# Computer Project

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*"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

```
1  public class Unique {
2         public static void main (String[] args) {
3                 try {
4                         long number = Long.parseLong(args[0]);
5                         if (isUnique(number)) {
6                                 System.out.println("Unique Number!");
7                         } else {
8                                 System.out.println("Not a Unique Number!");
9                         }
10                } catch (NumberFormatException e) {
11                        System.out.println("Enter an integer as the first argument!");
12                } catch (IndexOutOfBoundsException e) {
13                        System.out.println("Enter 1 argument (integer)!");
14                }
15        }
16
17        public static boolean isUnique (long number) {
18                int[] count = new int[10];
19                for (long n = Math.abs(number); n > 0; n /= 10) {
20                        int digit = (int) n % 10;
21                        count[digit]++;
22                        if (count[digit] > 1){
23                                return false;
24                        }
25                }
26                return true;
27        }
28 }
```

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

```
                }
                System.out.println(ciphertext);
            } catch (NumberFormatException e) {
                System.out.println("Enter an integer as the first argument!");
            } catch (IndexOutOfBoundsException e) {
                System.out.println("Enter 2 arguments (shift, plaintext)!");
            }
        }

        public static int charToNum (char letter) {
            return Character.toUpperCase(letter) - 'A';
        }

        public static char numToChar (int number) {
            return (char) ('A' + Math.floorMod(number, 26));
        }
}
```

*"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  public 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 foundPalindrome = false;
8                System.out.println("Palindromes : ");
9                foundPalindrome |= checkWords(sentence);
10               foundPalindrome |= checkSentence(sentence);
11               if (!foundPalindrome) {
12                      System.out.println("(No palindromes found!)");
13               }
14        }
15
16        public static boolean checkWords (String sentence) {
17               boolean foundPalindrome = 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() &&
                            !Character.isWhitespace(sentence.charAt(end++)));
24                      String word = sentence.substring(start, end).trim();
25                      if (isPalindrome(word)) {
26                              foundPalindrome = true;
27                              System.out.println(getAlphabets(word));
28                      }
29                      start = end - 1;
30              }
31              return foundPalindrome;
32      }
33
34      public static boolean checkSentence (String sentence) {
35              if (isPalindrome(sentence)) {
36                      System.out.println(sentence);
37                      return true;
38              }
39              return false;
40      }
41
42      public static boolean isPalindrome (String text) {
43              String rawText = getAlphabets(text).toUpperCase();
44              for (int i = 0, j = rawText.length() - 1; i < j; i++, j--) {
45                      if (rawText.charAt(i) != rawText.charAt(j)) {
46                              return false;
47                      }
48              }
49              return (rawText.length() > 1);
50      }
51
52      public static String getAlphabets (String text) {
53              String rawText = "";
54              for (int i = 0; i < text.length(); i++) {
55                      if (Character.isAlphabetic(text.charAt(i))) {
56                              rawText += text.charAt(i);
57                      }
58              }
59              return rawText;
60      }
61  }
```

*"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

```
1  public class Marksheet {
2          public static final int SCREEN_WIDTH = 100;
3          private final double maxMarks;
4          private final int numberOfStudents;
5          private int lastStudent;
6          private String[] names;
7          private double[] marks;
8
9          public Marksheet (double maxMarks, int numberOfStudents) {
10                 this.maxMarks = maxMarks;
11                 this.numberOfStudents = numberOfStudents;
12                 this.names = new String[numberOfStudents];
13                 this.marks = new double[numberOfStudents];
14                 this.lastStudent = -1;
15         }
16
17         public boolean addMarks (String name, double score) {
18                 try {
19                         names[++lastStudent] = name;
20                         marks[lastStudent] = score;
21                         return true;
22                 } catch (IndexOutOfBoundsException e) {
23                         return false;
24                 }
25         }
26
27         public void displayChart () {
28                 System.out.println(Marksheet.multiplyString("-",
                       Marksheet.SCREEN_WIDTH));
29                 for (int i = 0; i <= lastStudent; i++) {
30                         double fraction = marks[i] / maxMarks;
```

```
31                  String name = (names[i].length() < 16)
32                                ? names[i]
33                                : (names[i].substring(0,13) + "...");
34                  int points = (int) (fraction * (SCREEN_WIDTH - 34));
35                  String bar = multiplyString("*", points)
36                         + multiplyString(" ", SCREEN_WIDTH - 34 - points);
37                  System.out.printf("| %16s | %s | %6.2f %% |%n"
38                                                , name
39                                                , bar
40                                                , fraction * 100);
41          }
42          System.out.println(Marksheet.multiplyString("-",
                Marksheet.SCREEN_WIDTH));
43      }
44
45      public void displayMaxScorers () {
46          String maxScorers = "";
47          double maxScore = getMaxScore();
48          for (int i = 0; i <= lastStudent; i++) {
49                  if (marks[i] == maxScore) {
50                          maxScorers += ", " + names[i];
51                  }
52          }
53          System.out.println(maxScorers.substring(1)
54                                  + " scored the highest ("
55                                  + maxScore + "/"
56                                  + maxMarks + ")");
57      }
58
59      public void sortByName () {
60          for (int right = lastStudent; right > 0; right--)
61                  for (int i = 1; i <= right; i++)
62                          if (names[i-1].compareToIgnoreCase(names[i]) > 0)
63                                  swapRecords(i, i - 1);
64
65      }
66
67      public double getMaxScore () {
68          double max = Integer.MIN_VALUE;
69          for (int i = 0; i <= lastStudent; i++) {
70                  max = Math.max(max, marks[i]);
71          }
72          return max;
73      }
74
75      private void swapRecords (int x, int y) {
```

```
76                String tempName = names[x];
77                double tempMark = marks[x];
78                names[x] = names[y];
79                marks[x] = marks[y];
80                names[y] = tempName;
81                marks[y] = tempMark;
82        }
83
84        public static String multiplyString (String s, int n) {
85                String out = "";
86                while (n --> 0)
87                        out += s;
88                return out;
89        }
90  }
```

```
1   import java.util.Scanner;
2   import java.util.InputMismatchException;
3
4   public 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 : ");
24                        for (int i = 0; i < numberOfStudents; i++) {
25                              String name = "";
26                              while (!inp.hasNextDouble()) {
```

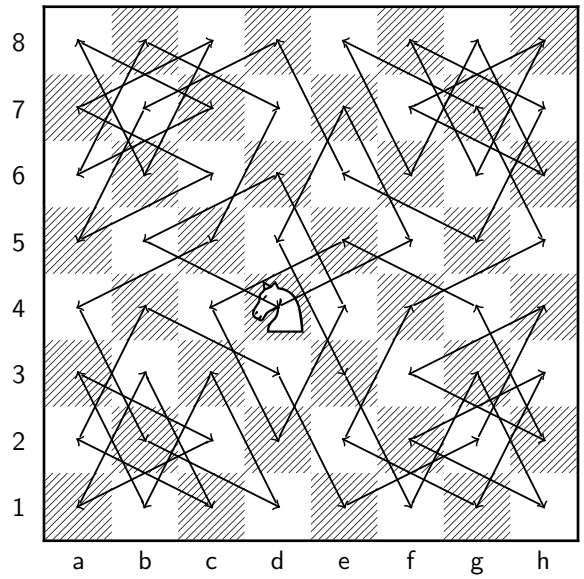
```
27                                      name += inp.next() + " ";
28                              }
29                              double marks = inp.nextDouble();
30                              if (marks <= 0 || marks > maxMarks) {
31                                      System.out.println("Marks must be within 0.0 and
                                            " + maxMarks + "!");
32                                      System.exit(0);
33                              }
34                              sheet.addMarks(name.trim(), marks);
35                      }
36                      sheet.sortByName();
37                      sheet.displayChart();
38                      sheet.displayMaxScorers();
39              } catch (InputMismatchException e) {
40                      System.out.println("Invalid Input!");
41                      System.exit(0);
42              }
43      }
44  }
```

*"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 $8 \times 8$ board, there are no less than $26,534,728,821,064$ *directed*[1] *closed* tours. Below is one of them.

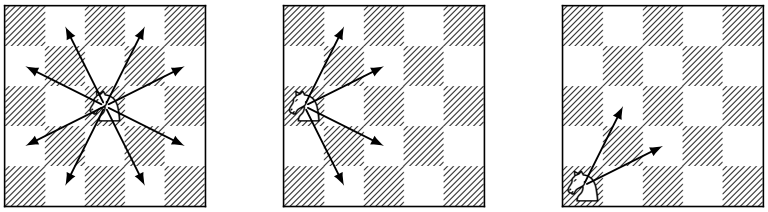



Construct a *Knight's Tour* (*open* or *closed*) on an $n \times n$ board, starting from a given square.

*(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** A knight on a chessboard can move to a square that is two squares away horizontally and one square vertically, or two squares vertically and one square horizontally.



## Source Code

```
1  public class TourSolver {
2         private final int size;
3         private Position[] path;
4         private int numberOfMoves;
5         private int[][] board;
6         private int[][] degreesOfFreedom;
7         private Position initPosition;
8
9         private static final int[][] KNIGHT_MOVES = {
10               {-1, -2}, {-1, 2}, {1, -2}, {1, 2},
11               {-2, -1}, {-2, 1}, {2, -1}, {2, 1}
12        };
13
14        public TourSolver (int size, Position initPosition) {
15               this.size = size;
16               this.initPosition = initPosition;
17               this.path = new Position[size * size];
18               this.numberOfMoves = 0;
19               this.initBoard();
20               this.initDegreesOfFreedom();
21        }
22
23        private void initBoard () {
24               board = new int[size][size];
25               for (int i = 0; i < size; i++)
26                      for (int j = 0; j < size; j++)
27                             board[i][j] = 0;
28        }
29
30        private void initDegreesOfFreedom () {
31               degreesOfFreedom = new int[size][size];
```

```
32              for (int i = 0; i < size; i++)
33                      for (int j = 0; j < size; j++)
34                              degreesOfFreedom[i][j] = getPossibleMovesCount(new
                                    Position(i, j));
35      }
36
37      public boolean addMove (Position p) {
38              if (numberOfMoves < (size * size)) {
39                      path[numberOfMoves++] = p;
40                      board[p.getX()][p.getY()] = numberOfMoves;
41                      return true;
42              }
43              return false;
44      }
45
46      public boolean removeMove () {
47              if (numberOfMoves > 0) {
48                      Position p = path[numberOfMoves - 1];
49                      board[p.getX()][p.getY()] = 0;
50                      path[--numberOfMoves] = null;
51                      return true;
52              }
53              return false;
54      }
55
56      public int[][] getBoard () {
57              return board;
58      }
59
60      public Position[] getSolution () {
61              if (size < 5)
62                      return null;
63              addMove(initPosition);
64              if(solve(initPosition))
65                      return path;
66              return null;
67      }
68
69      public boolean solve (Position p) {
70              if (numberOfMoves == (size * size))
71                      return true;
72              Position[] possibleMoves = getPossibleMoves(p);
73              if (possibleMoves[0] == null)
74                      return false;
75              sortMoves(possibleMoves);
76              for (Position move : possibleMoves) {
```

```
77                      if (move != null) {
78                              addMove(move);
79                              if (solve(move))
80                                      return true;
81                              removeMove();
82                      }
83              }
84              return false;
85      }
86
87      public void sortMoves (Position[] moves) {
88              int count = 0;
89              for (Position p : moves)
90                      if (p != null)
91                              count++;
92              for (int right = count; right > 0; right--)
93                      for (int i = 1; i < right; i++)
94                              if (compareMoves(moves[i-1], moves[i]) > 0)
95                                      swapMoves(i-1, i, moves);
96      }
97
98      public int compareMoves (Position a, Position b) {
99              int aCount = getPossibleMovesCount(a);
100             int bCount = getPossibleMovesCount(b);
101             if (aCount != bCount)
102                     return aCount - bCount;
103             int aFree = degreesOfFreedom[a.getX()][a.getY()];
104             int bFree = degreesOfFreedom[b.getX()][b.getY()];
105             if (aFree != bFree)
106                     return aFree - bFree;
107             return (Math.random() < 0.4)? 1 : -1;
108     }
109
110     private static void swapMoves (int x, int y, Position[] moves) {
111             Position t = moves[x];
112             moves[x] = moves[y];
113             moves[y] = t;
114     }
115
116     public Position[] getPossibleMoves (Position start) {
117             Position[] possibleMoves = new Position[KNIGHT_MOVES.length];
118             int i = 0;
119             for (int[] move : KNIGHT_MOVES) {
120                     int x = start.getX() + move[0];
121                     int y = start.getY() + move[1];
122                     if (isWithinBoard(x, y) && board[x][y] == 0) {
```

```
                        possibleMoves[i++] = new Position(x, y);
                    }
                }
                return possibleMoves;
        }

        public int getPossibleMovesCount (Position start) {
                int i = 0;
                for (Position p : getPossibleMoves(start))
                        if (p != null)
                                i++;
                return i;
        }

        public boolean isWithinBoard (int x, int y) {
                return (x >= 0 && x < size && y >= 0 && y < size);
        }
}
```

```
public class Position {
        private final int x;
        private final int y;

        public Position (int x, int y) {
                this.x = x;
                this.y = y;
        }

        public Position (String s) {
                int x = 0;
                int i = 0;
                while (i < s.length() && Character.isAlphabetic(s.charAt(i))) {
                        x = (x * 26) + Character.toLowerCase(s.charAt(i)) - 'a' + 1;
                        i++;
                }
                int y = Integer.parseInt(s.substring(i));
                this.x = x - 1;
                this.y = y - 1;
        }

        public int getX () {
                return x;
        }

        public int getY () {
```

```
27                 return y;
28         }
29
30         public boolean equals (Position p) {
31                 return (p != null)
32                         && (this.getX() == p.getX()) && (this.getY() == p.getY());
33         }
34
35         @Override
36         public String toString () {
37                 return xToString(this.x) + (this.y + 1);
38         }
39
40         public static String xToString (int n) {
41                 int x = n + 1;
42                 String letters = "";
43                 while (x > 0) {
44                         letters = (char) ('a' + (--x % 26)) + letters;
45                         x /= 26;
46                 }
47                 return letters;
48         }
49 }
```

```
1  public class KnightTour {
2          public static void main (String[] args) {
3                  try {
4                          int boardSize = Integer.parseInt(args[0]);
5                          if (boardSize <= 0)
6                                  throw new NumberFormatException();
7                          String initSquare = (args.length > 1)? args[1] : "a1";
8                          TourSolver t = new TourSolver(boardSize, new
                               Position(initSquare));
9                          Position[] solution = t.getSolution();
10                         if (solution != null) {
11                                 showBoard(t.getBoard());
12                                 showMoves(solution);
13                                 if (isClosed(solution))
14                                         System.out.println("\nThe tour is Closed!");
15                         } else {
16                                 System.out.println("No Knight's Tours found!");
17                         }
18                 } catch (Exception e) {
19                         System.out.print("Enter an integer (> 1) as the first
                               argument, ");
```

```
20                  System.out.println("and a well formed chessboard coordinate as
                        the second! [size, startSquare]\n");
21                  System.out.println("(size     -> Solve a Tour on a (size x
                        size) board)");
22                  System.out.println("(startSquare -> A square in algebraic
                        chess notation of the form 'fr',");
23                  System.out.println("             where f = the letter
                        representing the file(column)");
24                  System.out.println("             and  r = the number
                        representing the rank(row).)");
25                  System.out.println("(startSquare is set to 'a1' by default)");
26          }
27      }
28
29      public static void showBoard (int[][] board) {
30          String hLine = " " + multiplyString("+-----", board.length) + "+";
31          System.out.println(hLine);
32          for (int column = board.length - 1; column >= 0; column--) {
33              System.out.printf(" %2d ", column + 1);
34              for (int row = 0; row < board.length; row++) {
35                  System.out.printf("| %3d ", board[row][column]);
36              }
37              System.out.printf("|%n%s%n", hLine);
38          }
39          System.out.print(" ");
40          for (int i = 0; i < board.length; i++) {
41              System.out.printf(" %2s ", Position.xToString(i));
42          }
43          System.out.println();
44      }
45
46      public static void showMoves (Position[] moves) {
47          System.out.print("\nMoves : ");
48          String movesOut = "";
49          for (int i = 1; i < moves.length; i++) {
50              movesOut += (moves[i-1] + "-" + moves[i] + ", ");
51          }
52          System.out.println(movesOut.substring(0, movesOut.length() - 2));
53      }
54
55      public static String multiplyString (String s, int n) {
56          String result = "";
57          while (n --> 0)
58              result += s;
59          return result;
60      }
```

```
61
62          public static boolean isClosed (Position[] path) {
63                  int l = path.length - 1;
64                  int dX = Math.abs(path[0].getX() - path[l].getX());
65                  int dY = Math.abs(path[0].getY() - path[l].getY());
66                  return (dX == 1 && dY == 2) || (dX == 2 && dY == 1);
67          }
68  }
```

*"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 $i$th row and $j$th column from $A_{n,n}$.

The determinant of a $(2 \times 2)$ matrix is simply given by

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

For example, the determinant of a $(3 \times 3)$ 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**