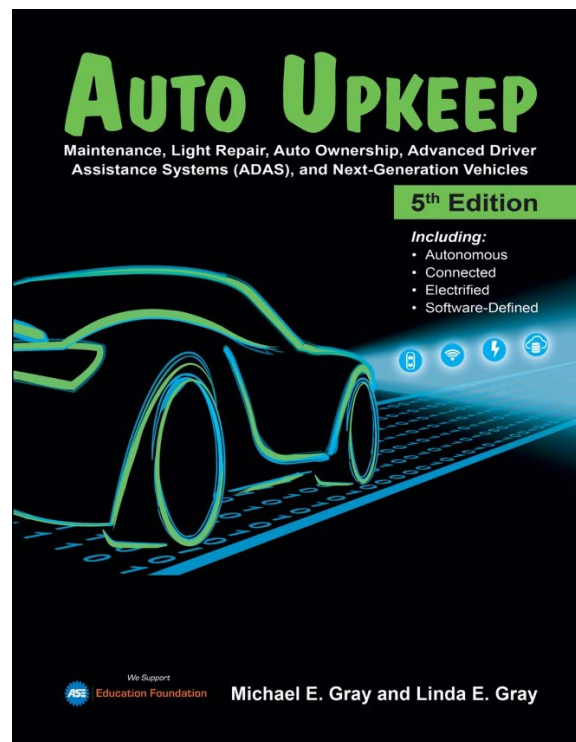


Auto Upkeep

5th 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)**

5th Edition

Michael E. Gray and Linda E. Gray

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

Copyright © 2025 by Rolling Hills Publishing, LLC. Previous Editions Copyright: © 2018, 2013, 2007, 2003. All rights reserved. No part of this book may be reproduced, stored in a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise) without prior written permission from the publisher, except by a reviewer, who may quote brief passages in a review or as permitted by the United States Copyright Act.

Printed in the United States of America

30 29 28 27 26 25

10 9 8 7 6 5 4 3 2

Publisher's Cataloging-in-Publication Data

Names: Gray, Michael E., 1973- . | Gray, Linda E., 1972- .

Title: Auto upkeep : maintenance, light repair, auto ownership, advanced driver assistance systems (ADAS), and next-generation vehicles (including: autonomous, connected, electrified, and software-defined) / Michael E. Gray and Linda E. Gray.

Description: 5th ed. | Ozark, MO : Rolling Hills Publishing, 2025. | Includes over 1,100 full color illustrations including photos, line art, and tables. | Audience: Ages 15 to adult.

Identifiers: LCCN 2024934799 | ISBN 9781627020503 (hardcover) | ISBN 9781627020534 (ebook)

Subjects: LCSH: Automobiles – Maintenance and repair – Popular works. | Automobile driving. | BISAC: YOUNG ADULT NONFICTION / Transportation / Cars & Trucks. | TRANSPORTATION / Automotive / Repair & Maintenance. | TECHNOLOGY & ENGINEERING / Automotive.

Classification: LCC TL152.G739 2025 | DDC 629.28/72 G--dc23

LC record available at <https://lccn.loc.gov/2024934799>

For more information contact: Rolling Hills Publishing, LLC

Phone: 1-800-918-READ (1-800-918-7323)

Fax:

1-888-FAX-2RHP (1-888-329-2747)

Email: info@autoupkeep.com

Website:

www.AutoUpkeep.com

NOTICE TO THE READER

The publisher, authors, www.rollinghillspublishing.com, www.autoupkeep.com, reviewers, and those associated with the text do not warrant or guarantee any procedure, process, products, or websites presented in the text. Extensive effort has been made to ensure accuracy in the text and illustrations throughout the book. However, due to the vast number of automotive manufacturers and related products, the reader should follow all procedures provided with the vehicle or by the product manufacturer. The book is sold with the understanding that the publisher, authors, www.rollinghillspublishing.com, www.autoupkeep.com, reviewers, and those associated with the text are not engaged in rendering any specific mechanical, safety, diagnostic, legal, accounting, or any other professional advice. The reader assumes all risks while following activity procedures, is warned to follow all safety guidelines, and should avoid all potentially hazardous situations. The publisher, authors, www.rollinghillspublishing.com, www.autoupkeep.com, reviewers, and associates shall not be liable for damages to vehicles, their components, or injuries to individuals using or relying on this material.

PRODUCT DISCLAIMER

The publisher, authors, www.rollinghillspublishing.com, www.autoupkeep.com, reviewers, and associates do not endorse any company, product, service, or website mentioned or pictured in the book. The company names, products, services, and websites were noted and pictured because they are readily available, easily recognizable, and may help the reader understand the content. It is acknowledged that other company names, products, services, and websites could work as substitutes for those given throughout the text.

www.AutoUpkeep.com

Preface

INTRODUCTION

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

UPDATES TO THE 5TH EDITION

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

ASE EDUCATION FOUNDATION

CORRELATIONS

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



We Support

Education Foundation

Reviewers

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

TECHNICAL REVIEWERS

Colin Dyvig

Automotive Technology Instructor
High Desert State Prison
Indian Springs, NV

Carl S. Fedele, Jr.

Lead Automotive Instructor
Proviso West High School
Hillside, IL

Robert Green

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

Jed Alan Metzler

Automotive Instructor
South Branch Career & Technical Center
Petersburg, WV

Bryan D. Monaco

Automotive Instructor
Trenton High School
Trenton, MI

Larry Muhlstadt

Automotive Instructor
Glenciff High School
Nashville, TN

Rudolph Petrella

Automotive Instructor
West Orange High School
West Orange, NJ

Sean Reisdorf

Automotive Instructor
North Farmington High School
Farmington Hills, MI

Jack Stow, Jr.

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

STUDENT REVIEWERS

Aiden Gray

Ozark, MO

Landen Gray

Ozark, MO

Aaron Riley

Springfield, MO

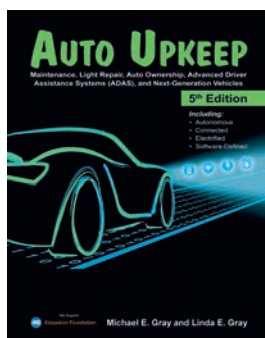
Michael Riley

Springfield, MO

Curriculum Resources

TEXTBOOK

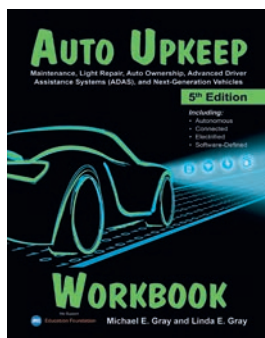
Auto Upkeep is available in hardcover binding.
ISBN: 978-1-62702-050-3 (hardcover)



WORKBOOK

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

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



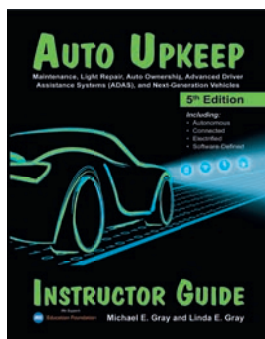
eBOOK

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

INSTRUCTOR GUIDE

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

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



INSTRUCTOR RESOURCES

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

- [Course Syllabus Outline](#)
- [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.



AUTO UPKEEP ACADEMY

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



VIDEOS

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



Features of the Text

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

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

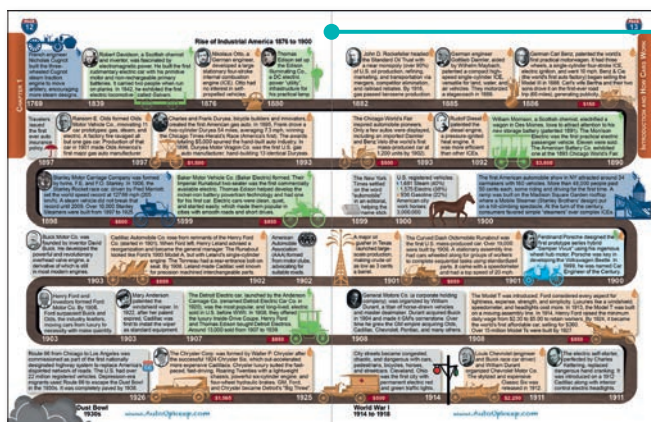
Objectives - What you should know and be able to do upon completion of the chapter and activities.



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

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

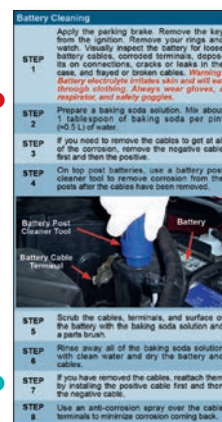
Illustrations - To clarify concepts and develop further understanding.



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

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

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



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

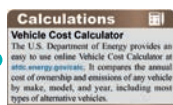
Apps - Helpful apps to extend learning can be accessed at www.AutoUpkeep.com/apps.

Calculations - Integrating practical math problems.

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

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

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



Servicing - General guides to maintenance schedules.

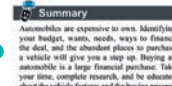
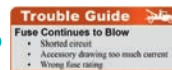
Tech Tip - Insightful, useful, and practical information, supplementing the content.

Trouble Guide - Quick reference for troubleshooting.

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

Weblinks - Expand learning through online resources.

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



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

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

Authors

ABOUT MIKE

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

ABOUT LINDA

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

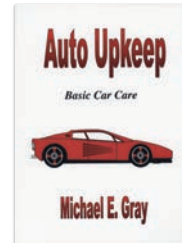
Acknowledgments

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

Auto Upkeep History

OVER 25 YEARS OF AUTO UPKEEP

1999



Manuscript
13 Chapters
154 Pages (Including Activities)

2003



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

2008



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

2013



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

2018



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

2020



Academy
Online Learning
Interactive Lessons
Gamified Design
Connected Community
Detailed Reporting

2025



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

Table of Contents

CHAPTER 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



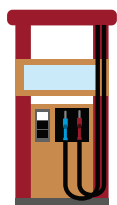
Introduction	116
Objectives	116
Opening the Hood	116
Fluid Specifications	116
Types of Fluids.....	116
Storage and Disposal.....	125
Summary.....	125

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)	136
Battery	138
Starting System	140
Charging System	141
Computers	142
Drive Belt	144
Lights	145
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

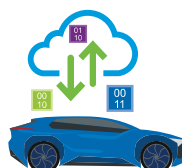
Electric Vehicles



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?

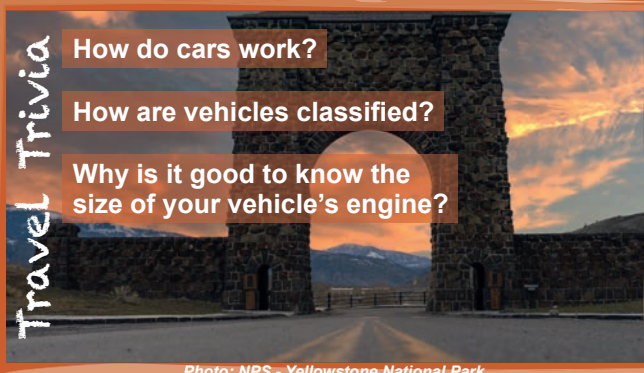


Photo: NPS - Yellowstone National Park



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 20th century, the automobile would change society forever. Today, there are millions of vehicles on the roadways.



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



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.

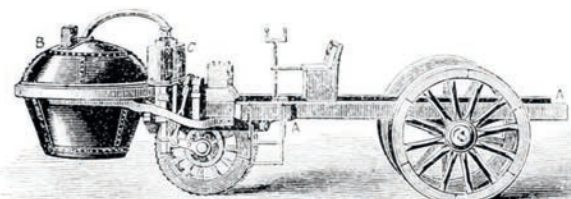


Figure 1.2 1769-1770 Cugnot Steam Engine
Source: Popular Science Monthly Volume 12 - Public Domain

Weblinks

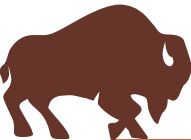


Automotive
Museums



www.AutoUpkeep.com/resources

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.

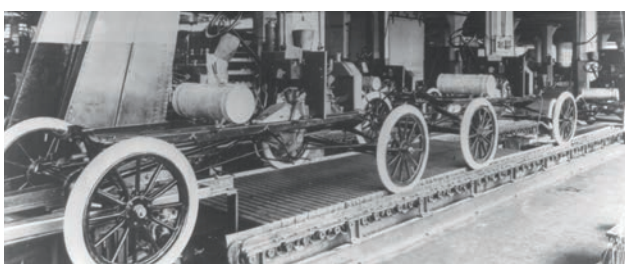


Figure 1.3 Ford Model T Assembly Line
Photo: Library of Congress

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 and search *CPI Inflation Calculator* to find the inflation rate for any year after 1913.

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

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



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

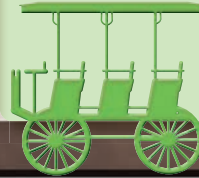
1893



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

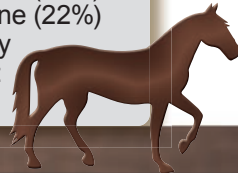
1890

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.

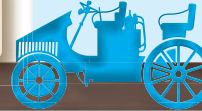


\$650

1901



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.



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.



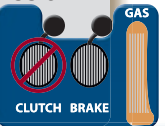
World War II 1941 to 1945

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

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).



1942

1940

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

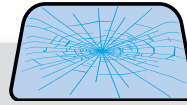
Limited range and high prices slowed sales of electric cars. The Detroit Electric Model 99, one of the last produced, had a more-modern Dodge sourced body, but antiquated tiller steering and parlor style seating.

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.



1956

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

1956

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.

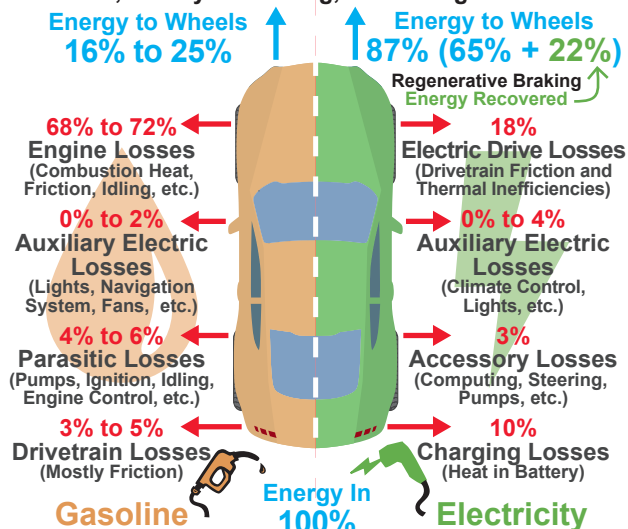


Figure 1.5 Gasoline vs. Electrical Energy Usage
Source: U.S. Department of Energy EERE - www.fueleconomy.gov

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.

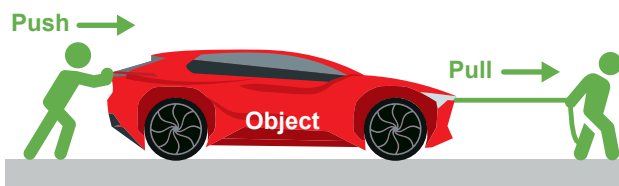


Figure 1.6

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*).

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

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

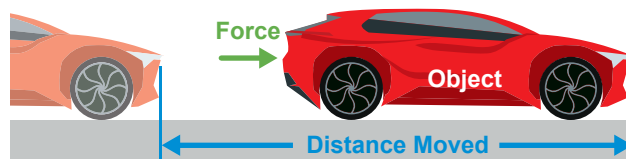


Figure 1.7

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
Work	= 250 ft-lb

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

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

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

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.

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

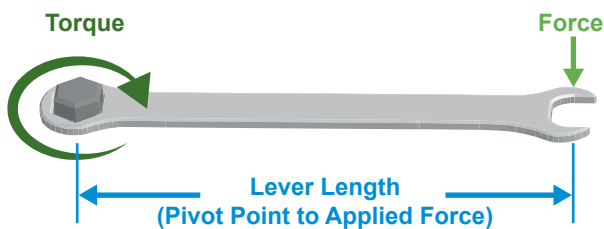


Figure 1.8 $\text{Torque} = \text{Force} \times \text{Lever Length}$

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

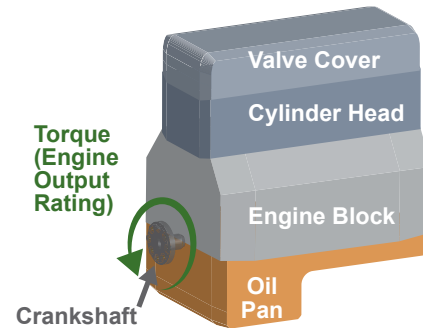
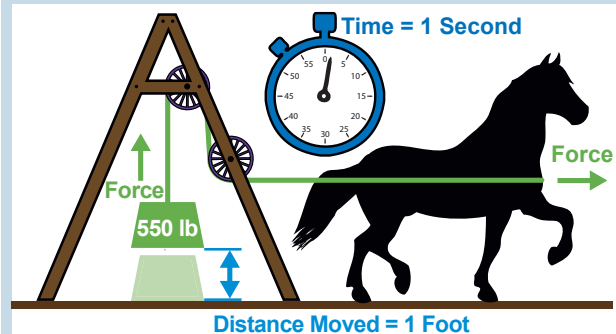


Figure 1.9 **Crankshaft Torque**

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*).

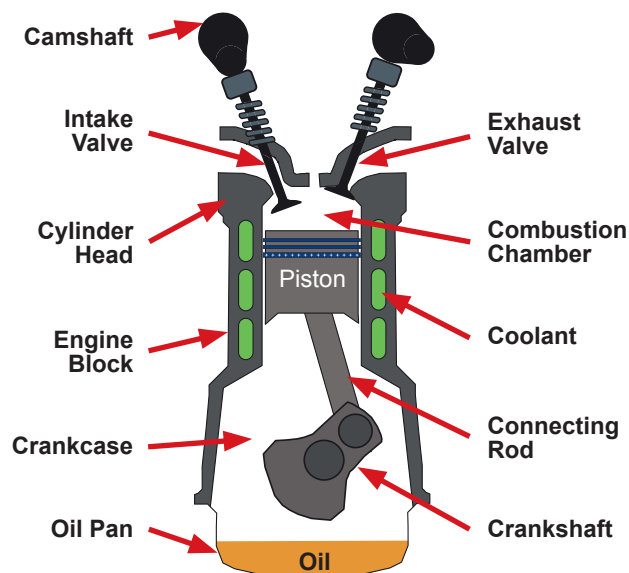


Figure 1.12 Dual Overhead Camshaft (DOHC) Engine

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.*

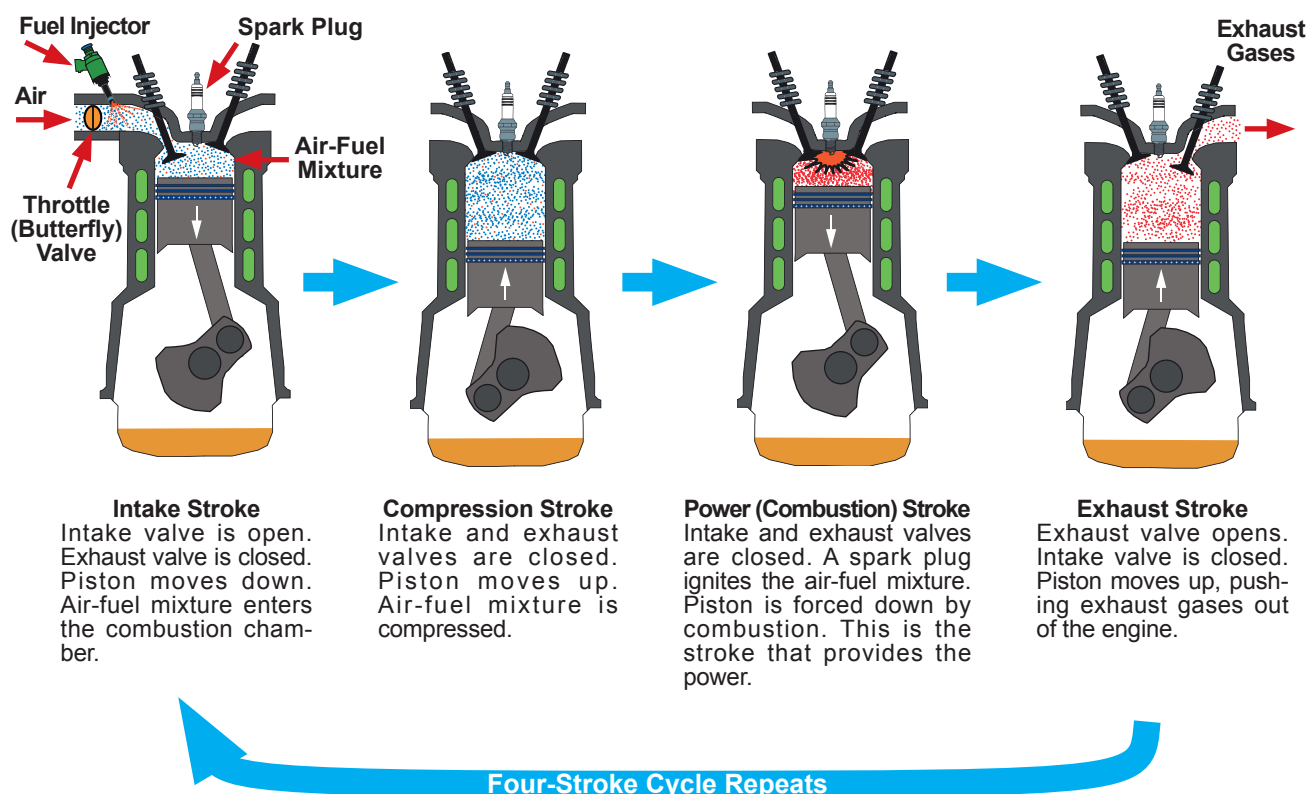
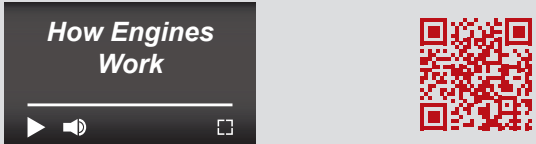


Figure 1.13

*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



www.Video.AutoUpkeep.com
Click on Chapter 1

Tech Tip



ICE Requirements

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

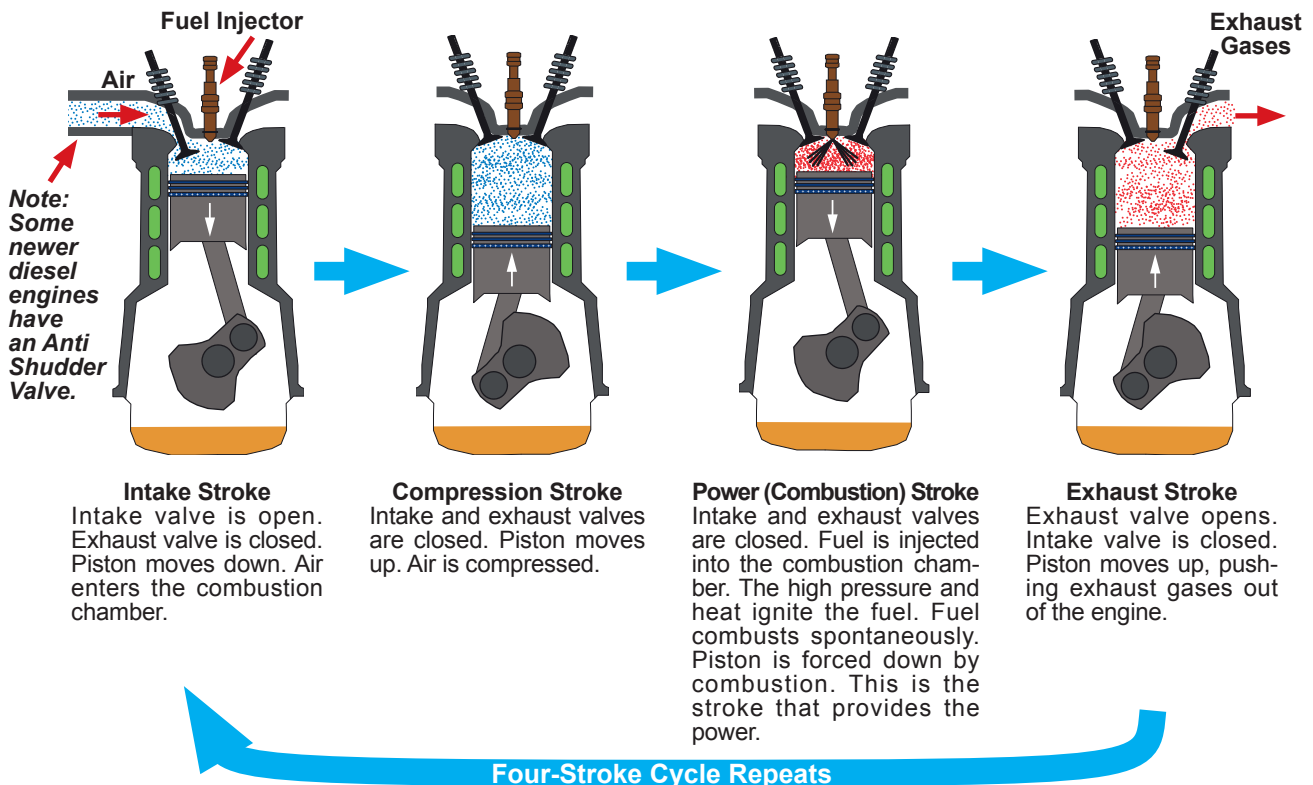
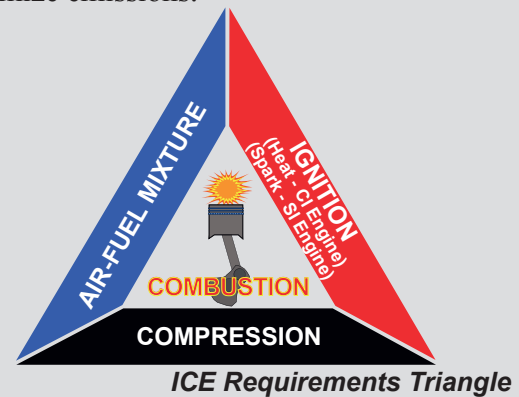


Figure 1.14

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

Power Transfer

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

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

Figure 1.15 How Power is Transferred



Fuels and Designs

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

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

Gasoline-Powered Vehicles

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

Gasoline. One of the major disadvantages of gasoline is that once the fuel is burned, it is gone forever. In addition, gasoline engines emit hydrocarbons (HC), nitrogen oxides (NO_x), carbon monoxide (CO), and carbon dioxide (CO₂). See [Chapter 17](#) to learn more about gasoline emissions.

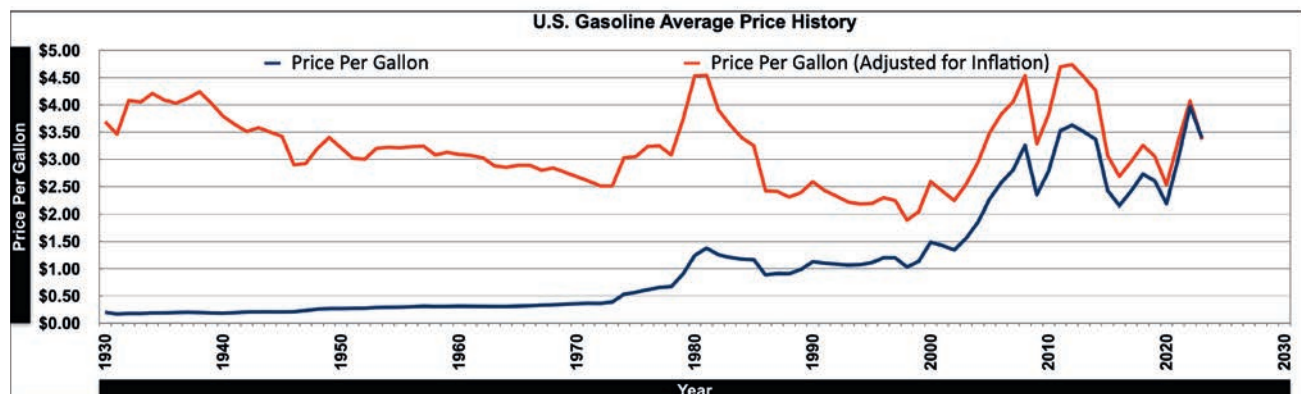


Figure 1.16

U.S. Gasoline Price History

Diesel-Powered Vehicles

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

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



Figure 1.17 Diesel Fuel Dispenser

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



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

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

Emerging Technologies

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

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

Figure 1.19 2024 Electric Vehicles MPGe

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



Figure 1.20 Tesla Superchargers
Photo: Tesla

Weblinks

EV Charging
Stations



www.AutoUpkeep.com/resources

Click on Chapter 1



Engine Identification

A vehicle's engine is classified by its:

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

Configuration

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

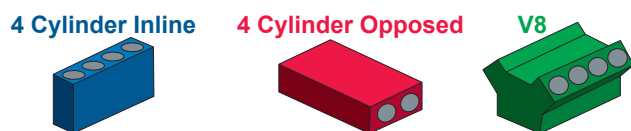


Figure 1.21 Common Engine Configurations

Size/Displacement

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

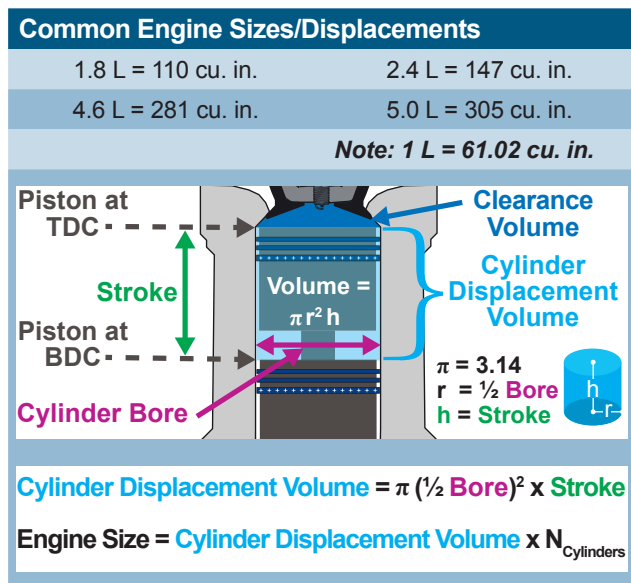


Figure 1.22 Common Engine Sizes/Displacements

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.)

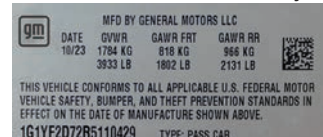


Figure 1.23

VIN Locations

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

How to Decode a 17-Digit Vehicle Identification Number

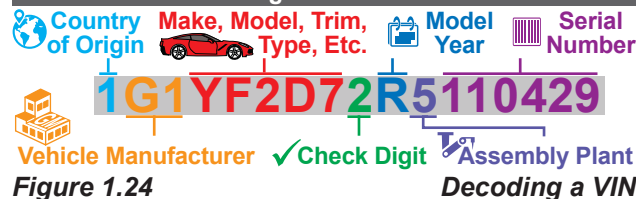


Figure 1.24

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

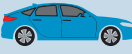
Trim levels (**Figure 1.27**) identify versions (different equipment and features) of the same vehicle model. Entry-level models, often called the base model, are the most affordable. A badge on the vehicle’s back or side displays the trim level or a free online VIN decoder will identify it.

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

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

Figure 1.28 Vehicle Types with Examples



Parts and Systems

The automobile is made up of:

- Parts
- Systems

Parts

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

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



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

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

Tech Tip



Identifying Vehicle Parts

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

Systems

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

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

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

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

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

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

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

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

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

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

Weblinks



Automotive
Manufacturers



www.AutoUpkeep.com/resources

Click on Chapter 1



Careers

Many careers exist in the automotive industry:

- Manufacturing Careers
- Service and Repair Careers
- Support Careers

Manufacturing Careers

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



Figure 1.30 *Automotive Manufacturing*
Photo: Tesla

Service and Repair Careers

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



Figure 1.31 *Repair Facility*
Photo: Hyundai Motor Group

Support Careers

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



Workplace Skills

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



Summary

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

Activities



Introduction and How Cars Work

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

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

Career Paths



Automotive Teacher

Education: Bachelor's Degree and/or ASE Cert.

Median Income: \$65,220

Abilities: Good communication with students in a technical hands-on environment.

Find your career at www.bls.gov/ooh.

Appendix A - Workbook Activities

Chapter 1

Workplace Skills Activity

Identify important workplace skills.

Car Identification and Preparing for Vehicle Service Activity

Identify an automobile by model year, make, model, and trim level. Prepare a vehicle for service.

Owner's Manual Activity

Locate and use an online owner's manual.

Chapter 2

Towing and Hauling Activity

Identify towing and hauling capabilities.

Advanced Driver Assistance System (ADAS) Activity

Research vehicles with ADAS to identify differences, limitations, and capabilities.

Buying a New Automobile Activity

Differentiate between MSRP, dealer invoice, and dealer cost.

Buying a Used Automobile Activity

Research prices, reliability ratings, and safety ratings on used automobiles.

Chapter 3

Automotive Expenses Activity

Calculate automotive expenses.

Chapter 4

Repair Facilities Activity

Choose a quality repair facility. Interpret a work order.

Chapter 5

Automotive Safety Activity

Identify the location of emergency and safety equipment.

Safety Data Sheet (SDS) Activity

Locate and interpret a safety data sheet.

Personal Protection Equipment (PPE) and Fire Safety Activity

Identify the importance of using PPE.

Chapter 6

Tools and Equipment Activity

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

Fasteners Activity

Identify fasteners that are used on automobiles.

Service Manual Activity

Navigate an online service manual.

Chapter 7

Interior Cleaning Activity

Clean the inside of a vehicle.

Exterior Cleaning Activity

Clean the outside of a vehicle.

Waxing Activity

Wax the finish on a vehicle

Chapter 8

Fluid Level Check Activity

Check the fluid level in various vehicle components.

Chapter 9

Ohm's Law Activity

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

Circuit Construction Simulator Activity

Use a circuit construction simulator to build and analyze circuits.

Simple Circuits Activity

Build and test a simple circuit.

Voltage Drop Activity

Identify voltage drop and how to perform various voltage drop tests.

Wiring Diagram Activity

Locate and interpret a wiring diagram.

Battery Activity

Clean and test a 12-volt SLI battery.

Charging Activity

Test an alternator and replace a belt.

Starting Activity

Test a starter.

Chapter 10

Oil and Filter Change Activity

Change the oil and filter on an ICE vehicle.

Chapter 11

Fuel System Part Identification Activity

Use an online auto parts catalog to identify fuel system parts.

Fuel System Maintenance Activity

Identify the components of the fuel system. Change an air filter, PCV valve, and fuel filter.

Chapter 12

Air Conditioning Activity

Inspect and identify the components within the air conditioning system.

Cabin Air Filter Activity

Replace a cabin air filter.

Cooling System Activity

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

Chapter 13

Ignition System Activity

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

Chapter 14

Suspension and Steering Activity

Inspect and perform basic service procedures on suspension and steering components.

Tire Inspection and Rotation Activity

Inspect and rotate tires.

Choosing the Right Tires Activity

Identify tires based on classification, tread, EV-specific, and new technologies.

Chapter 15

Brake Inspection Activity

Identify brake components and inspect disc brakes.

Chapter 16

Drivetrain Activity

Identify and inspect drivetrain components.

Chapter 17

Exhaust and Emission Activity

Identify and inspect exhaust and emission components.

Chapter 18

Payback Period Activity

Calculate payback period.

Future Vehicle Activity

Predict the role of the automobile in 2050.

Chapter 19

Automotive Accessories Activity

Estimate the cost of accessories for a vehicle.

Chapter 20

Changing a Flat Tire Activity

Change a flat tire.

Jump-Starting Activity

Jump-start a vehicle.

Lighting Activity

Replace various lights on a vehicle.

Replacing Wipers Activity

Replace wipers on a vehicle.

On-Board Diagnostics Activity

Retrieve diagnostic trouble codes (DTCs) from an OBD II system using a basic scan tool.

Chapter 21

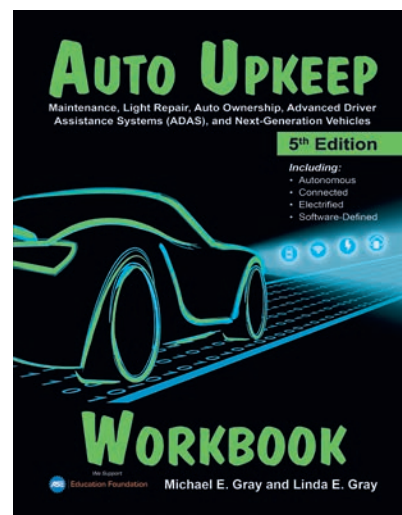
Electric Vehicles Activity

Identify and compare current electric vehicles for sale.

Chapter 22

ADAS and Vehicle Automation Level Identification Activity

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



Appendix B - Acronyms/Abbreviations

Symbols

°	Degree
'	Foot
"	Inch
2WD	Two-Wheel Drive
3PMSF	Three-Peak Mountain Snowflake
4WD	Four-Wheel Drive
4x4	Four-Wheel Drive
4G	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 ₂	Carbon Dioxide
COP	Coil-On-Plug
CPS	Cyber-Physical System
CPU	Central Processing Unit
CR	Compression Ratio
CT	Continuous Testing
CTB	Cell-to-Body
CTC	Cell-to-Chassis
CTP	Cell-to-Pack
CV	Constant Velocity
CVT	Continuously Variable Transmission
CW	Clockwise

D

DAS	Driver Assistance Systems
dB	Decibels
DC	Direct Current
DDT	Dynamic Driving Task
DEF	Diesel Exhaust Fluid
DI	Distributor Ignition
DL	Deep Learning
DLC	Data Link Connector
DMM	Digital Multimeter
DMS	Driver Monitoring System
DOC	Diesel Oxidation Catalyst

DOE	Department of Energy
DOHC	Dual Overhead Cam
DOT	Department of Transportation
DPF	Diesel Particulate Filter
DRL	Daytime Running Lights
DSRC	Dedicated Short-Range Communications
DT	Digital Twin
DTC	Diagnostic Trouble Code
DTC	Direct-to-Consumer
DTV	Disc Thickness Variation

E

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

F

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

G

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

H

H	Hydrogen
H ₂ ICE	Hydrogen Internal Combustion Engine
H ₂ 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 ₂	Oxygen
OAT	Organic Acid Technology
OBD	On-Board Diagnostics
OBC	Onboard Charger
ODD	Operational Design Domain
OEDR	Object and Event Detection and Response
OEM	Original Equipment Manufacturer
OPEC	Organization of Petroleum Exporting Countries
OS	Operating System
OSHA	Occupational Safety and Health Administration
OSS	Open Source Software
OTA	Over-the-Air

P

P	Passenger
Pa	Pascal
PCM	Powertrain Control Module
PCU	Powertrain Control Unit
PCV	Positive Crankcase Ventilation
PDC	Power Data Center
PDR	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



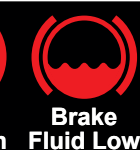
Assistance



Body



Brake System



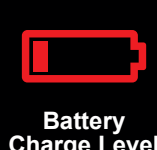
Charging System



Drive Modes



Electric Vehicle

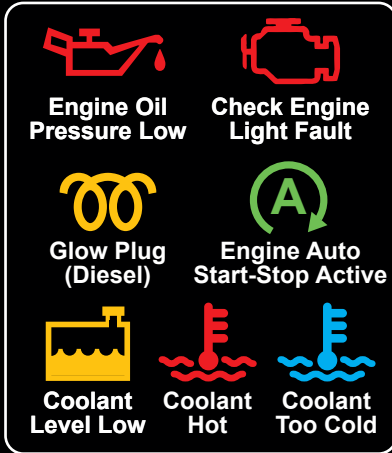


Electronic Throttle



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

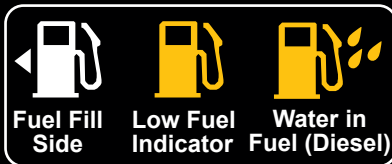
Engine



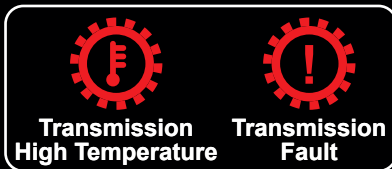
Filters



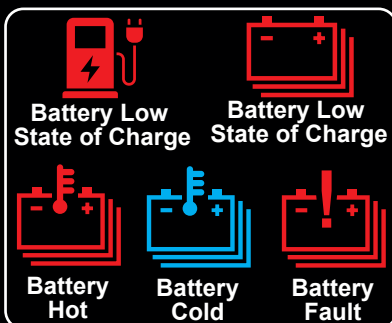
Fuel



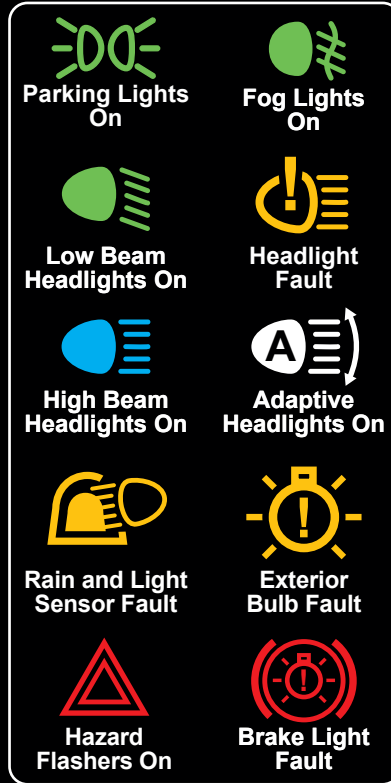
Gearbox



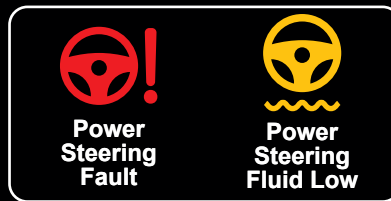
High-Voltage Battery



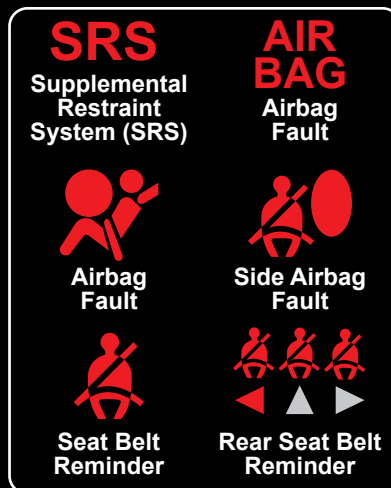
Lights



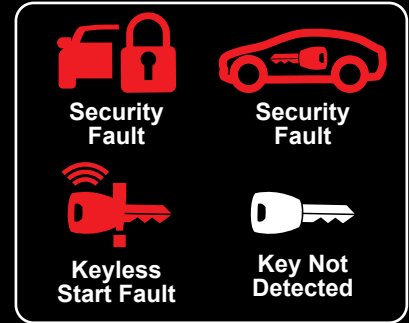
Power Steering



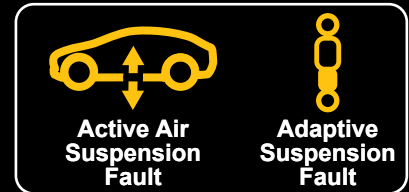
Restraint System



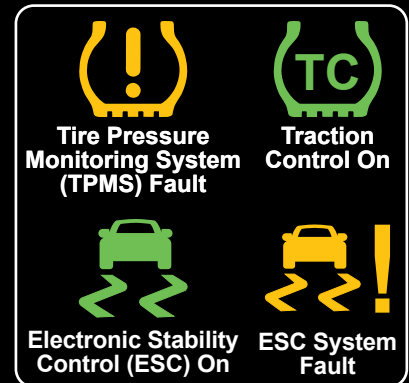
Security



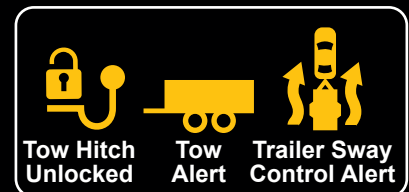
Suspension



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 (Ω), is used to identify the degree of an opposing electron flow (electricity).

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

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

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

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

S

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

Saturation – beyond its holding point.

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

Series – an electrical circuit with a single path.

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

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

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

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

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

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

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

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

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

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

Symmetrical – the same on both sides.

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

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

T

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

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

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

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

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

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

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

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

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

Tow capacity – the trailer pulling capacity of a vehicle.

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

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

U

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

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

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

V

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

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

Voltage – the electrical potential measured in volts.

W

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

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

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

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

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

X

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

Z

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

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

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

Index

Symbols

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 (CO₂), 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_x)**, 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 (CO₂), 20. *See also Carbon dioxide (CO₂)*
 - carbon monoxide (CO), 20. *See also Carbon monoxide (CO)*
 - hydrocarbons (HC), 20. *See also Hydrocarbons (HC)*
 - nitrogen oxides (NO_x), 20. *See also Nitrogen oxides (NO_x)*
 - 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 (SO₂)**, 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

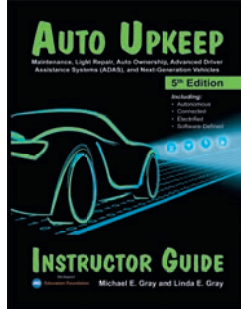
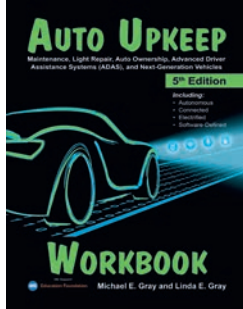
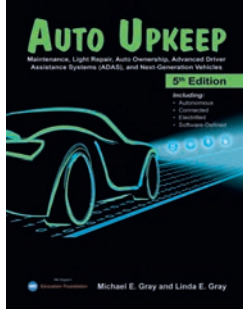
Yield point, 96

Z

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

AUTO UPKEEP

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



EDITION
5TH

Including:

- Autonomous
- Connected
- Electrified
- Software-Defined



ORDER INFO
(800) 918-READ
www.AutoUpkeep.com

Michael E. Gray and Linda E. Gray

PRINT BOOKS*

* Similar Content - Delivered in Three Ways

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



Easy-to-Read



Durable Binding



Life Skill Building



Over 1,100 Illustrations



Related Videos



Workbook Activities



Related Apps



Related Weblinks



Glossary/Index

eBooks*

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



Read Anywhere



Skim, Jump, and Search



Bookmark Navigation



Related Videos



Printable Activities



Text-to-Speech



Digital Notes



Highlight Text



Build Study Guides

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

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

ONLINE ACADEMY*

Academy.AutoUpkeep.com



Interactive Lessons



Gamified Design



Private Groups



Embedded Videos



Fillable PDF Activities



Human Voice Read Aloud



Graded Online Tests



Printable Certificates



Online Gradebook

Instructor Resources

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



Course Syllabus Outline



Competency Profile



Lesson Plans



Chapter Tests and Final



Answer Keys



LMS Common Cartridge File



ASE Correlation Matrix



Readability Worksheets



PowerPoint Slides



Learning Extensions

www.AutoUpkeep.com