



AP[®] Computer Science A

2016 Free-Response Questions

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2016 AP[®] COMPUTER SCIENCE A FREE-RESPONSE QUESTIONS

COMPUTER SCIENCE A SECTION II

Time—1 hour and 30 minutes

Number of questions—4

Percent of total score—50

Directions: SHOW ALL YOUR WORK. REMEMBER THAT PROGRAM SEGMENTS ARE TO BE WRITTEN IN JAVA.

Notes:

- Assume that the classes listed in the Java Quick Reference have been imported where appropriate.
- Unless otherwise noted in the question, assume that parameters in method calls are not `null` and that methods are called only when their preconditions are satisfied.
- In writing solutions for each question, you may use any of the accessible methods that are listed in classes defined in that question. Writing significant amounts of code that can be replaced by a call to one of these methods will not receive full credit.

1. This question involves the implementation and extension of a `RandomStringChooser` class.

- (a) A `RandomStringChooser` object is constructed from an array of non-null `String` values. When the object is first constructed, all of the strings are considered available. The `RandomStringChooser` class has a `getNext` method, which has the following behavior. A call to `getNext` returns a randomly chosen string from the available strings in the object. Once a particular string has been returned from a call to `getNext`, it is no longer available to be returned from subsequent calls to `getNext`. If no strings are available to be returned, `getNext` returns `"NONE"`.

The following code segment shows an example of the behavior of `RandomStringChooser`.

```
String[] wordArray = {"wheels", "on", "the", "bus"};
RandomStringChooser sChooser = new RandomStringChooser(wordArray);
for (int k = 0; k < 6; k++)
{
    System.out.print(sChooser.getNext() + " ");
}
```

One possible output is shown below. Because `sChooser` has only four strings, the string `"NONE"` is printed twice.

```
bus the wheels on NONE NONE
```

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Write the entire `RandomStringChooser` class. Your implementation must include an appropriate constructor and any necessary methods. Any instance variables must be `private`. The code segment in the example above should have the indicated behavior (that is, it must compile and produce a result like the possible output shown). Neither the constructor nor any of the methods should alter the parameter passed to the constructor, but your implementation may copy the contents of the array.

Part (b) begins on page 4.

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- (b) The following partially completed `RandomLetterChooser` class is a subclass of the `RandomStringChooser` class. You will write the constructor for the `RandomLetterChooser` class.

```
public class RandomLetterChooser extends RandomStringChooser
{
    /** Constructs a random letter chooser using the given string str.
     *   Precondition: str contains only letters.
     */
    public RandomLetterChooser(String str)
    { /* to be implemented in part (b) */ }

    /** Returns an array of single-letter strings.
     *   Each of these strings consists of a single letter from str. Element k
     *   of the returned array contains the single letter at position k of str.
     *   For example, getSingleLetters("cat") returns the
     *   array { "c", "a", "t" }.
     */
    public static String[] getSingleLetters(String str)
    { /* implementation not shown */ }
}
```

The following code segment shows an example of using `RandomLetterChooser`.

```
RandomLetterChooser letterChooser = new RandomLetterChooser("cat");
for (int k = 0; k < 4; k++)
{
    System.out.print(letterChooser.getNext());
}
```

The code segment will print the three letters in "cat" in one of the possible orders. Because there are only three letters in the original string, the code segment prints "NONE" the fourth time through the loop. One possible output is shown below.

actNONE

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Assume that the `RandomStringChooser` class that you wrote in part (a) has been implemented correctly and that `getSingleLetters` works as specified. You must use `getSingleLetters` appropriately to receive full credit.

Complete the `RandomLetterChooser` constructor below.

```
/** Constructs a random letter chooser using the given string str.  
 * Precondition: str contains only letters.  
 */  
public RandomLetterChooser(String str)
```

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2. This question involves two classes that are used to process log messages. A list of sample log messages is given below.

```
CLIENT3:security alert - repeated login failures
Webserver:disk offline
SERVER1:file not found
SERVER2:read error on disk DSK1
SERVER1:write error on disk DSK2
Webserver:error on /dev/disk
```

Log messages have the format *machineId:description*, where *machineId* identifies the computer and *description* describes the event being logged. Exactly one colon (":") appears in a log message. There are no blanks either immediately before or immediately after the colon.

The following `LogMessage` class is used to represent a log message.

```
public class LogMessage
{
    private String machineId;
    private String description;

    /** Precondition: message is a valid log message. */
    public LogMessage(String message)
    { /* to be implemented in part (a) */ }

    /** Returns true if the description in this log message properly contains keyword;
     *      false otherwise.
     */
    public boolean containsWord(String keyword)
    { /* to be implemented in part (b) */ }

    public String getMachineId()
    { return machineId; }

    public String getDescription()
    { return description; }

    // There may be instance variables, constructors, and methods that are not shown.
}
```

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- (a) Write the constructor for the `LogMessage` class. It must initialize the private data of the object so that `getMachineId` returns the *machineId* part of the message and `getDescription` returns the *description* part of the message.

Complete the `LogMessage` constructor below.

```
/** Precondition: message is a valid log message. */  
public LogMessage(String message)
```

Part (b) begins on page 8.

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- (b) Write the `LogMessage` method `containsWord`, which returns `true` if the description in the log message *properly contains* a given keyword and returns `false` otherwise.

A description *properly contains* a keyword if all three of the following conditions are true.

- the keyword is a substring of the description;
- the keyword is either at the beginning of the description or it is immediately preceded by a space;
- the keyword is either at the end of the description or it is immediately followed by a space.

The following tables show several examples. The descriptions in the left table properly contain the keyword `"disk"`. The descriptions in the right table do not properly contain the keyword `"disk"`.

Descriptions that properly contain `"disk"`

<code>"disk"</code>
<code>"error on disk"</code>
<code>"error on /dev/disk disk"</code>
<code>"error on disk DSK1"</code>

Descriptions that do not properly contain `"disk"`

<code>"DISK"</code>
<code>"error on disk3"</code>
<code>"error on /dev/disk"</code>
<code>"diskette"</code>

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Assume that the `LogMessage` constructor works as specified, regardless of what you wrote in part (a).
Complete method `containsWord` below.

```
/** Returns true if the description in this log message properly contains keyword;  
 *      false otherwise.  
 */  
public boolean containsWord(String keyword)
```

Part (c) begins on page 10.

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- (c) The `SystemLog` class represents a list of `LogMessage` objects and provides a method that removes and returns a list of all log messages (if any) that properly contain a given keyword. The messages in the returned list appear in the same order in which they originally appeared in the system log. If no message properly contains the keyword, an empty list is returned. The declaration of the `SystemLog` class is shown below.

```
public class SystemLog
{
    /** Contains all the entries in this system log.
     *  Guaranteed not to be null and to contain only non-null entries.
     */
    private List<LogMessage> messageList;

    /** Removes from the system log all entries whose descriptions properly contain keyword,
     *  and returns a list (possibly empty) containing the removed entries.
     *  Postcondition:
     *  - Entries in the returned list properly contain keyword and
     *    are in the order in which they appeared in the system log.
     *  - The remaining entries in the system log do not properly contain keyword and
     *    are in their original order.
     *  - The returned list is empty if no messages properly contain keyword.
     */
    public List<LogMessage> removeMessages(String keyword)
    { /* to be implemented in part (c) */ }

    // There may be instance variables, constructors, and methods that are not shown.
}
```

Write the `SystemLog` method `removeMessages`, which removes from the system log all entries whose descriptions properly contain `keyword` and returns a list of the removed entries in their original order. For example, assume that `theLog` is a `SystemLog` object initially containing six `LogMessage` objects representing the following list of log messages.

```
CLIENT3:security alert - repeated login failures
Webserver:disk offline
SERVER1:file not found
SERVER2:read error on disk DSK1
SERVER1:write error on disk DSK2
Webserver:error on /dev/disk
```

The call `theLog.removeMessages("disk")` would return a list containing the `LogMessage` objects representing the following log messages.

```
Webserver:disk offline
SERVER2:read error on disk DSK1
SERVER1:write error on disk DSK2
```

After the call, `theLog` would contain the following log messages.

```
CLIENT3:security alert - repeated login failures
SERVER1:file not found
Webserver:error on /dev/disk
```

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Assume that the `LogMessage` class works as specified, regardless of what you wrote in parts (a) and (b). You must use `containsWord` appropriately to receive full credit.

Complete method `removeMessages` below.

```
/** Removes from the system log all entries whose descriptions properly contain keyword,
 * and returns a list (possibly empty) containing the removed entries.
 * Postcondition:
 *   - Entries in the returned list properly contain keyword and
 *     are in the order in which they appeared in the system log.
 *   - The remaining entries in the system log do not properly contain keyword and
 *     are in their original order.
 *   - The returned list is empty if no messages properly contain keyword.
 */
public List<LogMessage> removeMessages(String keyword)
```

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3. A crossword puzzle grid is a two-dimensional rectangular array of black and white squares. Some of the white squares are labeled with a positive number according to the *crossword labeling rule*.

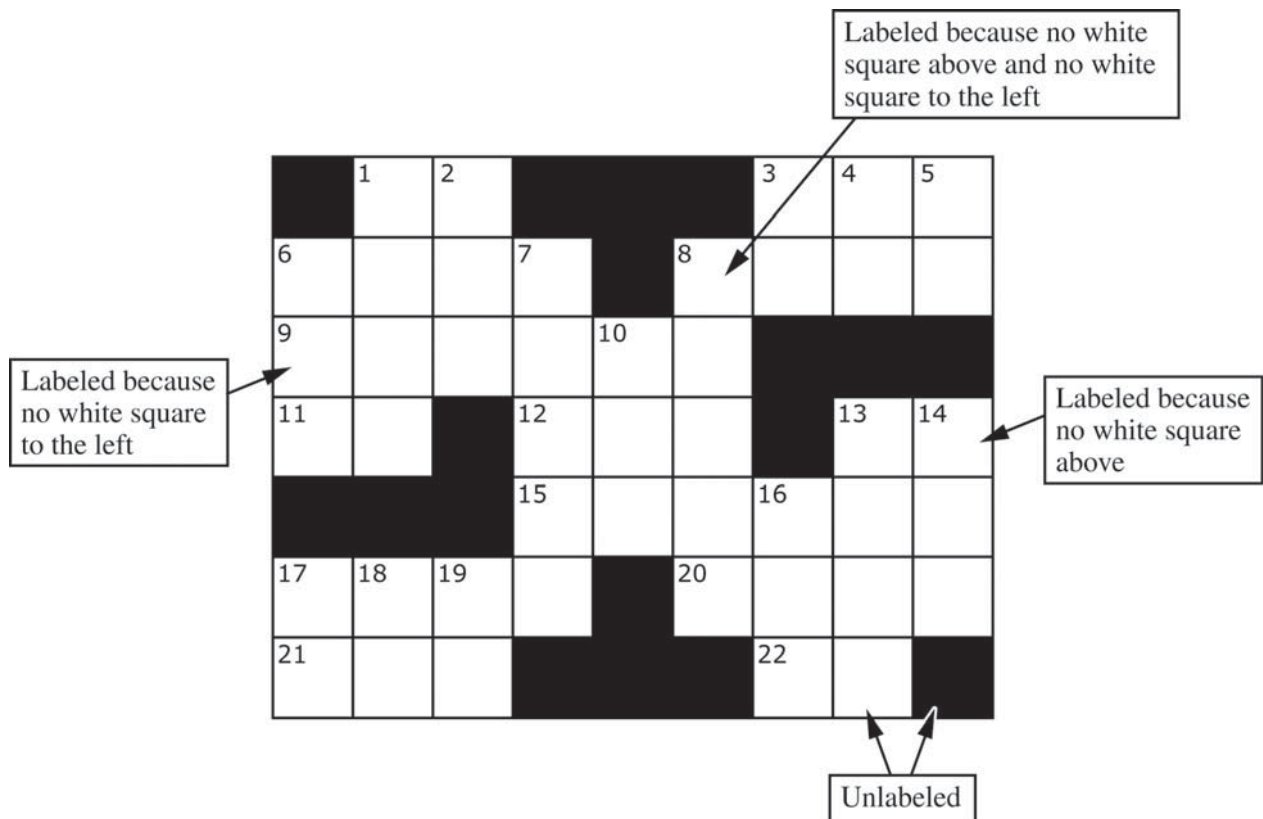
The crossword labeling rule identifies squares to be labeled with a positive number as follows.

A square is labeled with a positive number if and only if

- the square is white and
- the square does not have a white square immediately above it, or it does not have a white square immediately to its left, or both.

The squares identified by these criteria are labeled with consecutive numbers in row-major order, starting at 1.

The following diagram shows a crossword puzzle grid and the labeling of the squares according to the crossword labeling rule.



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This question uses two classes, a `Square` class that represents an individual square in the puzzle and a `Crossword` class that represents a crossword puzzle grid. A partial declaration of the `Square` class is shown below.

```
public class Square
{
    /** Constructs one square of a crossword puzzle grid.
     * Postcondition:
     *     - The square is black if and only if isBlack is true.
     *     - The square has number num.
     */
    public Square(boolean isBlack, int num)
    { /* implementation not shown */ }

    // There may be instance variables, constructors, and methods that are not shown.
}
```

A partial declaration of the `Crossword` class is shown below. You will implement one method and the constructor in the `Crossword` class.

```
public class Crossword
{
    /** Each element is a Square object with a color (black or white) and a number.
     * puzzle[r][c] represents the square in row r, column c.
     * There is at least one row in the puzzle.
     */
    private Square[][] puzzle;

    /** Constructs a crossword puzzle grid.
     * Precondition: There is at least one row in blackSquares.
     * Postcondition:
     *     - The crossword puzzle grid has the same dimensions as blackSquares.
     *     - The Square object at row r, column c in the crossword puzzle grid is black
     *       if and only if blackSquares[r][c] is true.
     *     - The squares in the puzzle are labeled according to the crossword labeling rule.
     */
    public Crossword(boolean[][] blackSquares)
    { /* to be implemented in part (b) */ }

    /** Returns true if the square at row r, column c should be labeled with a positive number;
     *     false otherwise.
     * The square at row r, column c is black if and only if blackSquares[r][c] is true.
     * Precondition: r and c are valid indexes in blackSquares.
     */
    private boolean toBeLabeled(int r, int c, boolean[][] blackSquares)
    { /* to be implemented in part (a) */ }

    // There may be instance variables, constructors, and methods that are not shown.
}
```

Part (a) begins on page 14.

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- (a) Write the `Crossword` method `toBeLabeled`. The method returns `true` if the square indexed by row `r`, column `c` in a crossword puzzle grid should be labeled with a positive number according to the crossword labeling rule; otherwise it returns `false`. The parameter `blackSquares` indicates which squares in the crossword puzzle grid are black.

Class information for this question

```
public class Square
```

```
public Square(boolean isBlack, int num)
```

```
public class Crossword
```

```
private Square[][] puzzle
```

```
public Crossword(boolean[][] blackSquares)
```

```
private boolean toBeLabeled(int r, int c, boolean[][] blackSquares)
```

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Complete method `toBeLabeled` below.

```
/** Returns true if the square at row r, column c should be labeled with a positive number;
 *     false otherwise.
 *     The square at row r, column c is black if and only if blackSquares[r][c] is true.
 *     Precondition: r and c are valid indexes in blackSquares.
 */
private boolean toBeLabeled(int r, int c, boolean[][] blackSquares)
```

Part (b) begins on page 16.

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- (b) Write the `Crossword` constructor. The constructor should initialize the crossword puzzle grid to have the same dimensions as the parameter `blackSquares`. Each element of the puzzle grid should be initialized with a reference to a `Square` object with the appropriate color and number. The number is positive if the square is labeled and 0 if the square is not labeled.

Class information for this question

```
public class Square
```

```
public Square(boolean isBlack, int num)
```

```
public class Crossword
```

```
private Square[][] puzzle
```

```
public Crossword(boolean[][] blackSquares)
```

```
private boolean toBeLabeled(int r, int c, boolean[][] blackSquares)
```

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Assume that `toBeLabeled` works as specified, regardless of what you wrote in part (a). You must use `toBeLabeled` appropriately to receive full credit.

Complete the `Crossword` constructor below.

```
/** Constructs a crossword puzzle grid.
 * Precondition: There is at least one row in blackSquares.
 * Postcondition:
 *   - The crossword puzzle grid has the same dimensions as blackSquares.
 *   - The Square object at row r, column c in the crossword puzzle grid is black
 *     if and only if blackSquares[r][c] is true.
 *   - The squares in the puzzle are labeled according to the crossword labeling rule.
 */
public Crossword(boolean[][] blackSquares)
```

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4. This question involves the process of taking a list of words, called `wordList`, and producing a formatted string of a specified length. The list `wordList` contains at least two words, consisting of letters only.

When the formatted string is constructed, spaces are placed in the gaps between words so that as many spaces as possible are evenly distributed to each gap. The equal number of spaces inserted into each gap is referred to as the *basic gap width*. Any *leftover spaces* are inserted one at a time into the gaps from left to right until there are no more leftover spaces.

The following three examples illustrate these concepts. In each example, the list of words is to be placed into a formatted string of length 20.

Example 1: wordList: ["AP", "COMP", "SCI", "ROCKS"]

Total number of letters in words: 14

Number of gaps between words: 3

Basic gap width: 2

Leftover spaces: 0

Formatted string:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A	P			C	O	M	P			S	C	I			R	O	C	K	S

Example 2: wordList: ["GREEN", "EGGS", "AND", "HAM"]

Total number of letters in words: 15

Number of gaps between words: 3

Basic gap width: 1

Leftover spaces: 2

The leftover spaces are inserted one at a time between the words from left to right until there are no more leftover spaces. In this example, the first two gaps get an extra space.

Formatted string:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
G	R	E	E	N			E	G	G	S			A	N	D		H	A	M

Example 3: wordList: ["BEACH", "BALL"]

Total number of letters in words: 9

Number of gaps between words: 1

Basic gap width: 11

Leftover spaces: 0

Formatted string:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
B	E	A	C	H												B	A	L	L

You will implement three `static` methods in a class named `StringFormatter` that is not shown.

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- (a) Write the `StringFormatter` method `totalLetters`, which returns the total number of letters in the words in its parameter `wordList`. For example, if the variable `List<String> words` is `["A", "frog", "is"]`, then the call `StringFormatter.totalLetters(words)` returns 7. You may assume that all words in `wordList` consist of one or more letters.

Complete method `totalLetters` below.

```
/** Returns the total number of letters in wordList.  
 * Precondition: wordList contains at least two words, consisting of letters only.  
 */  
public static int totalLetters(List<String> wordList)
```

Part (b) begins on page 20.

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- (b) Write the `StringFormatter` method `basicGapWidth`, which returns the basic gap width as defined earlier.

Class information for this question

```
public class StringFormatter  
  
public static int totalLetters(List<String> wordList)  
public static int basicGapWidth(List<String> wordList,  
                                int formattedLen)  
public static int leftoverSpaces(List<String> wordList,  
                                int formattedLen)  
public static String format(List<String> wordList, int formattedLen)
```

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Assume that `totalLetters` works as specified regardless of what you wrote in part (a). You must use `totalLetters` appropriately to receive full credit.

Complete method `basicGapWidth` below.

```
/** Returns the basic gap width when wordList is used to produce
 * a formatted string of formattedLen characters.
 * Precondition: wordList contains at least two words, consisting of letters only.
 * formattedLen is large enough for all the words and gaps.
 */
public static int basicGapWidth(List<String> wordList,
                                int formattedLen)
```

Part (c) begins on page 22.

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- (c) Write the `StringFormatter` method `format`, which returns the formatted string as defined earlier. The `StringFormatter` class also contains a method called `leftoverSpaces`, which has already been implemented. This method returns the number of leftover spaces as defined earlier and is shown below.

```
/** Returns the number of leftover spaces when wordList is used to produce
 * a formatted string of formattedLen characters.
 * Precondition: wordList contains at least two words, consisting of letters only.
 * formattedLen is large enough for all the words and gaps.
 */
public static int leftoverSpaces(List<String> wordList,
                                int formattedLen)
{ /* implementation not shown */ }
```

Class information for this question

```
public class StringFormatter

public static int totalLetters(List<String> wordList)
public static int basicGapWidth(List<String> wordList,
                                int formattedLen)
public static int leftoverSpaces(List<String> wordList,
                                int formattedLen)
public static String format(List<String> wordList, int formattedLen)
```

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Assume that `basicGapWidth` works as specified, regardless of what you wrote in part (b). You must use `basicGapWidth` and `leftoverSpaces` appropriately to receive full credit.

Complete method `format` below.

```
/** Returns a formatted string consisting of the words in wordList separated by spaces.
 * Precondition: The wordList contains at least two words, consisting of letters only.
 * formattedLen is large enough for all the words and gaps.
 * Postcondition: All words in wordList appear in the formatted string.
 * - The words appear in the same order as in wordList.
 * - The number of spaces between words is determined by basicGapWidth and the
 *   distribution of leftoverSpaces from left to right, as described in the question.
 */
public static String format(List<String> wordList, int formattedLen)
```

STOP

END OF EXAM