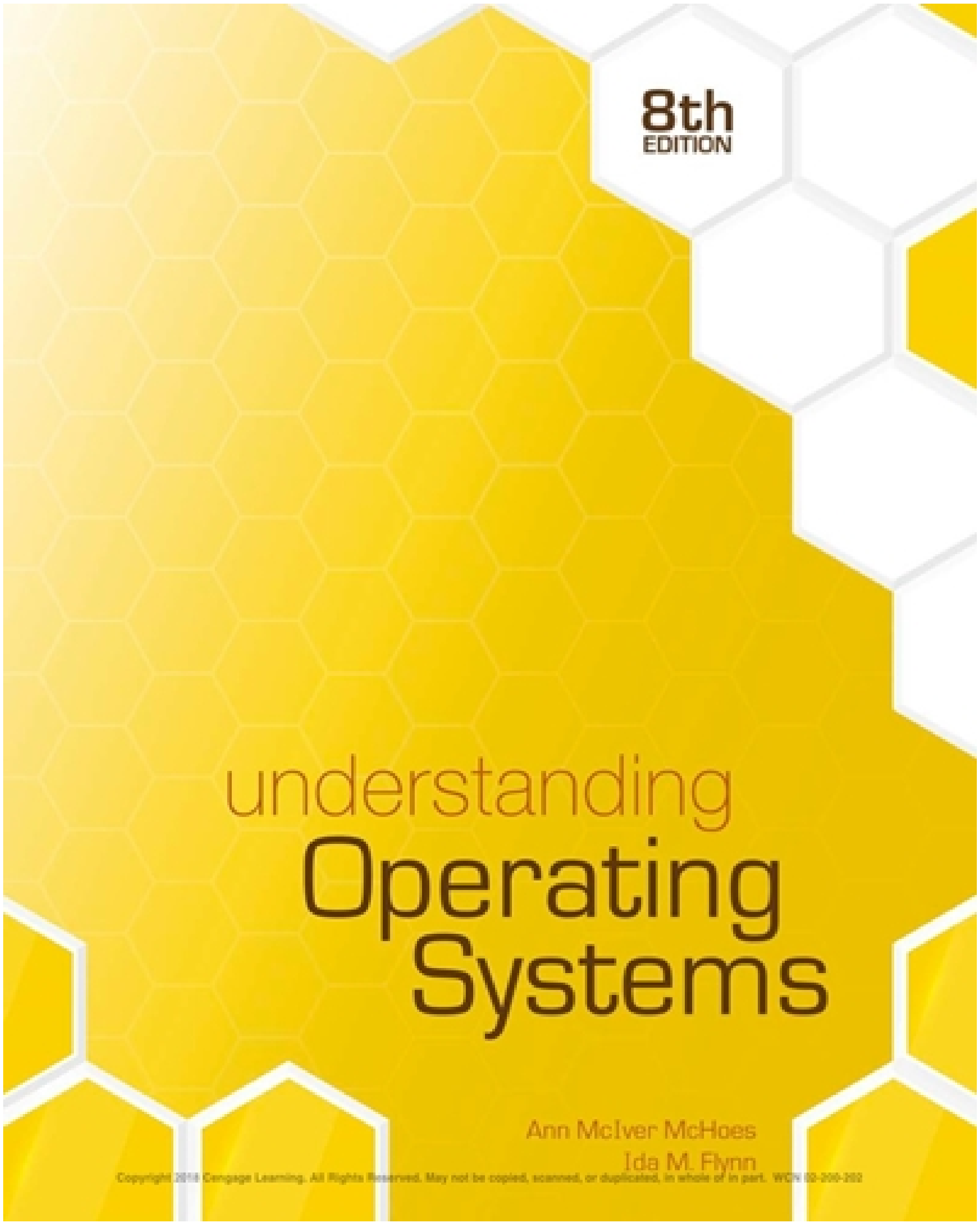
Solutions for Understanding Operating Systems 8th Edition by McHoes



Solutions

Answers to Exercises

Note: we have discovered that some parties have unfairly and illegally posted the solutions to these exercises on the web for students to download, copy, and paste. Therefore, we have included exercises in this book designed to encourage students to analyze problems and explain their thoughts in an original form. We believe this type of question inspires more original thinking and allows students to more completely demonstrate their understanding of the material regardless of their ability to cut and paste the answers. – Author

Chapter 1

Research Topics, Answers to all Research Topics:

Although answers to all Research Topics will vary greatly, this is an opportunity for students to learn the difference between authentic research and merely cutting and pasting from a Wiki site. These assignments can also lead to a discussion of the hazards of plagiarism. Encourage students to research science sites as well as academic or medical sources. They should cite the sources of their research and paraphrase the results that they find.

A. Write a one-page review of an article about the subject of operating systems that appeared in a recent computing magazine or academic journal. Give a summary of the article, including the primary topic, your own summary of the information presented, and the author's conclusion. Give your personal evaluation of the article, including topics that made the article interesting to you (or not) and its relevance to your own experiences. Be sure to cite your sources.

B. In computing literature the numerical value represented by the prefixes kilo-, mega-, giga-, etc. can vary depending on whether they are describing bytes of main memory or bits of data transmission speed. Research the actual value (the number of bytes) in a megabyte (MB) and then compare that value to the number of bits in a megabit (Mb). Are they the same or different? If there is a difference or uncertainty, explain why that is the case. Cite your sources.

ANS: This is a quirky situation that has resulted from the fact that a megabyte and a megabit are based on different numbering systems. One Megabyte (MB) is based on a power of two, whereas a Megabit (often seen as megabit per second (Mbps)) is based on a power of ten. Therefore 1 MB = 1,048,576 bytes, and 1 Mbps = 1,000,000 bits per second. The issue is the same for gigabytes vs. gigabits, etc. Therefore, although the prefixes for each are similar, they represent very different values.

Exercises

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1. Give a real-world example of a task that you perform everyday via cloud computing. Explain how you would cope if the network connection suddenly became unavailable.

ANSWER: Common answers are email, calendar management, social networks, etc. Of interest is how students cope with a lost connection. You can take this discussion further by asking their reaction to a loss of electrical power. This is an opportunity to discuss the sudden expansion of tasks to the cloud and clarify their understanding of it.

2. In your opinion, what would be the consequences if the Memory Manager and the File Manager stopped communicating with each other?

ANSWER: this situation would swiftly deadlock the system because files could no longer be accessed to be read, modified, executed, or deleted. The goal of this question is to explore the interdependencies of different parts of the operating system.

3. In your opinion, what would be the consequences if the Memory Manager and the Processor Manager stopped communicating with each other?

ANSWER: this situation would swiftly deadlock the system because the processor could no longer access parts of main memory to retrieve data or write data. Jobs would stop executing. The goal of this question is to explore the interdependencies of different parts of the operating system.

4. Gordon Moore predicted the dramatic increase in transistors per chip in 1965 and his prediction has held for decades. Some industry analysts insist that Moore's Law been a predictor of chip design, but others say it is a motivator for designers of new chips? In your opinion, who is correct? Explain your answer.

ANSWER: Opinions vary here. There is evidence that Moore's Law has set the expectations of the industry and chip development teams and that they are driven to make the impressive leaps in chip technology every 18 to 24 months. The law was not expected to hold, yet it has for a very long time. This continuing achievement has led others to say that the development curve does not drive the innovations but is instead a mere predictor. Researchers have not yet concluded which side is correct. Look for the students' original reasoning here.

5. Give an example of an organization that might find batch-mode processing useful and explain why.

ANS: One example would be an archival environment that is backing up a system every night. Another might be an environment where routine processing every day follows the same pattern. Look for evidence in the discussion that the student understands batch processing.

6. Give an example of a situation that might need a real-time operating system and explain in detail why you believe that would be the case.

ANS: One example could be a hospital operating room with life-saving devices controlling many varied aspects of the rooms environment. Another could be the cockpit of an aircraft where the operating system controls many aspects of flight. Look for evidence in the discussion that the student understands real-time processing.

7. Name five current operating systems (other than those mentioned in Table 1.1) and identify the computers, platforms, or configurations where each is used. ANS: With each student naming five different operating systems, the accumulation of these answers should demonstrate the numerous operating systems in existence and the environments in which they are used. This is a good opportunity to explore multiple platforms, multiple situations in which operating systems can be found. The answers should not merely include five versions of a single operating system.

8. Many people confuse main memory and secondary storage. Explain why this might happen and describe how you would explain the differences to classmates so they would no longer confuse the two. ANS: One cause of the confusion is that both use identical units of measurement -- bytes (MB, GB, etc.) Another is that they both store programs and instructions. However, main memory (primary storage) is temporary and secondary storage is much more permanent. Look for evidence that the student understands the differences between them. When students describe a technique or argument to explain the differences to classmates, look for original thinking and a convincing explanation. Emphasize that the ability to communicate clearly is a bonus to anyone in a technical field.

9. Name the five key concepts about an operating system that you think a typical user needs to know and understand. ANS:

This answer can vary greatly but look for originality here as there is no one correct answer. As the chief piece of software, many users know of the existence of an operating system but few can name its functions or why it's important. A technician would want to know how it works, a novice might want to know why it is important. Good answers could include:

- What an operating system is, and why it is important.
- The key role that the operating systems software plays regarding all other software on the computer or system.
- The key role that operating systems software plays regarding all hardware interactions on the computer or system.
- That operating systems evolve as hardware capability evolves.
- The trade-offs that an operating system might make to increase efficiency.
- The role of the sub managers: memory manager, process manager, device manager, file manager, and network manager.
- That every computer, even cell phones and games, rely on an operating system.

10. Explain the impact of the continuing evolution of computer hardware and the accompanying evolution of operating systems software.

ANS: Look for students to explain the IMPACT of new computer hardware and software. Historically, the operating system software was developed hand-in-hand with the hardware – that is, as the hardware changed, so did the software supporting it. However, over time, and as operating systems became more multi-platform, they have evolved separately.

11. List three tangible, physical, resources of a computer system.

This question is designed to help beginning students differentiate between hardware and software resources. Tangible resources would include the processor, memory, printer, monitor, keyboard, mouse, disk drives, sound card, etc. It does not include files, data, or software.

12. Select two of the following professionals: an insurance adjuster, a delivery person for a courier service, a newspaper reporter, a doctor (general practitioner), or a manager in a supermarket. Suggest at least two ways that each person might use a mobile computer to work more efficiently.

ANS: Answers here should vary from one student to the next. Look for answers that explore the role of mobile computing to everyday life.

13. Give real-world examples of interactive, batch, real-time, and embedded systems and explain the fundamental differences among them. ANS: The students should not cut and paste the definitions shown below but should use original language and give thoughtful examples of each.

- Interactive systems, in simplest terms, are those that allow each user to interact directly with the operating system accommodating interruptions, multiple processes, and sometime multiple users.
- Batch systems are a type of computing system that executes programs, each of which is submitted in its entirety, can be grouped into batches, and execute without external intervention.
- Real-time systems are used in time-critical environments that require guaranteed response times, such as navigation systems, rapid transit systems, and industrial control systems.
- Embedded systems are dedicated computer systems that often reside inside a larger physical system, such as jet aircraft or automobiles. Often, they must be small and fast and work with real-time constraints, fail-safe execution, and nonstandard I/O devices.

14. Briefly compare active and passive multiprogramming and give examples of each.

ANS: Look for students to explain in their own words active multiprogramming vs. passive multiprogramming and give at least one good example of each.

Advanced Exercises

Advanced Exercises explore topics not discussed in this chapter and are appropriate for readers with supplementary knowledge of operating systems.

15. Give at least two reasons why a state-wide bank might decide to buy six networked servers instead of one mainframe. ANS: There are several reasons but many would hinge on the potential reliability of interconnected servers. Because students have not yet learned much about this subject in this book (it is covered later in the text), they can be expected to speculate as to the reasons so they can independently explore the concepts behind networking.

16. Compare the development of two operating systems described in Chapters 13-16 of this text, including design goals and evolution.

Answer: These answers will vary. This question is designed to encourage students to explore two operating systems in detail and perhaps learn more about an operating system outside of their expertise. You may want include other system not described in Part 2 of this book, to further their exploration.

17. Draw a system flowchart illustrating the steps performed by an operating system as it executes the instruction to back up a disk on a single-user computer system. Begin with the user typing the command on the keyboard or choosing an option from a menu, and conclude with the result being displayed on the monitor.

ANSWER: The pseudo code for the flowchart is below:

1.·User·issues·command·to·BACKUP·via·the·User·Interface¶
2.·User·Interface·interprets·command¶
–·awakens·File·Manager¶
3.·File·Manager·resolves·address·of·file·to·be·backed·up¶
–·awakens·Device·Manager¶
4.·Device·Manager·opens·access·path·to·drive·from·where·files·are·to·be·backed·up¶
–·reads·file·(or·portion·of·it)·into·I/O·buffer¶
–·awakens·Memory·Manager¶
5.·Memory·Manager·allocates·memory·for·file·in·I/O·buffer¶
–·awakens·Processor·Manager¶
6.·Processor·Manager·loads·file·from·I/O·buffer·to·memory¶
–·awakens·File·Manager¶
7.·File·Manager·resolves·address·of·file·to·be·copied·to·new·disk¶
–·awakens·Processor·Manager¶
8.·Processor·Manager·copies·file·from·memory·to·I/O·buffer¶
–·awakens·Device·Manager¶
9.·Device·Manager·opens·access·path·to·drive·where·file·will·be·copied¶
–·reads·file·from·I/O·buffer·to·new·disk¶
–·awakens·File·Manager¶

10. File Manager determines if file is completely copied
    – if yes, writes Trailer Label
        – jump forward to step 11
    – if no, resolves address of next section of file to be backed up
    – awakens Device Manager returns to step 4
11. File Manager determines if this is the last file to be backed up
    – if no, awakens Processor Manager
        – Processor Manager activates user interface
            – sends *File N has been backed up* message to user
        – jump back to step 3
    – if yes, awakens Processor Manager
        – Processor Manager activates user interface
            – sends *"All files have been backed up"* message to user
    – Continue with other functions

18. In a multiprogramming and time-sharing environment, several users share a single system at the same time. This situation can result in various security problems. Name two such problems. Can we ensure the same degree of security in a time-share machine as we have in a dedicated machine? Explain your answers.

ANSWER: The only secure computing environment is one that is not networked and is dedicated to only a single task or a single user. Among the security issues that arise in a shared processing environment are:

- inadvertent or intentional access to user ids and passwords
- unauthorized access to private data
- unauthorized access to, or alteration of, the operating system software
- inadvertent or intentional spreading of viruses and other malware

19. Give an example of an application where multithreading gives improved performance over single-threading.

Answers will vary but two examples are web browsing and database searching.

20. If a process terminates, will its threads also terminate or will they continue to run? Explain your

answer.

Once the process terminates, the threads will terminate because control of each thread is held by the parent process.

21. The boot sequence is the series of instructions that enable the operating system to get installed and running. In your own words, describe the role of firmware and the boot process for an operating system of your choice. ANS: In general, firmware begins the loading of the operating system and each boot process is loaded in a special sequence. Students should describe, for the operating system chosen, the role of the firmware and its interaction with the booting sequence for the operating system chosen.

22. A "dual boot" system gives users the opportunity to choose from among a list of operating systems when powering on a computer. Describe how this process works. Explain whether or not there is a risk that one operating system could intrude on the space reserved for another operating system. ANS: Dual booting, by definition, allows two operating systems to be loaded onto the same computer at the same time. Multi-booting would allow more than two. If the dual booting software is working correctly, there is no risk that either operating system will intrude, even inadvertently on the other operating system. A common configuration would be having Windows and Linux loaded on the same computer so that the user can choose on the opening screen which operating system to load. Thereafter, one can switch operating systems by rebooting the computer.

Chapter 1

Introducing Operating Systems

At a Glance

Instructor's Manual Table of Contents

- Overview
- Objectives
- Teaching Tips
- Quick Quizzes
- Class Discussion Topics
- Additional Projects
- Additional Resources
- Key Terms

Lecture Notes

Overview

To understand an operating system is to begin to understand the workings of an entire computer system, because the operating system software manages each and every piece of hardware and software. In the pages that follow, students will explore what operating systems are, how they work, what they do, and why.

Learning Objectives

After completing this chapter, the student should be able to describe:

- How operating systems have evolved through the decades
- The basic role of an operating system
- How operating system software manages its subsystems
- The role of computer system hardware on the development of its operating system
- How operating systems are adapted to serve batch, interactive, real-time, hybrid, and embedded systems
- How operating systems designers envision their role and plan their work

Teaching Tips

What Is an Operating System?

1. Point out that every computer system consists of software (programs) and hardware.

2. A computer system typically consists of software (programs) and hardware (the tangible machine and its electronic components). Note that the operating system software is the chief piece of software, the portion of the computing system that manages all of the hardware and all of the other software.

Operating System Software

1. Provide an outline of the following essential managers of an operating system: Memory Manager, Processor Manager, Device Manager, and File Manager.

2. Discuss the importance of the user interface. Note that this communication mechanism allows users to interact directly with the operating system. Review Figure 1.1 to reinforce the abstract view of how the user interface interacts with the four essential managers in a non-networked environment.

3. Explain that each manager works closely with the other managers and performs a unique role. Use the examples on page 6 of the text and Figure 1.2 to clarify this point. There are four main tasks each manager performs:
   - Monitor its resources continuously
   - Enforce the policies that determine who gets what, when, and how much
   - Allocate the resource when appropriate
   - Deallocate the resource when appropriate

4. Note that the vast majority of major operating systems today, incorporate a Network Manager to coordinate the services required for multiple systems to work cohesively together.

Main Memory Management

1. Describe the role of the Memory Manager and explain how it allocates and deallocates memory.

2. Introduce the terms **Random Access Memory (RAM), Read- Only Memory (ROM**), and **firmware**. Use Figure 1.4 to aid the discussion.

Processor Management

1. Explain that an important function of the Processor Manager is to keep track of the status of each job, process, thread, and so on.

2. Discuss the Processor Manager's role as a traffic controller.

Device Management

1. Discuss the role of the Device Manager.

2. Note that good device management requires that this part of the operating system uniquely identify each device, start its operation when appropriate, monitor its progress, and finally deallocate the device to make the operating system available to the next waiting process.

File Management

1. Describe the various management roles of the File Manager.

2. Discuss access control as it relates to file management.

Network Management

1. Describe the roles of the Network Manager.

2. Point out that regardless of the size and complexity of the network, these operating systems must be prepared to properly manage the available memory, CPUs, devices, and files.

User Interface

1. Describe the functions of a user interface.

2. Introduce the terms **graphical user interface (GUI)** and **command line interface**. Use Figure 1.6 to aid the discussion.

3. Discuss the evolution from typed commands to graphical user interfaces. Use Figures 1.6 and 1.7 to aid the discussion.

Cooperation Issues

1. None of the elements of an operating system can perform its individual tasks in isolation; each must also work harmoniously with every other manager. Use the example on pages 11-12 to discuss the actions that occur when someone chooses a menu option to open a program.

Cloud Computing

1. Introduce the term **cloud computing**. Use Figure 1.8 to aid the discussion.

2. Note that regardless of where the resource is located (in the box, under the desk, or the cloud, the role of the operating system is the same) to access those resources and manage the system as efficiently as possible.

Quick Quiz 1

1. Which of the following are essential managers of every operating system? (Choose all that apply.)
   a. Memory Manager
   b. System Manager
   c. Directory Manager
   d. Process Manager
   Answer: a and d

2. The term ____ is used to describe the programming code that is used to start the computer and perform other necessary tasks.
   Answer: firmware

3. (True or False) The contents of ROM are volatile, meaning that they are erased when the power is turned off, unlike the contents of RAM.
   Answer: False

4. ____ is the practice of using Internet-connected resources to perform processing, storage, or other operations.
   Answer: Cloud computing

An Evolution of Computing Hardware

1. Provide an outline of the essential hardware components found in computers, explaining the basic functions of each. This includes main memory, also known as random access memory (RAM); the various input/output devices (I/O devices); and the central processing unit (CPU). Storage devices may also be considered at this time.

2. Use Table 1.1 to explore a brief list of platforms and a few of the operating systems designed to run on them.

3. Explain that in 1965, Intel executive Gordon Moore observed that each new processor chip contained roughly twice as much capacity as its predecessor (number of components per integrated function), and that each chip was released within 18–24 months of the previous chip. Use Figure 1.9 to aid the discussion.

Teaching Tip	For additional information on the basics of computer hardware, refer students to the following Web site: http://www.computernetworkingnotes.com/computer-hardware/review.html

Teaching Tip	For additional information on Moore's law, refer students to the following Web site: http://www.intel.com/content/www/us/en/silicon-innovations/moores-law-technology.html

Types of Operating Systems

1. Provide an outline of the different categories of operating systems, including **batch**, **interactive**, **real-time**, **hybrid**, and **embedded systems**. Mention that each category is distinguished by response time and how data is entered into the system.

2. Provide students with an overview of batch systems. Point out that in the past, such systems relied on a stack of cards or tape for input, and efficiency was measured in throughput.

3. Discuss the characteristics of interactive systems. Note that these systems offered huge improvements in response over batch-only systems with turnaround times in seconds or minutes instead of hours or days.

4. Real-time systems are used in time-critical environments where reliability is critical and data must be processed within a strict time limit. Note that there are two types: hard and soft systems.

5. Provide students with an overview of hybrid systems. Point out that a hybrid system takes advantage of the free time between high-demand usage of the system and low demand times

6. Introduce the concepts of networks and network operating systems. Use Figure 1.10 to aid the discussion.

7. Provide students with an overview of embedded systems, which are computers placed inside other products to add features and capabilities. Note that operating systems for embedded computers are very different from those for general computer systems. Each one is designed to perform a set of specific programs, which are not interchangeable among systems.

Teaching Tip	For additional information on real-time operating systems, refer to the following Web site: http://www.ni.com/white-paper/3938/en

Timeline of Operating Systems Development

1. Begin this section by explaining that the evolution of operating system software parallels the evolution of the computer hardware they were designed to control.

1940s

1. Mention that the machines from this era were poorly utilized, i.e., the CPU processed data and made calculations for only a fraction of the available time. Basically, early programs were designed to use the resources conservatively at the expense of understandability.

2. Review Figure 1.11 and discuss the origins of the term computer "bug."

1950s

1. Outline two major improvements that were widely adopted: computer operators were hired to facilitate each machine's operation and job scheduling was instituted.

2. Discuss various factors that helped improve the performance of the CPU, such as the increase in the speed of I/O devices, the introduction of "blocking" to improve storage, and the introduction of control units and buffers.

1960s

1. Provide students with an overview of third-generation computers dated from the mid-1960s. Point out that they were designed with faster CPUs, but their speed caused problems when they interacted with the relatively slow I/O devices. Explain how the concept of multiprogramming helped solve this problem and discuss the mechanism of its implementation.

2. Use examples to explain the concepts of passive multiprogramming and active multiprogramming. Point out the disadvantages of passive multiprogramming and how these were overcome by active multiprogramming.

1970s

1. Note that during the late 1970s, computers had faster CPUs, thus creating a disparity between their rapid processing speed and slower I/O time. Multiprogramming schemes to increase CPU use were limited by the physical capacity of main memory.

2. Discuss how the concept of virtual memory solved the physical limitation issue.

1980s

1. Discuss the various developments in the 1980s, such as improved cost/performance ratio of computer components, greater flexibility of hardware, and the introduction of the concept of firmware.

2. Point out that the evolution of personal computers and high-speed communications sparked the move to distributed processing and networked systems, enabling users in remote locations to share hardware and software resources.

3. Provide students with an overview of distributed operating systems.

1990s

1. Point out that the demand for Internet capability in the mid-1990s sparked the proliferation of networking capability. The World Wide Web, conceived by Tim Berners-Lee, made the Internet accessible by computer users worldwide. Use Figure 1.12 to aid the discussion.

2. Be sure to note that increased networking also created increased demand for tighter security to protect hardware and software.

3. Point out that the decade also introduced the proliferation of multimedia applications demanding additional power, flexibility, and device compatibility for most operating systems.

2000s

1. The new century emphasized the need for improved flexibility, reliability, and speed. The concept of virtual machines was expanded to allow computers to accommodate multiple operating systems that ran at the same time and shared resources.

2. Introduce the term **virtualization**.

3. Note that processing speed enjoyed a similar advancement with the commercialization of multicore processors, which can contain two to many cores. Use Figure 1.13 to aid the discussion.

2010s

1. Increased mobility and wireless connectivity spawned a proliferation of dual-core, quad-core, and other multicore CPUs with more than one processor (also called a core) on a computer chip. Discuss the driving force behind this innovation.

Teaching Tip	For additional information on the history of operating systems, refer to the following Web site: http://www.osdata.com/kind/history.htm

Role of the Software Designer

1. The people who write operating systems are faced with many choices that can affect every part of the software and the resources it controls. Before beginning, designers typically start by asking key questions, using the answers to guide them in their work.

2. Point out that no single operating system is perfect for every environment. Some systems can be best served with a UNIX system, others benefit from the structure of a Windows system, and still others work best using Linux, Mac OS, or Android, or even a custom-built operating system.

Quick Quiz 2

1. ____ allows separate partitions of a single server to support a different operating system.
   Answer: Virtualization

2. ____ was developed in the late 1970s and allowed portions of multiple programs to reside in memory at the same time.
   Answer: Virtual memory

5. ____ are computers that are physically placed inside the products in which they operate to add very specific features and capabilities.
   Answer: Embedded systems

6. ____ allow users to manipulate resources that may be located over a wide geographical area.
   Answer: Networks

Class Discussion Topics

1. Discuss the primary design features of current operating systems and the security implications.

2. Ask students to discuss the security measures that they would take to protect hardware and software.

Additional Projects

1. Submit a two-page report that discusses the requirements of operating systems for use in embedded computers. Be sure to cite your sources.

2. Submit a two-page report that discusses the advantages and disadvantages of cloud computing and the security risks involved. Be sure to cite your sources.

Additional Resources

1. Windows Products and Technologies History: http://www.ibtimes.com/microsoft-windows-30-short-history-one-most-iconic-tech-products-ever-2194091

2. History of UNIX: https://www.bell-labs.com/usr/dmr/www/hist.html

3. The untold story behind Apple's $13,000 operating system: https://www.cnet.com/news/the-untold-story-behind-apples-13000-operating-system/

Key Terms

- **batch system:** a type of computing system that executes programs, each of which is submitted in its entirety, can be grouped into batches, and is executed without external intervention.
- **central processing unit (CPU):** a component with circuitry that controls the interpretation and execution of instructions. See also *processor*.

- **cloud computing:** a multifaceted technology that allows computing, data storage and retrieval, and other computer functions to take place via a large network, typically the Internet.
- **Device Manager:** the section of the operating system responsible for controlling the use of devices. It monitors every device, channel, and control unit and chooses the most efficient way to allocate all of the system's devices.
- **embedded system:** a dedicated computer system that is often part of a larger physical system, such as a jet aircraft or automobile. Often, it must be small, fast, and able to work with real-time constraints, fail-safe execution, and nonstandard I/O devices.
- **File Manager:** the section of the operating system responsible for controlling the use of files.
- **firmware:** software instructions, or data, that are stored in a fixed or "firm" way, usually implemented on some type of read-only memory (ROM).
- **hardware:** the tangible machine and its components, including main memory, I/O devices, I/O channels, direct access storage devices, and the central processing unit.
- **hybrid system:** a computer system that supports both batch and interactive processes.
- **interactive system:** a system that allows each user to interact directly with the operating system.
- **kernel:** the primary part of the operating system that remains in random access memory (RAM), and is charged with performing the system's most essential tasks, such as managing main memory and disk access.
- **main memory (RAM):** the memory unit that works directly with the CPU, and in which the data and instructions must reside in order to be processed. Also called primary storage, RAM, or internal memory.
- **Memory Manager:** the section of the operating system responsible for controlling the use of memory. It checks the validity of each request for memory space, and if it's a legal request, allocates the amount of memory required to execute the job.
- **multiprogramming:** a technique that allows a single processor to process several programs residing simultaneously in main memory, and interleaving their execution by overlapping I/O requests with CPU requests.
- **Network Manager:** the section of the operating system responsible for controlling the access to, and use of, networked resources.
- **network:** a system of interconnected computer systems and peripheral devices that exchange information with one another.
- **operating system:** the primary software on a computing system that manages its resources, controls the execution of other programs, and manages communications and data storage.
- **process:** an instance of execution of a program that is identifiable and controllable by the operating system.
- **processor:** (1) another term for the CPU (central processing unit); (2) any component in a computing system capable of performing a sequence of activities. It controls the interpretation and execution of instructions.
- **Processor Manager:** a composite of two submanagers, the Job Scheduler and the Process Scheduler, that decides how to allocate the CPU.
- **RAM:** short for random access memory. See main memory.

- **real-time system:** a computing system used in time-critical environments that require guaranteed response times. Examples include navigation systems, rapid transit systems, and industrial control systems.
- **server:** a node that provides clients with various network services, such as file retrieval, printing, or database access services.
- **storage:** the place where data is stored in the computer system. Primary storage is main memory. Secondary storage is nonvolatile media, such as disks and flash memory.
- **user interface:** the portion of the operating system that users interact with directly—is one of the most unique and most recognizable components of an operating system.