Computer Project

(2017-2019)

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Class: XI B

Roll number: 24

"Writing code a computer can understand is science. Writing code other programmers can understand is an art."

— **Jason Gorman**

"When in doubt, use brute force."

— **Ken Thompson**

Problem 1 An n digit integer $(a_1 a_2 \dots a_n)$, where each digit $a_i \in \{0, 1, \dots, 9\}$, is said to have *unique digits* if no digits are repeated, i.e., there is no i, j such that $a_i = a_j$ $(i \neq j)$.

Verify whether an inputted number has *unique digits*.

Solution

Source Code

```
class Unique {
	public static void main (String[] args) {
		try {
			long number = Long.parseLong(args[0]);
			if (isUnique(number)) {
				System.out.println("Unique Number!");
			} else {
				System.out.println("Not a Unique Number!");
			}
		} catch (NumberFormatException e) {
			System.out.println("Enter an integer as the first argument!");
		} catch (IndexOutOfBoundsException e) {
			System.out.println("Enter 1 argument (integer)!");
		}
	}
	public static boolean isUnique (long number) {
		int[] count = new int[10];
		String rawNumber = Long.toString(Math.abs(number));
		for (int i = 0; i < rawNumber.length(); i++) {
			int digit = rawNumber.charAt(i) - '0';
			count[digit]++;
			if (count[digit] > 1) {
				return false;
			}
		}
		return true;
	}
}
```

"Elegance is not a dispensable luxury but a factor that decides between success and failure."

— **Edsger W. Dijkstra**

Problem 2 A *partition* of a positive integer n is defined as a collection of other positive integers such that their sum is equal to n. Thus, if $(a_1, a_2, \ldots, a_k)$ is a partition of n,

$$n = a_1 + a_2 + \cdots + a_k \qquad (a_i \in \mathbb{Z}^+)$$

Display every *unique partition* of an inputted number.

Solution

Source Code

```
1
2  class Partition {
3          public static void main (String[] args) {
4                  try {
5                          int n = Integer.parseInt(args[0]);
6                          if (n < 1) {
7                                  throw new NumberFormatException();
8                          }
9                          partition(n);
10                 } catch (NumberFormatException e) {
11                         System.out.println("Enter a natural number as the first
                               argument!");
12                 } catch (IndexOutOfBoundsException e) {
13                         System.out.println("Enter 1 argument (natural number)!");
14                 }
15         }
16         public static void partition (int n) {
17                 partition(n, n, "");
18         }
19         public static void partition (int target, int previousTerm, String suffix) {
20                 if (target == 0)
21                         System.out.println(suffix);
22                 for (int i = 1; i <= target && i <= previousTerm; i++)
23                         partition(target - i, i, suffix + " " + i);
24         }
25 }
```

"Simplicity is the ultimate sophistication."

— **Leonardo da Vinci**

Problem 3 A *Caesar cipher* is a type of monoalphabetic substitution cipher in which each letter in the plaintext is replaced by a letter some fixed number of positions down the alphabet. The positions are circular, i.e., after reaching Z, the position wraps around to A. For example, following is some encrypted text, using a right shift of 5.

```
Plain:   ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher:  FGHIJKLMNOPQRSTUVWXYZABCDE
```

Thus, after mapping the alphabet according to the scheme $A \mapsto 0, B \mapsto 1, \ldots, Z \mapsto 23$, we can define an encryption function E_n, in which a letter x is shifted rightwards by n as follows.

$$E_n(x) \;=\; (x + n) \mod 26$$

The corresponding decryption function D_n is simply

$$D_n(x) \;=\; (x - n) \mod 26$$

Implement a simple version of a *Caesar cipher*, encrypting capitalized plaintext by shifting it by a given value. Interpret positive shifts as rightwards, negative as leftwards.

Solution

Source Code

```
1  class CaesarShift {
2         public static void main (String[] args) {
3                 try {
4                         int shift = Integer.parseInt(args[0]) % 26;
5                         String plaintext = args[1].toUpperCase();
6                         String ciphertext = "";
7
8                         for (int i = 0; i < plaintext.length(); i++) {
9                                 char plain = plaintext.charAt(i);
10                                char crypt = ' ';
11                                if ('A' <= plain && plain <= 'Z') {
12                                        crypt = numToChar(charToNum(plain) + shift);
13                                } else {
14                                        crypt = plain;
15                                }
```

```
16                              ciphertext += crypt;
17                      }
18                      System.out.println(ciphertext);
19              } catch (NumberFormatException e) {
20                      System.out.println("Enter an integer "
21                                      + "as the first argument!");
22              } catch (IndexOutOfBoundsException e) {
23                      System.out.println("Enter 2 arguments "
24                                      + "(shift, plaintext)!");
25              }
26      }
27
28      public static int charToNum (char letter) {
29              return Character.toUpperCase(letter) - 'A';
30      }
31
32      public static char numToChar (int number) {
33              return (char) ('A' + Math.floorMod(number, 26));
34      }
35  }
```

"There are 2 hard problems in computer science: cache invalidation, naming things, and off-by-1 errors."

— **Leon Bambrick**

Problem 4 A *palindrome* is a sequence of characters which reads the same backwards as well as forwards. For example, *madam*, *racecar* and *kayak* are words which are palindromes. Similarly, the sentence *"A man, a plan, a canal, Panama!"* is also a plaindrome.

Analyze a sentence of input and display all *words* which are palindromes. If the entire *sentence* is also a palindrome, display it as well.

(A word is an unbroken sequence of characters, separated from other words by whitespace. Ignore single letter words such as I *and* a*. Ignore punctuation, numeric digits, whitespace and case while analyzing the entire sentence.)*

Solution

Source Code

```
1  import java.util.Scanner;
2
3  class Palindrome {
4         public static void main (String[] args) {
5                 System.out.print("Enter your sentence : ");
6                 String sentence = (new Scanner(System.in)).nextLine().trim();
7                 boolean noMatch = true;
8                 System.out.println("Palindromes : ");
9                 noMatch &= checkWords(sentence);
10                noMatch &= checkSentence(sentence);
11                if (noMatch) {
12                        System.out.println("(None found!)");
13                }
14        }
15
16        public static boolean checkWords (String sentence) {
17                boolean noMatch = true;
18                int start = -1;
19                int end = 0;
20                while (end < sentence.length()) {
21                        while (Character.isWhitespace(sentence.charAt(++start)));
22                        end = start;
```

```
23                      while (end < sentence.length()
24                              && !Character.isWhitespace(sentence.charAt(end++)));
25
26                      String word = sentence.substring(start, end).trim();
27                      if (isPalindrome(word)) {
28                              noMatch = false;
29                              System.out.println(getAlphabets(word));
30                      }
31                      start = end - 1;
32              }
33              return noMatch;
34      }
35
36      public static boolean checkSentence (String sentence) {
37              if (isPalindrome(sentence)) {
38                      System.out.println(sentence);
39                      return false;
40              }
41              return true;
42      }
43
44      public static boolean isPalindrome (String text) {
45              String rawText = getAlphabets(text).toUpperCase();
46              for (int i = 0, j = rawText.length() - 1; i < j; i++, j--) {
47                      if (rawText.charAt(i) != rawText.charAt(j)) {
48                              return false;
49                      }
50              }
51              return (rawText.length() > 1);
52      }
53
54      public static String getAlphabets (String text) {
55              String rawText = "";
56              for (int i = 0; i < text.length(); i++) {
57                      if (Character.isAlphabetic(text.charAt(i))) {
58                              rawText += text.charAt(i);
59                      }
60              }
61              return rawText;
62      }
63  }
```

"Any fool can use a computer. Many do."

— **Ted Nelson**

Problem 5 Design a simple interface for an examiner which can format and display marks scored by a group of students in a particular examination. Calculate the percentage scored by each candidate and display the list of students and percentages in an ASCII bar chart, arranged alphabetically.

Solution

Source Code

```
class Marksheet {

	public static final int SCREEN_WIDTH = 80;

	double maxMarks;
	int numberOfStudents;
	int lastStudent;

	String[] names;
	double[] marks;

	Marksheet (double maxMarks, int numberOfStudents) {
		this.maxMarks = maxMarks;
		this.numberOfStudents = numberOfStudents;
		names = new String[numberOfStudents];
		marks = new double[numberOfStudents];
		lastStudent = -1;
	}

	boolean addMarks (String name, double score) {
		try {
			names[++lastStudent] = name;
			marks[lastStudent] = score;
			return true;
		} catch (IndexOutOfBoundsException e) {
			return false;
		}
	}

	void displayChart () {
```

```
31              System.out.println(Marksheet.multiplyString("-",
                    Marksheet.SCREEN_WIDTH));
32              for (int i = 0; i <= lastStudent; i++) {
33                      double fraction = marks[i] / maxMarks;
34                      String name = (names[i].length() < 16)
35                                      ? names[i]
36                                      : (names[i].substring(0,13) + "...");
37                      int points = (int) (fraction * (SCREEN_WIDTH - 32));
38                      String bar = multiplyString("*", points)
39                              + multiplyString(" ", SCREEN_WIDTH - 32 - points);
40                      System.out.printf("| %16s | %s | %5.2f %%%n"
41                                                      , name
42                                                      , bar
43                                                      , fraction * 100);
44              }
45              System.out.println(Marksheet.multiplyString("-",
                    Marksheet.SCREEN_WIDTH));
46      }
47
48      void displayMaxScorers () {
49              String maxScorers = "";
50              double maxScore = getMaxScore();
51              for (int i = 0; i <= lastStudent; i++) {
52                      if (marks[i] == maxScore) {
53                              maxScorers += ", " + names[i];
54                      }
55              }
56              System.out.println(maxScorers.substring(1)
57                                      + " scored the highest ("
58                                      + maxScore + "/"
59                                      + maxMarks + ")");
60      }
61
62      void sortByName () {
63              for (int right = lastStudent; right > 0; right--)
64                      for (int i = 1; i <= right; i++)
65                              if (names[i-1].compareTo(names[i]) > 0)
66                                      swapRecords(i, i - 1);
67
68      }
69
70      double getMaxScore () {
71              double max = Integer.MIN_VALUE;
72              for (int i = 0; i <= lastStudent; i++) {
73                      max = Math.max(max, marks[i]);
74              }
```

```
75              return max;
76      }
77
78      void swapRecords (int x, int y) {
79              String tempName = names[x];
80              double tempMark = marks[x];
81              names[x] = names[y];
82              marks[x] = marks[y];
83              names[y] = tempName;
84              marks[y] = tempMark;
85      }
86
87      public static String multiplyString (String s, int n) {
88              String out = "";
89              for (int i = 0; i < n; i++)
90                      out += s;
91              return out;
92      }
93  }
```

```
1   import java.util.Scanner;
2   import java.util.InputMismatchException;
3
4   class ScoreRecorder {
5           public static void main (String[] args) {
6                   Scanner inp = new Scanner(System.in);
7                   double maxMarks = 0.0;
8                   int numberOfStudents = 0;
9                   try {
10                          System.out.print("Enter the maximum marks alotted for each
                                student : ");
11                          maxMarks = inp.nextDouble();
12                          System.out.print("Enter the total number of students : ");
13                          numberOfStudents = inp.nextInt();
14                          if (maxMarks <= 0) {
15                                  System.out.println("Maximum marks must be positive!");
16                                  System.exit(0);
17                          }
18                          if (numberOfStudents <= 0) {
19                                  System.out.println("Number of students must be
                                        positive!");
20                                  System.exit(0);
21                          }
22                          Marksheet sheet = new Marksheet(maxMarks, numberOfStudents);
23                          System.out.println("Enter " + numberOfStudents
```

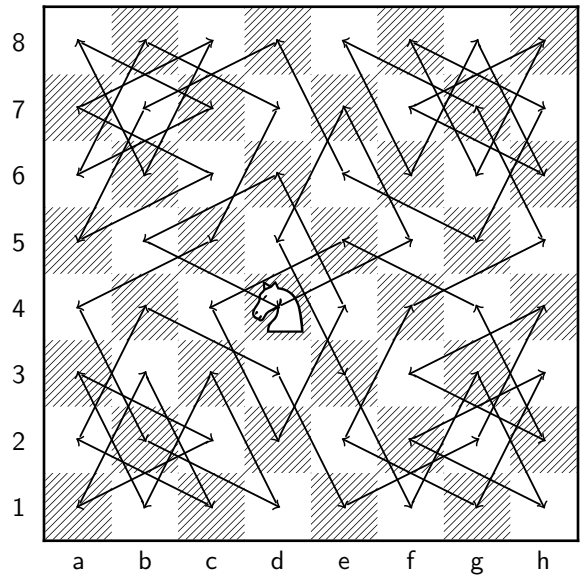
```
                                        + " students' names and marks : ");
                for (int i = 0; i < numberOfStudents; i++) {
                        String name = "";
                        while (!inp.hasNextDouble()) {
                                name += inp.next() + " ";
                        }
                        double marks = inp.nextDouble();
                        if (marks <= 0 || marks > maxMarks) {
                                System.out.println("Marks must be within 0.0 and
                                    " + maxMarks + "!");
                                System.exit(0);
                        }
                        sheet.addMarks(name.trim(), marks);
                }

                sheet.sortByName();
                sheet.displayChart();
                sheet.displayMaxScorers();
            } catch (InputMismatchException e) {
                System.out.println("Invalid Input!");
                System.exit(0);
            }
        }
}
```

"My project is 90% done. I hope the second half goes as well."

— **Scott W. Ambler**

Problem 6 A *Knight's Tour* is a sequence of moves of a knight on a chessboard such that the *knight* visits every square only once. If the knight ends on a square that is one knight's move from the beginning square, the tour is *closed* forming a closed loop, otherwise it is *open*.

There are many ways of constructing such paths on an empty board. On an 8×8 board, there are no less than $26,534,728,821,064$ *directed*[1] *closed* tours. Below is one of them.



Construct a *Knight's Tour* (*open* or *closed*) on an $n \times n$ board, starting from a given square.

(Mark each square with the move number on which the knight landed on it. Mark the starting square 1*.)*

[1]Two tours along the same path that travel in opposite directions are counted separately, as are rotations and reflections.

Solution

"To iterate is human, to recurse divine"

— L. Peter Deutsch

Problem 7 The *determinant* of a square matrix $A_{n,n}$ is defined recursively as follows.

$$det(A_{n,n}) \;=\; \begin{vmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n,1} & a_{n,2} & \cdots & a_{n,n} \end{vmatrix} \;=\; \sum_{j=1}^{n} (-1)^{i+j} a_{i,j} \cdot det(M_{i,j})$$

where $M_{i,j}$ is defined as the minor of $A_{n,n}$, an $(n-1) \times (n-1)$ matrix formed by removing the ith row and jth column from $A_{n,n}$.

The determinant of a (2×2) matrix is simply given by

$$\begin{vmatrix} a & b \\ c & d \end{vmatrix} \;=\; ad \;-\; bc$$

For example, the determinant of a (3×3) matrix is given by the following expression.

$$\begin{aligned} \begin{vmatrix} a & b & c \\ d & e & f \\ g & h & i \end{vmatrix} \;&=\; a \begin{vmatrix} e & f \\ h & i \end{vmatrix} - b \begin{vmatrix} d & f \\ g & i \end{vmatrix} + c \begin{vmatrix} d & e \\ g & h \end{vmatrix} \\ &=\; aei + bfg + cdh - ceg - bdi - afh \end{aligned}$$

Calculate the *determinant* of an inputted $(n \times n)$ square matrix.

Solution