Lecture 2

- Functions
  - Declaration (prototype)
  - Definition (implementation)
  - Function calls
  - Parameters
    - Call by reference
    - Call by value
  - Return value
- Function overloading
- Header files
- Standard library: **`cmath`**, **`cstdlib`**, **`iomanip`**
- Variables of reference type

Functions in C++

- Structured programming
- Programs constructed from functions
- Performing **one task**
  - **E.g.** Compute the n!, sort a sequence of names
- Divide and conquer
  - Construct a program from smaller pieces or components
  - Each piece more manageable than the original program

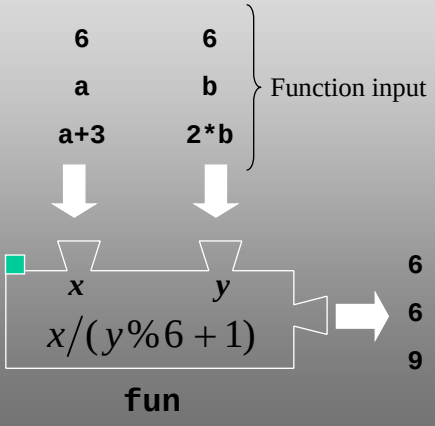
Program Components in C++

- C++ programs composed of
  - Programmer-defined functions
  - Prepackaged: from the C++ Standard Library

See Fig03_03.cpp

Functions

```
int a = 6, b = 6;
cout << fun(a,b);
```



Function definition

```
int fun(int x, int y)
{
  return x /(y%6 + 1);
}
```

```
// fig03_04.cpp
// Finding the maximum of three floating-point numbers.
#include <iostream>
using namespace std;

double maximum( double, double, double ); // function prototype

int main()
{
      double number1;
      double number2;
      double number3;

      cout << "Enter three floating-point numbers: ";
      cin >> number1 >> number2 >> number3;

      // number1, number2 and number3 are arguments to
      // the maximum function
      cout << "Maximum is: "
           << maximum( number1, number2, number3 ) << endl;

      return 0;  // indicates successful termination
}
```



```
// function maximum definition;
// x, y and z are parameters
double maximum( double x, double y, double z )
{
     double max = x;   // assume x is largest
                       // max is a local variable

     if ( y > max )    // if y is larger,
      max = y;       // assign y to max

     if ( z > max )    // if z is larger,
      max = z;       // assign z to max

     return max;       // max is largest value
} // end function maximum
```

Functions

- Local variables
  - Variables declared in the function
  - Known only in the function in which they are defined
- Parameters (arguments)
  - Local variables
    - Initialized with the arguments of the function call
  - Provide outside information

Important Concepts about Functions

- Function prototype
  - Function header
  - Function declaration
- Function call
- Function definition
  - Function implementation

Function Prototype

- Function prototype
  - Tells compiler argument type and return type of function

```
int square( int );
```

    - Function takes an **int** and returns an **int**
  - Function prototypes should appear before the function is called

Function Prototypes

- Function prototype contains
  - Function name
  - Parameters (number and data type)
  - Return type (**void** if returns nothing)
  - Only needed if function definition after function call
- Prototype must match function definition
  - Function prototype

```
double maximum( double, double, double );
```

  - Definition

```
double maximum( double x, double y, double z )
{
 …
}
```

Function Definitions

- Format for function definition

return-value-type *function-name*(*parameter-list*)
{
  declarations and statements
}

  - Parameter list
    - Comma separated list of arguments
      - Data type needed for each argument
  - Return-value type
    - Data type of result returned (use **void** if nothing returned)

Function Definitions

```
int square1( int y )
{
  return y * y;
}
```

```
void square2( int y )
{
  cout << y * y ;
}
```

- **return** keyword
  - Returns data, and control goes to function's caller
    - If no data to return, use **return;**
  - Function ends when reaches right brace or return
    - Control goes to caller
- Functions cannot be defined inside other functions

Function Arguments

- Argument Coercion

See mathfunk.cpp

  - Force arguments to be of proper type
    - Converting **int** (4) to **double** (4.0)

```
cout << sqrt(4);
```

Library <cmath>

  - Conversion rules
    - Arguments usually converted automatically
    - Changing from **double** to **int** can truncate data

E.g. `int k = square1(3.4);  //3.4 to 3`

Function Arguments

- Can be
  - Constants

```
square1( 4 );
```

  - Variables

```
square1( x );
```

  - Expressions

```
square1( factorial( x ) ) ;
square1( 3 - 6*x );
```

Function Overloading

```
int max( int x, int y )
{
  return x > y ? x : y;
}
double max(double x, double y );
char max(char x, char y );
```

See overload.cpp

Math Library Functions

- Perform common mathematical calculations
  - Include the header file

```
#include <cmath>
```

  - Trignometric functions (e.g. **cos**, **sin**, **tan**)
  - Exponential and logarithmic functions (e.g. **exp**, **log**)
  - Power functions (e.g. **pow**, **sqrt**)
  - Rounding, absolute value and remainder functions (e.g. **ceil**, **floor**)
  - All functions in math library return a **double**
- Example

```
cout << sqrt( 900 );
```

- See http://www.cplusplus.com/reference/clibrary/cmath/

Method	Description	Example
`ceil( x )`	rounds *x* to the smallest integer not less than *x*	`ceil( 9.2 )` is `10.0` `ceil( -9.8 )` is `-9.0`
`cos( x )`	trigonometric cosine of *x* (*x* in radians)	`cos( 0.0 )` is `1.0`
`exp( x )`	exponential function *ex*	`exp( 1.0 )` is `2.71828` `exp( 2.0 )` is `7.38906`

`fabs( x )`	absolute value of *x*	`fabs( 5.1 )` is `5.1`
		`fabs( 0.0 )` is `0.0`
		`fabs( -8.76 )` is `8.76`

`floor( x )`	rounds *x* to the largest integer not greater than *x*	`floor( 9.2 )` is `9.0` `floor( -9.8 )` is `-10.0`
`fmod( x, y )`	remainder of *x/y* as a floating-point number	`fmod( 13.657, 2.333 )` is `1.992`
`log( x )`	natural logarithm of *x* (base *e*)	`log( 2.718282 )` is `1.0` `log( 7.389056 )` is `2.0`
`log10( x )`	logarithm of *x* (base 10)	`log10( 10.0 )` is `1.0` `log10( 100.0 )` is `2.0`
`pow( x, y )`	*x* raised to power *y* (*xy*)	`pow( 2, 7 )` is `128` `pow( 9, .5 )` is `3`
`sin( x )`	trigonometric sine of *x* (*x* in radians)	`sin( 0.0 )` is `0`
`sqrt( x )`	square root of *x*	`sqrt( 900.0 )` is `30.0` `sqrt( 9.0 )` is `3.0`
`tan( x )`	trigonometric tangent of *x* (*x* in radians)	`tan( 0.0 )` is `0`

Fig. 3.2 Math library functions.

Header Files

- Header files contain
  - Function prototypes
  - Definitions of data types and constants
- Header files end with `.h`
  - Programmer-defined header files

```
#include "myheader.h"
```

- Library header files

```
#include <cmath>
```

Random Numbers

- **rand** function (#include **<cstdlib>**)
  - **i = rand();**
  - Generates unsigned integer between 0 and RAND_MAX (at least 32767)
- Scaling and shifting
  - Modulus (remainder) operator: %
    - **x % y** is between **0** and **y - 1**
  - Example

```
i = rand() % 6 + 1;
```

    - **"rand() % 6"** generates a number between **0** and **5** (scaling)
    - **"+ 1"** makes the range 1 to 6 (shift)
  - See program to roll dice **dice.cpp**

References

- A **reference** is an alias for a variable
- Mostly used for function arguments

```
int x = 1;
int& xref = x; // xref alias for x
xref = 4; // x changed via xref
```

- References must be initialized at declaration (compile error)
- References cannot be reassigned as aliases to other variable

Example

```
int squareByValue(int a)
{
   return a *= a; //a = a * a;
}

int squareByRef(int& b )
{
   return b *= b; //b = b * b;
}

int x = 4;
cout << squareByValue( x ) << x << endl;

int z = 4;
cout << squareByRef( z ) << z << endl;
```

- What do you think is the output?

Call by Value versus Call by Reference

- **Call by value** (used by default)
  - Copy of data passed to function
  - Changes to copy do not change original
  - Prevent unwanted side effects
- **Call by reference**
  - Function can directly access data
  - Changes affect original
  - See **`Fig03_20.cpp`**

Call by Value

- Why should I need call by value?
  - It is safer
    - Arguments protected from side effects
    - It works with a copy of the arguments passed in the function call
  - But, it implies overhead
    - Memory space and time needed to make the copies
    - What if an argument is many bytes long?

Call by Reference

- Why should I need call by reference?
  - Efficiency
  - But, there's more
    - Next example should help to answer this question

Call by Value

```
//swap the value of two variables
void swap1(int x, int y)
{
  int temp = x;
  x = y;
  y = temp;
}
```


Call by Reference

```
//swap the value of two variables
void swap2(int &x, int &y)
{
  int temp = x;
  x = y;
  y = temp;
}
```

Calling **swap1** and **swap2**

- **Call by value** `swap1(a, b);`
  - x and y in swap gets copies of a and b
  - Local copies of the arguments are changed
- **Call by reference** `swap2(a, b);`
  - Reference (address) to a and b is copied to x and y
  - Arguments are changed

Further reading …

- About recursive functions