

C++ Programming: From Problem Analysis to Program Design, Fourth Edition

Chapter 2: Basic Elements of C++

Objectives

In this chapter, you will:

- Become familiar with the basic components of a C++ program, including functions, special symbols, and identifiers
- Explore simple data types
- Discover how to use arithmetic operators
- Examine how a program evaluates arithmetic expressions

Objectives (continued)

- Learn what an assignment statement is and what it does
- Become familiar with the `string` data type
- Discover how to input data into memory using input statements
- Become familiar with the use of increment and decrement operators
- Examine ways to output results using output statements

Objectives (continued)

- Learn how to use preprocessor directives and why they are necessary
- Explore how to properly structure a program, including using comments to document a program
- Learn how to write a C++ program

The Basics of a C++ Program

- Function: collection of statements; when executed, accomplishes something
 - May be predefined or standard
- Syntax: rules that specify which statements (instructions) are legal
- Programming language: a set of rules, symbols, and special words
- Semantic rule: meaning of the instruction

Comments

- Comments are for the reader, not the compiler
- Two types:

- Single line

```
// This is a C++ program. It prints the sentence:  
// Welcome to C++ Programming.
```

- Multiple line

```
/*  
    You can include comments that can  
    occupy several lines.  
*/
```

Special Symbols

- Special symbols

+

?

-

,

*

<=

/

!=

.

==

;

>=

Reserved Words (Keywords)

- Reserved words, keywords, or word symbols
 - Include:
 - `int`
 - `float`
 - `double`
 - `char`
 - `const`
 - `void`
 - `return`

Identifiers

- Consist of letters, digits, and the underscore character (`_`)
- Must begin with a letter or underscore
- C++ is case sensitive
 - `NUMBER` is not the same as `number`
- Two predefined identifiers are `cout` and `cin`
- Unlike reserved words, predefined identifiers may be redefined, but it is not a good idea

Identifiers (continued)

- The following are legal identifiers in C++:
 - `first`
 - `conversion`
 - `payRate`

TABLE 2-1 Examples of Illegal Identifiers

Illegal Identifier	Description
<code>employee Salary</code>	There can be no space between <code>employee</code> and <code>Salary</code> .
<code>Hello!</code>	The exclamation mark cannot be used in an identifier.
<code>one + two</code>	The symbol <code>+</code> cannot be used in an identifier.
<code>2nd</code>	An identifier cannot begin with a digit.

Whitespaces

- Every C++ program contains whitespaces
 - Include blanks, tabs, and newline characters
- Used to separate special symbols, reserved words, and identifiers
- Proper utilization of whitespaces is important
 - Can be used to make the program readable

Data Types

- Data type: set of values together with a set of operations
- C++ data types fall into three categories:

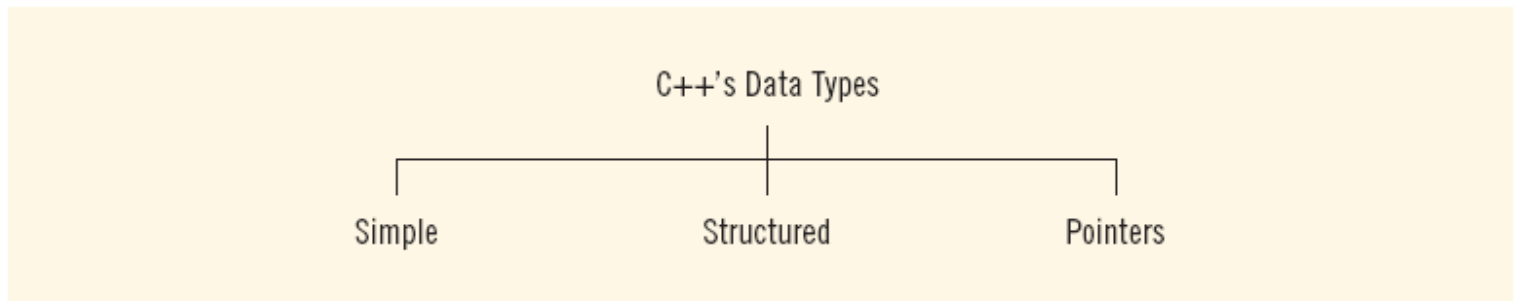


FIGURE 2-1 C++ data types

Simple Data Types

- Three categories of simple data
 - Integral: integers (numbers without a decimal)
 - Floating-point: decimal numbers
 - Enumeration type: user-defined data type

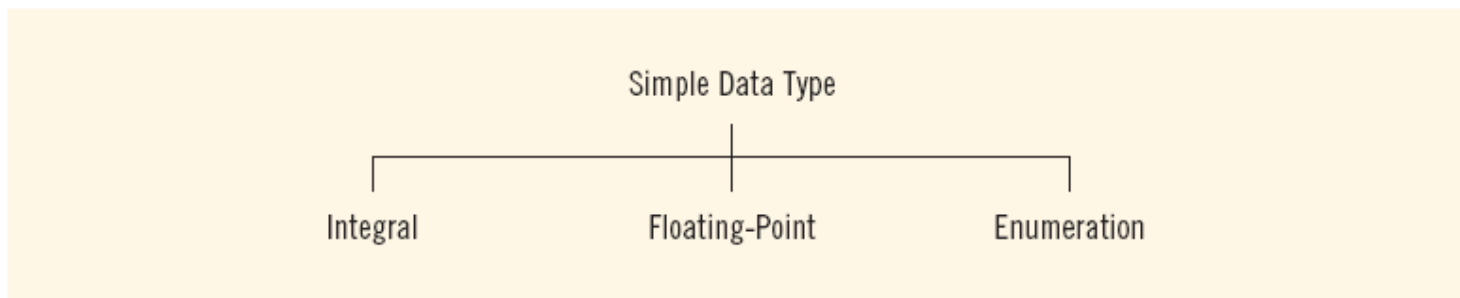


FIGURE 2-2 Simple data types

Simple Data Types (continued)

- Integral data types are further classified into nine categories:

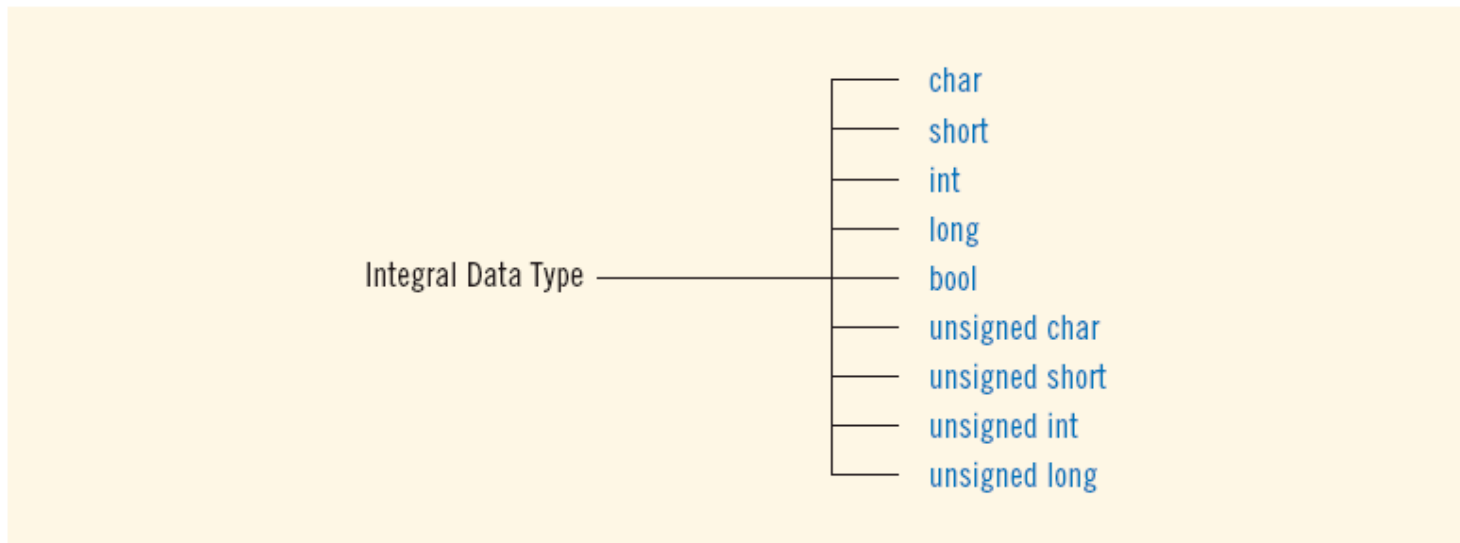


FIGURE 2-3 Integral data types

Simple Data Types (continued)

TABLE 2-2 Values and Memory Allocation for Three Simple Data Types

Data Type	Values	Storage (in bytes)
<code>int</code>	-2147483648 to 2147483647	4
<code>bool</code>	<code>true</code> and <code>false</code>	1
<code>char</code>	-128 to 127	1

- Different compilers may allow different ranges of values

int Data Type

- Examples:

-6728

0

78

+763

- Positive integers do not need a + sign
- No commas are used within an integer
 - Commas are used for separating items in a list

bool Data Type

- `bool` type
 - Two values: `true` and `false`
 - Manipulate logical (Boolean) expressions
- `true` and `false` are called logical values
- `bool`, `true`, and `false` are reserved words

char Data Type

- The smallest integral data type
- Used for characters: letters, digits, and special symbols
- Each character is enclosed in single quotes
 - 'A', 'a', '0', '*', '+', '\$', '&'
- A blank space is a character and is written ' ', with a space left between the single quotes

Floating-Point Data Types

- C++ uses scientific notation to represent real numbers (floating-point notation)

TABLE 2-3 Examples of Real Numbers Printed in C++ Floating-Point Notation

Real Number	C++ Floating-Point Notation
75.924	7.592400E1
0.18	1.800000E-1
0.0000453	4.530000E-5
-1.482	-1.482000E0
7800.0	7.800000E3

Floating-Point Data Types (continued)

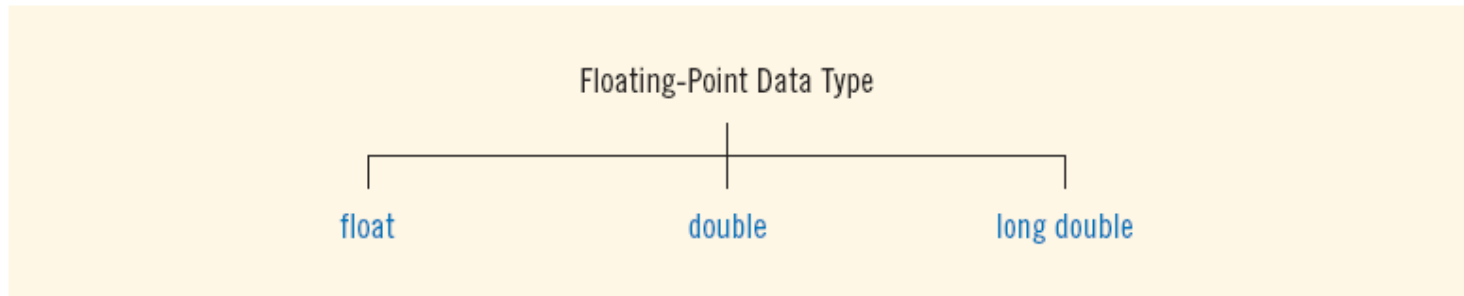


FIGURE 2-4 Floating-point data types

- `float`: represents any real number
 - Range: $-3.4\text{E}+38$ to $3.4\text{E}+38$ (four bytes)
- `double`: represents any real number
 - Range: $-1.7\text{E}+308$ to $1.7\text{E}+308$ (eight bytes)
- On most newer compilers, data types `double` and `long double` are same

Floating-Point Data Types (continued)

- Maximum number of significant digits (decimal places) for float values is 6 or 7
- Maximum number of significant digits for double is 15
- Precision: maximum number of significant digits
 - Float values are called single precision
 - Double values are called double precision

Arithmetic Operators and Operator Precedence

- C++ arithmetic operators:
 - + addition
 - - subtraction
 - * multiplication
 - / division
 - % modulus operator
- +, -, *, and / can be used with integral and floating-point data types
- Operators can be unary or binary

Order of Precedence

- All operations inside of $()$ are evaluated first
- $*$, $/$, and $\%$ are at the same level of precedence and are evaluated next
- $+$ and $-$ have the same level of precedence and are evaluated last
- When operators are on the same level
 - Performed from left to right (associativity)
- $3 * 7 - 6 + 2 * 5 / 4 + 6$ means
 $(((3 * 7) - 6) + ((2 * 5) / 4)) + 6$

Expressions

- If all operands are integers
 - Expression is called an integral expression
 - Yields an integral result
 - Example: $2 + 3 * 5$
- If all operands are floating-point
 - Expression is called a floating-point expression
 - Yields a floating-point result
 - Example: $12.8 * 17.5 - 34.50$

Mixed Expressions

- Mixed expression:
 - Has operands of different data types
 - Contains integers and floating-point
- Examples of mixed expressions:

$2 + 3.5$

$6 / 4 + 3.9$

$5.4 * 2 - 13.6 + 18 / 2$

Mixed Expressions (continued)

- Evaluation rules:
 - If operator has same types of operands
 - Evaluated according to the type of the operands
 - If operator has both types of operands
 - Integer is changed to floating-point
 - Operator is evaluated
 - Result is floating-point
 - Entire expression is evaluated according to precedence rules

Type Conversion (Casting)

- Implicit type coercion: when value of one type is automatically changed to another type
- Cast operator: provides explicit type conversion

```
static_cast<dataTypeName> (expression)
```

Type Conversion (continued)

EXAMPLE 2-9

Expression	Evaluates to
<code>static_cast<int>(7.9)</code>	7
<code>static_cast<int>(3.3)</code>	3
<code>static_cast<double>(25)</code>	25.0
<code>static_cast<double>(5+3)</code>	= <code>static_cast<double>(8)</code> = 8.0
<code>static_cast<double>(15) / 2</code>	= 15.0 / 2 (because <code>static_cast<double>(15)</code> = 15.0) = 15.0 / 2.0 = 7.5
<code>static_cast<double>(15 / 2)</code>	= <code>static_cast<double>(7)</code> (because $15 / 2 = 7$) = 7.0
<code>static_cast<int>(7.8 +</code> <code>static_cast<double>(15) / 2)</code>	= <code>static_cast<int>(7.8 + 7.5)</code> = <code>static_cast<int>(15.3)</code> = 15
<code>static_cast<int>(7.8 +</code> <code>static_cast<double>(15 / 2))</code>	= <code>static_cast<int>(7.8 + 7.0)</code> = <code>static_cast<int>(14.8)</code> = 14

string Type

- Programmer-defined type supplied in ANSI/ISO Standard C++ library
- Sequence of zero or more characters
- Enclosed in double quotation marks
- Null: a string with no characters
- Each character has relative position in string
 - Position of first character is 0
- Length of a string is number of characters in it
 - Example: length of "William Jacob" is 13

Input

- Data must be loaded into main memory before it can be manipulated
- Storing data in memory is a two-step process:
 - Instruct computer to allocate memory
 - Include statements to put data into memory

Allocating Memory with Constants and Variables

- Named constant: memory location whose content can't change during execution
- The syntax to declare a named constant is:

```
const dataType identifier = value;
```

- In C++, `const` is a reserved word

EXAMPLE 2-11

Consider the following C++ statements:

```
const double CONVERSION = 2.54;  
const int NO_OF_STUDENTS = 20;  
const char BLANK = ' ';  
const double PAY_RATE = 15.75;
```

Allocating Memory with Constants and Variables (continued)

- Variable: memory location whose content may change during execution
- The syntax to declare a named constant is:

```
dataType identifier, identifier, . . . ;
```

EXAMPLE 2-12

Consider the following statements:

```
double amountDue;  
int counter;  
char ch;  
int x, y;  
string name;
```


Putting Data into Variables

- Ways to place data into a variable:
 - Use C++'s assignment statement
 - Use input (read) statements

Assignment Statement

- The assignment statement takes the form:

```
variable = expression;
```

- Expression is evaluated and its value is assigned to the variable on the left side
- In C++, = is called the assignment operator

Assignment Statement (continued)

EXAMPLE 2-13

```
int num1, num2;  
double sale;  
char first;  
string str;  
  
num1 = 4;  
num2 = 4 * 5 - 11;  
sale = 0.02 * 1000;  
first = 'D';  
str = "It is a sunny day.";
```

EXAMPLE 2-14

1. num1 = 18;
2. num1 = num1 + 27;
3. num2 = num1;
4. num3 = num2 / 5;
5. num3 = num3 / 4;

Saving and Using the Value of an Expression

- To save the value of an expression:
 - Declare a variable of the appropriate data type
 - Assign the value of the expression to the variable that was declared
 - Use the assignment statement
- Wherever the value of the expression is needed, use the variable holding the value

Declaring & Initializing Variables

- Variables can be initialized when declared:

```
int first=13, second=10;
```

```
char ch=' ';
```

```
double x=12.6;
```

- All variables must be initialized before they are used
 - But not necessarily during declaration

Input (Read) Statement

- `cin` is used with `>>` to gather input

```
cin >> variable >> variable ...;
```

- The stream extraction operator is `>>`
- For example, if `miles` is a double variable

```
cin >> miles;
```

- Causes computer to get a value of type `double`
- Places it in the variable `miles`

Input (Read) Statement (continued)

- Using more than one variable in `cin` allows more than one value to be read at a time
- For example, if `feet` and `inches` are variables of type `int`, a statement such as:

```
cin >> feet >> inches;
```

- Inputs two integers from the keyboard
- Places them in variables `feet` and `inches` respectively

Input (Read) Statement (continued)

EXAMPLE 2-17

```
#include <iostream>

using namespace std;

int main()
{
    int feet;
    int inches;

    cout << "Enter two integers separated by spaces: ";
    cin >> feet >> inches;
    cout << endl;

    cout << "Feet = " << feet << endl;
    cout << "Inches = " << inches << endl;

    return 0;
}
```

Sample Run: (In this sample run, the user input is shaded.)

Enter two integers separated by spaces: 23 7

Feet = 23

Inches = 7

Variable Initialization

- There are two ways to initialize a variable:

```
int feet;
```

- By using the assignment statement

```
feet = 35;
```

- By using a read statement

```
cin >> feet;
```

Increment & Decrement Operators

- Increment operator: increment variable by 1
 - Pre-increment: `++variable`
 - Post-increment: `variable++`
- Decrement operator: decrement variable by 1
 - Pre-decrement: `--variable`
 - Post-decrement: `variable--`
- What is the difference between the following?

```
x = 5;  
y = ++x;
```

```
x = 5;  
y = x++;
```

Output

- The syntax of `cout` and `<<` is:

```
cout << expression or manipulator << expression or manipulator...;
```

- Called an output statement
- The stream insertion operator is `<<`
- Expression evaluated and its value is printed at the current cursor position on the screen

Output (continued)

- A manipulator is used to format the output
 - Example: `endl` causes insertion point to move to beginning of next line

EXAMPLE 2-21

Statement	Output
1 <code>cout << 29 / 4 << endl;</code>	7
2 <code>cout << "Hello there." << endl;</code>	Hello there.
3 <code>cout << 12 << endl;</code>	12
4 <code>cout << "4 + 7" << endl;</code>	4 + 7
5 <code>cout << 4 + 7 << endl;</code>	11
6 <code>cout << 'A' << endl;</code>	A
7 <code>cout << "4 + 7 = " << 4 + 7 << endl;</code>	4 + 7 = 11
8 <code>cout << 2 + 3 * 5 << endl;</code>	17
9 <code>cout << "Hello \nthere." << endl;</code>	Hello there.

Output (continued)

- The new line character is `'\n'`
 - May appear anywhere in the string

```
cout << "Hello there.";  
cout << "My name is James.";
```

- **Output:**
Hello there.My name is James.

```
cout << "Hello there.\n";  
cout << "My name is James.";
```

- **Output :**
Hello there.
My name is James.

Output (continued)

TABLE 2-4 Commonly Used Escape Sequences

	Escape Sequence	Description
<code>\n</code>	Newline	Cursor moves to the beginning of the next line
<code>\t</code>	Tab	Cursor moves to the next tab stop
<code>\b</code>	Backspace	Cursor moves one space to the left
<code>\r</code>	Return	Cursor moves to the beginning of the current line (not the next line)
<code>\\</code>	Backslash	Backslash is printed
<code>\'</code>	Single quotation	Single quotation mark is printed
<code>\"</code>	Double quotation	Double quotation mark is printed

Preprocessor Directives

- C++ has a small number of operations
- Many functions and symbols needed to run a C++ program are provided as collection of libraries
- Every library has a name and is referred to by a header file
- Preprocessor directives are commands supplied to the preprocessor
- All preprocessor commands begin with #
- No semicolon at the end of these commands

Preprocessor Directives (continued)

- Syntax to include a header file:

```
#include <headerFileName>
```

- For example:

```
#include <iostream>
```

- Causes the preprocessor to include the header file `iostream` in the program

namespace and Using cin and cout in a Program

- `cin` and `cout` are declared in the header file `iostream`, but within `std` namespace
- To use `cin` and `cout` in a program, use the following two statements:

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

Using the `string` Data Type in a Program

- To use the `string` type, you need to access its definition from the header file `string`
- Include the following preprocessor directive:

```
#include <string>
```

Creating a C++ Program

- C++ program has two parts:
 - Preprocessor directives
 - The program
- Preprocessor directives and program statements constitute C++ source code (.cpp)
- Compiler generates object code (.obj)
- Executable code is produced and saved in a file with the file extension .exe

Creating a C++ Program (continued)

- A C++ program is a collection of functions, one of which is the function `main`
- The first line of the function `main` is called the heading of the function:
`int main()`
- The statements enclosed between the curly braces (`{` and `}`) form the body of the function
 - Contains two types of statements:
 - Declaration statements
 - Executable statements

EXAMPLE 2-29

```
#include <iostream>                                //Line 1

using namespace std;                                //Line 2

const int NUMBER = 12;                              //Line 3

int main()                                           //Line 4
{                                                     //Line 5
    int firstNum;                                    //Line 6
    int secondNum;                                   //Line 7

    firstNum = 18;                                    //Line 8
    cout << "Line 9: firstNum = " << firstNum
         << endl;                                    //Line 9

    cout << "Line 10: Enter an integer: ";           //Line 10
    cin >> secondNum;                                //Line 11
    cout << endl;                                    //Line 12

    cout << "Line 13: secondNum = " << secondNum
         << endl;                                    //Line 13

    firstNum = firstNum + NUMBER + 2 * secondNum;    //Line 14

    cout << "Line 15: The new value of "
         << "firstNum = " << firstNum << endl;        //Line 15

    return 0;                                        //Line 16
}                                                     //Line 17
```

Creating a C++ Program (continued)

Sample Run:

Line 9: `firstNum = 18`

Line 10: Enter an integer: `15`

Line 13: `secondNum = 15`

Line 15: The new value of `firstNum = 60`

Program Style and Form

- Every C++ program has a function `main`
- It must also follow the syntax rules
- Other rules serve the purpose of giving precise meaning to the language

Syntax

- Errors in syntax are found in compilation

```
int x;           //Line 1
int y           //Line 2: error
double z;       //Line 3

y = w + x;      //Line 4: error
```


Use of Blanks

- In C++, you use one or more blanks to separate numbers when data is input
- Used to separate reserved words and identifiers from each other and from other symbols
- Must never appear within a reserved word or identifier

Use of Semicolons, Brackets, and Commas

- All C++ statements end with a semicolon
 - Also called a statement terminator
- { and } are not C++ statements
- Commas separate items in a list

Semantics

- Possible to remove all syntax errors in a program and still not have it run
- Even if it runs, it may still not do what you meant it to do

- For example,

$2 + 3 * 5$ and $(2 + 3) * 5$

are both syntactically correct expressions, but have different meanings

Naming Identifiers

- Identifiers can be self-documenting:
 - `CENTIMETERS_PER_INCH`
- Avoid run-together words :
 - `annualsale`
 - Solution:
 - Capitalize the beginning of each new word
 - `annualSale`
 - Inserting an underscore just before a new word
 - `annual_sale`

Prompt Lines

- Prompt lines: executable statements that inform the user what to do

```
cout << "Please enter a number between 1 and 10 and "  
      << "press the return key" << endl;  
cin >> num;
```

Documentation

- A well-documented program is easier to understand and modify
- You use comments to document programs
- Comments should appear in a program to:
 - Explain the purpose of the program
 - Identify who wrote it
 - Explain the purpose of particular statements

Form and Style

- Consider two ways of declaring variables:

- Method 1

```
int feet, inch;
```

```
double x, y;
```

- Method 2

```
int a,b;double x,y;
```

- Both are correct; however, the second is hard to read

More on Assignment Statements

- C++ has special assignment statements called compound assignments

`+=`, `-=`, `*=`, `/=`, and `%=`

- Example:

```
x *= y;
```


Programming Example: Convert Length

- Write a program that takes as input a given length expressed in feet and inches
 - Convert and output the length in centimeters
- Input: length in feet and inches
- Output: equivalent length in centimeters
- Lengths are given in feet and inches
- Program computes the equivalent length in centimeters
- One inch is equal to 2.54 centimeters

Programming Example: Convert Length (continued)

- Convert the length in feet and inches to all inches:
 - Multiply the number of feet by 12
 - Add given inches
- Use the conversion formula (1 inch = 2.54 centimeters) to find the equivalent length in centimeters

Programming Example: Convert Length (continued)

- The algorithm is as follows:
 - Get the length in feet and inches
 - Convert the length into total inches
 - Convert total inches into centimeters
 - Output centimeters

Programming Example: Variables and Constants

- Variables

```
int feet;           //variable to hold given feet
int inches;         //variable to hold given inches
int totalInches;    //variable to hold total inches
double centimeters; //variable to hold length in
                    //centimeters
```

- Named Constant

```
const double CENTIMETERS_PER_INCH = 2.54;
const int INCHES_PER_FOOT = 12;
```

Programming Example: Main Algorithm

- Prompt user for input
- Get data
- Echo the input (output the input)
- Find length in inches
- Output length in inches
- Convert length to centimeters
- Output length in centimeters

Programming Example: Putting It Together

- Program begins with comments
- System resources will be used for I/O
- Use input statements to get data and output statements to print results
- Data comes from keyboard and the output will display on the screen
- The first statement of the program, after comments, is preprocessor directive to include header file `iostream`

Programming Example: Putting It Together (continued)

- Two types of memory locations for data manipulation:
 - Named constants
 - Usually put before `main`
 - Variables
- This program has only one function (`main`), which will contain all the code
- The program needs variables to manipulate data, which are declared in `main`

Programming Example: Body of the Function

- The body of the function `main` has the following form:

```
int main ()  
{  
    declare variables  
    statements  
    return 0;  
}
```


Programming Example: Writing a Complete Program

- Begin the program with comments for documentation
- Include header files
- Declare named constants, if any
- Write the definition of the function `main`

```

using namespace std;

    //Named constants
const double CENTIMETERS_PER_INCH = 2.54;
const int INCHES_PER_FOOT = 12;
int main ()
{
    //Declare variables
    int feet, inches;
    int totalInches;
    double centimeter;

    //Statements: Step 1 - Step 7
    cout << "Enter two integers, one for feet and "
         << "one for inches: ";           //Step 1
    cin >> feet >> inches;                 //Step 2
    cout << endl;
    cout << "The numbers you entered are " << feet
         << " for feet and " << inches
         << " for inches. " << endl;       //Step 3

    totalInches = INCHES_PER_FOOT * feet + inches; //Step 4

    cout << "The total number of inches = "
         << totalInches << endl;           //Step 5

    centimeter = CENTIMETERS_PER_INCH * totalInches; //Step 6

    cout << "The number of centimeters = "
         << centimeter << endl;           //Step 7

    return 0;
}

```

Programming Example: Sample Run

Enter two integers, one for feet, one for inches: 15 7

The numbers you entered are 15 for feet and 7 for inches.

The total number of inches = 187

The number of centimeters = 474.98

Summary

- C++ program: collection of functions where each program has a function called `main`
- Identifier consists of letters, digits, and underscores, and begins with letter or underscore
- The arithmetic operators in C++ are addition (+), subtraction (-), multiplication (*), division (/), and modulus (%)
- Arithmetic expressions are evaluated using the precedence associativity rules

Summary (continued)

- All operands in an integral expression are integers and all operands in a floating-point expression are decimal numbers
- Mixed expression: contains both integers and decimal numbers
- Use the cast operator to explicitly convert values from one data type to another
- A named constant is initialized when declared
- All variables must be declared before used

Summary (continued)

- Use `cin` and stream extraction operator `>>` to input from the standard input device
- Use `cout` and stream insertion operator `<<` to output to the standard output device
- Preprocessor commands are processed before the program goes through the compiler
- A file containing a C++ program usually ends with the extension `.cpp`