

STARTING OUT WITH

C++

From Control Structures
through Objects

sixth edition

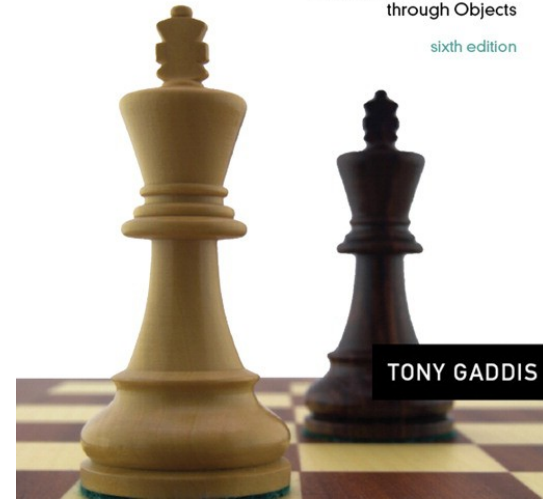
Chapter 3:

Expressions and Interactivity

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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



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.



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

Reading Strings with `cin`



- Can be used to read in a string
- Must first declare an array to hold characters in string:

```
char myName[21];
```

- `myName` is name of array, 21 is the number of characters that can be stored (the size of the array), including the NULL character at the end
- Can be used with `cin` to assign a value:

```
cin >> myName;
```

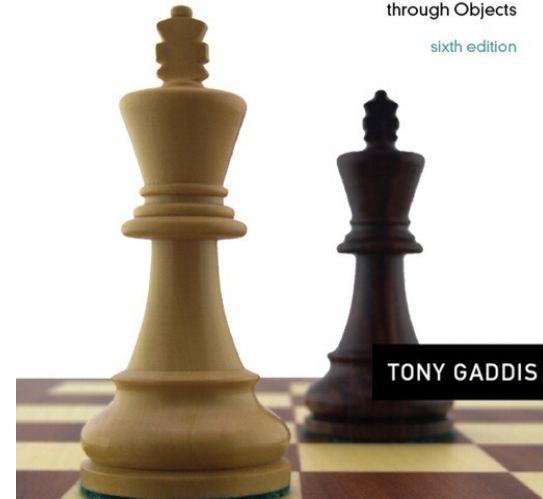


Program 3-4

```
1  // This program demonstrates how cin can read a string into
2  // a character array.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8      char name[21];
9
10     cout << "What is your name? ";
11     cin >> name;
12     cout << "Good morning " << name << endl;
13     return 0;
14 }
```

Program Output with Example Input Shown in Bold

What is your name? **Charlie** [Enter]
Good morning Charlie



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*(1+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 $2 + 2 * 2 - 2$

Diagram illustrating the order of evaluation for the expression $2 + 2 * 2 - 2$:

- The multiplication operator ($*$) is evaluated first.
- The addition operator ($+$) is evaluated second.
- The subtraction operator ($-$) is evaluated third.

Order of Operations



Table 3-2 Some Expressions

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 Expressions

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 = (y2 - y1) / (x2 - x1);`

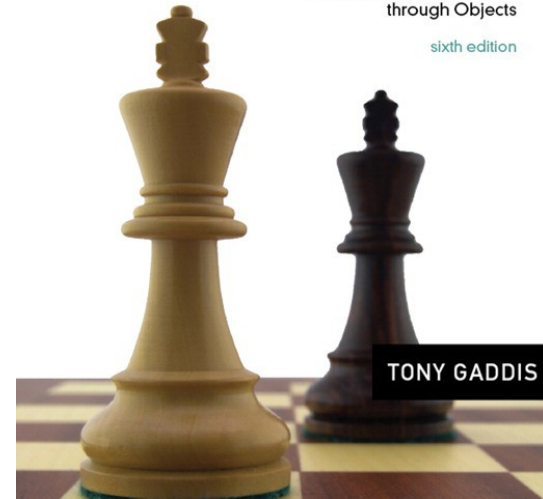
Algebraic Expressions



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 and Oranges: *Type Conversion*

When You Mix Apples and 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

Lowest: int

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

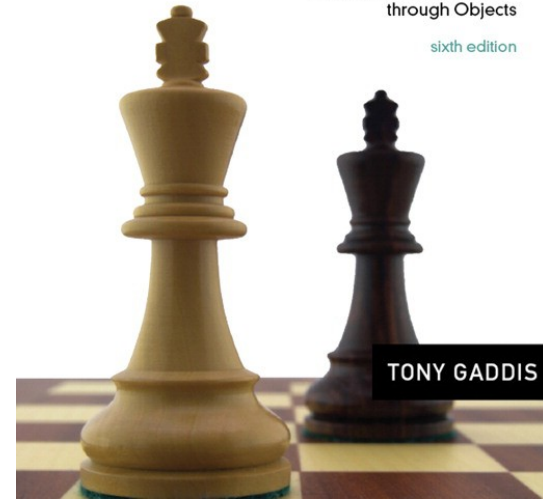
Coercion Rules



- 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

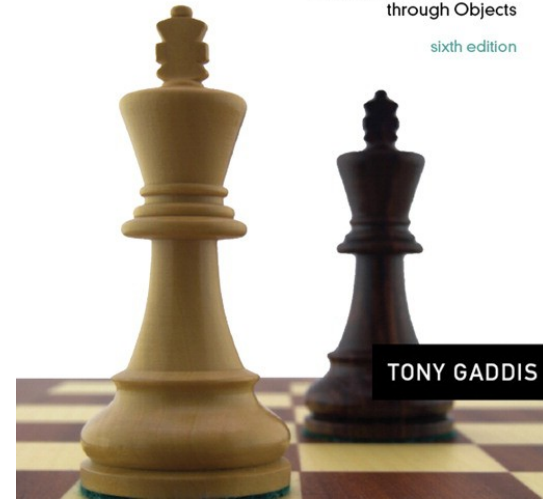


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Overflow and Underflow



- 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);
```



Program 3-11

```
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



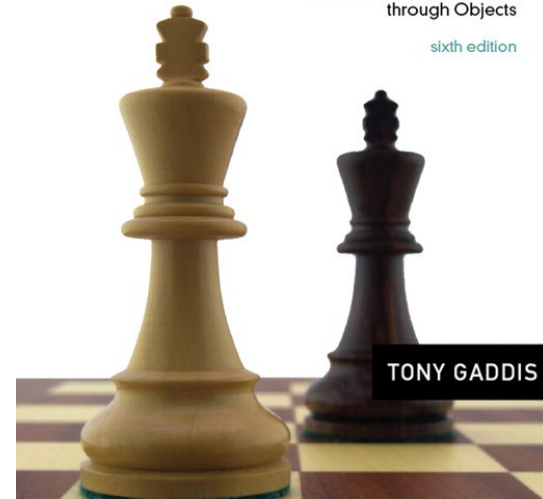
- C-Style cast: data type name in ()

```
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

Named Constants



Named Constants



- Named constant (constant variable): variable whose content cannot be changed during program execution
- Used for representing constant values with descriptive names:

```
const double TAX_RATE = 0.0675;
```

```
const int NUM_STATES = 50;
```

- Often named in uppercase letters



Program 3-13

```
1  // This program calculates the area of a circle.
2  // The formula for the area of a circle is PI times
3  // the radius squared. PI is 3.14159.
4  #include <iostream>
5  #include <cmath>    // needed for pow function
6  using namespace std;
7
8  int main()
9  {
10     const double PI = 3.14159;
11     double area, radius;
12
13     cout << "This program calculates the area of a circle.\n";
14     cout << "What is the radius of the circle? ";
15     cin >> radius;
16     area = PI * pow(radius, 2.0);
17     cout << "The area is " << area << endl;
18     return 0;
19 }
```


Constants and Array Sizes



- It is a common practice to use a named constant to indicate the size of an array:

```
const int SIZE = 21;  
char name[SIZE];
```

const vs. #define

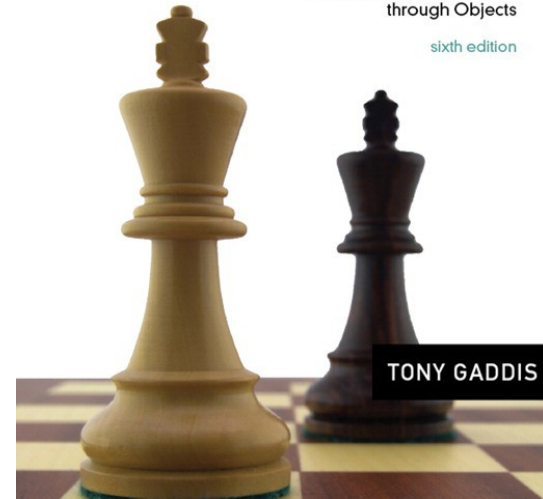


- `#define` – C-style of naming constants:

```
#define NUM_STATES 50
```

 - Note no semicolon at end
- Interpreted by pre-processor rather than compiler
- Does not occupy memory location like `const`

3.7



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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

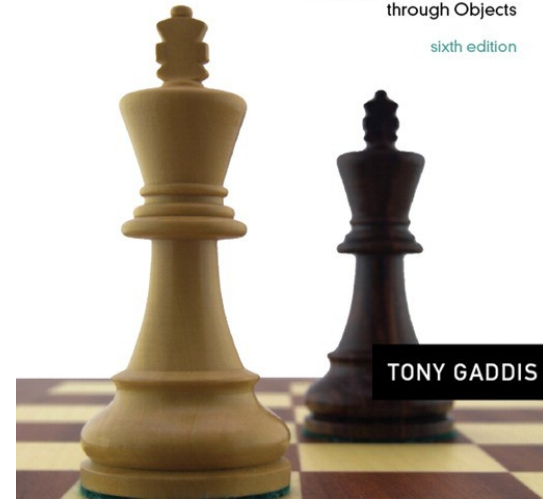
```
sum += 1;
```

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>



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3.8

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



Program 3-17

```
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...



Program 3-17

(continued)

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



Program 3-21

```
1  // This program asks for sales figures 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
```

Continued...



```
19      // Calculate the total sales.
20      total = day1 + day2 + day3;
21
22      // Display the sales figures.
23      cout << "\nSales Figures\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]

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

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

Sales Figures

Day 1: 1321.87

Day 2: 1869.26

Day 3: 1403.77

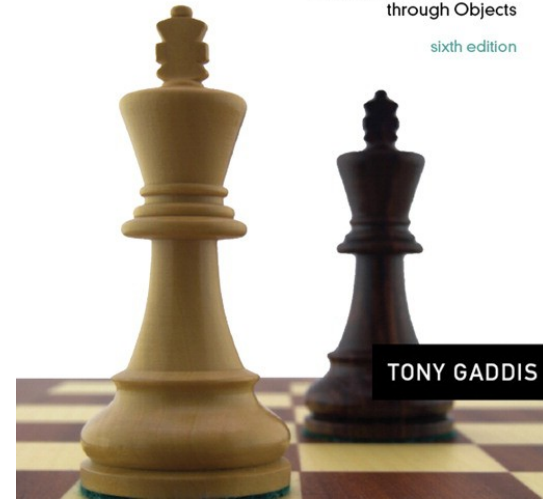
Total: 4594.90

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.



3.9

Formatted Input

Formatted Input



- Can format field width for use with `cin`
- Useful when reading string data to be stored in a character array:

```
const int SIZE = 10;  
char firstName[SIZE];  
cout << "Enter your name: ";  
cin >> setw(SIZE) >> firstName;
```

- `cin` reads one less character than specified with the `setw()` manipulator

Formatted Input



- To read an entire line of input, use `cin.getline()`:

```
const int SIZE = 81;  
char address[SIZE];  
cout << "Enter your address: ";  
cin.getline(address, SIZE);
```
- `cin.getline` **takes two arguments**:
 - Name of array to store string
 - Size of the array



Program 3-23

```
1  // This program demonstrates cin's getline member function.
2  #include <iostream>
3  using namespace std;
4
5  int main()
6  {
7      const int SIZE = 81;
8      char sentence[SIZE];
9
10     cout << "Enter a sentence: ";
11     cin.getline(sentence, SIZE);
12     cout << "You entered " << sentence << endl;
13     return 0;
14 }
```

Program Output with Example Input Shown in Bold

Enter a sentence: **To be, or not to be, that is the question. [Enter]**
You entered To be, or not to be, that is the question.

Formatted Input



- 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

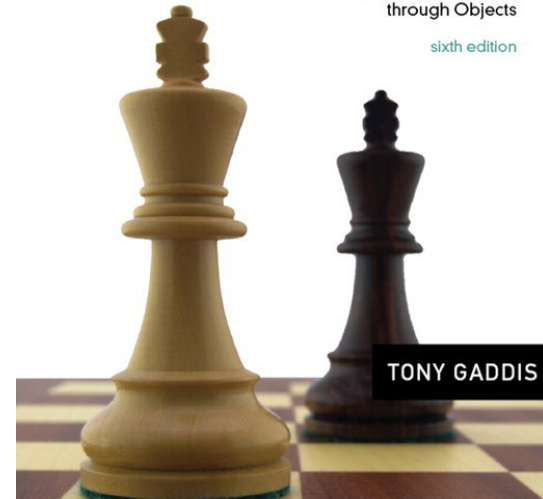
Formatted Input



- 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'
```

3.10



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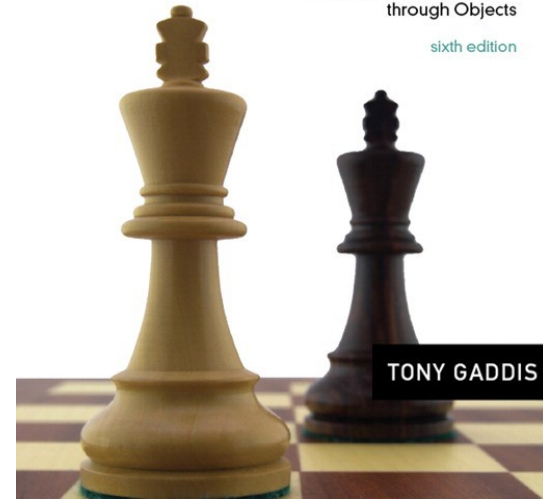
More About Member Functions

More About Member Functions



- Member Function: procedure that is part of an object
- `cout`, `cin` are objects
- Some member functions of the `cin` object:
 - `getline`
 - `get`
 - `ignore`

3.11



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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)

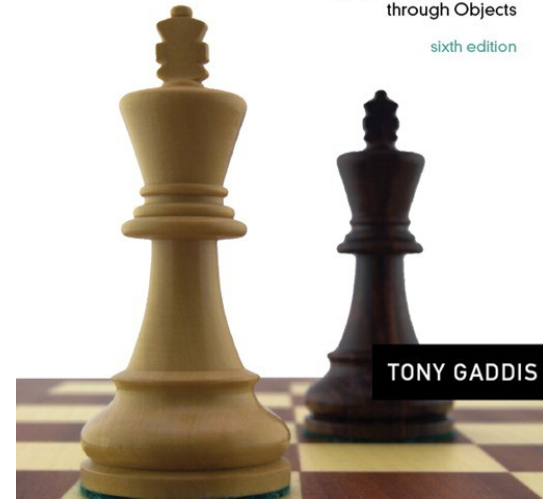
More Mathematical Library Functions



- 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`

3.12

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 filled)

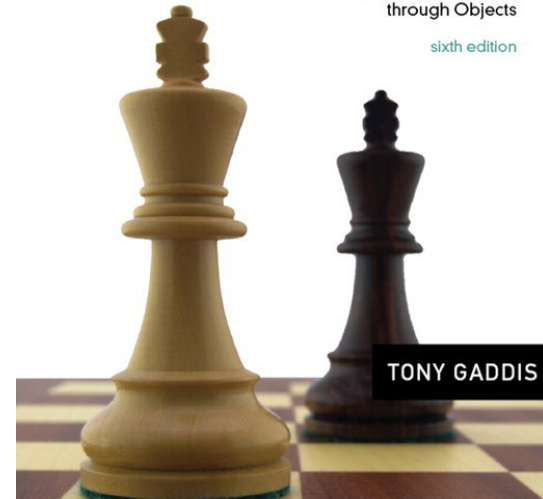
```
1 // This program asks for three numbers, then
2 // displays the average of the numbers.
3 #include <iostream>
4 using namespace std;

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

3.14



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Introduction to File Input and Output

Introduction to File Input and Output



- Can use files instead of keyboard, monitor screen for program input, output
- Allows data to be retained between program runs
- Steps:
 - *Open* the file
 - *Use* the file (read from, write to, or both)
 - *Close* the file

Files: What is Needed



- Use `fstream` header file for file access
- File stream types:
 - `ifstream` for input from a file
 - `ofstream` for output to a file
 - `fstream` for input from or output to a file
- Define file stream objects:
 - `ifstream infile;`
 - `ofstream outfile;`

Opening Files



- Create a link between file name (outside the program) and file stream object (inside the program)
- Use the `open` member function:

```
infile.open("inventory.dat");  
outfile.open("report.txt");
```
- Filename may include drive, path info.
- Output file will be created if necessary; existing file will be erased first
- Input file must exist for `open` to work

Using Files



- Can use output file object and `<<` to send data to a file:

```
outfile << "Inventory report";
```

- Can use input file object and `>>` to copy data from file to variables:

```
infile >> partNum;
```

```
infile >> qtyInStock >>  
qtyOnOrder;
```

Closing Files



- Use the `close` member function:

```
infile.close();  
outfile.close();
```
- Don't wait for operating system to close files at program end:
 - may be limit on number of open files
 - may be buffered output data waiting to send to file



Program 3-29

```
1  // This program writes data to a file.
2  #include <iostream>
3  #include <fstream>
4  using namespace std;
5
6  int main()
7  {
8      ofstream outputFile;
9      outputFile.open("demofile.txt");
10
11     cout << "Now writing data to the file.\n";
12
13     // Write 4 great names to the file
14     outputFile << "Bach\n";
15     outputFile << "Beethoven\n";
16     outputFile << "Mozart\n";
17     outputFile << "Schubert\n";
18
19     // Close the file
20     outputFile.close();
21     cout << "Done.\n";
22     return 0;
23 }
```

Continued...



Program Screen Output

```
Now writing data to the file.  
Done.
```

Output to File demofile.txt

```
Bach  
Beethoven  
Mozart  
Schubert
```



Program 3-30

```
1  // This program reads data from a file.
2  #include <iostream>
3  #include <fstream>
4  using namespace std;
5
6  int main()
7  {
8      ifstream inFile;
9      const int SIZE = 81;
10     char name[SIZE];
11
12     inFile.open("demofile.txt");
13     cout << "Reading data from the file.\n\n";
14
15     inFile >> name;           // Read name 1 from the file
16     cout << name << endl;    // Display name 1
17
```

Continued...
3-72



Program 3-30 *(continued)*

```
18     inFile >> name;           // Read name 2 from the file
19     cout << name << endl;      // Display name 2
20
21     inFile >> name;           // Read name 3 from the file
22     cout << name << endl;      // Display name 3
23
24     inFile >> name;           // Read name 4 from the file
25     cout << name << endl;      // Display name 4
26
27     inFile.close();           // Close the file
28     cout << "\nDone.\n";
29     return 0;
30 }
```

Program Screen Output

Reading data from the file.

Bach
Beethoven
Mozart
Schubert

Done.