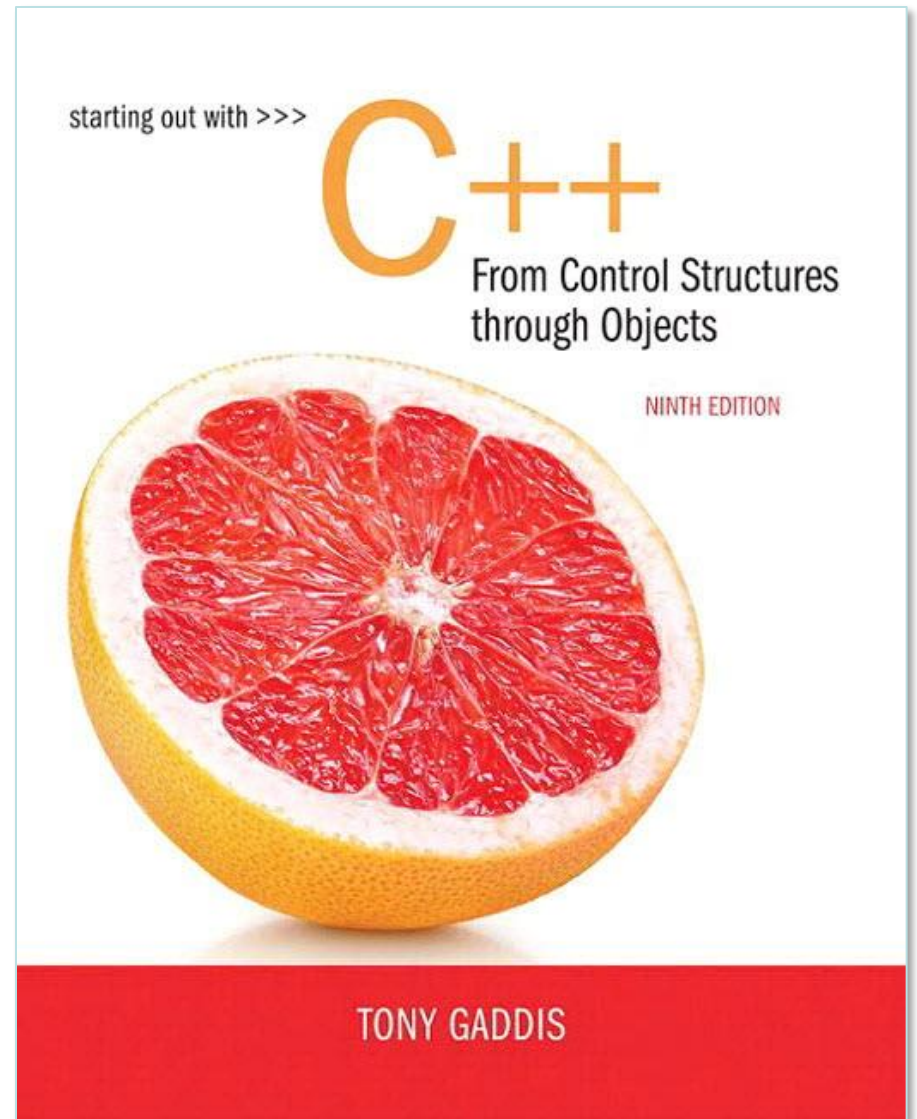
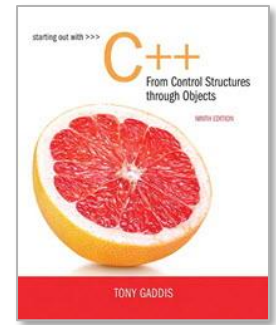


# Chapter 3:

## Expressions and Interactivity





# 3.1

## The `cin` Object

# The `cin` Object

- Standard input object
- Like `cout`, requires `iostream` file
- Used to read input from keyboard
- Information retrieved from `cin` with `>>`
- Input is stored in one or more variables

# The `cin` Object in Program 3-1

## Program 3-1

```
1  // This program asks the user to enter the length and width of
2  // a rectangle. It calculates the rectangle's area and displays
3  // the value on the screen.
4  #include <iostream>
5  using namespace std;
6
7  int main()
8  {
9      int length, width, area;
10
11      cout << "This program calculates the area of a ";
12      cout << "rectangle.\n";
13      cout << "What is the length of the rectangle? ";
14      cin >> length;
15      cout << "What is the width of the rectangle? ";
16      cin >> width;
17      area = length * width;
18      cout << "The area of the rectangle is " << area << ".\n";
19      return 0;
20 }
```

### Program Output with Example Input Shown in Bold

This program calculates the area of a rectangle.  
What is the length of the rectangle? **10 [Enter]**  
What is the width of the rectangle? **20 [Enter]**  
The area of the rectangle is 200.



# The `cin` Object

🍊 **`cin`** converts data to the type that matches the variable:

```
int height;  
cout << "How tall is the room? ";  
cin >> height;
```

# Displaying a Prompt

- A prompt is a message that instructs the user to enter data.
- You should always use **cout** to display a prompt before each **cin** statement.

```
cout << "How tall is the room? ";  
cin >> height;
```

# The `cin` Object

- Can be used to input more than one value:

```
cin >> height >> width;
```

- Multiple values from keyboard must be separated by spaces
- Order is important: first value entered goes to first variable, etc.

# The `cin` Object Gathers Multiple Values in Program 3-2

## Program 3-2

```
1  // This program asks the user to enter the length and width of
2  // a rectangle. It calculates the rectangle's area and displays
3  // the value on the screen.
4  #include <iostream>
5  using namespace std;
6
7  int main()
8  {
9      int length, width, area;
10
11      cout << "This program calculates the area of a ";
12      cout << "rectangle.\n";
13      cout << "Enter the length and width of the rectangle ";
14      cout << "separated by a space.\n";
15      cin >> length >> width;
16      area = length * width;
17      cout << "The area of the rectangle is " << area << endl;
18      return 0;
19  }
```

### Program Output with Example Input Shown in Bold

This program calculates the area of a rectangle.

Enter the length and width of the rectangle separated by a space.

**10 20 [Enter]**

The area of the rectangle is 200





# The `cin` Object Reads Different Data Types in Program 3-3

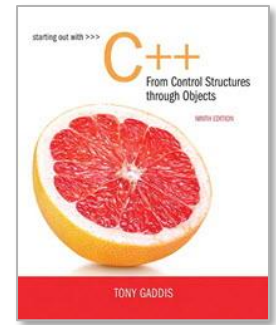
## Program 3-3

```
1 // This program demonstrates how cin can read multiple values
2 // of different data types.
3 #include <iostream>
4 using namespace std;
5
6 int main()
7 {
8     int whole;
9     double fractional;
10    char letter;
11
12    cout << "Enter an integer, a double, and a character: ";
13    cin >> whole >> fractional >> letter;
14    cout << "Whole: " << whole << endl;
15    cout << "Fractional: " << fractional << endl;
16    cout << "Letter: " << letter << endl;
17    return 0;
18 }
```

## Program Output with Example Input Shown in Bold

```
Enter an integer, a double, and a character: 4 5.7 b [Enter]
Whole: 4
Fractional: 5.7
Letter: b
```





# 3.2

## Mathematical Expressions

# Mathematical Expressions

- Can create complex expressions using multiple mathematical operators
- An expression can be a literal, a variable, or a mathematical combination of constants and variables
- Can be used in assignment, `cout`, other statements:

```
area = 2 * PI * radius;  
cout << "border is: " << 2*(l+w);
```

# Order of Operations

In an expression with more than one operator, evaluate in this order:

- (unary negation), in order, left to right
- \* / %, in order, left to right
- + –, in order, left to right

In the expression  $2 + 2 * 2 - 2$

evaluate second      evaluate first      evaluate third

# Order of Operations

**Table 3-2 Some Simple Expressions and Their Values**

Expression	Value
$5 + 2 * 4$	13
$10 / 2 - 3$	2
$8 + 12 * 2 - 4$	28
$4 + 17 \% 2 - 1$	4
$6 - 3 * 2 + 7 - 1$	6



# Associativity of Operators

- (unary negation) associates right to left
- $*$ ,  $/$ ,  $\%$ ,  $+$ ,  $-$  associate right to left
- parentheses ( ) can be used to override the order of operations:

$$2 + 2 * 2 - 2 = 4$$

$$(2 + 2) * 2 - 2 = 6$$

$$2 + 2 * (2 - 2) = 2$$

$$(2 + 2) * (2 - 2) = 0$$

# Grouping with Parentheses

**Table 3-4 More Simple Expressions and Their Values**

Expression	Value
$(5 + 2) * 4$	28
$10 / (5 - 3)$	5
$8 + 12 * (6 - 2)$	56
$(4 + 17) \% 2 - 1$	0
$(6 - 3) * (2 + 7) / 3$	9



# Algebraic Expressions

- Multiplication requires an operator:

$Area = lw$  is written as `Area = l * w;`

- There is no exponentiation operator:

$Area = s^2$  is written as `Area = pow(s, 2);`

- Parentheses may be needed to maintain order of operations:

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

is written as

$$m = (y_2 - y_1) / (x_2 - x_1);$$

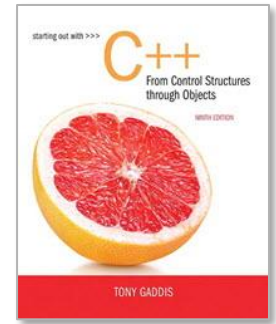


# Algebraic Expressions

**Table 3-5 Algebraic and C++ Multiplication Expressions**

Algebraic Expression	Operation	C++ Equivalent
$6B$	6 times B	<code>6 * B</code>
$(3)(12)$	3 times 12	<code>3 * 12</code>
$4xy$	4 times x times y	<code>4 * x * y</code>





# 3.3

## When You Mix Apples with Oranges: Type Conversion

# When You Mix Apples with Oranges: Type Conversion

- Operations are performed between operands of the same type.
- If not of the same type, C++ will convert one to be the type of the other
- This can impact the results of calculations.

# Hierarchy of Types

Highest: long double  
double  
float  
unsigned long  
long  
unsigned int  
int

Lowest:

Ranked by largest number they can hold

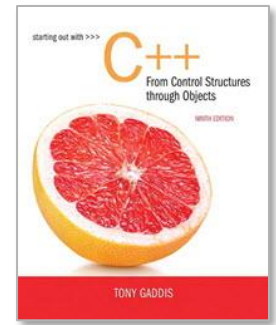


# Type Coercion

- Type Coercion: automatic conversion of an operand to another data type
- Promotion: convert to a higher type
- Demotion: convert to a lower type

# Coercion Rules

- 1) `char`, `short`, `unsigned short` automatically promoted to `int`
- 2) When operating on values of different data types, the lower one is promoted to the type of the higher one.
- 3) When using the `=` operator, the type of expression on right will be converted to type of variable on left



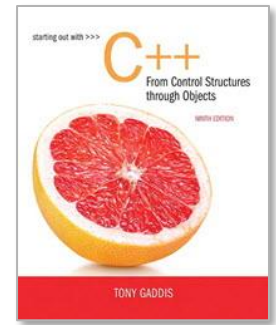
# 3.4

## Overflow and Underflow

# Overflow and Underflow

- Occurs when assigning a value that is too large (overflow) or too small (underflow) to be held in a variable
- Variable contains value that is 'wrapped around' set of possible values
- Different systems may display a warning/error message, stop the program, or continue execution using the incorrect value





# 3.5

## Type Casting

# Type Casting

- Used for manual data type conversion
- Useful for floating point division using ints:

```
double m;  
m = static_cast<double>(y2-y1)  
                        / (x2-x1);
```

- Useful to see `int` value of a `char` variable:

```
char ch = 'C';  
cout << ch << " is "  
      << static_cast<int>(ch);
```

# Type Casting in Program 3-9

## Program 3-9

```
1  // This program uses a type cast to avoid integer division.
2  #include <iostream>
3  using namespace std;
4
5  int main()
6  {
7      int books;           // Number of books to read
8      int months;          // Number of months spent reading
9      double perMonth;     // Average number of books per month
10
11     cout << "How many books do you plan to read? ";
12     cin >> books;
13     cout << "How many months will it take you to read them? ";
14     cin >> months;
15     perMonth = static_cast<double>(books) / months;
16     cout << "That is " << perMonth << " books per month.\n";
17     return 0;
18 }
```

### Program Output with Example Input Shown in Bold

```
How many books do you plan to read? 30 [Enter]
How many months will it take you to read them? 7 [Enter]
That is 4.28571 books per month.
```



# C-Style and Prestandard Type Cast Expressions

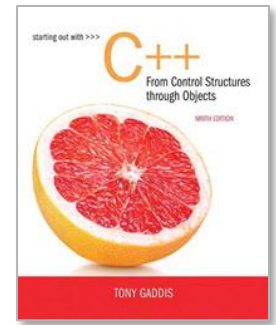
- C-Style cast: data type name in ( )

```
cout << ch << " is " << (int)ch;
```

- Prestandard C++ cast: value in ( )

```
cout << ch << " is " << int(ch);
```

- Both are still supported in C++, although `static_cast` is preferred



# 3.6

## Multiple Assignment and Combined Assignment

# Multiple Assignment and Combined Assignment

- The = can be used to assign a value to multiple variables:

`x = y = z = 5;`

- Value of = is the value that is assigned

- Associates right to left:

`x = (y = (z = 5)) ;`

↑  
value  
is 5

↑  
value  
is 5

↑  
value  
is 5

# Combined Assignment

🍊 Look at the following statement:

```
sum = sum + 1;
```

This adds 1 to the variable **sum**.

# Other Similar Statements

**Table 3-8 (Assume  $x = 6$ )**

Statement	What It Does	Value of $x$ After the Statement
$x = x + 4;$	Adds 4 to $x$	10
$x = x - 3;$	Subtracts 3 from $x$	3
$x = x * 10;$	Multiplies $x$ by 10	60
$x = x / 2;$	Divides $x$ by 2	3
$x = x \% 4$	Makes $x$ the remainder of $x / 4$	2





# Combined Assignment

- The combined assignment operators provide a shorthand for these types of statements.
- The statement

`sum = sum + 1;`

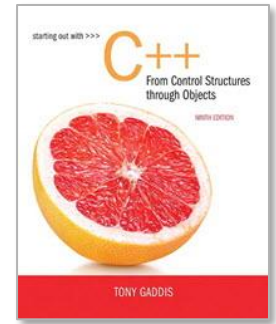
is equivalent to

`sum += 1;`

# Combined Assignment Operators

**Table 3-9**

Operator	Example Usage	Equivalent to
<code>+=</code>	<code>x += 5;</code>	<code>x = x + 5;</code>
<code>-=</code>	<code>y -= 2;</code>	<code>y = y - 2;</code>
<code>*=</code>	<code>z *= 10;</code>	<code>z = z * 10;</code>
<code>/=</code>	<code>a /= b;</code>	<code>a = a / b;</code>
<code>%=</code>	<code>c %= 3;</code>	<code>c = c % 3;</code>



# 3.7

## Formatting Output

# Formatting Output

- Can control how output displays for numeric, string data:
  - size
  - position
  - number of digits
- Requires `iomanip` header file

# Stream Manipulators

- Used to control how an output field is displayed
- Some affect just the next value displayed:
  - `setw(x)` : print in a field at least `x` spaces wide. Use more spaces if field is not wide enough

# The `setw` Stream Manipulator in Program 3-13

## Program 3-13

```
1  // This program displays three rows of numbers.
2  #include <iostream>
3  #include <iomanip>          // Required for setw
4  using namespace std;
5
6  int main()
7  {
8      int num1 = 2897, num2 = 5,    num3 = 837,
9          num4 = 34,   num5 = 7,    num6 = 1623,
10         num7 = 390,  num8 = 3456, num9 = 12;
11
12     // Display the first row of numbers
13     cout << setw(6) << num1 << setw(6)
14          << num2 << setw(6) << num3 << endl;
15
16     // Display the second row of numbers
17     cout << setw(6) << num4 << setw(6)
18          << num5 << setw(6) << num6 << endl;
19
20     // Display the third row of numbers
21     cout << setw(6) << num7 << setw(6)
22          << num8 << setw(6) << num9 << endl;
23     return 0;
24 }
```

Continued...



# The `setw` Stream Manipulator in Program 3-13

## Program Output

2897	5	837
34	7	1623
390	3456	12



# Stream Manipulators

- Some affect values until changed again:
  - `fixed`: use decimal notation for floating-point values
  - `setprecision(x)`: when used with `fixed`, print floating-point value using `x` digits after the decimal. Without `fixed`, print floating-point value using `x` significant digits
  - `showpoint`: always print decimal for floating-point values



# More Stream Manipulators in Program 3-17

## Program 3-17

```
1  // This program asks for sales amounts for 3 days. The total
2  // sales are calculated and displayed in a table.
3  #include <iostream>
4  #include <iomanip>
5  using namespace std;
6
7  int main()
8  {
9      double day1, day2, day3, total;
10
11     // Get the sales for each day.
12     cout << "Enter the sales for day 1: ";
13     cin >> day1;
14     cout << "Enter the sales for day 2: ";
15     cin >> day2;
16     cout << "Enter the sales for day 3: ";
17     cin >> day3;
18
19     // Calculate the total sales.
20     total = day1 + day2 + day3;
21
```

Continued...



# More Stream Manipulators in Program 3-17

```
22      // Display the sales amounts.
23      cout << "\nSales Amounts\n";
24      cout << "-----\n";
25      cout << setprecision(2) << fixed;
26      cout << "Day 1: " << setw(8) << day1 << endl;
27      cout << "Day 2: " << setw(8) << day2 << endl;
28      cout << "Day 3: " << setw(8) << day3 << endl;
29      cout << "Total: " << setw(8) << total << endl;
30      return 0;
31  }
```

## Program Output with Example Input Shown in Bold

Enter the sales for day 1: **1321.87**

Enter the sales for day 2: **1869.26**

Enter the sales for day 3: **1403.77**

Sales Amounts

-----

Day 1: 1321.87

Day 2: 1869.26

Day 3: 1403.77

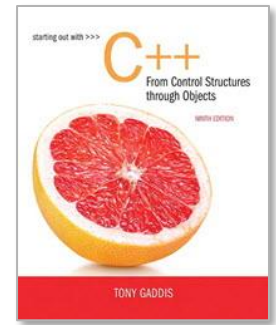
Total: 4594.90



# Stream Manipulators

**Table 3-12**

Stream Manipulator	Description
<code>setw(<i>n</i>)</code>	Establishes a print field of <i>n</i> spaces.
<code>fixed</code>	Displays floating-point numbers in fixed point notation.
<code>showpoint</code>	Causes a decimal point and trailing zeroes to be displayed, even if there is no fractional part.
<code>setprecision(<i>n</i>)</code>	Sets the precision of floating-point numbers.
<code>left</code>	Causes subsequent output to be left justified.
<code>right</code>	Causes subsequent output to be right justified.



# 3.8

## Working with Characters and `string` Objects

# Working with Characters and `string` Objects

- Using `cin` with the `>>` operator to input strings can cause problems:
- It passes over and ignores any leading *whitespace characters* (*spaces, tabs, or line breaks*)
- To work around this problem, you can use a C++ function named `getline`.

# Using `getline` in Program 3-19

## Program 3-19

```
1  // This program demonstrates using the getline function
2  // to read character data into a string object.
3  #include <iostream>
4  #include <string>
5  using namespace std;
6
7  int main()
8  {
9      string name;
10     string city;
11
12     cout << "Please enter your name: ";
13     getline(cin, name);
14     cout << "Enter the city you live in: ";
15     getline(cin, city);
16
17     cout << "Hello, " << name << endl;
18     cout << "You live in " << city << endl;
19     return 0;
20 }
```

### Program Output with Example Input Shown in Bold

```
Please enter your name: Kate Smith [Enter]
Enter the city you live in: Raleigh [Enter]
Hello, Kate Smith
You live in Raleigh
```



# Working with Characters and `string` Objects

- To read a single character:

- Use `cin`:

- `char ch;`

- `cout << "Strike any key to continue";`

- `cin >> ch;`

- Problem: will skip over blanks, tabs, <CR>

- Use `cin.get()`:

- `cin.get(ch);`

- Will read the next character entered, even whitespace

# Using `cin.get()` in Program 3-21

## Program 3-21

```
1  // This program demonstrates three ways
2  // to use cin.get() to pause a program.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8      char ch;
9
10     cout << "This program has paused. Press Enter to continue.";
11     cin.get(ch);
12     cout << "It has paused a second time. Please press Enter again.";
13     ch = cin.get();
14     cout << "It has paused a third time. Please press Enter again.";
15     cin.get();
16     cout << "Thank you!";
17     return 0;
18 }
```

### Program Output with Example Input Shown in Bold

This program has paused. Press Enter to continue. **[Enter]**  
It has paused a second time. Please press Enter again. **[Enter]**  
It has paused a third time. Please press Enter again. **[Enter]**  
Thank you!





# Working with Characters and `string` Objects

- Mixing `cin >>` and `cin.get()` in the same program can cause input errors that are hard to detect
- To skip over unneeded characters that are still in the keyboard buffer, use `cin.ignore()`:

```
cin.ignore(); // skip next char
cin.ignore(10, '\n'); // skip the next
                    // 10 char. or until a '\n'
```

# string Member Functions and Operators

- To find the length of a string:

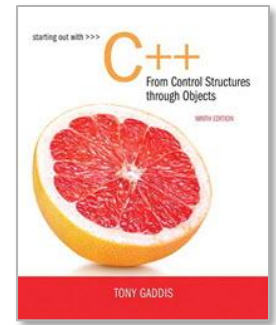
```
string state = "Texas";  
int size = state.length();
```

- To concatenate (join) multiple strings:

```
greeting2 = greeting1 + name1;  
greeting1 = greeting1 + name2;
```

Or using the += combined assignment operator:

```
greeting1 += name2;
```



# 3.9

## More Mathematical Library Functions

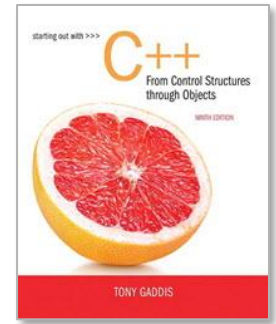
# More Mathematical Library Functions

- Require `cmath` header file
- Take `double` as input, return a `double`
- Commonly used functions:

<code>sin</code>	Sine
<code>cos</code>	Cosine
<code>tan</code>	Tangent
<code>sqrt</code>	Square root
<code>log</code>	Natural (e) log
<code>abs</code>	Absolute value (takes and returns an int)

# More Mathematical Library Functions

- These require `cstdlib` header file
- `rand()`: returns a random number (`int`) between 0 and the largest `int` the computer holds. Yields same sequence of numbers each time program is run.
- `srand(x)`: initializes random number generator with unsigned `int` `x`



# 3.10

## Hand Tracing a Program



# Hand Tracing a Program

- Hand trace a program: act as if you are the computer, executing a program:
  - step through and 'execute' each statement, one-by-one
  - record the contents of variables after statement execution, using a hand trace chart (table)
- Useful to locate logic or mathematical errors

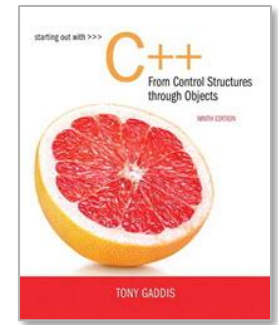
# Program 3-27 with Hand Trace Chart

**Program 3-27** (with hand trace chart filled)

```
1 // This program asks for three numbers, then
2 // displays the average of the numbers.
3 #include <iostream>
4 using namespace std;
5 int main()
6 {
7     double num1, num2, num3, avg;
8     cout << "Enter the first number: ";
9     cin >> num1;
10    cout << "Enter the second number: ";
11    cin >> num2;
12    cout << "Enter the third number: ";
13    cin >> num3;
14    avg = num1 + num2 + num3 / 3;
15    cout << "The average is " << avg << endl;
16    return 0;
17 }
```

num1	num2	num3	avg
?	?	?	?
?	?	?	?
10	?	?	?
10	?	?	?
10	20	?	?
10	20	?	?
10	20	30	?
10	20	30	40
10	20	30	40





# 3.11

## A Case Study

# A Case Study

- General Crates, Inc. builds custom-designed wooden crates.
- You have been asked to write a program that calculates the:
  - Volume (in cubic feet)
  - Cost
  - Customer price
  - Profit of any crate GCI builds

# Variables

**Table 3-14**

Constant or Variable	Description
<code>COST_PER_CUBIC_FOOT</code>	A named constant, declared as a <code>double</code> and initialized with the value 0.23. This represents the cost to build a crate, per cubic foot.
<code>CHARGE_PER_CUBIC_FOOT</code>	A named constant, declared as a <code>double</code> and initialized with the value 0.5. This represents the amount charged for a crate, per cubic foot.
<code>length</code>	A <code>double</code> variable to hold the length of the crate, which is input by the user.
<code>width</code>	A <code>double</code> variable to hold the width of the crate, which is input by the user.
<code>height</code>	A <code>double</code> variable to hold the height of the crate, which is input by the user.
<code>volume</code>	A <code>double</code> variable to hold the volume of the crate. The value stored in this variable is calculated.
<code>cost</code>	A <code>double</code> variable to hold the cost of building the crate. The value stored in this variable is calculated.
<code>charge</code>	A <code>double</code> variable to hold the amount charged to the customer for the crate. The value stored in this variable is calculated.
<code>profit</code>	A <code>double</code> variable to hold the profit GCI makes from the crate. The value stored in this variable is calculated.

# Program Design

The program must perform the following general steps:

Step 1:

Ask the user to enter the dimensions of the crate

Step 2:

Calculate:

the crate's volume

the cost of building the crate

the customer's charge

the profit made

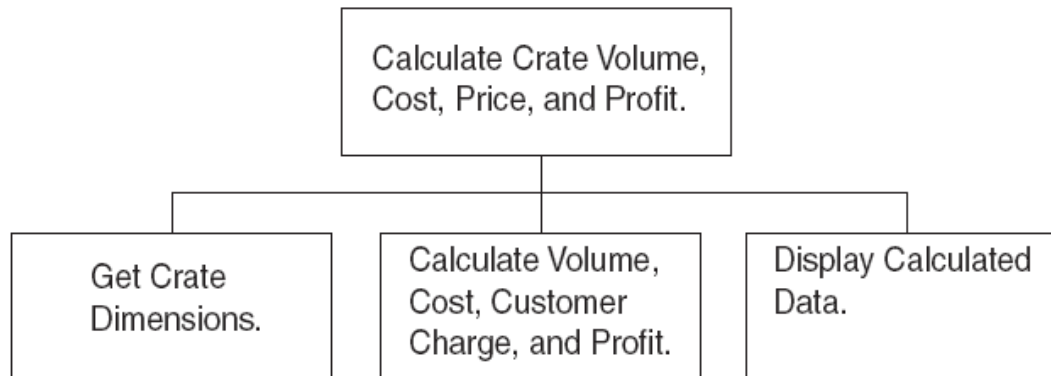
Step 3:

Display the data calculated in Step 2.

# General Hierarchy Chart

**Figure 3-7**

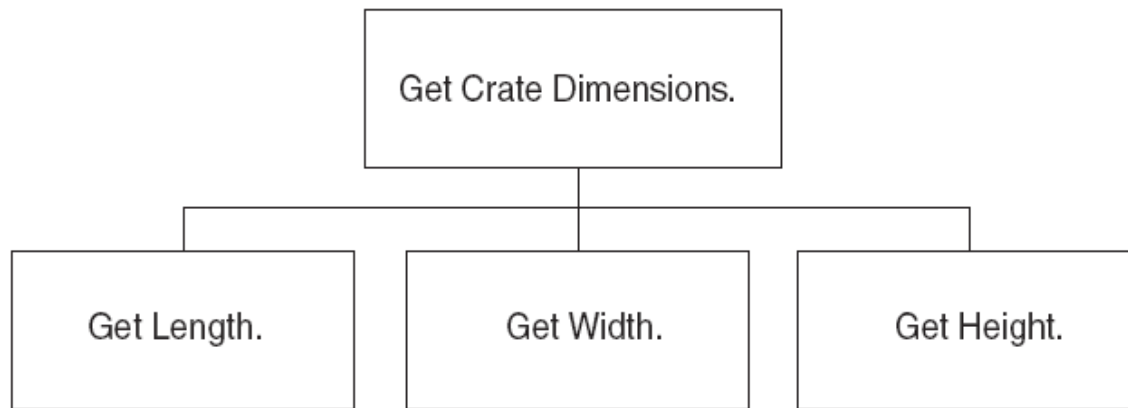
---



# Get Crate Dimensions

**Figure 3-8**

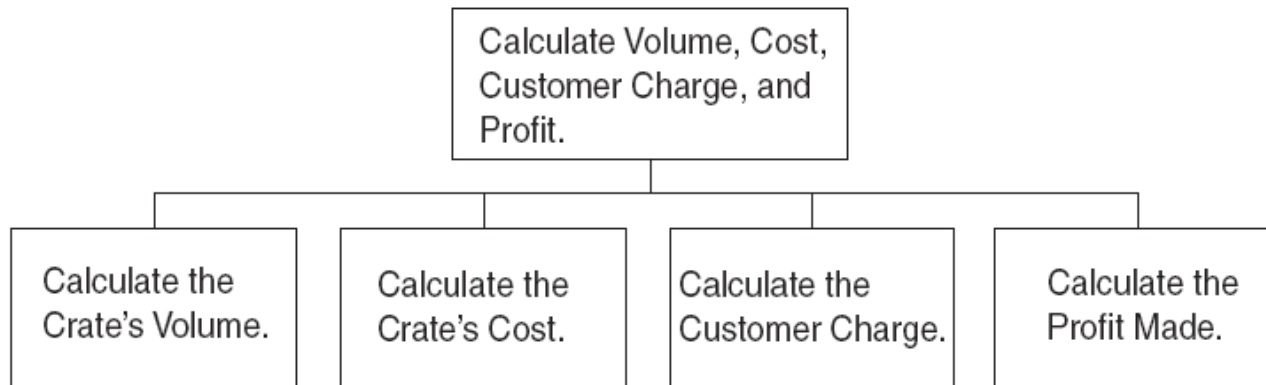
---



# Calculate Volume, Cost, Customer Charge, and Profit

**Figure 3-9**

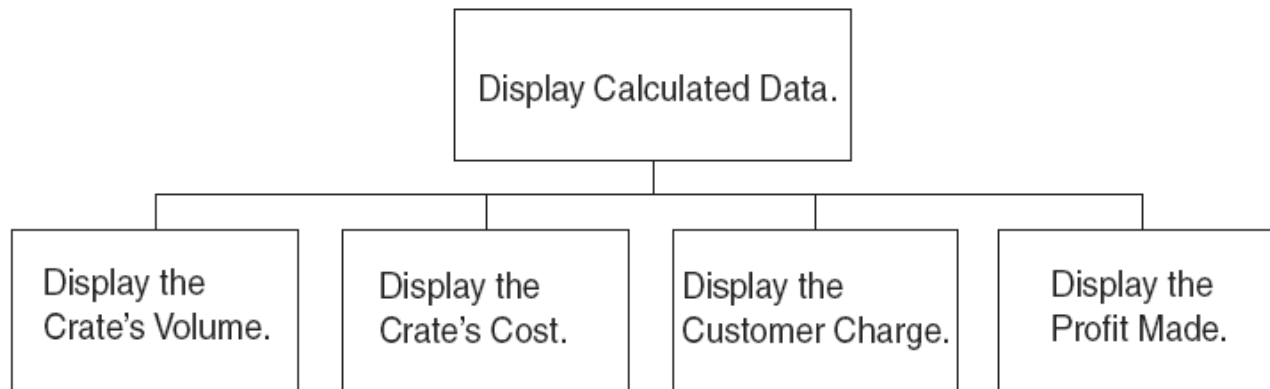
---



# Display Calculated Data

**Figure 3-10**

---





# Psuedocode

*Ask the user to input the crate's length.*  
*Ask the user to input the crate's width.*  
*Ask the user to input the crate's height.*  
*Calculate the crate's volume.*  
*Calculate the cost of building the crate.*  
*Calculate the customer's charge for the crate.*  
*Calculate the profit made from the crate.*  
*Display the crate's volume.*  
*Display the cost of building the crate.*  
*Display the customer's charge for the crate.*  
*Display the profit made from the crate.*

# Calculations

The following formulas will be used to calculate the crate's volume, cost, charge, and profit:

$$\text{volume} = \text{length} \times \text{width} \times \text{height}$$

$$\text{cost} = \text{volume} \times 0.23$$

$$\text{charge} = \text{volume} \times 0.5$$

$$\text{profit} = \text{charge} - \text{cost}$$



# The Program

## Program 3-28

```
1  // This program is used by General Crates, Inc. to calculate
2  // the volume, cost, customer charge, and profit of a crate
3  // of any size. It calculates this data from user input, which
4  // consists of the dimensions of the crate.
5  #include <iostream>
6  #include <iomanip>
7  using namespace std;
8
9  int main()
10 {
11     // Constants for cost and amount charged
12     const double COST_PER_CUBIC_FOOT = 0.23;
13     const double CHARGE_PER_CUBIC_FOOT = 0.5;
14
15     // Variables
16     double length,    // The crate's length
17             width,    // The crate's width
18             height,   // The crate's height
19             volume,   // The volume of the crate
20             cost,     // The cost to build the crate
21             charge,   // The customer charge for the crate
22             profit;   // The profit made on the crate
23
24     // Set the desired output formatting for numbers.
25     cout << setprecision(2) << fixed << showpoint;
26
```

Continued...



# The Program

```
27     // Prompt the user for the crate's length, width, and height
28     cout << "Enter the dimensions of the crate (in feet):\n";
29     cout << "Length: ";
30     cin >> length;
31     cout << "Width: ";
32     cin >> width;
33     cout << "Height: ";
34     cin >> height;
35
36     // Calculate the crate's volume, the cost to produce it,
37     // the charge to the customer, and the profit.
38     volume = length * width * height;
39     cost = volume * COST_PER_CUBIC_FOOT;
40     charge = volume * CHARGE_PER_CUBIC_FOOT;
41     profit = charge - cost;
42
43     // Display the calculated data.
44     cout << "The volume of the crate is ";
45     cout << volume << " cubic feet.\n";
46     cout << "Cost to build: $" << cost << endl;
47     cout << "Charge to customer: $" << charge << endl;
48     cout << "Profit: $" << profit << endl;
49     return 0;
50 }
```

Continued...



# The Program

## Program Output with Example Input Shown in Bold

```
Enter the dimensions of the crate (in feet):  
Length: 10 [Enter]  
Width: 8 [Enter]  
Height: 4 [Enter]  
The volume of the crate is 320.00 cubic feet.  
Cost to build: $73.60  
Charge to customer: $160.00  
Profit: $86.40
```

## Program Output with Different Example Input Shown in Bold

```
Enter the dimensions of the crate (in feet):  
Length: 12.5 [Enter]  
Width: 10.5 [Enter]  
Height: 8 [Enter]  
The volume of the crate is 1050.00 cubic feet.  
Cost to build: $241.50  
Charge to customer: $525.00  
Profit: $283.50
```

