2023

AP® Computer Science A

Free-Response Questions

COMPUTER SCIENCE A

SECTION II

Time—1 hour and 30 minutes

4 Questions

Directions: SHOW ALL YOUR WORK. REMEMBER THAT PROGRAM SEGMENTS ARE TO BE WRITTEN IN JAVA. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

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.

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1. This question involves the `AppointmentBook` class, which provides methods for students to schedule appointments with their teacher. Appointments can be scheduled during one of eight class periods during the school day, numbered 1 through 8. A requested appointment has a duration, which is the number of minutes the appointment will last. The 60 minutes within a period are numbered 0 through 59. In order for an appointment to be scheduled, the teacher must have a block of consecutive, available minutes that contains at least the requested number of minutes in a requested period. Scheduled appointments must start and end within the same period.

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The `AppointmentBook` class contains two helper methods, `isMinuteFree` and `reserveBlock`. You will write two additional methods of the `AppointmentBook` class.

```
public class AppointmentBook
{
   /**
    *  Returns true if minute in period is available for an appointment and returns
    *  false otherwise
    *  Preconditions: 1 <= period <= 8;  0 <= minute <= 59
    */
   private boolean isMinuteFree(int period, int minute)
   {  /* implementation not shown */  }

   /**
    *  Marks the block of minutes that starts at startMinute in period and
    *  is duration minutes long as reserved for an appointment
    *  Preconditions: 1 <= period <= 8; 0 <= startMinute <= 59;
    *      1 <= duration <= 60
    */
   private void reserveBlock(int period, int startMinute, int duration)
   {  /* implementation not shown */  }

   /**
    *  Searches for the first block of duration free minutes during period, as described in
    *  part (a). Returns the first minute in the block if such a block is found or returns -1 if no
    *  such block is found.
    *  Preconditions: 1 <= period <= 8; 1 <= duration <= 60
    */
   public int findFreeBlock(int period, int duration)
   {  /* to be implemented in part (a) */  }

   /**
    *  Searches periods from startPeriod to endPeriod, inclusive, for a block
    *  of duration free minutes, as described in part (b). If such a block is found,
    *  calls reserveBlock to reserve the block of minutes and returns true; otherwise
    *  returns false.
    *  Preconditions: 1 <= startPeriod <= endPeriod <= 8; 1 <= duration <= 60
    */
   public boolean makeAppointment(int startPeriod, int endPeriod,
                                  int duration)
   {  /* to be implemented in part (b) */  }

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

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(a) Write the `findFreeBlock` method, which searches `period` for the first block of free minutes that is `duration` minutes long. If such a block is found, `findFreeBlock` returns the first minute in the block. Otherwise, `findFreeBlock` returns `-1`. The `findFreeBlock` method uses the helper method `isMinuteFree`, which returns `true` if a particular minute is available to be included in a new appointment and returns `false` if the minute is unavailable.

Consider the following list of unavailable and available minutes in period 2.

Minutes in Period 2	Available?
0–9 (10 minutes)	No
10–14 (5 minutes)	Yes
15–29 (15 minutes)	No
30–44 (15 minutes)	Yes
45–49 (5 minutes)	No
50–59 (10 minutes)	Yes

The method call `findFreeBlock(2, 15)` would return `30` to indicate that a 15-minute block starting with minute `30` is available. No steps should be taken as a result of the call to `findFreeBlock` to mark those 15 minutes as unavailable.

The method call `findFreeBlock(2, 9)` would also return `30`. Whenever there are multiple blocks that satisfy the requirement, the earliest starting minute is returned.

The method call `findFreeBlock(2, 20)` would return `-1`, since no 20-minute block of available minutes exists in period 2.

Complete method `findFreeBlock`. You must use `isMinuteFree` appropriately in order to receive full credit.

```
/**
 *  Searches for the first block of duration free minutes during period, as described in
 *  part (a). Returns the first minute in the block if such a block is found or returns -1 if no
 *  such block is found.
 *  Preconditions: 1 <= period <= 8; 1 <= duration <= 60
 */
public int findFreeBlock(int period, int duration)
```

Begin your response at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number. If there are multiple parts to this question, write the part letter with your response.

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(b) Write the `makeAppointment` method, which searches the periods from `startPeriod` to `endPeriod`, inclusive, for the earliest block of `duration` available minutes in the lowest-numbered period. If such a block is found, the `makeAppointment` method calls the helper method `reserveBlock` to mark the minutes in the block as unavailable and returns `true`. If no such block is found, the `makeAppointment` method returns `false`.

Consider the following list of unavailable and available minutes in periods 2, 3, and 4 and three successive calls to `makeAppointment`.

Period	Minutes	Available?
2	0–24 (25 minutes)	No
2	25–29 (5 minutes)	Yes
2	30–59 (30 minutes)	No
3	0–14 (15 minutes)	Yes
3	15–40 (26 minutes)	No
3	41–59 (19 minutes)	Yes
4	0–4 (5 minutes)	No
4	5–29 (25 minutes)	Yes
4	30–43 (14 minutes)	No
4	44–59 (16 minutes)	Yes

The method call `makeAppointment(2, 4, 22)` returns `true` and results in the minutes 5 through 26, inclusive, in period 4 being marked as unavailable.

The method call `makeAppointment(3, 4, 3)` returns `true` and results in the minutes 0 through 2, inclusive, in period 3 being marked as unavailable.

The method call `makeAppointment(2, 4, 30)` returns `false`, since there is no block of 30 available minutes in periods 2, 3, or 4.

The following shows the updated list of unavailable and available minutes in periods 2, 3, and 4 after the three example method calls are complete.

Period	Minutes	Available?
2	0–24 (25 minutes)	No
2	25–29 (5 minutes)	Yes
2	30–59 (30 minutes)	No
3	0–2 (3 minutes)	No
3	3–14 (12 minutes)	Yes
3	15–40 (26 minutes)	No
3	41–59 (19 minutes)	Yes
4	0–26 (27 minutes)	No
4	27–29 (3 minutes)	Yes
4	30–43 (14 minutes)	No
4	44–59 (16 minutes)	Yes

GO ON TO THE NEXT PAGE.

Complete method `makeAppointment`. Assume that `findFreeBlock` works as intended, regardless of what you wrote in part (a). You must use `findFreeBlock` and `reserveBlock` appropriately in order to receive full credit.

```
/**
 *  Searches periods from startPeriod to endPeriod, inclusive, for a block
 *  of duration free minutes, as described in part (b). If such a block is found,
 *  calls reserveBlock to reserve the block of minutes and returns true; otherwise
 *  returns false.
 *  Preconditions: 1 <= startPeriod <= endPeriod <= 8; 1 <= duration <= 60
 */
public boolean makeAppointment(int startPeriod, int endPeriod,
                               int duration)
```

Begin your response at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number. If there are multiple parts to this question, write the part letter with your response.

Class information for this question

```
public class AppointmentBook

private boolean isMinuteFree(int period, int minute)
private void reserveBlock(int period, int startMinute,
   int duration)
public int findFreeBlock(int period, int duration)
public boolean makeAppointment(int startPeriod, int endPeriod,
   int duration)
```

2. This question involves methods that distribute text across lines of an electronic sign. The electronic sign and the text to be displayed on it are represented by the `Sign` class. You will write the complete `Sign` class, which contains a constructor and two methods.

   The `Sign` class constructor has two parameters. The first parameter is a `String` that contains the message to be displayed on the sign. The second parameter is an `int` that contains the *width* of each line of the sign. The width is the positive maximum number of characters that can be displayed on a single line of the sign.

   A sign contains as many lines as are necessary to display the entire message. The message is split among the lines of the sign without regard to spaces or punctuation. Only the last line of the sign may contain fewer characters than the width indicated by the constructor parameter.

   The following are examples of a message displayed on signs of different widths. Assume that in each example, the sign is declared with the width specified in the first column of the table and with the message `"Everything on sale, please come in"`, which contains 34 characters.

Width of the Sign	Sign Display

15	`Everything on s`
	`ale, please com`
	`e in`

17	`Everything on sal` `e, please come in`
40	`Everything on sale, please come in`

   In addition to the constructor, the `Sign` class contains two methods.

   The `numberOfLines` method returns an `int` representing the number of lines needed to display the text on the sign. In the previous examples, `numberOfLines` would return `3`, `2`, and `1`, respectively, for the sign widths shown in the table.

   The `getLines` method returns a `String` containing the message broken into lines separated by semicolons `(;)` or returns `null` if the message is the empty string. The constructor parameter that contains the message to be displayed will not include any semicolons. As an example, in the first row of the preceding table, `getLines` would return `"Everything on s;ale, please com;e in"`. No semicolon should appear at the end of the `String` returned by `getLines`.

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The following table contains a sample code execution sequence and the corresponding results. The code execution sequence appears in a class other than `Sign`.

Statement	Method Call Return Value (blank if none)	Explanation
`String str;`		
`int x;`		
`Sign sign1 = new Sign("ABC222DE", 3);`		The message for `sign1` contains 8 characters, and the sign has lines of width 3.
`x = sign1.numberOfLines();`	`3`	The sign needs three lines to display the 8-character message on a sign with lines of width 3.
`str = sign1.getLines();`	`"ABC;222;DE"`	Semicolons separate the text displayed on the first, second, and third lines of the sign.
`str = sign1.getLines();`	`"ABC;222;DE"`	Successive calls to `getLines` return the same value.
`Sign sign2 = new Sign("ABCD", 10);`		The message for `sign2` contains 4 characters, and the sign has lines of width 10.
`x = sign2.numberOfLines();`	`1`	The sign needs one line to display the 4-character message on a sign with lines of width 10.
`str = sign2.getLines();`	`"ABCD"`	No semicolon appears, since the text to be displayed fits on the first line of the sign.
`Sign sign3 = new Sign("ABCDEF", 6);`		The message for `sign3` contains 6 characters, and the sign has lines of width 6.
`x = sign3.numberOfLines();`	`1`	The sign needs one line to display the 6-character message on a sign with lines of width 6.
`str = sign3.getLines();`	`"ABCDEF"`	No semicolon appears, since the text to be displayed fits on the first line of the sign.
`Sign sign4 = new Sign("", 4);`		The message for `sign4` is an empty string.
`x = sign4.numberOfLines();`	`0`	There is no text to display.
`str = sign4.getLines();`	`null`	There is no text to display.
`Sign sign5 = new Sign("AB_CD_EF", 2);`		The message for `sign5` contains 8 characters, and the sign has lines of width 2.
`x = sign5.numberOfLines();`	`4`	The sign needs four lines to display the 8-character message on a sign with lines of width 2.
`str = sign5.getLines();`	`"AB;_C;D_;EF"`	Semicolons separate the text displayed on the four lines of the sign.

Write the complete `Sign` class. Your implementation must meet all specifications and conform to the examples shown in the preceding table.

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Begin your response at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number. If there are multiple parts to this question, write the part letter with your response.

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3. This question involves the analysis of weather data. The following `WeatherData` class has an instance variable, `temperatures`, which contains the daily high temperatures recorded on consecutive days at a particular location. The class also contains methods used to analyze that data. You will write two methods of the `WeatherData` class.

```
public class WeatherData
{
    /** Guaranteed not to be null and to contain only non-null entries */
    private ArrayList<Double> temperatures;

    /**
     *  Cleans the data by removing from temperatures all values that are less than
     *  lower and all values that are greater than upper, as described in part (a)
     */
    public void cleanData(double lower, double upper)
    {  /* to be implemented in part (a) */  }

    /**
     *  Returns the length of the longest heat wave found in temperatures, as described in
     *  part (b)
     *  Precondition: There is at least one heat wave in temperatures based on threshold.
     */
    public int longestHeatWave(double threshold)
    {  /* to be implemented in part (b) */  }

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

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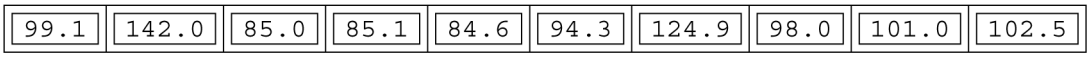
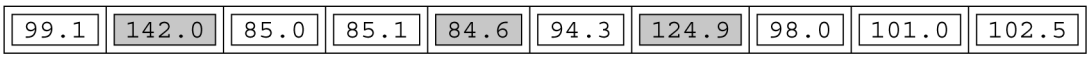
(a) Write the `cleanData` method, which modifies the `temperatures` instance variable by removing all values that are less than the `lower` parameter and all values that are greater than the `upper` parameter. The order of the remaining values in `temperatures` must be maintained.

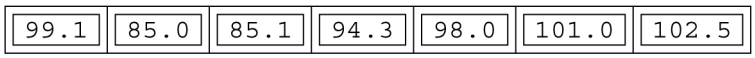
For example, consider a `WeatherData` object for which `temperatures` contains the following.



The three shaded values shown would be removed by the method call `cleanData(85.0, 120.0)`.



The following shows the contents of `temperatures` after the three shaded values are removed as a result of the method call `cleanData(85.0, 120.0)`.



Complete method `cleanData`.

```
/**
 *  Cleans the data by removing from temperatures all values that are less than
 *  lower and all values that are greater than upper, as described in part (a)
 */
public void cleanData(double lower, double upper)
```

Begin your response at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number. If there are multiple parts to this question, write the part letter with your response.

(b) Write the `longestHeatWave` method, which returns the length of the longest heat wave found in the `temperatures` instance variable. A heat wave is a sequence of two or more consecutive days with a daily high temperature greater than the parameter `threshold`. The `temperatures` instance variable is guaranteed to contain at least one heat wave based on the `threshold` parameter.

For example, consider the following contents of `temperatures`.

100.5	98.5	102.0	103.9	87.5	105.2	90.3	94.8	109.1	102.1	107.4	93.2

In the following sample contents of `temperatures`, all heat waves based on the `threshold` temperature of `100.5` are shaded. The method call `longestHeatWave(100.5)` would return `3`, which is the length of the longest heat wave.

100.5	98.5	102.0	103.9	87.5	105.2	90.3	94.8	109.1	102.1	107.4	93.2

In the following sample contents of `temperatures`, all heat waves based on the `threshold` temperature of `95.2` are shaded. The method call `longestHeatWave(95.2)` would return `4`, which is the length of the longest heat wave.

100.5	98.5	102.0	103.9	87.5	105.2	90.3	94.8	109.1	102.1	107.4	93.2

Complete method `longestHeatWave`.

```
/**
 *  Returns the length of the longest heat wave found in temperatures, as described in
 *  part (b)
 *  Precondition: There is at least one heat wave in temperatures based on threshold.
 */
public int longestHeatWave(double threshold)
```

Begin your response at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number. If there are multiple parts to this question, write the part letter with your response.

Class information for this question

```
public class WeatherData

private ArrayList<Double> temperatures

public void cleanData(double lower, double upper)
public int longestHeatWave(double threshold)
```

4. This question involves pieces of candy in a box. The `Candy` class represents a single piece of candy.

```
public class Candy
{
    /** Returns a String representing the flavor of this piece of candy */
    public String getFlavor()
    {  /* implementation not shown */  }

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

The `BoxOfCandy` class represents a candy box where the candy is arranged in a rectangular grid. The instance variable of the class, `box`, is a rectangular two-dimensional array of `Candy` objects. A location in the candy box may contain a piece of candy or may be empty. A piece of candy is represented by a `Candy` object. An empty location is represented by `null`.

You will write two methods of the `BoxOfCandy` class.

```
public class BoxOfCandy
{
    /** box contains at least one row and is initialized in the constructor. */
    private Candy[][] box;

    /**
     *  Moves one piece of candy in column col, if necessary and possible, so that the box
     *  element in row 0 of column col contains a piece of candy, as described in part (a).
     *  Returns false if there is no piece of candy in column col and returns true otherwise.
     *  Precondition: col is a valid column index in box.
     */
    public boolean moveCandyToFirstRow(int col)
    {  /* to be implemented in part (a) */  }

    /**
     *  Removes from box and returns a piece of candy with flavor specified by the parameter, or
     *  returns null if no such piece is found, as described in part (b)
     */
    public Candy removeNextByFlavor(String flavor)
    {  /* to be implemented in part (b) */  }

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

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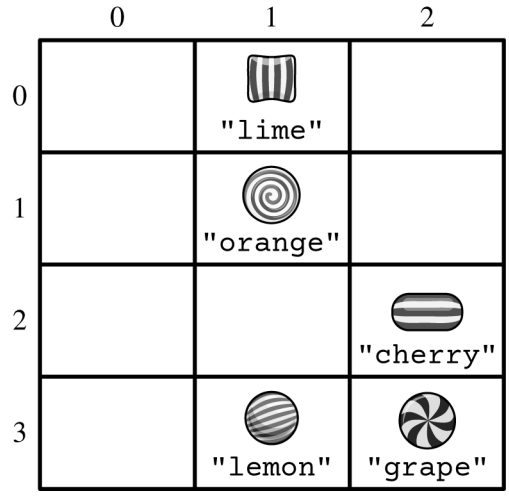
(a) Write the `moveCandyToFirstRow` method, which attempts to ensure that the `box` element at row `0` and column `col` contains a piece of candy, using the following steps.

- If the element at row `0` and column `col` already contains a piece of candy, then `box` is unchanged and the method returns `true`.
- If the element at row `0` and column `col` does not contain a piece of candy, then the method searches the remaining rows of column `col` for a piece of candy. If a piece of candy can be found in column `col`, it is moved to row `0`, its previous location is set to `null`, and the method returns `true`; otherwise, the method returns `false`.

In the following example, the grid represents the contents of `box`. An empty square in the grid is `null` in `box`. A non-empty square in the grid represents a `box` element that contains a `Candy` object. The string in the square of the grid indicates the flavor of the piece of candy.



The method call `moveCandyToFirstRow(0)` returns `false` because the `box` element at row `0` and column `0` does not contain a piece of candy and there are no pieces of candy in column `0` that can be moved to row `0`. The contents of `box` are unchanged.

The method call `moveCandyToFirstRow(1)` returns `true` because the `box` element at row `0` and column `1` already contains a piece of candy. The contents of `box` are unchanged.

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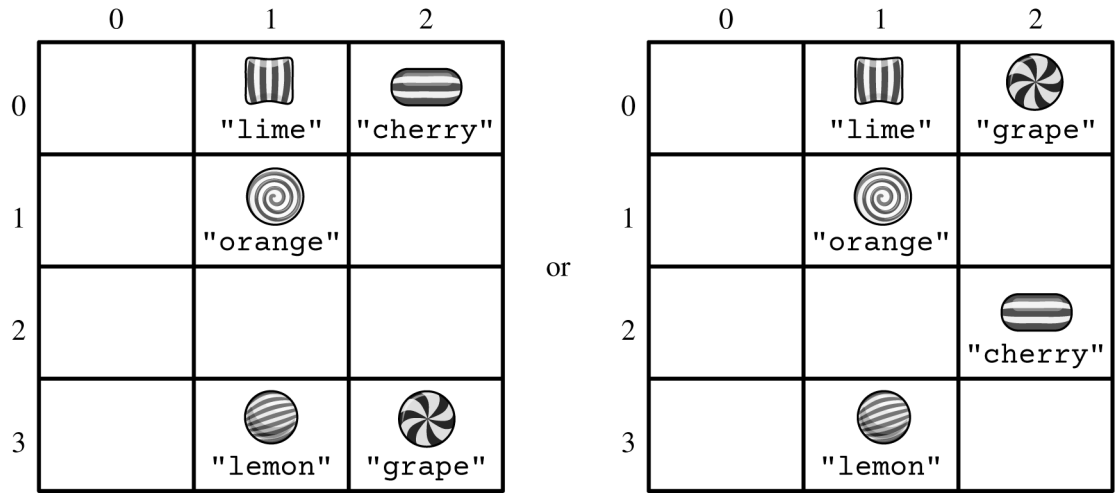
The method call `moveCandyToFirstRow(2)` moves one of the two pieces of candy in column `2` to row `0` of column `2`, sets the previous location of the piece of candy that was moved to `null`, and returns `true`. The new contents of `box` could be either of the following.



Complete the `moveCandyToFirstRow` method.

```
/**
 * Moves one piece of candy in column col, if necessary and possible, so that the box
 * element in row 0 of column col contains a piece of candy, as described in part (a).
 * Returns false if there is no piece of candy in column col and returns true otherwise.
 * Precondition: col is a valid column index in box.
 */
public boolean moveCandyToFirstRow(int col)
```

Begin your response at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number. If there are multiple parts to this question, write the part letter with your response.

Class information for this question

```
public class Candy

public String getFlavor()

public class BoxOfCandy

private Candy[][] box

public boolean moveCandyToFirstRow(int col)
public Candy removeNextByFlavor(String flavor)
```

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(b) Write the `removeNextByFlavor` method, which attempts to remove and return one piece of candy from the box. The piece of candy to be removed is the first piece of candy with a flavor equal to the parameter `flavor` that is encountered while traversing the candy box in the following order: the last row of the box is traversed from left to right, then the next-to-last row of the box is traversed from left to right, etc., until either a piece of candy with the desired flavor is found or until the entire candy box has been searched.

If the `removeNextByFlavor` method finds a `Candy` object with the desired flavor, the corresponding `box` element is assigned `null`, all other `box` elements are unchanged, and the removed `Candy` object is returned. Otherwise, `box` is unchanged and the method returns `null`.

The following examples show three consecutive calls to the `removeNextByFlavor` method. The traversal of the candy box always begins in the last row and first column of the box.

The following grid shows the contents of `box` before any of the `removeNextByFlavor` method calls.

	0	1	2	3	4
0	"lime"	"lime"		"lemon"	
1	"orange"			"lime"	"lime"
2	"cherry"		"lemon"		"orange"

The method call `removeNextByFlavor("cherry")` removes and returns the `Candy` object located in row `2` and column `0`. The following grid shows the updated contents of `box`.

	0	1	2	3	4
0	"lime"	"lime"		"lemon"	
1	"orange"			"lime"	"lime"
2			"lemon"		"orange"

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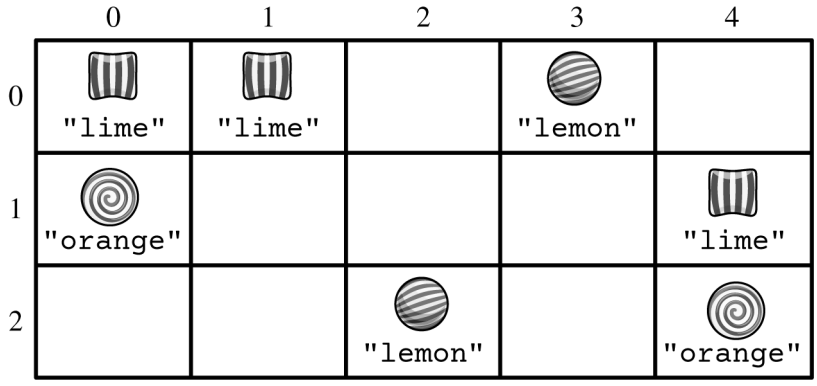
The method call `removeNextByFlavor("lime")` removes and returns the `Candy` object located in row `1` and column `3`. The following grid shows the updated contents of `box`.



The method call `removeNextByFlavor("grape")` returns `null` because no grape-flavored candy is found. The contents of `box` are unchanged.

Complete the `removeNextByFlavor` method.

```
/**
 *  Removes from box and returns a piece of candy with flavor specified by the parameter, or
 *  returns null if no such piece is found, as described in part (b)
 */
public Candy removeNextByFlavor(String flavor)
```

Begin your response at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number. If there are multiple parts to this question, write the part letter with your response.

Class information for this question

```
public class Candy

public String getFlavor()

public class BoxOfCandy

private Candy[][] box

public boolean moveCandyToFirstRow(int col)
public Candy removeNextByFlavor(String flavor)
```

GO ON TO THE NEXT PAGE.

STOP

END OF EXAM