .....	356
Artificial Intelligence (AI) .....	360
Software .....	362
Connectivity .....	364
Vehicle-to-Everything (V2X) .....	366
Maintenance Challenges .....	368
Life Cycle Management .....	368
Mobility Strategies .....	369
Summary .....	369

## APPENDIX A

Workbook Activities .....	370
---------------------------	-----

## APPENDIX B

Acronyms/Abbreviations .....	371
------------------------------	-----

## APPENDIX C

Text Features .....	374
---------------------	-----

## APPENDIX D

Symbols and Indicator Lights .....	376
------------------------------------	-----

## GLOSSARY

Glossary .....	378
----------------	-----

## INDEX

Index .....	382
-------------	-----

## ORDER INFORMATION

Order Information .....	400
-------------------------	-----





# INTRODUCTION AND HOW CARS WORK

## CHAPTER 1



Photo: Library of Congress

### Travel Trivia

How do cars work?

How are vehicles classified?

Why is it good to know the size of your vehicle's engine?

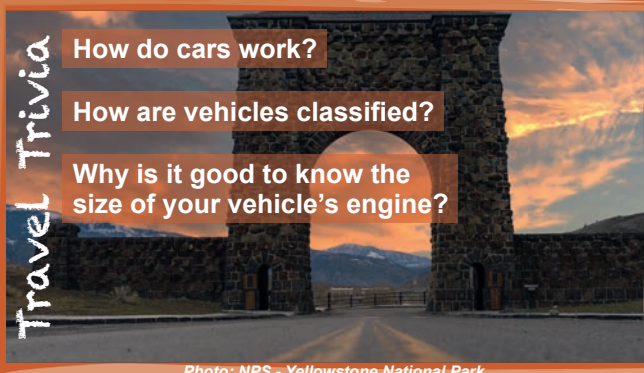


Photo: NPS - Yellowstone National Park



## 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 20<sup>th</sup> 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



## 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.



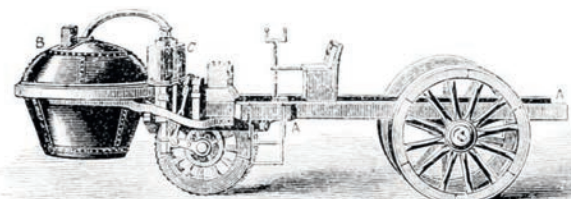
## Automotive Timeline

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

## Weblinks

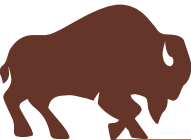


Automotive  
Museums



[www.AutoUpkeep.com/resources](http://www.AutoUpkeep.com/resources)

Click on Chapter 1

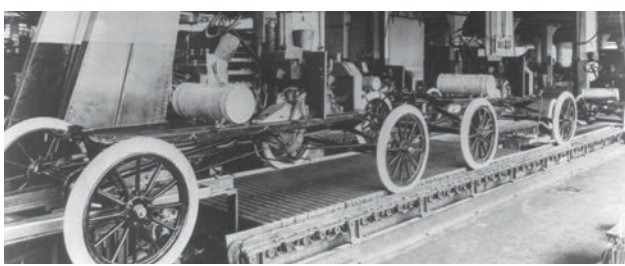


Learn More



## 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

## 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)



## 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](http://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
<b>2024 Adjusted Price</b>	<b>= \$4,635.80</b>





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

## Rise of Industrial America 1876 to 1900



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.



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.

1897

\$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

1899

\$850

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.



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

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.

\$850

1902

1902

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



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



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.

1882



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.

1885



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.

1886

\$150



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

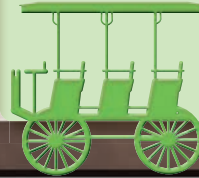
1893



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

1892

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

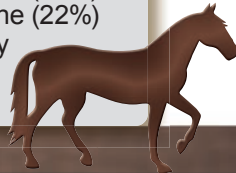
1890

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



1899

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

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



1901

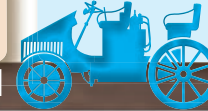
The Curved Dash Oldsmobile Runabout was the first U.S. mass-produced car. Over 19,000 were built by 1906. A stationary assembly line had cars wheeled along for groups of workers to complete sequential tasks using standardized parts. It came with a speedometer and had a top speed of 20 mph.



\$650



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

1900



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.

1908

\$850



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

1914



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

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

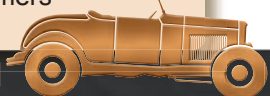
World War I  
1914 to 1918



## Great Depression 1929 to 1939

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



UNITED  
WE  
STAND

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



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.



## World War II 1941 to 1945

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

1942

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).



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.



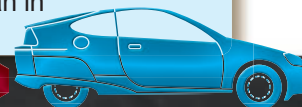
1984

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.)

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.



2032

\$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.

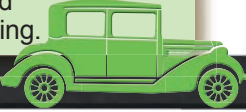
START  
RIDE

2016



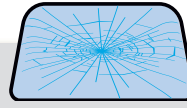
Limited range and high prices slowed sales of electric cars. The Detroit Electric Model 99, one of the last produced, had a more-modern Dodge sourced body, but antiquated tiller steering and parlor style seating.

1937 \$4,500

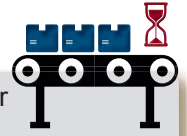


1937

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.



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



1937

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.



1939

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).



\$800

1938

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.



1954 \$6,820

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.



1939

1939

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.



1957 \$2,299

1938

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.



\$4,776

1970

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



1965

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.



\$2,368

1964

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.



2000 \$19,995

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 \$98,950

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



2006

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



2007

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.



\$35,000

2017

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.



\$33,600

2011

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



2009



## How Cars Work

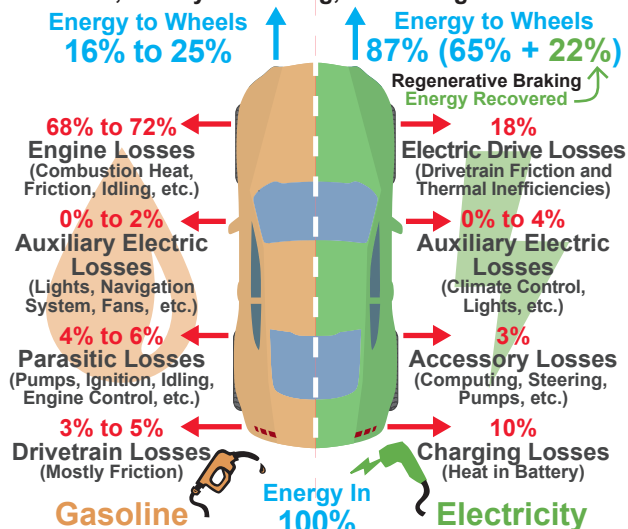
Currently, the most common propulsion system in an automobile is the internal combustion engine (ICE). ICEs burn fuel in a combustion chamber inside the engine. This section focuses on:

- Conservation of Energy
- Force, Work, Power, and Energy
- Measuring Engine Output
- Engine Components
- Four-Stroke 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*).

As the wheels turn, **energy dissipates** through braking friction, aerodynamic drag, and rolling resistance.

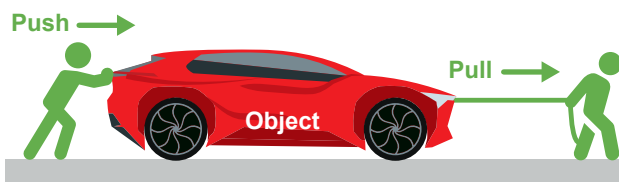


**Figure 1.5 Gasoline vs. Electrical Energy Usage**  
Source: U.S. Department of Energy EERE - [www.fueleconomy.gov](http://www.fueleconomy.gov)

## 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.



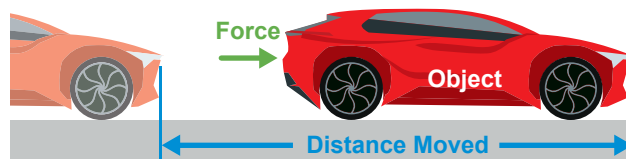
**Figure 1.6**

**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*).

$$\text{Work} = \text{Force} \times \text{Distance}$$

$$1 \text{ ft-lb} = 1 \text{ pound} \times 1 \text{ foot}$$



**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
<b>Work</b>	<b>= 250 ft-lb</b>

*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).

$$\text{Power} = \text{Work} / \text{Time}$$

**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).

$$\text{Energy} = \text{Power} \times \text{Time}$$

$$1 \text{ kWh} = 1 \text{ kilowatt} \times 1 \text{ hour}$$

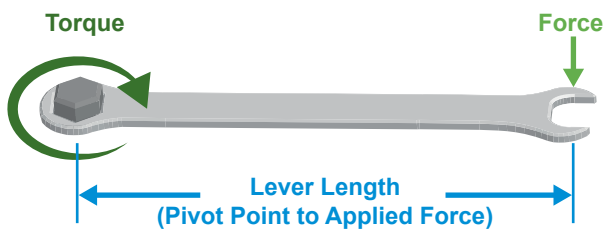
For example, an electric vehicle might have a battery capacity of 60 kWh. Think of energy as the amount of “fuel” stored or used to perform work.

### Measuring Engine Output

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

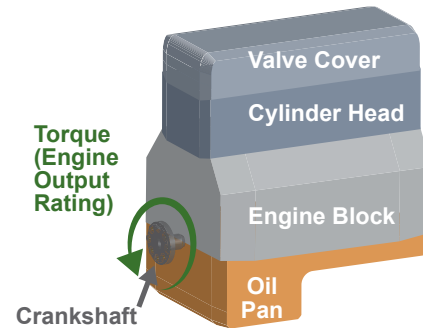
**Torque.** When force is in a twisting motion it is called torque. Tightening a bolt with a wrench is an example of torque (*Figure 1.8*). A special wrench, a torque wrench, is used to tighten bolts to an exact specification. A pound-foot (lb-ft) of torque is 1 pound of force at a lever length of 1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

$$\text{Torque} = \text{Force} \times \text{Lever Length}$$



**Figure 1.8**  $\text{Torque} = \text{Force} \times \text{Lever Length}$

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

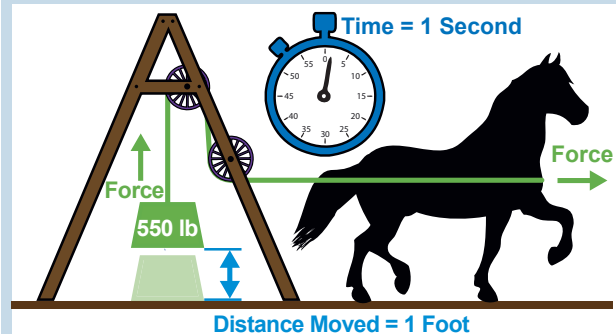


**Figure 1.9** **Crankshaft Torque**

**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*).

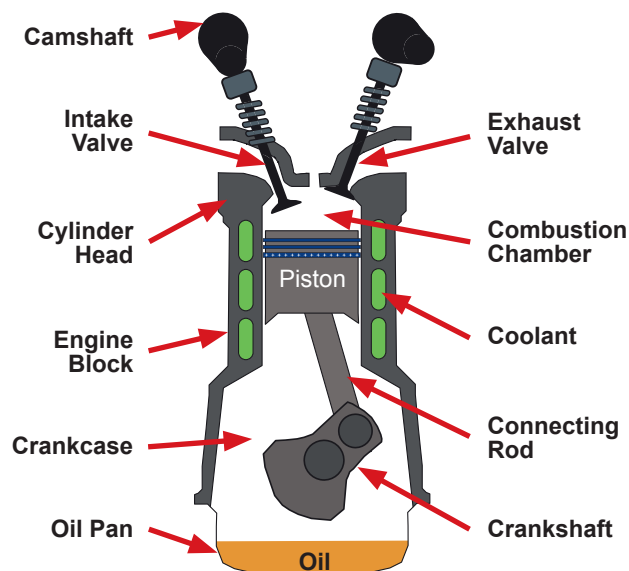
	1920 Ford Model T	2024 Ford Super Duty
Engine	2.9 L Gasoline	6.7 L Turbo Diesel
HP	20 hp @ 1,600 rpm	475 hp @ 2,600 rpm
Torque	83 lb-ft @ 900 rpm	1,050 lb-ft @ 1,600 rpm

**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*).

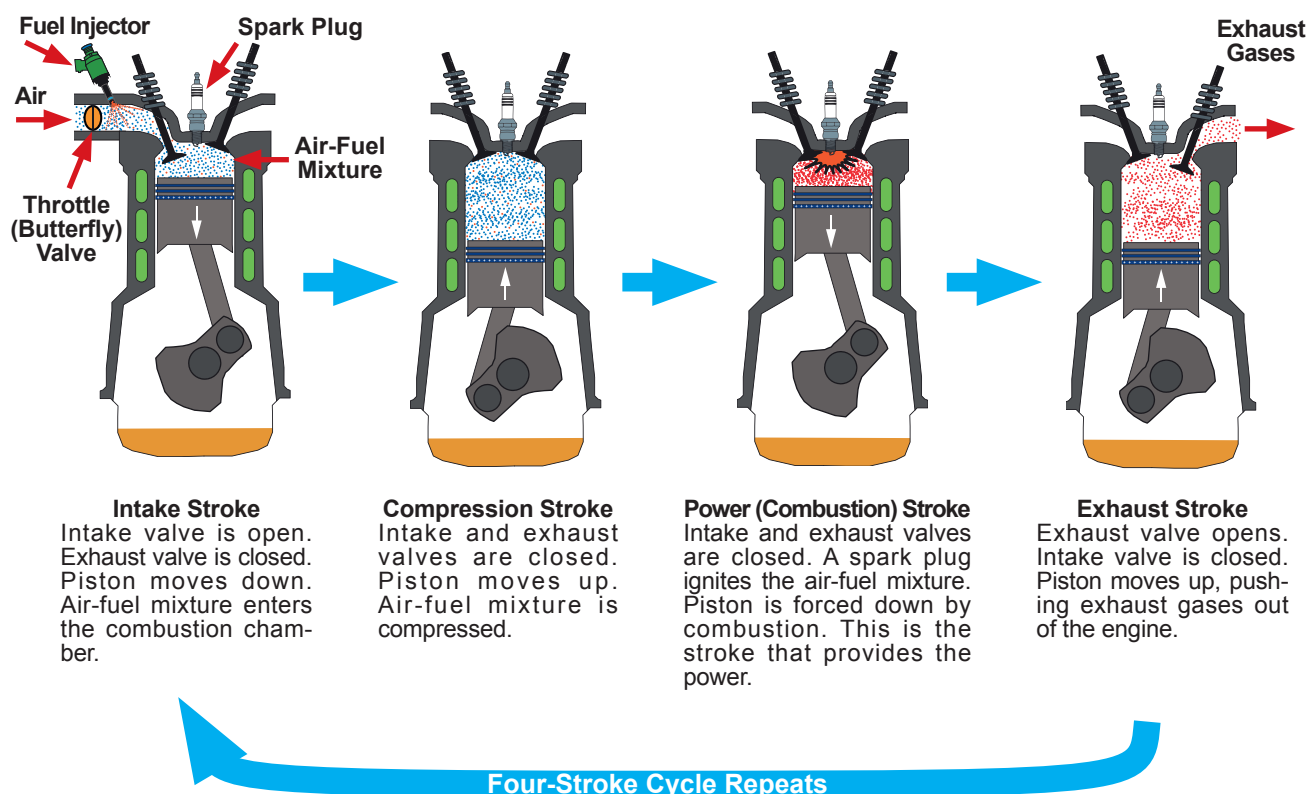


*Figure 1.12 Dual Overhead Camshaft (DOHC) Engine*

## 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.*



*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**



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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.

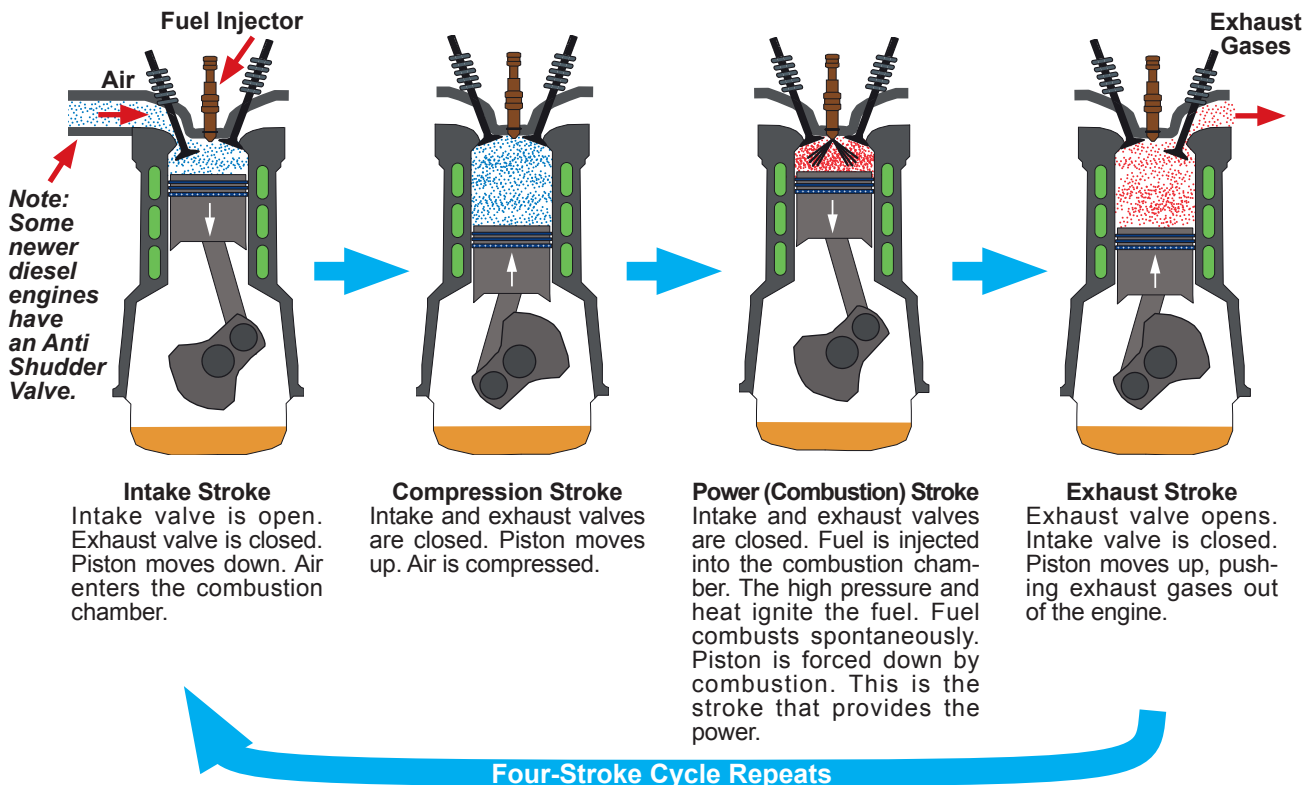
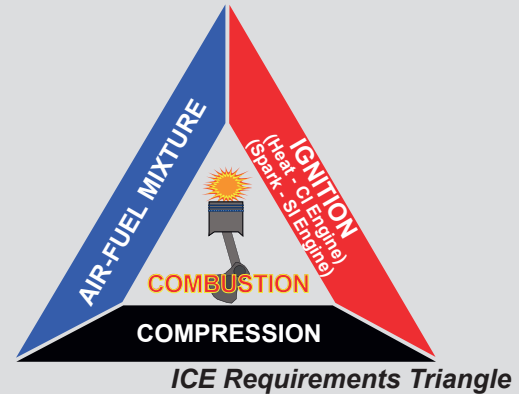


Figure 1.14

**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

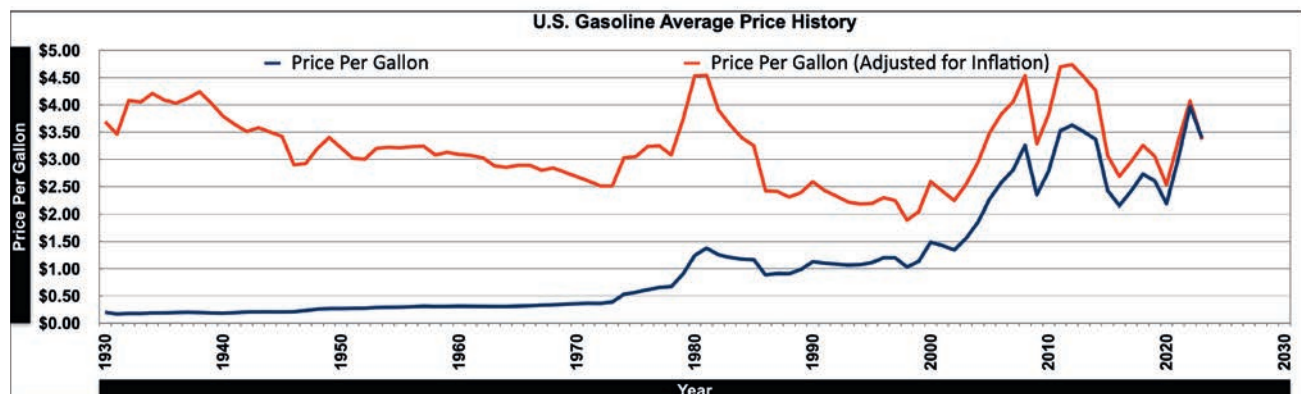
Most of the 278 million vehicles registered in the United States today burn either gasoline or diesel in an internal combustion engine. The simplest way to describe the difference between them is air is throttled in a gas engine and fuel is regulated in a diesel engine. This section focuses on:

- 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<sub>x</sub>), carbon monoxide (CO), and carbon dioxide (CO<sub>2</sub>). 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<sub>x</sub> 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](http://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



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## 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.

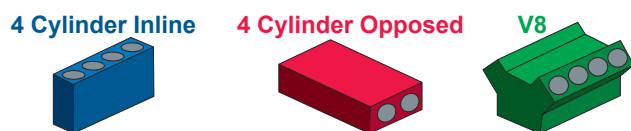


Figure 1.21 Common Engine Configurations

### 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*).

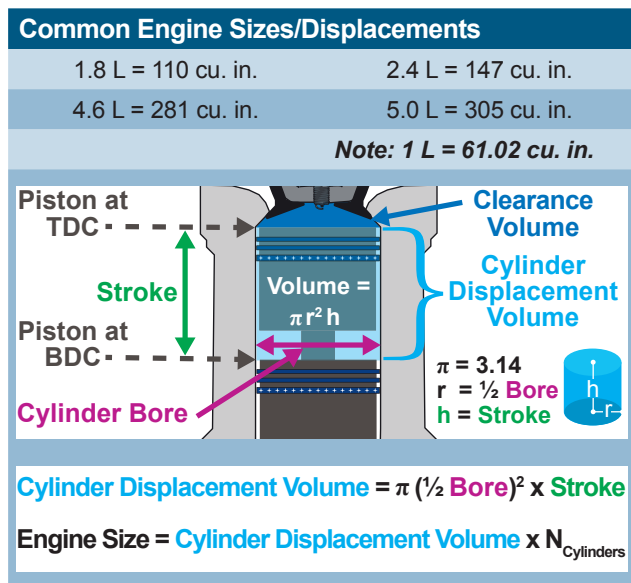


Figure 1.22 Common Engine Sizes/Displacements

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

### 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*).

**VIN on Driver's Side Dash**  
 (Viewable from outside the vehicle.)

VEHICLE IDENTIFICATION NUMBER  
**1G1YF2D72R5110429**

**VIN on Vehicle Certification Label**  
 (Viewable inside driver's doorjamb.)

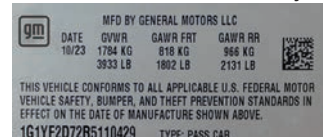


Figure 1.23

VIN Locations

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

**How to Decode a 17-Digit Vehicle Identification Number**

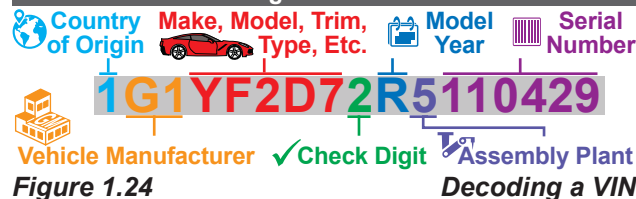


Figure 1.24

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



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## 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](http://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

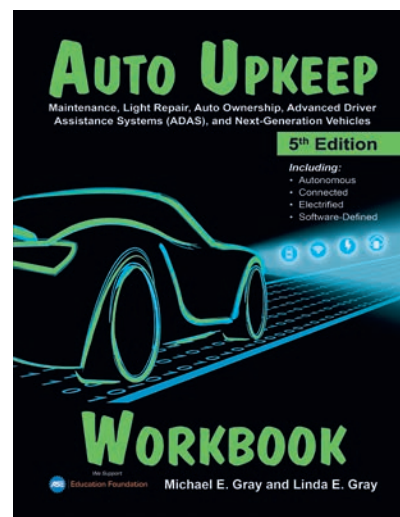
### Electric Vehicles Activity

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	Fourth 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 <sub>2</sub>	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 <sub>2</sub> ICE	Hydrogen Internal Combustion Engine
H <sub>2</sub> O	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 <sub>2</sub>	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	Painless 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

Alternative Fueling Station Locator.....	249
Automotive Expenses.....	58
Belt Routing Diagrams.....	143
Buying a Car.....	51
Charging Station Locator.....	316
EV Remote Climate Control.....	176
First Aid.....	73
Fluid Level Check.....	125
Ignition System Parts Lookup.....	188
Manufacturer Connected Services.....	60
OBD II Scan.....	281
Vehicle Safety.....	46
Waxing and Polishing.....	109



## Calculations

Auto Loan Calculator.....	27
Calculating a Reasonable Offer.....	47
Calculating Work.....	16
Consumer Price Index (CPI).....	11
Converting Pounds (lbs) to Kilograms (kg).....	205
Cost to Own a Car.....	59
Determining Gear Ratios.....	223
Fuel Economy Payback Period.....	263
Gasoline Gallon Equivalent.....	245
Monthly Fuel Expense.....	56
Ohm's Law Formula ( $E = I \times R$ ).....	128
Vehicle Cost Calculator.....	248



## Career Paths

ADAS Calibration Technician.....	369
Automobile Salesperson.....	51
Automotive Teacher.....	25
Automotive Technician.....	67
Brake Technician.....	221
Collision Repair Technician.....	115
Electrical Engineer.....	145
Electronics Installer.....	279
Emissions Inspection Technician.....	243
Engineering Technician.....	191
Health and Safety Specialist.....	83
Heating and A/C Technician.....	183
Industrial Designer.....	105
Insurance Claims Adjuster.....	59
Petroleum Engineer.....	167
Public Relations Specialist.....	263
Quick Lube Technician.....	125
Service Writer.....	155
Software Developer.....	339
Tire Manufacturing Engineer.....	211
Tow Truck Driver.....	299
Transmission Specialist.....	231



## Procedures

Air Filter Replacement.....	159
Battery Cleaning.....	291
Changing a Flat Tire.....	298
Changing the Oil and Filter.....	154
Checking Tire Pressure.....	208
Chip and Scratch Repair.....	115
Finding a Tire Leak.....	290
Greasing.....	197
How to Properly Insert Foam Earplugs.....	76
Jacking Up a Vehicle.....	82
Jump-Starting a Vehicle.....	296
Manual Transmission Servicing.....	227
Opening and Closing the Hood.....	116
Refueling.....	166
Replacing a Headlight Bulb.....	287
Serpentine Belt Replacement.....	295
Steps for Engine Overheating.....	170
Wiper Blade Replacement.....	289



## Q & A

AC Generator (Alternator) or Battery.....	291
Augmented Reality Head-Up Display (AR-HUD).....	36
Auto Club Membership.....	52
Brake Fluid Mix-Up.....	123
Carbon Monoxide.....	234
Car Rental Insurance.....	55
Catalytic Converter Clogged.....	240
Choosing an Auto Repair Facility.....	63
Clicking Noise.....	228
Clutch Slipping.....	224
Dirty Front Wheels.....	108
E85 Compatible Vehicles.....	246
Electron Flow and Current Flow.....	320
Exchange a New Car.....	45
Free Credit Report.....	27
Fuel Pump Replacement.....	156
Gasoline on Paint.....	110
Gasoline vs. Diesel Engine.....	166
Hybrid Vehicle Upkeep.....	255
Keyless Entry Not Working.....	269
Lemon Law.....	47
Mechatronic Engineer.....	362
No Heat Inside Vehicle.....	173
Octane and High Compression.....	162
Oil Dripping After Oil Change.....	284
Oil Recycling.....	151
Pressure Washing an Engine.....	111
Radiator Hose Collapse.....	170
Radio Waves vs. Sound Waves.....	344
Reducing Insurance Premiums.....	54
Technical Service Bulletins.....	280
Temporary Spare Tire Speed.....	299
Towing with a Car.....	32
Traction Battery Cost.....	325
Used Oil Precaution.....	75
Water Pump "Weep" Hole.....	173
Wax or Polish.....	110
When to Add Oil.....	118
White Smoke.....	179
Wrong Oil in Engine.....	153



## Servicing

All Fluid Level Checks.....	125
Auto Care and Cleaning.....	111
Brake Fluid.....	214
Brake Pads and Shoes.....	216
Cabin Air Filter.....	181
Coolant (Antifreeze).....	178
Distributor Cap and Rotor.....	187
Drive Belts.....	143
Exhaust.....	234
Lubricate Grease Fittings (Zerks).....	197
Oxygen Sensors.....	240
Radiator Hoses.....	172
Sensors and Cameras.....	37
Spark Plugs.....	187
Spark Plug Wires.....	187
Timing Belt System.....	189
Tire Rotation.....	210
Transmission Fluid.....	227
Windshield Wipers.....	288



## Trouble Guides

Automatic Transmission Slips.....	227
Body Rolls Around Corners.....	199
Brake Pedal Travels to the Floor.....	215
Common Charging Problems.....	140
Common Starting Problems.....	138
Coolant Loss.....	178
Engine Lacks Power.....	158
Engine Misses.....	185
Engine Oil Leaks.....	154
Engine Overcooling.....	174
Engine Overheating.....	174
Engine Performance Issues.....	240
Engine Rotates, but No-Start.....	191
Excessively Loud Exhaust.....	233
Excessive Oil Consumption.....	118
Excessive Tire Wear.....	209
Fuse Continues to Blow.....	134
Gears Difficult to Shift.....	224
GPS Inaccurate.....	268
Grinding Brakes.....	217
Hard Steering.....	199
High-Pitched Brake Squeal.....	217
Howling Sound When Steering.....	199
Light Not Working.....	287
Musty Odor when Running Air.....	174
Pulsating Brakes.....	217
Squeaking Suspension.....	199
Sweet Odor when Running Heat.....	174
Transmission "Clunk" Sound.....	227
Vehicle Pulls to One Side.....	209
Vibration.....	209



## Tech Tips

Accident Liability Potential Shift.....	359
All Makes and Models Coolant.....	175
Anti-Seize Compound.....	187
Automatic Car Washes.....	107
Bounce Test.....	195
Brake Pedal Pulsation.....	216
Buying a Lift.....	102
Buying a New AC Generator (Alternator).....	140
Buying Tires.....	200
Check Engine Light.....	282
Check Vehicle Warranty.....	280
Clear Fluid Drip.....	284
Community Education Programs.....	61
Connectivity and Privacy.....	369
Coolant Temperature Light.....	180
Custom Spoilers.....	274
Dash Without Physical Controls.....	38
Diagnose Misfire with Coil Swap.....	186
Do Maintenance When Required.....	57
Do Not Shop Based on kWh.....	332
Driving on a Flat Tire.....	298
Efficiency is Key to EVs.....	318
Engine Heater and Emissions.....	270
Engine Oil Warning Light.....	151
Flip the Wrench.....	85
Help Passing an Emission Test.....	242
ICE Requirements.....	19
Identifying Vehicle Parts.....	24
Know What to Do.....	73
Leaking Fluids.....	122
Loading a Trailer.....	33
Locating an Owner's Manual.....	282
Locking Lug Nut Key Tool.....	275
Navigate Safely.....	268
Oil Filter Wrench Size.....	94
OSHA Card.....	68
Over the Air Updates and Recalls.....	363
Part Replacement.....	64
Pollution from Remote Starters.....	269
Public Fast Charge Etiquette.....	315
Quiet Vehicle Warning Sounds.....	39
Recycle Used Coolant.....	178
Replacing Exhaust Components.....	234
Right-to-Know Laws.....	71
Search for Safety Recalls.....	67
Suspected Faulty System.....	40
Switching to Biodiesel.....	246
Tire Recalls.....	211
Tow Rope/Strap Rating.....	279
Trailer Light Check.....	277
Undercoating a New Vehicle.....	274
Voltage Drop Testing.....	127
Wash Before You Wax.....	109
Wrench and Socket Selection.....	85



## Videos

Auto Insurance.....	53
Buying a Car.....	42
Changing a Flat Tire.....	298
Changing the Oil and Filter.....	155
Checking Fluids.....	125
Choosing a Repair Facility.....	62
Diesel Emission Technologies.....	242
Do Not Text and Drive.....	266
Driver Assistance Technologies.....	34
How Active Warm-Up Works.....	181
How Adaptive Cruise Control Works.....	220
How Automatic Emergency Braking Works.....	219
How Autonomous Vehicles Work.....	261
How Charge-Air Coolers Work.....	175
How Cooling Systems Work.....	178
How Differentials Work.....	229
How Drive-By-Wire Systems Work.....	159
How Drivetrains Work.....	222
How e-Fluids Work.....	177
How Electricity Works.....	127
How Engines Work.....	19
How Fuel Cells Work.....	251
How Hybrids Work.....	256
How Regenerative Braking Works.....	212
How Suspension Systems Work.....	192
How to Install Shocks and Struts.....	196
How to Repair Fasteners and Threads.....	98
How Torque Converters Work.....	225
Installing a Headlight.....	144
Installing a Serpentine Belt.....	295
Installing a Starter.....	139
Jump-Starting.....	297
Paintless Dent Repair.....	114
Personal Protection Equipment.....	74
Replacing a Timing Belt.....	189
Replacing Spark Plugs.....	187
Restoring Headlight Lenses.....	108
Servicing Transmissions.....	227
Student Tool Programs.....	84
Understanding Octane and Cetane Ratings.....	164
Understanding Warranties.....	66
What to Do After an Automobile Accident.....	294
What to Do if Your Vehicle Catches on Fire.....	293



## Weblinks

Alternative Fueled Vehicles.....	249
Alternative Vehicles.....	263
Antifreeze (Coolant).....	179
Auto Buying.....	48
Auto Lifts and Equipment.....	103
Automotive Care.....	111
Automotive Trade Organizations.....	63
Automotive Manufacturers.....	24
Automotive Museums.....	10
Automotive Parts.....	288
Auto Research.....	46
Batteries.....	137
Belts.....	142
Brake Systems.....	220
Car Rental Sales.....	49
Certified Pre-Owned Autos.....	48
Chain Repair Centers.....	63
Cooling Systems.....	172
Driver Assistance Technologies.....	35
Drivetrains.....	223
Electrical.....	138
Electronic Accessories.....	266
Emissions.....	237
Energy Organizations.....	167
EV Charging Stations.....	21
Exhaust.....	232
Exterior Accessories.....	272
Filters.....	151
Fuel Calculators and Expenses.....	56
General Accessories.....	265
Hauling and Towing Accessories.....	277
Ignition Systems.....	189
Insurance Companies.....	59
Lubricant Companies.....	149
Measurements.....	91
NMVTIS Data Providers.....	50
Oil Companies.....	164
Oil Ratings.....	153
Performance Accessories.....	275
Safety.....	72
Safety Advocacy.....	221
Safety Equipment.....	78
Safety Training.....	71
Timing Belts.....	189
Tire Manufacturers.....	211
Tool Manufacturers.....	91
Transportation Safety.....	295
Vehicle Service Manuals.....	104

# 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



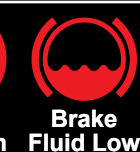
## Assistance



## Body



## Brake System



## Charging System



## Drive Modes



## Electric Vehicle



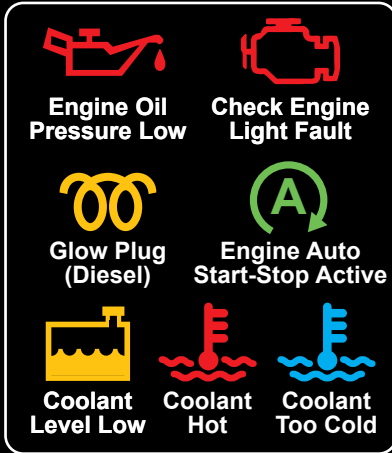
## Electronic Throttle



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



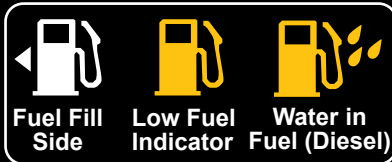
## Engine



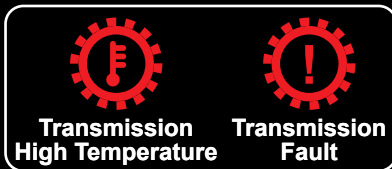
## Filters



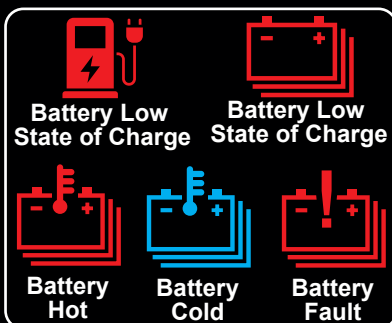
## Fuel



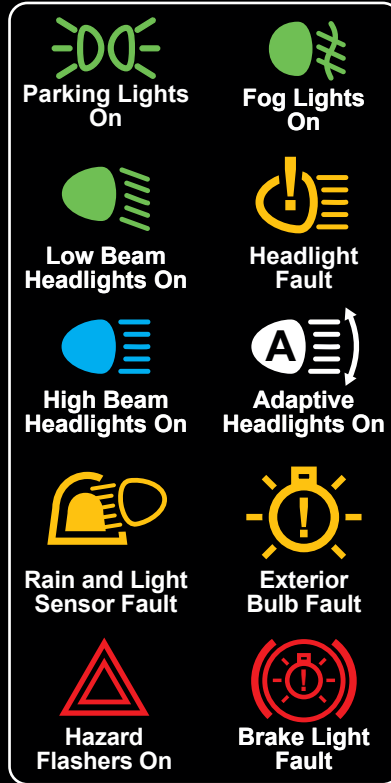
## Gearbox



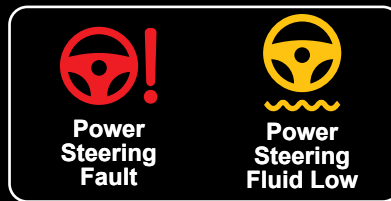
## High-Voltage Battery



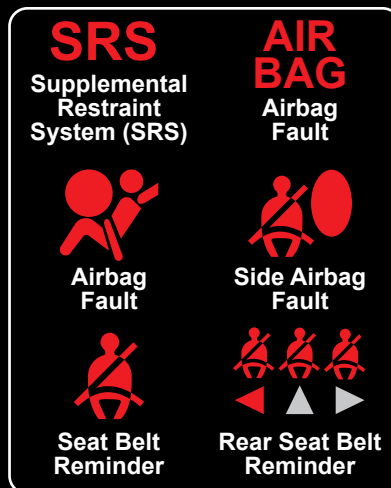
## Lights



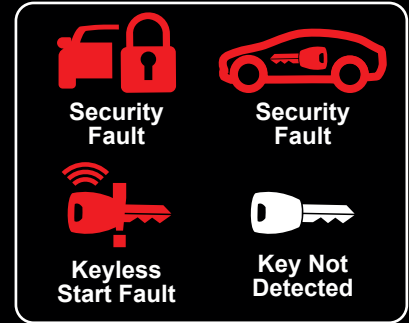
## Power Steering



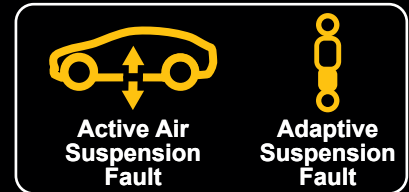
## Restraint System



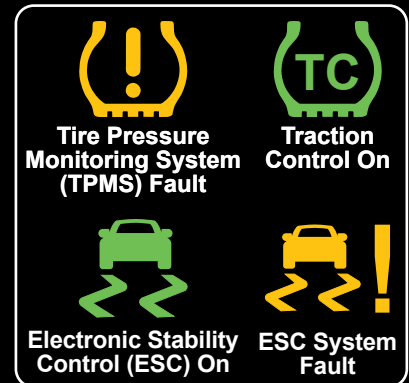
## Security



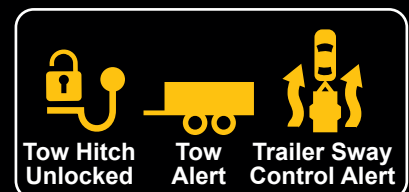
## Suspension



## Tires/Traction



## Tow/Haul



## Wipers



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

**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 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 ( $\Omega$ ), 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

### 3D high-definition mapping

point cloud, 37, 348  
real-time, 361

### 4-way tire tool, 89

### 5G (fifth generation), 346. *See also Wireless network*

### 6G (sixth generation), 347. *See also Wireless network*

### 12-volt system, 354 starting, lighting, and ignition (SLI), 136

### 48-volt system architecture, 309 DC to DC converter, 310 drive system, 260 mild hybrid, 254 operating range, 354

## A

### AAA. *See American Automobile Association (AAA)*

### ABS. *See Antilock brake system (ABS)*

### Absorbed glass mat (AGM) battery, 136

### ACC. *See Adaptive cruise control (ACC)*

### Accessories, 264-279

### Accessory power points power outlets, 145 USB ports (DC), 145

### Accident

after the accident, 294  
animal collision, 294  
emergency exit tool, 292  
vehicle fire, 293

### Accumulator - A/C system, 182

### AC/DC converter, 266

### AC generator (alternator), 140-142. *See also Alternator*

### Active grille shutters, 181

### Active lane change assist (ALCA), 41

### Active parking assist, 41

### Active suspension, 193

### Active warm-up, 181

### Activity in Workbook

ADAS and Vehicle Automation Level Identification. *See Workbook Chapter 22*  
Advanced Driver Assistance System (ADAS). *See Workbook Chapter 2*  
Air Conditioning. *See Workbook Chapter 12*  
Automotive Accessories. *See Workbook Chapter 19*  
Automotive Expenses. *See Workbook Chapter 3*

### Automotive Safety.

*See Workbook Chapter 5*

### Battery.

*See Workbook Chapter 9*

### Brake Inspection.

*See Workbook Chapter 15*

### Buying a New Automobile.

*See Workbook Chapter 2*

### Buying a Used Automobile.

*See Workbook Chapter 2*

### Cabin Air Filter.

*See Workbook Chapter 12*

### Car Identification and Preparing for Vehicle Service.

*See Workbook Chapter 1*

### Changing a Flat Tire.

*See Workbook Chapter 20*

### Charging.

*See Workbook Chapter 9*

### Choosing the Right Tires.

*See Workbook Chapter 14*

### Circuit Construction Simulator.

*See Workbook Chapter 9*

### Cooling System.

*See Workbook Chapter 12*

### Drivetrain.

*See Workbook Chapter 16*

### Electric Vehicles.

*See Workbook Chapter 21*

### Exhaust and Emission.

*See Workbook Chapter 17*

### Exterior Cleaning.

*See Workbook Chapter 7*

### Fasteners.

*See Workbook Chapter 6*

### Fluid Level Check.

*See Workbook Chapter 8*

### Fuel System Maintenance.

*See Workbook Chapter 11*

### Fuel System Part Identification.

*See Workbook Chapter 11*

### Future Vehicle.

*See Workbook Chapter 18*

### Ignition System.

*See Workbook Chapter 13*

### Interior Cleaning.

*See Workbook Chapter 7*

### Jump-Starting.

*See Workbook Chapter 20*

### Lighting.

*See Workbook Chapter 20*

### Ohm's Law.

*See Workbook Chapter 9*

### Oil and Filter Change.

*See Workbook Chapter 10*

### On-Board Diagnostics.

*See Workbook Chapter 20*

### Owner's Manual.

*See Workbook Chapter 1*

### Payback Period.

*See Workbook Chapter 18*

### Personal Protection Equipment (PPE) and Fire Safety.

*See Workbook Chapter 5*

### Repair Facilities.

*See Workbook Chapter 4*

### Replacing Wipers.

*See Workbook Chapter 20*

### Safety Data Sheet (SDS).

*See Workbook Chapter 5*

### Service Manual.

*See Workbook Chapter 6*

### Simple Circuits.

*See Workbook Chapter 9*

### Starting.

*See Workbook Chapter 9*

### Suspension and Steering.

*See Workbook Chapter 14*

### Tire Inspection and Rotation.

*See Workbook Chapter 14*

### Tools and Equipment.

*See Workbook Chapter 6*

### Towing and Hauling.

*See Workbook Chapter 2*

### Voltage Drop.

*See Workbook Chapter 9*

### Waxing.

*See Workbook Chapter 7*

### Wiring Diagram.

*See Workbook Chapter 9*

### Workplace Skills.

*See Workbook Chapter 1*

### Actuator, 352

### Adaptive cruise control (ACC),

41, 218, 220  
active lane change assist (ALCA), 41  
automotive night vision, 347  
cameras, 349  
driver assistance, 357  
SAE driving automation levels, 356

### Adaptive driving beam (ADB), 38

### ADAS. *See Advanced driver assistance systems*

### Adhesives, 97, 99

### Adjustable wrench, 85

### Advanced driver assistance systems (ADAS), 36-41

area detection limit, 38  
ASE certifications, 61  
autonomous, 341  
bridge to Level 5, 261  
calibration, 37, 368  
calibration technician, 369  
cameras, 37, 349  
collision warning, 39  
components, 37  
domain controller, 352  
driver monitoring system (DMS), 348  
driving control assistance, 41  
electric power steering (EPS), 199  
electronic involved maintenance, 368  
environment conditions, 38  
Ethernet connectivity, 353  
infrastructure, 366  
lack of standardization, 38  
mode of alert, 36  
operating system (OS), 362  
over-the-air (OTA) updates, 363

- researching vehicles, 46
- sensors, 37
- speed limitations, 38
- usage-based insurance, 55
- vehicle-to-everything (V2X), 366
- AEB. See Automatic emergency braking**
- Aerodynamics**
  - drag coefficient (Cd), 307
  - rolling resistance, 307
- Aftermarket part**, 134, 271
- AI. See Artificial intelligence (AI)**
- Airbags**, 82-83
  - advanced systems, 82
  - deployment, 82
  - error code, 83
  - safety, 82
  - types, 82
  - working near, 83
  - working on, 83
- Air compressor**, 100
- Air conditioning (A/C)**, 182-183
  - accumulator, 182
  - compressor, 182-183
  - condenser, 182
  - drain tube, 183
  - evaporator, 183
  - orifice tube, 183
  - receiver-drier, 182
  - refrigerant, 182
- Air filter**, 158-159
  - cabin air filter, 181
  - changing procedure, 159
- Air-fuel mixture**, 20, 184-185
  - black tailpipe smoke, 285
  - fuel injectors, 158
- Alarms**, 269
- ALCA. See Active lane change assist (ALCA)**
- All-terrain (A/T) tires**, 202
- All-wheel drive (AWD) vehicle**, 231
- Alternating current (AC)**, 127, 312
- Alternative fuels**, 244-263
  - bi-fuel, 249
  - biodiesel, 245-246, 262
  - E85, 245-246
  - electricity, 258-259
  - ethanol, 163, 246
  - hydrogen, 250-252.
    - See also Hydrogen (H)**
    - fuel cell, 251-252
  - mixed-fuel, 249
  - natural gas, 247
    - CNG, 247
    - LNG, 247
  - non-petroleum energy sources
    - biomass, 262
    - hydro (water), 262
    - solar (sun), 260
    - wind, 262
  - propane, 248
- Alternator**, 140-142
  - belt-alternator-starter (BAS), 254
  - buying tips, 140
  - problem, 142, 283, 295
- American Automobile Association (AAA)**, 12
  - approved auto repair, 62
  - membership, 52
- American automobile show**, 13
- American Petroleum Institute (API)**, 152-153
  - rating defined, 152
- Amps**, 128
  - charging levels, 314
  - continuous draw, 312
  - measuring current, 133
  - ratings, 312
- Anderson Electric Car Company**, 301
- Anderson, Mary**, 12
- Antifreeze. See also Coolant**
  - properties, 178-179
  - types, 120-121
- Antilock brake system (ABS)**, 34, 218-219
  - hydraulic control unit, 218
  - malfunction indicator light, 284
- Anti-seize compound**, 97
- API. See Application programming interface (API)**
- Application programming interface (API)**, 352, 363
- ARB (Air Resources Board)**, 236
- Arc flash face shield**, 329
- Article, website, or video review form. See Workbook Appendix**
- Artificial intelligence (AI)**, 360
  - automotive night vision, 38
  - blended control, 261
  - cognitive cyber-physical systems, 347
  - connectivity, 364
  - data transfer rates, 346
  - digital twin (DT), 359
  - dynamic driving task, 358
  - ethics, 361
  - machine learning (ML), 360
  - sensor fusion, 361
  - strong, 360
  - systems, 360
  - virtual assistant, 365
  - weak, 360
- Artificial neural networks (ANN)**, 360
- Asbestos**, 215
- ASE. See Automotive Service Excellence (ASE)**
- ASE maintenance and light repair (MLR) task list. See Workbook Appendix**
- Asymmetrical and directional tire**, 202
- Asymmetrical tire**, 202
- ATF. See Automatic transmission fluid (ATF)**
- Atom**, 126
  - electron, 126
  - hydrogen, 250
  - lithium, 318
  - neutron, 126
  - power fundamentals, 312
  - proton, 126
- Audio systems**, 267
- Augmented reality HUD**, 36
- Auto clubs**, 52
- Autogas. See Propane**
- Auto loan calculation**, 52
- Automatic car washes**, 107
- Automatic emergency braking (AEB)**, 40, 219
  - automotive night vision, 347
  - cameras, 349
  - momentary assistance, 357
- Automatic reverse braking (ARB)**, 40, 220
- Automatic transmission. See Transmission**
- Automatic transmission fluid (ATF)**, 119
  - adding ATF, 119
  - checking, 119
  - CVT, 119
  - reading the dipstick, 119
  - type, 119
- Automobile word**, 13
- Automotive finishes**, 106
- Automotive head-up display (Auto-HUD)**, 36
- Automotive lift**, 102-104
  - inground, 102
  - operating procedure, 81
  - safety, 80-81
  - surface-mounted
    - four-post, 102
    - rolling lift jacks, 102
    - two-post, 102
- Automotive Lift Institute**
  - certification, 102
  - lift manuals, 80
- Automotive night vision (NV)**, 38, 347
- Automotive Service Excellence (ASE)**, 60-61
  - certifications, 61
  - choosing a repair facility, 63
  - code of ethics, 61
  - training, 60
- Automotive timeline**, 10-15
  - early years, 10
  - electric vehicle, 301



**Autonomous driving**, 337  
**Autonomous emergency braking (AEB)**. *See Automatic emergency braking (AEB)*  
**Autonomous vehicle**, 261, 356-359  
 advanced driver assistance systems (ADAS), 341

**Axles**, 194  
 dead axle, 194  
 e-axle, 194  
 live axle, 194

## B

**Backup camera**, 41  
**Baker Electric**, 12, 301, 302  
**Ball joints**, 197  
 lubricating procedure, 197  
**Battery**, 136-137  
 48-volt system, 309  
 4680 cylindrical cell, 324  
 AGM, 136  
 anode, 320  
 battery life and warranty (SLI), 137  
 BCI group number (SLI), 136  
 brush, 93  
 cable, 291  
 capacity, 308  
 cathode, 320  
 cell, 93, 124  
   caps, 124  
   electrolyte level check, 124  
 cell form factor - shape  
   cylindrical cell, 322  
   pouch cell, 322  
   prismatic blade cells, 322  
   prismatic cells, 322  
 cell organization, 324  
   parallel, 324  
   series, 324  
 charger, 101  
 charge time (high-voltage), 315  
 charging (Lithium-ion), 321  
 charging procedure (SLI), 137  
 charging system (SLI), 140  
 cleaning (SLI), 137  
   steps, 291  
 cold cranking amps (CCA) (SLI), 136  
 condensed (high-voltage), 325  
 cranking amps (CA) (SLI), 136  
 dead, 291, 296  
 degradation (high-voltage), 334  
 discharging (Lithium-ion), 321  
 electrolyte  
   checking (SLI), 124, 137  
   electrolytic properties, 320  
   galvanic properties, 320  
   health (high-voltage), 338  
   high-voltage systems, 137, 257-259  
     battery pack, 257-259  
     charging dock, 271  
 hold-down, 136

hydrometer, 93, 137  
 ignition system, 185  
 jumper cables, 93  
 jump-start procedure, 296  
 lead acid, 124-125  
 LFP blade, 324  
 lithium-ion (Li-ion), 257, 258-259, 318  
 load tester, 92  
 maintenance (flooded lead acid), 137  
 maintenance-free (SLI), 124, 137, 291  
 maintenance (SLI), 124  
 mount systems (SLI), 136  
 nickel metal hydride (NiMH), 257-258  
 onboard charger (OBC), 309  
 oxidation reaction, 320  
 recycling (SLI), 137  
 reduction reaction, 320  
 safety (SLI), 137  
 separator, 320  
 size (SLI), 136  
 solid-state, 325  
 starting, lighting, and ignition (SLI), 136-137  
 starting system, 138  
 state of charge (SoC), 309  
 terminal  
   cables, 93  
   puller, 93  
   spreader, 93  
 terminals (SLI), 136  
 tester, 92  
 types of 12-volt SLI batteries, 136  
   dry battery (AGM), 136  
   flooded battery, 136  
   visual inspection (SLI), 137  
   voltage regulation, 141  
   warning label, 124  
   warranty (SLI), 137  
   warranty (traction battery), 338

**Battery management system (BMS)**, 309  
 cell balancing, 309  
 charging, 315  
 state of charge (SoC), 309  
 thermal, 177

**Battery swapping (high-voltage)**, 316

**BBB**. *See Better Business Bureau*

**BCI group number (SLI)**, 136

**Bed mount hitch**, 278

**Belts**, 142-143  
 belt wear, 143  
 buying a new belt, 143  
 serpentine belt, 142  
   automatic belt tensioner, 142  
   construction, 142  
 stretch belt, 143  
   installation, 143  
 v-belts, 143  
 wear gauges, 143

**Bench grinder**, 101

**Bench vise**, 101

**Benz, Carl**, 10, 13

**Better Business Bureau (BBB)**, 48, 62

**B.F. Goodrich Company**, 14

**Bidirectional charging**, 313

**Bidirectional power**, 313

**Bi-fuel vehicles**, 249

**Big data**, 341, 364  
 Artificial Intelligence (AI), 356, 360

**Bike rack**, 276

**Biodiesel**, 246

**Blind spot intervention**, 40

**Blind spot warning**, 39, 357

**Block heater**, 270

**Bloodborne pathogens**, 73

**Blow-by**, 150, 239

**Blue tailpipe smoke**, 285

**Bluetooth**, 267

**Body control module (BCM)**, 141

**Body-on-frame**, 28, 194

**Bolts**, 97

## Brake

caliper, 215  
   stuck, 209  
 disc, 216  
 disc thickness variation (DVT), 216  
 drum, 217  
 fluid. *See Brake fluid*  
 grinding, 217  
 lines, 215  
 master cylinder, 123, 215  
 mechanical cable, 221  
 pads, 216  
   grinding noise, 217  
   high-pitched squeal, 217  
   screech, 285  
 pedal, 167, 215  
   travels to the floor, 215  
 pulsating, 216  
 rotor, 216  
   runout, 216  
 shoe, 217  
 wear indicator, 216  
 wheel cylinder, 217

**Brake assist system (BAS)**, 34, 219

**Brake-by-wire (BbW)**, 355

**Brake fluid**, 123, 214  
 adding, 123  
 checking, 123  
 master cylinder reservoir, 215  
 types, 123, 214

**Brake system**, 212-217  
 regenerative braking, 253, 257

## Brake types

- electric parking brake (EPB), 221
- hydraulic brakes, 213
  - disc brakes, 216
  - drum brakes, 217
- regenerative braking, 213

## British Thermal Unit (BTU), 245

## Brush guard, 272

## Budget, 26, 59

## Bug and tar remover, 107

## Buick, David, 12

## Bulb. *See* [Lights](#)

## Bulkhead. *See* [Firewall](#)

## Business ethics, 61

## Buying a car, 26-37

- auto buying programs, 43
- budget, 26
- cost to own a car, 59
- credit report, 27
- dealer cost, 47
- dealer invoice, 47
- dealership internet sales, 43
- depreciation, 58
- financing, 27
- fleet sales department, 43
- interest rate, 27, 52
- lemon law, 47
- lien holder, 56
- loan calculator, 27
- locating places to purchase, 43
- model history, 46
- monthly payment, 52
- MSRP, 47
- negotiate, 47
- reading window stickers, 44
- sticker price, 47

## Buying an EV, 332

- incentives, 332
- used, 58

## Buying a new belt, 143

## Buying a used car

- auctions, 48
- car rental sales, 49
- comparables, 50
- dealership, 48
- depreciation, 58
- independent repair facilities, 49
- independent used car lot, 48
- inspect and test drive, 49
- internet, 49
- making an offer, 50
- private-party seller, 49

## C

## Cabin air filter, 181

## Cadillac Automobile Company, 12

## California Air Resources Board (CARB), 304

## Caliper, 209

## Caliper in braking system, 215-216

## Caliper measuring tool, 91

## Caliper stuck, 209

## Camber, 207

- Camera**, 33, 37-41, 220, 266, 269
  - ADAS features, 349
  - biometric authentication, 365
  - driver monitoring system, 348
  - frequency band, 343
  - system-on-chip (SoC), 352
  - thermal imaging, 348
  - ultra-high bandwidth, 349
  - vehicle-to-everything (V2X), 366
  - visual light, 343

## Camshaft, 18, 188

## Camshaft position sensor, 188

## Capacitors, 135

## Cap screws, 97

## CARB (California Air Resources Board), 236

## Carbon dioxide (CO<sub>2</sub>), 20, 235-237, 246

## Carbon monoxide (CO), 20, 235-237

- exhaust leak, 234

## Car covers, 273

## Career exploration form.

- See* [Workbook Appendix](#)

## Careers

- ADAS calibration technician, 369
- automobile salesperson, 51
- automotive manufacturing, 25
- automotive service, 25
- automotive support, 25
- automotive teacher, 25
- automotive technician, 25, 67
- brake technician, 221
- collision repair technician, 115
- electrical engineer, 145
- electronics installer, 279
- emissions inspection technician, 243
- engineering technician, 191
- health and safety specialist, 83
- heating and A/C technician, 183
- industrial designer, 105
- insurance claims adjuster, 59
- petroleum engineer, 167
- public relations specialist, 263
- quick lube technician, 125
- service writer, 155
- software developer, 339
- tire manufacturing engineer, 211
- tow truck driver, 299
- transmission specialist, 231

## Cargo carriers, 276

## Cargo organizers, 265

## Caster, 207

## Catalytic converter, 233-239

- catalyst, 240
- check engine light, 282
- clogged, 285
- lead gasoline, 163
- rotten egg smell, 285
- three-way converter (TWC), 240

## CAT III and CAT IV multimeters, 327

## Cell phone kits, 267

## Cellular vehicle-to-everything (C-V2X), 367

## Center of gravity (CG), 81, 336

## Certified pre-owned (CPO), 66

## Cetane number, 164

## Chamois, 109

## Changing a flat tire, 298

## Charcoal canister, 239

## Charge-air cooler, 175

## Charge port, 306

## Charging an EV, 21, 314

- automated, 315
- connectors, 314
- contactless dynamic charging, 316
- cost, 317
- DC fast, 314
- DC ultra-fast, 314
- dock, 271
- etiquette, 315
- home, 316
- level 1, 314
- level 2, 314
- off-peak electricity rates, 317
- source - emissions, 317
- trickle charge, 314
- wireless, 315

## Charging system, 140-141

- alternator, 140-141
  - replacing belt, 295
- computer-controlled regulation, 141
- drive belt, 142-143
- intelligent battery sensor (IBS), 140
- powertrain control module (PCM), 141
- voltage regulator, 141

## Chassis, 28

## Chassis lubrication, 197

## Check engine light, 282

- emission testing, 243
- on-board diagnostics, 141
- pressure washing engine, 111

## Checking fluid levels

- automatic transmission, 119, 226
- battery electrolyte, 124, 137
- brake, 123
- clutch, 123
- continuously variable transmission (CVT), 119
- coolant, 121
- differential, 122
- engine oil, 118
- manual transmission, 119
- power steering, 122
- windshield washer, 117

## Chemical and fluid storage and disposal, 125

**Chemical energy**

battery storage of, 136, 140  
 charging system, 140  
 converted to electricity, 138, 258  
 fuel tank storage, 156  
 ignition system, 184  
 power transfer, 18  
 starting system, 138

**Chevrolet Bel Air**, 15**Chevrolet Bolt EV**, 305**Chevrolet, Louis**, 13**Chicago World's Fair**, 13**Chip repair**, 115**Chisel**, 95**Chrysler, Walter P.**, 12**Circuit analysis**, 129-131

chart, 129, 129-131  
 equivalent resistance, 130  
 parallel circuit, 130  
 parallel rules, 129  
 reciprocal method, 130  
 series circuit, 130  
 series-parallel circuit, 131  
 series rules, 129-131  
 voltage drop, 130

**Circuit breakers**, 135**Circuit connections**, 129**Circuit control devices**, 135

solid-state devices, 135  
 switch, 135  
   flashers, 135  
   manual, 135  
   relays, 135

**Circuit problems**

high resistance circuit, 132  
 open circuit, 132  
 short circuit, 132

**Circuit protection devices**, 134

capacitors, 135  
 circuit breakers, 135  
 fuses, 134  
 fusible links, 135

**Circuit types**, 129

parallel, 129  
 series, 129  
 series-parallel, 129

**CitiCar**, 14, 301, 303**Clamps**

cooling system hose, 172  
 exhaust, 234  
 jumper cable, 296

**Claying**, 109**Cleaning**

car wash soap, 107  
 chamois, 109  
 detailing, 109  
 floor mats, 112  
 headlight lenses, 108  
 microfiber towel, 109  
 removing bugs and road tar, 107  
 vehicle information displays, 113

wheels, 108  
 windows, 112  
 windshield, 108  
 wiper blades, 108

**Clips**, 99**Clutch**, 123, 224

disc, 224  
 fluid  
   adding, 123  
   checking, 123  
   types, 123  
 manual transmission, 224  
 master fluid reservoir, 123  
 slipping, 224

**Cognitive cyber-physical systems (CPS)**, 347**Coil**, 185-186

solenoid, 138

**Coil-on-plug (COP)**, 186**Coil-on-plug (COP) system**, 191**Coil springs**, 196**Cold chisel**, 95**Cold cranking amps (CCA) (SLI)**, 136**Collapsible temporary spare tire**, 206**Columbia (motor car company)**, 301**Combination wrench**, 85**Combustible metals**, 78**Combustion**, 19

remove excess heat, 169

**Compact temporary spare tire**, 206**Competency profile/task list**

*See Workbook Appendix*

**Compliance cars**, 304**Composite headlights**, 144**Compressed-air vehicle**, 260**Compression ignition (CI) engines**, 19**Compressor - A/C system**, 182-183**Computer**. *See Powertrain control module (PCM)***Computer-controlled starting circuits**, 139**Condenser - A/C system**, 182-183

**Conductor**, 127, 128  
 copper, 127  
 electromagnetic waves  
   propagating, 312  
 sequential in electric traction  
   motor, 311

**Connected vehicle**, 341, 364-367

data, 364  
 digital cabin, 365  
 over-the-air (OTA), 341

**Connecting rods**, 18**Constant velocity (CV) shafts**, 228

clicking noise, 285

**Consumer price index (CPI)**, 11**Contact point ignition (CPI)**, 190**Containerization (software)**, 363**Continuously variable transmission (CVT) fluid**

adding, 119  
 checking, 119  
 types, 119

**Conventional oil**, 147**Coolant**, 120-121, 178-179, 297, 310

additive/corrosion inhibitors, 121  
 checking/adding coolant at  
   radiator, 121  
 checking/adding coolant at  
   recovery tank, 121  
 dye color, 120  
 environmentally friendly, 120  
 flow, 169  
 flow ICE, 174  
 HEV electronic component, 175  
 high-voltage battery coolant, 121  
 hybrid organic acid technology  
   (HOAT), 120  
 inorganic acid technology (IAT),  
   120  
 leak color, 285  
 loss, 178  
 mixing, 121, 179  
 organic acid technology (OAT),  
   120  
 overheating, 286  
 properties, 178  
 recovery tank, 117, 121, 170-171,  
   297  
 recycle used, 178  
 recycling, 69  
 servicing, 178  
 steam, 170  
 sweet smell, 285  
 temperature indicator light, 180  
 testing, 179  
 types of glycol, 120  
 universal, 120  
 white tailpipe smoke, 179

**Coolant testers**, 90

hydrometer, 90  
 refractometer, 90

**Cooling methods**, 176

direct immersion, 176  
 indirect air, 176  
 indirect liquid, 176

**Cooling system**, 117, 168-175, 183

charge-air coolers, 175  
 EV and HEV, 121, 175  
 high-voltage battery coolant,  
   121  
 power electronics, 121  
 hoses, 172  
 overheating, 286  
   trouble guide, 174  
 powertrain control module  
   (PCM), 169  
 radiator, 121, 169-177, 286, 297  
 safety, 69, 121



radiator cap, 69, 121, 170,  
179-180, 286, 297  
radiator fan, 169, 171  
thermostat, 167, 169-171, 174-175  
water pump, 173-176  
    faulty, 286  
    weep hole, 173

**Corporate Average Fuel  
Economy (CAFE)**, 245

**Co-sign**, 27

**Cost to own calculator**, 59

**Cotter pin**, 99

**Cradle-to-grave emissions**, 317

**Crankcase**, 118, 150, 153, 155

**Cranking amps (CA)**, 136

**Crankshaft**, 18, 20, 188, 224

**Crankshaft position sensor**, 188

**Credit report**, 27

**Credit score**, 27

**Creeper**, 101

**Cross-threading**, 96

**Crude oil**, 162  
    distillation process, 56, 164  
    fuel expense impact, 166

**Crude oil production**, 13

**Cruise control (CC)**, 34

**Cugnot, Nicholas**, 12

**Cugnot steam traction engine**, 10

**Curb weight**, 30, 205

**Current clamp/clamp meter**, 133

**Current (I)**, 127  
    flow, 320

**Custom wheels**, 275

**CVT**. *See Continuously variable  
transmission (CVT)*

**Cybersecurity**, 365

**Cylinder deactivation**, 161

**Cylinder head**, 18  
    cracked, 286

## D

**Daily reflection log**.  
*See Workbook Appendix*

**Daimler, Gottlieb**, 13

**Data privacy**, 364

**Davenport, Thomas**, 301

**Davidson, Robert**, 12, 300, 301

**DC fast charging**, 314

**DC to DC converter**, 310

**DC ultra-fast charging**, 314

**Dead battery**, 296

**Dealerships**, 47, 61, 62

**Dealer terms**  
    cost, 47  
    incentives, 47  
    invoice, 47

**Decibel noise level chart**, 77

**Dedicated short-range  
communications (DSRC)**, 367

**Deductible**, 53

**Deep learning (DL)**, 360

**DEF**. *See Diesel exhaust fluid  
(DEF)*

**Department of Transportation  
(DOT)**, 202

**Dependent suspension**, 192

**Depreciation**, 58

**Detroit Electric**, 12, 15, 302

**Detroit Electric Car**, 301

**Diagnose problems**, 280

**Diagnose problems with codes**,  
145

**Die**, 98

**Die-cast technology**, 24, 28, 323

**Dielectric boots**, 329

**Dielectric properties**, 148

**Diesel**, 19-21, 164-165, 246  
    anti-gel additives, 165  
    cetane number, 164  
    cloud point, 164  
    cold filter plugging point (CFPP),  
    165  
    compression ignition engine,  
    19-20  
    disadvantages, 262  
    fuel, 21  
    fuel grades, 164  
    fuel maintenance, 165  
    filters and water separators,  
    165  
    saturation point, 165  
    pollution, 21  
    ultra-low sulfur diesel (ULSD),  
    21, 165

**Diesel emissions technology**,  
241-242  
    aftertreatment technologies, 242  
    diesel oxidation catalyst (DOC),  
    242  
    diesel particulate filter (DPF), 242  
    selective catalytic reduction  
    (SCR), 242

**Diesel exhaust fluid (DEF)**  
    adding, 124  
    cap, 124  
    checking, 124

**Diesel, Rudolf**, 13

**Differential**, 20, 229  
    ABS speed sensors, 218  
    limited-slip, 229  
    ring and pinion, 229  
    standard (also called open), 229  
    torque vectoring, 229

**Differential fluid**  
    adding, 122  
    checking, 122  
    types, 122

**Digital multimeter (DMM)**, 92,  
132-133  
    measuring current, 133  
    measuring dc voltage, 133-134  
    measuring resistance, 133

**Digital twin (DT)**, 359

**Dipstick**, 118-119, 122, 226

**Direct current (DC)**, 127  
    alternator, 140

**Directional tire**, 202

**Direct-to-consumer (DTC) sales**,  
43

**Disc brakes**, 216  
    brake pads, 216  
    caliper, 216  
    rotor, 216  
    wear indicators, 216

**Disc thickness variation (DVT)**,  
216

**Disposable gloves**, 75

**Distributor**, 186  
    cap, 186  
    contact point ignition (CPI)  
    system, 190  
    distributor ignition (DI) system,  
    190  
    rotor, 186

**DMS**. *See Driver Monitoring  
System*

**Domain controller**, 351-352

**Donating vehicle**, 51

**Door hinge**, 113

**Drill bit**, 95

**Drive axles**, 228

**Drive belts**, 142-143, 173  
    automatic tensioner, 142  
    buying, 143  
    replacing, 295  
    routing diagram, 142, 295  
    serpentine belt, 142-143, 254  
    broken, 295  
    replacing, 295  
    squeal when accelerating,  
    285  
    stretch, 143  
    V-belt, 143  
    wear, 143

**Drive-on ramps**, 88

**Driver assistance systems  
(DAS)**, 34, 46, 357  
    antilock brake system (ABS), 34,  
    35, 218, 219, 272, 284  
    brake assist system (BAS), 34,  
    218, 219  
    cruise control (CC), 34  
    electronic stability control (ESC),  
    34, 35, 218  
    hill descent assist (HDA), 35  
    hill start assist (HSA), 35, 218,  
    219  
    traction control system (TCS),  
    35, 218

**Driverless.** *See Autonomous vehicle*

**Driver monitoring system (DMS),** 36, 38, 348

**Drive shaft,** 228  
constant velocity (CV), 20, 285  
CV axle, 228  
standard, 228  
universal joints, 227-228

**Drivetrain**  
automatic transmissions, 119  
fluid, 119  
constant velocity (CV) shafts, 228  
continuously variable transmissions (CVTs), 119, 226  
drive axles, 228  
drive shafts, 228  
gears, 223-226  
difficult to shift, 224  
losses, 161  
manual transmissions  
fluid, 123  
transaxle, 20, 226, 228, 230

**Drivetrain configurations**  
all-wheel drive (AWD), 231  
four-wheel drive (4WD), 230  
front-wheel drive (FWD), 230  
rear-wheel drive (RWD), 230

**Driving automation levels,** 356-357  
Level 0 to Level 5, 357

**Driving range,** 258

**Drum brakes,** 217  
brake shoes, 217  
drum, 217  
hold-down springs, 217  
return springs, 217  
wheel cylinder, 217

**Durant, William,** 13

**Duryea, Charles and Frank,** 12

**DVD and entertainment systems,** 266, 267

**Dynamic driving task (DDT),** 356-357  
fallback, 356  
Levels 0 to Level 5, 356  
object and event detection and response (OEDR), 356-357  
operational functions, 356  
tactical functions, 356

## E

**E85,** 245-246

**Earmuffs,** 76

**Earplugs,** 76  
inserting foam earplugs, 76

**Ear protection,** 76-77

**Earth Stations in Motion (ESIM),** 345

**E-clip ring,** 99

**ECU.** *See Electronic control unit (ECU)*

**Edison, Thomas,** 12

**Edmunds,** 50

**Efficiency of electric vehicle,** 333

**e-Fluid,** 149, 149  
cooling properties, 177  
dielectric properties, 148  
heat transfer, 148  
materials compatibility, 148  
minimizing friction, 148  
requirements, 148  
synthetic, 147  
transmission, 149

**e-Fuse,** 354. *See also Fuse*

**e-Grease,** 149  
key characteristics, 149

**Electrical circuits,** 128  
conductor, 128  
load, 128  
parallel circuit, 130  
power source, 128  
series-parallel circuit, 131  
simple circuit, 129

**Electrical/electronic (E/E) systems,** 350  
decoupling, 350  
distributed legacy, 350-351  
functional safety, 358  
integrated power electronics, 354  
layered, 350  
restructuring, 350-351  
tightly coupled, 350

**Electrical energy,** 136-140  
regenerative braking, 257  
renewable, 262  
starting system, 139  
to mechanical energy, 140

**Electrical symbols,** 128

**Electrical system,** 127-144  
fuse box, 134

**Electrical terms**  
ampere, 127  
current, 127  
ohm, 127  
Ohm's law, 128  
resistance, 127  
voltage, 127-131, 136  
Watt's law, 128

**Electrical tools,** 92

**Electricity,** 127  
electric vehicle, 258  
conductor, 127-128, 138  
electrons, 136, 138, 251  
insulator, 127  
potential difference, 127  
sources of, 259

**Electric motor (e-motor),** 253-261, 311  
acceleration and speed, 335  
conversion kit, 339  
cooling, 168

current draw control, 355  
drivetrain, 258-259  
dry, 149  
gear reduction, 311  
high-voltage traction battery, 308  
induction, 311  
integrated configuration, 311  
in-wheel electric, 311  
magnet temperature limits, 177  
maintenance, 338  
mild hybrid, 254  
operating temperature, 169  
overheating, 170  
permanent magnet, 311  
power density, 177  
power electronics controller, 310  
power transfer, 306  
range, 335  
thermal management, 177  
or engine, 146  
wet, 149

**Electric power steering (EPS),** 199. *See also Power steering*

**Electric self-starter,** 301

**Electric vehicle (EV),** 258-259, 300-339  
bidirectional power, 313  
buying, 332-335  
charging, 314-317  
classifications, 253  
conversion kits, 339  
design efficiency, 307  
driving, 336-337  
driving range, 334-335  
efficiency, 308  
emergencies, 330-331  
extended range electric vehicles (EREVs), 259  
extreme temperatures, 335  
flow cell, 260  
high-capacity batteries, 258  
high-voltage PPE, 328  
high-voltage safety, 326-329  
high-voltage traction battery, 308  
how an EV works, 306  
maintaining, 338  
payback period, 334  
power and energy, 312  
powertrain components, 308-311  
range, 258  
rechargeable batteries, 318-321  
solar vehicles, 260  
timeline, 300-305

**Electric vehicle supply equipment (EVSE),** 314

**Electric pump,** 172

**Electrification,** 341, 350-355

**Electrolysis of water,** 262

**Electrolyte,** 124  
checking, 124  
readings, 137  
warnings, 124

## Electromagnetic (EM)

energy, 343  
spectrum, 340, 342, 343, 348  
wave, 342, 343  
wave formation, 343

## Electromotive force, 128

## Electron, 126

## Electronic control unit (ECU), 141, 350-353

## Electronic ignition (EI) system, 190

## Electronic stability control (ESC), 35, 218

## Electronic throttle control (ETC), 159, 355

## Electrovair, 301, 303

## Electrovette, 303

## e-Machine (mild hybrid), 254. *See also Electric motor (e-motor)* architectures (P0 to P5), 254

## Emergency brake. *See Parking brake*

## Emergency exit tool, 293

## Emergency response guides (ERGs), 79, 331

## Emergency roadside kit, 292

## Emission control system warranty, 42, 243

## Emissions. *See also Pollution*

California standards, 236  
CARB, 236  
diesel emission, 241-242  
federal standards, 236  
EPA tier 3, 236  
smog, 235  
source, 235  
types of emissions, 235  
upstream, 244  
vehicle emission control information (VECI) sticker, 237

## Emission system, 232

catalytic converter, 238-240. *See also Catalytic converter*  
evaporative emissions (EVAP) control canister, 239  
exhaust gas recirculation (EGR) system, 239  
oxygen sensors, 240  
positive crankcase ventilation (PCV), 239  
valve, 158  
powertrain control module (PCM), 239  
types, 118

## Emission testing, 243

analyzers, 237  
consumer assistance program, 242  
emission performance warranty, 243

## e-Motor. *See Electric motor (e-motor)*

## Energy, 17

conservation, 16  
content of fuels, 245  
distribution  
hybrid cruising, 255  
regenerative braking, 253

## Engine

block, 18, 22  
components, 18  
compression ignition, 21, 164  
compression ratio, 22  
displacement volume, 22  
four-stroke, 18-20, 185  
internal combustion, 10, 18, 20, 150, 162, 255  
misfire, 282  
oil. *See Engine oil*  
overheating, 180  
size, 22  
spark ignition, 18-19  
top dead center (TDC), 22

## Engine compartment cleaning, 111

## Engine control module (ECM), 141

## Engine coolant temperature (ECT), 160 sensor, 171

## Engine drive belt routing diagram, 142

## Engine heaters, 270

## Engine identification, 22 engine configuration, 22 engine size, 22

## Engine oil, 118 adding, 118 additives, 151 blow-by, 150 changing, 151-153 checking, 118 engine overheating, 150 excessive consumption, 118 filter, 94, 150, 154 installation, 150, 155 wrench, 94 multigrade, 153 purpose, 150 cleans, 150 cools, 150 lubricates, 150 seals, 150 ratings, 152 reading the dipstick, 118 recycling, 151 types, 118, 147-148 conventional, 147 synthetic, 147 viscosity ratings, 153

## Engine or motor, 146

## Entertainment gaming systems, 267

## Environment

emission system, 232  
emission testing, 243  
refrigerant recycling, 182

## Environmental Protection

Agency (EPA), 68, 70, 151

## EREV. *See Extended range electric vehicles (EREVs)*

## Estimates, 64

## Ethanol, 163, 246

## Ethernet, 349, 353, 364

## Ethical dilemmas, 361

## Ethylene glycol, 120

## European Automobile Manufacturers' Association (ACEA), 152-153

## EUV. *See Electric utility vehicle (EUV)*

## EV. *See Electric vehicle (EV)*

## EV1, 14, 301

## EV and HEV cooling systems, 121, 175

## Evaporative emissions (EVAP) control canister, 238, 239

## Evaporator - A/C system, 183

## EV platform, 28, 193, 194 layered architecture, 350 modular architecture, 351 x-by-wire, 355

## EVSE. *See Electric vehicle supply equipment (EVSE)*

## Exhaust gas heat recovery (EGHR), 181

## Exhaust problems

leak, 285  
rotten egg/sulfur smell, 285  
smoke  
black, 285  
blue, 285  
white, 179

## Exhaust system, 232-234

clamps, 234  
excessively loud, 233  
gasket or seal ring, 234  
hangers, 234  
header, 233  
leak, 234  
manifolds, 233  
muffler, 102, 233-234, 240, 285  
pipes, 233  
resonator, 234  
tailpipe, 233-234, 238  
valves, 18-19, 161

## Exhaust ventilation system, 69

## Expansion tank, 121

## Expenses

car payments, 52-53, 59  
fuel, 56  
insurance after accident, 294  
license and registration, 56  
routine maintenance, 59  
tire road hazard warranty, 200, 209  
unexpected repairs, 57, 59



**Extended range electric vehicles**, 259

**Extractor set**, 95, 98

**Extra load (XL) tires**, 205

**Eye and face protection**, 74

**Eyewash stations**, 74

## F

**Fabric cleaners**, 112

**Face shields**, 74

**Factory warranty**, 42, 66

**Fail-operational**, 358

**Fail-safe**, 358

**Fair credit reporting act**, 27

**Fan belt**. *See Drive belts*

**Fasteners**

- clips, 99
- grade, 96
- head styles, 97
- keys, 99
- metric-sized, 96
- non-threaded, 98
- pins, 99
- rivets, 99
- snap rings, 99
- splines, 99
- tensile strength, 96
- threaded, 97
- thread insert, 98
- U.S. customary-sized, 96
- washers, 99

**Faults (E/E system)**, 358

**FCW**. *See Forward collision warning (FCW)*

**Federal-Aid Highway Act of 1956**, 15

**Feeler gauges**, 91

**Fender cover**, 101

**File (machinist tool)**, 95

**Final drive assembly**, 20

**Finish**, 106

- basecoat, 106
- claying, 109
- clearcoat, 106
- failure, 115
- paintless dent repair (PDR), 114
  - PDR glue pulling, 114
  - PDR rods, 114
- paint protection film, 106
- repair, 114
- types, 106

**Fire**

- blanket, 331
- burning vehicle, 293
- chemical chain reaction, 330
- electric vehicle, 330
- exothermic reactions, 330
- oily waste can, 79
- oxygen generation, 331
- prevention, 79
- propagation, 330
- storage of flammables, 79

- tetrahedron, 330
- triangle, 78, 330
- types, 330

**Fire extinguishers**, 78

- class D, 78
- classifications, 78
- combination class ABC, 78
- shop safety rules, 69

**Firewall (bulkhead)**, 123, 173

**First aid**, 73

- bloodborne pathogens, 73
- kit, 73
- know what to do, 73

**First responder loop**, 331

**Five-star rating system**, 46

**Flammable cabinet**, 79

**Flammable liquids**, 78

**Flares**, 294

**Flashers**, 135

**Flat rate**, 62

**Flat tire**, 298

**Flex-fuel vehicle**, 246

**Floor dry**, 105

**Floor mats**, 264

**Flow cell electric vehicle**, 260

**Fluid leak color**, 284

**Fluid specifications**, 116

**Flushing the cooling system**, 179

**FlyDrive vehicles**, 262

**Foot protection**, 75

**Force**, 16, 215

**Ford, Henry**, 11, 12, 302

**Ford Motor Company**, 15

**Ford Mustang**, 15

**Ford Roadster**, 14

**Forward collision warning**

- (FCW), 39-40, 218, 220
- automatic emergency braking (AEB), 40
- automotive night vision, 347
- cameras, 349

**Four cylinder**

- inline, 22
- opposed, 22

**Four-strokes**, 18-20, 185

- compression, 19-20, 185
- exhaust, 18-19, 185
- intake, 18-19, 185
- power, 18-19, 185

**Four-wheel drive (4WD) vehicle**, 230

**Frame**, 24, 194, 199

- jump-starting, 296
- lifting on, 88, 102-103

**Freeze plugs**, 270

**Frequency**, 343-350

- band, 343
- electromagnetic spectrum, 342
- infrared radiation, 343
- radar, 346

- radio, 344
- visual light, 343
- wave, 343

**Friction**, 150, 212-213

- adhesive (traction), 200
- drivetrain, 230
- engine, 150
- minimizing, 148
- minimizing with e-fluid, 148
- wheel alignment, 167

**Front-wheel drive (FWD) vehicle**, 230

**Fuel**. *See also Diesel;*

*See also Gasoline*

- cap, 157
- economy, 56, 167
- filter, 157
- lines, 157
- petroleum refining, 162
- pressure regulator, 160
- prices, 166
- stoichiometric ratio, 156, 240

**Fuel cell technology**, 251

**Fuel injector**, 158

- gasoline direct injection (GDI), 158
- port fuel injection (PFI), 158
- throttle body injection (TBI), 158

**Fuel pump**

- high-pressure mechanical, 157
- in-tank electric, 157
- low-pressure mechanical, 157

**Fuel system**, 156-160

- air-fuel ratio, 156
- components, 157-160
- powertrain control module (PCM), 159, 160

**Functional safety**, 358

**Funnel**, 94

- special for Easy Fuel, 157

**Fuse**, 134

- blade, 134
- blocks, 111
- blown, 134, 287, 289
- box, 134
- cartridge, 134
- e-fuse, 354
- glass cylinder, 134
- junction block, 92, 134
- puller, 92
- ratings, 134
- smart electrical centers, 354

**Fusible links**, 135

## G

**Gaskets**, 150, 173

- exhaust manifold, 233

**Gasoline**, 162-163

- bi-fuel vehicle, 249
- flex-fuel vehicle, 246
- fuel expense, 56, 166
- price history, 20
- properties, 162-163
  - additives, 163
  - knocking, 163

octane rating, 163  
oxygenates, 163  
refueling, 166  
saving tips, 167

**Gasoline direct injection (GDI)**, 161  
gasoline direct injector, 158  
turbocharging, 161

**Gasoline engines**, 20, 162-163

**Gasoline gallon equivalent (GGE)**, 245

**Gateway security**, 366

**Gauges**, 271

**Gear oil**, 122

**Gears**, 223  
differential, 122, 229  
e-fluid, 148  
planetary, 149, 257, 311  
powertrain parts, 146  
ratios, 223  
reduction drive system, 306, 311  
timing, 188  
transmission, 119, 224-225

**General Motors (GM)**, 23, 301-305  
EV1, 304

**Glass cleaner**, 112

**Global Navigation Satellite System (GNSS)**, 345  
augmented GPS/GNSS, 345  
frequency, 343

**Global Positioning System (GPS)**, 35, 268, 345  
frequency, 343

**Glove size**, 328

**GNSS**. *See Global Navigation Satellite System (GNSS)*

**GPS**. *See Global Positioning System (GPS)*

**Grease**  
fittings, 197  
greasing procedure, 197  
gun, 94  
selecting, 197  
zerk, 197

**Greenhouse gases**, 163, 262

**Grille insert**, 275

**Gross axle weight rating (GAWR)**, 32

**Gross combination weight (GCW)**, 32

**Gross combination weight rating (GCWR)**, 32

**Gross trailer weight rating (GTWR)**, 29, 31

**Gross vehicle weight rating (GVWR)**, 29-30, 204  
payload, 30

## H

**Hacksaw**, 95  
**Hammer**, 87

ball peen, 87  
rubber mallet, 87

**Hand cleaner**, 105

**Hand protection**, 75

**Hands-free cell devices**, 267

**Hazard lights**, 135, 294, 298

**Hazardous wastes**, 70  
corrosivity, 70  
ignitability, 70  
reactivity, 70  
toxicity, 70

**Header**, 233

**Headlight restoration**, 108

**Headlights**, 144-145, 287  
composite, 144  
replacing, 287  
sealed beam, 144

**Hearing protection**, 76

**Heater blower**, 174

**Heater core**, 169, 173

**Heat exchanger**, 169

**Heating, ventilation, and air conditioning system (HVAC)**, 181

**Heat pump**, 180, 310

**Heat transfer**, 168

**Henney Kilowatt**, 303

**High-voltage systems**, 137, 258  
battery pack, 257  
charging dock, 271  
safety, 326

**High load (HL) tires**, 205

**High-performance computing (HPC)**, 353  
software, 362  
software-defined, 341, 350

**High-resistance circuit**, 132

**High-voltage tools**, 327

**High-voltage traction battery**. *See also Battery*  
identifying, 326  
service disconnect, 326

**Highway terrain (H/T) tires**, 202

**Hill descent assist (HDA)**, 35

**Hill start assist (HSA)**, 35, 219

**Hitch rack**, 276

**Honda Insight**, 14

**Hood**  
latch lubrication, 113  
opening and closing, 116  
protector, 271

**Horsepower (HP)**, 17

**How cars work**, 16-17

**How EVs work**, 306

**HPC**. *See High-performance computing (HPC)*

**Hybrid electric vehicle (HEV)**, 253-257  
drivetrain, 256  
electric motor, 253, 253-254

high-voltage battery pack, 255, 257

lithium-ion (Li-ion) batteries, 257  
mild, 254. *See also Mild hybrid*  
nickel metal hydride (NiMH) batteries, 257  
orange color cables, 69, 135, 137  
parallel drivetrain, 256  
payback calculation, 263  
planetary gear set, 257  
plug-in, 256. *See also Plug-in hybrid electric vehicle (PHEV)*  
preventative maintenance, 243  
regenerative braking, 213, 253, 257  
series drivetrain, 256  
series-parallel drivetrain, 257  
start-stop technology, 253

**Hydra-Matic Drive**, 14

**Hydraulic-assisted power steering**, 14

**Hydraulic brake pressure**, 123

**Hydrocarbons (HC)**, 20, 162, 235  
autogas, 248  
evaporative emissions control canister, 239

**Hydrogen (H)**, 250  
fuel cell vehicle, 252  
proton exchange membrane (PEM), 251  
gas production, 250  
hydrogen ICE (H2ICE) vehicle, 251

**Hydrometer**, 93, 137

## I

**Ice grip tire symbol**, 201

**ICE to EV Conversions**, 339

**Idle air control (IAC) valve**, 160

**Ignition**  
module, 187-188  
faulty, 191  
switch, 138-139

**Ignition system**, 184-189  
air-fuel mixture, 185  
battery, 185  
coil, 186-187  
coil-near-plug (CNP), 186  
coil-on-plug (COP), 191  
contact point ignition (CPI), 190  
crankshaft and camshaft sensors, 188  
distributor cap and rotor, 186  
distributor ignition (DI), 190  
electric spark, 184  
electronic ignition (EI), 191  
fuel injection timing, 188  
heat from compression, 184  
insulator boot, 186  
misfire, 186  
spark plugs, 19-20, 185-190  
tune-up, 167, 190-191  
worn, 185

- spark plug wires, 186
    - faulty, 185
    - safety, 69
    - voltage, 185
  - IIHS safety ratings**, 46
  - i-MiEV**, 301
  - Improving fuel economy**, 167
  - In-cabin monitoring**, 346
    - camera, 349
    - driver monitoring, 348
    - life presence detection, 346
  - Independent suspension**, 193
    - MacPherson strut, 193
    - short-long arm (SLA), 193
  - Indicator lights**, 376-377
  - Inertial measurement unit (IMU)**, 345
  - Inertial navigation system (INS)**, 345
  - Information assistance**, 35
  - Infrared thermometer**, 90
  - Infrared waves**, 347
  - Infrastructure**, 366
  - Inspecting**, 49
  - Inspection and maintenance (I/M) testing**, 243
  - Insulating electrical safety gloves**, 328
  - Insulating hand tools**, 327
  - Insulating rubber apron**, 329
  - Insulator**, 127
  - Insulator boot**, 186
  - Insurance**, 53-55, 200, 294
    - accidents, 53
    - automaker issued, 55
    - budget, 26
    - claim, 47, 53-54
    - collision insurance, 54
    - comprehensive insurance, 54, 294
    - deductible, 53-54, 294
    - driving-based, 53
    - liability insurance, 54
    - medical payment insurance, 54
    - mileage-based, 53
    - moving violations, 53
    - no-fault protection, 54
    - personal injury protection, 54
    - rental, towing, and total replacement, 55
    - umbrella insurance, 55
    - underinsured motorist coverage, 55
    - uninsured motorist coverage, 55
    - usage-based insurance (UBI), 53
  - Insurance Institute for Highway Safety (IIHS)**, 46
  - Intake valves**, 18-19
  - Integrated power electronics controller (IPEC)**, 354
  - Intelligent battery sensor (IBS)**, 140
  - Interest rates**, 27, 52
  - Interference engines**, 189
  - Interior cleaners**, 113
  - Internal combustion engine (ICE)**, 18-19
    - as hybrid vehicle power source, 255
    - as onboard generator, 259
    - burning hydrogen, 251
    - development, 10
    - exhaust and emission, 232
    - fuels and designs, 20
  - International Lubricant Standardization and Approval Committee (ILSAC)**, 152-153
  - International System of Units (SI)**, 90
  - Internet of Things (IoT)**, 340
    - data transfer rates, 346-347
  - In-vehicle navigation**, 35
  - In-vehicle network (IVN)**, 364
  - Inverter**, 310
  - IoT**. *See Internet of Things (IoT)*
- J**
- Jack**, 82, 88, 298
    - bottle, 89
    - floor, 69, 88, 89
    - how to use, 82
      - when changing flat tire, 298
      - when changing oil, 154-155
    - safety, 69
    - scissor, 89
  - Jacking a vehicle**, 82
  - Jack stands**, 88
    - how to use, 82
    - when changing oil, 154-155
    - safety, 69
  - Jedik, Anyos**, 301
  - Jumper cables**, 93
    - choosing type, 93
    - using to jump-start, 296
  - Jump-start procedure**, 296
  - Just-in-Time (JIT)**, 15
- K**
- Kelley Blue Book (KBB)**, 50
  - Kettering, Charles**, 13, 301
  - Keyless entry system**, 269
    - key fob, 139
  - Keys**, 99
  - Kilowatt-hour**, 333
  - Kinetic energy**, 18
    - captured with regenerative braking, 213, 253
    - converted to heat conventional brakes, 212
  - Kit cars**, 339
  - Knocking**, 162-163
  - Knock sensor (KS)**, 163, 188
- L**
- Laboratory safety**, 68-69
  - Labor rates**, 62
  - Ladder rack**, 277
  - Laminated glass**, 15, 293
  - Lane centering assistance (LCA)**, 41, 199, 357
  - Lane departure warning (LDW)**, 39, 357
  - Lane keeping assist (LKA)**, 40, 357
  - Lead acid battery**, 136-137
    - electrolyte reading, 137
  - Leaf springs**, 196
  - Lease**, 42
  - License and registration**, 56
    - license plate tags, 56
    - title, 22, 56
  - Lidar**, 37, 219, 348
    - autonomous vehicles, 261
    - frequency, 343
    - vehicle-to-everything (V2X), 366
  - Life cycle management**, 368
  - Lifting and carrying safety**, 73
    - material handling practices, 73
  - Lifting a vehicle**, 80-81.
    - See also Automotive lift*
    - center of gravity, 81
    - lifting points, 81
    - lift manuals/online courses, 80
    - safety, caution, and warning labels, 80
  - Lifting tools**, 88
    - drive-on ramps, 88
    - floor jack, 88
    - jack stands, 88
    - wheel chocks, 88
  - Lights**, 144-145, 270, 287
    - brake, 277, 287
    - bulbs, 287
    - bulb socket, 287
    - daytime running, 144, 270
    - fog, 270
    - halogen, 144
    - hazard flasher, 135, 294
    - headlights, 144-145, 287
      - composite headlights, 144
      - sealed beam headlights, 144
    - HID (high-intensity discharge), 144
    - indicator, 376-377
    - LED (light-emitting diode), 144
    - miniature light bulbs, 144
    - non-serviceable assemblies, 145
    - off-road, 270
    - trailer wiring, 277
    - turn signal, 287
    - xenon, 144



**Light wave.** *See*  
*also Electromagnetic (EM)*  
interaction behavior, 342  
speed of light, 342

**Liquefied petroleum gas (LPG).**  
*See Propane*

**Liquid cooled AC generators,** 175

**Lithium Ferrophosphate (LFP),**  
319

**Lithium-ion (Li-ion) battery**  
cell chemistry, 318, 319  
cell components, 318, 320  
service disconnect, 257

**Lithium (Li),** 318

**Lithium Nickel Cobalt Aluminum  
(NCA),** 319

**Lithium Nickel Manganese  
Cobalt Oxide (NMC),** 319

**Loading a trailer,** 33

**Loan calculator,** 27

**Loan payments,** 52

**Lockout,** 292, 297

**Lockout box,** 329

**Lock washers,** 97

**Lohner-Porsche Electromobile,**  
301

**Longitudinal engine,** 223

**Low Earth Orbit (LEO) satellites,**  
345

**Lower radiator hose,** 172

**Lubricants,** 113, 146-149  
additive packages, 151  
e-fluid parameters, 148  
e-fluid types, 149  
types, 147

**Lubrication,** 113  
application, 113  
forgotten parts, 113

**Lucid Motors,** 311

**Luggage racks,** 276

**Lug nuts,** 275, 298  
4-way tire tool, 89  
changing a flat tire, 298  
checking torque, 210  
locking, 275  
star pattern, 298  
torque patterns, 210  
unevenly torqued, 216  
wheel lock lug nuts, 210

**Lug wrench,** 89-90, 298

**M**

**Machine learning (ML),** 360  
data privacy, 364  
deep learning (DL), 360  
digital industrial revolution, 347

**Maintaining an EV,** 338

**Maintenance**  
extreme service schedule, 57

normal service schedule, 57  
severe service schedule, 57  
unexpected repair, 57

**Make,** 23

**Making an offer**  
new car, 47  
used car, 50

**Malfunction indicator light (MIL),**  
282  
ABS, 284  
airbag, 83  
brake warning, 284  
check engine, 111, 141, 243, 282  
coolant temperature, 282  
electric power steering (EPS), 284  
fuel cap, 166  
low fuel, 283, 284  
oil pressure, 151, 283  
powertrain fault, 283  
TPMS, 284  
worn brake pads, 216

**Manifold absolute pressure  
(MAP) sensor,** 160

**Manual switches,** 135

**Manual transmission.**  
*See Transmission*

**Manual transmission fluid**  
adding, 122  
checking, 119  
type, 119

**Manufacturer's suggested retail  
price (MSRP),** 47, 332

**Mass airflow sensor (MAF),** 160

**Massive MIMO (Multiple Input  
Multiple Output),** 346

**Master cylinder,** 215

**Maybach, Wilhelm,** 13

**Measuring current (amps),** 133  
current clamp/clamp on meter,  
133

**Measuring DC voltage (volts),** 133

**Measuring resistance (ohms),** 133

**Measuring tools,** 90-91  
caliper, 91  
coolant testers, 90  
feeler gauge, 91  
infrared thermometer, 90  
micrometers, 91  
precision, 91  
torque wrench, 90

**Mechanical energy**  
charging system, 140  
from chemical energy, 18, 184  
ignition system, 185  
starting system, 139  
to electrical energy, 140

**Mechanic gloves,** 75

**Metalworking tools,** 95

**Metric system,** 90, 340  
thread, 96

**Micrometer,** 91

**Microwaves,** 344

**Middleware,** 363

**Mild hybrid,** 254  
architectures, 254  
belt-alternator-starter (BAS)  
system, 254  
belt driven electric motor/  
generator, 254  
crank driven electric motor/  
generator, 254  
regenerative braking, 254

**Miles per gallon (MPG),** 21  
gasoline gallon equivalent (GGE)  
calculation, 245  
CNG, 247  
energy comparison with  
BTU, 245  
miles per gallon equivalent  
(MPGe), 21, 245

**Miniature light bulbs,** 144

**ML.** *See Machine learning (ML)*

**Mobility strategies,** 369

**Model T,** 11, 13, 17, 301, 302

**Model year (MY),** 22-23

**Modular architecture,** 351

**Morrison, William,** 13, 301  
electric horseless carriage, 301

**Motor.** *See Electric motor (e-motor)*

**Motor Vehicle Air Pollution  
Control Act,** 15

**MP3 players,** 267

**MPGe (miles per gallon  
equivalent),** 333

**MSDS.** *See Safety data sheet (SDS)*

**MSRP.** *See Manufacturer's  
suggested retail price (MSRP)*

**Mud and snow (M+S),** 201

**Mud flaps,** 273

**Mud-terrain (M/T) tires,** 202

**Muffler,** 233-234  
loud or rumbling noise, 233

**Multimeter,** 92

**Multi-point vehicle inspection  
form.** *See Workbook Appendix*

**N**

**NASA Lunar Roving Vehicle,** 301

**NASCAR,** 14

**National Automotive Dealers  
Association (NADA),** 50

**National Fire Protection  
Association (NFPA),** 79, 331

**National Highway Traffic Safety  
Administration (NHTSA),** 14,  
46, 218  
corporate average fuel economy  
(CAFE), 245  
safety ratings, 46

- technical service bulletin (TSB), 280
- tire pressure monitoring system (TPMS), 208
- National Motor Vehicle Title Information System (NMVTIS)**, 50
- Natural gas**, 247
  - bi-fuel vehicle, 248
  - CNG and LNG vehicle, 247
  - conversion, 247
  - fleet vehicles, 247
  - refueling, 247
  - spark ignition engine, 18
- Navigation system**, 268
- Near-infrared (NIR)**, 347-348
  - driver monitoring system (DMS), 348
- Nerf bars**, 272
- Neutrons**, 126
- New radio (NR)**, 346
- Next-generation vehicle**, 341
- Nickel metal hydride (NiMH) battery**, 257. *See also* **Battery**
- Nissan LEAF**, 15, 301, 305
- Nitrogen (N)**, 237, 240
- Nitrogen oxides (NO<sub>x</sub>)**, 20, 235-237, 241-242
  - catalytic converter, 240
  - emission testing, 243
  - exhaust gas recirculation (EGR), 239
- No-cut zones**, 331
- Noise-induced hearing loss (NIHL)**, 76
  - decibel, 76
  - decibel noise level chart, 77
  - factors affecting, 76
  - noise levels, 76
  - sound level meter (decibel meter), 76
- Noise-reducing tires**, 203
- Non-interference engines**, 189
- Non-pneumatic tires (NPT)**, 203
- Nonrenewable energy resource**, 162
- North American Charging Standard (NACS)**, 314
- No-start conditions**, 191, 291
- Nuts**, 97
  - castle nut, 99
  - lock nut, 97
  - slotted nut, 99
- O**
- OBD II scan tool**, 281
- Object and event detection and response (OEDR)**, 356-357
- Occupant detection**, 346
- Occupational Safety and Health Administration (OSHA)**, 68, 71
  - employer responsibilities, 71
  - health and safety standards, 71, 327
  - right-to-know laws, 71
- Octane**, 158-160, 166
  - fuel price, 56
  - pinging while accelerating, 162
  - ratings, 163
- Ohms**, 127
- Ohm's law**, 128
- Oil**. *See* **Engine oil**
- Oil change**, 154-155
- Oil drain pan**, 94, 154-155
- Oil filter**, 94, 150, 152-153, 154-155
  - gasket, 150
  - wrenches, 94
- Oil life monitoring system**, 154
- Oil pan**, 18, 150
  - checking engine oil, 118
  - engine heat dissipation, 150
  - plug threads, 154-155
- Oil recycling**, 151
- Oldsmobile Curved Dash**, 13
- Olds, Ransom**, 12
- Onboard charger (OBC)**, 309
  - capability, 258
  - electronics consolidation, 354
  - how EVs work, 306
  - where AC to DC occurs, 313
- On-board diagnostics (OBD)**, 281-282
  - emissions, 141
  - OBD II app, 281
- One-pedal driving**, 337
  - regenerative braking, 335
- Online sales**, 43, 48
- OnStar**, 268
  - lockout service, 297
- Open circuit**, 132
- Open source software (OSS)**, 362
- Operating system (OS)**, 362
- Operating temperature**, 169
- Operational design domain (ODD)**, 356-357, 366
- Orange cables**, 69, 137
- Organization of Petroleum Exporting Countries (OPEC)**, 14
- Orifice tube - A/C system**, 182-183
- Otto cycle**, 18
- Otto, Nikolaus**, 12
- Overheating**, 170, 286
  - burst radiator hose, 297
  - temperature indicator, 282
- Oversteer**, 218
- Over-the-air (OTA) updates**, 363
  - firmware, 363
  - software, 363
- Owner's manual**, 104
- Oxygenates**, 163
  - ethanol, 163
  - ethyl tertiary butyl ether (ETBE), 163
  - methyl tertiary butyl ether (MTBE), 163
  - tertiary amyl methyl ether (TAME), 163
- Oxygen sensors**, 240
  - downstream, 240
  - exhaust system, 233
  - upstream, 240, 242
- P**
- Paint**, 114-115
  - brake fluid spill, 123, 214
  - chip and scratch repair process, 115
  - color code, 114, 115
  - finish types, 106
  - gasoline spill, 110
- Paintless dent repair**, 114
- Paint protection film (PPF)**, 106
- Parallelogram steering system**, 198
- Parking brake**, 217, 221
- Particulate matter (PM)**, 21, 165, 235, 241-242
- Payload**, 30-31, 335
- Pedestrian detection AEB**, 40
- Perimeter marking tape**, 329
- Personally identifiable information (PII)**, 364
- Personal protection equipment (PPE)**, 74-77, 328
  - ear protection, 76
  - eye and face, 74
  - foot protection, 75
  - hand protection, 75
  - respiratory protection, 74
- Pet travel**, 265
- Photovoltaic cells**, 260
- pH scale**, 70
- Pinging**, 162-163
  - while accelerating, 285
- Pins**, 99
- Piston**, 18-19, 150
  - position sensors, 188
- Piston rings**, 150
  - worn, 118
- Planetary gear set**. *See* **Gears**
- Pliers**, 86-87
  - diagonal, 86
  - groove joint, 86
  - locking, 87
  - needle nose, 86
  - slip joint, 86
- Plug-in hybrid electric vehicle (PHEV)**, 256

- Plymouth Superbird**, 15
- Polish**, 109-110
  - applying wax, 110
  - types of wax, 110
  - wax or polish, 110
- Pollution**, 235. *See also Emissions*
  - acid rain, 235, 262
  - carbon dioxide (CO<sub>2</sub>), 20. *See also Carbon dioxide (CO<sub>2</sub>)*
  - carbon monoxide (CO), 20. *See also Carbon monoxide (CO)*
  - hydrocarbons (HC), 20. *See also Hydrocarbons (HC)*
  - nitrogen oxides (NO<sub>x</sub>), 20. *See also Nitrogen oxides (NO<sub>x</sub>)*
  - particulate matter (PM), 21. *See also Particulate matter (PM)*
  - smog. *See also Smog*
- Porsche, Ferdinand**, 13
- Port fuel injection (PFI)**, 158
- Positive crankcase ventilation (PCV)**, 158, 285
- Power**
  - Watt's Law, 128
- Power electronics**
  - cooling, 177
- Power electronics controller**, 310
- Power formula**, 17
  - horsepower, 17
  - watt, 17
- Power steering**, 122, 199
  - electric power steering (EPS), 199
  - hard steering, 199
  - hydraulic, 199
  - leak color, 284
  - pump, 122, 199, 295
  - reservoir, 122
- Power steering fluid**
  - adding, 122
  - checking, 122
  - reading the dipstick, 122
  - types, 122
- Power tools**, 100
  - air-powered (pneumatic), 100
  - battery-powered, cordless, 100
  - electric-powered, 100
- Powertrain components of EV**, 308
- Powertrain control module (PCM)**, 141, 238-240
  - charging system, 141
  - check engine light, 282. *See also Malfunction indicator light (MIL)*
  - cooling system, 169
  - emission system, 238-240
  - fuel system, 159
  - ignition system, 187
  - malfunction, 187
- Power transfer process EV**, 306
- Preconditioning**, 177, 310, 336
- Predictive maintenance**, 365
- Pressure gauge**, 89
- Prius**, 253, 255-256
- Product life cycle**, 70
- Propane**, 18, 248
  - fleet vehicles, 248
  - refueling, 248
- Proton exchange membrane (PEM)**, 251
- Protons**, 126, 251
  - hydrogen atom, 250
- Pry bar**, 87
- Public charging stations**, 314
- Pulling in one direction**, 286
- Punch**, 95
- Q**
- Quiet vehicle warning sounds**, 39
- R**
- Rack and pinion steering system**, 198
- Radar**, 37, 219
  - communication, 344
  - frequency, 343
  - sensors, 346
- Radiator**, 121, 169, 286
  - burst radiator hose, 297
  - cap, 69, 121, 174, 179, 297
    - pressure rating, 170
  - coolant recovery tank, 117, 121, 170, 171, 297
  - electrical fan, 171
  - expansion tank, 121
  - fins, 174
  - hoses, 172
  - leaking, 286
  - mechanical fan, 171
  - overheating, 170
- Radio waves**, 344
- Range**
  - anxiety, 336
  - driving estimates, 45, 333-335
  - extender, 259
- Ratchet**, 85
- Ratchet tie-down straps**, 277
- Real-time operating system (RTOS)**, 362
- Rear cross traffic warning**, 39, 357
- Rear differential**, 229-231
- Rear spoilers**, 274
- Rear-wheel drive (RWD) vehicle**, 230
- Recalls**. *See Safety recalls*
- Receiver-drier - A/C system**, 182
- Recycling**
  - carbon dioxide, 246
  - refrigerant recover/recycle, 182
  - used oil, 94, 151
- Reflective triangles**, 294
- Refractometer**, 179
- Refrigerant**, 182-183, 310
  - R-12, 182
  - R-134a, 182
  - R-1234yf, 182
- Regenerative braking**, 213
  - hybrids, 253
  - kinetic energy, 257
  - mild hybrid, 254
  - range extender, 335
- Relays**, 135
- Remanufactured part**, 64
- Remote starters**, 269
  - pollution from, 269
- Renewable energy**, 317
- Repair facility**, 62-63
  - AAA approved, 62
  - auto repair chains, 63
  - dealership, 62
  - independent, 61
  - specialized, 63
- Repair invoice**, 64-65
- Repair order**, 64-65
  - cause, 64-65
  - concern, 64-65
  - correction, 64-65
- Replacement parts**, 64
- Resistance**, 127
- Resistive heater**, 180
- Resonator**, 234
- Respiratory protection**, 74, 215
- Restoring threads**, 98
- Revolutions per minute (RPM)**, 17
- Rivets**, 99
- Rivian**, 14
- Roadside emergencies**, 292-299
  - accident, 294
  - animal collision, 294
  - broken belt, 295
  - burst radiator hose, 297
  - dead battery, 296
  - emergency roadside kit, 292
  - flat tire, 298
  - jump-starting, 296
  - lockout, 297
  - road trip checklist, 292
  - run out of fuel, 297
  - traction in snow, 299
  - vehicle fire, 293
  - winter safety kit, 293
- Rockefeller, John D.**, 13
- Rolling resistance**
  - low rolling resistance tires, 203
  - tire pressure, 208
  - tread design, 307
- Roof cargo containers**, 276
- Rotor**
  - braking system, 216. *See also Brake*
  - e-motor, 148, 311
  - ignition system, 186



no-start, 191  
worn, 185

**Route 66**, 12

**Rubber boots**, 228

**Rugged-terrain (R/T) tires**, 202

**Rulers**, 90

**Run flat tires**, 203, 206

**Running boards**, 272

**Rust**, 115, 274  
inhibitors (in antifreeze), 178  
inhibitors (in gasoline additives), 163  
removing from metal, 115

**Rustproofing**, 274-275

## S

**SAE**. *See Society of Automotive Engineers (SAE)*

### Safety

ABS, 218, 221, 284  
accident, 294  
airbags, 83, 199  
around battery electrolyte, 291  
automotive lifts, 80, 102  
cones, 294  
eye and face protection, 71, 327  
fire extinguishers, 69, 78  
first aid kit, 73  
glasses, 68, 74, 328  
goggles, 74  
hand protection, 75  
lifting and handling, 73  
OnStar, 268  
rules, 68  
seat belt, 82  
trailer chains, 278  
vehicle model safety history, 46  
winter safety kit, 293

**Safety chains**, 278

**Safety data sheets (SDSs)**, 72  
available online, 72  
readily accessible, 72  
specific uniform format, 72

**Safety glass**, 15

**Safety glasses**, 68, 74, 328

**Safety recalls**, 67  
tires, 211

### Scan

electric vehicle, 103  
tool, 103

**Scratch repair**, 115

**Screwdrivers**, 87

### Screws

machine screw, 97  
self-drilling screw, 97  
self-tapping screw, 97  
set screw, 97  
sheet metal screw, 97

**Sealed beam headlights**, 144

**Seals**, 173

**Seat belts**, 14

**Seat covers**, 265

**Sebring-Vanguard**, 301

**Security systems**, 269

**Selective catalytic reduction (SCR)**, 124, 242

**Self-sealing tires**, 203, 206

**Self-supporting tires**, 203

**Selling a car**, 51

**Semiconductor**, 14

**Semiconductor e-fuses**, 354

**Semi-synthetic oil**, 147

**Sensor fusion**, 361

**Serpentine belt**, 142, 173.

*See also Drive belts*

### Service manuals

consumer, 104  
online, 104  
professional, 104

### Service schedule

extreme, 57  
normal, 57  
severe, 57

**Shaking or vibrating**, 286

**Sheet metal screws**, 97

**Shift-by-wire**, 355

### Shocks

air, 195  
bounce test, 195  
defective, 199  
gas charged, 195  
inspection, 195  
magnetic ride, 195

**Shop towels**, 105

**Short circuit**, 132

short to ground (grounded circuit), 132  
short to power, 132

**Simple circuit**, 129

**SLI**. *See Battery (SLI)*

**Smart electrical center**, 354

**Smog**, 235, 262

**Smoke from tailpipe**, 285

**Snap ring pliers**, 99

**Snap rings**, 99

**Society of Automotive Engineers (SAE)**

fastener grade, 96  
oil viscosity, 153  
SAE J3016 levels of driving automation, 261, 337, 356

**Sockets**, 85-86

6-point and 12-point, 85  
deep well, 86  
impact, 86  
spark plug, 86  
standard, 86

**Software-defined vehicle (SDV)**,

11, 339, 340-342  
analysis life cycle loops, 359  
brake-by-wire (BbW), 355

cybersecurity, 365  
digital twin (DT), 359  
in-vehicle network (IVN), 364  
maintenance, 368  
operating system (OS), 362  
performance data, 365  
x-by-wire, 355

**Software platform**, 350  
open source, 362

**Solenoid**, 138-139

**Solid-state battery cell**, 325

**Solid-state devices**, 135

**Sound level meter (decibel meter)**, 76

**Spare tire**, 206

**Spark ignition (SI) engines**, 18

**Spark plug**, 18, 20, 187

electrodes, 91, 187  
fouled, 285  
fuel economy, 167  
gap, 91  
setting, 187  
gauge tool, 91  
specialty socket, 86  
worn, 185

**Spark plug wires**, 186-187

dielectric grease, 186  
faulty, 185  
firing order, 186  
safety, 69

**Speakers**, 267

**Specialty tools**, 84, 103

**Speed sensors**, 231

**Splines**, 99

**Sports car of the century**, 15

**Springs**, 196

air springs, 196  
coil springs, 196  
leaf springs, 196  
torsion bar springs, 196

**Stain treatment**, 112

**Standard load (SL) tires**, 205

**Stanley, F.E. and F.O.**, 12

**Starter**, 138-139

belt-alternator-starter (BAS), 254

**Starting, lighting, ignition (SLI)**

battery, 136-137  
charging procedure, 137

**Starting system**, 138

battery, 138  
computer-controlled starting circuits, 139  
ignition switch, 138-139  
park/neutral safety switch, 139  
problems, 138  
solenoid, 138-139  
starter, 138-139  
starter relay, 138

**Start-stop technology**, 139, 253

**State of charge (SoC)**

electrolyte readings, 137

- extending battery life, 338
- grace capacity, 309
- hybrid, 255
- Steer-by-wire (SbW)**, 355
- Steering linkage**, 199-200
  - parallelogram system, 198
  - pitman arm, 198
  - rack and pinion system, 198
  - recirculating ball system, 198
- Steering system**, 198-199
  - electric power steering (EPS), 199
  - power steering pump, 122, 199, 295
  - steering linkage, 199
  - steering wheel, 113
    - lock, 269
- Steering wheel**, 198-199
  - airbag components, 83
  - howling sound, 199
  - key will not turn, 291
- Stoichiometric ratio**, 156, 240
- Stranded energy**, 331
- Struts**, 196
  - defective, 199
- Studebaker**, 301
- Studs**
  - exhaust manifold, 97
  - wheel, 97
- Sturgeon, William**, 301
- Subframe**, 24
- Sulfur dioxide (SO<sub>2</sub>)**, 235
- Sunroof defectors**, 274
- Sun shades**, 265
- Supercomputer**, 341
  - artificial intelligence (AI), 360
  - autonomous vehicles, 261
  - high-performance computing (HPC), 353
  - upgradable, 368
  - zone controller, 353
- Supplemental restraint system (SRS)**, 82, 83
- Support ring run-flat tire**, 203
- Surface protection**, 113
- Surround view camera**, 41
- Suspension system**
  - dependent, 192
  - frame, 194-196
  - independent, 193
  - springs, 196
  - tires, 200-205
  - unibody, 81
- Sway bar**, 196
- Switch**, 135
  - circuit control device, 135
  - ignition, 138
  - park/neutral safety switch, 139
- Symbols**, 376-377
- Symmetrical tire**, 202
- Synthetic oil**
  - advantages and disadvantages, 147
  - applications, 147
- System-on-chip (SoC)**, 352
- T**
- Tailpipe**, 233-234, 238
  - emissions. *See Pollution*
- Tap**, 98
- Tap and die set**, 95
- Technical service bulletin (TSB)**, 280
- Telematics**, 35
- Temperature gauge**, 168
- Tempered window**, 293
- Tensile strength**, 96
- Tesla Motors**, 301
  - Model 3, 15, 21, 301, 305, 334
  - Model Y, 305, 308
  - Roadster, 15, 301, 304
  - superchargers, 21
- Test driving**, 47, 49
- Test light**, 92
- Thermal heat energy**, 168, 173
  - conduction, 168
  - convection, 168
  - radiation, 168
- Thermal management system**, 310
  - cabin, 177
  - EV, 168
- Thermal runaway**, 330
  - propagation, 330
- Thermostat**, 169-171, 174-175
  - checking the cooling system, 167
  - conventional thermostat, 171
  - electrically controlled thermostat, 171
  - faulty, 174
  - how it works, 171, 174
  - rating, 174
- Thread chaser**, 98
- Threaded fasteners**, 97
- Threaded inserts**, 98
- Thread pitch gauge**, 96
- Thread repair**, 98
- Three-peak mountain snowflake tire symbol**, 201
- Throttle body injection (TBI)**, 158
- Throttle position sensor**, 160
- Throttle valve**, 159
  - electronic throttle controls, 159
  - mechanical throttle controls, 159
- Timeline**. *See Automotive timeline*
- Timing belt**, 188
  - failure, 189
  - replacement intervals, 188
  - servicing, 189
- Timing chain**, 188
- Timing gears**, 188
- Tire equipment**, 103
- Tire placard**, 208
- Tire pressure**, 204, 208
  - check steps, 208
  - nitrogen, 208
  - overinflation, 207
  - underinflation, 207
  - uneven, 209
- Tire pressure monitoring system (TPMS)**, 15, 35, 208
  - resetting the TPMS, 211
  - tool, 89
  - TPMS sensor, 208
- Tires**, 200-209
  - abnormal wear, 207
  - acoustic technology, 203
  - all-season tires, 201
  - all-weather tires, 201
  - changing a flat, 298
  - construction, 201
  - date code, 209
  - directional, 202, 210
  - Euro-metric, 200
  - EV-specific, 200, 205, 206, 211, 203
  - hydroplane, 207
  - ice grip, 201
  - leak finding, 290
  - liquid sprays, 299
  - load capacity, 204
  - load category, 205
  - load index, 204
  - load range, 204
  - low rolling resistance (LRR), 203
  - lug nuts, 210, 275
  - mud and snow (M+S), 201
  - non-pneumatic tires (NPT), 203
  - parts, 201
  - placard, 201, 208
  - ply rating, 204
  - P-metric, 200
  - pressure, 167
    - checking, 208
    - inflator kit, 206
  - repair, 209
  - replacing, 200-202
  - road hazard warranty, 200, 209
  - rotation pattern, 210
  - run flat, 203, 206
  - self-sealing tire, 203, 206
  - self-supporting run-flat tire, 203
  - sidewall information, 200
  - sizes, 201
  - snow tires, 201, 299
  - speed ratings, 205
  - summer tires, 201
  - support ring run-flat tire, 203
  - temporary spare, 206, 299
  - three-peak mountain snowflake (3PMSF), 201
  - traction devices, 299
  - tread, 201-202, 207, 290

- UTQG (uniform tire quality grading), 202
  - valve stem, 290
  - warranty, 67, 200, 209
  - wear indicator bars, 207
  - winter tires, 201
  - Tire tools**, 89
    - 4-way tire tool, 89
    - air pressure gauge, 89
    - tire iron, 89
    - tire pressure monitoring system (TPMS), 89
    - tread depth gauge, 89
  - Toe**, 207
  - Tongue weight (TW)**, 32, 278
  - Tonneau covers**, 272
  - Tools**
    - hammer, 87
    - pliers, 86
    - pry bars, 87
    - ratchet, 85
    - screwdrivers, 87
    - sockets, 86
    - wrenches, 85
  - Torque**, 17
    - at zero RPM, 148
    - crankshaft, 17
    - fastener specifications, 98
    - pattern, 98
    - torque-to-yield, 98
  - Torque versus speed characteristics**, 148
  - Torque wrenches and drivers**, 90, 98
  - Torsion bar spring**, 196
  - Touchless car wash**, 107
  - Tow bars**, 279
  - Towing**
    - capacity, 29, 31
    - gross axle weight rating (GAWR), 32
    - gross combination weight (GCW), 32
    - gross combination weight rating (GCWR), 32
    - gross trailer weight rating (GTWR), 31
    - hitch classes, 33
    - insurance, 55
    - loading a trailer, 33
    - tongue weight (TW), 31
    - trailer brakes/wiring, 33
    - with a car, 32
  - Towing mirrors**, 279
  - Tow ropes**, 279
  - Toyota Prius**, 15, 253, 255
  - Traction battery**. *See also Battery*
    - battery management system (BMS), 177, 309
    - capacity in kWh, 308, 334
    - charging calculation, 317, 336
    - cooling, 168-169
    - cost, 325
    - DC to DC converter, 310
    - electrification, 341
    - excess heat, 177
    - form factor, 322, 325
    - health, 338
    - high-voltage, 258
    - how EVs work, 306
    - kWh, 313
    - no-cut zones, 331
    - onboard charger (OBC), 309
    - overheating, 170
    - power electronics controller, 310
    - temperature impact, 177
  - Traction control system (TCS)**, 35, 218
  - Traction motor**. *See Electric motor (e-motor)*
  - Trading in vehicle**, 51
  - Traffic light**, 13
  - Traffic monitoring**, 347
  - Trailer assistance**, 41
  - Trailer brake controller**, 277
    - brakes and wiring, 33
  - Trailer hitch balls**, 278
  - Trailer hitches**, 33, 278
  - Trailer information**, 29
    - label, 30, 32
    - payload, 30, 335
  - Transaxle**, 20, 226, 230
  - Transesterification**, 246
  - Transfer case**, 229
  - Transmission**, 20, 119
    - automatic, 119, 225
      - electronic, 225
      - fluid, 119
      - fluid coupling, 225
      - fluid level, 226
      - slips, 227
      - torque converter, 225
      - transmission oil cooler, 226
    - continuously variable transmission (CVT), 226
    - fluid flushed, 227
    - manual, 119, 122
      - fluid, 119
      - fluid check, 224
  - Transmission control module (TCM)**, 141
  - Transportation future**, 11, 14
  - Transverse engine**, 223
  - Tread depth gauge**, 89
  - Tread designs**, 202
  - Tread terrain types**, 202
  - Trilateration**, 268
  - Trim detailing**, 110
  - Trim level**, 23
  - Truck bed accessories**, 272-273
  - Turbocharger**, 161
  - Turn signal**, 15
- ## U
- U-joints**, 228
    - clunk sound, 227
  - Ultra-low sulfur diesel (ULSD)**, 21, 165
  - Ultrasonic sensors**, 37, 261
    - strengths, 361
  - Undercoating**, 274
  - Understeer**, 218
  - Unibody**, 24, 28, 81, 194
  - Unified National Coarse (UNC) thread**, 96
  - Unified National Fine (UNF) thread**, 96
  - Uniform tire quality grading (UTQG)**, 202
  - United Auto Workers**, 14
  - United States Fire Administration (USFA)**, 79, 331
  - Unusual smells**, 285
  - Unusual sounds**, 285
  - Upholstery cleaning**, 112
  - Upper radiator hose**, 172
  - Usage-based insurance (UBI)**
    - driving-based, 53
    - mileage-based, 53
  - USB ports (DC)**, 145
  - U.S. customary units**, 90
    - threads, 96
  - Used car lot**, 48
  - User experience (UX)**, 26
- ## V
- V8**, 22
  - Vacuuming**, 112
  - V-belts**
    - buying, 143
    - worn, 143
  - Vehicle architecture**, 28
    - distributed legacy, 341, 350
    - intelligent power distribution, 354
    - legacy, 28, 141, 311
    - restructuring, 351
    - tightly coupled, 350
  - Vehicle emission control information (VECI)**, 22-23
    - EPA and CARB identification, 237
    - spark plug gap, 91, 187
  - Vehicle graphics**, 275
  - Vehicle history reports**, 50
  - Vehicle identification**
    - make, 23
    - manufacturer, 23
    - model, 23
    - model year (MY), 23
    - type, 23
    - VIN (vehicle identification number), 22-23, 64



**Vehicle lifting points**, 81  
**Vehicle-to-cloud (V2C)**, 367  
**Vehicle-to-everything (V2X)**, 366  
**Vehicle-to-grid (V2G)**, 313  
**Vehicle-to-home (V2H)**, 313  
**Vehicle-to-infrastructure (V2I)**, 367  
**Vehicle-to-pedestrian (V2P)**, 367  
**Vehicle-to-vehicle (V2V)**, 367  
**Vehicle walk-around inspection form**. *See Workbook Appendix*  
**Viscosity**, 118, 146, 153-154  
**Visible light**, 348  
**Volkswagen Beetle**, 15  
**Voltage drop testing**, 132  
**Voltage regulator**, 141  
**Voltage safety glove classes**, 328  
**Voltage (V)**, 127.  
*See also Battery; See also High-voltage systems*  
 smart electrical center, 354

## W

**Warranty**, 66-67  
 battery, 67  
 booklet, 60  
 bumper-to-bumper, 42, 57, 66, 280  
 certified pre-owned car (CPO), 66  
 chain, 66  
 corrosion perforation, 42, 274  
 emission, 42, 66, 141  
 emission warranty, 243  
 extended, 66  
 factory, 42, 66  
 hybrid related components, 42  
 independent, 67  
 lemon law, 47  
 manufacturer, 57  
 powertrain, 66  
 powertrain warranty, 42, 49, 57, 280  
 safety restraint, 42  
 tire, 67, 200, 209  
**Wartime production**, 14  
**Washers**, 97, 99  
**Washing**, 107-110  
 before waxing, 109  
 formulated car wash soap, 107  
 removing bugs and tar, 107  
 wheel care, 108  
**Waste heat**, 310  
**Water pump**, 173  
 broken belt, 295  
 electric, 172  
 faulty, 286  
 mechanical, 172-173  
**Watt's law**, 128, 312  
**Watts (W)**, 17, 128, 312-313, 354  
**Wavelength**, 343  
 visible light, 348

**Wave measurement**, 343  
**Wax**  
 cleaner, 110  
 natural - carnauba, 110  
 synthetic, 110  
**Waxing**, 110  
**Waymo**, 14  
**Weather Eye conditioned air**, 15  
**Weatherstripping conditioning**, 111  
 dielectric silicone grease, 111  
**Well-to-wheel emissions**, 317  
**Wheel alignment**  
 abnormal tire wear, 207  
 camber, 207  
 caster, 207  
 toe, 207  
**Wheel chocks**, 88  
**Wheel cylinder**, 215, 217-218  
**Wheels**, 275  
 balancing, 211  
 lock lug nuts, 275  
 lug nut torque specification, 210  
**Wheel speed sensors**, 217  
**White tailpipe smoke**, 179, 285  
**Wi-Fi hotspot**, 266  
**Willys-Overland 4x4**, 14  
**Winch**, 279  
**Wind deflector**, 274  
**Window**  
 glass cleaner, 112  
 laminated, 15, 293  
 tempered, 293  
 tint, 265  
 treatment for rain, 108  
**Windows media audio (WMA)**, 267  
**Window sticker**, 44-45, 332-333  
 additional Information, 44  
 dealer addendum sticker, 44  
 driving range estimates, 45  
 electric vehicle, 332-333  
 fuel economy and environment  
 label, 45, 333  
 fuel economy estimates, 245, 333  
**Windshield**, 289  
 chip, 290  
 sun shade, 265  
 washing, 108  
**Windshield washer fluid**, 117  
 adding, 117  
 checking, 117  
 reservoir, 117  
 types, 117  
**Winter safety kit**, 293  
**Wipers**, 288-289  
 buying, 288  
 frozen, 289  
 inspecting, 117, 288  
 replacing, 289  
 types of arms, 289  
 worn or damaged, 288

**Wireless network**  
 5G, 341, 343, 346, 347, 367  
 6G, 343, 346, 347  
 terahertz, 347  
**Wire strippers**, 92  
**Wiring diagram symbols**, 128  
**Work formula**, 16  
**Work gloves**, 75  
**Work light**, 101  
**Work order/repair invoice**, 64-65  
*See also Workbook Appendix*  
**Wrenches**, 85  
 adjustable wrench, 85  
 box-end, 85  
 combination wrench, 85  
 oil filter, 94  
 torque, 90

## X

**X-by-wire**, 355

## Y

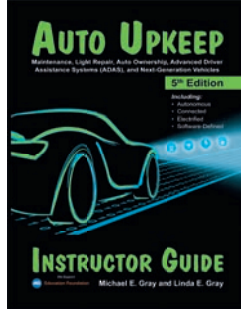
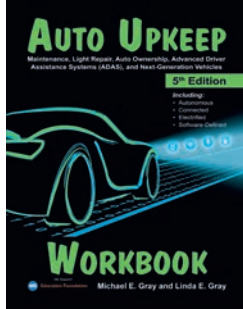
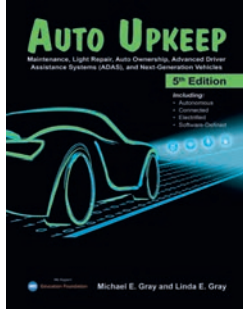
**Yield point**, 96

## Z

**Zerks**, 197  
**Zero emission vehicle (ZEV)**, 301, 304  
**Zone architecture**, 353  
**Zone controller**, 351, 353  
**Z Speed Tire Rating**, 205

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