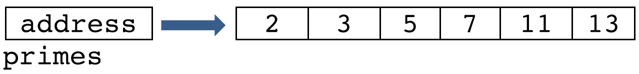
CS 212 – Lab 1

In a one-dimensional *array,* the array elements are specified using one index.

Example:

```
int[] primes = {2, 3, 5, 7, 11, 13};
```



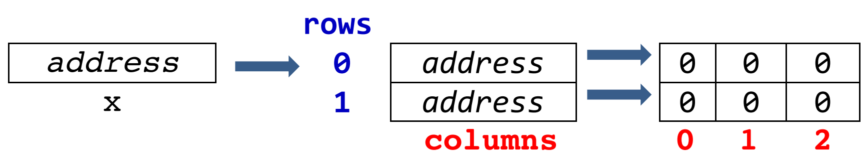
The following code prints all the components of the array:

```
for(int i = 0; i < primes.length; i++)
    System.out.print(primes[i] + ");
System.out.println();
```

A two-dimensional array is an array where its elements are specified using two indices.

type [ ] [ ] reference variable = ***new type***[*row-size*][*column-size*];

int[ ] [ ] x = **new int**[*2*][*3*];

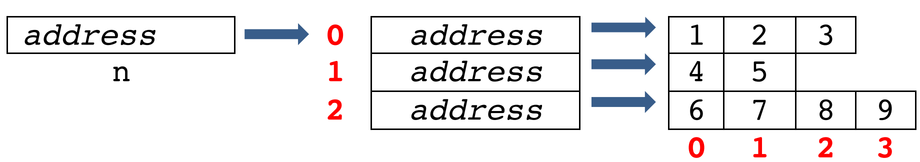


The following code prints all the components of the array:

```
for(int i=0; i < x.length; i++){
    for(int j=0; j < x[i].length; j++){
        System.out.print(x[i][j] + " ");
    }
    System.out.println();
}
```

In Java, multi-dimensional arrays are really arrays of arrays. Thus the following is permissible.

```
int[][] n = {{1,2,3},{4,5},{6,7,8,9}};
```



The number of columns vary; ***n[row].length*** stores the number of columns.
The value in **n[0][1]** is 2, and the value in **n[2][3]** is 9.

Array Declaration:

Declare an array object reference variable referring to a 2-dimensional array.

```
double[][] a;
```

Create the array and store the location of the first element of the array in the array object reference variable.

```
a = new double[3][4];     // defines an array with 3 rows and 4 columns
```

The following **declares** and **initializes** a 2-dimensional array.

```
int[][] a = {{0,1,2,3}, {4,5,6,7}, {8,9,0,1}};
```

The following nested loop traverses a 2-dimensional array.

```
for(int i=0;i < a.length; i++){
      for(int j=0;j < a[i].length; j++){
            System.out.print(a[i][j] + " ");
      }
      System.out.println();
}
```

The following declares and initializes a 3-dimensional array.

```
int[][][] a = { { {0,1},{2,3} }, { {4,5},{6,7} } };
```

`a` stores a reference to an array of 2 items, where each item is a reference to an array of 2 items.

The following nested loop traverses a 3-dimensional array.

```
for(int i=0;i < a.length; i++){
      for(int j=0;j < a[i].length; j++){
            for(int k=0;k < a[i][j].length; k++){
                  System.out.print(a[i][j][k] + " ");
            }
            System.out.println();
      }
      System.out.println();
}
```

The purpose of this lab is to learn how to create and use two-dimensional arrays in Java. In this exercise, you will create a matrix class, as specified below, and create a driver class to test the methods created in the matrix class.

A matrix is a collection of numbers arranged in a rectangular array with a fixed number of rows and columns – an *m x n* array.
Arithmetic operations such as addition and multiplication are defined for matrices. For example, two matrices may be added or multiplied together to yield a new matrix.

Matrix Addition and Subtraction:

Given A = (a_{ij}) and B = (b_{ij}) to be m × n matrices. We define their *sum*, denoted by A+B, and their *difference*, denoted by A−B, to be the respective matrices $(a_{ij}+b_{ij})$ and $(a_{ij}-b_{ij})$.
When two matrices have the same dimensions, we just add or subtract their corresponding entries.

Example:

Given $A = \begin{bmatrix} 1 & 2 \\ 5 & 3 \end{bmatrix}$ and $B = \begin{bmatrix} 3 & 2 \\ 4 & 5 \end{bmatrix}$

$$A + B = \begin{bmatrix} 1 & 2 \\ 5 & 3 \end{bmatrix} + \begin{bmatrix} 3 & 2 \\ 4 & 5 \end{bmatrix} = \begin{bmatrix} 1+3 & 2+2 \\ 5+4 & 3+5 \end{bmatrix} = \begin{bmatrix} 4 & 4 \\ 9 & 8 \end{bmatrix}$$

$$A - B = \begin{bmatrix} 1 & 2 \\ 5 & 3 \end{bmatrix} - \begin{bmatrix} 3 & 2 \\ 4 & 5 \end{bmatrix} = \begin{bmatrix} 1-3 & 2-2 \\ 5-4 & 3-5 \end{bmatrix} = \begin{bmatrix} -2 & 0 \\ 1 & -2 \end{bmatrix}$$

Matrix Multiplication:

To multiply two matrices, Matrix *A* must have the same number of columns as the rows in Matrix *B*. If A is an m × p matrix and B is a p × n matrix. We define their product, denoted by AB, to be the m × n matrix whose *ij*-entry, 1 ≤ i ≤ m and 1 ≤ j ≤ n, is the product of the i-th row of A and the *j*-th column of B.

Example:

Given $A = \begin{bmatrix} 1 & 2 \\ 4 & 3 \end{bmatrix}$ and $B = \begin{bmatrix} 3 & 2 \\ 4 & 5 \end{bmatrix}$

$$AB = \begin{bmatrix} 1 & 2 \\ 4 & 3 \end{bmatrix} \times \begin{bmatrix} 3 & 2 \\ 4 & 5 \end{bmatrix} = \begin{bmatrix} 1(3)+2(4) & 1(2)+2(5) \\ 4(3)+3(4) & 4(2)+3(5) \end{bmatrix} = \begin{bmatrix} 11 & 12 \\ 24 & 23 \end{bmatrix}$$

Scalar Multiplication:
Scalar multiplication is defined by, for any r ∈ R, rA is the matrix (ra_{ij}). The *scalar multiplication* rA of a matrix A and a number r is given by multiplying every entry of A by r.

Example:

Given $A = \begin{bmatrix} 1 & 2 \\ 4 & 3 \end{bmatrix}$

$$2A \quad = \quad 2\begin{bmatrix} 1 & 2 \\ 4 & 3 \end{bmatrix} \quad = \quad \begin{bmatrix} 2 \text{ x } 1 & 2 \text{ x } 2 \\ 2 \text{ x } 4 & 2 \text{ x } 3 \end{bmatrix} \quad = \quad \begin{bmatrix} 2 & 4 \\ 8 & 6 \end{bmatrix}$$

Transpose a Matrix:

Given A = (a_{ij}) to be an $m \times n$ matrix. The *transpose* of A, denoted by A^T, is the matrix whose *i*-th column is the *i*-th row of A, or equivalently, whose *j*-th row is the *j*-th column of A. Notice that A^T is an $n \times m$ matrix. We write $A^T = \left(a^T_{ji}\right)$ where $a^T_{ji} = a_{ij}$.

Examples:

Suppose A= $\begin{bmatrix} 1 & 2 \\ 5 & 3 \end{bmatrix}$ then A^T is: $\begin{bmatrix} 1 & 5 \\ 2 & 3 \end{bmatrix}$

Suppose A= $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$ then A^T is: $\begin{bmatrix} 1 & 4 \\ 2 & 5 \\ 3 & 6 \end{bmatrix}$

Equality.

Two matrices A = (a_{ij}) and B = (b_{ij}) are equal, written A = B, provided they have the same size and their corresponding entries are equal, that is, their sizes are both m × n and for each $1 \leq i \leq m$ and $1 \leq j \leq n$, $a_{ij} = b_{ij}$.

Examples:

Given A= $\begin{bmatrix} 1 & 2 \\ 5 & 3 \end{bmatrix}$ and B= $\begin{bmatrix} 1 & 2 \\ 5 & 3 \end{bmatrix}$ then A = B is true

Given A= $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$ and B= $\begin{bmatrix} 1 & 4 \\ 2 & 5 \\ 3 & 6 \end{bmatrix}$ then A = B is false

Instructions

Part 1

1. Create a Java Project named Lab1.
2. Create a package named lab1_YourLastName_FirstInitial.
3. Import the Matrix class that implements addition, subtraction, multiplication, scalar multiplication, equal, and transpose methods for *m* x *n* matrices. **<u>Copy, paste, and modify the template from Lab 0 to the Matrix class.</u>** The class should also include a ***constructor Matrix(int [ ] [ ] m)***, and a ***toString*** method. Add another class (driver class with main method) to test those methods.

Part 2

Write Java code for the following and create a word document with the answers. Test whether or not the following are true by writing the necessary statements in the driver class:

1. $(A^T)^T = A$
2. $(A + B)^T = A^T + B^T$
3. $(rA)^T = rA^T$
4. $(AB)^T = B^T A^T$
5. $AB \neq BA$
6. $A(BC) = (AB)C$
7. $A(B+C) = AB + AC$
8. $(A+B)C = AC + BC$
9. $(rA)B = r(AB) = A(rB)$

```java
// Java code to verify (A+B)C = AC + BC
Matrix a = new Matrix(new int[][]{{1,2},{2,0}});
Matrix b = new Matrix(new int[][]{{1,2},{2,0}});
Matrix c = new Matrix(new int[][]{{1,2},{2,0}});
System.out.println(a.add(b).mult(c));
System.out.println(a.mult(c).add(b.mult(c)));
```

For the following, write the java code in the main method.

Given $A = \begin{bmatrix} 1 & -2 & 3 \\ 1 & -1 & 0 \end{bmatrix}$ $B = \begin{bmatrix} 3 & 4 \\ 5 & -1 \\ 1 & -1 \end{bmatrix}$ $C = \begin{bmatrix} 4 & -1 & 2 \\ -1 & 5 & 1 \end{bmatrix}$ $D = \begin{bmatrix} -1 & 0 & 1 \\ 0 & 2 & 1 \end{bmatrix}$

$E = \begin{bmatrix} 3 & 4 \\ -2 & 3 \\ 0 & 1 \end{bmatrix}$ $F = \begin{bmatrix} 2 \\ -3 \end{bmatrix}$ $G = \begin{bmatrix} 2 & -1 \end{bmatrix}$

Compute each of the following and simplify, whenever possible. If a computation is not possible, state why.

(a) $3C - 4D$ (b) $A - (D + 2C)$ (c) $A - E$ (d) AE

(e) $3BC - 4BD$ (f) $CB + D$ (g) GC (h) FG

(i) C^2 (j) $C + D$