Lab 06

Objectives

After performing this lab, students will be able to

- Understand nested loops and create programs using them
- Understand functions and use them in programs

Nested Loops

A nested loop is a loop that appears inside another loop. A clock is a good example of something that works like a nested loop. The seconds' hand, minutes' hand, and hours' hand all spin around the face of the clock. Each time the hour hand increments, the minute hand increments 60 times. Each time the minute hand increments, the second hand increments 60 times.

Here is a program segment with a ***for*** loop that partially simulates a digital clock. It displays the seconds from 0 to 59:

```
for (int seconds = 0; seconds < 60; seconds++) {
      cout << seconds << endl;
}
```

We can add a minutes variable and nest the loop above inside another loop that cycles through 60 minutes (or that minutes' loop):

```
for (int minutes = 0; minutes < 60; minutes++) {
      for (int seconds = 0; seconds < 60; seconds++) {
            cout << minutes << ":" << seconds << endl;
      }
}
```

To also consider/add hours, we can add another loop to denote the hours and put these two (nested) loops inside that third loop to make another level of nesting (or create three nested loops).

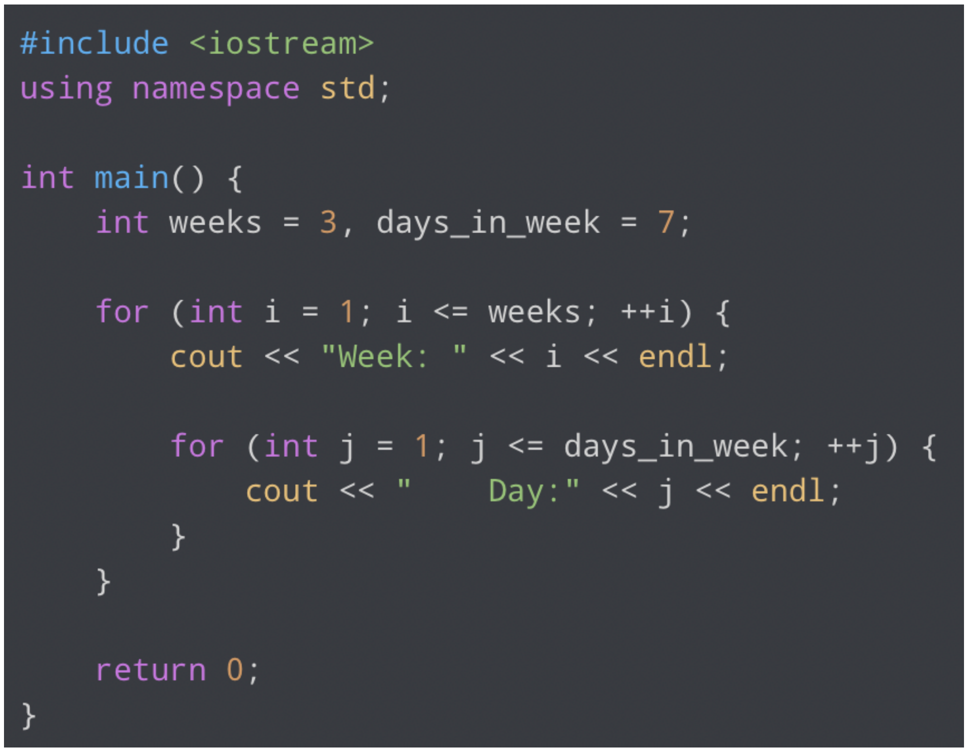
```
for (int hours = 0; hours < 24; hours++) {
      for (int minutes = 0; minutes < 60; minutes++) {
            for (int seconds = 0; seconds < 60; seconds++) {
                  cout<<hours <<":"<< minutes <<":"<< seconds << endl;
            }
      }

}
```

The innermost loop will iterate 60 times for each iteration of the middle loop. The middle loop will iterate 60 times for each iteration of the outermost loop. When the outermost loop has iterated 24 times, the middle loop will have iterated 1,440 times and the innermost loop will have iterated 86,400 times

Following are some of the points related to nested loops

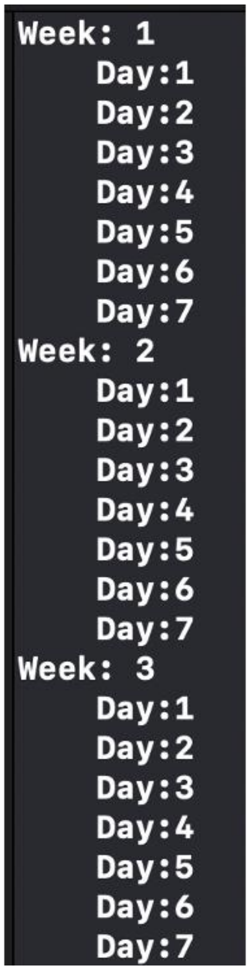
- An inner loop goes through all of its iterations (or runs from beginning to end) for each/one iteration of an outer loop.
- Inner loops complete their iterations faster than outer loops.
- To get the total number of iterations of an inner-most loop, multiply the number of iterations of all the loops.

Another example could be looping through each day of a week. Suppose we want to loop through each day of a week for 3 weeks. To achieve this, we can create a loop to iterate three times (3 weeks let suppose in this example). And inside that loop, we can create another loop to iterate 7 times (to denote 7 days of a week), as shown below.



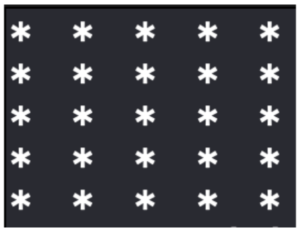
```cpp
#include <iostream>
using namespace std;

int main() {
    int weeks = 3, days_in_week = 7;

    for (int i = 1; i <= weeks; ++i) {
        cout << "Week: " << i << endl;

        for (int j = 1; j <= days_in_week; ++j) {
            cout << "    Day:" << j << endl;
        }
    }

    return 0;
}
```

Output:



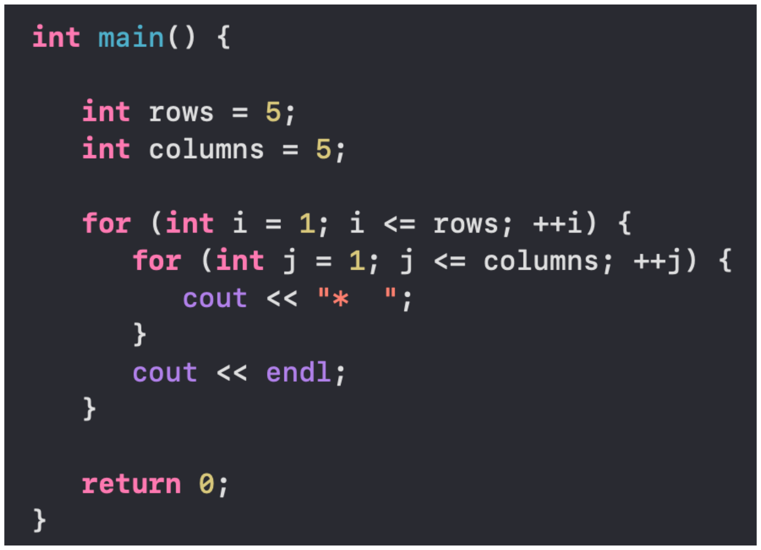
```
Week: 1
    Day:1
    Day:2
    Day:3
    Day:4
    Day:5
    Day:6
    Day:7
Week: 2
    Day:1
    Day:2
    Day:3
    Day:4
    Day:5
    Day:6
    Day:7
Week: 3
    Day:1
    Day:2
    Day:3
    Day:4
    Day:5
    Day:6
    Day:7
```

Imagine we are required to print the asterisks “*” in the pattern shown below



```
*   *   *   *   *
*   *   *   *   *
*   *   *   *   *
*   *   *   *   *
*   *   *   *   *
```

We can use nested loops to do so. One loop will represent rows and one loop will denote columns



```
int main() {

   int rows = 5;
   int columns = 5;

   for (int i = 1; i <= rows; ++i) {
      for (int j = 1; j <= columns; ++j) {
         cout << "*  ";
      }
      cout << endl;
   }

   return 0;
}
```

Functions

A **function** is a block of code that performs a specific task. A function is written/created once and can be called again and again as many times as required whenever/wherever needed.

It is a good practice that we should create such programs that use functions to solve the problem. Imagine we need to create a program that creates a circle and then gives some color to it. We can create two functions to solve this problem:

- a function to draw the circle
- a function to color the circle

Dividing a complex problem into smaller chunks makes our program easy to understand and reusable.

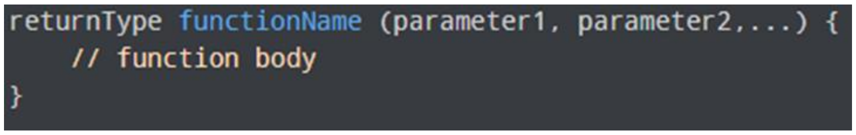
There are two types of function:

1. **User-defined Function**: Created by users/programmers
2. **Standard Library Functions**: Predefined in C++

User-defined Functions

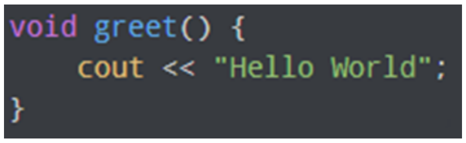
C++ allows the programmers to define their own function. A user-defined function groups code to perform a specific task and that group of code is given a name (identifier). After that, when we invoke/call that function, then all the code inside it is executed.

The syntax to define a function is:



```
returnType functionName (parameter1, parameter2,...) {
    // function body
}
```

Here is an example



```
void greet() {
    cout << "Hello World";
}
```

Here

- the name of the function is **greet ()**
- the return type of the function is **void**
- the empty parentheses mean it does not have any parameters
- the function body is written inside curly brackets {}

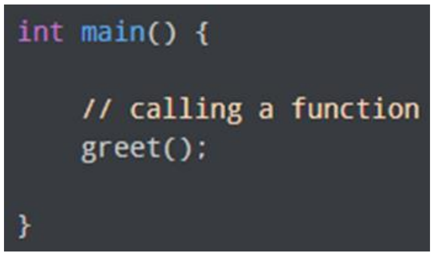
Defining a function

A function definition will be different from the example discussed above depending on the need of the problem being solved. For example, in previous case, we just wanted to print a fixed/hardcoded string “Hello World” to the screen. But a function used to add two numbers and then return that value will be different. Similarly, a function used to check whether a number is even or not will also be different.

Note: You should define a function before calling it (like above the main () function).

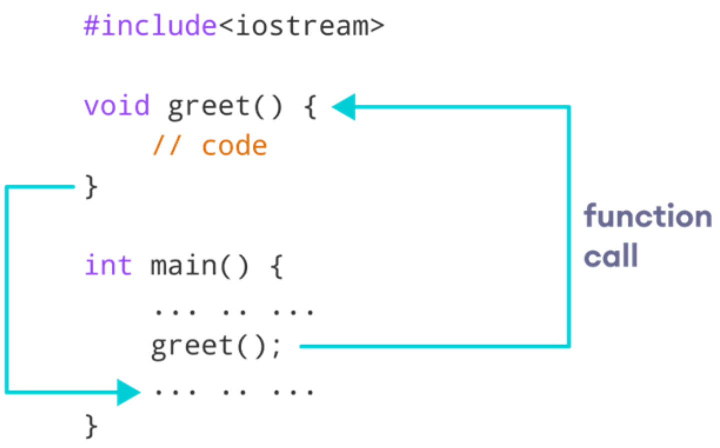
Calling/Invoking a Function

In the example program given above, we have just defined a function named greet (). Until now, its body will not be executed. To actually use a function (like greet () in our case), we need to call/invoke it. Here's how we can call the above greet () function.



```
int main() {

    // calling a function
    greet();

}
```

When a function is called, whatever is written inside its body will be executed. In this case, **Hello World** will be printed onto the screen.



```
#include<iostream>

void greet() {
    // code
}

int main() {
    ... .. ...
    greet();
    ... .. ...
}
```

When a function is called, then the flow of execution jumps to the body of the function being called. And when the body of the function being called is finished, then the remaining code of the caller function (in the example above, main function) resumes.

Example

```
#include <iostream>

using namespace std;

void test() {
    cout << "This is the body of the function" << endl;
}

int main()
{
    cout << "This line will be executed before the function body" << endl;
    test();
    cout << "This line will be executed after the function body" << endl;

    return 0;
}
```

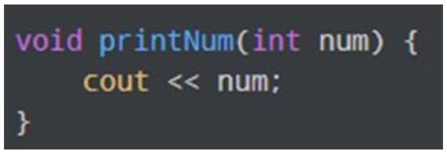
Output:

```
This line will be executed before the function body
This is the body of the function
This line will be executed after the function body
```

Function Parameters

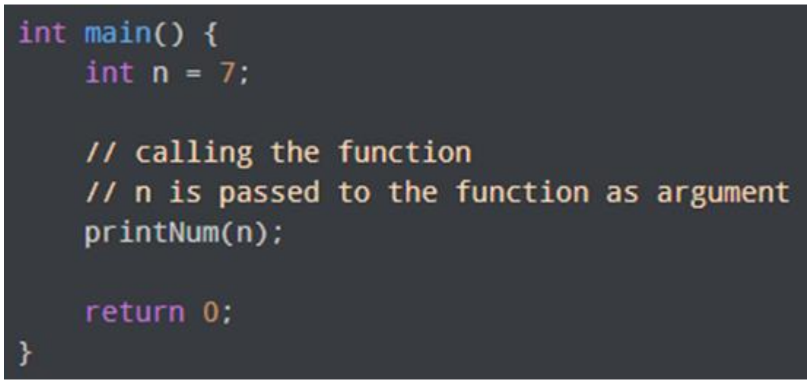
A parameter is a value that is used when defining a function. A function can be defined with or without parameters depending on the need. For example, in previous case, we did not use any parameter because we just needed to print a fixed/hardcoded string. But for example, we want to create a function that adds two numbers, then it will require two parameters. Similarly, a function used to test if a value is even or not will require one parameter, and so on.

Example:



```
void printNum(int num) {
    cout << num;
}
```

Here, the **int** variable **num** is the function parameter. We pass a value to the function parameter while calling the function.

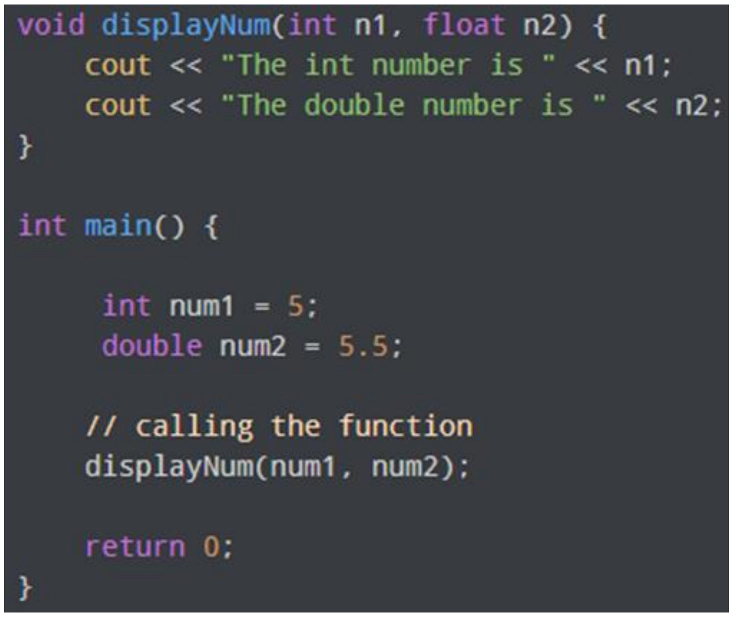


```
int main() {
    int n = 7;

    // calling the function
    // n is passed to the function as argument
    printNum(n);

    return 0;
}
```

Output:

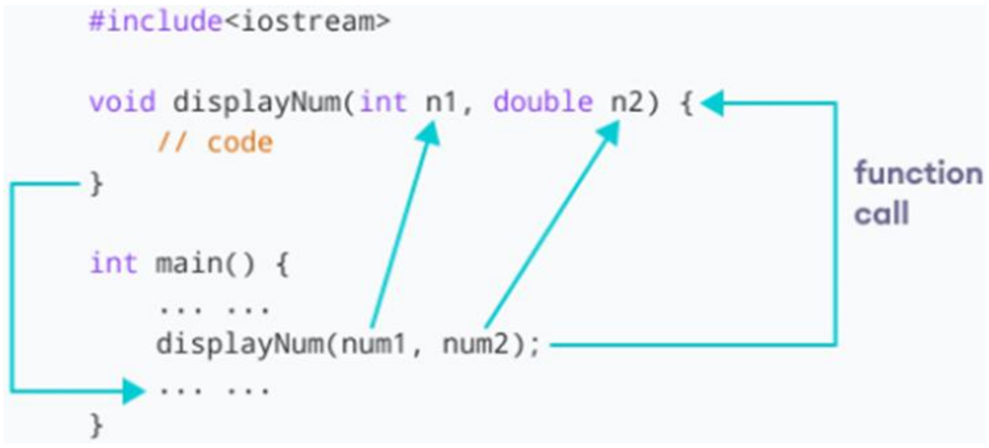
The number 7 will be printed

Example 2: A function with two parameters



```
void displayNum(int n1, float n2) {
    cout << "The int number is " << n1;
    cout << "The double number is " << n2;
}

int main() {

     int num1 = 5;
     double num2 = 5.5;

    // calling the function
    displayNum(num1, num2);

    return 0;
}
```

In the above program, we have used a function that has one **int** parameter and one **double** parameter. We then pass **num1** and **num2** as arguments. These values are stored by the function parameters **n1** and **n2**, respectively.



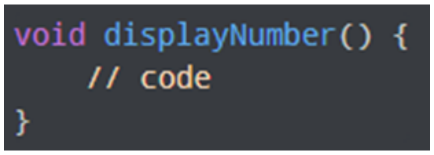
```
#include<iostream>

void displayNum(int n1, double n2) {
    // code
}

int main() {
    ... ...
    displayNum(num1, num2);
    ... ...
}
```

Note: The type of the arguments passed while calling the function **must** match with the corresponding parameters defined in the function declaration.

The value passed to a function parameter while calling it is also called as an **argument**.

The return statement

In the above programs, we have used **void** in the function definition. For example,

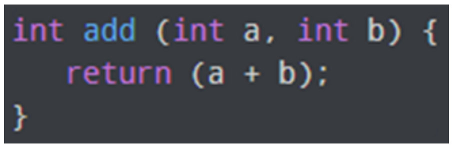


```
void displayNumber() {
    // code
}
```

This means the function is not returning any value.

It is also possible to return a value from a function. For this, we need to specify the **returnType** of the function during function declaration/definition. Then, the **return** statement can be used to return a value from a function.

For example,

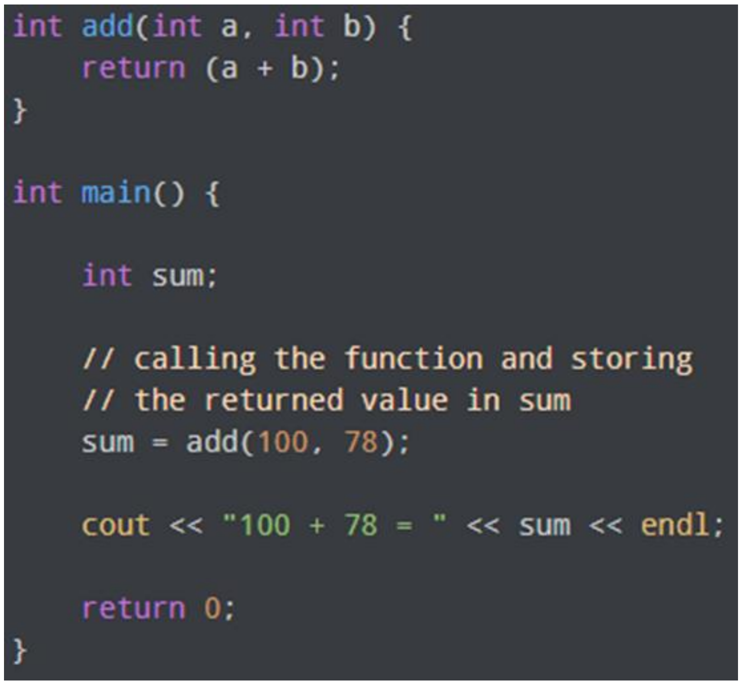


```
int add (int a, int b) {
   return (a + b);
}
```

Here, we have the data type **int** instead of **void**. This means that the function returns an **int** value. The code **return (a + b);** returns the sum of the two parameters as the function value.

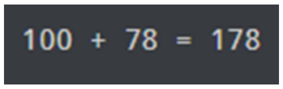
The **return** statement denotes that the function has ended. Any code after **return** inside the function is not executed.

Example: Adding two numbers and returning their sum



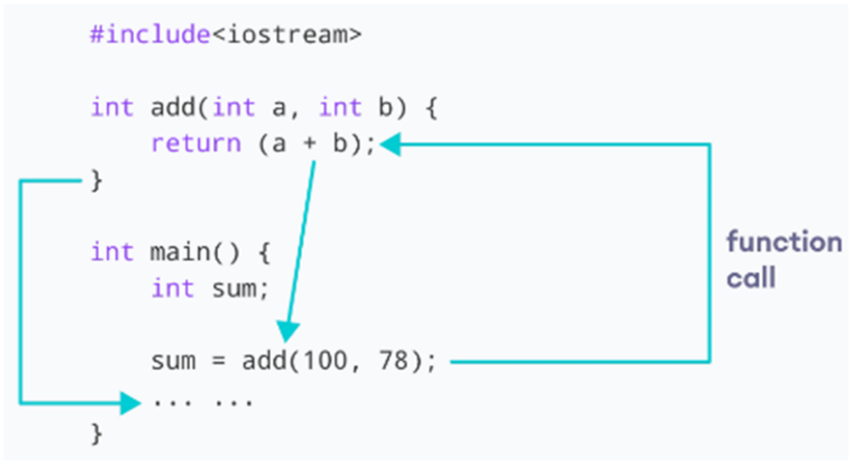
```
int add(int a, int b) {
    return (a + b);
}

int main() {

    int sum;

    // calling the function and storing
    // the returned value in sum
    sum = add(100, 78);

    cout << "100 + 78 = " << sum << endl;

    return 0;
}
```

Output:



```
100 + 78 = 178
```

In the above program, the **add ()** function is used to find the sum of two numbers. We pass two **int** literals 100 and 78 while calling the function. We store the returned value of the function in the variable **sum**, and then we print it. Notice that **sum** is a variable of **int** type. This is because the return value of **add ()** is of **int** type.



```
#include<iostream>

int add(int a, int b) {
    return (a + b);
}

int main() {
    int sum;

    sum = add(100, 78);
    ... ...
}
```

Function Prototype

In C++, the code of function definition should be before the function call. However, if we want to define a function after the function call, we need to use the function prototype (also called **function declaration**). For example,

```
// function prototype
void add(int, int);

int main() {
    // calling the function before declaration.
    add(5, 3);
    return 0;
}

// function definition
void add(int a, int b) {
    cout << (a + b);
}
```

In the example shown above, the function prototype is:

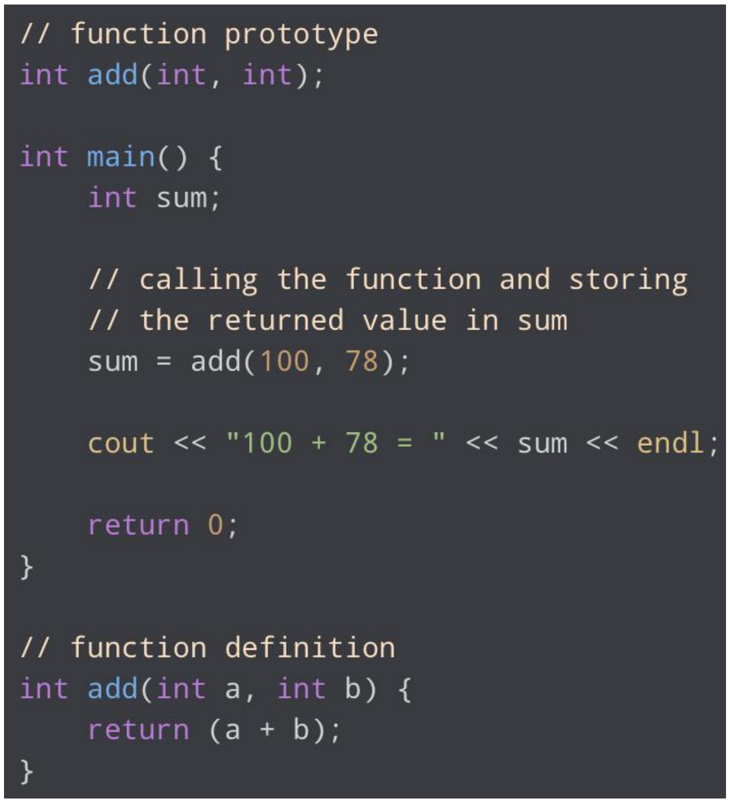
```
void add(int, int);
```

This provides the compiler with information about the function name and its parameters. That's why we can use the code to call a function before the function has been defined.

The syntax of a function prototype is:

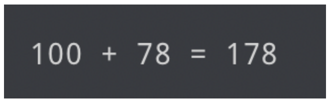
```
returnType functionName(dataType1, dataType2, ...);
```

Example:



```
// function prototype
int add(int, int);

int main() {
    int sum;

    // calling the function and storing
    // the returned value in sum
    sum = add(100, 78);

    cout << "100 + 78 = " << sum << endl;

    return 0;
}

// function definition
int add(int a, int b) {
    return (a + b);
}
```

Output:



```
100 + 78 = 178
```

Library Functions

Library functions are the built-in functions in C++ programming. Programmers can use library functions by invoking the functions directly; they do not need to write the functions by themselves. Some of the common library functions in C++ are **sqrt ()**, **abs ()**, **isdigit ()**, etc.

In order to use library functions, we usually need to include the header file in which these library functions are defined. For instance, in order to use mathematical functions such as **sqrt()** and **abs ()**, we need to include the header file **cmath**.

Example:

```cpp
#include <iostream>
#include <cmath>
using namespace std;

int main() {
    double number, squareRoot;

    number = 25.0;

    // sqrt() is a library function to calculate the square root
    squareRoot = sqrt(number);

    cout << "Square root of " << number << " = " << squareRoot;

    return 0;
}
```

Output:

```
Square root of 25 = 5
```

Function Overloading

In C++, two functions can have the same name if the number and/or type of arguments passed is different. These functions having the same name, but different arguments are known as **overloaded functions**. For example:

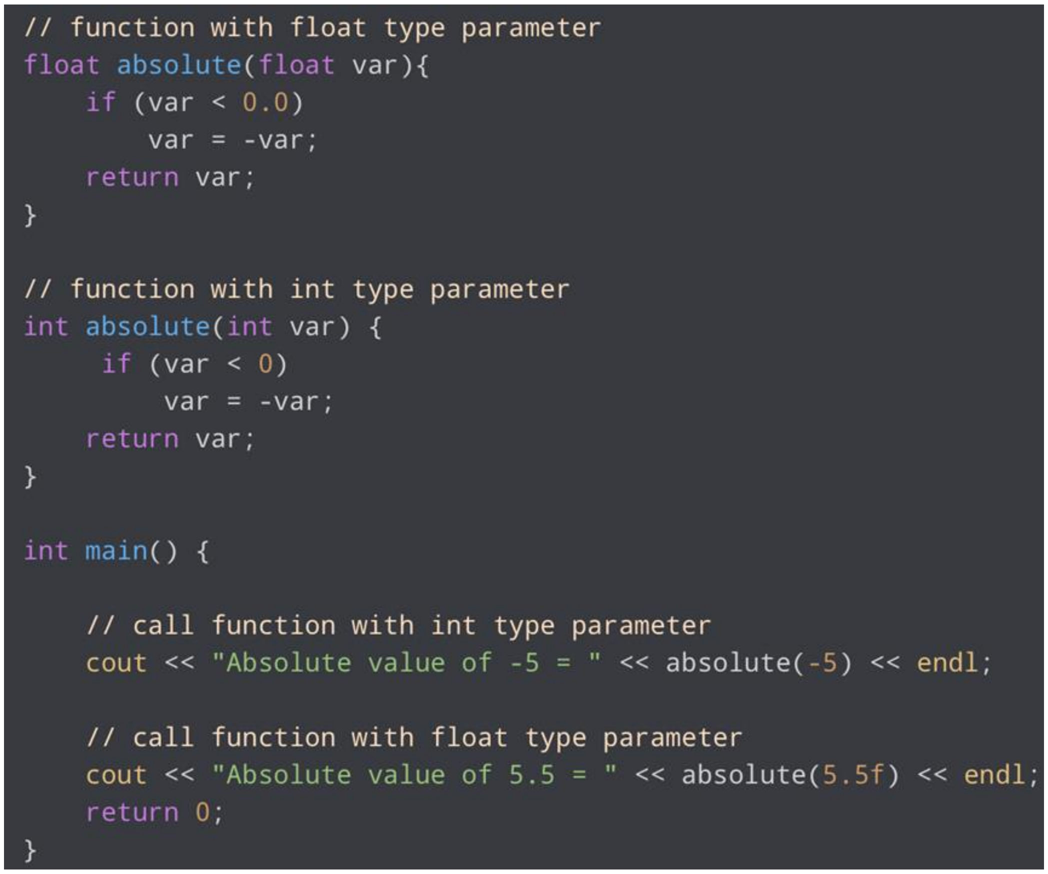
```cpp
// same name different arguments
int test() { }
int test(int a) { }
float test(double a) { }
int test(int a, double b) { }
```

Here, all 4 functions are overloaded functions. Notice that the return types of all these 4 functions are not the same. Overloaded functions may or may not have different return types but they **must** have different arguments. For example,

```cpp
// Error code
int test(int a) { }
double test(int b){ }
```

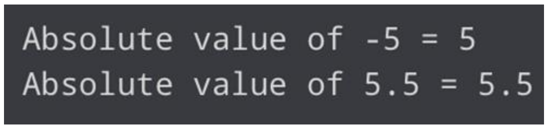
Here, both functions have the same name, the same type of argument, and the same number of arguments. Hence, the compiler will throw an error.

Example: Function overloading using different types of parameters



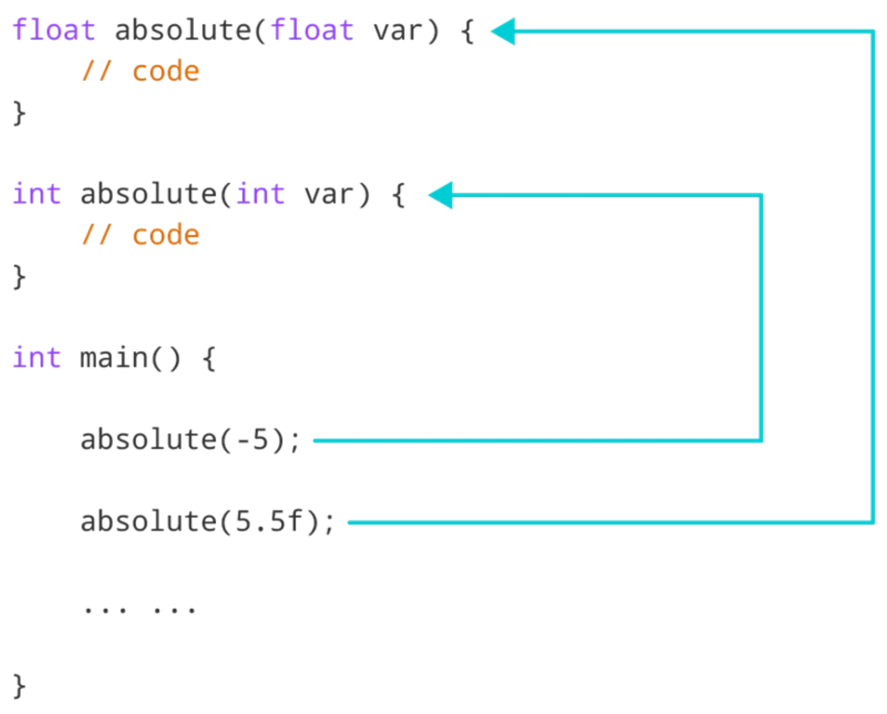
```cpp
// function with float type parameter
float absolute(float var){
    if (var < 0.0)
        var = -var;
    return var;
}

// function with int type parameter
int absolute(int var) {
     if (var < 0)
         var = -var;
    return var;
}

int main() {

    // call function with int type parameter
    cout << "Absolute value of -5 = " << absolute(-5) << endl;

    // call function with float type parameter
    cout << "Absolute value of 5.5 = " << absolute(5.5f) << endl;
    return 0;
}
```

Output:



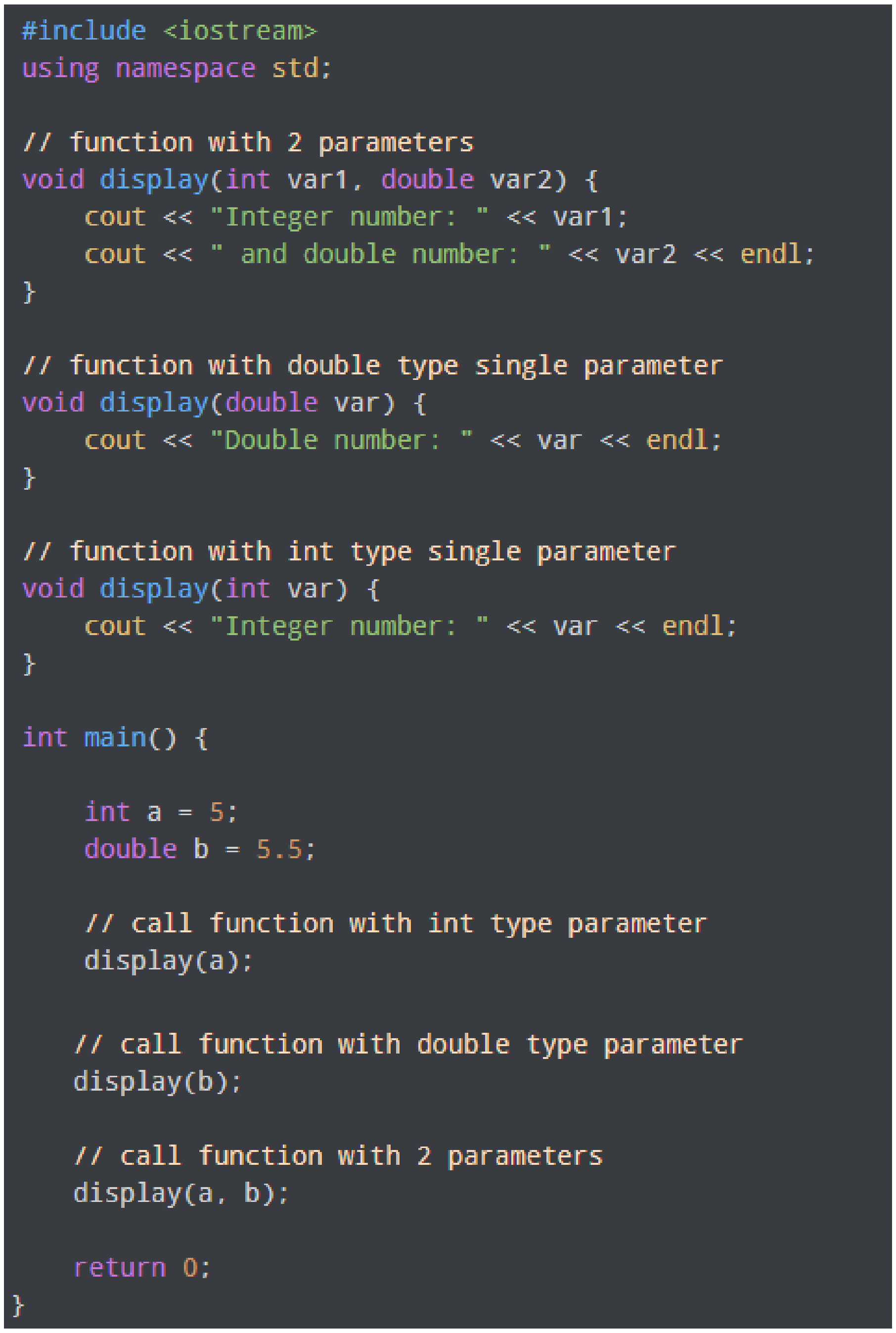
```
Absolute value of -5 = 5
Absolute value of 5.5 = 5.5
```

In this program, we overload the **absolute ()** function. Based on the type of parameter passed during the function call, the corresponding function is called, like shown below.



```
float absolute(float var) {
    // code
}

int absolute(int var) {
    // code
}

int main() {

    absolute(-5);

    absolute(5.5f);

    ... ...

}
```

Example 2: Function overloading using different number of parameters

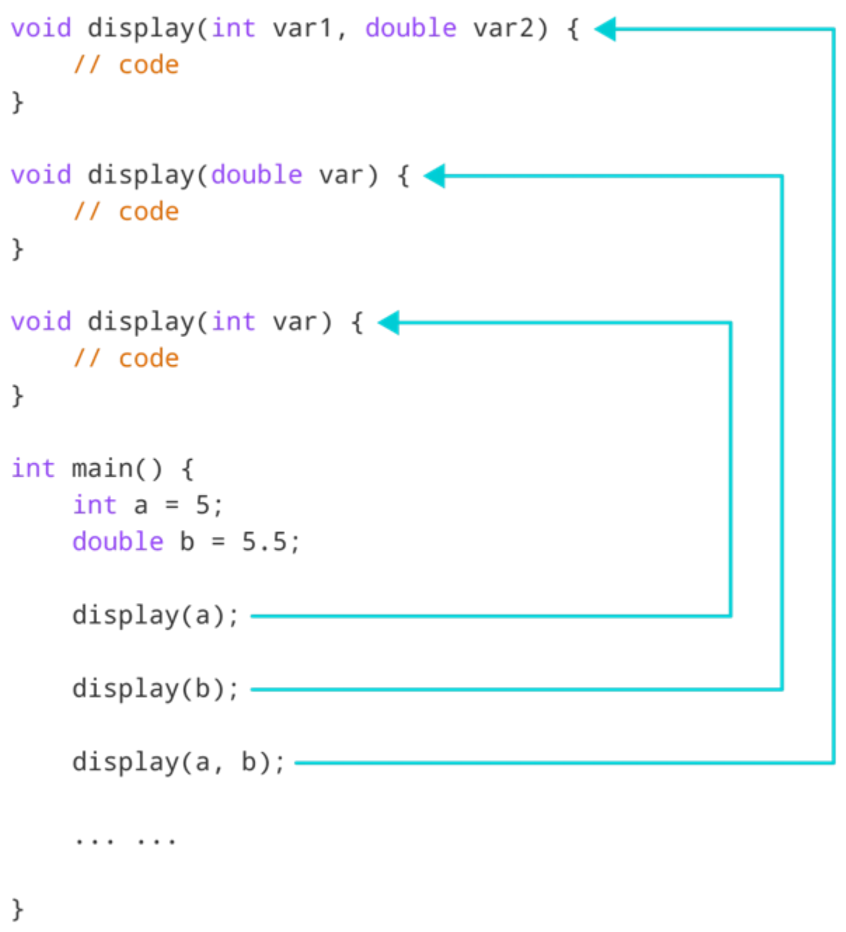


```cpp
#include <iostream>
using namespace std;

// function with 2 parameters
void display(int var1, double var2) {
    cout << "Integer number: " << var1;
    cout << " and double number: " << var2 << endl;
}

// function with double type single parameter
void display(double var) {
    cout << "Double number: " << var << endl;
}

// function with int type single parameter
void display(int var) {
    cout << "Integer number: " << var << endl;
}

int main() {

    int a = 5;
    double b = 5.5;

    // call function with int type parameter
    display(a);

   // call function with double type parameter
   display(b);

   // call function with 2 parameters
   display(a, b);

   return 0;
}
```

Output:

```
Integer number: 5
Double number: 5.5
Integer number: 5 and double number: 5.5
```

Here, the **display ()** function is called three times with different arguments. Depending on the number and type of arguments passed, the corresponding **display ()** function is called.

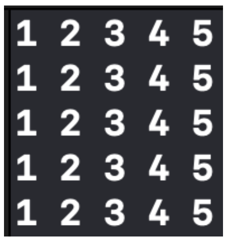


```
void display(int var1, double var2) {
    // code
}

void display(double var) {
    // code
}

void display(int var) {
    // code
}

int main() {
    int a = 5;
    double b = 5.5;

    display(a);

    display(b);

    display(a, b);

    ... ...

}
```

Note: In C++, many standard library functions are overloaded. For example, the **sqrt ()** function can take **double**, **float**, **int**, etc. as parameters. This is possible because the **sqrt ()** function is overloaded in C++.

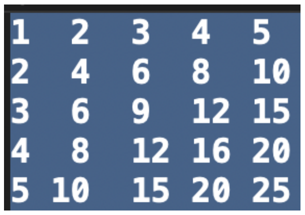
<u>**Exercises**</u>

1. Tasks related to nested loops
   a. Using **nested loops**, write separate C++ programs to generate each of the following outputs.
      i.



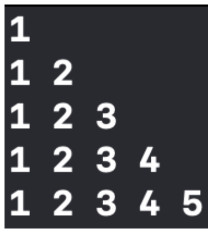
```
1 2 3 4 5
1 2 3 4 5
1 2 3 4 5
1 2 3 4 5
1 2 3 4 5
```

      ii.



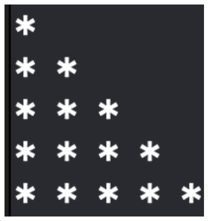
```
1  2  3  4  5
2  4  6  8  10
3  6  9  12 15
4  8  12 16 20
5 10  15 20 25
```

iii.



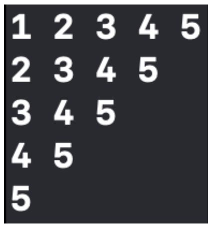
```
1
1 2
1 2 3
1 2 3 4
1 2 3 4 5
```

iv.



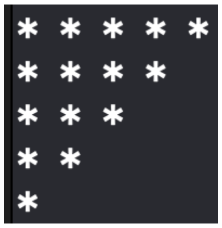
```
*
* *
* * *
* * * *
* * * * *
```

v.



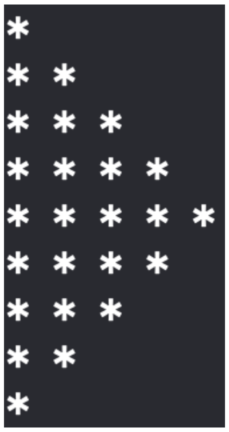
```
1 2 3 4 5
2 3 4 5
3 4 5
4 5
5
```

vi.



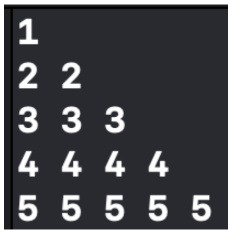
```
* * * * *
* * * *
* * *
* *
*
```

vii.



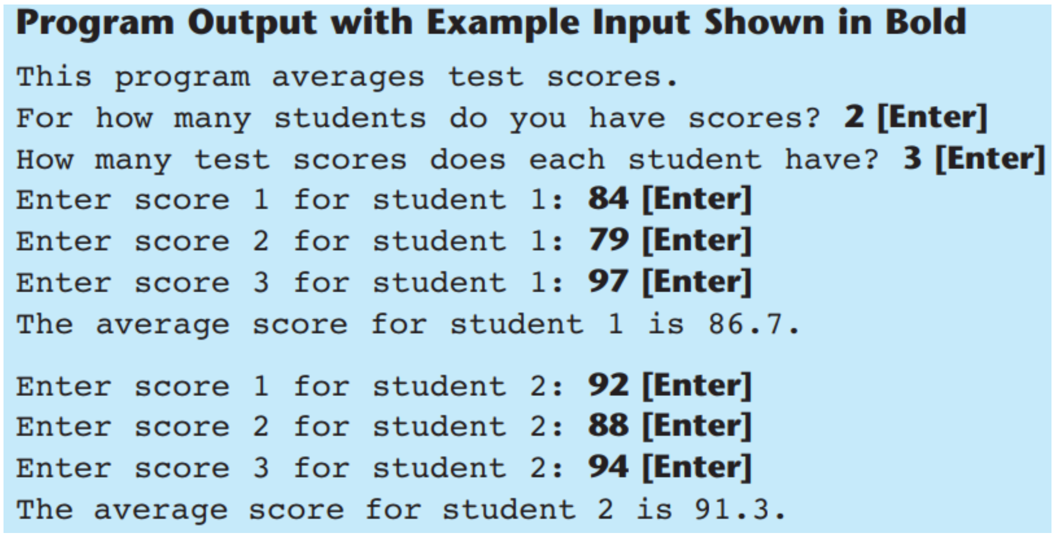
```
*
* *
* * *
* * * *
* * * * *
* * * *
* * *
* *
*
```

viii.



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

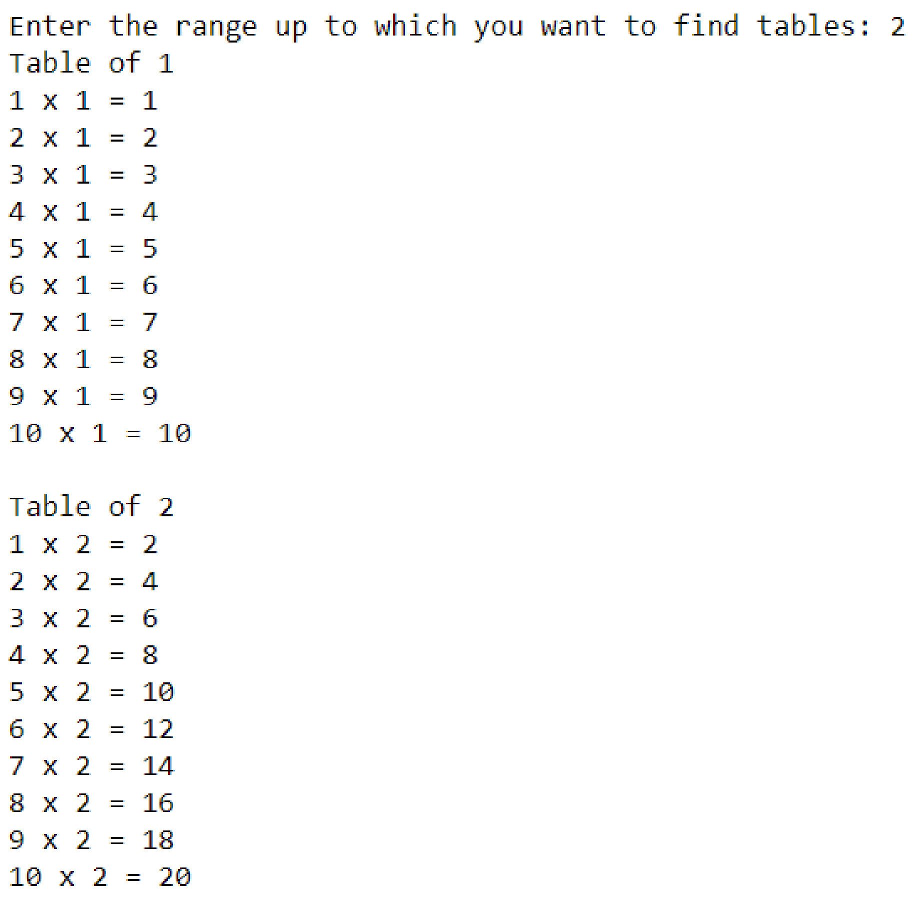
b. Write a program that computes average test scores of students. The program should first ask the user to input total number of students and then the number of test scores per student. After that, for each student, ask the user to enter test scores and compute (and display) the average test score of every student, as shown in the sample output below:



Program Output with Example Input Shown in Bold

```
This program averages test scores.
For how many students do you have scores? 2 [Enter]
How many test scores does each student have? 3 [Enter]
Enter score 1 for student 1: 84 [Enter]
Enter score 2 for student 1: 79 [Enter]
Enter score 3 for student 1: 97 [Enter]
The average score for student 1 is 86.7.

Enter score 1 for student 2: 92 [Enter]
Enter score 2 for student 2: 88 [Enter]
Enter score 3 for student 2: 94 [Enter]
The average score for student 2 is 91.3.
```

c. Write a program that asks the user to input an integer value that denotes the range up to which tables of number should be printed. Then, tables of all the numbers from 1 to that range value should be displayed, as shown below:



```
Enter the range up to which you want to find tables: 2
Table of 1
1 x 1 = 1
2 x 1 = 2
3 x 1 = 3
4 x 1 = 4
5 x 1 = 5
6 x 1 = 6
7 x 1 = 7
8 x 1 = 8
9 x 1 = 9
10 x 1 = 10

Table of 2
1 x 2 = 2
2 x 2 = 4
3 x 2 = 6
4 x 2 = 8
5 x 2 = 10
6 x 2 = 12
7 x 2 = 14
8 x 2 = 16
9 x 2 = 18
10 x 2 = 20
```

Here, the user has entered the value 2. That is why tables of only 1 and 2 are displayed. But if the user enters 5 as the range value, then tables of all numbers 1, 2, 3, 4, and 5 should be displayed in the way shown above.

2. Tasks related to functions
   a. Just like the sample program discussed in the class that was performing the addition of two numbers, create four (04) separate functions, each of which gets two integer values as parameters and returns the subtraction, multiplication, division, and the modulus (remainder) of those two values, respectively.

      Then call these functions in the main () function and print the values returned by them.

      Note: Each user-defined function should only return a value after performing the respective arithmetic operation. The remaining logic, which prints the results, should be put in the main () function.

   b. Create a function named **square** that takes one integer number as parameter and returns the square of that number. Then, call that function in the main () by passing any value, and display the result.

c. Create a function that takes two integer values as parameters and returns the greater value of those two. Then, call that function in the main () and display the result.

   Note: We are assuming that the values of parameters will be unique (the caller will NOT give the same value for both parameters)

d. Create a function that takes one integer value as a parameter and then return the word **Even** (if that number is an even number) or **Odd** (if the value is odd). After that, call that function in the main () and display the result.
e. Create a function that computes the percentage of a student. The function should take two values (**obtained marks** and **total marks**) as parameters and return the percentage (that can be a value with a decimal point). Then, call that function in the main () by passing two values to it, and display the result.
f. Create a function that takes the percentage (a value that might contain value with decimal point) as a parameter and returns the grade (A, B, C, or F). The rules for calculating the grade are:
   i. If the percentage is between 80 and 100 (inclusive), the grade will be **A**
   ii. If the percentage is between 70 and 79, the grade should be **B**
   iii. If the percentage is between 60 and 69, the function should return the grade **C**
   iv. If the percentage is less than 60, the grade will be **F**

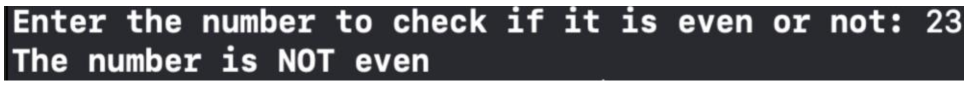
   Then, call that function in the main () by passing the percentage and show/display the result/grade returned by the function.

   Note: The value of percentage passed to this function should be the one returned by the function created in the **previous** task (the **f** part above this task). In other words, first, call the function created in the **previous** task, save the result returned by that function in a variable, and then pass that variable as the argument to the function created in **this** task.

g. Create a function that takes an integer value as a parameter and returns a **boolean** value (true or false) depending on whether the parameter value is even or not. If that value is **even**, the function should return **true**; otherwise, it should return **false**.

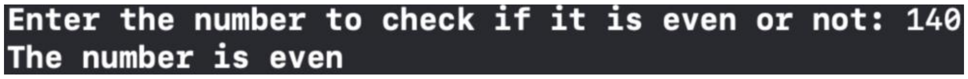
   In the end, call that function in the main () function by passing a value taken as input from the user, and depending on the returned value, print whether the number is even or not. For example,

   Sample Output 1



```
Enter the number to check if it is even or not: 23
The number is NOT even
```

   Sample Output 2

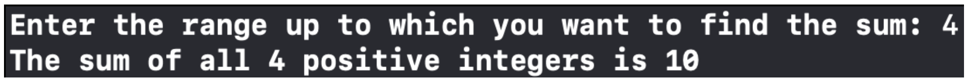


```
Enter the number to check if it is even or not: 140
The number is even
```

Note: The user-defined function should only return a boolean value (**true** or **false**). The remaining logic, which prints the respective message whether a number is even or not, should be put in the main () function.

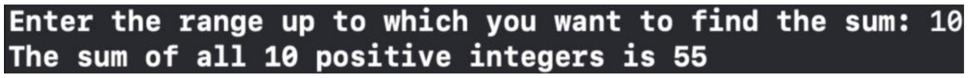
h. Create a user-defined function that takes on parameter **range** and returns the sum of all positive integers up to that **range**. For example,

Sample Output 1



```
Enter the range up to which you want to find the sum: 4
The sum of all 4 positive integers is 10
```

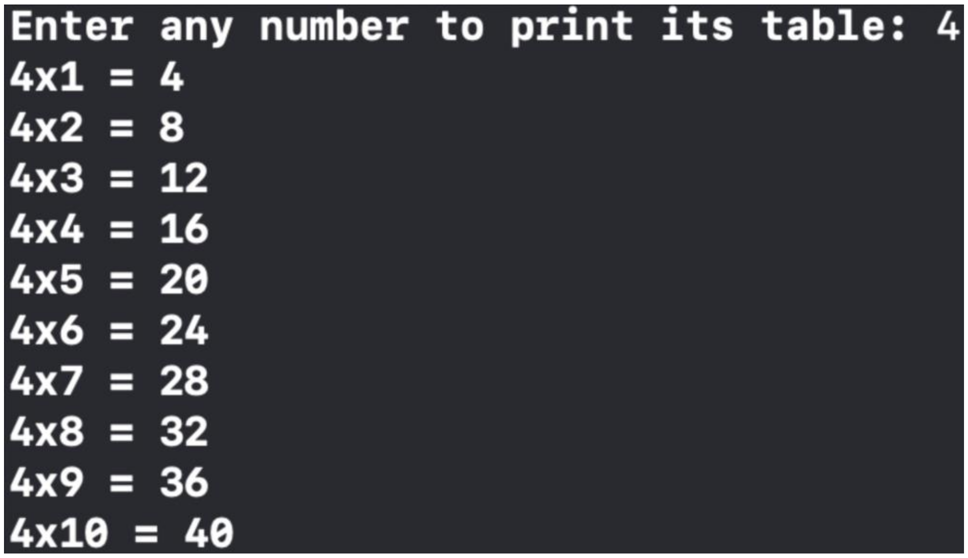
Sample Output 2



```
Enter the range up to which you want to find the sum: 10
The sum of all 10 positive integers is 55
```

Note: Again, the user-defined function should only return the **sum**. The remaining logic, which prints the result, should be put in the main () function.

i. Create a function named **printTable** that gets one integer value as a parameter and prints its table of that number (from 1 to 10). Then, in the main function, get a value as input from the user and call the function by passing that input value as an argument. As shown below:



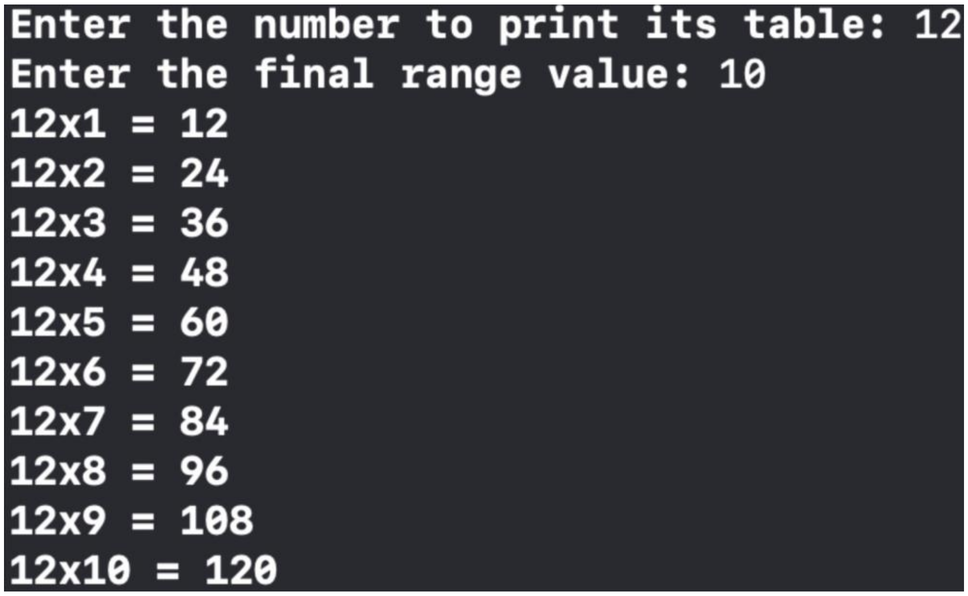
```
Enter any number to print its table: 4
4x1 = 4
4x2 = 8
4x3 = 12
4x4 = 16
4x5 = 20
4x6 = 24
4x7 = 28
4x8 = 32
4x9 = 36
4x10 = 40
```

However, this printing operation should be performed inside the user-defined function.

Then, create another function with the same name **printTable** but it gets two integer values (**num** and **range**) as parameters and prints the table of **num** up to the **range** value (in the previous task, the code was printing a table up to 10; thus, the range value was always 10 but here it should be equal to the **range** parameter).

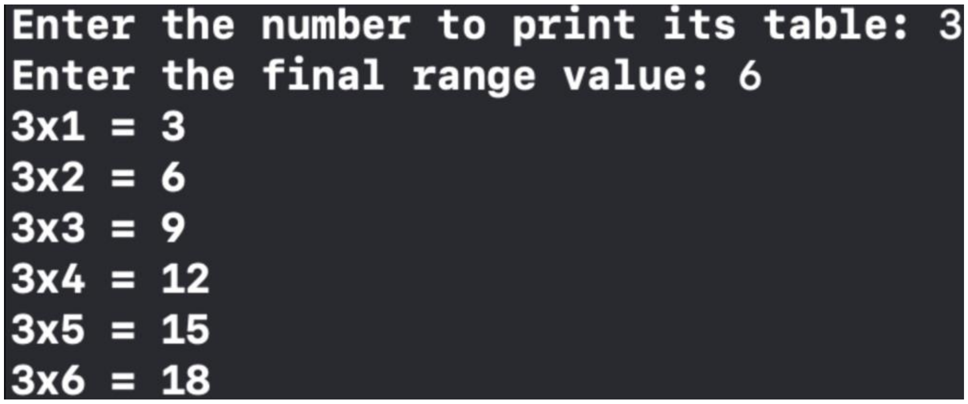
Then, in the main function, get two values as input from the user and call the function by passing those input values as arguments. For example:

Sample Output 1:



```
Enter the number to print its table: 12
Enter the final range value: 10
12x1 = 12
12x2 = 24
12x3 = 36
12x4 = 48
12x5 = 60
12x6 = 72
12x7 = 84
12x8 = 96
12x9 = 108
12x10 = 120
```

Sample Output 2:



```
Enter the number to print its table: 3
Enter the final range value: 6
3x1 = 3
3x2 = 6
3x3 = 9
3x4 = 12
3x5 = 15
3x6 = 18
```

Hint/Note: Here, you will use the concept of **function overloading**.