Preface

What is engineering? *Engineering Fundamentals* provides a complete introduction to the field. It is written to help you learn about engineering and how it affects our everyday lives. You will learn how engineering is different from science and technology. You will also learn how science, math, and technology are an integral part of engineering design.

Engineering Fundamentals begins by giving you a clear picture of the basics of engineering. First, you will learn about what engineering is, the historical and future developments of engineering, and the various impacts of design solutions on the world. The next chapter discusses engineering as a profession. This includes such topics as the functions of engineers; required knowledge areas and skills; regulating bodies; and an overview of disciplines.

You will then read an extensive, five-chapter introduction to the engineering design process. Real-world examples are given to help you understand why each step of the process is necessary when designing new products, devices, or systems.

This section is followed by 10 chapters that focus on engineering disciplines. Each of these chapters describes the specific engineering career, its educational requirements, and examples of real-world engineering projects. *Engineering Fundamentals* also discusses the principles associated with each discipline. The basic science and math required to understand the engineering and technology principles are explained in these chapters.

Engineering Fundamentals is illustrated with photographs and drawings to help explain chapter concepts. Each chapter begins with one Think Like an Engineer essential question and a list of learning outcomes. Important terms related to engineering are shown in bold italics where they are defined. Several features throughout the chapter enhance chapter content while explaining related math, science, history, design, tools, or green concepts. At the end of each chapter, a variety of questions (Know and Understand, Apply and Analyze, and Critical Thinking) help check your understanding of chapter material. Communicating about Engineering activities helps you develop and improve your language skills. Chapter activities provide opportunities to apply what you have learned in each chapter.

Engineering Fundamentals will educate you about career opportunities in engineering and provide practical applications of math and science principles. *Engineering Fundamentals* will inspire you to consider engineering-related careers and to be more successful in your math and science courses.

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About the Authors

Ryan A. Brown is an Associate Dean and Professor in the College of Education at Illinois State University. Dr. Brown has taught courses for preservice teachers on topics such as instructional methods and assessment, and graduate courses focused on teacher education and curriculum theory. Previously, he taught a variety of courses at the secondary level, including design processes, transportation systems, and fundamentals of engineering. Dr. Brown coauthored *Exploring Design, Technology, and Engineering* with Dr. R. Thomas Wright and Michael Berkiehiser and *Energy, Power, and Transportation* with Dr. Len S. Litowitz. Dr. Brown's educational background includes a bachelor's degree and master's degree from Ball State University in technology education and a PhD in curriculum studies from Indiana University.

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Michael Berkeihiser is a Technology and Engineering teacher and Chair of the Technology and Engineering Department at Unionville High School in Kennett Square, Pennsylvania. He teaches courses in engineering, engineering design, architectural design, electronics, and robotics. Mr. Berkeihiser coauthored *Exploring Design, Technology, and Engineering* with Dr. Ryan A. Brown and Dr. R. Thomas Wright and *Manufacturing and Automation Technology* with Dr. R. Thomas Wright. His educational background includes a bachelor's degree from Millersville University and a master's degree from Ball State University.

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Reviewers

The author and publisher wish to thank the following industry and teaching professionals for their valuable input into the development of *Engineering Fundamentals*.

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New to This Edition

The following additions and updates were made to the fourth edition of *Engineering Fundamentals*:

- Added sections as well as reorganized some content at the chapter level to better suit instructional design best practices, scaffold key concepts to support student learning, and group similar topics to reduce repetition.
- More than 100 new images to capture current materials, methods, and machines.
- Assessment questions have been revised to further support the student with real-world scenarios they would need to apply the skills they as learning. Assessment revisions also provide the student with opportunities to practice their communication, writing, speaking, and listening skills; working and collaborating in a team; and building confidence in their ideas.
- Expanded content coverage of employability skills, professional roles and responsibilities, and careers to include more information on time management, conflict resolution, and ethics.
- Expanded content coverage of the engineering design process to include emphasis on the iterative nature of the process, provide additional brainstorming techniques, and explain some ways to identify and ethically source verified and reliable digital information.
- Expanded content coverage of engineering disciplines to include additional safety measures to prevent hazards in the workplace and create emergency plans, as well as explore current and future trending topics that students will encounter in their daily lives, including AI and robotics.
- Correlation charts help instructors determine what areas of the text meet these important standards. Updated correlation charts to the new edition for the following standards and credentials:
  - ITEEA Standards for Technological and Engineering Literacy (STEL)
  - NOCTI Pre-Engineering/Engineering Technology Credential
  - YouScience Engineering Technology industry certification
- For digital subscribers, additional animations with assessment questions and interactive identification activities are available to enrich learning.

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Credentialing Partners and Support

Goodheart-Willcox appreciates the value of industry credentials, certifications, and accreditation. We are pleased to partner with leading organizations to support students and programs in achieving credentials. Integrating industry-recognized credentialing into a career and technical education (CTE) program provides many benefits for the student and for the institution. By achieving third-party certificates, students gain confidence, have proof of a measurable level of knowledge and skills, and earn a valuable achievement to include in their résumés. For educators and administrators, industry-recognized credentials and accreditation validate learning, enhance the credibility of programs, and provide valuable data to measure student performance and help guide continuous program improvement.

Engineering Fundamentals is correlated to the following:

- Standards for Technological and Engineering Literacy for High School offered by ITEEA
- Pre-Engineering/Engineering Technology credential offered by NOCTI
- Engineering Technology YouScience® Industry Certification

ITEEA Partnership

Goodheart-Willcox is pleased to partner with the International Technology and Engineering Educators Association (ITEEA) by correlating *Engineering Fundamentals* to their Standards for Technological and Engineering Literacy (STEL). The STELs provide an up-to-date roadmap for classroom teachers, district supervisors, administrators, states, and curriculum developers to promote technology and engineering education program development and curriculum design from Pre-K through twelfth grade.

NOCTI Certifications

Goodheart-Willcox is pleased to partner with NOCTI and Nocti Business Solutions (NBS), a leading provider of industry certification solutions for skill verification across the nation. With over 55 years of experience, NOCTI/NBS is a valuable partner both within the CTE community and industry to improve America's workforce. Goodheart-Willcox has created correlations between select products and the standards and competencies that are the basis for NOCTI/NBS credentials, to the benefit of states, instructors, and students working toward NOCTI/NBS credentials.

NOCTI/NBS certifications (knowledge-based and skill-based) are developed by national teams of subject matter experts as part of the process that meets personnel accrediting standards and requirements under ISO 17024, resulting in credentials measuring skills and competencies critical for learner success outside the classroom. NOCTI/NBS offers test development, test delivery, and psychometric services to support skill verification, using the latest tools and methods to provide relevant and helpful solutions for workforce development. For more information about NOCTI, visit www.nocti.org.

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YouScience® Industry Certifications, part of the YouScience Brightpath academic and career guidance platform, offer students entry- to mid-level certifications that act as tangible proof of their skills and knowledge. For more information about YouScience, including a complete listing of their Industry Certifications, please visit https://www.youscience.com/certifications/.

To see how *Engineering Fundamentals* correlates to credentialing and certification standards, visit the Correlations tab at https://www.g-w.com/engineering-fundamentals-2028.

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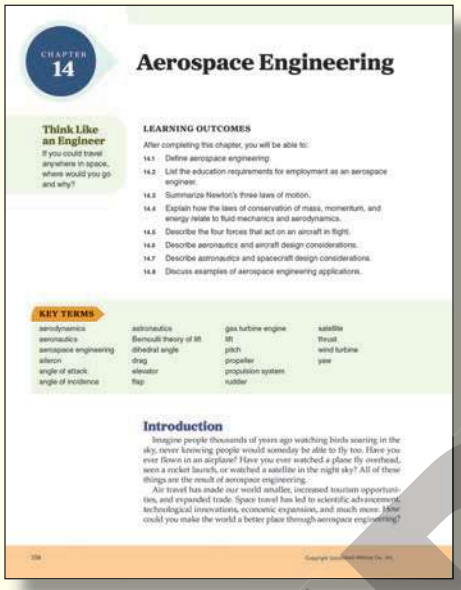
Guided Tour

The instructional design includes student-focused learning tools to help students succeed. This visual guide highlights the features designed for the textbook.

Learning Outcomes clearly identify the knowledge and skills to be obtained when the chapter is completed. These outcomes are labeled and correlated to related assessment elements to facilitate reporting and remediation.

Key Terms list the key terms to be learned in the chapter.

Think Like an Engineer questions spur discussion with your classmates and require you to use your critical thinking skills.


CHAPTER 14

Aerospace Engineering

Think Like an Engineer

If you could travel anywhere in space, where would you go and why?

LEARNING OUTCOMES

After completing this chapter, you will be able to:

14.1 Define aerospace engineering.
14.2 List the education requirements for employment as an aerospace engineer.
14.3 Summarize Newton's three laws of motion.
14.4 Explain how the laws of conservation of mass, momentum, and energy relate to fluid mechanics and aerodynamics.
14.5 Describe the four forces that act on an aircraft in flight.
14.6 Describe aeronautics and aircraft design considerations.
14.7 Describe astronautics and spacecraft design considerations.
14.8 Discuss examples of aerospace engineering applications.

KEY TERMS

aerodynamics, aeronautics, aerospace engineering, aileron, angle of attack, angle of incidence, astronautics, Bernoulli theory of lift, dihedral angle, drag, elevator, flap, gas turbine engine, lift, pitch, propeller, propulsion system, rudder, satellite, thrust, wind turbine, yaw

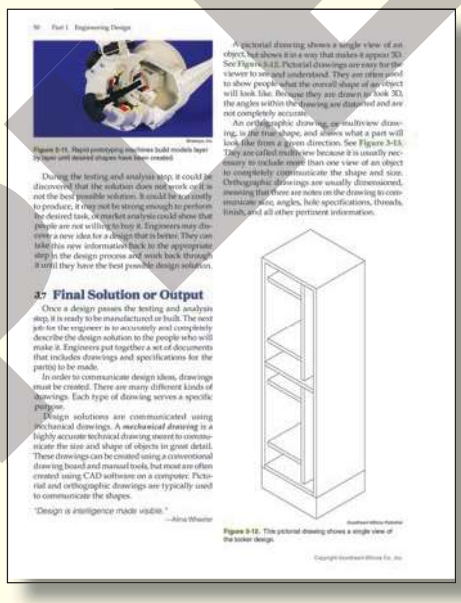
Introduction

Imagine people thousands of years ago watching birds soaring in the sky, never knowing people would someday be able to fly too. Have you ever flown in an airplane? Have you ever watched a plane fly overhead, seen a rocket launch, or watched a satellite in the night sky? All of these things are the result of aerospace engineering.

Air travel has made our world smaller, increased tourism opportunities, and expanded trade. Space travel has led to scientific advancement, technological innovations, economic expansion, and much more. How could you make the world a better place through aerospace engineering?

Introduction provides an overview and preview of the chapter content.

Illustrations have been designed to clearly and simply communicate the specific topic. Illustrations have been completely replaced and updated for this edition. Photographic images have been updated to show the latest equipment.


3.7 Final Solution or Output

Once a design passes the testing and analysis step, it is ready to be manufactured or built. The next job for the engineer is to accurately and completely describe the design solution to the people who will make it. Engineers put together a set of documents that includes drawings and specifications for the part(s) to be made.

In order to communicate design ideas, drawings must be created. There are many different kinds of drawings. Each type of drawing serves a specific purpose.

Design solutions are communicated using mechanical drawings. A *mechanical drawing* is a highly accurate technical drawing meant to communicate the size and shape of objects in great detail. These drawings can be created using a conventional drawing board and manual tools, but most are often created using CAD software on a computer. Pictorial and orthographic drawings are typically used to communicate the shapes.

"Design is intelligence made visible."
—Alina Wheeler

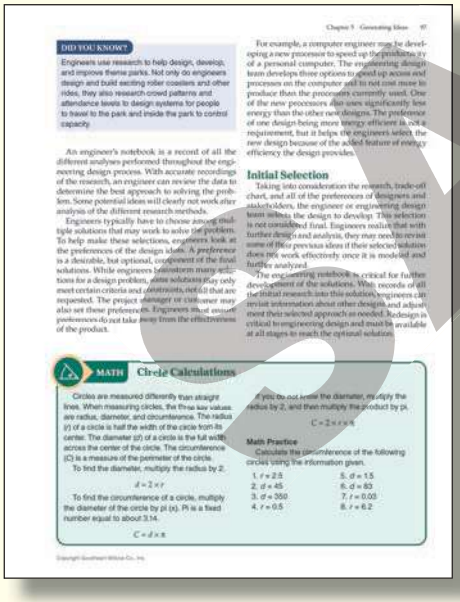
A pictorial drawing shows a single view of an object, but shows it in a way that makes it appear 3D. See Figure 3-12. Pictorial drawings are easy for the viewer to see and understand. They are often used to show people what the overall shape of an object will look like. Because they are drawn to look 3D, the angles within the drawing are distorted and are not completely accurate.

An orthographic drawing, or multiview drawing, is the true shape, and shows what a part will look like from a given direction. See Figure 3-13. They are called multiview because it is usually necessary to include more than one view of an object to completely communicate the shape and size. Orthographic drawings are usually dimensioned, meaning that there are notes on the drawing to communicate size, angles, hole specifications, threads, finish, and all other pertinent information.

Figure 3-12. This pictorial drawing shows a single view of the locker design.

Engineering Quotes help motivate and inspire you.

Did You Know? Notes provide facts about engineering and engineers.


DID YOU KNOW?

Engineers use research to help design, develop, and improve theme parks. Not only do engineers design and build exciting roller coasters and other rides, they also research crowd patterns and attendance levels to design systems for people to travel to the park and inside the park to control capacity.

An engineer's notebook is a record of all the different analyses performed throughout the engineering design process. With accurate recordings of the research, an engineer can review the data to determine the best approach to solving the problem. Some potential ideas will clearly not work after analysis of the different research methods.

Engineers typically have to choose among multiple solutions that may work to solve the problem. To help make these selections, engineers look at the preferences of the design ideas. A *preference* is a desirable, but optional, component of the final solutions. While engineers brainstorm many solutions for a design problem, some solutions may only meet certain criteria and constraints, not all that are requested. The project manager or customer may also set these preferences. Engineers must ensure preferences do not take away from the effectiveness of the product.

For example, a computer engineer may be developing a new processor to speed up the productivity of a personal computer. The engineering design team develops three options to speed up access and processes on the computer and to not cost more to produce than the processors currently used. One of the new processors can uses significantly less energy than the other new designs. The preference of one design being more energy efficient is not a requirement, but it helps the engineers select the new design because of the added feature of energy efficiency the design provides.

Initial Selection

Taking into consideration the research, trade-off chart, and all of the preferences of designers and stakeholders, the engineer or engineering design team selects the design to develop. This selection is not considered final. Engineers realize that with further design and analysis, they may need to revisit some of their previous ideas if their selected solution does not work effectively once it is modeled and further analyzed.

The engineering notebook is critical for further development of the solutions. With records of all the initial research into this solution, engineers can revisit information about other designs and adjustment their selected approach as needed. Redesign is critical to engineering design and must be available at all stages to reach the optimal solution.

MATH Circle Calculations

Circles are measured differently than straight lines. When measuring circles, the three key values are radius, diameter, and circumference. The radius (r) of a circle is half the width of the circle from its center. The diameter (d) of a circle is the full width across the center of the circle. The circumference (C) is a measure of the perimeter of the circle.

To find the diameter, multiply the radius by 2.

$d = 2 \times r$

To find the circumference of a circle, multiply the diameter of the circle by pi (π). Pi is a fixed number equal to about 3.14.

$C = d \times \pi$

If you do not know the diameter, multiply the radius by 2, and then multiply the product by pi.

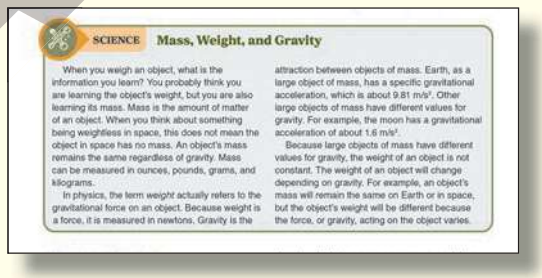
$C = 2 \times r \times \pi$

Math Practice

Calculate the circumference of the following circles using the information given.

1. $r = 2.5$
2. $d = 45$
3. $d = 350$
4. $r = 0.5$
5. $d = 1.5$
6. $d = 83$
7. $r = 0.05$
8. $r = 6.2$

Math features provide a review of math concepts associated with chapter content.

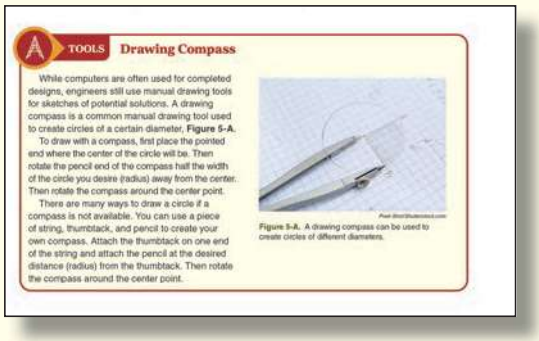

SCIENCE Mass, Weight, and Gravity

When you weigh an object, what is the information you learn? You probably think you are learning the object's weight, but you are also learning its mass. Mass is the amount of matter of an object. When you think about something being weightless in space, this does not mean the object in space has no mass. An object's mass remains the same regardless of gravity. Mass can be measured in ounces, pounds, grams, and kilograms.

In physics, the term *weight* actually refers to the gravitational force on an object. Because weight is a force, it is measured in newtons. Gravity is the attraction between objects of mass. Earth, as a large object of mass, has a specific gravitational acceleration, which is about 9.81 m/s². Other large objects of mass have different values for gravity. For example, the moon has a gravitational acceleration of about 1.6 m/s².

Because large objects of mass have different values for gravity, the weight of an object is not constant. The weight of an object will change depending on gravity. For example, an object's mass will remain the same on Earth or in space, but the object's weight will be different because the force, or gravity, acting on the object varies.

Science features review science concepts related to chapter material.


TOOLS Drawing Compass

While computers are often used for completed designs, engineers still use manual drawing tools for sketches of potential solutions. A drawing compass is a common manual drawing tool used to create circles of a certain diameter, **Figure 5-A**.

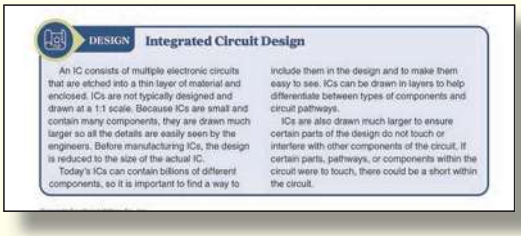
To draw with a compass, first place the pointed end where the center of the circle will be. Then rotate the pencil end of the compass half the width of the circle you desire (radius) away from the center. Then rotate the compass around the center point.

There are many ways to draw a circle if a compass is not available. You can use a piece of string, thumbtack, and pencil to create your own compass. Attach the thumbtack on one end of the string and attach the pencil at the desired distance (radius) from the thumbtack. Then rotate the compass around the center point.

Figure 5-A. A drawing compass can be used to create circles of different diameters.

Tools features detail the types of tools that are used in a particular area of engineering, as well as how to use them safely and effectively.

SAMPLE


DESIGN

Integrated Circuit Design

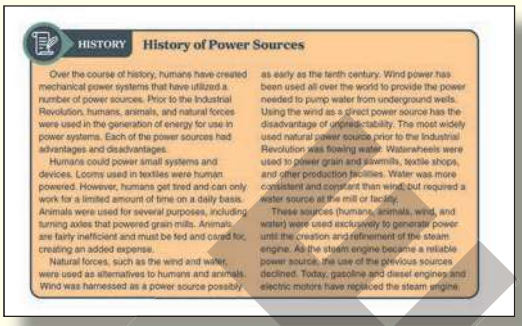
An IC consists of multiple electronic circuits that are etched into a thin layer of material and enclosed. ICs are not typically designed and drawn at a 1:1 scale. Because ICs are small and contain many components, they are drawn much larger so all the details are easily seen by the engineers. Before manufacturing ICs, the design is reduced to the size of the actual IC.

Today's ICs can contain billions of different components, so it is important to find a way to include them in the design and to make them easy to see. ICs can be drawn in layers to help differentiate between types of components and circuit pathways.

ICs are also drawn much larger to ensure certain parts of the design do not touch or interfere with other components of the circuit. If certain parts, pathways, or components within the circuit were to touch, there could be a short within the circuit.

Design features showcase elements of the engineering design process and explain its role in finding a final solution.

History features explore engineers and their designs throughout history and explain how their knowledge has led to today's designs.


HISTORY

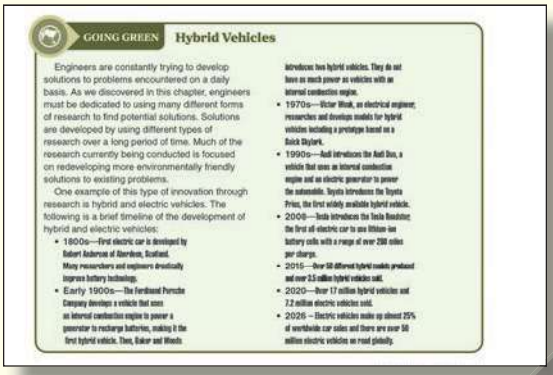
History of Power Sources

Over the course of history, humans have created mechanical power systems that have utilized a number of power sources. Prior to the Industrial Revolution, humans, animals, and natural forces were used in the generation of energy for use in power systems. Each of the power sources had advantages and disadvantages.

Humans could power small systems and devices. Looms used in textiles were human powered. However, humans get tired and can only work for a limited amount of time on a daily basis. Animals were used for several purposes, including turning axles that powered grain mills. Animals are fairly inefficient and must be fed and cared for, creating an added expense.

Natural forces, such as the wind and water, were used as alternatives to humans and animals. Wind was harnessed as a power source possibly as early as the tenth century. Wind power has been used all over the world to provide the power needed to pump water from underground wells. Using the wind as a direct power source has the disadvantage of unpredictability. The most widely used natural power source prior to the Industrial Revolution was flowing water. Waterwheels were used to power grain and sawmills, textile shops, and other production facilities. Water was more consistent and constant than wind, but required a water source at the mill or facility.

These sources (humans, animals, wind, and water) were used exclusively to generate power until the creation and refinement of the steam engine. As the steam engine became a reliable power source, the use of the previous sources declined. Today, gasoline and diesel engines and electric motors have replaced the steam engine.


GOING GREEN

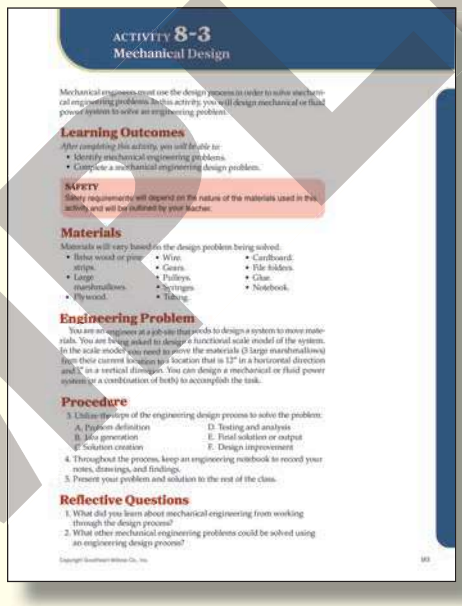
Hybrid Vehicles

Engineers are constantly trying to develop solutions to problems encountered on a daily basis. As we discovered in this chapter, engineers must be dedicated to using many different forms of research to find potential solutions. Solutions are developed by using different types of research over a long period of time. Much of the research currently being conducted is focused on redeveloping more environmentally friendly solutions to existing problems.

One example of this type of innovation through research is hybrid and electric vehicles. The following is a brief timeline of the development of hybrid and electric vehicles:

- 1800s—first electric car is developed by Robert Anderson of Aberdeen, Scotland. Many researchers and engineers drastically improve battery technology.
- Early 1900s—The Ferdinand Porsche Company develops a vehicle that uses an internal combustion engine to power a generator to recharge batteries, making it the first hybrid vehicle. Then, Baker and Woods introduces two hybrid vehicles. They do not have as much power as vehicles with an internal combustion engine.
- 1970s—Victor Wouk, an electrical engineer, researches and develops models for hybrid vehicles including a prototype based on a Buick Skylark.
- 1990s—Audi introduces the Audi Duo, a vehicle that uses an internal combustion engine and an electric generator to power the automobile. Toyota introduces the Toyota Prius, the first widely available hybrid vehicle.
- 2008—Tesla introduces the Tesla Roadster, the first all-electric car to use lithium-ion battery cells with a range of over 250 miles per charge.
- 2015—Over 50 different hybrid models produced and over 2.5 million hybrid vehicles sold.
- 2020—Over 17 million hybrid vehicles and 7.2 million electric vehicles sold.
- 2026—Electric vehicles make up almost 25% of worldwide car sales and there are over 50 million electric vehicles on road globally.

Going Green features highlight key items related to sustainability, energy efficiency, and environmental issues.


ACTIVITY 8-3

Mechanical Design

Mechanical engineers must use the design process in order to solve mechanical engineering problems. In this activity, you will design mechanical or fluid power system to solve an engineering problem.

Learning Outcomes

After completing this activity, you will be able to:

- Identify mechanical engineering problems.
- Complete a mechanical engineering design problem.

SAFETY

Safety requirements will depend on the nature of the materials used in this activity and will be outlined by your teacher.

Materials

Materials will vary based on the design problem being solved.

- Balsa wood or pine strips.
- Large marshmallows.
- Plywood.
- Wire.
- Gears.
- Pulleys.
- Springs.
- Tubing.
- Cardboard.
- File folders.
- Glue.
- Notebook.

Engineering Problem

You are an engineer at a job site that needs to design a system to move materials. You are being asked to design a functional scale model of the system. In the scale model you need to move the materials (3 large marshmallows) from their current location to a location that is 12" in a horizontal direction and 5" in a vertical direction. You can design a mechanical or fluid power system (or a combination of both) to accomplish the task.

Procedure

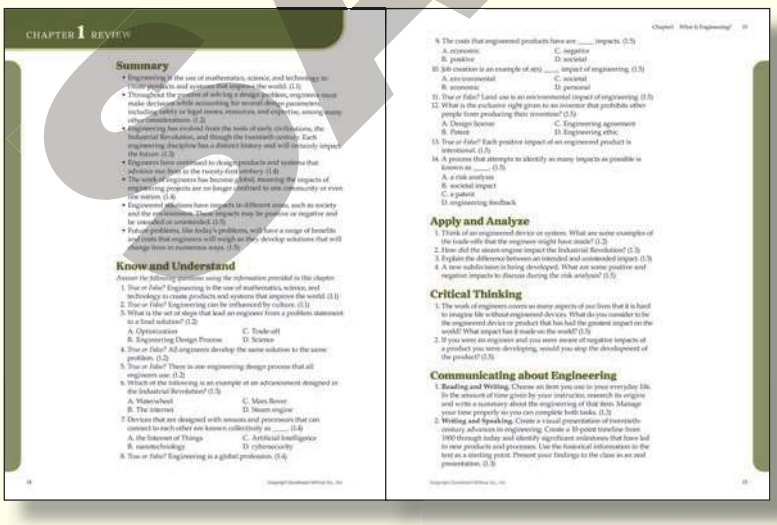
3. Utilize the steps of the engineering design process to solve the problem:
   A. Problem definition
   B. Idea generation
   C. Solution creation
   D. Testing and analysis
   E. Final solution or output
   F. Design improvement
4. Throughout the process, keep an engineering notebook to record your notes, drawings, and findings.
5. Present your problem and solution to the rest of the class.

Reflective Questions

1. What did you learn about mechanical engineering from working through the design process?
2. What other mechanical engineering problems could be solved using an engineering design process?

Safety Notes alert you to potentially dangerous materials and practices.

Summary feature provides an additional review tool for you and reinforces key learning objectives.


CHAPTER 1 REVIEW

Summary

- Engineering is the use of mathematics, science, and technology to create products and systems that improve the world. (1.1)
- Throughout the process of solving a design problem, engineers must make decisions while accounting for several design parameters, including safety or legal issues, resources, and expertise, among many other considerations. (1.2)
- Engineering has evolved from the tools of early civilizations, the Industrial Revolution, and through the twentieth century. Each engineering discipline has a distinct history and will certainly impact the future. (1.3)
- Engineers have continued to design products and systems that advance our lives in the twenty-first century. (1.4)
- The work of engineers has become global, meaning the impacts of engineering projects are no longer confined to one community or even one nation. (1.4)
- Engineered solutions have impacts in different areas, such as society and the environment. These impacts may be positive or negative and be intended or unintended. (1.5)
- Future problems, like today's problems, will have a range of benefits and costs that engineers will weigh as they develop solutions that will change lives in numerous ways. (1.5)

Know and Understand

Answer the following questions using the information provided in this chapter.

1. *True or False?* Engineering is the use of mathematics, science, and technology to create products and systems that improve the world. (1.1)
2. *True or False?* Engineering can be influenced by culture. (1.1)
3. What is the set of steps that lead an engineer from a problem statement to a final solution? (1.2)
   A. Optimization
   B. Engineering Design Process
   C. Trade-off
   D. Science
4. *True or False?* All engineers develop the same solution to the same problem. (1.2)
5. *True or False?* There is one engineering design process that all engineers use. (1.2)
6. Which of the following is an example of an advancement designed in the Industrial Revolution? (1.3)
   A. Waterwheel
   B. The internet
   C. Mars Rover
   D. Steam engine
7. Devices that are designed with sensors and processors that can connect to each other are known collectively as _____. (1.4)
   A. the Internet of Things
   B. nanotechnology
   C. Artificial Intelligence
   D. cybersecurity
8. *True or False?* Engineering is a global profession. (1.4)

9. The costs that engineered products have are _____ impacts. (1.5)
   A. economic
   B. positive
   C. negative
   D. societal
10. Job creation is an example of any _____ impact of engineering. (1.5)
    A. environmental
    B. economic
    C. societal
    D. personal
11. *True or False?* Land use is an environmental impact of engineering. (1.5)
12. What is the exclusive right given to an inventor that prohibits other people from producing their invention? (1.5)
    A. Design license
    B. Patent
    C. Engineering agreement
    D. Engineering ethic
13. *True or False?* Each positive impact of an engineered product is intentional. (1.5)
14. A process that attempts to identify as many impacts as possible is known as _____. (1.5)
    A. a risk analysis
    B. societal impact
    C. a patent
    D. engineering feedback

Apply and Analyze

1. Think of an engineered device or system. What are some examples of the trade-offs that the engineers might have made? (1.2)
2. How did the steam engine impact the Industrial Revolution? (1.3)
3. Explain the difference between an intended and unintended impact. (1.5)
4. A new subdivision is being developed. What are some positive and negative impacts to discuss during the risk analysis? (1.5)

Critical Thinking

1. The work of engineers covers so many aspects of our lives that it is hard to imagine life without engineered devices. What do you consider to be the engineered device or product that has had the greatest impact on the world? What impact has it made on the world? (1.5)
2. If you were an engineer and you were aware of negative impacts of a product you were developing, would you stop the development of the product? (1.5)

Communicating about Engineering

1. **Reading and Writing.** Choose an item you use in your everyday life. In the amount of time given by your instructor, research its origins and write a summary about the engineering of that item. Manage your time properly so you can complete both tasks. (1.3)
2. **Writing and Speaking.** Create a visual presentation of twenty-first century advances in engineering. Create a 10-point timeline from 1900 through today and identify significant milestones that have led to new products and processes. Use the historical information in the text as a starting point. Present your findings to the class in an oral presentation. (1.3)

Know and Understand questions enable you to demonstrate knowledge, identification, and comprehension of chapter material.

Apply and Analyze questions extend learning and develop your abilities to use learned material in new situations and to break down material into its component parts.

Critical Thinking questions develop higher-order thinking and problem-solving abilities.

Communicating about Engineering activities designed to improve and develop language skills such as reading, speaking, and listening.

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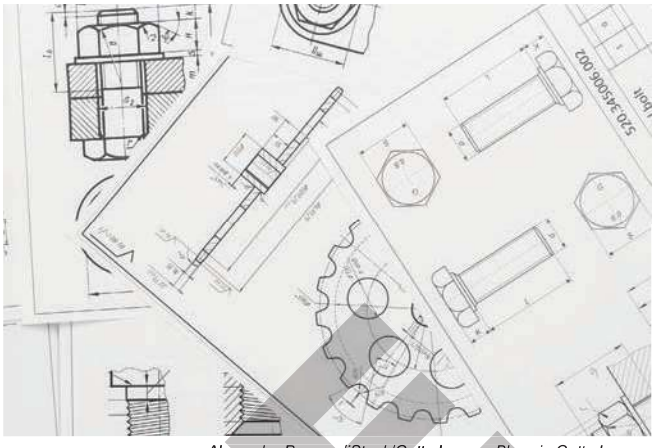
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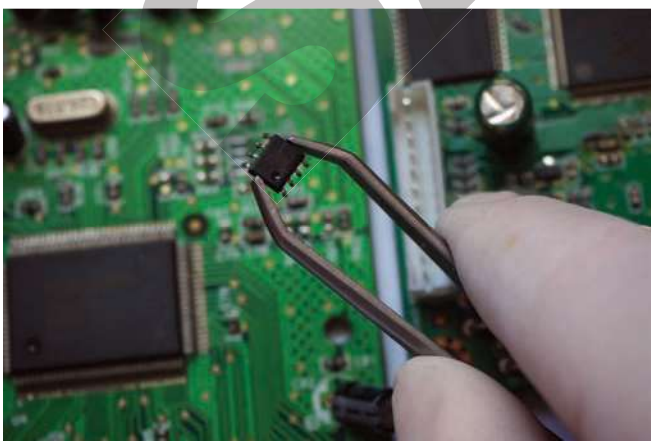
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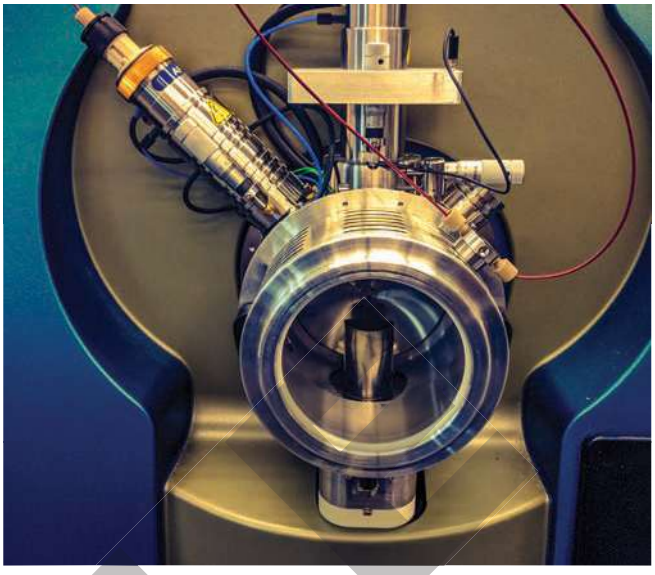
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