COMPUTER SCIENCE A
SECTION I
Time—1 hour and 15 minutes
Number of questions—40
Percent of total score—50

Directions: Determine the answer to each of the following questions or incomplete statements, using the available space for any necessary scratch work. Then decide which is the best of the choices given and fill in the corresponding circle on the answer sheet. No credit will be given for anything written in the examination booklet. Do not spend too much time on any one problem.

Notes:

- Assume that the classes listed in the Java Quick Reference have been imported where appropriate.
- Assume that declarations of variables and methods appear within the context of an enclosing class.
- Assume that method calls that are not prefixed with an object or class name and are not shown within a complete class definition appear within the context of an enclosing class.
- 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.

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1. Consider the following incomplete method, which is intended to return the number of integers that evenly divide the integer `inputVal`. Assume that `inputVal` is greater than 0.

```
public static int numDivisors(int inputVal)
{
  int count = 0;
  for (int k = 1; k <= inputVal; k++)
  {
    if ( /* condition */ )
    {
      count++;
    }
  }
  return count;
}
```

Which of the following can be used to replace `/* condition */` so that `numDivisors` will work as intended?

(A) `inputVal % k == 0`

(B) `k % inputVal == 0`

(C) `inputVal % k != 0`

(D) `inputVal / k == 0`

(E) `k / inputVal > 0`

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GO ON TO THE NEXT PAGE.

2. Consider the following code segment.

```
for (int r = 3; r > 0; r--)
{
  int c;

  for (c = 1; c < r; c++)
  {
    System.out.print("-");
  }
  for (c = r ; c <= 3; c++)
  {
    System.out.print("*");
  }

  System.out.println();
}
```

What is printed as a result of executing the code segment?

(A)
```
--*
-**
***
```

(B)
```
*--
**-
***
```

(C)
```
***
-**
--*
```

(D)
```
***
**-
*--
```

(E)
```
--*
***
--*
```

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3. Consider the following two classes.

```
public class A
{
  public void show()
  {
    System.out.print("A");
  }
}


public class B extends A
{
  public void show()
  {
    System.out.print("B");
  }
}
```

What is printed as a result of executing the following code segment?

```
A obj = new B();
obj.show();
```

(A) `A`

(B) `B`

(C) `AB`

(D) `BA`

(E) The code results in a runtime error.

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4. Consider the following instance variable and method.

```
private int[] arr;

/** Precondition: arr.length > 0
 *  @return the largest value in array arr
 */
public int findMax()
{
  int maxVal = 0;

  for (int val : arr)
  {
    if (val > maxVal)
    {
      maxVal = val;
    }
  }

  return maxVal;
}
```

Method `findMax` is intended to return the largest value in the array `arr`. Which of the following best describes the conditions under which the method `findMax` will not work as intended?

(A) The largest value in `arr` occurs only once and is in `arr[0]`.

(B) The largest value in `arr` occurs only once and is in `arr[arr.length - 1]`.

(C) The largest value in `arr` is negative.

(D) The largest value in `arr` is zero.

(E) The largest value in arr occurs more than once.

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5. Assume that x and y are boolean variables and have been properly initialized.

```
(x || y) && x
```

Which of the following always evaluates to the same value as the expression above?

(A) `x`

(B) `y`

(C) `x && y`

(D) `x || y`

(E) `x != y`

---

6. Consider the following method, which is intended to return `true` if at least one of the three strings `s1`, `s2`, or `s3` contains the substring "`art`". Otherwise, the method should return `false`.

```
public static boolean containsArt(String s1, String s2, String s3)
{

  String all = s1 + s2 + s3;

  return (all.indexOf("art") != -1);

}
```

Which of the following method calls demonstrates that the method does not work as intended?

(A) `containsArt("rattrap", "similar", "today")`

(B) `containsArt("start", "article", "Bart")`

(C) `containsArt("harm", "chortle", "crowbar")`

(D) `containsArt("matriculate", "carat", "arbitrary")`

(E) `containsArt("darkroom", "cartoon", "articulate")`

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7. Consider the following code segment.

```
for (int outer = 1; outer <= 6; outer++)
{
  for (int inner = outer; inner <= 6; inner++)
  {
    if (inner % 2 == 0)
    {
      System.out.print(inner + "  ");
    }
  }
  System.out.println();
}
```

What will be printed as a result of executing the code segment?

(A)
```
2  4  6
4  6
6
```

(B)
```
2  4  6
2  4  6
2  4  6
```

(C)
```
2  4  6
2  4  6
4  6
4  6
6
6
```

(D)
```
2  4  6
2  4  6
2  4  6
2  4  6
2  4  6
2  4  6
```

(E)
```
2  4
2  4
4
4
```

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8. Consider the following method.

```
public static int[] operation(int[][] matrix, int r, int c)
{
  int[] result = new int[matrix.length];

  for (int j = 0 ; j < matrix.length ; j++)
  {
    result[j] = matrix[r][j] * matrix[j][c];
  }
  return result;
}
```

The following code segment appears in another method in the same class.

```
int[][] mat = {{3, 2, 1, 4},
               {1, 2, 3, 4},
               {2, 2, 1, 2},
               {1, 1, 1, 1}};

int[] arr = operation(mat, 1, 2);
```

Which of the following represents the contents of arr as a result of executing the code segment?

(A) {6, 4, 2, 4}

(B) {1, 6, 3, 4}

(C) {4, 3, 6, 1}

(D) {4, 4, 2, 2}

(E) {2, 2, 4, 4}

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9. A pair of number cubes is used in a game of chance. Each number cube has six sides, numbered from 1 to 6, inclusive, and there is an equal probability for each of the numbers to appear on the top side (indicating the cube's value) when the number cube is rolled. The following incomplete statement appears in a program that computes the sum of the values produced by rolling two number cubes.

```
int sum = /* missing code */ ;
```

Which of the following replacements for `/* missing code */` would best simulate the value produced as a result of rolling two number cubes?

(A) `2 * (int) (Math.random() * 6)`

(B) `2 * (int) (Math.random() * 7)`

(C) `(int) (Math.random() * 6) + (int) (Math.random() * 6)`

(D) `(int) (Math.random() * 13)`

(E) `2 + (int) (Math.random() * 6) + (int) (Math.random() * 6)`

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10. Consider the following interface and class declarations.

```
public interface Student
{   /* implementation not shown */   }

public class Athlete
{   /* implementation not shown */   }

public class TennisPlayer extends Athlete implements Student
{   /* implementation not shown */   }
```

Assume that each class has a zero-parameter constructor. Which of the following is NOT a valid declaration?

(A) `Student a = new TennisPlayer();`

(B) `TennisPlayer b = new TennisPlayer();`

(C) `Athlete c = new TennisPlayer();`

(D) `Student d = new Athlete();`

(E) `Athlete e = new Athlete();`

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11. Consider the following method.

```
public static boolean mystery (String str)
{
  String temp = "";

  for (int k = str.length(); k > 0; k--)
  {
    temp = temp + str.substring(k - 1, k);
  }

  return temp.equals(str);
}
```

Which of the following calls to mystery will return true?

(A) `mystery("no")`

(B) `mystery("on")`

(C) `mystery("nnoo")`

(D) `mystery("nono")`

(E) `mystery("noon")`

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12. Assume that x and y are boolean variables and have been properly initialized.

```
(x && y) && !(x || y)
```

Which of the following best describes the result of evaluating the expression above?

(A) `true` always

(B) `false` always

(C) true only when x is true and y is true

(D) `true` only when `x` and `y` have the same value

(E) true only when x and y have different values

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13. Consider the following instance variable and method.

```
private int[] numbers;

public void mystery(int x)
{
  for (int k = 1; k < numbers.length; k = k + x)
  {
    numbers[k] = numbers[k - 1] + x;
  }
}
```

Assume that numbers has been initialized with the following values.

```
{17, 34, 21, 42, 15, 69, 48, 25, 39}
```

Which of the following represents the order of the values in `numbers` as a result of the call `mystery(3)` ?

(A) `{17, 20, 21, 42, 45, 69, 48, 51, 39}`

(B) `{17, 20, 23, 26, 29, 32, 35, 38, 41}`

(C) `{17, 37, 21, 42, 18, 69, 48, 28, 39}`

(D) `{20, 23, 21, 42, 45, 69, 51, 54, 39}`

(E) `{20, 34, 21, 45, 15, 69, 51, 25, 39}`

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14. Consider the following method, biggest, which is intended to return the greatest of three integers. It does not always work as intended.

```
public static int biggest(int a, int b, int c)
{
  if ((a > b) && (a > c))
  {
    return a;
  }
  else if ((b > a) && (b > c))
  {
    return b;
  }
  else
  {
    return c;
  }
}
```

Which of the following best describes the error in the method?

(A) `biggest` always returns the value of `a`.

(B) biggest may not work correctly when c has the greatest value.

(C) biggest may not work correctly when a and b have equal values.

(D) biggest may not work correctly when a and c have equal values.

(E) biggest may not work correctly when b and c have equal values.

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15. Consider the following method.

```
public static void showMe(int arg)
{
  if (arg < 10)
  {
    showMe(arg + 1);
  }
  else
  {
    System.out.print(arg + " ");
  }
}
```

What will be printed as a result of the call `showMe(0)` ?

(A) `10`

(B) `11`

(C) `0 1 2 3 4 5 6 7 8 9`

(D) `9 8 7 6 5 4 3 2 1 0`

(E) `0 1 2 3 4 5 6 7 8 9 10`

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16. Consider the following method.

```
/** Precondition: values has at least one row */
public static int calculate(int[][] values)
{
  int found = values[0][0];
  int result = 0;
  for (int[] row : values)
  {
    for (int y = 0; y < row.length; y++)
    {
      if (row[y] > found)
      {
        found = row[y];
        result = y;
      }
    }
  }
  return result;
}
```

Which of the following best describes what is returned by the calculate method?

(A) The largest value in the two-dimensional array

(B) The smallest value in the two-dimensional array

(C) The row index of an element with the largest value in the two-dimensional array

(D) The row index of an element with the smallest value in the two-dimensional array

(E) The column index of an element with the largest value in the two-dimensional array

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17. Consider the following method.

```
//* Precondition: num > 0 */
public static int doWhat(int num)
{
  int var = 0;

  for (int loop = 1; loop <= num; loop = loop + 2)
  {
    var += loop;
  }

  return var;
}
```

Which of the following best describes the value returned from a call to dowhat?

(A) `num`

(B) The sum of all integers between `1` and `num`, inclusive

(C) The sum of all even integers between `1` and `num`, inclusive

(D) The sum of all odd integers between `1` and `num`, inclusive

(E) No value is returned because of an infinite loop.

---

18. What is printed as a result of executing the following statement?

```
System.out.println(404 / 10 * 10 + 1);
```

(A) `4`

(B) 5

(C) `41`

(D) `401`

(E) `405`

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19. Consider the following code segment.

```
int x = 1;
while ( /* condition */ )
{
  if (x % 2 == 0)
  {
    System.out.print(x + " ");
  }
  x = x + 2;
}
```

The following conditions have been proposed to replace `/* condition */` in the code segment.

I. `x < 0`

II. `x <= 1`

III. `x < 10`

For which of the conditions will nothing be printed?

(A) I only

(B) II only

(C) I and II only

(D) I and III only

(E) I, II, and III

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20. Consider the following method.

```
/** Precondition: arr.length > 0 */
public static int mystery(int[] arr)
{
  int index = 0;
  int count = 0;
  int m = -1;

  for (int outer = 0; outer < arr.length; outer++)
  {
    count = 0;
    for (int inner = outer + 1; inner < arr.length; inner++)
    {
      if (arr[outer] == arr[inner])
      {
        count++;
      }
    }

    if (count > m)
    {
      index = outer;
      m = count;
    }
  }

  return index;
}
```

Assume that nums has been declared and initialized as an array of integer values. Which of the following best describes the value returned by the call mystery (nums) ?

(A) The maximum value that occurs in nums

(B) An index of the maximum value that occurs in nums

(C) The number of times that the maximum value occurs in nums

(D) A value that occurs most often in `nums`

(E) An index of a value that occurs most often in nums

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21. Consider the following recursive method.

```
public static void whatsItDo(String str)
{
  int len = str.length();
  if (len > 1)
  {
    String temp = str.substring(0, len - 1);
    System.out.println(temp);
    whatsItDo(temp);
  }
}
```

What is printed as a result of the call `whatsItDo("WATCH")` ?

(A)
```
H
```

(B)
```
WATC
```

(C)
```
ATCH
ATC
AT
A
```

(D)
```
WATC
WAT
WA
W
```

(E)
```
WATCH
WATC
WAT
WA
```

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22. Consider the following definition.

```
int[][] numbers = {{1, 2, 3},
                   {4, 5, 6}};
```

Which of the following code segments produces the output `123456` ?

(A)
```
for (int[] row : numbers)
{
  for (int n : row)
  {
    System.out.print(n);
  }
}
```

(B)
```
for (int[] row : numbers)
{
  for (int n : row)
  {
    System.out.print(row[n]);
  }
}
```

(C)
```
for (int rc = 0; rc < numbers.length; rc++)
{
  System.out.print(numbers[rc]);
}
```

(D)
```
for (int r = 0; r < numbers[0].length; r++)
{
  for (int c = 0; c < numbers.length; c++)
  {
    System.out.print(numbers[r][c]);
  }
}
```

(E)
```
for (int c = 0; c < numbers[0].length; c++)
{
  for (int r = 0; r < numbers.length; r++)
  {
    System.out.print(numbers[r][c]);
  }
}
```

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23. Consider the following code segment from an insertion sort program.

```
for (int j = 1; j < arr.length; j++)
{
  int insertItem = arr[j];
  int k = j - 1;

  while (k >= 0 && insertItem < arr[k])
  {
    arr[k + 1] = arr[k];
    k--;
  }

  arr[k + 1] = insertItem;

  /* end of for loop */
}
```

Assume that array `arr` has been defined and initialized with the values `{5, 4, 3, 2, 1}`. What are the values in array `arr` after two passes of the `for` loop (i.e., when `j = 2` at the point indicated by `/* end of for loop */`) ?

(A) `{2, 3, 4, 5, 1}`

(B) `{3, 2, 1, 4, 5}`

(C) `{3, 4, 5, 2, 1}`

(D) `{3, 5, 2, 3, 1}`

(E) `{5, 3, 4, 2, 1}`

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24. Consider the following class.

```
public class SomeMethods
{
  public void one(int first)
  {  /* implementation not shown */  }

  public void one(int first, int second)
  {  /* implementation not shown */  }

  public void one (int first, String second)
  {  /* implementation not shown */  }
}
```

Which of the following methods can be added to the `SomeMethods` class without causing a compile-time error?

I.
```
public void one(int value)
{  /* implementation not shown */  }
```

II.
```
public void one(String first, int second)
{  /* implementation not shown */  }
```

III.
```
public void one(int first, int second, int third)
{  /* implementation not shown */  }
```

(A) I only

(B) I and II only

(C) I and III only

(D) II and III only

(E) I, II, and III

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25. Consider the following code segment.

```
int count = 0;

for (int x = 0; x < 4; x++)
{
  for (int y = x; y < 4; y++)
  {
    count++;
  }
}
System.out.println(count);
```

What is printed as a result of executing the code segment?

(A) 4

(B) 8

(C) 10

(D) 16

(E) 20

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26. Consider the following two methods, which appear within a single class.

```
public static void changeIt(int[] arr, int val, String word)
{
  arr = new int[5];
  val = 0;
  word = word.substring(0, 5);

  for (int k = 0; k < arr.length; k++)
  {
    arr[k] = 0;
  }
}


public static void start()
{
  int[] nums = {1, 2, 3, 4, 5};
  int value = 6;
  String name = "blackboard";

  changeIt(nums, value, name);

  for (int k = 0; k < nums.length; k++)
  {
    System.out.print(nums[k] + " ");
  }

  System.out.print(value + " ");
  System.out.print(name);
}
```

What is printed as a result of the call start () ?

(A) 0 0 0 0 0 0 black

(B) 0 0 0 0 0 6 blackboard

(C) 1 2 3 4 5 6 black

(D) 1 2 3 4 5 0 black

(E) 1 2 3 4 5 6 blackboard

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Questions 27-28 refer to the following information.

Consider the following sort method. This method correctly sorts the elements of array data into increasing order.

```
public static void sort(int[] data)
{
  for (int j = 0; j < data.length - 1; j++)
  {
    int m = j;
    for (int k = j + 1; k < data.length; k++)
    {
      if (data[k] < data[m])     /* Compare values */
      {
        m = k;
      }
    }
    int temp = data[m];          /* Assign to temp */
    data[m] = data[j];
    data[j] = temp;

    /* End of outer loop */
  }
}
```

27. Assume that `sort` is called with the array `{6, 3, 2, 5, 4, 1}`. What will the value of `data` be after three passes of the outer loop (i.e., when `j = 2` at the point indicated by `/* End of outer loop */`) ?

(A) `{1, 2, 3, 4, 5, 6}`

(B) `{1, 2, 3, 5, 4, 6}`

(C) `{1, 2, 3, 6, 5, 4}`

(D) `{1, 3, 2, 4, 5, 6}`

(E) `{1, 3, 2, 5, 4, 6}`

---

28. Assume that `sort` is called with the array `{1, 2, 3, 4, 5, 6}`. How many times will the expression indicated by `/* Compare values */` and the statement indicated by `/* Assign to temp */` execute?

	Compare values	*Assign to temp*
(A)	15	0
(B)	15	5
(C)	15	6
(D)	21	5
(E)	21	6

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29. Consider the following recursive method.

```
/** Precondition: num ≥ 0 */
public static int what(int num)
{
  if (num < 10)
  {
    return 1;
  }
  else
  {
    return 1 + what(num / 10);
  }
}
```

Assume that `int val` has been declared and initialized with a value that satisfies the precondition of the method. Which of the following best describes the value returned by the call `what(val)` ?

(A) The number of digits in the decimal representation of val is returned.

(B) The sum of the digits in the decimal representation of val is returned.

(C) Nothing is returned. A run-time error occurs because of infinite recursion.

(D) The value 1 is returned.

(E) The value `val/10` is returned.

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30. The price per box of ink pens advertised in an office supply catalog is based on the number of boxes ordered. The following table shows the pricing.

Number of Boxes	Price per Box
1 up to but not including 5	$5.00
5 up to but not including 10	$3.00
10 or more	$1.50

The following incomplete method is intended to return the total cost of an order based on the value of the parameter `numBoxes`.

```
/** Precondition: numBoxes > 0 */
public static double getCost(int numBoxes)
{
  double totalCost = 0.0;

  /* missing code */

  return totalCost;
}
```

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Which of the following code segments can be used to replace `/* missing code */` so that method `getCost` will work as intended?

I.
```
if (numBoxes >= 10)
{
  totalCost = numBoxes * 1.50;
}
if (numBoxes >= 5)
{
  totalCost = numBoxes * 3.00;
}
if (numBoxes > 0)
{
  totalCost = numBoxes * 5.00;
}
```

II.
```
if (numBoxes >= 10)
{
  totalCost = numBoxes * 1.50;
}
else if (numBoxes >= 5)
{
  totalCost = numBoxes * 3.00;
}
else
{
  totalCost = numBoxes * 5.00;
}
```

III.
```
if (numBoxes > 0)
{
  totalCost = numBoxes * 5.00;
}
else if (numBoxes >= 5)
{
  totalCost = numBoxes * 3.00;
}
else if (numBoxes >= 10)
{
  totalCost = numBoxes * 1.50;
}
```

(A) I only

(B) II only

(C) III only

(D) I and II

(E) II and III

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31. Consider the following code segment.

```
String[][] board = new String[5][5];

for (int row = 0; row < 5; row++)
{
  for (int col = 0; col < 5; col++)
  {
    board[row][col] = "O";
  }
}

for (int val = 0; val < 5; val++)
{
  if (val % 2 == 1)
  {
    int row = val;
    int col = 0;
    while (col < 5 && row >= 0)
    {
      board[row][col] = "X";
      col++;
      row--;
    }
  }
}
```

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Which of the following represents `board` after this code segment is executed?

(A)

	0	1	2	3	4
0	X	O	X	O	X
1	O	X	O	X	O
2	X	O	X	O	X
3	O	X	O	X	O
4	X	O	X	O	X

(B)

	0	1	2	3	4
0	O	X	O	X	O
1	X	O	X	O	X
2	O	X	O	X	O
3	X	O	X	O	X
4	O	X	O	X	O

(C)

	0	1	2	3	4
0	X	O	O	O	X
1	O	X	O	X	O
2	O	O	X	O	O
3	O	X	O	X	O
4	X	O	O	O	X

(D)

	0	1	2	3	4
0	O	X	O	O	O
1	O	O	X	O	O
2	X	O	O	X	O
3	O	X	O	O	X
4	O	O	X	O	O

(E)

	0	1	2	3	4
0	O	X	O	X	O
1	X	O	X	O	O
2	O	X	O	O	O
3	X	O	O	O	O
4	O	O	O	O	O

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32. Consider the following class declaration.

```
public class StudentInfo
{
  private String major;
  private int age;

  public String getMajor()
  {  return major;  }

  public int getAge()
  {  return age;  }

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

The following instance variable and method appear in another class.

```
private List<StudentInfo> students;

/** @return the average age of students with the given major;
 *          -1.0 if no such students exist
 */
public double averageAgeInMajor(String theMajor)
{
  double sum = 0.0;
  int count = 0;
  for (StudentInfo k : students)
  {
    /* missing code */
  }

  if (count > 0)
  {
    return sum / count;
  }
  else
  {
    return -1.0;
  }
}
```

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Which of the following could be used to replace `/* missing code */` so that `averageAgeInMajor` will compile without error?

(A)
```
if (theMajor.equals(k.major))
{
  sum += k.age;
  count++;
}
```

(B)
```
if (theMajor.equals(k.getMajor()))
{
  sum += k.getAge();
  count++;
}
```

(C)
```
if (theMajor.equals(k.major))
{
  sum += k.getAge();
  count++;
}
```

(D)
```
if (theMajor.equals(students[k].getMajor()))
{
  sum += students[k].getAge();
  count++;
}
```

(E)
```
if (theMajor.equals(getMajor(k)))
{
  sum += getAge(k);
  count++;
}
```

---

33. Which of the following statements regarding interfaces is FALSE?

(A) All methods in an interface are public.

(B) An interface cannot be instantiated.

(C) An interface can declare an instance variable.

(D) A non-abstract class can implement an interface.

(E) An abstract class can implement an interface.

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34. Consider the problem of finding the maximum value in an array of integers. The following code segments are proposed solutions to the problem. Assume that the variable arr has been defined as an array of int values and has been initialized with one or more values.

I.
```
int max = Integer.MIN_VALUE;
for (int value : arr)
{
  if (max < value)
  {
    max = value;
  }
}
```

II.
```
int max = 0;
boolean first = true;
for (int value : arr)
{
  if (first)
  {
    max = value;
    first = false;
  }
  else if (max < value)
  {
    max = value;
  }
}
```

III.
```
int max = arr[0];
for (int k = 1; k < arr.length; k++)
{
  if (max < arr[k])
  {
    max = arr[k];
  }
}
```

Which of the code segments will always correctly assign the maximum element of the array to the variable `max`?

(A) I only

(B) II only

(C) III only

(D) II and III only

(E) I, II, and III

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35. Consider the following instance variable and method. Method `wordsWithCommas` is intended to return a string containing all the words in `listOfWords` separated by commas and enclosed in braces. For example, if `listOfWords` contains `["one", "two", "three"]`, the string returned by the call `wordsWithCommas()` should be `"{one, two, three}"`.

```
private List<String> listOfWords;

public String wordsWithCommas()
{
  String result = "{";

  int sizeOfList = /* expression */ ;

  for (int k = 0; k < sizeOfList; k++)
  {
    result = result + listOfWords.get(k);

    if ( /* condition */ )
    {
      result = result + ", ";
    }
  }

  result = result + "}";
  return result;
}
```

Which of the following can be used to replace `/* expression */` and `/* condition */` so that `wordsWithCommas` will work as intended?

	`/* expression */`	*`/* condition */`*
(A)	`listOfWords.size() - 1`	`k != 0`
(B)	`listOfWords.size()`	`k != 0`
(C)	`listOfWords.size() - 1`	`k != sizeOfList - 1`
(D)	`listOfWords.size()`	`k != sizeOfList - 1`
(E)	`result.length()`	`k != 0`

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Questions 36-37 refer to the following information.

Consider the following `binarySearch` method. The method correctly performs a binary search.

```
/** Precondition: data is sorted in increasing order. */
public static int binarySearch(int[] data, int target)
{
  int start = 0;
  int end = data.length - 1;
  while (start <= end)
  {
    int mid = (start + end) / 2;      /* Calculate midpoint */
    if (target < data[mid])
    {
      end = mid - 1;
    }
    else if (target > data[mid])
    {
      start = mid + 1;
    }
    else
    {
      return mid;
    }
  }
  return -1;
}
```

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36. Consider the following code segment.

```
int[] values = {1, 2, 3, 4, 5, 8, 8, 8};
int target = 8;
```

What value is returned by the call binarysearch (values, `target)` ?

(A) -1

(B) 3

(C) 5

(D) 6

(E) 8

---

37. Suppose the `binarySearch` method is called with an array containing 2,000 elements sorted in increasing order. What is the maximum number of times that the statement indicated by `/*` *Calculate midpoint* `*/` could execute?

(A) 2,000

(B) 1,000

(C) 20

(D) 11

(E) 1

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38. Consider the following incomplete method that is intended to return a string formed by concatenating elements from the parameter `words`. The elements to be concatenated start with `startIndex` and continue through the last element of words and should appear in reverse order in the resulting string.

```
/** Precondition: words.length > 0;
 *                startIndex >= 0
 */
public static String concatWords(String[] words, int startIndex)
{
  String result = "";

  /* missing code */

  return result;
}
```

For example, the following code segment uses a call to the concatwords method.

```
String[] things = {"Bear", "Apple", "Gorilla", "House", "Car"};
System.out.println(concatWords(things, 2));
```

When the code segment is executed, the string `"CarHouseGorilla"` is printed.

The following three code segments have been proposed as replacements for `/* missing code */`.

I.
```
for (int k = startIndex; k < words.length; k++)
{
  result += words[k] + words[words.length - k - 1];
}
```

II.
```
int k = words.length - 1;
while (k >= startIndex)
{
  result += words[k];
  k--;
}
```

III.
```
String[] temp = new String[words.length];
for (int k = 0; k <= words.length / 2; k++)
{
  temp[k] = words[words.length - k - 1];
  temp[words.length - k - 1] = words[k];
}

for (int k = 0; k < temp.length - startIndex; k++)
{
  result += temp[k];
}
```

Which of these code segments can be used to replace `/* missing code */` so that `concatWords` will work as intended?

(A) I only

(B) II only

(C) III only

(D) I and II

(E) II and III

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39. Consider the following method.

```
/** Precondition: 0 < numVals <= nums.length */
public static int mystery(int[] nums, int v, int numVals)
{
  int k = 0;

  if (v == nums[numVals - 1])
  {
    k = 1;
  }

  if (numVals == 1)
  {
    return k;
  }
  else
  {
    return k + mystery(nums, v, numVals - 1);
  }
}
```

Which of the following best describes what the call mystery (numbers, val, numbers. length) does? You may assume that variables numbers and val have been declared and initialized.

(A) Returns 1 if the last element in `numbers` is equal to `val`; otherwise, returns 0

(B) Returns the index of the last element in numbers that is equal to val

(C) Returns the number of elements in numbers that are equal to val

(D) Returns the number of elements in numbers that are not equal to val

(E) Returns the maximum number of adjacent elements that are not equal to val

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40. Consider the following code segment.

```
List<String> students = new ArrayList<String>();

students.add("Alex");
students.add("Bob");
students.add("Carl");

for (int k = 0; k < students.size(); k++)
{
  System.out print (students.set (k, "Alex") + "   ");
}

System.out.println();

for (String str : students)
{
  System.out.print(str + "   ");
}
```

What is printed as a result of executing the code segment?

(A)
```
Alex  Alex  Alex
Alex  Alex  Alex
```

(B)
```
Alex  Alex  Alex
Alex  Bob  Carl
```

(C)
```
Alex  Bob  Carl
Alex  Alex  Alex
```

(D)
```
Alex  Bob  Carl
Alex  Bob  Carl
```

(E) Nothing is printed because the first print statement will cause a runtime exception to be thrown.

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END OF SECTION I

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

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

MAKE SURE YOU HAVE DONE THE FOLLOWING.

- **PLACED YOUR AP NUMBER LABEL ON YOUR ANSWER SHEET**
- **WRITTEN AND GRIDDED YOUR AP NUMBER CORRECTLY ON YOUR ANSWER SHEET**
- **TAKEN THE AP EXAM LABEL FROM THE FRONT OF THIS BOOKLET AND PLACED IT ON YOUR ANSWER SHEET**

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Java Quick Reference

Accessible Methods from the Java Library That May Be Included on the Exam

class java.lang.Object

- `boolean equals(Object other)`
- `String toString()`

class java.lang.Integer

- `Integer(int value)`
- `int intValue()`
- `Integer.MIN_VALUE` // minimum value represented by an `int` or `Integer`
- `Integer.MAX_VALUE` // maximum value represented by an `int` or `Integer`

class java.lang.Double

- `Double(double value)`
- `double doubleValue()`

class java.lang.String

- `int length()`
- `String substring(int from, int to)` // returns the substring beginning at `from`
  // and ending at `to-1`
- `String substring(int from)` // returns `substring(from, length())`
- `int indexOf(String str)` // returns the index of the first occurrence of `str`;
  // returns `-1` if not found
- `int compareTo(String other)` // returns a value < 0 if `this` is less than `other`
  // returns a value = 0 if `this` is equal to `other`
  // returns a value > 0 if `this` is greater than `other`

class java.lang.Math

- `static int abs(int x)`
- `static double abs(double x)`
- static double pow (double base, double exponent)
- `static double sqrt(double x)`
- `static double random()` // returns a `double` in the range [0.0, 1.0)

interface java.util.List<E>

- `int size()`
- `boolean add(E obj)` // appends `obj` to end of list; returns `true`
- `void add(int index, E obj)` // inserts `obj` at position `index` (0 ≤ `index` ≤ size),
  // moving elements at position `index` and higher
  // to the right (adds 1 to their indices) and adjusts size
- `E get(int index)`
- `E set(int index, E obj)` // replaces the element at position `index` with `obj`
  // returns the element formerly at the specified position
- `E remove(int index)` // removes element from position `index`, moving elements
  // at position `index + 1` and higher to the left
  // (subtracts 1 from their indices) and adjusts size
  // returns the element formerly at the specified position

class java.util.ArrayList<E> implements java.util.List<E>

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AP® Computer Science A Exam

SECTION II: Free Response

2015

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

At a Glance

Total Time
1 hour, 45 minutes
Number of Questions
4
Percent of Total Score
50%
Writing Instrument
Pencil
Electronic Device
None allowed
Weight
The questions are weighted equally.

IMPORTANT Identification Information

PLEASE PRINT WITH PEN:

1. First two letters of your last name ☐☐
   First letter of your first name ☐
2. Date of birth
   ☐☐ Month ☐☐ Day ☐☐☐☐ Year
3. Six-digit school code
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Instructions

The questions for Section II are printed in this booklet. You may use any of the blank pages to organize your answers and for scratch work, but you must write your answers on the pages that correspond with the questions.

The Java Quick Reference is located at the back of this booklet.

Write your answer to each question in the space provided for the question in this booklet. Some questions require you to write program segments, and these must be written in Java. Show all your work. Credit for partial solutions will be given. Write clearly and legibly. Cross out any errors you make. Erased or crossed-out work will not be scored.

Manage your time carefully. Do not spend too much time on any one question. You may proceed freely from one question to the next. You may review your responses if you finish before the end of the exam is announced.

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Form O
Form Code 4LBP

COMPUTER SCIENCE A

SECTION II

Time—1 hour and 45 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.

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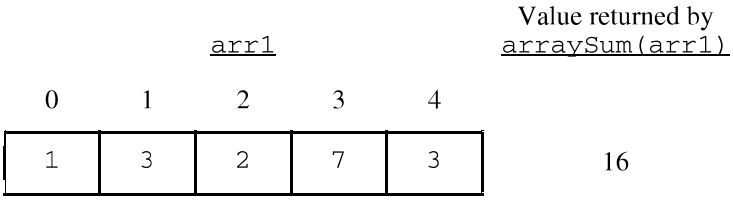
1. This question involves reasoning about one-dimensional and two-dimensional arrays of integers. You will write three static methods, all of which are in a single enclosing class, named `DiverseArray` (not shown). The first method returns the sum of the values of a one-dimensional array; the second method returns an array that represents the sums of the rows of a two-dimensional array; and the third method analyzes row sums.

   (a) Write a `static` method `arraySum` that calculates and returns the sum of the entries in a specified one-dimensional array. The following example shows an array `arr1` and the value returned by a call to `arraySum`.



WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Complete method `arraySum` below.

```
/** Returns the sum of the entries in the one-dimensional array arr.
 */
public static int arraySum(int[] arr)
```

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Part (b) begins on page 6.

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(b) Write a `static` method `rowSums` that calculates the sums of each of the rows in a given two-dimensional array and returns these sums in a one-dimensional array. The method has one parameter, a two-dimensional array `arr2D` of `int` values. The array is in row-major order: `arr2D[r][c]` is the entry at row `r` and column `c`. The method returns a one-dimensional array with one entry for each row of `arr2D` such that each entry is the sum of the corresponding row in `arr2D`. As a reminder, each row of a two-dimensional array is a one-dimensional array.

For example, if `mat1` is the array represented by the following table, the call `rowSums(mat1)` returns the array `{16, 32, 28, 20}`.

`mat1`

	0	1	2	3	4
0	1	3	2	7	3
1	10	10	4	6	2
2	5	3	5	9	6
3	7	6	4	2	1

Methods written in this question

```
public static int arraySum(int[] arr)
public static int[] rowSums(int[][] arr2D)
public static boolean isDiverse(int[][] arr2D)
```

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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

Complete method `rowSums` below.

```
/** Returns a one-dimensional array in which the entry at index k is the sum of
 *  the entries of row k of the two-dimensional array arr2D.
 */
public static int[] rowSums(int[][] arr2D)
```

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Part (c) begins on page 8.

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(c) A two-dimensional array is *diverse* if no two of its rows have entries that sum to the same value. In the following examples, the array `mat1` is diverse because each row sum is different, but the array `mat2` is not diverse because the first and last rows have the same sum.

`mat1`

	0	1	2	3	4	Row sums
0	1	3	2	7	3	16
1	10	10	4	6	2	32
2	5	3	5	9	6	28
3	7	6	4	2	1	20

`mat2`

	0	1	2	3	4	Row sums
0	1	1	5	3	4	14
1	12	7	6	1	9	35
2	8	11	10	2	5	36
3	3	2	3	0	6	14

Write a `static` method `isDiverse` that determines whether or not a given two-dimensional array is diverse. The method has one parameter: a two-dimensional array `arr2D` of `int` values. The method should return `true` if all the row sums in the given array are unique; otherwise, it should return `false`. In the arrays shown above, the call `isDiverse(mat1)` returns `true` and the call `isDiverse(mat2)` returns `false`.

Methods written in this question

```
public static int arraySum(int[] arr)
public static int[] rowSums(int[][] arr2D)
public static boolean isDiverse(int[][] arr2D)
```

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Assume that `arraySum` and `rowSums` work as specified, regardless of what you wrote in parts (a) and (b). You must use `rowSums` appropriately to receive full credit.

Complete method `isDiverse` below.

```
/** Returns true  if all rows in arr2D have different row sums;
 *          false otherwise.
 */
public static boolean isDiverse(int[][] arr2D)
```

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2. Consider a guessing game in which a player tries to guess a hidden word. The hidden word contains only capital letters and has a length known to the player. A guess contains only capital letters and has the same length as the hidden word.

   After a guess is made, the player is given a hint that is based on a comparison between the hidden word and the guess. Each position in the hint contains a character that corresponds to the letter in the same position in the guess. The following rules determine the characters that appear in the hint.

If the letter in the guess is …	**the corresponding character in the hint is**
also in the same position in the hidden word,	the matching letter
also in the hidden word, but in a different position,	`"+"`
not in the hidden word,	`"*"`

The `HiddenWord` class will be used to represent the hidden word in the game. The hidden word is passed to the constructor. The class contains a method, `getHint`, that takes a guess and produces a hint.

For example, suppose the variable puzzle is declared as follows.

```
HiddenWord puzzle = new HiddenWord("HARPS");
```

The following table shows several guesses and the hints that would be produced.

Call to `getHint`	**String returned**
`puzzle.getHint("AAAAA")`	`"+A+++"`
`puzzle.getHint("HELLO")`	`"H****"`
`puzzle.getHint("HEART")`	`"H*++*"`
`puzzle.getHint("HARMS")`	`"HAR*S"`
`puzzle.getHint("HARPS")`	`"HARPS"`

Write the complete `HiddenWord` class, including any necessary instance variables, its constructor, and the method, `getHint`, described above. You may assume that the length of the guess is the same as the length of the hidden word.

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ADDITIONAL WORK SPACE

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GO ON TO THE NEXT PAGE.

3. A two-dimensional array of integers in which most elements are zero is called a *sparse array*. Because most elements have a value of zero, memory can be saved by storing only the non-zero values along with their row and column indexes. The following complete `SparseArrayEntry` class is used to represent non-zero elements in a sparse array. A `SparseArrayEntry` object cannot be modified after it has been constructed.

```
public class SparseArrayEntry
{
  /** The row index and column index for this entry in the sparse array */
  private int row;
  private int col;

  /** The value of this entry in the sparse array */
  private int value;

  /** Constructs a SparseArrayEntry object that represents a sparse array element
   *  with row index r and column index c, containing value v.
   */
  public SparseArrayEntry(int r, int c, int v)
  {
    row = r;
    col = c;
    value = v;
  }

  /** Returns the row index of this sparse array element. */
  public int getRow()
  { return row; }

  /** Returns the column index of this sparse array element. */
  public int getCol()
  { return col; }

  /** Returns the value of this sparse array element. */
  public int getValue()
  { return value; }
}
```

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The `SparseArray` class represents a sparse array. It contains a list of `SparseArrayEntry` objects, each of which represents one of the non-zero elements in the array. The entries representing the non-zero elements are stored in the list in no particular order. Each non-zero element is represented by exactly one entry in the list.

```
public class SparseArray
{
  /** The number of rows and columns in the sparse array. */
  private int numRows;
  private int numCols;

  /** The list of entries representing the non-zero elements of the sparse array. Entries are stored in the
   *  list in no particular order. Each non-zero element is represented by exactly one entry in the list.
   */
  private List<SparseArrayEntry> entries;

  /** Constructs an empty SparseArray. */
  public SparseArray()
  {  entries = new ArrayList<SparseArrayEntry>();  }

  /** Returns the number of rows in the sparse array. */
  public int getNumRows()
  {  return numRows;  }

  /** Returns the number of columns in the sparse array. */
  public int getNumCols()
  {  return numCols;  }

  /** Returns the value of the element at row index row and column index col in the sparse array.
   *  Precondition: 0 ≤ row < getNumRows()
   *                0 ≤ col < getNumCols()
   */
  public int getValueAt(int row, int col)
  {  /* to be implemented in part (a) */  }

  /** Removes the column col from the sparse array.
   *  Precondition: 0 ≤ col < getNumCols()
   */
  public void removeColumn(int col)
  {  /* to be implemented in part (b) */  }

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

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The following table shows an example of a two-dimensional sparse array. Empty cells in the table indicate zero values.

	0	1	2	3	4
0					
1		5			4
2	1				
3		-9			
4					
5					

The sample array can be represented by a `SparseArray` object, `sparse`, with the following instance variable values. The items in `entries` are in no particular order; one possible ordering is shown below.

```
numRows: 6

numCols: 5

entries: [ row: 1 col: 4 value: 4 ] [ row: 2 col: 0 value: 1 ] [ row: 3 col: 1 value: -9 ] [ row: 1 col: 1 value: 5 ]
```

(a) Write the `SparseArray` method `getValueAt`. The method returns the value of the sparse array element at a given row and column in the sparse array. If the list `entries` contains an entry with the specified row and column, the value associated with the entry is returned. If there is no entry in `entries` corresponding to the specified row and column, 0 is returned.

In the example above, the call `sparse.getValueAt(3, 1)` would return -9, and `sparse.getValueAt(3, 3)` would return 0.

WRITE YOUR SOLUTION ON THE NEXT PAGE.

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Complete method `getValueAt` below.

```
/** Returns the value of the element at row index row and column index col in the sparse array.
 *  Precondition: 0 ≤ row < getNumRows()
 *                0 ≤ col < getNumCols()
 */
public int getValueAt(int row, int col)
```

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Part (b) begins on page 16.

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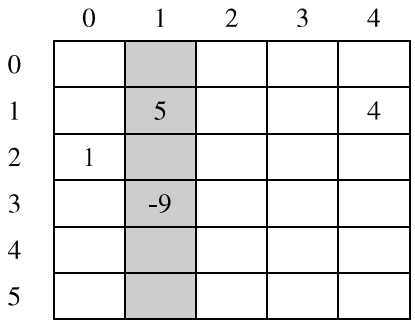
(b) Write the `SparseArray` method `removeColumn`. After removing a specified column from a sparse array:

- All entries in the list entries with column indexes matching col are removed from the list.
- All entries in the list `entries` with column indexes greater than `col` are replaced by entries with column indexes that are decremented by one (moved one column to the left).
- The number of columns in the sparse array is adjusted to reflect the column removed.

The sample object sparse from the beginning of the question is repeated for your convenience.



The shaded entries in `entries`, below, correspond to the shaded column above.

```
numRows: 6

numCols: 5

entries:  [ row: 1 col: 4 value: 4 ]  [ row: 2 col: 0 value: 1 ]  [ row: 3 col: 1 value: -9 ]  [ row: 1 col: 1 value: 5 ]
```

When `sparse` has the state shown above, the call `sparse.removeColumn(1)` could result in `sparse` having the following values in its instance variables (since `entries` is in no particular order, it would be equally valid to reverse the order of its two items). The shaded areas below show the changes.

```
numRows: 6

numCols: 4

entries:  [ row: 1 col: 3 value: 4 ]  [ row: 2 col: 0 value: 1 ]
```

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Class information repeated from the beginning of the question

```
public class SparseArrayEntry

public SparseArrayEntry(int r, int c, int v)
public int getRow()
public int getCol()
public int getValue()

public class SparseArray

private int numRows
private int numCols
private List<SparseArrayEntry> entries
public int getNumRows()
public int getNumCols()
public int getValueAt(int row, int col)
public void removeColumn(int col)
```

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Complete method `removeColumn` below.

```
/** Removes the column col from the sparse array.
 *  Precondition: 0 ≤ col < getNumCols()
 */
public void removeColumn(int col)
```

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ADDITIONAL WORK SPACE

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GO ON TO THE NEXT PAGE.

4. This question involves the design of an interface, writing a class that implements the interface, and writing a method that uses the interface.

(a) A *number group* represents a group of integers defined in some way. It could be empty, or it could contain one or more integers.

Write an interface named `NumberGroup` that represents a group of integers. The interface should have a single `contains` method that determines if a given integer is in the group. For example, if `group1` is of type `NumberGroup`, and it contains only the two numbers `-5` and `3`, then `group1.contains(-5)` would return `true`, and `group1.contains(2)` would return `false`.

Write the complete `NumberGroup` interface. It must have exactly one method.

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Part (b) begins on page 21.

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(b) A *range* represents a number group that contains all (and only) the integers between a minimum value and a maximum value, inclusive.

Write the `Range` class, which is a `NumberGroup`. The `Range` class represents the group of `int` values that range from a given minimum value up through a given maximum value, inclusive. For example, the declaration

```
NumberGroup range1 = new Range(-3, 2);
```

represents the group of integer values -3, -2, -1, 0, 1, 2.

Write the complete Range class. Include all necessary instance variables and methods as well as a constructor that takes two `int` parameters. The first parameter represents the minimum value, and the second parameter represents the maximum value of the range. You may assume that the minimum is less than or equal to the maximum.

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Part (c) begins on page 22.

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(c) The `MultipleGroups` class (not shown) represents a collection of `NumberGroup` objects and is a `NumberGroup`. The `MultipleGroups` class stores the number groups in the instance variable grouplist (shown below), which is initialized in the constructor.

```
private List<NumberGroup> groupList;
```

Write the `MultipleGroups` method `contains`. The method takes an integer and returns `true` if and only if the integer is contained in one or more of the number groups in grouplist.

For example, suppose `multiple1` has been declared as an instance of `MultipleGroups` and consists of the three ranges created by the calls `new Range(5, 8)`, `new Range(10, 12)`, and `new Range(1, 6)`. The following table shows the results of several calls to `contains`.

Call	Result
`multiple1.contains(2)`	`true`
`multiple1.contains(9)`	`false`
`multiple1.contains(6)`	`true`

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Complete method `contains` below.

```
/** Returns true if at least one of the number groups in this multiple group contains num;
 *          false otherwise.
 */
public boolean contains(int num)
```

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GO ON TO THE NEXT PAGE.

STOP

END OF EXAM

THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE SECTION II BOOKLET.

- **MAKE SURE YOU HAVE COMPLETED THE IDENTIFICATION INFORMATION AS REQUESTED ON THE FRONT AND BACK COVERS OF THE SECTION II BOOKLET.**
- **CHECK TO SEE THAT YOUR AP NUMBER LABEL APPEARS IN THE BOX ON THE COVER.**
- **MAKE SURE YOU HAVE USED THE SAME SET OF AP NUMBER LABELS ON ALL AP EXAMS YOU HAVE TAKEN THIS YEAR.**

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Java Quick Reference

Accessible Methods from the Java Library That May Be Included on the Exam

class java.lang.Object

- `boolean equals(Object other)`
- `String toString()`

class java.lang.Integer

- `Integer(int value)`
- `int intValue()`
- `Integer.MIN_VALUE` // minimum value represented by an `int` or `Integer`
- `Integer.MAX_VALUE` // maximum value represented by an `int` or `Integer`

class java.lang.Double

- `Double(double value)`
- `double doubleValue()`

class java.lang.String

- `int length()`
- `String substring(int from, int to)` // returns the substring beginning at `from`
  // and ending at `to-1`
- `String substring(int from)` // returns `substring(from, length())`
- `int indexOf(String str)` // returns the index of the first occurrence of `str`;
  // returns `-1` if not found
- `int compareTo(String other)` // returns a value < 0 if `this` is less than `other`
  // returns a value = 0 if `this` is equal to `other`
  // returns a value > 0 if `this` is greater than `other`

class java.lang.Math

- `static int abs(int x)`
- `static double abs(double x)`
- static double pow (double base, double exponent)
- `static double sqrt(double x)`
- `static double random()` // returns a `double` in the range [0.0, 1.0)

interface java.util.List<E>

- `int size()`
- `boolean add(E obj)` // appends `obj` to end of list; returns `true`
- `void add(int index, E obj)` // inserts `obj` at position `index` (0 ≤ `index` ≤ size),
  // moving elements at position `index` and higher
  // to the right (adds 1 to their indices) and adjusts size
- `E get(int index)`
- `E set(int index, E obj)` // replaces the element at position `index` with `obj`
  // returns the element formerly at the specified position
- `E remove(int index)` // removes element from position `index`, moving elements
  // at position `index + 1` and higher to the left
  // (subtracts 1 from their indices) and adjusts size
  // returns the element formerly at the specified position

class java.util.ArrayList<E> implements java.util.List<E>

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