Effective Fall 2018

AP® CollegeBoard

AP Computer Science Principles

Practice Exam and Notes

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Further distribution of these materials outside of the secure College Board site disadvantages teachers who rely on uncirculated questions for classroom testing. Any additional distribution is in violation of the College Board's copyright policies and may result in the termination of Practice Exam access for your school as well as the removal of access to other online services such as the AP Teacher Community and Online Score Reports.

About the College Board

The College Board is a mission-driven not-for-profit organization that connects students to college success and opportunity. Founded in 1900, the College Board was created to expand access to higher education. Today, the membership association is made up of over 6,000 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, the College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success—including the SAT® and the Advanced Placement Program®. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools. For further information visit **www.collegeboard.org**.

AP® Equity and Access Policy

The College Board strongly encourages educators to make equitable access a guiding principle for their AP® programs by giving all willing and academically prepared students the opportunity to participate in AP. We encourage the elimination of barriers that restrict access to AP for students from ethnic, racial, and socioeconomic groups that have been traditionally underrepresented. Schools should make every effort to ensure their AP classes reflect the diversity of their student population. The College Board also believes that all students should have access to academically challenging course work before they enroll in AP classes, which can prepare them for AP success. It is only through a commitment to equitable preparation and access that true equity and excellence can be achieved.

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Contents

Introduction 4

I. Practice Exam

Exam Content and Format 7

Administering the Practice Exam 7

Answer Sheet for Multiple-Choice Questions 8

AP® Computer Science Principles Practice Exam 12

II. Notes on the Practice Exam

Introduction 69

Multiple-Choice Questions 70

Answers to Multiple-Choice Questions 112

Introduction

The AP Computer Science Principles course is designed to be equivalent to a first-semester introductory college computing course. In this course, students will develop computational thinking skills vital for success across all disciplines, such as using computational tools to analyze and study data and working with large data sets to analyze, visualize, and draw conclusions from trends. The course engages students in the creative aspects of the field by allowing them to develop computational artifacts based on their interests. Students will also develop effective communication and collaboration skills by working individually and collaboratively to solve problems, and will discuss and write about the impacts these solutions could have on their community, society, and the world.

The AP Computer Science Principles assessment consists of two parts: completion of a through-course assessment and the end-of-course AP Exam. The through-course assessment consists of two performance tasks and is worth 40 percent of a student's AP score. The performance tasks require students to upload digital artifacts and written responses via a Web-based digital portal. The end-of-course exam is worth 60 percent of a student's AP score and consists of 74 multiple-choice questions. **This practice exam is intended as preparation for the end-of-course exam only.** The exam features multiple-choice questions, presented as either single-select questions in which students will select one answer choice, or multiple-select questions in which students will be required to select two answer choices.

Part I of this publication is the AP Computer Science Principles Practice Exam. This will mirror the look and feel of an actual AP Exam, including instructions and sample questions. However, these exam items have never been administered in an operational exam, and, therefore, statistical analysis is **not** available. The purpose of this section is to provide educators with sample exam questions that accurately reflect the composition/design of the exam and to offer these questions in a way that gives teachers the opportunity to test their students in an exam situation that closely resembles the actual exam administration.

Important: Final instructions for every AP Exam are published in the *AP Exam Instructions* book. Please reference that publication, which is posted at **www.collegeboard.org/apexaminstructions** in March and included in schools' exam shipments, for the final instructions and format of this AP Exam.

Part II is the Notes on the AP Computer Science Principles Practice Exam. This section offers an explanation of how each question in the practice exam links back to the curriculum framework in order to provide a clear link between curriculum and assessment. The multiple-choice rationales explain the correct and incorrect options.

How AP Courses and Exams Are Developed

AP courses and exams are designed by committees of college faculty and expert AP teachers who ensure that each AP course and exam reflects and assesses college-level expectations. AP Development Committees define the scope and expectations of the course, articulating through a course framework what students should know and be able to do upon completion of the AP course. Their work is informed by data collected from a range of colleges and universities to ensure that AP course work reflects current scholarship and advances in the discipline.

The AP Development Committees are also responsible for drawing clear and well-articulated connections between the AP course and AP Exam—work that includes designing and approving exam specifications and exam questions. The AP Exam development process is a multiyear endeavor; all AP Exams undergo extensive review, revision, piloting, and analysis to ensure that questions are high quality and fair and that the questions comprise an appropriate spread of difficulty across the questions.

Throughout AP course and exam development, the College Board gathers feedback from various stakeholders in both secondary schools and higher education institutions. This feedback is carefully considered to ensure that AP courses and exams are able to provide students with a college-level learning experience and the opportunity to demonstrate their qualifications for advanced placement upon college entrance.

How AP Exams Are Scored

The exam scoring process, like the course and exam development process, relies on the expertise of both AP teachers and college faculty. While multiple-choice questions are scored by machine, the through-course performance tasks are scored by college faculty and expert AP teachers at the annual AP Reading.

AP Exam Readers are thoroughly trained, and their work is monitored throughout the Reading for fairness and consistency. In each subject, a highly respected college faculty member fills the role of Chief Reader, who, with the help of AP Readers in leadership positions, maintains the accuracy of the scoring standards. Scores on the performance assessments are weighted and combined with the results of the computer-scored multiple-choice questions and this composite score is converted into an AP Exam score of 5, 4, 3, 2, or 1.

The score-setting process is both precise and labor intensive, involving numerous psychometric analyses of the results of a specific AP Exam in a specific year and of the particular group of students who took that exam. Additionally, to ensure alignment with college-level standards, part of the score-setting process involves comparing the performance of AP students with the performance of students enrolled in comparable courses in colleges throughout the United States. In general, the AP composite score points are set so that the lowest raw score needed to earn an AP score of 5 is equivalent to the average score among college students earning grades of A in the college course. Similarly, AP Exam scores of 4 are equivalent to college grades of A–, B+, and B. AP Exam scores of 3 are equivalent to college grades of B–, C+, and C.

Using and Interpreting AP Scores

College faculty are involved in every aspect of AP, from course and exam development to scoring and standards alignment. These faculty members ensure that the courses and exams meet colleges' expectations for content taught in comparable college courses. Based on outcomes research and program evaluation, the American Council on Education (ACE) and the Advanced Placement Program recommend that colleges grant credit and/or placement to students with AP Exam scores of 3 and higher. The AP score of 3 is equivalent to grades of B–, C+, and C in the equivalent college course. However, colleges and universities set their own AP credit, advanced standing, and course placement policies based on their unique needs and objectives.

AP Score	Recommendation
5	Extremely well qualified
4	Well qualified
3	Qualified
2	Possibly qualified
1	No recommendation

Additional Resources

Visit apcentral.collegeboard.org for more information about the AP Program.

Practice Exam

Exam Content and Format

The AP Computer Science Principles End-of-Course Exam is 2 hours long and consists of 74 multiple-choice questions.

Administering the Practice Exam

This section contains instructions for administering the AP Computer Science Principles Practice Exam. You may wish to use these instructions to create an exam situation that resembles an actual administration. If so, read the indented, boldface directions to the students; all other instructions are for administering the exam and need not be read aloud. Before beginning testing, have all exam materials ready for distribution. These include test booklets and answer sheets.

When you are ready to begin the exam, say:

> **You will be given 2 hours to answer 74 multiple-choice questions. Each question has four answer choices.**
>
> - **For question numbers 1 through 66, mark only the single best answer to each question.**
> - **For the remaining questions, numbered 131 through 138, mark the two best answer choices for each question.**
>
> **Your total score on this multiple-choice exam is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions. When you do not know the answer to a question, you should eliminate as many choices as you can, and then select the best answer among the remaining choices. If you finish before time is called, you may check your work.**
>
> **Programming reference materials are located at the front of the exam. The reference materials provide instructions and explanations to help you understand the format and meaning of the questions on the test. As you encounter programming questions on the test, you should use the reference materials to clarify the behavior of programming statements found in those questions.**
>
> **You have 2 hours for this exam. Open your exam booklet and begin.**

Note Start Time here_____ . Note Stop Time here_____ . After 2 hours, say:

> **Stop working. The exam is over. I will now collect your exam materials.**

Collect an exam booklet and answer sheet from each student.

CollegeBoard AP

Answer Sheet 2018

AP Number Label
(from Student Pack)

AP FPO X123456789 X

AP Exam Label
(from Section I Booklet)

PAGE 1

COMPLETE THIS AREA AT EVERY EXAM. **USE NO. 2 PENCIL ONLY**

I am aware of and agree to follow the policies and procedures in the *2017-18 Bulletin for AP Students and Parents* to maintain the security of the exam and the validity of my AP score. I understand and accept that my exam score may be canceled if I do not follow these policies and procedures, if I disregard any exam day instructions, or if my exam is administered improperly. I certify that I am the person whose information appears on this answer sheet.

A. SIGNATURE Sign your legal name as it will appear on your college applications. Date

B. LEGAL NAME Omit apostrophes, Jr., II.

Legal Last Name — First 15 Letters | Legal First Name — First 12 Letters | MI

C. YOUR AP NUMBER

D. EXAM DATE Month Day

E. EXAM START TIME AM PM: 6 12, 7 1, 8 2, 9 3, 10 4, 11 5

F. MULTIPLE-CHOICE BOOKLET SERIAL NUMBER S

G. ONLINE PROVIDER CODE

COMPLETE THIS AREA ONLY ONCE.

I. AREA CODE AND PHONE NUMBER

INTERNATIONAL PHONE

J. SCHOOL YOU ATTEND

SCHOOL CODE | School Name | City | State | Country

K. DATE OF BIRTH

Month: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec | Day | Year

L. SOCIAL SECURITY NUMBER (Optional)

M. COLLEGE TO RECEIVE YOUR AP SCORE REPORT

COLLEGE CODE

Using the college code listed in the AP Student Pack, indicate the **ONE** college that you want to receive your AP score report.

College Name | City | State | Country

N. CURRENT GRADE LEVEL

Not yet in 9th grade | 9th | 10th | 11th | 12th | No longer in high school

O. STUDENT SEARCH SERVICE®

Colleges and scholarship programs may request your information to inform you of educational opportunities and financial aid.

Would you like us to supply your information?

Yes No

If you don't answer and previously chose to participate in this service, we will continue providing your information.

H. AP EXAM I AM TAKING USING THIS ANSWER SHEET Exam Name: Form: Form Code:

801356

SCHOOL USE ONLY

Section Number: 1 2 3 4 5 6 7 8 9

Fee Reduction Granted: 1 Option 1 2 Option 2

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PAGE 2

COMPLETE THIS AREA AT EACH EXAM (IF APPLICABLE).

P. SURVEY QUESTIONS — Answer the survey questions in the AP Student Pack. Do not put responses to exam questions in this section.

1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	4 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	7 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	5 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	8 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ
3 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	6 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ	9 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ Ⓖ Ⓗ Ⓘ

Q. LANGUAGE — Do not complete this section unless instructed to do so.

If this answer sheet is for the French Language and Culture, German Language and Culture, Italian Language and Culture, Spanish Language and Culture, or Spanish Literature and Culture Exam, please answer the following questions. Your responses will not affect your score.

1. Have you lived or studied for one month or more in a country where the language of the exam you are now taking is spoken?

◯ Yes ◯ No

2. Do you regularly speak or hear the language at home?

◯ Yes ◯ No

QUESTIONS 1–75

Indicate your answers to the exam questions in this section (pages 2 and 3). Mark only one response per question for Questions 1 through 120. If a question has only four answer options, do not mark option E. Answers written in the multiple-choice booklet will not be scored.

COMPLETE MARK ●

EXAMPLES OF INCOMPLETE MARKS

You must use a No. 2 pencil and marks must be complete. Do not use a mechanical pencil. It is very important that you fill in the entire circle darkly and completely. If you change your response, erase as completely as possible. Incomplete marks or erasures may affect your score.

1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	26 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	51 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	27 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	52 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
3 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	28 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	53 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
4 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	29 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	54 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
5 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	30 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	55 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
6 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	31 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	56 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
7 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	32 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	57 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
8 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	33 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	58 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
9 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	34 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	59 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
10 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	35 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	60 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
11 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	36 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	61 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
12 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	37 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	62 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
13 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	38 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	63 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
14 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	39 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	64 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
15 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	40 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	65 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
16 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	41 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	66 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
17 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	42 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	67 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
18 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	43 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	68 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
19 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	44 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	69 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
20 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	45 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	70 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
21 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	46 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	71 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
22 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	47 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	72 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
23 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	48 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	73 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
24 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	49 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	74 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
25 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	50 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	75 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

FOR OFFICIAL USE ONLY

Exam		0 1 2 3 4 5 6 7 8 9
		0 1 2 3 4 5 6 7 8 9
Exam		0 1 2 3 4 5 6 7 8 9
		0 1 2 3 4 5 6 7 8 9

SELECTED MEDIA EXAMS	R	W	O	OTHER EXAMS	R	W	O
PT02				TOTAL			
PT03				Subscore (if applicable)			
PT04				Subscore (if applicable)			

DO NOT WRITE IN THIS AREA

QUESTIONS 76–120

Be sure each mark is dark and completely fills the circle. If a question has only four answer options, do not mark option E.

76	A B C D E	91	A B C D E	106	A B C D E
77	A B C D E	92	A B C D E	107	A B C D E
78	A B C D E	93	A B C D E	108	A B C D E
79	A B C D E	94	A B C D E	109	A B C D E
80	A B C D E	95	A B C D E	110	A B C D E
81	A B C D E	96	A B C D E	111	A B C D E
82	A B C D E	97	A B C D E	112	A B C D E
83	A B C D E	98	A B C D E	113	A B C D E
84	A B C D E	99	A B C D E	114	A B C D E
85	A B C D E	100	A B C D E	115	A B C D E
86	A B C D E	101	A B C D E	116	A B C D E
87	A B C D E	102	A B C D E	117	A B C D E
88	A B C D E	103	A B C D E	118	A B C D E
89	A B C D E	104	A B C D E	119	A B C D E
90	A B C D E	105	A B C D E	120	A B C D E

QUESTIONS 121–126

For Students Taking AP Biology

Write your answer in the boxes at the top of the griddable area and fill in the corresponding circles. Mark only one circle in any column. You will receive credit only if the circles are filled in correctly.

121 122 123 124 125 126

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DO NOT WRITE IN THIS AREA

QUESTIONS 131–142

For Students Taking AP Computer Science Principles, AP Physics 1, or AP Physics 2

Mark two responses per question. You will receive credit only if both correct responses are selected.

131	A B C D	135	A B C D	139	A B C D
132	A B C D	136	A B C D	140	A B C D
133	A B C D	137	A B C D	141	A B C D
134	A B C D	138	A B C D	142	A B C D

COMPLETE THIS AREA ONLY ONCE.

R. YOUR MAILING ADDRESS Use the address abbreviations from your AP Student Pack. Fill in only one circle per column. Indicate a space in your address by leaving a blank box; do not grid that column.

STREET ADDRESS (include street number, street name, apartment number, etc.)

CITY

ZIP OR POSTAL CODE

COUNTRY CODE

STATE

AK HI MI NY VT
AL IA MN OH WA
AR ID MO OK WI
AZ IL MS OR WV
CA IN MT PA WY
CO KS NC RI Puerto Rico
CT KY ND SC
DC LA NE SD AA
DE MA NH TN AE
FL MD NJ TX AP
GA ME NM UT Other
NV VA

S. FOR STUDENTS OUTSIDE THE UNITED STATES ONLY If your address does not fit in the spaces provided in Item R, fill in as many circles as you can, then fill in the circle in Item S and print the remainder of your address in the spaces provided.

Address | City | State or Province | Country | ZIP or Postal Code

U. EMAIL ADDRESS By providing your email address, you are granting the College Board permission to use your email address in accordance with the policies in the *2017-18 Bulletin for AP Students and Parents*.

T. STUDENT IDENTIFIER (Student ID Number)

V. SEX

- Female
- Male

W. WHICH LANGUAGE DO YOU KNOW BEST?

- English
- English and another language about the same
- Another language

X. RACIAL/ETHNIC GROUP

Please answer both questions about Hispanic origin and about race. For the following questions about your identity, Hispanic origins are not races.

(You may mark all that apply.)

a. Are you of Hispanic, Latino, or Spanish origin?

- No, not of Hispanic, Latino, or Spanish origin
- Yes, Cuban
- Yes, Mexican
- Yes, Puerto Rican
- Yes, another Hispanic, Latino, or Spanish origin

b. What is your race?

- American Indian or Alaska Native
- Asian (including Indian subcontinent and Philippines origin)
- Black or African American (including Africa and Afro-Caribbean origin)
- Native Hawaiian or other Pacific Islander
- White (including Middle Eastern origin)

Y. PARENTAL EDUCATION LEVEL

In the first column, indicate the highest level of education of one parent/guardian, and indicate whether this is your mother/female guardian or father/male guardian. Then, if applicable, indicate the highest level of education of your other parent/guardian in the second column, and indicate whether this is your mother/female guardian or father/male guardian.

- **Mother or female guardian**
- **Father or male guardian**

- Grade school
- Some high school
- High school diploma or equivalent
- Vocational or trade school
- Some college
- Associate or two-year degree
- Bachelor's or four-year degree
- Some graduate or professional school
- Graduate or professional degree

AP® Computer Science Principles Exam

Multiple Choice

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
2 hours
Number of Questions
74
Percent of Total Score
60%
Writing Instrument
Pencil required
Electronic Device
None allowed

Instructions

Exam reference materials are located at the front of this booklet.

This exam contains 74 multiple-choice questions. Indicate all of your answers to the multiple-choice questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work.

For questions 1 through 66, select the single best answer choice for each question. After you have decided which of the choices is best, fill in the appropriate letter in the corresponding space on the answer sheet.

For questions 131 through 138, select the two best answer choices for each question. After you have decided which two of the choices are best, enter both letters in the corresponding space on the answer sheet.

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all of the multiple-choice questions.

Your total score on the exam is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

COMPUTER SCIENCE PRINCIPLES

Time—2 Hours

Number of Questions—74

Programming reference materials are included on the following pages. As AP Computer Science Principles does not designate any particular programming language, these reference materials provide instructions and explanations to help you understand the format and meaning of the questions you will see on the exam. The reference materials include two programming formats, text-based and block-based.

Programming instructions use four data types: numbers, Booleans, strings, and lists.

Instructions from any of the following categories may appear on the exam:

- Assignment, Display, and Input
- Arithmetic Operators and Numeric Procedures
- Relational and Boolean Operators
- Selection
- Iteration
- List Operations
- Procedures
- Robot

GO ON TO THE NEXT PAGE.

REFERENCE MATERIALS

Instruction	Explanation
Assignment, Display, and Input	
Text: `a ← expression` Block: `a ← expression`	Evaluates `expression` and assigns the result to the variable `a`.

Text:
`DISPLAY (expression)`
 	
Block:
`DISPLAY expression`
	Displays the value of `expression`, followed by a space.

Text:
`INPUT ()`
 	
Block:
`INPUT`
	Accepts a value from the user and returns it.

Arithmetic Operators and Numeric Procedures	

Text and Block:
`a + b`
`a - b`
`a * b`
`a / b`
	The arithmetic operators `+`, `-`, `*`, and `/` are used to perform arithmetic on `a` and `b`.
	
	For example, `3 / 2` evaluates to `1.5`.

Text and Block: `a MOD b`	Evaluates to the remainder when `a` is divided by `b`. Assume that `a` and `b` are positive integers. For example, `17 MOD 5` evaluates to `2`.

Text:
`RANDOM (a, b)`
 	
Block:
`RANDOM a, b`
	Evaluates to a random integer from `a` to `b`, including `a` and `b`.
	
	For example, `RANDOM (1, 3)` could evaluate to `1`, `2`, or `3`.

Relational and Boolean Operators	

Text and Block:
`a = b`
`a ≠ b`
`a > b`
`a < b`
`a ≥ b`
`a ≤ b`
	The relational operators `=`, `≠`, `>`, `<`, `≥`, and `≤` are used to test the relationship between two variables, expressions, or values.
	
	For example, `a = b` evaluates to `true` if `a` and `b` are equal; otherwise it evaluates to `false`.

Text: `NOT condition` Block: `NOT condition`	Evaluates to `true` if condition is `false`; otherwise evaluates to `false`.
Text: `condition1 AND condition2` Block: `condition1 AND condition2`	Evaluates to `true` if both `condition1` and `condition2` are `true`; otherwise evaluates to `false`.

REFERENCE MATERIALS

Instruction	Explanation
Relational and Boolean Operators (continued)	

Text:
`condition1 OR condition2`
 	
Block:
`condition1` `OR` `condition2`
	Evaluates to `true` if `condition1` is `true` or if `condition2` is `true` or if both `condition1` and `condition2` are `true`; otherwise evaluates to `false`.

Selection	

Text:
`IF (condition)`
`{`
`  <block of statements>`
`}`
 	
Block:
`IF condition`
`  block of statements`
	The code in `block of statements` is executed if the Boolean expression `condition` evaluates to `true`; no action is taken if `condition` evaluates to `false`.

Text:
`IF (condition)`
`{`
`  <first block of statements>`
`}`
`ELSE`
`{`
`  <second block of statements>`
`}`
 	
Block:
`IF condition`
`  first block of statements`
`ELSE`
`  second block of statements`
	The code in `first block of statements` is executed if the Boolean expression `condition` evaluates to `true`; otherwise the code in `second block of statements` is executed.

Iteration	

Text:
`REPEAT n TIMES`
`{`
`  <block of statements>`
`}`
 	
Block:
`REPEAT n TIMES`
`  block of statements`
	The code in `block of statements` is executed `n` times.

Instruction	Explanation
Iteration (continued)	

Text:
`REPEAT UNTIL (condition)`
`{`
`  <block of statements>`
`}`
 	
Block:
`REPEAT UNTIL condition`
`  block of statements`
	The code in `block of statements` is repeated until the Boolean expression `condition` evaluates to `true`.

List Operations	
For all list operations, if a list index is less than 1 or greater than the length of the list, an error message is produced and the program terminates.	

Text:
`list[i]`
 	
Block:
`list [i]`
	Refers to the element of `list` at index `i`. The first element of `list` is at index `1`.

Text:
`list[i] ← list[j]`
 	
Block:
`list [i] ← list [j]`
	Assigns the value of `list[j]` to `list[i]`.

Text: `list ← [value1, value2, value3]` Block: `list ← [value1, value2, value3]`	Assigns `value1`, `value2`, and `value3` to `list[1]`, `list[2]`, and `list[3]`, respectively.

Text:
`FOR EACH item IN list`
`{`
`  <block of statements>`
`}`
 	
Block:
`FOR EACH item IN list`
`  block of statements`
	The variable `item` is assigned the value of each element of `list` sequentially, in order from the first element to the last element. The code in `block of statements` is executed once for each assignment of `item`.

REFERENCE MATERIALS

Instruction	Explanation
List Operations (continued)	
Text: `INSERT (list, i, value)` Block: `INSERT` [`list, i, value`]	Any values in `list` at indices greater than or equal to `i` are shifted to the right. The length of list is increased by 1, and `value` is placed at index `i` in `list`.
Text: `APPEND (list, value)` Block: `APPEND` [`list, value`]	The length of `list` is increased by 1, and `value` is placed at the end of `list`.
Text: `REMOVE (list, i)` Block: `REMOVE` [`list, i`]	Removes the item at index `i` in `list` and shifts to the left any values at indices greater than `i`. The length of `list` is decreased by 1.
Text: `LENGTH (list)` Block: `LENGTH` [`list`]	Evaluates to the number of elements in `list`.
Procedures	

Text:
`PROCEDURE name (parameter1,`
`parameter2, ...)`
`{`
`<instructions>`
`}`
 	
Block:
`PROCEDURE name` [`parameter1,`
`parameter2,...`]
[`instructions`]
	A procedure, `name`, takes zero or more parameters. The procedure contains programming instructions.

Text:
`PROCEDURE name (parameter1,`
`parameter2, ...)`
`{`
`<instructions>`
`RETURN (expression)`
`}`
 	
Block:
`PROCEDURE name` [`parameter1,`
`parameter2,...`]
[`instructions`]
`RETURN` [`expression`]
	A procedure, `name`, takes zero or more parameters. The procedure contains programming instructions and returns the value of `expression`. The `RETURN` statement may appear at any point inside the procedure and causes an immediate return from the procedure back to the calling program.

REFERENCE MATERIALS

Instruction	Explanation
Robot	
If the robot attempts to move to a square that is not open or is beyond the edge of the grid, the robot will stay in its current location and the program will terminate.	

Text:
`MOVE_FORWARD ()`
 	
Block:
`MOVE_FORWARD`
	The robot moves one square forward in the direction it is facing.

Text:
`ROTATE_LEFT ()`
 	
Block:
`ROTATE_LEFT`
	The robot rotates in place 90 degrees counterclockwise (i.e., makes an in-place left turn).

Text:
`ROTATE_RIGHT ()`
 	
Block:
`ROTATE_RIGHT`
	The robot rotates in place 90 degrees clockwise (i.e., makes an in-place right turn).

Text:
`CAN_MOVE (direction)`
 	
Block:
`CAN_MOVE` `direction`
	Evaluates to `true` if there is an open square one square in the direction relative to where the robot is facing; otherwise evaluates to `false`. The value of direction can be `left`, `right`, `forward`, or `backward`.

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

1. The code segment below is intended to swap the values of the variables `first` and `second` using a temporary variable, `temp`.

```
temp ← first
first ← second
<MISSING CODE>
```

Which of the following can be used to replace `<MISSING CODE>` so that the code segment works as intended?

(A) `second ← first`

(B) `second ← temp`

(C) `temp ← first`

(D) `temp ← second`

---

2. A bank customer receives an e-mail from a sender claiming to be a bank employee. The e-mail asks the customer to provide personal information and to call a phone number if he or she has any questions. The customer suspects the e-mail might be a phishing attempt. Which of the following responses is most likely to be a privacy risk for the bank customer?

(A) Calling the bank at its official phone number to ask whether the request for personal information is legitimate

(B) Calling the phone number given in the e-mail and providing the personal information over the phone

(C) Checking that the domain name of the sender's e-mail address is associated with the bank

(D) Conducting a Web search to see if other people have received similar requests for personal information

GO ON TO THE NEXT PAGE.

3. Which of the following would be the best use of citizen science?

(A) An experiment that requires all participants to be working in the same laboratory

(B) An experiment that requires expensive equipment to conduct

(C) An experiment that requires data measurements to be taken in many different locations

(D) An experiment that requires specialized knowledge and training to conduct

---

4. A student is writing a program to model different real-world events using simulations. Which of the following simulations will generate a result that would best be stored using a Boolean variable?

(A) A simulation of flipping a fair coin

(B) A simulation of rolling a fair die (with sides numbered 1 through 6)

(C) A simulation of the temperature in a location over time

(D) A simulation of traffic patterns on a road

GO ON TO THE NEXT PAGE.

5. The ticket prices at a movie theater are given below.

Type of Ticket	Price (in dollars)
Regular	12
Child (ages 12 and below)	9
Senior (ages 60 and above)	9

Additional $5 fee for 3-D movies

A programmer is creating an algorithm to set the value of `ticketPrice` based on the information in the table. The programmer uses the integer variable `age` for the age of the moviegoer. The Boolean variable `is3D` is `true` when the movie is 3-D and `false` otherwise.

Which of the following code segments correctly sets the value of `ticketPrice` ?

(A)

```
ticketPrice ← 12
IF (age ≤ 12) OR (age ≥ 60)
    ticketPrice ← 9
IF (is3D)
    ticketPrice ← 17
```

(B)

```
ticketPrice ← 12
IF (age ≤ 12) OR (age ≥ 60)
    ticketPrice ← 9
ELSE
    ticketPrice ← 17
```

(C)

```
ticketPrice ← 12
IF (age ≤ 12) OR (age ≥ 60)
    ticketPrice ← 9
IF (is3D)
    ticketPrice ← ticketPrice + 5
```

(D)

```
ticketPrice ← 12
IF (age ≤ 12) OR (age ≥ 60)
    ticketPrice ← 9
ELSE
    ticketPrice ← ticketPrice + 5
```

GO ON TO THE NEXT PAGE.

6. Which of the following best describes the role of the Internet Engineering Task Force (IETF) ?

(A) Developing standards and protocols for Internet communication

(B) Preventing copyrighted materials from being illegally distributed online

(C) Preventing malicious software from being distributed online

(D) Verifying the ownership of encrypted keys used in secured messages

---

7. Consider the following program, which uses the variables `start`, `end`, and `current`.

```
start ← 1
end ← 20
current ← 3
start ← current
current ← current + 1
DISPLAY (start)
DISPLAY (current)
```

What is displayed as a result of executing the program?

(A) `1 3`

(B) `3 3`

(C) `3 4`

(D) `4 4`

GO ON TO THE NEXT PAGE.

8. Which of the following best characterizes a high-level programming language?

(A) A language comprised entirely of hardware logic gates

(B) A language in which each instruction corresponds directly to an instruction in a computer's machine code

(C) A language that is easy for a computer to interpret but difficult for humans to interpret

(D) A language that uses multiple abstractions to manage complexity

---

9. A smartphone stores the following data for each photo that is taken using the phone.

- The file name of the photo
- The date and time the photo was taken
- The geographic location where the photo was taken

Assume that all of the photos that have been taken on the phone are accessible. Which of the following can be determined using the photo data described above?

I. The number of photos that were taken at a particular geographic location

II. The number of photos that were taken in the last year

III. The name of the person who took the most recent photo

(A) III only

(B) I and II only

(C) I and III only

(D) I, II, and III

GO ON TO THE NEXT PAGE.

10. Which of the following best describes one of the benefits of using an iterative and incremental process of program development?

(A) It allows programmers to implement algorithmic solutions to otherwise unsolvable problems.

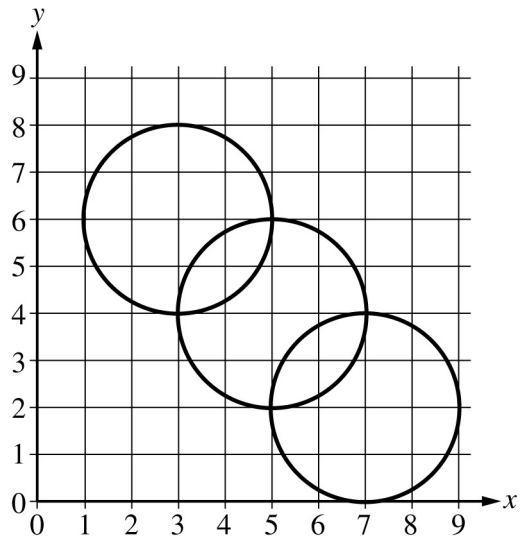
(B) It eliminates the need for programmers to test completed programs.

(C) It enables programmers to create programs that use the lowest-level abstractions available.

(D) It helps programmers identify errors as components are added to a working program.

GO ON TO THE NEXT PAGE.

11. The procedure `DrawCircle (x, y, r)` can be used to draw a circle on a coordinate grid. The circle is centered at the coordinate `(x, y)` and has a radius of `r` units. The procedure will be used to draw the following figure on a coordinate grid.



Which of the following code segments can be used to draw the figure?

(A)
```
xPos ← 3
yPos ← 6
REPEAT 3 TIMES
{
   DrawCircle (xPos, yPos, 2)
   xPos ← xPos + 2
   yPos ← yPos + 2
}
```

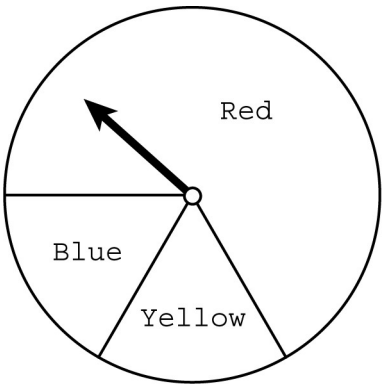
(B)
```
xPos ← 3
yPos ← 6
REPEAT 3 TIMES
{
   DrawCircle (xPos, yPos, 2)
   xPos ← xPos + 2
   yPos ← yPos - 2
}
```

(C)
```
xPos ← 7
yPos ← 2
REPEAT 3 TIMES
{
   DrawCircle (xPos, yPos, 2)
   xPos ← xPos + 2
   yPos ← yPos + 2
}
```

(D)
```
xPos ← 7
yPos ← 2
REPEAT 3 TIMES
{
   DrawCircle (xPos, yPos, 2)
   xPos ← xPos + 2
   yPos ← yPos - 2
}
```

GO ON TO THE NEXT PAGE.

12. A spinner is divided into three sections. The sector labeled `Red` is four times as large as each of the sectors labeled `Blue` and `Yellow`, which are of equal size.



The procedure below is intended to simulate the behavior of the spinner.

```
PROCEDURE Spinner
    <MISSING CODE>
```

Which of the following can be used to replace `<MISSING CODE>` so that the procedure correctly simulates the spinner?

(A)

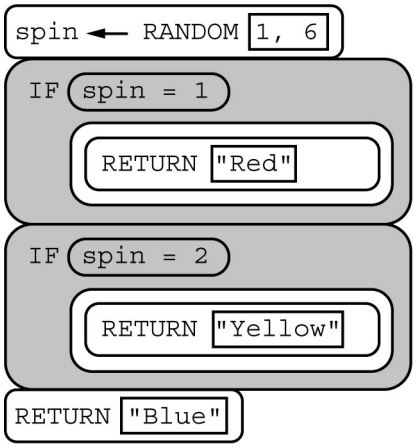
```
spin ← RANDOM [1, 3]
IF (spin = 1)
    RETURN ["Red"]
IF (spin = 2)
    RETURN ["Yellow"]
RETURN ["Blue"]
```

(B)

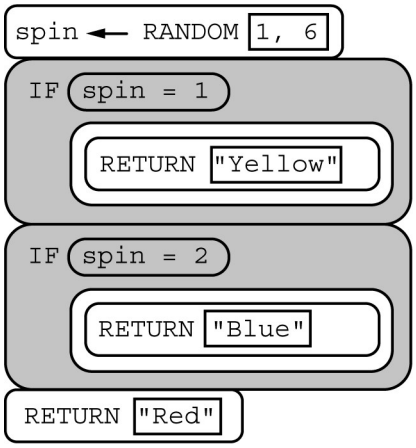
```
spin ← RANDOM [1, 3]
IF (spin = 1)
    RETURN ["Yellow"]
IF (spin = 2)
    RETURN ["Blue"]
RETURN ["Red"]
```

GO ON TO THE NEXT PAGE.

(C)



(D)



GO ON TO THE NEXT PAGE.

Questions 13–14 refer to the information below.

A social media site allows users to send messages to each other. A group of researchers gathered user data for the first 10 years of the site's existence. Some of the data are summarized in the table below, along with some of the company milestones.

Year	Milestone	Total Number of Registered Users (in millions)	Average Number of Active Daily Users (in millions)	Average Number of Daily Messages Sent Per User	Average Number of Characters Per Message
1	Web site launched	25.4	0.8	3.6	360
2		26.0	0.7	3.5	362
3		26.5	0.6	3.5	358
4		26.9	0.6	3.4	360
5	Mobile app released	27.4	0.9	3.3	269
6		28.0	0.9	3.4	242
7		28.6	1.1	3.5	195
8		29.1	1.2	3.5	176
9		29.6	1.1	3.6	104
10		30.2	1.1	3.6	96

13. The researchers noticed that the total number of registered users appears to be increasing at about a constant rate. If this pattern continues, which of the following best approximates the total number of registered users, in millions, in year 12 (two years after the last entry in the table) ?

(A) 30.6

(B) 31.2

(C) 31.8

(D) 32.4

14. Which of the following hypotheses is most consistent with the data in the table?

(A) The mobile app release did not have any effect on the average number of daily messages sent per user.

(B) The mobile app release discouraged new user registration on the site.

(C) The mobile app release led to users being less frequently active on the site.

(D) The mobile app release led to users tending to write shorter messages.

GO ON TO THE NEXT PAGE.

15. Consider the two programs below.

Program A:

```
i ← 1
REPEAT UNTIL (i > 10)
    DISPLAY [i]
    i ← i + 1
```

Program B:

```
i ← 1
REPEAT UNTIL (i > 10)
    i ← i + 1
    DISPLAY [i]
```

Which of the following best compares the values displayed by programs A and B?

(A) Program A and program B display identical values.

(B) Program A and program B display the same values in different orders.

(C) Program A and program B display the same number of values, but the values differ.

(D) Program A and program B display a different number of values.

---

16. Which of the following is a true statement about Internet communication?

(A) Devices from different manufacturers are required to run the same operating system to communicate over the Internet.

(B) Every device connected to the Internet is assigned a digital certificate by a certificate authority.

(C) Every device connected to the Internet is assigned an Internet protocol (IP) address.

(D) Every device connected to the Internet requires a high-bandwidth connection to enable redundant routing to each device.

GO ON TO THE NEXT PAGE.

17. A user reads reviews of a popular artist's new album and then downloads the album from the Web site of a licensed online music seller. Which of the following is LEAST likely to be a consequence of this action?

(A) Advertisements for the artist's other albums will be displayed when the user visits a different Web site.

(B) Album reviews from other people who live nearby will be displayed to the user.

(C) Similar artists will be recommended to the user based on the user's download selection.

(D) The user will be in violation of the Digital Millennium Copyright Act (DMCA).

---

18. Which of the following actions could be used to help reduce the digital divide?

I. Providing free education and training on how to use computing devices

II. Providing free or low-cost computing devices to low-income individuals

III. Providing networks and infrastructure to people in remote areas

(A) III only

(B) I and II only

(C) II and III only

(D) I, II, and III

GO ON TO THE NEXT PAGE.

19. A population researcher is interested in predicting the number of births that will occur in a particular community. She created a computer model that uses data from the past ten years, including number of residents and the number of babies born. The model predicted that there would be 200 births last year, but the actual number of births last year was only 120. Which of the following strategies is LEAST likely to provide a more accurate prediction?

(A) Gathering data for additional years to try to identify patterns in birth rates

(B) Refining the model used in the computer simulation to more closely reflect the data from the past ten years

(C) Removing as many details from the model as possible so that calculations can be performed quickly

(D) Taking into consideration more information about the community, such as the ages of residents

---

20. A library of e-books contains metadata for each book. The metadata are intended to help a search feature find books that users are interested in. Which of the following is LEAST likely to be contained in the metadata of each e-book?

(A) An archive containing previous versions of the e-book

(B) The author and title of the e-book

(C) The date the e-book was first published

(D) The genre of the e-book (e.g., comedy, fantasy, romance, etc.)

GO ON TO THE NEXT PAGE.

21. An application program interface (API) provides a procedure `Max`, which returns the greater of its two integer arguments.

A programmer would like to find the greatest of three integer values `a`, `b`, and `c`. Which of the following expressions will produce the desired result in every case?

(A) `Max (Max (a, b), c)`

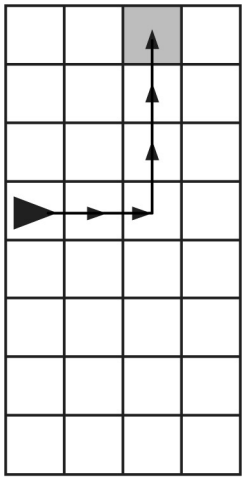
(B) `Max (a, b) - Max (b, c)`

(C) `Max (a, b) + Max (b, c) - Max (a, c)`

(D) `(Max (a, b) + Max (b, c)) / 2`

GO ON TO THE NEXT PAGE.

22. The following question uses a robot in a grid of squares. The robot is represented by a triangle, which is initially facing right.



Consider the procedures below.

```
PROCEDURE MoveXTimes [x]
    REPEAT x TIMES
        MOVE_FORWARD
```

```
PROCEDURE RightXTimes [x]
    REPEAT x TIMES
        ROTATE_RIGHT
```

Which of the following code segments will move the robot to the gray square?

(A)

```
MoveXTimes [2]
RightXTimes [1]
MoveXTimes [3]
```

(B)

```
MoveXTimes [2]
RightXTimes [3]
MoveXTimes [3]
```

(C)

```
MoveXTimes [3]
RightXTimes [1]
MoveXTimes [3]
```

(D)

```
MoveXTimes [3]
RightXTimes [3]
MoveXTimes [3]
```

GO ON TO THE NEXT PAGE.

23. A student is creating a procedure to determine whether the weather for a particular month was considered very hot. The procedure takes as input a list containing daily high temperatures for a particular month. The procedure is intended to return `true` if the daily high temperature was at least 90 degrees for a majority of days in the month and return `false` otherwise.

```
PROCEDURE IsHot (temperatureList)
{
   total ← 0
   counter ← 0
   FOR EACH temperature IN temperatureList
   {
      IF (temperature ≥ 90)
      {
         counter ← counter + 1
      }
      total ← total + 1
   }
   RETURN (<MISSING CODE>)
}
```

Which of the following can be used to replace `<MISSING CODE>` so that the procedure works as intended?

(A) `counter < 0.5 * total`

(B) `counter > 0.5 * total`

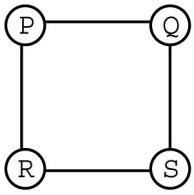
(C) `total < 0.5 * counter`

(D) `total > 0.5 * counter`

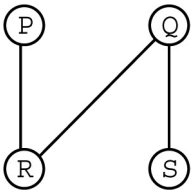
GO ON TO THE NEXT PAGE.

24. The following figures represent different ways of configuring a network of physically linked computers labeled P, Q, R, and S. A line between two computers indicates that the computers can communicate directly with each other. In which configuration is it NOT possible to have redundant routing between computers P and S?

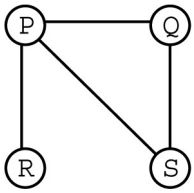
(A)



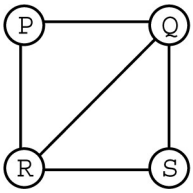
(B)



(C)



(D)



GO ON TO THE NEXT PAGE.

Questions 25–26 refer to the information below.

Byte pair encoding is a data encoding technique. The encoding algorithm looks for pairs of characters that appear in the string more than once and replaces each instance of that pair with a corresponding character that does not appear in the string. The algorithm saves a list containing the mapping of character pairs to their corresponding replacement characters.

For example, the string `"THIS_IS_THE_BEST_WISH"` can be encoded as `"%#_#_%E_BEST_W#H"` by replacing all instances of `"TH"` with `"%"` and replacing all instances of `"IS"` with `"#"`.

25. Which of the following statements about byte pair encoding is true?

    (A) Byte pair encoding is an example of a lossy transformation because it discards some of the data in the original string.

    (B) Byte pair encoding is an example of a lossy transformation because some pairs of characters are replaced by a single character.

    (C) Byte pair encoding is an example of a lossless transformation because an encoded string can be restored to its original version.

    (D) Byte pair encoding is an example of a lossless transformation because it can be used to transmit messages securely.

---

26. For which of the following strings is it NOT possible to use byte pair encoding to shorten the string's length?

    (A) `"BANANA"`

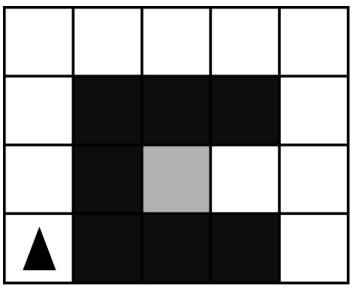
    (B) `"LEVEL_UP"`

    (C) `"MEET_ME_LATER"`

    (D) `"NEITHER_HERE_NOR_THERE"`

GO ON TO THE NEXT PAGE.

27. The grid below contains a robot represented as a triangle, initially facing up. The robot can move into a white or gray square but cannot move into a black region.



The code segment below uses the procedure `GoalReached`, which evaluates to `true` if the robot is in the gray square and evaluates to `false` otherwise.

```
REPEAT UNTIL (GoalReached ())
{
   <MISSING CODE>
}
```

Which of the following replacements for `<MISSING CODE>` can be used to move the robot to the gray square?

(A)
```
IF (CAN_MOVE (right))
{
   ROTATE_RIGHT ()
}
MOVE_FORWARD ()
```

(B)
```
IF (CAN_MOVE (right))
{
   ROTATE_RIGHT ()
   MOVE_FORWARD ()
}
```

(C)
```
IF (CAN_MOVE (forward))
{
   MOVE_FORWARD ()
}
ROTATE_RIGHT ()
```

(D)
```
IF (CAN_MOVE (forward))
{
   MOVE_FORWARD ()
   ROTATE_RIGHT ()
}
```

GO ON TO THE NEXT PAGE.

28. Which of the following allows users to refer to Web sites using names, such as `example.com`, rather than numbers, such as `93.184.216.34` ?

(A) A digital certificate

(B) The domain name system (DNS)

(C) The hypertext transfer protocol (HTTP)

(D) The simple mail transfer protocol (SMTP)

---

29. Which of the following is an underlying assumption that is made when Moore's law is used?

(A) As computer hardware improves, the algorithms used in programs will become more efficient.

(B) As computer hardware improves, developers will become more skilled at writing code.

(C) As computer hardware improves, future computers will be able to run faster than current computers.

(D) As computer hardware improves, the number of cybersecurity concerns will increase.

GO ON TO THE NEXT PAGE.

30. A student wrote the following code for a guessing game.

```
Line 1:  secretNumber ← RANDOM (1, 100)
Line 2:  win ← false
Line 3:  REPEAT UNTIL (win)
Line 4:  {
Line 5:     DISPLAY ("Guess a number.")
Line 6:     guess ← INPUT ()
Line 7:     IF (guess = secretNumber)
Line 8:     {
Line 9:        DISPLAY ("You got it right!")
Line 10:    }
Line 11:    ELSE
Line 12:    {
Line 13:       IF (guess > secretNumber)
Line 14:       {
Line 15:          DISPLAY ("Your guess is too high.")
Line 16:       }
Line 17:       ELSE
Line 18:       {
Line 19:          DISPLAY ("Your guess is too low.")
Line 20:       }
Line 21:    }
Line 22: }
```

While debugging the code, the student realizes that the loop never terminates. The student plans to insert the instruction `win ← true` somewhere in the code. Where could `win ← true` be inserted so that the code segment works as intended?

(A) Between line 6 and line 7

(B) Between line 9 and line 10

(C) Between line 20 and 21

(D) Between line 21 and 22

GO ON TO THE NEXT PAGE.

31. A text-editing application uses binary sequences to represent each of 200 different characters. What is the minimum number of bits needed to assign a unique bit sequence to each of the possible characters?

(A) 4

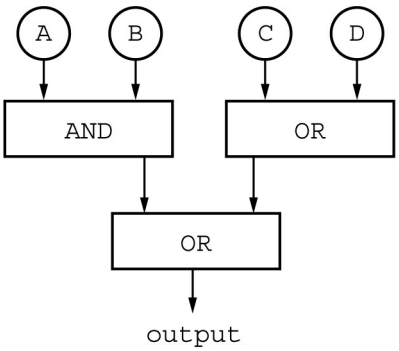
(B) 6

(C) 7

(D) 8

---

32. The diagram below shows a circuit composed of three logic gates. Each gate takes two inputs and produces a single output.



For which of the following input values will the circuit have an output of `false`?

(A) `A = true, B = false, C = false, D = false`

(B) `A = true, B = true, C = false, D = false`

(C) `A = false, B = false, C = true, D = true`

(D) `A = false, B = false, C = false, D = true`

GO ON TO THE NEXT PAGE.

33. A video-streaming service maintains a database of information about its customers and the videos they have watched.

The program below analyzes the data in the database and compares the number of viewers of science fiction videos to the number of viewers of videos of other genres. It uses the procedure `Analysis (category)`, which returns the number of unique users who viewed videos of a given category in the past year. The `Analysis` procedure takes approximately 1 hour to return a result, regardless of the number of videos of the given genre. All other operations happen nearly instantaneously.

```
sciFiFans ← Analysis ("science fiction")
genreList ← ["comedy", "drama", "mystery", "romance"]
FOR EACH genre IN genreList
{
   IF (Analysis (genre) > sciFiFans)
   {
      DISPLAY (genre)
   }
}
```

Which of the following best approximates the amount of time it takes the program to execute?

(A) 1 hour

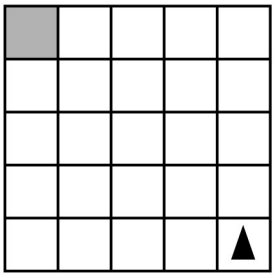
(B) 2 hours

(C) 4 hours

(D) 5 hours

GO ON TO THE NEXT PAGE.

34. The question below uses a robot in a grid of squares. The robot is represented as a triangle, which is initially in the bottom right square of the grid and facing toward the top of the grid.



The following programs are each intended to move the robot to the gray square. Program II uses the procedure `GoalReached`, which returns `true` if the robot is in the gray square and returns `false` otherwise.

Program I:

```
REPEAT 4 TIMES
    MOVE_FORWARD
    ROTATE_LEFT
    MOVE_FORWARD
    ROTATE_RIGHT
```

Program II:

```
REPEAT UNTIL GoalReached
    IF CAN_MOVE forward
        MOVE_FORWARD
    ELSE
        ROTATE_LEFT
```

Which of the following statements is true?

(A) Program I correctly moves the robot to the gray square, but program II does not.

(B) Program II correctly moves the robot to the gray square, but program I does not.

(C) Both program I and program II correctly move the robot to the gray square.

(D) Neither program I nor program II correctly moves the robot to the gray square.

GO ON TO THE NEXT PAGE.

35. A color is often represented by a 6-digit hexadecimal number that describes how the colors red, green, and blue are mixed to create the desired color. From left to right, the first two digits represent the amount of red, the second two digits represent the amount of green, and the last two digits represent the amount of blue. Which of the following hexadecimal numbers represents the color with the greatest amount of blue in it?

(A) 0099A1

(B) A10099

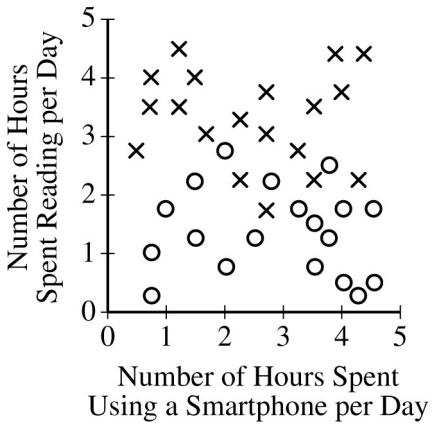
(C) A100B0

(D) FFA100

---

36. Participants in a survey were asked how many hours per day they spend reading, how many hours per day they spend using a smartphone, and whether or not they would be interested in a smartphone application that lets users share book reviews.

The data from the survey are represented in the graph below. Each × represents a survey participant who said he or she was interested in the application, and each O represents a participant who said he or she was not interested.



Which of the following hypotheses is most consistent with the data in the graph?

(A) Participants who read more were generally more likely to say they are interested in the application.

(B) Participants who read more were generally less likely to say they are interested in the application.

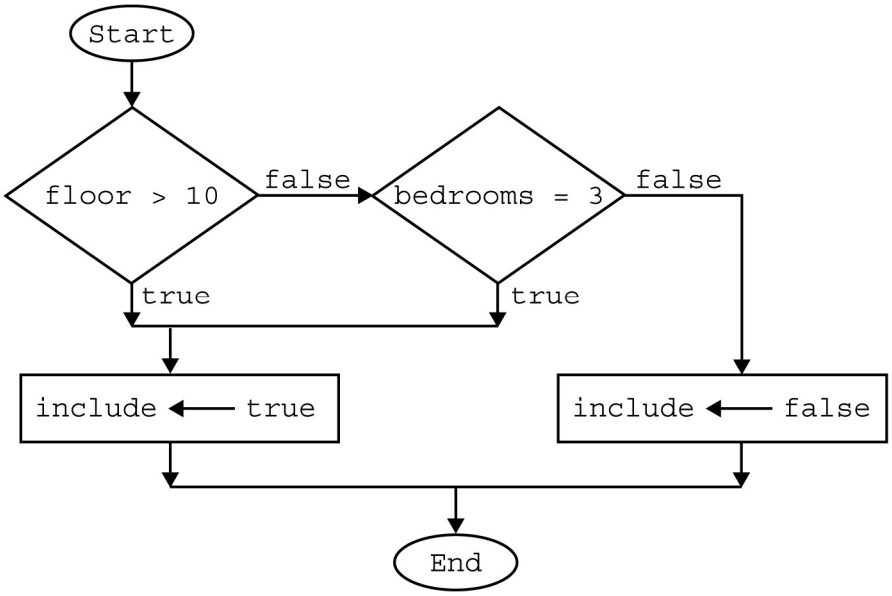
(C) Participants who use a smartphone more were generally more likely to say they read more.

(D) Participants who use a smartphone more were generally less likely to say they read more.

GO ON TO THE NEXT PAGE.

37. A flowchart is a way to visually represent an algorithm. The flowchart below is used by an apartment rental Web site to set the variable `include` to `true` for apartments that meet certain criteria.

Block	Explanation
Oval	The start or end of the algorithm
Diamond	A conditional or decision step, where execution proceeds to the side labeled `true` if the condition is true and to the side labeled `false` otherwise
Rectangle	One or more processing steps, such as a statement that assigns a value to a variable



Which of the following statements is equivalent to the algorithm in the flowchart?

(A) `include ← (floor > 10) OR (bedrooms = 3)`

(B) `include ← (floor > 10) AND (bedrooms = 3)`

(C) `include ← (floor ≤ 10) OR (bedrooms = 3)`

(D) `include ← (floor ≤ 10) AND (bedrooms = 3)`

GO ON TO THE NEXT PAGE.

38. A researcher wrote a program to simulate the number of mice in an environment that contains predators. The program uses the following procedures.

Procedure Call	Explanation
`InitialMousePopulation ()`	Returns the number of mice at the start of the simulation
`InitialPredatorPopulation ()`	Returns the number of predators at the start of the simulation
`NextDayPopulation (numberOfMice, numberOfPredators)`	Based on the current numbers of mice and predators, returns the number of mice after one day

Code for the simulation is shown below.

```
days ← 0
numMice ← InitialMousePopulation ()
numPredators ← InitialPredatorPopulation ()
REPEAT UNTIL (days = 365)
{
   numMice ← NextDayPopulation (numMice, numPredators)
   days ← days + 1
}
DISPLAY ("There are")
DISPLAY (numMice)
DISPLAY ("mice after one year.")
```

Based on the code, which of the following assumptions is made in the simulation?

(A) The number of mice increases by 1 each day.

(B) The number of mice does not change from day to day.

(C) The number of predators increases by 1 each day.

(D) The number of predators does not change from day to day.

---

39. The latency of a network connection is most appropriately measured with which of the following units?

(A) Bits per byte

(B) Bits per second

(C) Bytes

(D) Milliseconds

GO ON TO THE NEXT PAGE.

40. A musician is creating a song using audio samples. Which of the following actions will minimize the risk of a copyright violation when creating sample-based music?

(A) Using samples found on popular music-streaming sites

(B) Using samples found on peer-to-peer networks

(C) Using samples from nondigital sound sources (vinyl records, tapes, etc.)

(D) Using samples published with a no-rights-reserved Creative Commons license

---

41. A computer program performs the operation `2 ÷ 3` and represents the result as the value `0.6666667`. Which of the following best explains this result?

(A) An overflow error occurred.

(B) The precision of the result is limited due to the constraints of using a floating-point representation.

(C) The program attempted to execute the operation with the arguments in reverse order.

(D) The program attempted to represent a floating-point number as an integer.

GO ON TO THE NEXT PAGE.

42. The two code segments below are each intended to display the average of the numbers in the list `numList`. Assume that `numList` contains more than one value.

Program I:

```
sum ← 0
FOR EACH num IN numList
    sum ← sum + num
    avg ← sum / LENGTH numList
DISPLAY avg
```

Program II:

```
sum ← 0
FOR EACH num IN numList
    sum ← sum + num
avg ← sum / LENGTH numList
DISPLAY avg
```

Which of the following best describes the two code segments?

(A) Code segment I displays the correct average, but code segment II does not.

(B) Code segment II displays the correct average, but code segment I does not.

(C) Both code segments display the correct average, but code segment I requires more arithmetic operations than code segment II.

(D) Both code segments display the correct average, but code segment II requires more arithmetic operations than code segment I.

GO ON TO THE NEXT PAGE.

43. A snack bar has a frequent customer program in which every 10th purchase is free. Customers are enrolled in the program when they make their first purchase. A programmer is writing a program to implement the frequent customer program. In one code segment, `cost` is set to `0` for every 10th purchase by a given customer. The programmer will use the procedure `GetCount (customerID)`, which returns the total number of purchases a customer has made since enrolling in the frequent customer program, including his or her first purchase.

Which of the following code segments will set `cost` to `0` for every 10th purchase a customer makes after enrolling in the frequent customer program?

(A)
```
count ← GetCount (customerID)
IF (count / 10 = 0)
{
   cost ← 0
}
```

(B)
```
count ← GetCount (customerID)
IF (NOT (count / 10 = 0))
{
   cost ← 0
}
```

(C)
```
count ← GetCount (customerID)
IF (count MOD 10 = 0)
{
   cost ← 0
}
```

(D)
```
count ← GetCount (customerID)
IF (NOT (count MOD 10 = 0))
{
   cost ← 0
}
```

GO ON TO THE NEXT PAGE.

44. Which of the following explains a benefit of using open standards and protocols for Internet communication?

(A) Open standards and protocols allow different manufacturers and developers to build hardware and software that can communicate with hardware and software on the rest of the network.

(B) Open standards and protocols provide ways for users to eliminate the latency of messages they send on the Internet.

(C) Open standards and protocols allow users to freely share or reuse material found on the Internet for noncommercial purposes.

(D) Open standards and protocols prevent developers from releasing software that contains errors.

GO ON TO THE NEXT PAGE.

Questions 45–46 refer to the information below.

Grades in a computer science course are based on total points earned on a midterm exam and a final exam. The teacher provides a way for students to improve their course grades if they receive high scores on the final exam: if a student's final exam score is greater than the student's midterm exam score, the final exam score replaces the midterm exam score in the calculation of total points.

The table below shows two students' scores on the midterm and final exams and the calculated total points each student earns.

Student Name	Midterm Exam Score	Final Exam Score	Total Points Calculation
Khalil	90	80	90 + 80 = 170
Josefina	70	90	90 + 90 = 180

- Khalil does better on the midterm exam than on the final exam, so his original midterm and final exam scores are added to compute his total points.
- Josefina does better on the final exam than on the midterm exam, so her final exam score replaces her midterm exam score in the total points calculation.

GO ON TO THE NEXT PAGE.

45. The teacher has data representing the scores of thousands of students. For each student, the data contain the student name, the midterm exam score, the final exam score, and the result of the total points calculation. Which of the following could be determined from the data?

I. The average total points earned per student

II. The average increase in total points per student as a result of the score replacement policy

III. The proportion of students who improved their total points as a result of the score replacement policy

(A) III only

(B) I and II only

(C) I and III only

(D) I, II, and III

---

46. A programmer is writing a procedure to calculate a student's final grade in the course using the score replacement policy described. The student's exam scores are stored in the variables `midtermExam` and `finalExam`. The procedure `Max (a, b)` returns the larger of `a` and `b`.

Which of the following could be used in the procedure to calculate a student's total points earned in the course and store the result in the variable `adjustedTotal`?

(A) `adjustedTotal ← Max (midtermExam, finalExam)`

(B) `adjustedTotal ← Max (midtermExam, finalExam) + finalExam`

(C) `adjustedTotal ← Max (midtermExam, finalExam) + midtermExam`

(D) `adjustedTotal ← 2 * Max (midtermExam, finalExam)`

GO ON TO THE NEXT PAGE.

47. Internet protocol version 4 (IPv4) represents each IP address as a 32-bit binary number. Internet protocol version 6 (IPv6) represents each IP address as a 128-bit binary number. Which of the following best describes the result of using 128-bit addresses instead of 32-bit addresses?

(A) 4 times as many addresses are available.

(B) 96 times as many addresses are available.

(C) 2^4 times as many addresses are available.

(D) 2^{96} times as many addresses are available.

---

48. An online retailer uses an algorithm to sort a list of n items by price. The table below shows the approximate number of steps the algorithm takes to sort lists of different sizes.

Number of Items	Number of Steps
10	100
20	400
30	900
40	1,600
50	2,500
60	3,600

Based on the values in the table, which of the following best characterizes the algorithm for very large values of n ?

(A) The algorithm runs in reasonable time.

(B) The algorithm runs, but not in reasonable time.

(C) The algorithm attempts to solve an undecidable problem.

(D) The algorithm attempts to find an approximate solution whenever it fails to find an exact solution.

GO ON TO THE NEXT PAGE.

49. A computer program uses 4 bits to represent nonnegative integers. Which of the following statements describe a possible result when the program uses this number representation?

I. The operation `4 + 8` will result in an overflow error.

II. The operation `7 + 10` will result in an overflow error.

III. The operation `12 + 3` will result in an overflow error.

(A) I only

(B) II only

(C) II and III only

(D) I, II, and III

---

50. A `NAND` gate is a type of logic gate that produces an output of `false` only when both of its two inputs are `true`. Otherwise, the gate produces an output of `true`. Which of the following Boolean expressions correctly models a `NAND` gate with inputs `P` and `Q` ?

(A) `(NOT P) AND (NOT Q)`

(B) `(NOT P) AND Q`

(C) `NOT (P AND Q)`

(D) `NOT (P OR Q)`

GO ON TO THE NEXT PAGE.

51. A student wants to create an algorithm that can determine, given any program and program input, whether or not the program will go into an infinite loop for that input.

The problem the student is attempting to solve is considered an undecidable problem. Which of the following is true?

(A) It is possible to create an algorithm that will solve the problem for all programs and inputs, but the algorithm can only be implemented in a low-level programming language.

(B) It is possible to create an algorithm that will solve the problem for all programs and inputs, but the algorithm requires simultaneous execution on multiple CPUs.

(C) It is possible to create an algorithm that will solve the problem for all programs and inputs, but the algorithm will not run in reasonable time.

(D) It is not possible to create an algorithm that will solve the problem for all programs and inputs.

---

52. In public key cryptography, the sender uses the recipient's public key to encrypt a message. Which of the following is needed to decrypt the message?

(A) The sender's public key

(B) The sender's private key

(C) The recipient's public key

(D) The recipient's private key

GO ON TO THE NEXT PAGE.

53. In a certain science experiment, 75 percent of trials are expected to be successful and 25 percent of trials are expected to be unsuccessful. The program below is intended to simulate the results of repeated trials of the experiment.

```
successful ← 0
unsuccessful ← 0
REPEAT 1000 TIMES
{
   IF (<MISSING CODE>)
   {
      successful ← successful + 1
   }
   ELSE
   {
      unsuccessful ← unsuccessful + 1
   }
}
DISPLAY (successful)
DISPLAY ("trials were successful,")
DISPLAY (unsuccessful)
DISPLAY ("trials were unsuccessful.")
```

Which of the following can be used to replace `<MISSING CODE>` so that the simulation works as intended?

(A) `RANDOM (1, 100) = 25`

(B) `RANDOM (1, 100) ≤ 25`

(C) `RANDOM (1, 100) = 75`

(D) `RANDOM (1, 100) ≤ 75`

GO ON TO THE NEXT PAGE.

54. The code segment below is intended to display all multiples of 5 between the values `start` and `end`, inclusive. For example, if `start` has the value `35` and `end` has the value `50`, the code segment should display the values `35`, `40`, `45`, and `50`. Assume that `start` and `end` are multiples of 5 and that `start` is less than `end`.

```
Line 1:  i ← start
Line 2:  REPEAT <MISSING EXPRESSION> TIMES
Line 3:  {
Line 4:     DISPLAY (i)
Line 5:     i ← i + 5
Line 6:  }
```

Which of the following could replace `<MISSING EXPRESSION>` in line 2 so that the code segment works as intended?

(A) `end - start + 1`

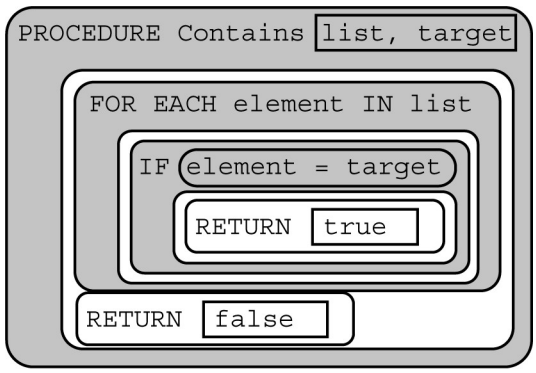
(B) `end - start + 6`

(C) `((end - start) / 5) + 1`

(D) `5 * (end - start) + 1`

GO ON TO THE NEXT PAGE.

55. The procedure below searches for the value `target` in `list`. It returns `true` if `target` is found and returns `false` otherwise.



Which of the following are true statements about the procedure?

I. It implements a binary search.

II. It implements a linear search.

III. It only works as intended when `list` is sorted.

(A) I only

(B) II only

(C) I and III

(D) II and III

GO ON TO THE NEXT PAGE.

56. Which of the following is an example of symmetric encryption?

(A) Evy buys a locked box that operates using two different codes. When the first code is entered, a slot opens that allows a message to be put in the box. When the second code is entered, the door to the box opens. Evy gives the first code to her friends so they can leave messages for her and keeps the second code to herself so that she is the only one who can retrieve the messages.

(B) Finn and Gwen develop a system that maps each letter of the alphabet to a unique symbol using a secret key. Finn uses the key to write a message to Gwen where each letter is replaced with the corresponding symbol. Gwen uses the key to map each symbol back to the original letter.

(C) Hannah writes a message to send to Isabel and hides the message under a rock behind the soccer field. Hannah gives Isabel the exact location of the rock so that only Isabel can find the message.

(D) Juan writes a message to send to Kelly and slides the message through a slot in the front of Kelly's locker. Juan knows that Kelly has not shared her locker combination with anyone, so no one other than Kelly will be able to read the message.

GO ON TO THE NEXT PAGE.

57. A programmer is developing a word game. The programmer wants to create an algorithm that will take a list of words and return a list containing the first letter of all words that are palindromes (words that read the same backward or forward). The returned list should be in alphabetical order. For example, if the list contains the words `["banana", "kayak", "mom", "apple", "level"]`, the returned list would contain `["k", "l", "m"]` (because `"kayak"`, `"level"`, and `"mom"` are palindromes).

The programmer knows that the following steps are necessary for the algorithm but is not sure in which order they should be executed.

Step	Explanation
Shorten	Takes a list of words and returns a new list that contains only the first letter of each word from the input list
Keep palindromes	Takes a list of words and returns a list that contains only the palindromes from the input list
Sort	Takes a list of words and returns a copy of the list in alphabetical order

Executing which of the following sequences of steps will enable the algorithm to work as intended?

I. First shorten, then keep palindromes, then sort

II. First keep palindromes, then shorten, then sort

III. First sort, then keep palindromes, then shorten

(A) I only

(B) II only

(C) I and III

(D) II and III

---

58. Which of the following best describes the purpose of machine learning programs?

(A) To analyze large data sets, recognize patterns, and make predictions based on data

(B) To automatically translate algorithms from natural language to machine language

(C) To determine whether an algorithm can be constructed to answer “yes” or “no” for all possible inputs

(D) To find approximate solutions to problems that would otherwise require an unreasonably long amount of time to solve

GO ON TO THE NEXT PAGE.

59. A programmer notices the following two procedures in a library. The procedures do similar, but not identical, things.

- Procedure `Square (n)` returns the value n^2.
- Procedure `Cube (n)` returns the value n^3.

Which of the following procedures is a generalization of the procedures described above?

(A) Procedure `Add (n, m)`, which returns the value $n + m$

(B) Procedure `Fourth (n)`, which returns the value n^4

(C) Procedure `Polynomial(n)`, which returns the value $n^3 + n^2$

(D) Procedure `Power (n, m)`, which returns the value n^m

---

60. A student wrote the procedure below, which is intended to ask whether a user wants to keep playing a game. The procedure does not work as intended.

```
PROCEDURE KeepPlaying ()
{
   DISPLAY ("Do you want to continue playing (y/n)?")
   response ← INPUT ()
   IF ((response = "y") AND (response = "yes"))
   {
      RETURN (true)
   }
   ELSE
   {
      RETURN (false)
   }
}
```

Which of the following best describes the result of running the procedure?

(A) The procedure returns `true` when the user inputs the value `"y"` and returns `false` otherwise.

(B) The procedure returns `true` when the user inputs the value `"n"` and returns `false` otherwise.

(C) The procedure returns `true` no matter what the input value is.

(D) The procedure returns `false` no matter what the input value is.

GO ON TO THE NEXT PAGE.

61. Which of the following describes a benefit of using hexadecimal numbers instead of binary numbers to represent data?

(A) Hexadecimal can be used to represent fractional values, but binary can only represent integers.

(B) Hexadecimal can be used to represent a wider variety of data types than binary can, including color and geolocation data.

(C) Hexadecimal is easier for a computer to understand than binary is.

(D) A hexadecimal representation of a value generally requires fewer digits than a binary representation of the same value.

---

62. Consider the following program.

```
count ← 1
sum ← 0
REPEAT 10 TIMES
    sum ← sum + count
    count ← count + 2
DISPLAY sum
```

Which of the following describes the result of executing the program?

(A) The program displays the sum of the even integers from 0 to 10.

(B) The program displays the sum of the even integers from 0 to 20.

(C) The program displays the sum of the odd integers from 1 to 9.

(D) The program displays the sum of the odd integers from 1 to 19.

GO ON TO THE NEXT PAGE.

63. Which of the following describes how a distributed denial-of-service (DDoS) attack is most likely to compromise an online store's Web site?

(A) By causing incorrect information about services to be displayed

(B) By making it difficult for the site to safeguard customer login information

(C) By preventing customers from placing orders

(D) By preventing the store from filling previously placed orders

---

64. A program contains the following procedures for string manipulation.

Procedure Call	Explanation
`Concat (str1, str2)`	Returns a single string consisting of `str1` followed by `str2`. For example, `Concat("key", "board")` returns `"keyboard"`.
`Substring (str, start, length)`	Returns a substring of consecutive characters from `str`, starting with the character at position `start` and containing `length` characters. The first character of `str` is located at position `1`. For example, `Substring ("delivery", 3, 4)` returns `"live"`.

Which of the following expressions can be used to generate the string `"Happy"` ?

(A) `Concat (Substring ("Harp", 1, 1), Substring ("Puppy", 2, 4))`

(B) `Concat (Substring ("Harp", 1, 2), Substring ("Puppy", 3, 3))`

(C) `Concat (Substring ("Harp", 1, 2), Substring ("Puppy", 4, 2))`

(D) `Concat (Substring ("Harp", 2, 2), Substring ("Puppy", 4, 2))`

GO ON TO THE NEXT PAGE.

65. Which of the following are true statements about how the Internet enables crowdsourcing?

I. The Internet can provide crowdsourcing participants access to useful tools, information, and professional knowledge.

II. The speed and reach of the Internet can lower geographic barriers, allowing individuals from different locations to contribute to projects.

III. Using the Internet to distribute solutions across many users allows all computational problems to be solved in reasonable time, even for very large input sizes.

(A) I and II only

(B) I and III only

(C) II and III only

(D) I, II, and III

---

66. A media librarian at a movie studio is planning to save digital video files for archival purposes. The movie studio would like to be able to access full-quality videos if they are needed for future projects. Which of the following actions is LEAST likely to support the studio's goal?

(A) Using video file formats that conform to published standards and are supported across many different devices

(B) Using lossy compression software to reduce the size requirements of the data being stored

(C) Using storage media that can be expanded for additional data capacity

(D) Using a system that incorporates redundancy to handle disk failure

GO ON TO THE NEXT PAGE.

Directions: For each of the questions or incomplete statements below, two of the suggested answers are correct. For each of these questions, you must select both correct choices to earn credit. No partial credit will be earned if only one correct choice is selected. Select the two that are best in each case and then fill in the corresponding circles that begin with number 131 on the answer sheet.

131. Which of the following statements accurately describe the hierarchy of the Web pages `example.org` and `about.example.org` ?

Select two answers.

(A) The Web page `about.example.org` is a subdomain of `about.org`.

(B) The Web page `about.example.org` is a subdomain of `example.org`.

(C) The Web page `example.org` is a domain under the top-level domain `.org`.

(D) The Web page `example.org` is a domain under the top-level domain `example`.

---

132. Which of the following are ways in which a programmer can use abstraction to manage the complexity of a program?

Select two answers.

(A) Replacing each instance of repeated code with a call to a procedure

(B) Replacing longer variable names with shorter variable names to reduce typing errors

(C) Replacing several lines of documentation with a single line of documentation

(D) Replacing the string variables `name1`, `name2`, `name3`, and `name4` with a list of strings called `names`

GO ON TO THE NEXT PAGE.

133. Two different schools maintain data sets about their currently enrolled students. No individual student is enrolled at both schools. Each line of data contains information, separated by commas, about one student.

East High School stores the data in the following format.

Data format	**School Name, Last Name, First Name, Age, ZIP Code, Days Absent**
Sample line of data	`East H.S., Ableson, Carlton, 16, 98987, 8`

West High School stores the data in the following format.

Data format	**Student ID, First Name, Last Name, Age, Days Absent**
Sample line of data	`87667721, Kendra, Angelos, 14, 12`

The two schools would like to combine their data to make a single data set. Which of the following can be done with the combined data?

Select two answers.

(A) The schools can create a single list of student names, sorted by last name.

(B) The schools can determine the average number of days students are absent.

(C) The schools can determine which ZIP code is represented by the most students.

(D) The schools can determine the student ID of the student with the greatest number of absences.

---

134. A free online encyclopedia contains articles that can be written and edited by any user. Which of the following are advantages the online encyclopedia has over a traditional paper-based encyclopedia?

Select two answers.

(A) The ability to easily check that the encyclopedia is free of copyrighted content

(B) The ability to ensure that encyclopedia content is the same every time it is accessed

(C) The ability to have a larger number of perspectives reflected in the encyclopedia content

(D) The ability to quickly update encyclopedia content as new information becomes available

GO ON TO THE NEXT PAGE.

135. The program below is intended to count the number of prime numbers in a list called `numbers` and display the result. The program uses the procedure `isPrime (n)`, which returns `true` if `n` is a prime number and `false` otherwise.

The program does not work as intended.

```
Line 1:  count ← 0
Line 2:  FOR EACH value IN numbers
Line 3:  {
Line 4:     count ← 0
Line 5:     IF (isPrime (value))
Line 6:     {
Line 7:        count ← count + 1
Line 8:     }
Line 9:     count ← count + 1
Line 10: }
Line 11: DISPLAY (count)
```

Which two lines of code should be removed so that the program will work as intended?

Select two answers.

(A) Line 1

(B) Line 4

(C) Line 7

(D) Line 9

---

136. Which of the following statements describe how cloud computing has affected Internet communication?

Select two answers.

(A) Cloud computing has eliminated the need to provide redundancy in Internet routing.

(B) Cloud computing has helped enhance collaboration.

(C) Cloud computing has introduced new data-security concerns.

(D) Cloud computing has reduced concerns about intellectual property rights.

GO ON TO THE NEXT PAGE.

137. A program is created to perform arithmetic operations on positive and negative integers. The program contains the following incorrect procedure, which is intended to return the product of the integers `x` and `y`.

```
PROCEDURE Multiply (x, y)
{
   count ← 0
   result ← 0
   REPEAT UNTIL (count = y)
   {
      result ← result + x
      count ← count + 1
   }
   RETURN (result)
}
```

A programmer suspects that an error in the program is caused by this procedure. Under which of the following conditions will the procedure NOT return the correct product?

Select two answers.

(A) When the values of `x` and `y` are both positive.

(B) When the value of `x` is positive and the value of `y` is negative.

(C) When the value of `x` is negative and the value of `y` is positive.

(D) When the values of `x` and `y` are both negative.

GO ON TO THE NEXT PAGE.

138. The procedure `Smallest` is intended to return the least value in the list `numbers`. The procedure does not work as intended.

```
PROCEDURE Smallest (numbers)
{
   min ← numbers[1]
   FOR EACH number IN numbers
   {
      IF (number < min)
      {
         RETURN (number)
      }
   }
   RETURN (min)
}
```

For which of the following values of `theList` will `Smallest (theList)` NOT return the intended value?

Select two answers.

(A) `theList ← [10, 20, 30, 40]`

(B) `theList ← [20, 10, 30, 40]`

(C) `theList ← [30, 40, 20, 10]`

(D) `theList ← [40, 30, 20, 10]`

STOP

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS TEST.

Notes on the AP Computer Science Principles Practice Exam

Introduction

This section provides a description of how the questions in the AP Practice Exam correspond to the components of the course framework included in the *AP Computer Science Principles Course and Exam Description*. For each question in the AP Practice Exam, the enduring understandings, learning objectives, computational thinking practices, and essential knowledge statements from the course framework are indicated. In addition, the correct response is provided along with a justification for why it is correct. There are additional explanations that address why the other responses are incorrect.

The AP Computer Science Principles End-of-Course Exam is 2 hours long and includes 74 multiple-choice questions. There are two types of multiple-choice questions:

- Single-select multiple-choice questions: *Students select one answer from among four options*.
- Multiple-select multiple-choice questions: *Students select two answers from among four options*.

Multiple-choice questions on the exam are classified according to learning objectives within each big idea in the AP Computer Science Principles curriculum framework. The questions on the end-of-course exam may assess achievement of multiple learning objectives. They may also address content from more than one essential knowledge statement. Exam questions may be accompanied by nontextual stimulus material such as diagrams, charts, or other graphical illustrations.

Multiple-Choice Questions

The multiple-choice questions on this exam are designed to elicit evidence of student achievement of the course learning objectives. This includes the application of computational thinking practices and course content as specified in the essential knowledge statements.

Course Framework Alignment and Rationales

Question 1

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.1 Algorithms are precise sequences of instructions for processes that can be executed by a computer and are implemented using programming languages.	**4.1.2** Express an algorithm in a language.	**P5** Communicating	4.1.2A 4.1.2B

(A)	This option is incorrect. The code segment assigns the initial value of `first` to `temp`, then assigns the initial value of `second` to `first`. The initial value of `second`, which has been stored in `first`, is then assigned to `second`. Therefore, the value of `second` has not changed from its initial value.
(B)	**This option is correct.** The code segment assigns the initial value of `first` to `temp`, then assigns the initial value of `second` to `first`. The initial value of `first`, which has been stored in `temp`, is then assigned to `second`. Therefore, the initial values of `first` and `second` have been interchanged.
(C)	This option is incorrect. The code segment never changes the value of `second`.
(D)	This option is incorrect. The code segment never changes the value of `second`.

Question 2

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.3 Cybersecurity is an important concern for the Internet and the systems built on it.	**6.3.1** Identify existing cybersecurity concerns and potential options that address these issues with the Internet and the systems built on it.	**P1** Connecting computing	6.3.1C 6.3.1D 6.3.1F

(A)	This option is incorrect. Contacting the bank at its official phone number would help verify whether or not the e-mail was legitimate.
(B)	**This option is correct.** Providing personal information to a person using an unverified phone number is a privacy risk.
(C)	This option is incorrect. Checking the domain name of the sender's email address would help verify whether or not the e-mail was legitimate.
(D)	This option is incorrect. Performing a Web search would help indicate whether the message is a common phishing scam.

Question 3

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.1 Computing enhances communication, interaction, and cognition.	**7.1.2** Explain how people participate in a problem-solving process that scales.	**P4** Analyzing problems and artifacts	7.1.2A 7.1.2B

(A)	This option is incorrect. If the participants must all be in the same location, there would be no need to use a distributed approach.
(B)	This option is incorrect. Requiring expensive equipment may prevent most members of the general public from participating in the experiment.
(C)	**This option is correct.** If data measurements need to be taken from many locations, it would be beneficial to have participants from around the world collect the data.
(D)	This option is incorrect. Requiring specialized knowledge and training may prevent most members of the general public from participating in the experiment.

Question 4

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.3 Models and simulations use abstraction to generate new understanding and knowledge.	**2.3.1** Use models and simulations to represent phenomena.	**P3** Abstracting	2.1.3A 2.1.3B

(A)	**This option is correct.** There are only two possible results of a coin flip, which can be stored in a Boolean variable as `true` or `false`.
(B)	This option is incorrect. There are six possible results of rolling a die, which is more than can be stored in a Boolean variable.
(C)	This option is incorrect. There are many possible temperature values, which would require each temperature to be stored as a numerical value instead of a Boolean value.
(D)	This option is incorrect. Traffic patterns are too complicated to be stored as a Boolean value.

Question 5

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.1 Algorithms are precise sequences of instructions for processes that can be executed by a computer and are implemented using programming languages.	**4.1.1** Develop an algorithm for implementation in a program.	**P2** Creating computational artifacts	4.1.1A 4.1.1B 4.1.1C

(A)	This option is incorrect. This code segment will set `ticketPrice` to `17` for all 3-D movies, regardless of the age of the purchaser.
(B)	This option is incorrect. This code segment will set `ticketPrice` to `17` for all purchasers between the ages of 12 and 60, regardless of whether or not the movie is 3-D.
(C)	**This option is correct.** This code segment initially sets `ticketPrice` to `12`, and then changes the price to `9` only for children and seniors. The code segment then increases `ticketPrice` by `5` for 3-D movies.
(D)	This option is incorrect. This code segment will set `ticketPrice` to `17` for all purchasers between the ages of 12 and 60, regardless of whether or not the movie is 3-D.

Question 6

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.1 The Internet is a network of autonomous systems.	**6.1.1** Explain the abstractions in the Internet and how the Internet functions.	**P3** Abstracting	6.1.1I

(A)	**This option is correct.** The IETF develops and oversees standards such as hypertext transfer protocol (HTTP), Internet protocol (IP), and simple mail transfer protocol (SMTP).
(B)	This option is incorrect. The IETF does not prevent copyrighted materials from being distributed online.
(C)	This option is incorrect. The IETF does not prevent malware from being distributed online.
(D)	This option is incorrect. The ownership of encrypted keys is verified by certificate authorities, not the IETF.

Question 7

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.2 People write programs to execute algorithms.	**5.2.1** Explain how programs implement algorithms.	**P3** Abstracting	5.2.1B 5.2.1C

(A)	This option is incorrect. The values `1` and `3` are the original values of `start` and `current`, not the final values.
(B)	This option is incorrect. The value `3` is the final value of `start`, but not the final value of `current`.
(C)	**This option is correct.** The code segment initially sets `start` to `1`, `end` to `20`, and `current` to `3`. Next, the code segment sets `start` to the value of `current`, which is `3`. Then `current` is increased from `3` to `4`. The final values of `start` and `current` are `3` and `4`, respectively.
(D)	This option is incorrect. The value `4` is the final value of `current`, but not the final value of `start`.

Question 8

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.2 Multiple levels of abstraction are used to write programs or to create other computational artifacts.	**2.2.3** Identify multiple levels of abstractions being used when writing programs.	**P3** Abstracting	2.2.3A 2.2.3B

(A)	This option is incorrect. Hardware logic gates are low-level abstractions but are not part of high-level programming languages.
(B)	This option is incorrect. Machine languages (in which instructions correspond directly to machine instructions) are not high-level programming languages.
(C)	This option is incorrect. A language that is hard for a human to understand would be considered a low-level language. High-level languages are generally easier for humans to understand.
(D)	**This option is correct.** High-level languages provide abstractions that make it easy for humans to read and write programs without needing to understand the low-level details of how programming instructions are processed by a computer.

Question 9

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.2 Computing facilitates exploration and the discovery of connections in information.	**3.2.1** Extract information from data to discover and explain connections or trends.	**P1** Connecting computing	3.2.1A 3.2.1B 3.2.1C 3.2.1H

(A)	This option is incorrect. The name of the person who took a photo is not captured in the photo data.
(B)	**This option is correct.** The number of photos taken at a particular geographic location can be determined from the geographic data stored with each photo. The number of photos taken in the last year can be determined from the data and time data stored with each photo. The name of the person who took a photo is not captured in the photo data.
(C)	This option is incorrect. The number of photos taken at a particular geographic location can be determined, but the name of the person who took the most recent photo cannot be determined.
(D)	This option is incorrect. The number of photos taken at a particular geographic location and the number of photos that were taken in the last year can be determined, but the name of the person who took the most recent photo cannot be determined.

Question 10

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.1 Programs can be developed for creative expression, to satisfy personal curiosity, to create new knowledge, or to solve problems (to help people, organizations or society).	**5.1.2** Develop a correct program to solve problems.	**P2** Creating computational artifacts	5.1.2A 5.1.2B 5.1.2C 5.1.2J

(A)	This option is incorrect. Unsolvable problems cannot be solved with an algorithm.
(B)	This option is incorrect. Programs that were developed with an iterative and incremental process still typically require testing.
(C)	This option is incorrect. The use of low-level abstractions is unrelated to the development process used.
(D)	**This option is correct.** Incrementally adding code segments to correct, working programs can help programmers identify new errors that are introduced.

Question 11

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.1 Algorithms are precise sequences of instructions for processes that can be executed by a computer and are implemented using programming languages.	**4.1.1** Develop an algorithm for implementation in a program.	**P2** Creating computational artifacts	4.1.1A 4.1.1B 4.1.1D 4.1.1E 4.1.1F

(A)	This option is incorrect. The code segment draws a circle centered at the coordinates (3, 6), then moves to the right and up, drawing circles centered at (5, 8) and (7, 10).
(B)	**This option is correct.** The code segment draws a circle centered at the coordinates (3, 6), then moves to the right and down, drawing circles centered at (5, 4) and (7, 2).
(C)	This option is incorrect. The code segment draws a circle centered at the coordinates (7, 2), then moves to the right and up, drawing circles centered at (9, 4) and (11, 6).
(D)	This option is incorrect. The code segment draws a circle centered at the coordinates (7, 2), then moves to the right and down, drawing circles centered at (9, 0) and (11, –2).

Question 12

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.3 Models and simulations use abstraction to generate new understanding and knowledge.	**2.3.1** Use models and simulations to represent phenomena.	**P3** Abstracting	2.3.1B

(A)	This option is incorrect. The code segment simulates a spinner in which selecting each of three sections is equally likely.
(B)	This option is incorrect. The code segment simulates a spinner in which selecting each of three sections is equally likely.
(C)	This option is incorrect. The code segment selects `"Red"` one-sixth of the time, `"Yellow"` one-sixth of the time, and `"Blue"` the remaining two-thirds of the time.
(D)	**This option is correct.** The code segment selects `"Yellow"` one-sixth of the time, `"Blue"` one-sixth of the time, and `"Red"` the remaining two-thirds of the time.

Question 13

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.1 People use computer programs to process information to gain insight and knowledge.	**3.1.1** Find patterns and test hypotheses about digitally processed information to gain insight and knowledge.	**P4** Analyzing problems and artifacts	3.1.1D 3.1.1E

(A)	This option is incorrect. The approximation 30.6 million would be a better estimate for year 11.
(B)	**This option is correct.** The total number of registered users appears to be increasing by about 0.5 million each year, so in year 12, the number of users can be approximated at 31.2 million (30.2 + 0.5 + 0.5).
(C)	This option is incorrect. The approximation 31.8 million would be a better estimate for year 13.
(D)	This option is incorrect. The approximation 32.4 million would be a better estimate for year 14.

Question 14

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.1 People use computer programs to process information to gain insight and knowledge.	**3.1.1** Find patterns and test hypotheses about digitally processed information to gain insight and knowledge.	**P4** Analyzing problems and artifacts	3.1.1D 3.1.1E

(A)	This option is incorrect. The average number of daily messages sent per user appears to increase after the mobile app was released.
(B)	This option is incorrect. The number of registered users continued to increase after the mobile app was released.
(C)	This option is incorrect. The average number of active daily users appears to increase after the mobile app was released.
(D)	**This option is correct.** The average number of characters per message appears to decrease after the mobile app was released.

Question 15

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.2 People write programs to execute algorithms.	**5.2.1** Explain how programs implement algorithms.	**P3** Abstracting	5.2.1B 5.2.1C

(A)	This option is incorrect. The programs display different values.
(B)	This option is incorrect. The programs display different values.
(C)	**This option is correct.** The programs each display ten values, but each value displayed by program B is one greater than the corresponding value from program A. Program A displays `1 2 3 4 5 6 7 8 9 10` and program B displays `2 3 4 5 6 7 8 9 10 11`.
(D)	This option is incorrect. Both programs display ten values.

Question 16

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.1 The Internet is a network of autonomous systems.	**6.1.1** Explain the abstractions in the Internet and how the Internet functions.	**P3** Abstracting	6.1.1C 6.1.1E 6.1.1F

(A)	This option is incorrect. Devices running different operating systems can communicate over the Internet.
(B)	This option is incorrect. Digital certificates are used to verify encrypted keys. They are not assigned to every device connected to the Internet.
(C)	**This option is correct.** Connecting new devices to the Internet is enabled by assignment of an IP address.
(D)	This option is incorrect. Redundant routing on the Internet is not dependent on the bandwidth of a connection.

Question 17

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.3 Computing has global effects–both beneficial and harmful–on people and society.	**7.3.1** Analyze the beneficial and harmful effects of computing.	**P4** Analyzing problems and artifacts	7.3.1G 7.3.1H 7.3.1M 7.3.1P

(A)	This option is incorrect. Details of a user's browsing history can be stored in cookies, which could be used to deliver targeted advertisements on another Web site.
(B)	This option is incorrect. Geolocation data can be accessed by the Web site, which can use this information to provide album reviews from nearby users.
(C)	This option is incorrect. The user's download history can be used to recommend similar artists based on aggregated data from many users.
(D)	**This option is correct.** If the album was purchased and downloaded through a licensed music store, the user will not be in violation of the DMCA.

Question 18

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.4 Computing innovations influence and are influenced by the economic, social, and cultural contexts in which they are designed and used.	**7.4.1** Explain the connections between computing and real-world contexts, including economic, social, and cultural contexts.	**P1** Connecting computing	7.4.1A 7.4.1B 7.4.1C 7.4.1D

(A)	This option is incorrect. A lack of access to devices contributes to the digital divide. This issue could be addressed by providing free or low-cost devices. Providing networks and infrastructure would address a lack of access to networks which also contributes to the digital divide.
(B)	This option is incorrect. A lack of access to networks contributes to the digital divide. This issue could be addressed by providing networks and infrastructure.
(C)	This option is incorrect. Free education and training would address digital literacy and would reduce the digital divide.
(D)	**This option is correct.** Free education and training would address digital literacy. Providing free or low-cost devices would address a lack of access to devices. Providing networks and infrastructure would address a lack of access to networks.

Question 19

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.3 Models and simulations use abstraction to generate new understanding and knowledge.	**2.3.1** Use models and simulations to represent phenomena.	**P3** Abstracting	2.3.1A 2.3.1C

(A)	This option is incorrect. Gathering additional data may help the simulation to provide a more accurate prediction.
(B)	This option is incorrect. Refining the model used in the simulation may help provide a more accurate prediction.
(C)	**This option is correct.** Removing details from the model may help it run quickly, but is unlikely to provide more accurate results.
(D)	This option is incorrect. Gathering additional data may help the simulation provide a more accurate prediction.

Question 20

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.2 Computing facilitates exploration and the discovery of connections in information.	**3.2.1** Extract information from data to discover and explain connections or trends.	**P1** Connecting computing	3.2.1G 3.2.1H 3.2.1I

(A)	**This option is correct.** Metadata for an e-book would typically be used to provide descriptive information about the book. Previous versions of the e-book would likely be considered data, not metadata.
(B)	This option is incorrect. The author and title of an e-book are examples of descriptive metadata that would help support the search feature.
(C)	This option is incorrect. The date an e-book was published is an example of descriptive metadata that would help support the search feature.
(D)	This option is incorrect. The genre of an e-book is an examples of descriptive metadata that would help support the search feature.

Question 21

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.3 Programming is facilitated by appropriate abstractions.	**5.3.1** Use abstraction to manage complexity in programs.	**P3** Abstracting	5.3.1A 5.3.1B 5.3.1C 5.3.1D 5.3.1E 5.3.1G 5.3.1M 5.3.1N 5.3.1O

(A)	**This option is correct.** This expression will first determine the maximum of `a` and `b` and then determine the maximum of the resulting value and `c`. This will result in the maximum of all three values.
(B)	This option is incorrect. This expression produces the difference between the maximum of `a` and `b` and the maximum of `b` and `c`.
(C)	This option is incorrect. This expression produces the maximum of `a` and `c` subtracted from the sum of the maximum of `a` and `b` and the maximum of `b` and `c`.
(D)	This option is incorrect. This expression produces the average of the maximum of `a` and `b` and the maximum of `b` and `c`.

Question 22

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.3 Programming is facilitated by appropriate abstractions.	**5.3.1** Use abstraction to manage complexity in programs.	**P3** Abstracting	5.3.1A 5.3.1B 5.3.1C 5.3.1D 5.3.1E 5.3.1F 5.3.1G

(A)	This option is incorrect. This code segment moves the robot forward two squares, rotates it right one time so that the robot faces the bottom of the grid, and then moves the robot forward three squares.
(B)	**This option is correct.** This code segment moves the robot forward two squares, rotates it right three times so that the robot faces the top of the grid, and then moves the robot forward three squares to the gray square.
(C)	This option is incorrect. This code segment moves the robot forward three squares, rotates it right one time so that the robot faces the bottom of the grid, and then moves the robot forward three squares.
(D)	This option is incorrect. This code segment moves the robot forward three squares, rotates it right three times so that the robot faces the top of the grid, and then moves the robot forward three squares.

Question 23

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.5 Programming uses mathematical and logical concepts.	**5.5.1** Employ appropriate mathematical and logical concepts in programming.	**P1** Connecting computing	5.3.1A 5.3.1B 5.3.1C 5.3.1D 5.3.1E 5.3.1F 5.3.1G

(A)	This option is incorrect. This Boolean expression evaluates to `true` when `counter` (the number of temperatures greater than or equal to 90) is less than 50% of `total` (the number of entries in the list).
(B)	**This option is correct.** This Boolean expression evaluates to `true` when `counter` (the number of temperatures greater than or equal to 90) is greater than 50% of `total` (the number of entries in the list).
(C)	This option is incorrect. This Boolean expression will never evaluate to `true` because `total` (the number of temperatures in the list) will never be less than 50% of `counter` (the number of temperatures greater than or equal to 90).
(D)	This option is incorrect. This Boolean expression will always evaluate to `true` because `total` (the number of temperatures in the list) will always be greater than 50% of `counter` (the number of temperatures greater than or equal to 90).

Question 24

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.2 Characteristics of the Internet influence the systems built on it.	**6.2.1** Explain characteristics of the Internet and the systems built on it.	**P5** Communicating	6.2.1A 6.2.1D

(A)	This option is incorrect. There are multiple paths from P to S (for example, P to R to S and P to Q to S).
(B)	**This option is correct.** Redundant routing is impossible if there is only one possible path from one device to another. There is only one possible path from P to S (P to R to Q to S).
(C)	This option is incorrect. There are multiple paths from P to S (for example, P to S and P to Q to S).
(D)	This option is incorrect. There are multiple paths from P to S (for example, P to R to S, P to Q to S, P to R to Q to S, and P to Q to R to S).

Question 25

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.3 There are trade-offs when representing information as digital data.	**3.3.1** Analyze how data representation, storage, security, and transmission of data involve computational manipulation of information.	**P4** Analyzing problems and artifacts	3.3.1A 3.3.1C 3.3.1D 3.3.1E

(A)	This option is incorrect. While some of the characters of the original string do not appear in the encoded string, this transformation is not lossy because the original version can be restored.
(B)	This option is incorrect. While some pairs of characters of the original string are replaced in the encoded string with a single character, this transformation is not lossy because the original version can be restored.
(C)	**This option is correct.** The transformation is lossless because an encoded string can be restored to its original version. For example, `"%#_#_%E_BEST_W#H"` can be restored to `"THIS_IS_THE_BEST_WISH"` by replacing all instances of `"%"` with `"TH"` and by replacing all instances of `"#"` with `"IS"`.
(D)	This option is incorrect. Whether a transformation is lossy or lossless is not related to whether or not it can be used in secure communications.

Question 26

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.3 There are trade-offs when representing information as digital data.	**3.3.1** Analyze how data representation, storage, security, and transmission of data involve computational manipulation of information.	**P4** Analyzing problems and artifacts	3.3.1A 3.3.1C 3.3.1D 3.3.1E

(A)	This option is incorrect. This string can be shortened using byte pair encoding. For example, `"BANANA"` can be shortened to `"B**A"` by replacing each instance of `"AN"` with `"*"`.
(B)	**This option is correct.** It is not possible to use byte pair encoding in the string `"LEVEL_UP"` because no pair of characters appears in the string more than once.
(C)	This option is incorrect. This string can be shortened using byte pair encoding. For example, `"MEET_ME_LATER"` can be shortened to `"*ET_*_LATER"` by replacing each instance of `"ME"` with `"*"`.
(D)	This option is incorrect. This string can be shortened using byte pair encoding. For example, `"NEITHER_HERE_NOR_THERE"` can be shortened to `"NEIT*R_*&_NOR_T*&"` by replacing each instance of `"HE"` with `"*"` and each instance of `"RE"` with `"&"`.

Question 27

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.1 Algorithms are precise sequences of instructions for processes that can be executed by a computer and are implemented using programming languages.	**4.1.1** Develop an algorithm for implementation in a program.	**P2** Creating computational artifacts	4.1.1A 4.1.1B 4.1.1C 4.1.1D

(A)	**This option is correct.** This code segment rotates right whenever there is an open square to the right. The robot will move forward from its initial location to the upper-left corner of the grid, then rotate right, then move forward to the upper-right corner of the grid, then rotate right, then move down two squares, then rotate right, then move forward to the gray square.
(B)	This option is incorrect. This code segment does not move the robot at all. The robot cannot move right from its initial position, so the body of the `IF` statement is never executed.
(C)	This option is incorrect. This code segment moves the robot up and down between its initial location and the square above its initial location.
(D)	This option is incorrect. This code segment moves the robot one square forward from its initial location and then rotates the robot right. From there, the robot cannot move forward and the body of the `IF` statement is never executed again.

Question 28

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.1 The Internet is a network of autonomous systems.	**6.1.1** Explain the abstractions in the Internet and how the Internet functions.	**P3** Abstracting	6.1.1G

(A)	This option is incorrect. Digital certificates are used to verify the ownership of encrypted keys.
(B)	**This option is correct.** The domain name system translates names to IP addresses.
(C)	This option is incorrect. The hypertext transfer protocol is a set of rules for transferring files on the Web.
(D)	This option is incorrect. The simple mail transfer protocol is a set of rules for transmitting e-mail.

Question 29

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.2 Computing enables innovation in nearly every field.	**7.2.1** Explain how computing has impacted innovations in other fields.	**P1** Connecting computing	7.2.1F

(A)	This option is incorrect. The efficiency of algorithms is independent of the hardware used to run the algorithms.
(B)	This option is incorrect. The ability of software developers is independent of the hardware used to run the software.
(C)	**This option is correct.** Moore's law assumes that computing power will increase over time.
(D)	This option is incorrect. Cybersecurity concerns are not related to Moore's law.

Question 30

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.4 Programs are developed, maintained, and used by people for different purposes.	**5.4.1** Evaluate the correctness of a program.	**P4** Analyzing problems and artifacts	5.4.1E 5.4.1F 5.4.1I

(A)	This option is incorrect. Inserting `win ← true` between line 6 and line 7 will cause the loop to terminate regardless of whether the guess is correct.
(B)	**This option is correct.** Inserting `win ← true` between line 9 and line 10 will cause the loop to terminate when the guess is correct.
(C)	This option is incorrect. Inserting `win ← true` between line 20 and line 21 will cause the loop to terminate when the guess is incorrect.
(D)	This option is incorrect. Inserting `win ← true` between line 21 and line 22 will cause the loop to terminate after checking the first guess, regardless of whether the guess is correct.

Question 31

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.1 A variety of abstractions built upon binary sequences can be used to represent all digital data.	**2.1.1** Describe the variety of abstractions used to represent data.	**P3** Abstracting	2.1.1B 2.1.1C 2.1.1D 2.1.1E 2.1.1G

(A)	This option is incorrect. Using 4 bits will only allow for up to 16 characters $\left(2^4 = 16\right)$.
(B)	This option is incorrect. Using 6 bits will only allow for up to 64 characters $\left(2^6 = 64\right)$.
(C)	This option is incorrect. Using 7 bits will only allow for up to 128 characters $\left(2^7 = 128\right)$.
(D)	**This option is correct.** Using 8 bits will allow for up to 256 characters $\left(2^8 = 256\right)$.

Question 32

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.2 Multiple levels of abstraction are used to write programs or to create other computational artifacts.	**2.2.3** Identify multiple levels of abstractions being used when writing programs.	**P3** Abstracting	2.2.3E 2.2.3F

(A)	**This option is correct.** With these inputs, the `AND` gate will produce an output of `false` and the first `OR` gate will produce an output of `false`. Since both inputs to the second `OR` gate will be `false`, the circuit will have an output of `false`.
(B)	This option is incorrect. With these inputs, the `AND` gate will produce an output of `true` and the first `OR` gate will produce an output of `false`. The second `OR` gate will have one `true` input and one `false` input, causing the circuit to have an output of `true`.
(C)	This option is incorrect. With these inputs, the `AND` gate will produce an output of `false` and the first `OR` gate will produce an output of `true`. The second `OR` gate will have one `false` input and one `true` input, causing the circuit to have an output of `true`.
(D)	This option is incorrect. With these inputs, the `AND` gate will produce an output of `false` and the first `OR` gate will produce an output of `true`. The second `OR` gate will have one `false` input and one `true` input, causing the circuit to have an output of `true`.

Question 33

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.2 Algorithms can solve many, but not all, computational problems.	**4.2.4** Evaluate algorithms analytically and empirically for efficiency, correctness, and clarity.	**P4** Analyzing problems and artifacts	4.2.4A 4.2.4G

(A)	This option is incorrect. This approximation assumes that the `Analysis` procedure is called only once.
(B)	This option is incorrect. This approximation assumes that the `Analysis` procedure is called only twice.
(C)	This option is incorrect. This approximation assumes that the `Analysis` procedure is called only four times.
(D)	**This option is correct.** Each call to the `Analysis` procedure requires one hour of program execution time. The procedure is called once before the loop, and then four times inside the loop (once for each of the four entries in `genreList`). Therefore, the program will take approximately 5 hours to execute.

Question 34

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.4 Programs are developed, maintained, and used by people for different purposes.	**5.4.1** Evaluate the correctness of a program.	**P4** Analyzing problems and artifacts	5.4.1E 5.4.1F 5.4.1G 5.4.1I 5.4.1K

(A)	This option is incorrect. Program II also correctly moves the robot to the gray square by moving the robot forward to the upper-right corner of the grid, rotating left, and moving forward to the upper-left corner of the grid.
(B)	This option is incorrect. Program I also correctly moves the robot to the gray square by repeatedly moving the robot forward, rotating left, moving forward, and rotating right.
(C)	**This option is correct.** Program I correctly moves the robot to the gray square by repeatedly moving the robot forward, rotating left, moving forward, and rotating right. Program II correctly moves the robot to the gray square by moving the robot forward to the upper-right corner of the grid, rotating left, and moving forward to the upper-left corner of the grid.
(D)	This option is incorrect. Both programs correctly move the robot to the gray square.

Question 35

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.1 A variety of abstractions built upon binary sequences can be used to represent all digital data.	**2.1.1** Describe the variety of abstractions used to represent data.	**P3** Abstracting	2.1.1B 2.1.1C 2.1.1D 2.1.1F

(A)	This option is incorrect. Of the four numbers listed, 0099A1 has the second greatest amount of blue in it.
(B)	This option is incorrect. Of the four numbers listed, A10099 has the third greatest amount of blue in it.
(C)	**This option is correct.** The amount of blue in a color is determined by the last two digits in the hexadecimal number. Of the four numbers listed, A100B0 represents the color with the greatest amount of blue because in hexadecimal, B0 is greater than A1, 99, and 00.
(D)	This option is incorrect. Of the four numbers listed, FFA100 has the least amount of blue in it.

Question 36

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.1 People use computer programs to process information to gain insight and knowledge.	**3.1.1** Find patterns and test hypotheses about digitally processed information to gain insight and knowledge.	**P4** Analyzing problems and artifacts	3.1.1D 3.1.1E

(A)	**This option is correct.** The ×s, indicating participants who are interested in the application, are clustered toward the top of the graph. This indicates that participants who read more were generally more likely to say they are interested in the application.
(B)	This option is incorrect. Participants who read more are more likely, not less likely, to say they are interested in the application.
(C)	This option is incorrect. There does not appear to be any correlation between number of hours spent using a smartphone and number of hours spent reading.
(D)	This option is incorrect. There does not appear to be any correlation between number of hours spent using a smartphone and number of hours spent reading.

Question 37

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.1 Algorithms are precise sequences of instructions for processes that can be executed by a computer and are implemented using programming languages.	**4.1.1** Develop an algorithm for implementation in a program.	**P2** Creating computational artifacts	4.1.1A 4.1.1B 4.1.1C

(A)	**This option is correct.** The flowchart sets `include` to `true` whenever `floor` is greater than `10` or `bedrooms` equals `3`, and sets `include` to `false` otherwise. Therefore, the algorithm is equivalent to `include ← (floor > 10) OR (bedrooms = 3)`.
(B)	This option is incorrect. This expression would be used for a flowchart to set `include` to `true` whenever `floor` is greater than `10` and `bedrooms` equals `3`. This does not correctly set `include` to `true` in cases where only one of the two conditions is `true`.
(C)	This option is incorrect. This expression would be used for a flowchart to set `include` to `true` whenever `floor` is less than or equal to `10` or `bedrooms` equals `3`.
(D)	This option is incorrect. This expression would be used for a flowchart to set `include` to `true` whenever `floor` is less than or equal to `10` and `bedrooms` equals `3`.

Question 38

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.3 Models and simulations use abstraction to generate new understanding and knowledge.	**2.3.2** Use models and simulations to formulate, refine, and test hypotheses.	**P3** Abstracting	2.3.2E

(A)	This option is incorrect. The number of mice changes each day as determined by the `NextDayPopulation` procedure.
(B)	This option is incorrect. The number of mice changes each day as determined by the `NextDayPopulation` procedure.
(C)	This option is incorrect. The number of predators is initialized at the beginning of the program but is never updated.
(D)	**This option is correct.** The number of predators is initialized at the beginning of the program but is never updated.

Question 39

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.2 Characteristics of the Internet influence the systems built on it.	**6.2.2** Explain how the characteristics of the Internet influence the systems built on it.	**P4** Analyzing problems and artifacts	6.2.2K

(A)	This option is incorrect. Bits per byte is not a measure of time.
(B)	This option is incorrect. Bits per second is not a measure of time.
(C)	This option is incorrect. Bytes are not a measure of time.
(D)	**This option is correct.** Latency is a measure of the time elapsed between the transmission and the receipt of a request. Milliseconds are a unit of time that can be used to measure latency.

Question 40

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.2 Computing enables innovation in nearly every field.	**7.2.1** Explain how computing has impacted innovations in other fields.	**P1** Connecting computing	7.2.1D

(A)	This option is incorrect. Using samples from a music-streaming Web site could put the musician at risk of violating copyright laws.
(B)	This option is incorrect. Using samples found on a peer-to-peer network could put the musician at risk of violating copyright laws.
(C)	This option is incorrect. Using samples from nondigital sound sources could put the musician at risk of violating copyright laws.
(D)	**This option is correct.** Creative Commons licenses can be used by creators of digital music to specify how the samples can be used by others. A no-rights-reserved license allows others to freely make use of the samples.

Question 41

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.1 A variety of abstractions built upon binary sequences can be used to represent all digital data.	**2.1.2** Explain how binary sequences are used to represent digital data.	**P5** Communicating	2.1.2A 2.1.2C

(A)	This option is incorrect. Overflow errors occur when an arithmetic operation results in a value outside the range of numbers that can be represented by a certain number of bits.
(B)	**This option is correct.** The fixed number of bits used to represent real numbers (as floating-point numbers) limits the range of floating-point values.
(C)	This option is incorrect. If the operation was performed with the arguments in reverse order, the result would be 1.5.
(D)	This option is incorrect. If the fraction `2 / 3` were to be represented as an integer, it would be rounded or truncated to an integer value.

Question 42

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.2 Algorithms can solve many, but not all, computational problems.	**4.2.4** Evaluate algorithms analytically and empirically for efficiency, correctness, and clarity.	**P4** Analyzing problems and artifacts	4.2.4A 4.2.4C 4.2.4D 4.2.4G

(A)	This option is incorrect. Code segment II also displays the correct average.
(B)	This option is incorrect. Code segment I also displays the correct average.
(C)	**This option is correct.** Both code segments display the correct average. Code segment I requires more arithmetic operations because it performs the operation `sum / LENGTH (numList)` within the loop, while code segment II performs the same operation only once.
(D)	This option is incorrect. Both code segments display the correct average. Code segment I requires more arithmetic operations because it performs the operation `sum / LENGTH (numList)` within the loop, while code segment II performs the same operation only once.

Question 43

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.5 Programming uses mathematical and logical concepts.	**5.5.1** Employ appropriate mathematical and logical concepts in programming.	**P1** Connecting computing	5.5.1A 5.5.1B 5.5.1D

(A)	This option is incorrect. The expression `count / 10 = 0` does not evaluate to `true` when `count` is a multiple of `10`, so this code segment does not set `cost` to `0` appropriately.
(B)	This option is incorrect. The expression `NOT (count / 10 = 0)` does not evaluate to `true` when `count` is a multiple of `10`, so this code segment does not set `cost` to `0` appropriately.
(C)	**This option is correct.** The expression `count MOD 10 = 0` evaluates to `true` when `count` is a multiple of `10`, and so this code segment sets `cost` to `0` under the appropriate conditions.
(D)	This option is incorrect. The expression `NOT (count MOD 10 = 0)` does not evaluate to `true` when `count` is a multiple of `10`, so this code segment does not set `cost` to `0` appropriately.

Question 44

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.2 Characteristics of the Internet influence the systems built on it.	**6.2.2** Explain how the characteristics of the Internet influence the systems built on it.	**P4** Analyzing problems and artifacts	6.2.2D 6.2.2E

(A)	**This option is correct.** Open standards and protocols are used to prescribe the format of data sent over the Internet. This allows all connected hardware and software to communicate in a standard way.
(B)	This option is incorrect. Standards and protocols cannot be used to completely eliminate the latency of messages sent on the Internet.
(C)	This option is incorrect. Open standards and protocols cannot be used to allow copyrighted materials to be shared freely.
(D)	This option is incorrect. Open standards and protocols cannot prevent the release of software containing errors.

Question 45

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.2 Computing facilitates exploration and the discovery of connections in information.	**3.2.1** Extract information from data to discover and explain connections or trends.	**P1** Connecting computing	3.2.1A 3.2.1B

(A)	This option is incorrect. The average total points earned per student can also be determined using the result of the total points calculation for each student. The average increase in total points per student as a result of the score replacement policy can also be determined by calculating the differences between each student score before and after the replacement policy was applied.
(B)	This option is incorrect. The proportion of students who improved their total points as a result of the score replacement policy can also be determined by comparing the midterm and final scores for each student with the result of the total points calculation.
(C)	This option is incorrect. The average increase in total points per student as a result of the score replacement policy can also be determined by calculating the differences between each student score before and after the replacement policy was applied.
(D)	**This option is correct.** The average total points earned per student can be determined using the result of the total points calculation for each student. The average increase in total points per student as a result of the score replacement policy can be determined by calculating the differences between each student score before and after the replacement policy was applied. The proportion of students who improved their total points as a result of the score replacement policy can be determined by comparing the midterm and final scores for each student with the result of the total points calculation.

Question 46

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.5 Programming uses mathematical and logical concepts.	**5.5.1** Employ appropriate mathematical and logical concepts in programming.	**P1** Connecting computing	5.5.1A 5.5.1D

(A)	This option is incorrect. This expression assigns only one score to `adjustedTotal`.
(B)	**This option is correct.** This expression uses the `Max` procedure to replace the midterm score with the higher of the two scores. The selected value is then added to the final exam score and assigned to `adjustedTotal`.
(C)	This option is incorrect. This expression replaces the final exam score (rather than the midterm exam score) with the higher of the two scores.
(D)	This option is incorrect. This expression doubles the higher of the two scores. This produces the same `adjustedTotal` value for Josefina's scores, but not for Khalil's scores.

Question 47

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.1 A variety of abstractions built upon binary sequences can be used to represent all digital data.	**2.1.1** Describe the variety of abstractions used to represent data.	**P3** Abstracting	2.1.1A 2.1.1B 2.1.1E

(A)	This option is incorrect. IPv6 has 2^{96} times as many possible addresses as IPv4.
(B)	This option is incorrect. IPv6 has 2^{96} times as many possible addresses as IPv4.
(C)	This option is incorrect. IPv6 has 2^{96} times as many possible addresses as IPv4.
(D)	**This option is correct.** With 32-bit addressing, IPv4 has 2^{32} possible addresses. With 128-bit addressing, IPv6 has 2^{128} possible addresses. Since $2^{32} \times 2^{96} = 2^{128}$, IPv6 has 2^{96} times as many possible addresses as IPv4.

Question 48

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.2 Algorithms can solve many, but not all, computational problems.	**4.2.1** Explain the difference between algorithms that run in a reasonable time and those that do not run in a reasonable time.	**P1** Connecting computing	4.2.1A 4.2.1B 4.2.1C

(A)	**This option is correct.** The pattern in the table appears to indicate that there are n^2 steps for a list containing n items. This number of steps is a polynomial and therefore the algorithm runs in reasonable time.
(B)	This option is incorrect. The number of steps of the algorithm is a polynomial, so the algorithm runs in reasonable time.
(C)	This option is incorrect. Sorting a list is not considered an undecidable problem.
(D)	This option is incorrect. There is no indication that the algorithm is finding approximate solutions.

Question 49

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.1 A variety of abstractions built upon binary sequences can be used to represent all digital data.	**2.1.2** Explain how binary sequences are used to represent digital data.	**P5** Communicating	2.1.2A 2.1.2B

(A)	This option is incorrect. The operation `4 + 8` does not produce a result large enough to cause an overflow error.
(B)	**This option is correct.** With a 4-bit integer representation, 2^4 values can be represented, which allows for the values between `0` to `15`, inclusive. If an operation results in a value greater than `15`, an overflow error will occur. Of the operations given in the options, only `10 + 7` gives a result larger than `15`.
(C)	This option is incorrect. The operation `10 + 7` causes an overflow error, but `12 + 3` does not produce a result large enough to cause an overflow error.
(D)	This option is incorrect. The operation `10 + 7` causes an overflow error, but the operations `4 + 8` and `12 + 3` do not produce results large enough to cause an overflow error.

Question 50

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.2 Multiple levels of abstraction are used to write programs or to create other computational artifacts.	**2.2.1** Develop an abstraction when writing a program or creating other computational artifacts	**P3** Abstracting	2.2.1A 2.2.1C

(A)	This option is incorrect. The expression `(NOT P) AND (NOT Q)` evaluates to `false` when `P` and `Q` differ in value. A `NAND` gate should only evaluate to `false` when both inputs are `true`.
(B)	This option is incorrect. The expression `(NOT P) AND Q` evaluates to `false` when `P` is `false` and `Q` is `true`. A `NAND` gate should only evaluate to `false` when both inputs are `true`.
(C)	**This option is correct.** The expression `P AND Q` evaluates to `true` when both `P` and `Q` are `true`, and evaluates to `false` otherwise. Therefore, the expression `NOT (P AND Q)` evaluates to `false` when both `P` and `Q` are `true`, and evaluates to `true` otherwise.
(D)	This option is incorrect. The expression `NOT (P or Q)` evaluates to `false` when `P` and `Q` differ in value. A `NAND` gate should only evaluate to `false` when both inputs are `true`.

Question 51

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.2 Algorithms can solve many, but not all, computational problems.	**4.2.3** Explain the existence of undecidable problems in computer science.	**P1** Connecting computing	4.2.3A 4.2.3C

(A)	This option is incorrect. It is not possible to create an algorithm to solve an undecidable problem for all programs and inputs.
(B)	This option is incorrect. It is not possible to create an algorithm to solve an undecidable problem for all programs and inputs.
(C)	This option is incorrect. It is not possible to create an algorithm to solve an undecidable problem for all programs and inputs.
(D)	**This option is correct.** An undecidable problem is one in which no algorithm can be constructed that always leads to a correct yes-or-no answer.

Question 52

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.3 Cybersecurity is an important concern for the Internet and the systems built on it.	**6.3.1** Identify existing cybersecurity concerns and potential options that address these issues with the Internet and the systems built on it.	**P1** Connecting computing	6.3.1H 6.3.1I 6.3.1L

(A)	This option is incorrect. The sender's public key cannot be used to decrypt the message.
(B)	This option is incorrect. The sender's private key cannot be used to decrypt the message.
(C)	This option is incorrect. The recipient's public key cannot be used to decrypt the message.
(D)	**This option is correct.** In public cryptography, a message is encrypted with a recipient's public key and decrypted with the recipient's private key.

Question 53

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.3 Models and simulations use abstraction to generate new understanding and knowledge.	**2.3.1** Use models and simulations to represent phenomena.	**P3** Abstracting	2.3.1A 2.3.1B

(A)	This option is incorrect. This option causes the experiment to be successful when `RANDOM (1, 100)` results in exactly `25`, or 1% of the time.
(B)	This option is incorrect. This option causes the experiment to be successful when `RANDOM (1, 100)` produces a result from `1` to `25`, or 25% of the time.
(C)	This option is incorrect. This option causes the experiment to be successful when `RANDOM (1, 100)` results in exactly `75`, or 1% of the time.
(D)	**This option is correct.** This option causes the experiment to be successful when `RANDOM (1, 100)` produces a result from `1` to `75`, or 75% of the time.

Question 54

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.1 Algorithms are precise sequences of instructions for processes that can be executed by a computer and are implemented using programming languages.	**4.1.1** Develop an algorithm for implementation in a program.	**P2** Creating computational artifacts	4.1.1A 4.1.1B 4.1.1D

(A)	This option is incorrect. For the example given, `end - start + 1` evaluates to `16`. The loop should iterate 4 times, not 16 times.
(B)	This option is incorrect. For the example given, `end - start + 6` evaluates to `21`. The loop should iterate 4 times, not 21 times.
(C)	**This option is correct.** The loop should iterate once for each multiple of 5 from `start` to `end`. The number of multiples of 5 from `start` to `end` is given by `((end - start) / 5) + 1`. For the example given, `((end - start) / 5) + 1` evaluates to `4`.
(D)	This option is incorrect. For the example given, `5 * (end - start) + 1` evaluates to `76`. The loop should iterate 4 times, not 76 times.

Question 55

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.2 Algorithms can solve many, but not all, computational problems.	**4.2.4** Evaluate algorithms analytically and empirically for efficiency, correctness, and clarity.	**P4** Analyzing problems and artifacts	4.2.4H

(A)	This option is incorrect. The procedure does not implement a binary search.
(B)	**This option is correct.** The procedure implements a linear search, which sequentially compares each element of the list with the target value. The list does not need to be sorted because the procedure checks list elements until either the target is found or it reaches the end of the list.
(C)	This option is incorrect. The procedure does not implement a binary search and does not need to be in sorted order to implement a linear search.
(D)	This option is incorrect. The procedure implements a linear search, but the list does not need to be sorted.

Question 56

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.3 Cybersecurity is an important concern for the Internet and the systems built on it.	**6.3.1** Identify existing cybersecurity concerns and potential options that address these issues with the Internet and the systems built on it.	**P1** Connecting computing	6.3.1K

(A)	This option is incorrect. This is an example of an asymmetric system because different codes are used to send and receive messages.
(B)	**This option is correct.** This is an example of symmetric encryption because the secret key is used for both encryption and decryption of messages.
(C)	This option is incorrect. This system does not encrypt messages, it only hides them in a secret location.
(D)	This option is incorrect. This is an example of an asymmetric system because only Kelly knows the key used to receive messages.

Question 57

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.1 Algorithms are precise sequences of instructions for processes that can be executed by a computer and are implemented using programming languages.	**4.1.1** Develop an algorithm for implementation in a program.	**P2** Creating computational artifacts	4.1.1A 4.1.1B

(A)	This option is incorrect. Option I does not work because it performs the "shorten" step before the "keep palindromes" step.
(B)	This option is incorrect. Option II works correctly, but option III works as well.
(C)	This option is incorrect. Option III works correctly, but option I does not. Option I does not work because it performs the "shorten" step before the "keep palindromes" step.
(D)	**This option is correct.** Options II and III perform the steps in a correct order. In order to generate the desired list, the algorithm must perform the "shorten" step after the "keep palindromes" step, otherwise the "keep palindromes" step would not be able to determine whether the original word was a palindrome.

Question 58

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.2 Computing enables innovation in nearly every field.	**7.2.1** Explain how computing has impacted innovations in other fields.	**P1** Connecting computing	7.2.1A

(A)	**This option is correct.** Machine learning is the process of a computer analyzing data in order to make predictions and decisions based on trends in the data.
(B)	This option is incorrect. This option describes the process of using a computer to translate an algorithm to machine code.
(C)	This option is incorrect. This option describes the process of determining whether an algorithm is decidable.
(D)	This option is incorrect. This option describes the process of using a heuristic to find approximate solutions to a problem.

Question 59

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.2 Multiple levels of abstraction are used to write programs or to create other computational artifacts.	**2.2.1** Develop an abstraction when writing a program or creating other computational artifacts.	**P2** Creating computational artifacts	2.2.1A 2.2.1B 2.2.1C

(A)	This option is incorrect. The `Add` procedure does not generalize the `Square` and `Cube` procedures, which are used to calculate a power of `n`.
(B)	This option is incorrect. The `Fourth` procedure calculates a power of `n` (similar to the `square` and `cube` procedures), but it does not generalize this functionality to calculate any power of `n`.
(C)	This option is incorrect. The `Polynomial` procedure calculates the sum of the `Square` and `Cube` procedures, but does not generalize their functionality to calculate any power of `n`.
(D)	**This option is correct.** The procedures square and cube are each used to determine a power of `n`. A generalization of this procedure is `Power (n, m)`, which calculates `n` raised to the `m` power.

Question 60

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.2 Algorithms can solve many, but not all, computational problems.	**4.2.4** Evaluate algorithms analytically and empirically for efficiency, correctness, and clarity.	**P4** Analyzing problems and artifacts	4.2.4C

(A)	This option is incorrect. The procedure always returns `false`.
(B)	This option is incorrect. The procedure always returns `false`.
(C)	This option is incorrect. The procedure always returns `false`.
(D)	**This option is correct.** The expression `((response = "y") AND (response = "yes"))` always evaluates to `false` because it is not possible for the variable `response` to be equal to both `"y"` and `"yes"`. Therefore, the procedure will always return `false`.

Question 61

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
2.1 A variety of abstractions built upon binary sequences can be used to represent all digital data.	**2.1.1** Describe the variety of abstractions used to represent data.	**P3** Abstracting	2.1.1D 2.1.1F

(A)	This option is incorrect. Both binary and hexadecimal numbers can be used to represent fractional values.
(B)	This option is incorrect. Both binary and hexadecimal numbers can be used to represent any type of digital data.
(C)	This option is incorrect. At the lowest level of abstraction, computers use binary numbers to represent digital data.
(D)	**This option is correct.** Each hexadecimal digit can be used to represent up to four bits of data, so hexadecimal representations generally require fewer digits than binary representations.

Question 62

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.2 People write programs to execute algorithms.	**5.2.1** Explain how programs implement algorithms.	**P4** Analyzing problems and artifacts	5.2.1A 5.2.1B 5.2.1C 5.2.1D

(A)	This option is incorrect. The program counts odd integers, not even integers.
(B)	This option is incorrect. The program counts odd integers, not even integers.
(C)	This option is incorrect. The program counts up to 19, not 9.
(D)	**This option is correct.** The value of `count` starts at `1` and increases by twos, so it counts odd integers. The loop iterates 10 times, adding each intermediate value of count each time. Therefore, the program displays the sum of the odd integers starting at 1 and ending at 19.

Question 63

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.3 Cybersecurity is an important concern for the Internet and the systems built on it.	**6.3.1** Identify existing cybersecurity concerns and potential options that address these issues with the Internet and the systems built on it.	**P1** Connecting computing	6.3.1A 6.3.1C 6.3.1E

(A)	This option is incorrect. A successful DDoS attack would make the online store unavailable to users, but wouldn't cause the content of the online store to change.
(B)	This option is incorrect. A successful DDoS attack would make the online store unavailable to users, but wouldn't allow the attacker access to customer login information.
(C)	**This option is correct.** DDoS attacks compromise a target by flooding it with requests from multiple systems. A likely result of a DDoS attack on an online store would be that the online store would be unavailable to customers, preventing them from placing orders.
(D)	This option is incorrect. A successful DDoS attack would make the online store unavailable to users, but the online store could still fill previous orders while the site was down.

Question 64

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.3 Programming is facilitated by appropriate abstractions.	**5.3.1** Use abstraction to manage complexity in programs.	**P3** Abstracting	5.3.1I

(A)	This option is incorrect. This expression returns the string `"Huppy"`.
(B)	**This option is correct.** This expression concatenates the first two letters of `"Harp"` with the last three letters of `"puppy"`, resulting in `"Happy"`.
(C)	This option is incorrect. This expression returns the string `"Hapy"`.
(D)	This option is incorrect. This expression returns the string `"arpy"`.

Question 65

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.1 Computing enhances communication, interaction, and cognition.	**7.1.2** Explain how people participate in a problem-solving process that scales.	**P4** Analyzing problems and artifacts	7.1.2A 7.1.2C 7.1.2D 7.1.2E 7.1.2F

(A)	**This option is correct.** The Internet can provide tools, information, and knowledge to crowdsourcing participants and can lower geographic barriers to potential participants. However, there exist problems that cannot be solved in reasonable time, even with a distributed approach.
(B)	This option is incorrect. The Internet can provide tools, information, and knowledge to crowdsourcing participants. However, there exist problems that cannot be solved in reasonable time, even with a distributed approach.
(C)	This option is incorrect. The Internet can lower geographic barriers to potential participants. However, there exist problems that cannot be solved in reasonable time, even with a distributed approach.
(D)	This option is incorrect. Only statements I and II are correct. Option III is incorrect because there are some problems that cannot be solved in reasonable time.

Question 66

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.3 There are trade-offs when representing information as digital data.	**3.3.1** Analyze how data representation, storage, security, and transmission of data involve computational manipulation of information.	**P4** Analyzing problems and artifacts	3.3.1A 3.3.1C 3.3.1E 3.3.1G 3.3.1H

(A)	This option is incorrect. Using standard video formats would help ensure that the videos are accessible in the future.
(B)	**This option is correct.** Using lossy compression will provide only an approximation of the original video data. The full-quality original versions of the videos will be lost if lossy compression is used.
(C)	This option is incorrect. Using media that allows for additional storage capacity will help ensure that all of the full-quality videos can be archived.
(D)	This option is incorrect. Using redundancy will help ensure that video files are not lost if a storage device fails.

The following questions require the selection of two correct answer choices.

Question 131

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
6.2 Characteristics of the Internet influence the systems built on it.	**6.2.1** Explain characteristics of the Internet and the systems built on it.	**P5** Communicating	6.2.1A 6.2.1B

(A)	This option is incorrect. In the domain name hierarchy, `about.example.org` is not related to `about.org`.
(B)	**This option is correct.** In the domain name hierarchy, `about.example.org` is a subdomain of `example.org`.
(C)	**This option is correct.** In the domain name hierarchy, `example.org` is under the top-level domain `.org`.
(D)	This option is incorrect. The top-level domain associated with `example.org` is `.org`.

Question 132

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.3 Programming is facilitated by appropriate abstractions.	**5.3.1** Use abstraction to manage complexity in programs.	**P3** Abstracting	5.3.1C 5.3.1E 5.3.1L

(A)	**This option is correct.** Placing repeated code with procedure calls is an example of a procedural abstraction that may make it easier for a programmer to manage the complexity of a program.
(B)	This option is incorrect. Using shorter variable names would not help a programmer to manage the complexity of a program. In general, meaningful variable names help programmers better understand programs.
(C)	This option is incorrect. Placing all documentation in a single line does not help a programmer to manage the complexity of a program.
(D)	**This option is correct.** Creating a list of names is an example of a data abstraction that may make it easier for a programmer to manage the complexity of a program.

Question 133

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
3.2 Computing facilitates exploration and the discovery of connections in information.	**3.2.1** Extract information from data to discover and explain connections or trends.	**P1** Connecting computing	3.2.1A 3.2.1B 3.2.1C

(A)	**This option is correct.** It is possible to create a single list of student names, sorted by last name. Both data formats provide the first and last names of each student.
(B)	**This option is correct.** It is possible to determine the average number of days students are absent. Both data formats provide the number of absences for each student.
(C)	This option is incorrect. East High School provides the ZIP code of each student, but West High School does not.
(D)	This option is incorrect. West High School provides a student ID for each student, but East High School does not.

Question 134

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.1 Computing enhances communication, interaction, and cognition.	**7.1.2** Explain how people participate in a problem-solving process that scales.	**P4** Analyzing problems and artifacts	7.1.2D 7.1.2E

(A)	This option is incorrect. As users from around the world add content to the online encyclopedia, it may become difficult to determine whether any of the new content is copyrighted.
(B)	This option is incorrect. As articles can be edited by any user, an article may contain different content when it is accessed at different times.
(C)	**This option is correct.** As any user has the ability to edit articles, there will be many opportunities for people with different perspectives to contribute.
(D)	**This option is correct.** The online encyclopedia can be edited at any time, so it is easy to create or update articles as new information becomes available.

Question 135

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.4 Programs are developed, maintained, and used by people for different purposes.	**5.4.1** Evaluate the correctness of a program.	**P4** Analyzing problems and artifacts	5.4.1E 5.4.1F 5.4.1G

(A)	This option is incorrect. The variable `count` should be set to `0` before the loop so that it starts counting at `1`.
(B)	**This option is correct.** If `count` is set to `0` repeatedly inside the loop, it will not provide an accurate count of the number of prime numbers in the list.
(C)	This option is incorrect. The variable `count` should be incremented within the `IF` statement so that it only increases whenever `value` is prime.
(D)	**This option is correct.** If `count` is incremented outside the `IF` statement, it will increase for all entries in the list instead of just the prime entries.

Question 136

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
7.3 Computing has global effects–both beneficial and harmful–on people and society.	**7.3.1** Analyze the beneficial and harmful effects of computing.	**P4** Analyzing problems and artifacts	7.3.1A 7.3.1G 7.3.1N

(A)	This option is incorrect. Redundant routing provides fault tolerance, which enables a cloud storage site to continue to operate if some part of a network fails.
(B)	**This option is correct.** Cloud computing fosters new ways to communicate and collaborate, allowing users to share files and tools easily.
(C)	**This option is correct.** Cloud computing sites must consider security concerns in order to protect their users' private data.
(D)	This option is incorrect. Cloud storage sites allow users to share files easily, which could lead to increased concerns about copyrighted materials being illegally distributed online.

Question 137

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
5.4 Programs are developed, maintained, and used by people for different purposes.	**5.4.1** Evaluate the correctness of a program.	**P4** Analyzing problems and artifacts	5.4.1G 5.4.1I

(A)	This option is incorrect. If `x` and `y` are both positive, the procedure will correctly calculate the product by adding `x` to itself `y` times.
(B)	**This option is correct.** If `y` is negative, then the condition `count = y` will never be met since `count` begins at `0` and repeatedly increases.
(C)	This option is incorrect. If `x` is negative and `y` is positive, the procedure will correctly calculate the product by adding `x` to itself `y` times.
(D)	**This option is correct.** If `y` is negative, then the condition `count = y` will never be met since `count` begins at `0` and repeatedly increases.

Question 138

Enduring Understanding	Learning Objective	Computational Thinking Practice	Essential Knowledge
4.2 Algorithms can solve many, but not all, computational problems.	**4.2.4** Evaluate algorithms analytically and empirically for efficiency, correctness, and clarity.	**P4** Analyzing problems and artifacts	4.2.4B 4.2.4C

(A)	This option is incorrect. For the list `[10, 20, 30, 40]`, there are no values less than the first number in the list, so the procedure returns the correct value `10`.
(B)	This option is incorrect. For the list `[20, 10, 30, 40]`, `10` is the first value smaller than the first number in the list, so the procedure returns the correct value `10`.
(C)	**This option is correct.** The procedure returns the first number it encounters that is less than the first number in the list. For the list `[30, 40, 20, 10]`, the procedure returns `20`, which is not the least value in the list.
(D)	**This option is correct.** The procedure returns the first number it encounters that is less than the first number in the list. For the list `[40, 30, 20, 10]`, the procedure returns `30`, which is not the least value in the list.