Computer Science A: Sample Multiple-Choice Questions

Following is a representative set of questions. The answer key for the Computer Science A multiple-choice questions is on page 43. Multiple-choice scores are based on the number of questions answered correctly. Points are not deducted for incorrect answers, and no points are awarded for unanswered questions. Because points are not deducted for incorrect answers, students are encouraged to answer all multiple-choice questions. Students should eliminate as many choices as they can on any questions for which they do not know the answer, and then select the best answer among the remaining choices.

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.

1. Consider the following code segment.

```
for (int k = 0; k < 20; k = k + 2)
{
  if (k % 3 == 1)
  {
    System.out.print(k + "  ");
  }
}
```

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

(A) `4  16`

(B) `4  10  16`

(C) `0  6  12  18`

(D) `1  4  7  10  13  16  19`

(E) `0  2  4  6  8  10  12  14  16  18`

2. Consider the following code segment.

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

animals.add("dog");
animals.add("cat");
animals.add("snake");
animals.set(2, "lizard");
animals.add(1, "fish");
animals.remove(3);
System.out.println(animals);
```

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

(A) `[dog, fish, cat]`

(B) `[dog, fish, lizard]`

(C) `[dog, lizard, fish]`

(D) `[fish, dog, cat]`

(E) The code throws an `ArrayIndexOutOfBoundsException` exception.

3. Consider the following method.

```
public static void mystery(List<Integer> nums)
{
  for (int k = 0; k < nums.size(); k++)
  {
    if (nums.get(k).intValue() == 0)
    {
       nums.remove(k);
    }
  }
}
```

Assume that a `List<Integer> values` initially contains the following `Integer` values.

```
[0, 0, 4, 2, 5, 0, 3, 0]
```

What will `values` contain as a result of executing `mystery(values)`?

(A) `[0, 0, 4, 2, 5, 0, 3, 0]`

(B) `[4, 2, 5, 3]`

(C) `[0, 0, 0, 0, 4, 2, 5, 3]`

(D) `[0, 4, 2, 5, 3]`

(E) The code throws an `ArrayIndexOutOfBoundsException` exception.

4. At a certain high school students receive letter grades based on the following scale.

Integer Score	Letter Grade
93 or above	A
From 84 to 92 inclusive	B
From 75 to 83 inclusive	C
Below 75	F

Which of the following code segments will assign the correct string to `grade` for a given integer `score` ?

I.
```
if (score >= 93)
  grade = "A";
if (score >= 84 && score <= 92)
  grade = "B";
if (score >= 75 && score <= 83)
  grade = "C";
if (score < 75)
  grade = "F";
```

II.
```
if (score >= 93)
  grade = "A";
if (84 <= score <= 92)
  grade = "B";
if (75 <= score <= 83)
  grade = "C";
if (score < 75)
  grade = "F";
```

III.
```
if (score >= 93)
  grade = "A";
else if (score >= 84)
  grade = "B";
else if (score >= 75)
  grade = "C";
else
  grade = "F";
```

(A) II only

(B) III only

(C) I and II only

(D) I and III only

(E) I, II, and III

5. Consider the following output.

```
1  1  1  1  1
2  2  2  2
3  3  3
4  4
5
```

Which of the following code segments will produce this output?

(A)
```
for (int j = 1; j <= 5; j++)
{
  for (int k = 1; k <= 5; k++)
  {
    System.out.print(j + "  ");
  }
  System.out.println();
}
```

(B)
```
for (int j = 1; j <= 5; j++)
{
  for (int k = 1; k <= j; k++)
  {
    System.out.print(j + "  ");
  }
  System.out.println();
}
```

(C)
```
for (int j = 1; j <= 5; j++)
{
  for (int k = 5; k >= 1; k--)
  {
    System.out.print(j + "  ");
  }
  System.out.println();
}
```

(D)
```
for (int j = 1; j <= 5; j++)
{
  for (int k = 5; k >= j; k--)
  {
    System.out.print(j + "  ");
  }
  System.out.println();
}
```

(E)
```
for (int j = 1; j <= 5; j++)
{
  for (int k = j; k <= 5; k++)
  {
    System.out.print(k + "  ");
  }
  System.out.println();
}
```

6. A car dealership needs a program to store information about the cars for sale. For each car, they want to keep track of the following information: number of doors (2 or 4), whether the car has air conditioning, and its average number of miles per gallon. Which of the following is the best object-oriented program design?

   (A) Use one class, `Car`, with three instance variables: `int numDoors`, `boolean hasAir`, and `double milesPerGallon`.

   (B) Use four unrelated classes: `Car`, `Doors`, `AirConditioning`, and `MilesPerGallon`.

   (C) Use a class `Car` with three subclasses: `Doors`, `AirConditioning`, and `MilesPerGallon`.

   (D) Use a class `Car`, with a subclass `Doors`, with a subclass `AirConditioning`, with a subclass `MilesPerGallon`.

   (E) Use three classes: `Doors`, `AirConditioning`, and `MilesPerGallon`, each with a subclass `Car`.

7. Consider the following declarations.

```
public interface Shape
{
  int isLargerThan(Shape other);
  // Other methods not shown
}
public class Circle implements Shape
{
  // Other methods not shown
}
```

   Which of the following method headings of `isLargerThan` can be added to the declaration of the `Circle` class so that it will satisfy the `Shape` interface?

   I. `public int isLargerThan(Shape other)`

   II. `public int isLargerThan(Circle other)`

   III. `public boolean isLargerThan(Object other)`

   (A) I only

   (B) II only

   (C) III only

   (D) I and II only

   (E) I, II, and III

Questions 8–9 refer to the following incomplete class declaration.

```
public class TimeRecord
{
  private int hours;
  private int minutes; // 0 ≤ minutes < 60
  /** Constructs a TimeRecord object.
   *  @param h the number of hours
   *           Precondition: h ≥ 0
   *  @param m the number of minutes
   *           Precondition: 0 ≤ m < 60
   */
  public TimeRecord(int h, int m)
  {
    hours = h;
    minutes = m;
  }

  /** @return the number of hours
   */
  public int getHours()
  { /* implementation not shown */ }

  /** @return the number of minutes
   *  Postcondition: 0 ≤ minutes < 60
   */
  public int getMinutes()
  { /* implementation not shown */ }

  /** Adds h hours and m minutes to this TimeRecord.
   *  @param h the number of hours
   *           Precondition: h ≥ 0
   *  @param m the number of minutes
   *           Precondition: m ≥ 0
   */
  public void advance(int h, int m)
  {
    hours = hours + h;
    minutes = minutes + m;
    /* missing code */
  }
  // Other methods not shown
}
```

8. Which of the following can be used to replace /* *missing code* */ so that `advance` will correctly update the time?

   (A)
   ```
   minutes = minutes % 60;
   ```

   (B)
   ```
   minutes = minutes + hours % 60;
   ```

   (C)
   ```
   hours = hours + minutes / 60;
   minutes = minutes % 60;
   ```

   (D)
   ```
   hours = hours + minutes % 60;
   minutes = minutes / 60;
   ```

   (E)
   ```
   hours = hours + minutes / 60;
   ```

9. Consider the following declaration that appears in a class other than `TimeRecord`.

   ```
   TimeRecord[] timeCards = new TimeRecord[100];
   ```

   Assume that `timeCards` has been initialized with `TimeRecord` objects. Consider the following code segment that is intended to compute the total of all the times stored in `timeCards`.

   ```
   TimeRecord total = new TimeRecord(0,0);
   for (int k = 0; k < timeCards.length; k++)
   {
     /* missing expression */ ;
   }
   ```

   Which of the following can be used to replace /* *missing expression* */ so that the code segment will work as intended?

   (A)
   ```
   timeCards[k].advance()
   ```

   (B)
   ```
   total += timeCards[k].advance()
   ```

   (C)
   ```
   total.advance(timeCards[k].hours,
                 timeCards[k].minutes)
   ```

   (D)
   ```
   total.advance(timeCards[k].getHours(),
                 timeCards[k].getMinutes())
   ```

   (E)
   ```
   timeCards[k].advance(timeCards[k].getHours(),
                        timeCards[k].getMinutes())
   ```

10. Consider the following instance variable and method.

```
private int[] arr;

/** Precondition: arr contains no duplicates;
 *                the elements in arr are in ascending order.
 *  @param low an int value such that 0 ≤ low ≤ arr.length
 *  @param high an int value such that low - 1 ≤ high < arr.length
 *  @param num an int value
 */
public int mystery(int low, int high, int num)
{
  int mid = (low + high) / 2;
  if (low > high)
  {
    return low;
  }
  else if (arr[mid] < num)
  {
    return mystery(mid + 1, high, num);
  }
  else if (arr[mid] > num)
  {
    return mystery(low, mid - 1, num);
  }
  else // arr[mid] == num
  {
    return mid;
  }
}
```

What is returned by the call `mystery(0, arr.length - 1, num)`?

(A) The number of elements in `arr` that are less than `num`

(B) The number of elements in `arr` that are less than or equal to `num`

(C) The number of elements in `arr` that are equal to `num`

(D) The number of elements in `arr` that are greater than `num`

(E) The index of the middle element in `arr`

Questions 11–12 refer to the following information.

Consider the following instance variable `nums` and method `findLongest` with line numbers added for reference. Method `findLongest` is intended to find the longest consecutive block of the value `target` occurring in the array `nums`; however, `findLongest` does not work as intended.

For example, if the array `nums` contains the values [7, 10, 10, 15, 15, 15, 15, 10, 10, 10, 15, 10, 10], the call `findLongest(10)` should return 3, the length of the longest consecutive block of 10s.

```
private int[] nums;

public int findLongest(int target)
{
    int lenCount = 0;
    int maxLen = 0;

Line 1:  for (int val : nums)
Line 2:  {
Line 3:    if (val == target)
Line 4:    {
Line 5:      lenCount++;
Line 6:    }
Line 7:    else
Line 8:    {
Line 9:      if (lenCount > maxLen)
Line 10:     {
Line 11:       maxLen = lenCount;
Line 12:     }
Line 13:   }
Line 14: }
Line 15: if (lenCount > maxLen)
Line 16: {
Line 17:   maxLen = lenCount;
Line 18: }
Line 19: return maxLen;
    }
```

11. The method `findLongest` does not work as intended. Which of the following best describes the value returned by a call to `findLongest ?`

    (A) It is the length of the shortest consecutive block of the value `target` in `nums`.

    (B) It is the length of the array `nums`.

    (C) It is the number of occurrences of the value `target` in `nums`.

    (D) It is the length of the first consecutive block of the value `target` in `nums`.

    (E) It is the length of the last consecutive block of the value `target` in `nums`.

12. Which of the following changes should be made so that method `findLongest` will work as intended?

    (A) Insert the statement `lenCount = 0;` between lines 2 and 3.

    (B) Insert the statement `lenCount = 0;` between lines 8 and 9.

    (C) Insert the statement `lenCount = 0;` between lines 10 and 11.

    (D) Insert the statement `lenCount = 0;` between lines 11 and 12.

    (E) Insert the statement `lenCount = 0;` between lines 12 and 13.

13. Consider the following instance variable and method.

```
private int[] numbers;

/** Precondition: numbers contains int values in no particular order.
 */
public int mystery(int num)
{
  for (int k = numbers.length - 1; k >= 0; k--)
  {
    if (numbers[k] < num)
    {
      return k;
    }
  }
  return -1;
}
```

Which of the following best describes the contents of `numbers` after the following statement has been executed?

```
int m = mystery(n);
```

(A) All values in positions `0` through `m` are less than `n`.

(B) All values in positions `m+1` through `numbers.length-1` are less than `n`.

(C) All values in positions `m+1` through `numbers.length-1` are greater than or equal to `n`.

(D) The smallest value is at position `m`.

(E) The largest value that is smaller than `n` is at position `m`.

14. Consider the following method.

```
/** @param x an int value such that x >= 0
 */
public void mystery(int x)
{
  System.out.print(x % 10);
  if ((x / 10) != 0)
  {
    mystery(x / 10);
  }
  System.out.print(x % 10);
}
```

Which of the following is printed as a result of the call `mystery(1234)`?

(A) `1234`

(B) `4321`

(C) `12344321`

(D) `43211234`

(E) Many digits are printed due to infinite recursion.

15. Consider the following two classes.

```
public class Dog
{
  public void act()
  {
    System.out.print("run ");
    eat();
  }
  public void eat()
  {
    System.out.print("eat ");
  }
}
public class UnderDog extends Dog
{
  public void act()
  {
    super.act();
    System.out.print("sleep ");
  }
  public void eat()
  {
    super.eat();
    System.out.print("bark ");
  }
 }
```

Assume that the following declaration appears in a class other than `Dog`.

```
Dog fido = new UnderDog();
```

What is printed as a result of the call `fido.act()` ?

(A) `run eat`

(B) `run eat sleep`

(C) `run eat sleep bark`

(D) `run eat bark sleep`

(E) Nothing is printed due to infinite recursion.

16. Consider the following recursive method.

```
public static int mystery(int n)
{
  if (n <= 1)
  {
    return 0;
  }
  else
  {
    return 1 + mystery(n / 2);
  }
}
```

Assuming that k is a nonnegative integer and $m = 2^k$, what value is returned as a result of the call `mystery(`m`)` ?

(A) 0

(B) k

(C) m

(D) $\frac{m}{2} + 1$

(E) $\frac{k}{2} + 1$

17. Consider the following instance variable and method.

```
private int[] array;

/** Precondition: array.length > 0
 */
public int checkArray()
{
  int loc = array.length / 2;
  for (int k = 0; k < array.length; k++)
  {
    if (array[k] > array[loc])
    {
      loc = k;
    }
  }
  return loc;
}
```

Which of the following is the best postcondition for `checkArray` ?

(A) Returns the index of the first element in array `array` whose value is greater than `array[loc]`

(B) Returns the index of the last element in array `array` whose value is greater than `array[loc]`

(C) Returns the largest value in array `array`

(D) Returns the index of the largest value in array `array`

(E) Returns the index of the largest value in the second half of array `array`

18. Consider the following methods.

```
public void changer(String x, int y)
{
  x = x + "peace";
  y = y * 2;
}

public void test()
{
  String s = "world";
  int n = 6;
  changer(s, n);

  /* End of method */
 }
```

When the call `test()` is executed, what are the values of `s` and `n` at the point indicated by `/* End of method */` ?

	s	n
(A)	world	6
(B)	worldpeace	6
(C)	world	12
(D)	worldpeace	12
(E)	peace	12

19. Consider the following code segment.

```
int[][] mat = new int[3][4];
for (int row = 0; row < mat.length; row++)
{
   for (int col = 0; col < mat[0].length; col++)
   {
     if (row < col)
     {
       mat[row][col] = 1;
     }
     else if (row == col)
     {
       mat[row][col] = 2;
     }
     else
     {
       mat[row][col] = 3;
     }
   }
}
```

What are the contents of `mat` after the code segment has been executed?

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

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

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

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

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

20. Consider the following method.

```
/** Precondition: arr contains only positive values.
 */
public static void doSome(int[] arr, int lim)
{
  int v = 0;
  int k = 0;
  while (k < arr.length && arr[k] < lim)
  {
    if (arr[k] > v)
    {
      v = arr[k]; /* Statement S */
    }
    k++; /* Statement T */
  }
}
```

Assume that `doSome` is called and executes without error. Which of the following are possible combinations for the value of `lim`, the number of times *Statement S* is executed, and the number of times *Statement T* is executed?

	Value of `lim`	Executions of *Statement S*	Executions of *Statement T*
I.	5	0	5
II.	7	4	9
III.	3	5	2

(A) I only

(B) II only

(C) III only

(D) I and III only

(E) II and III only

21. Consider the following instance variable, `arr`, and incomplete method, `partialSum`. The method is intended to return an integer array `sum` such that for all `k`, `sum[k]` is equal to `arr[0] + arr[1] + ... + arr[k]`. For instance, if `arr` contains the values `{ 1, 4, 1, 3 }`, the array `sum` will contain the values `{ 1, 5, 6, 9 }`.

```
private int[] arr;
public int[] partialSum()
{
  int[] sum = new int[arr.length];
  for (int j = 0; j < sum.length; j++)
  {
    sum[j] = 0;
  }
  /* missing code */
  return sum;
}
```

The following two implementations of `/* missing code */` are proposed so that `partialSum` will work as intended.

Implementation 1

```
for (int j = 0; j < arr.length; j++)
{
  sum[j] = sum[j - 1] + arr[j];
}
```

Implementation 2

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

Which of the following statements is true?

(A) Both implementations work as intended, but implementation 1 is faster than implementation 2.

(B) Both implementations work as intended, but implementation 2 is faster than implementation 1.

(C) Both implementations work as intended and are equally fast.

(D) Implementation 1 does not work as intended, because it will cause an `ArrayIndexOutOfBoundsException`.

(E) Implementation 2 does not work as intended, because it will cause an `ArrayIndexOutOfBoundsException`.

22. Consider the following declaration for a class that will be used to represent points in the *xy*-coordinate plane.

```
public class Point
{
  private int x;      // x-coordinate of the point
  private int y;      // y-coordinate of the point

  public Point()
  {
    x = 0;
    y = 0;
  }

  public Point(int a, int b)
  {
    x = a;
    y = b;
  }

  // Other methods not shown
}
```

The following incomplete class declaration is intended to extend the above class so that points can be named.

```
public class NamedPoint extends Point
{
  private String name; // name of point

  // Constructors go here

  // Other methods not shown
}
```

Consider the following proposed constructors for this class.

I.
```
public NamedPoint()
{
  name = "";
}
```

II.
```
public NamedPoint(int d1, int d2, String pointName)
{
  x = d1;
  y = d2;
  name = pointName;
}
```

III.
```
public NamedPoint(int d1, int d2, String pointName)
{
  super(d1, d2);
  name = pointName;
}
```

Which of these constructors would be legal for the `NamedPoint` class?

(A) I only

(B) II only

(C) III only

(D) I and III only

(E) II and III only

23. Consider a `shuffle` method that is intended to return a new array that contains all the elements from `nums`, but in a different order. Let `n` be the number of elements in `nums`. The `shuffle` method should alternate the elements from `nums[0]` … `nums[n / 2 - 1]` with the elements from `nums[n / 2]` … `nums[n - 1]`, as illustrated in the following examples.

Example 1

	0	1	2	3	4	5	6	7
`nums`	10	20	30	40	50	60	70	80

	0	1	2	3	4	5	6	7
`result`	10	50	20	60	30	70	40	80

Example 2

	0	1	2	3	4	5	6
`nums`	10	20	30	40	50	60	70

	0	1	2	3	4	5	6
`result`	10	40	20	50	30	60	70

The following implementation of the `shuffle` method does not work as intended.

```
public static int[] shuffle(int[] nums)
{
  int n = nums.length;
  int[] result = new int[n];

  for (int j = 0; j < n / 2; j++)
  {
    result[j * 2] = nums[j];
    result[j * 2 + 1] = nums[j + n / 2];
  }

  return result;
}
```

Which of the following best describes the problem with the given implementation of the `shuffle` method?

(A) Executing `shuffle` may cause an `ArrayIndexOutOfBoundsException`.

(B) The first element of the returned array (`result[0]`) may not have the correct value.

(C) The last element of the returned array (`result[result.length - 1]`) may not have the correct value.

(D) One or more of `nums[0]` … `nums[nums.length / 2 - 1]` may have been copied to the wrong position(s) in the returned array.

(E) One or more of `nums[nums.length / 2]` … `nums[nums.length - 1]` may have been copied to the wrong position(s) in the returned array.

24. Consider the following `Util` class, which contains two methods. The completed `sum1D` method returns the sum of all the elements of the 1-dimensional array `a`. The incomplete `sum2D` method is intended to return the sum of all the elements of the 2-dimensional array `m`.

```
public class Util
{
  /** Returns the sum of the elements of the 1-dimensional array a */
  public static int sum1D(int[] a)
  {  /* implementation not shown */  }

  /** Returns the sum of the elements of the 2-dimensional array m */
  public static int sum2D(int[][] m)
  {
    int sum = 0;

    /* missing code */

    return sum;
  }
}
```

Assume that `sum1D` works correctly. Which of the following can replace `/* missing code */` so that the `sum2D` method works correctly?

I.
```
for (int k = 0; k < m.length; k++)
{
  sum += sum1D(m[k]);
}
```

II.
```
for (int[] row : m)
{
  sum += sum1D(row);
}
```

III.
```
for (int[] row : m)
{
  for (int v : row)
  {
    sum += v;
  }
}
```

(A) I only

(B) II only

(C) I and II only

(D) II and III only

(E) I, II, and III

25. The following `sort` method correctly sorts the integers in `elements` into ascending order.

```
Line 1:  public static void sort(int[] elements)
Line 2:  {
Line 3:    for (int j = 0; j < elements.length - 1; j++)
Line 4:    {
Line 5.      int index = j;
Line 6:
Line 7:      for (int k = j + 1; k < elements.length; k++)
Line 8:      {
Line 9:        if (elements[k] < elements[index])
Line 10:       {
Line 11:         index = k;
Line 12:       }
Line 13:     }
Line 14:
Line 15:     int temp = elements[j];
Line 16:     elements[j] = elements[index];
Line 17:     elements[index] = temp;
Line 18:   }
Line 19: }
```

Which of the following changes to the `sort` method would correctly sort the integers in `elements` into **descending** order?

I. Replace line 9 with:
Line 9: `if (elements[k] > elements[index])`

II. Replace lines 15–17 with:
Line 15: `int temp = elements[index];`
Line 16: `elements[index] = elements[j];`
Line 17: `elements[j] = temp;`

III. Replace line 3 with:
Line 3: `for (int j = elements.length − 1; j > 0; j−−)`
and replace line 7 with:
Line 7: `for (int k = 0; k < j; k++)`

(A) I only

(B) II only

(C) I and II only

(D) I and III only

(E) I, II, and III

Answers to Computer Science A Multiple-Choice Questions

1 – B	6 – A	11 – C	16 – B	21 – D
2 – A	7 – A	12 – E	17 – D	22 – D
3 – D	8 – C	13 – C	18 – A	23 – C
4 – D	9 – D	14 – D	19 – D	24 – E
5 – D	10 – A	15 – D	20 – B	25 – D

Sample Free-Response Questions

Following is a representative set of questions. Additional sample questions can be found in the AP section of the College Board website.

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. A travel agency maintains a list of information about airline flights. Flight information includes a departure time and an arrival time. You may assume that the two times occur on the same day. These times are represented by objects of the `Time` class.

   The declaration for the `Time` class is shown below. It includes a method `minutesUntil`, which returns the difference (in minutes) between the current `Time` object and another `Time` object.

```
public class Time
{
   /** @return difference, in minutes, between this time and other;
    *          difference is negative if other is earlier than this time
    */
   public int minutesUntil(Time other)
   {  /* implementation not shown */  }

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

   For example, assume that `t1` and `t2` are `Time` objects where `t1` represents 1:00 P.M. and `t2` represents 2:15 P.M. The call `t1.minutesUntil(t2)` will return `75` and the call `t2.minutesUntil(t1)` will return `-75`.

The declaration for the `Flight` class is shown below. It has methods to access the departure time and the arrival time of a flight. You may assume that the departure time of a flight is earlier than its arrival time.

```
public class Flight
{
  /** @return time at which the flight departs
   */
  public Time getDepartureTime()
  { /* implementation not shown */ }

  /** @return time at which the flight arrives
   */
  public Time getArrivalTime()
  { /* implementation not shown */ }

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

A trip consists of a sequence of flights and is represented by the `Trip` class. The `Trip` class contains a `List` of `Flight` objects that are stored in chronological order. You may assume that for each flight after the first flight in the list, the departure time of the flight is later than the arrival time of the preceding flight in the list. A partial declaration of the `Trip` class is shown below. You will write two methods for the `Trip` class.

```
public class Trip
{
  /** The list of flights (if any) that make up this trip, stored in chronological
      order */
  private List<Flight> flights;

  /** @return the number of minutes from the departure of the first flight to the
   *          arrival of the last flight if there are one or more flights in the trip;
   *          0, if there are no flights in the trip
   */
  public int getDuration()
  {  /* to be implemented in part (a) */  }

  /**  Precondition: the departure time for each flight is later than the arrival
   *                 time of its preceding flight
   *   @return the smallest number of minutes between the arrival of
   *           a flight and the departure of the flight immediately after it,
   *           if there are two or more flights in the trip;
   *           -1, if there are fewer than two flights in the trip
   */
  public int getShortestLayover()
  {  /* to be implemented in part (b) */  }

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

(a) Complete method `getDuration` below.

```
/**  @return the number of minutes from the departure of the first
 *           flight to the arrival of the last flight if there are one or
 *           more flights in the trip;
 *           0, if there are no flights in the trip
 */
public int getDuration()
```

(b) Write the `Trip` method `getShortestLayover`. A layover is the number of minutes from the arrival of one flight in a trip to the departure of the flight immediately after it. If there are two or more flights in the trip, the method should return the shortest layover of the trip; otherwise, it should return -1.

For example, assume that the instance variable `flights` of a `Trip` object `vacation` contains the following flight information.

	Departure Time	Arrival Time	Layover (minutes)
Flight 0	11:30 a.m.	12:15 p.m.	} 60
Flight 1	1:15 p.m.	3:45 p.m.	} 15
Flight 2	4:00 p.m.	6:45 p.m.	} 210
Flight 3	10:15 p.m.	11:00 p.m.	

The call `vacation.getShortestLayover()` should return 15.

Complete method `getShortestLayover` below.

```
/** Precondition: the departure time for each flight is later than the arrival
 *                time of its preceding flight
 *  @return the smallest number of minutes between the arrival of a
 *          flight and the departure of the flight immediately after it, if
 *          there are two or more flights in the trip;
 *          -1, if there are fewer than two flights in the trip
 */
public int getShortestLayover()
```

2. Consider the following incomplete `StringUtil` class declaration. You will write implementations for the two methods listed in this class. Information about the `Person` class used in the `replaceNameNickname` method will be presented in part (b).

```
public class StringUtil
{
  /** @param str a String with length > 0
   *  @param oldstr a String
   *  @param newstr a String
   *  @return a new String in which all occurrences of the substring
   *            oldstr in str are replaced by the substring newstr
   */
  public static String apcsReplaceAll(String str,
                                      String oldStr,
                                      String newStr)
  {  /* to be implemented in part (a) */  }

  /** @param str a String
   *  @param people a list of references to Person objects
   *  @return a copy of str modified so that each occurrence of a first
   *          name in people is replaced by the corresponding nickname
   */
  public static String replaceNameNickname(String str,
                                           List<Person>
                                           people)
  {  /* to be implemented in part (b) */  }

  // There may be methods that are not shown.
}
```

(a) Write the `StringUtil` method `apcsReplaceAll`, which examines a given `String` and replaces all occurrences of a designated substring with another specified substring. In writing your solution, you may NOT use the `replace`, `replaceAll`, or `replaceFirst` methods in the Java `String` class.

The following table shows several examples of the result of calling `StringUtil.apcsReplaceAll(str, oldstr,0 newstr)`.

str	oldstr	newstr	String returned	Comment
`"to be or not to be"`	`"to"`	`"2"`	`"2 be or not 2 be"`	Each occurrence of `"to"` in the original string has been replaced by "2"
`"advanced calculus"`	`"math"`	`"science"`	`"advanced calculus"`	No change, because the string `"math"` was not in the original string
`"gogogo"`	`"go"`	`"gone"`	`"gonegonegone"`	Each occurrence of `"go"` in the original string has been replaced by `"gone"`
`"aaaaa"`	`"aaa"`	`"b"`	`"baa"`	The first occurrence of `"aaa"` in the original string has been replaced by `"b"`

Complete method `apcsReplaceAll` below.

```
/** @param str a String with length > 0
 *  @param oldstr a String
 *  @param newstr a String
 *  @ return a new String in which all occurrences of the substring
 *            oldstr in str are replaced by the substring newstr
 */
public static String apcsReplaceAll(String str,
                                    String oldStr,
                                    String newStr)
```

(b) The following `Person` class contains information that includes a first (given) name and a nickname for the person.

```
public class Person
{
  /** @return the first name of this Person */
  public String getFirstName()
  { /* implementation not shown */ }

  /** @return the nickname of this Person */
  public String getNickname()
  { /* implementation not shown */ }

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

Write the `StringUtil` method `replaceNameNickname`, which takes a string and a list of `Person` objects that contain first names and a corresponding nicknames. The method is to replace all names by their nicknames in the given string. The list of `Person` objects is processed in order from lowest index to highest index. In writing your solution, you may NOT use the `replace`, `replaceAll`, or `replaceFirst` methods in the Java `String` class.

For example, assume the following table represents the data contained in the list `people`.

	`getFirstName()`	`getNickname()`
0	`"Henry"`	`"Hank"`
1	`"Elizabeth"`	`"Liz"`
2	`"John"`	`"Jack"`
3	`"Margaret"`	`"Peggy"`

Assume also that `String str` represents the following string.

```
"After Henry drove Elizabeth to dinner in Johnson City, Henry
paid for an appetizer and Elizabeth paid for dessert."
```

The call `StringUtil.replaceNameNickname(str, people)` should return the following string:

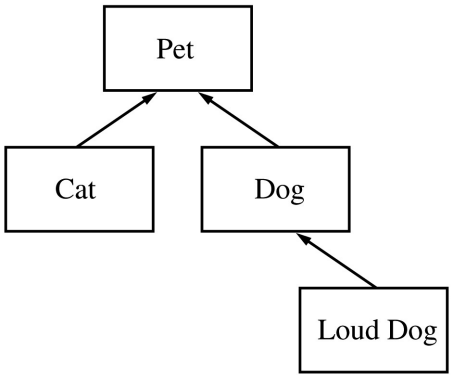
```
"After Hank drove Liz to dinner in Jackson City, Hank paid for
an appetizer and Liz paid for dessert."
```

In writing your solution, you must use the method `apcsReplaceAll` specified in the `StringUtil` class. Assume that `apcsReplaceAll` works as specified, regardless of what you wrote in part (a).

Complete method `replaceNameNickname` below.

```
/** @param str a String
 *  @param people a list of references to Person objects
 *  @return a copy of str modified so that each occurrence of a first
 *          name in people is replaced by the corresponding nickname
 */
public static String replaceNameNickname(String str,
                                         List<Person> people)
```

3. Consider the hierarchy of classes shown in the following diagram.



Note that a `Cat` "is-a" `Pet`, a `Dog` "is-a" `Pet`, and a `LoudDog` "is-a" `Dog`.

The class `Pet` is specified as an abstract class as shown in the following declaration. Each `Pet` has a name that is specified when it is constructed.

```
public abstract class Pet
{
  private String name;

  public Pet(String petName)
  {  name = petName;  }

  public String getName()
  {  return name;  }

  public abstract String speak();
}
```

The subclass `Dog` has the partial class declaration shown below.

```
public class Dog extends Pet
{
  public Dog(String petName)
  {  /* implementation not shown */  }

  public String speak()
  {  /* implementation not shown */  }
}
```

(a) Given the class hierarchy shown above, write a complete class declaration for the class `Cat`, including implementations of its constructor and method(s). The `Cat` method `speak` returns `"meow"` when it is invoked.

(b) Assume that class `Dog` has been declared as shown at the beginning of the question. If the `String` *dog-sound* is returned by the `Dog` method `speak`, then the `LoudDog` method speak returns a `String` containing *dog-sound* repeated two times.

Given the class hierarchy shown previously, write a complete class declaration for the class `LoudDog`, including implementations of its constructor and method(s).

(c) Consider the following partial declaration of class `Kennel`.

```
public class Kennel
{
  private List<Pet> petList;


  /** For every Pet in the kennel, prints the name followed by
   *  the result of a call to its speak method, one line per Pet.
   */
  public void allSpeak()
  {  /* to be implemented in part (c) */  }

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

Write the `Kennel` method `allSpeak`. For each `Pet` in the kennel, `allSpeak` prints a line with the name of the `Pet` followed by the result of a call to its `speak` method.

In writing `allSpeak`, you may use any of the methods defined for any of the classes specified for this problem. Assume that these methods work as specified, regardless of what you wrote in parts (a) and (b).

Complete method `allSpeak` below.

```
/** For each Pet in the kennel, prints the name followed by
 *  the result of a call to its speak method, one line per Pet.
 */
public void allSpeak()
```

4. This question involves manipulation of one-dimensional and two-dimensional arrays. In part (a), you will write a method to shift the elements of a one-dimensional array. In parts (b) and (c), you will write methods to shift the elements of a two-dimensional array.

   (a) Consider the following incomplete `ArrayUtil` class, which contains a `static shiftArray` method.

```
public class ArrayUtil
{
  /** Shifts each array element to the next higher index, discarding the
   *  original last element, and inserts the new number at the front.
   *  @param arr the array to manipulate
   *         Precondition: arr.length > 0
   *  @param num the new number to insert at the front of arr
   *  Postcondition: The original elements of arr have been shifted to
   *                 the next higher index, and arr[0] == num.
   *                 The original element at the highest index has been
   *                 discarded.
   */
  public static void shiftArray(int[] arr, int num)
  {  /* to be implemented in part (a) */  }

  // There may be methods that are not shown.
}
```

   Write the `ArrayUtil` method `shiftArray`. This method stores the integer `num` at the front of the array `arr` after shifting each of the original elements to the position with the next higher index. The element originally at the highest index is lost.

   For example, if `arr` is the array `{11, 12, 13, 14, 15}` and `num` is 27, the call to `shiftArray` changes `arr` as shown below.

Before call	0	1	2	3	4
arr:	11	12	13	14	15

After call	0	1	2	3	4
arr:	27	11	12	13	14

Complete method `shiftArray` below.

```
/** Shifts each array element to the next higher index, discarding the
 *  original last element, and inserts the new number at the front.
 *  @param arr the array to manipulate
 *             Precondition: arr.length > 0
 *  @Param num the new number to insert at the front of arr
 *  Postcondition: The original elements of arr have been shifted to
 *                 the next higher index, and arr[0] == num.
 *                 The original element at the highest index has been
 *                 discarded.
 */
public static void shiftArray(int[] arr, int num)
```

(b) Consider the following incomplete `NumberMatrix` class, which represents a two-dimensional matrix of integers. Assume that the matrix contains at least one integer.

```
public class NumberMatrix
{
  private int[][] matrix;

  /** Constructs a number matrix. */
  public NumberMatrix(int[][] m)
  {  matrix = m;  }

  /** Shifts each matrix element to the next position in row-major order
   *  and inserts the new number at the front. The last element in the last
   *  row is discarded.
   *  @param num the new number to insert at the front of matrix
   *  Postcondition: The original elements of matrix have been shifted to
   *                 the next higher position in row-major order, and
   *                 matrix[0][0] == num.
   *                 The original last element in the last row is discarded.
   */
  public void shiftMatrix(int num)
  {  /* to be implemented in part (b) */  }

  /** Rotates each matrix element to the next higher position in row-major
   *  order.
   *  Postcondition: The original elements of matrix have been shifted
   *                 to the next higher position in row-major order, and
   *                 matrix[0][0] == the original last element.
   */
  public void rotateMatrix()
  {  /* to be implemented in part (c) */  }

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

Write the `NumberMatrix` method `shiftMatrix`. This method stores a new value `num` into the two-dimensional array `matrix` after shifting the elements to the next higher position in row-major order. The element originally at the last position in row-major order is lost.

For example, if `m1` is a reference to a `NumberMatrix` object, then the call `m1.shiftMatrix(48)` will change the values in `matrix` as shown below.

Before call

	0	1	2
0	13	14	15
1	16	17	18
2	19	20	21
3	22	23	24

After call

	0	1	2
0	48	13	14
1	15	16	17
2	18	19	20
3	21	22	23

In writing `shiftMatrix`, you must call the `shiftArray` method in part (a). Assume that `shiftArray` works correctly regardless of what you wrote in part (a).

Complete method `shiftMatrix` below.

```
/** Shifts each matrix element to the next position in row-major order
 *  and inserts the new number at the front. The last element in the last
 *  row is discarded.
 *  @param num the new number to insert at the front of matrix
 *  Postcondition: The original elements of matrix have been shifted
 *                 to the next higher position in row-major order, and
 *                 matrix[0][0] == num.
 *                 The original last element in the last row is discarded.
 */
public void shiftMatrix(int num)
```

(c) Write the `NumberMatrix` method `rotateMatrix`. This method rotates all the elements to the next position in row-major order. The element originally at the last position is stored in the first position of the matrix.

In writing `rotateMatrix`, you must call the `shiftMatrix` method in part (b). Assume that `shiftMatrix` works correctly regardless of what you wrote in part (b).

Complete method `rotateMatrix` below.

```
/** Rotates each matrix element to the next higher position in row-major
 *  order.
 *  Postcondition: The original elements of matrix have been shifted to
 *                 the next higher position in row-major order, and
 *                 matrix[0][0] == the original last element.
 */
public void rotateMatrix()
```

Suggested Solutions to Free-Response Questions

Note: There are many correct variations of these solutions.

Question 1

(a)

```
public int getDuration()
{
  if (flights.size() == 0)
  {
    return 0;
  }

  Time depart = flights.get(0).getDepartureTime();
  Time arrive = flights.get(flights.size() - 1).getArrivalTime();
  return depart.minutesUntil(arrive);
}
```

(b)

```
public int getShortestLayover()
{
  if (flights.size() < 2)
  {
    return -1;
  }

  int shortest = getDuration();
  for (int k = 1; k < flights.size(); k++)
  {
    Flight flight1 = flights.get(k - 1);
    Flight flight2 = flights.get(k);
    Time arrive = flight1.getArrivalTime();
    Time depart = flight2.getDepartureTime();
    int layover = arrive.minutesUntil(depart);
    if (layover < shortest)
    {
      shortest = layover;
    }
  }

  return shortest;
}
```

Question 2

(a)
Iterative version:

```
public static String apcsReplaceAll(String str,
                                    String oldStr,
                                    String newStr)
{
  String firstPart = "";
  String lastPart = str;
  int pos = lastPart.indexOf(oldStr);
  while (pos >= 0)
  {
    firstPart += lastPart.substring(0, pos);
    firstPart += newStr;
    lastPart = lastPart.substring(pos + oldStr.length());
    pos = lastPart.indexOf(oldStr);
  }
  return firstPart + lastPart;
}
```

Recursive version:

```
public static String apcsReplaceAll(String str,
                                    String oldStr,
                                    String newStr)
{
  int pos = str.indexOf(oldStr);
  if (pos < 0)
  {
    return str;
  }
  else
  {
    String firstPart = str.substring(0, pos);
    String restOfStr = str.substring(pos + oldStr.length());
    String lastPart = apcsReplaceAll(restOfStr, oldStr, newStr);
    return firstPart + newStr + lastPart;
  }
}
```

(b)

```
public static String replaceNameNickname(String str,
                                         List<Person> people)
{
  for (Person p : people)
  {
    str = apcsReplaceAll(str, p.getFirstName(), p.getNickname());
  }
  return str;
}
```

Question 3

(a)

```
public class Cat extends Pet
{
  public Cat(String petName)
  {  super(petName);  }

  public String speak()
  {
    return "meow";
  }
}
```

(b)

```
public class LoudDog extends Dog
{
  public LoudDog(String petName)
  {  super(petName);  }

  public String speak()
  {
    return super.speak() + super.speak();
  }
}
```

(c)

```
public void allSpeak()
{
  for (Pet a : petList)
  {
    System.out.println(a.getName() + a.speak());
  }
}
```

Question 4

(a)

```
public static void shiftArray(int[] arr, int num)
{
  for (int k = arr.length − 1; k > 0; k−−)
  {
    arr[k] = arr[k - 1];
  }

  arr[0] = num;
}
```

(b)

```
public void shiftMatrix(int num)
{
  for (int[] row: matrix)
  {
    int temp = row[row.length − 1];
    ArrayUtil.shiftArray(row, num);
    num = temp;
  }
}
```

(c)

```
public void rotateMatrix()
{
  shiftMatrix(matrix[matrix.length − 1][matrix[0].length − 1]);
}
```